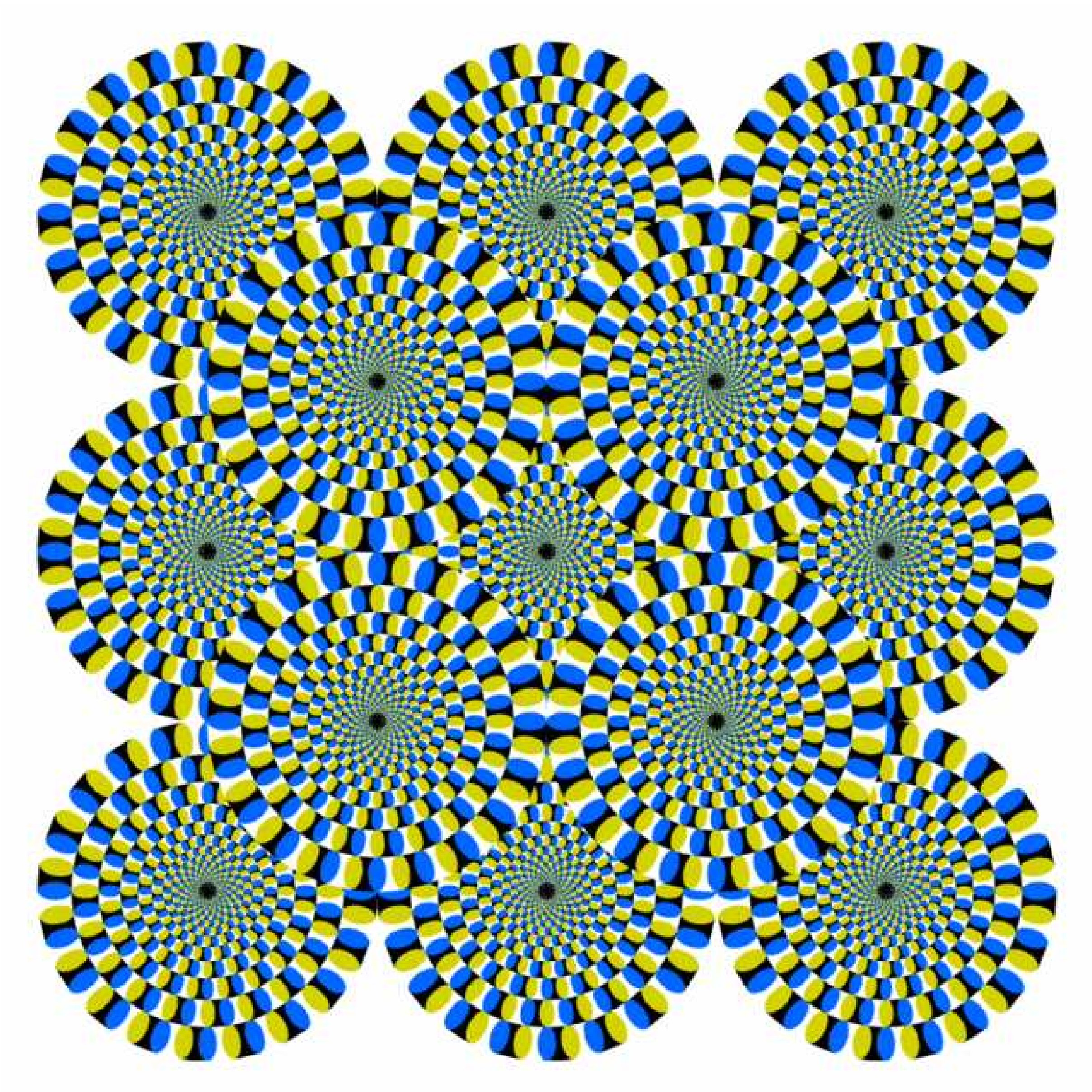
Optische illusie?

Een onderzoek naar voorwaarden voor- en eisen van het bewaarbeleid van optische schijven



Erasmus Universiteit, Informatie- en Documentmanagement (IDM) 2008-2009
Referaat, Eric-Jan Keulemans, 4 september 2009.
Begeleider ir. A. (Ad) C. van der Kolk, tweede lezer dr. O.(Otto) W. Hoogerhuis.

Samenvatting

In het essay voor module 2[1] is verslag gedaan van het onderzoek naar bewaarbeleid van optische schijven bij Zeeuwse archiefdiensten. Uit dit onderzoek, waaraan door negen van de tien archiefdiensten is meegewerkt, is gebleken dat alle organisaties optische schijven in hun collectie hebben, maar dat geen van hen bewaarbeleid voor optische schijven heeft ontwikkeld.

Geldt dit alleen voor de archiefdiensten in Zeeland? Of besteden andere archiefdiensten en cultuurinstellingen in Nederland ook weinig aandacht aan bewaarbeleid van optische schijven? De conclusies en aanbevelingen uit dit essay vormen de basis van verder onderzoek naar bewaarbeleid van optische schijven en de toegankelijkheid van de data op die optische schijven op lange termijn. Door middel van empirisch onderzoek is het bewaarbeleid van vijf (cultuur)instellingen in Nederland onderzocht.

In het onderzoek komt de geschiedenis van de optische schijf en de uitvinding van de laser aan bod, worden de huidige- en toekomstige generaties optische schijven behandeld en wordt ingegaan op de "randvoorwaarden bewaarbeleid optische schijven en toegankelijkheid op lange termijn", waarin duidelijk wordt dat aan bewaarbeleid van optische schijven vele voorwaarden en eisen zijn verbonden. Het is de combinatie van deze factoren die bepalend zijn voor de uiteindelijke levensduur van de optische schijf en de toegankelijkheid van de data op lange termijn.

De onderzoeksvraag luidt: "*Wat zijn de optimale voorwaarden voor bewaarbeleid van optische schijven en welke eisen kunnen worden geformuleerd?"*. Bovendien is onderzocht of een optische schijf geschikt is als opslagmedium voor de lange termijn en welke alternatieve opslagmedia voorhanden zijn.

Het primaire doel van dit onderzoek is te achterhalen aan welke voorwaarden en eisen bewaarbeleid van optische schijven moet voldoen. Het secundaire doel is het bevorderen van bewustzijn bij overheidsinstanties in Nederland. Het vermoeden bestaat dat bij overheidsinstellingen in Nederland inmiddels tienduizenden optische schijven worden bewaard maar dat deze organisaties tot op heden geen aandacht hebben besteed aan het beheer en het onderhoud ervan. Laat staan dat men zich heeft beziggehouden met de toegankelijkheid van de informatie op deze schijven.

Deze schijven kunnen mogelijk nog actuele, politiek vitale, informatie bevatten. Als deze informatie verloren gaat, ontstaat voor de overheid een enorm probleem. De mogelijkheid om het overheidshandelen te kunnen reconstrueren komt ernstig in gevaar. Ook is de overheid niet in staat om haar handelen juridisch te verantwoorden. Men kan hier met recht spreken van een tikkende informatietijdbom die, als men tijdig actie onderneemt, nog onschadelijk kan worden gemaakt.

Speciale dank gaat uit naar alle medewerkers van de onderzochte organisaties. In openhartige gesprekken heeft men de vragen beantwoord en additionele informatie verstrekt.

Last but not least, een woord van dank aan mijn twee begeleiders: Ad van der Kolk en Otto Hoogerhuis. Dankzij hun inspirerende bijdragen en hun commentaar op de conceptversies, zijn vooral de conclusies en aanbevelingen van dit onderzoek scherper geformuleerd.

Kleverskerke, 4 september 2009
Eric-Jan Keulemans.

[1] Keulemans, E.J. *To burn or not to burn? That's the question! Een onderzoek naar een doeltreffend en doelgericht bewaarbeleid voor optische gegevensdragers – succes- en faalfactoren bij Zeeuwse archiefdiensten.* Provincie Zeeland; Middelburg, 2009. Als bijlage 2 bij dit onderzoek opgenomen.

1 Onderzoeksvraag en onderzoeksmethodieken

Inleiding

In het essay voor module 2[2] is verslag gedaan van het onderzoek naar bewaarbeleid van optische schijven bij Zeeuwse archiefdiensten. Uit dit onderzoek, waaraan door negen van de tien archiefdiensten is meegewerkt, is gebleken dat alle organisaties optische schijven in hun collectie hebben, maar dat geen van hen bewaarbeleid voor optische schijven heeft ontwikkeld.

De optische schijven liggen vaak in dezelfde ruimte opgeslagen waar ook de papieren archieven zijn gearchiveerd, terwijl voor beide dragers andere bewaarcondities gelden. Bovendien worden de optische schijven nauwelijks onderworpen aan een (periodieke) controle, wat het risico op verkorting van de levensduur van een optische schijf alleen maar bespoedigt.

Situatieschets

Geldt dit alleen voor de archiefdiensten in Zeeland? Of besteden andere archiefdiensten en cultuurinstellingen in Nederland ook weinig aandacht aan bewaarbeleid van optische schijven? De conclusies en aanbevelingen uit dit essay vormen de basis van verder onderzoek naar bewaarbeleid van optische schijven en toegankelijkheid van de data op lange termijn. Door middel van empirisch onderzoek wordt het bewaarbeleid van vijf (cultuur)instellingen in Nederland onderzocht.

Omdat een optische schijf vele varianten kent (CDR, DVD-R, DVD+R, CD-RW, DVD-RW, CD-I, BD-R en vele andere benamingen), wordt in dit onderzoek de term optische schijf gebruikt, tenzij in de literatuur specifiek wordt verwezen naar één van de varianten.

Onderzoeksvraag

Wat zijn de optimale voorwaarden voor bewaarbeleid van optische schijven en welke eisen kunnen worden geformuleerd?

Subonderzoeksvragen

- Is de optische schijf geschikt als opslagmedium voor lange termijn archivering?
- Welke alternatieve opslagmedia zijn er voorhanden?

Doel van het onderzoek

Het primaire doel van dit onderzoek is te achterhalen aan welke voorwaarden en eisen bewaarbeleid van optische schijven moet voldoen.

Het secundaire doel is het bevorderen van bewustzijn bij overheidsinstanties in Nederland. Een optische schijf is aan slijtage onderhevig en moet periodiek worden gecontroleerd, om de toegankelijkheid van de data op lange termijn te kunnen garanderen. Dat lukt alleen als een optische schijf onder ideale omstandigheden duurzaam wordt bewaard.

Het vermoeden bestaat dat bij overheidsinstellingen in Nederland inmiddels tienduizenden optische schijven worden bewaard maar dat deze organisaties tot op heden geen aandacht hebben besteed aan het beheer en het onderhoud ervan. Laat staan dat men zich heeft beziggehouden met de toegankelijkheid van de informatie op deze schijven.

[2] Keulemans, E.J. *To burn or not to burn? That's the question! Een onderzoek naar een doeltreffend en doelgericht bewaarbeleid voor optische gegevensdragers – succes- en faalfactoren bij Zeeuwse archiefdiensten.* Provincie Zeeland; Middelburg, 2009. Als bijlage 2 bij dit onderzoek opgenomen.

Optische illusie?

Op optische schijven gearchiveerde data kunnen mogelijk nog actuele, politiek vitale, informatie bevatten. Als deze informatie verloren gaat, kan voor de overheid een probleem ontstaan. De mogelijkheid om het overheidshandelen te kunnen reconstrueren komt in gevaar. Ook is de overheid niet in staat om haar handelen juridisch te verantwoorden. Men kan hier met recht spreken van een tikkende informatietijdbom die, als men tijdig actie onderneemt, nog onschadelijk kan worden gemaakt.

Om het bewustzijn te bevorderen bij overheidsorganisaties in Nederland en om te proberen een bijdrage te leveren aan de discussie over het veiligstellen van, mogelijk actuele politieke, informatie, is een wiki[3] in voorbereiding over het bewaarbeleid van optische schijven. Uitgangspunt is het bevorderen van het bewustzijn dat optische schijven aan slijtage onderhevig zijn en dat informatie alleen toegankelijk blijft als optische schijven periodiek worden gecontroleerd en duurzaam worden bewaard.

Daarnaast is het een community, waarin het uitwisselen van informatie over de optische schijf, randvoorwaarden voor bewaarbeleid, achtergrondinformatie als het brandproces en best practices centraal staan. Ook zal aandacht worden besteed aan vroegere- en toekomstige generaties optische schijven. Deelname aan deze wiki is gratis, onder voorwaarde dat men zich (kosteloos) registreert op de website.

In een mindmap[4] is het onderzoeksvoorstel gedetailleerd uitgewerkt.

Onderzoeksmethodieken

Om de onderzoeksvraag en alle andere vragen te kunnen beantwoorden, wordt gebruik gemaakt van de volgende onderzoeksmethodieken:

- Literatuuronderzoek naar geschiedenis van de optische schijf en de laser, de bewaarcondities, het brandproces en alternatieve opslagmedia.
- Interviews[5] met contactpersonen bij vijf (cultuur)instellingen.

Opbouw

Hoofdstuk 1 behandelt de onderzoeksvraag, het doel van het onderzoek en de onderzoeksmethodieken. Hoofdstuk 2 gaat in op de geschiedenis van de optische schijf, de laser en de diverse generaties optische schijven. In hoofdstuk 3 worden de randvoorwaarden voor bewaarbeleid van optische schijven behandeld. Hoofdstuk 4 gaat in op de alternatieve opslagmedia. Hoofdstuk 5 laat de casestudy: “Onderzoek naar bewaarbeleid in de praktijk” zien.
Dit onderzoek wordt afgesloten met hoofdstuk 6 waarin de conclusies worden getrokken en aanbevelingen worden gedaan.

Doelgroep

Dit onderzoek is vervaardigd in het kader van de postacademische opleiding Informatie- en Documentmanagement, jaargang 2008-2009, aan de Erasmus Universiteit in Rotterdam.

Daarnaast is dit onderzoek bestemd voor iedereen die professioneel is belast met het beheer en onderhoud van optische schijven, opdat zij inzicht krijgen in de voorwaarden en de eisen waaraan bewaarbeleid van optische schijven moet voldoen.

[3] http://optischeschijven.wetpaint.com/ (aangemaakt op 29-08-2009). Ook is de domeinnaam www.optischeschijf.nl gereserveerd (gereserveerd op 03-09-2009)..
[4] Zie bijlage 1.
[5] De standaardvragen van deze interviews treft u aan in bijlage 3.

2 Oorsprong optische schijf

Geschiedenis

De optische schijf vindt zijn oorsprong in 1958, toen Arthur Schawlow en Charles Townes, verbonden aan Bell Labs, de laser uitvonden. In 1958 beschreven zij het principe van een laser in het artikel "Infrared and Optical Masers". Op dit idee kregen zij octrooi[6].
In 1960 werd het eerste exemplaar, een robijnlaser, geconstrueerd door Theodore Maiman[7].

Een laser is een lichtbron die in staat is een smalle bundel licht voort te brengen.

"Het woord laser is oorspronkelijk een afkorting van Light Amplification by Stimulated Emission of Radiation, in het Nederlands: lichtversterking door gestimuleerde uitzending van straling. De eerste lasers werden gemaakt in 1960 (Theodore H. Maiman), hoewel Einstein al veel eerder de theoretische basis ervoor had gelegd toen hij in 1917 zijn ontdekking van de gestimuleerde emissie van fotonen publiceerde"[8].

"Gestimuleerde emissie is een door Albert Einstein voorspeld verschijnsel, dat een atoom in een aangeslagen toestand dat botst met een foton zelf ook een foton uitzendt met zelfde golflengte en fase en daarbij naar de grondtoestand terugvalt. Het verschijnsel vormt de basis van de laser en de maser"[9].

Werking van een laser

Er zijn verschillende soorten lasers. Voor het lezen van een optische schijf wordt gebruik gemaakt van een diodelaser[10]. Hierbij leest de laser de schijf van binnenuit, startende met de Tabel of Contents[11], via het spoor, de helix genaamd, naar buiten toe.

De helix bestaat uit "pits" en "lands" met digitale informatie. Pits zijn hele kleine putjes in het oppervlak van de optische schijf, lands zijn de onbeschreven kuiltjes tussen de putjes.
Wanneer een optische schijf wordt afgespeeld, schijnt een laserstraal op de verschillende putjes en kuiltjes. De gegevens op de optische schijf worden door de terugkaatsingen van de laserstraal vanaf een foto-elektrische cel, omgezet in elektrische impulsen: de bitstroom[12].

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[6] United States Patent 2,929,922, Masers and Maser Communication Systems, A.J. Schalow, Madison, C.H. Townes, 22 Maart 1960. " *The extension of maser techniques to the infrared and optical region is considered. It is shown that by using a resonant cavity of centimeter dimensions, having many resonant modes, maser oscillation at these wavelengths can be achieved by pumping with reasonable amounts of incoherent light. For wavelengths much shorter than those of the ultraviolet region, maser-type amplification appears to be quite impractical. Although use of a multimode cavity is suggested, a single mode may be selected by making only the end walls highly reflecting, and defining a suitably small angular aperture. Then extremely monochromatic and coherent light is produced. The design principles are illustrated by reference to a system using potassium vapor*" Bron http://prola.aps.org/abstract/PR/v112/i6/p1940_1 (geraadpleegd op 04-07-2009).

[7] http://nl.wikipedia.org/wiki/Theodore_H._Maiman (geraadpleegd op 04-07-2009).

[8] http://nl.wikipedia.org/wiki/Laser_licht (geraadpleegd op 04-07-2009).

[9] http://nl.wikipedia.org/wiki/Gestimuleerde_emissie (geraadpleegd op 04-07-2009).

[10] "*Een diodelaser, ook wel laserdiode genoemd, is een laser waarbij het actieve medium een halfgeleider is, vergelijkbaar met het type dat gebruikt wordt in een led. Het meest voorkomende en praktische type is gemaakt van p-n combinatie halfgeleiders gevoed met geïnjecteerde elektrische stroom. Dit type wordt meestal geïnjecteerde diodelaser genoemd om ze te onderscheiden van optisch gepompte diode lasers die eenvoudiger te produceren zijn*" Bron: http://nl.wikipedia.org/wiki/Diodelaser (geraadpleegd op 04-07-2009). Uitgebreide informatie over de werking van een diodelaser, zie http://www.fransvaneeckhout.be/bijleren/geluid_cd_speler03.htm (geraadpleegd op 04-07-2009).

[11] "*The Table of Contents (TOC) is the area where the layout of the tracks on the disc is described. It is located in the lead-in area of the disc session. The TOC on discs is in principle similar to partition table on hard drives*" Bron: http://en.wikipedia.org/wiki/Optical_disc_authoring#TOC (geraadpleegd op 05-07-2009).

[12] "Een bitstroom is een ononderbroken stroom van bits" Bron: http://www.computerwoorden.nl/direct--19248--Bitstream.htm (geraadpleegd op 05-07-2009). Meer informatie over de werking van een optische schijf, zie http://members.chello.nl/~p.quene/cd/Cdmain.htm (geraadpleegd op 05-07-2009).

Uitvinding optische schijf

De eerste optische schijf ziet in 1957 het licht als de Italiaan Rubbiani op de Salone Internazionale della Tecnica een primitieve beeldplaat presenteert[13]. Een kleine tien jaar later vindt James T. Russell een optisch opbergsysteem uit voor digitale audio en video, waarvoor hij in 1970 patent aanvraagt[14].
Het eerste patent voor een OS werd echter aangevraagd door David Paul Gregg[15].
Paul Gregg deed zijn uitvinding toen hij werkte voor de Amerikaanse firma 3M. Hij begon later zijn eigen firma, Gauss Electrophysics Inc. Omdat een videoplaat de mogelijkheid gaf om goedkoop films aan de man te brengen, zag de filmproducent MCA wel wat in deze uitvinding. In 1968 kocht MCA Gauss Electrophysics Inc, uiteraard inclusief de 'optische' octrooiportefeuille[16].

Eerste generatie optische schijven

Geïnspireerd door deze Amerikaanse ontwikkelingen begon in 1969 een groepje onderzoekers in het Philips Natuurkundig Laboratorium (NatLab) te Waalre te experimenteren met videoplaten. In 1975 besloot Philips tot samenwerking met MCA. In 1978 werd eindelijk de lang verwachte Video Long Play (VLP) op de Amerikaanse markt geïntroduceerd[17].

Een VLP is 30 cm in doorsnede (11,81 inches)[18], dezelfde afmetingen als een grammofoonplaat[19].
Op afbeelding 1 is een VLP zichtbaar in het afspeelapparaat, erbovenop ligt een DVD.

Afbeelding 1: een VLP en een DVD
Bron: http://content.answers.com/main/content/img/CDE/_LDISC.GIF (geraadpleegd op 05-07-2009).

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[13] http://www.computable.nl/artikel/ict_topics/programmeren/1393645/1277180/het-eeuwige-leven-van-de-cdrom.html; (geraadpleegd op 08-07-2009).
[14] http://en.wikipedia.org/wiki/Optical_recording; (geraadpleegd op 08-07-2009). Meer informatie over deze uitvinder is te vinden op http://web.mit.edu/invent/iow/russell.html (geraadpleegd op 08-07-2009).
[15] http://en.wikipedia.org/wiki/Optical_disc; (geraadpleegd op 08-07-2009);
[16] http://nl.wikipedia.org/wiki/Compact_disc; (geraadpleegd op 08-07-2009).
[17] De complete geschiedenis van de videoplaat en al haar varianten kunt u vinden op http://nl.wikipedia.org/wiki/Cd-video_en_laserdisk (geraadpleegd op 08-07-2009).
[18] http://en.wikipedia.org/wiki/Laserdisc; (geraadpleegd op 08-07-2009).
[19] http://nl.wikipedia.org/wiki/Grammofoonplaat; (geraadpleegd op 08-07-2009).

Optische illusie?

Twee ingenieurs van Philips Audio, Loek Boonstra en Toon van Alem, experimenteerden al sinds 1975 met digitaal geluid. Sony werkte aan een optische digitale audioplaat. In 1978 gingen Philips en Sony samenwerken bij de ontwikkeling van een audioplaat. Al in maart 1979 had Philips een prototype van de audioplaat, de Compact Disc, en het afspeelapparaat gereed, zie afbeelding 2.

Afbeelding 2: prototype eerste Compact Disc en speler Bron: http://www.marantzphilips.nl/philips_press_first_philips_cd_prototype_1978 (geraadpleegd op 09-07-2009).

Afbeelding 3: de eerste CD-speler van Philips, de CD-100, die in 1982 op de markt verscheen Bron: http://www.marantzphilips.nl/philips_cd100_first_cdplayer (geraadpleegd op 09-07-2009).

Tweede generatie optische schijven

In 1990 ontwikkelden Toshiba en Time Warner een opvolger van de succesvolle Compact Disc, genaamd SuperDisc (SD). Op het Natlab van Philips werd al nagedacht over een opvolger. In 1994 presenteerden Philips en Sony de MultiMedia CD (MMCD).
De speelduur van de SD was aanzienlijk groter, namelijk 5 in plaats van 3,6 Gigabyte, dan die van MMCD, echter de MMCD zou beter uitwisselbaar zijn met de CD. Beide kampen namen hun posities in en het zag er naar uit dat de 'formatenoorlog' van VHS en Betamax zou worden herhaald[20] maar na jaren onderhandelen werd de gezamenlijke standaard, Digital Versatile Disc (DVD), in september 1995 beklonken en in 1997 geïntroduceerd.

De DVD kent vijf varianten[21] en de opslagcapaciteit wordt bepaald door het type:

- DVD-5: single sided (enkelzijdig), single layer (één laag), 4,7 Gigabyte (GB)
- DVD-9: single sided, dual layer (twee lagen), 8,5 GB
- DVD-10: double sided (dubbelzijdig), single layer op beide kanten, 9,4 GB
- DVD-14: double sided, double layer op één kant, single layer op de andere kant, 13,3 GB
- DVD-18: double sided, double layer op beide kanten, 17,1 GB

In bijlage 7 wordt uitgebreid ingegaan op de (on)mogelijkheden van de beschrijfbare (DVD +/- R) en herschrijfbare (DVD-RW) DVD.

Derde generatie optische schijven

Na de Video Lang Play (1978), de Compact Disc (1982) en de Digital Versatile Disc (DVD, 1995) is in 2006 de derde generatie optische schijven geïntroduceerd: **Blu-Ray**. Deze schijf heeft dezelfde afmetingen als een CD of een DVD (120 mm middellijn) maar het lezen gebeurt met behulp van een ander soort laser: blauw laserlicht. CD's en DVD's maken gebruik van een rode laser. Blu-ray is bedoeld voor de opslag van hoge kwaliteit televisie en- films en is de opvolger van de DVD. Door gebruik van de blauwe laser is het mogelijk een hogere informatiedichtheid te behalen, zodat meer informatie op dezelfde schijf kan worden opgeslagen. Een Blu-Ray heeft een capaciteit van ongeveer 25Gb. In de toekomst zal Blu-Ray een hogere capaciteit hebben van 250 GB tot 1 Terabyte.

High Definition-DVD (HD-DVD) maakt ook gebruik van een blauwe laser en is bedoeld als digitaal opslagmedium voor speelfilms in highdefinitionvideo (1080p) resolutie[22].

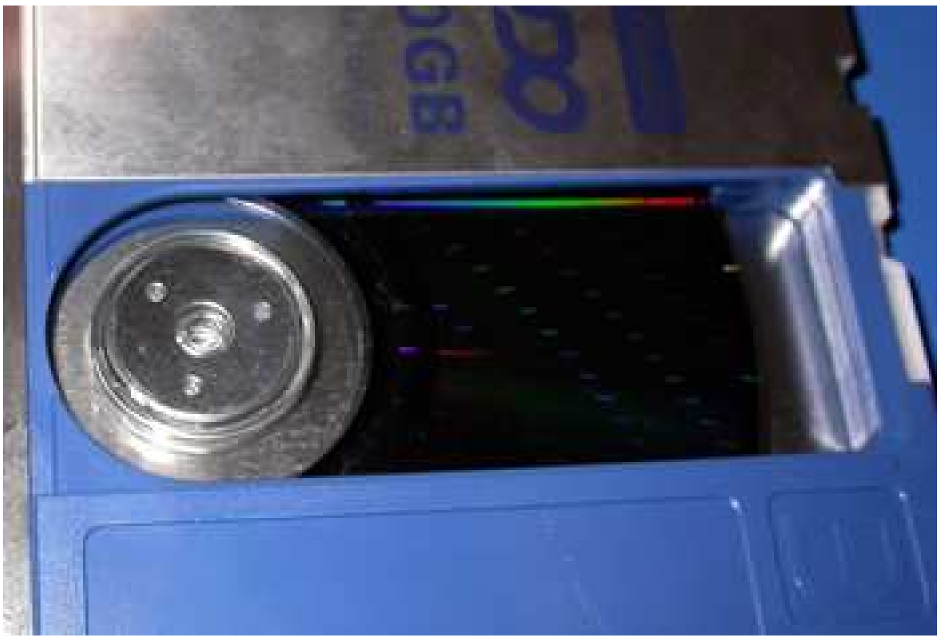
Sinds 2008 is er ook een beschrijfbare Blu-Ray Disc verkrijgbaar, **BD-R**. Deze kan eenmalig worden beschreven. Daarnaast is er een BD-RE disc beschikbaar die kan worden gewist en waarop weer nieuwe opnamen kunnen worden gemaakt[23]. De BD-RE kent drie versies (Version 1.0, Version 2.0 en Version 3.0), met specifieke kenmerken en mogelijkheden.

[20] Medio jaren zeventig van de twintigste eeuw waren er twee videoformaten beschikbaar: Betamax van Sony en Video Home System (VHS), ontwikkeld door JVC. Later kwam daar Video 2000 van Philips nog bij. Deze drie partijen raakten verwikkeld in een hevige strijd om de wereldstandaard voor opneembare videobanden. Deze strijd noemt men de formatenoorlog, die uiteindelijk werd gewonnen door VHS omdat zij toestond dat pornofilms op haar formaat werden uitgebracht. Zie ook http://www.mediacollege.com/video/format/compare/betamax-vhs.html (geraadpleegd op 10-07-2009).
[21] http://nl.wikipedia.org/wiki/Dvd (geraadpleegd op 10-07-2009).
[22] Meer info op http://nl.wikipedia.org/wiki/HD_DVD (geraadpleegd op 10-07-2009).
[23] http://en.wikipedia.org/wiki/Blu-ray_Disc_recordable (geraadpleegd 10-07-2009).

Optische illusie?

Ultra Dense Optical (UDO)
Er is nog een optische schijf op de markt die gebruik maakt van een blauwe laser: de Ultra Dense Optical (UDO). Men onderscheidt twee groottes: UDO1 van 30Gb en UDO2 met een capaciteit van 60Gb. Men[24] geeft een gegarandeerde houdbaarheid en toegankelijkheid van de data van 50 jaar of meer. Een UDO verschilt van alle andere optische schijven omdat het een afgesloten cassette van 5.25-inch is, waarin zich een optische schijf bevindt, die wordt gelezen met een UDO-drive. UDO is speciaal bedoeld voor lange termijn archivering. UDO maakt gebruik van een 405nm blauwviolet laser en technologie die overgenomen is van de Blu-Ray. De fabrikant, Plasmon, claimt dat een UDO-drive en UDO-cassette de perfecte combinatie is van de prestaties van een magneetband[25], de houdbaarheidstermijn van een 12-inch WORM (Write Once Read Many) en de kostprijs van een optische schijf. Afbeelding 4 laat een UDO-drive en –cartridge zien.

Afbeelding 4: een UDO-drive en –cartridge Bron: http://www.cdrinfo.com (geraadpleegd 10-07-2009).



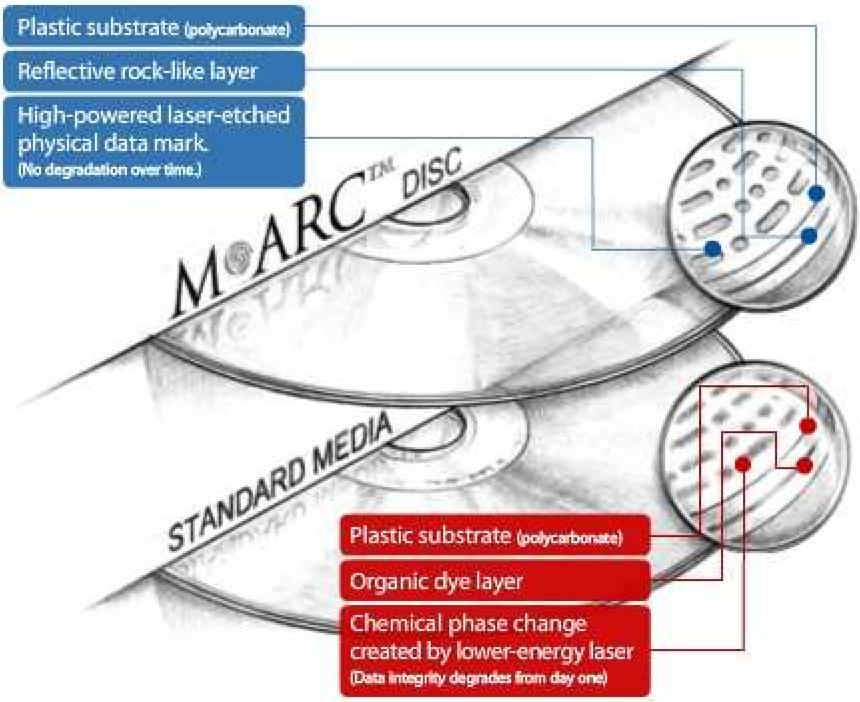
Afbeelding 5: de binnenkant van een UDO-schijf
Bron: www.cdrinfo.com/.../Plasmon/UDO_Disc_Inside.jpg (geraadpleegd 11-07-2009).

[24] http://www.plasmon.com, zie ook http://en.wikipedia.org/wiki/Ultra_Density_Optical (geraadpleegd 10-07-2009).
[25] Zie ook pagina 26 voor een uitgebreide uitleg.

Optische illusie?

M-ARC™ Disc

De meest recente ontwikkeling is een beschrijfbare optische schijf met een opnamelaag van vulkanisch glas, obsidiaan, waarin gegevens worden geëtst in plaats van gebrand. Het bedrijf Millenniata[26] heeft een optische schijf aangekondigd waarmee gegevens bij kamertemperatuur duizend jaar foutvrij zouden kunnen worden bewaard. De Millennial Disc, die eruitziet als een normale DVD, is speciaal bedoeld voor archiveringsdoeleinden en wordt beschreven met een speciale brander, die een laser bevat die in het harde materiaal kan 'etsen'. De beschreven schijf kan daarna in elke dvd-speler worden afgespeeld.



Afbeelding 6: *de verschillen tussen een conventionele optische schijf ("standard media") en een M-ARC™ Disc* bron: http://www.millenniata.com/products/m-arc.html (geraadpleegd op 13-08-2009).

"*Millenniata uses the world's first Write Once, Read Forever™technology. The Millennial Disc and Writer provide organizations a truly permanent archiving solution in the preservation of data and critical information. Millenniata's solution offers unprecedented advantages. The Millenniata solution is like no other existing technology and allows data to be archived at the point of origin. The M-ARC™ disc does not incorporate organic materials and will not delaminate or corrode under severe environmental and use conditions. It is also impervious to electro-magnetic pulses. Millenniata's technology has no specific environmental storage needs, which will drastically lower energy, space and maintenance costs*"[27].

Een probleem is dat de claim van een levensduur van 1000 jaar nog niet is bewezen. "*We testen de schijfjes momenteel met een verhoogde temperatuur en luchtvochtigheid, dompelen ze onder in zout water en voeren nog andere testen uit om de lange levensduur aan te tonen*"[28], aldus Doug Hansen, chief technical officer bij Millenniata.

[26] http://www.millenniata.com/index.html; (geraadpleegd op 13-08-2009).
[27] Email van Chris Gluch, VP Marketing & Sales-Europe, aan schrijver dezes op 12-08-2009.
[28] http://tweakers.mobi/nieuws/61359 (geraadpleegd op 13-08-2009).

Toekomstige generatie optische schijven

De opvolger van de Blu-Ray staat al in de steigers. De Chinese wetenschapper **Li Huang**[29] promoveerde in 2008 op de TU Eindhoven, op een optische schijf waar 100 Gb op past: 3,5 keer zoveel als op een Blu-Ray. Op deze schijf staan de putjes en kuiltjes nog dichter op elkaar, waardoor er meer data op een schijf past [30]. In bijlage 11 wordt de techniek van deze optische schijf behandeld.

Layer-Selection-Type Recordable Optical Disk (LS-R), een technologie om grotere hoeveelheden data op te slaan dan op DVD of Blu-Ray. Hierbij wordt gebruik gemaakt van een groot aantal datalagen op een enkele schijf[31].
In bijlage 13 wordt deze techniek beschreven.

Holographic Versatile Disc (HVD), met opslagmogelijkheden tot meerdere Terabytes. Het zou kunnen worden gebruikt voor iemands medisch dossier, inclusief alle ooit gemaakte MRI-scans. Er kunnen een half miljoen boeken van 300 pagina's op, een complete bibliotheek. De schijfjes zijn ook voor archiefdoeleinden zeer geschikt, aangezien ze een levensduur van minstens vijftig jaar zullen hebben[32].
Zie bijlage 14 voor een beknopte uitleg.

Protein-Coated Disc (**PCD**), een optische technologie waarbij een laag van licht gevoelige, genetisch gemanipuleerde, proteïne wordt aangebracht op een conventionele optische schijf. Hierdoor is het mogelijk tot 50 Terabyte aan data op één schijf op te slaan[33].

3D Optical Data Storage, is een techniek voor elke vorm van optische data archivering waarbij informatie kan worden opgenomen en/of kan worden gelezen door middel van driedimensionale lasers die in het optische opslagmedium functioneren. De laser die bij een conventionele optische schijf wordt gebruikt is tweedimensionaal en is gescheiden van de schijf. Met deze driedimensionale techniek is het mogelijk om vele Terabytes aan data op te slaan op een schijf. Er zijn nog geen commerciële producten beschikbaar maar de verwachting is dat in 2010 de eerste prototypen op de markt zullen verschijnen[34].

Nabije-veld optische opslag op schijven met een beschermlaag. Hierbij wordt een andere lens gebruikt om de opslagcapaciteit van optische data systemen te vergroten, tot voorbij de grenzen die bereikt kunnen worden met conventionele lenzen.
In bijlage 12 wordt deze techniek besproken.

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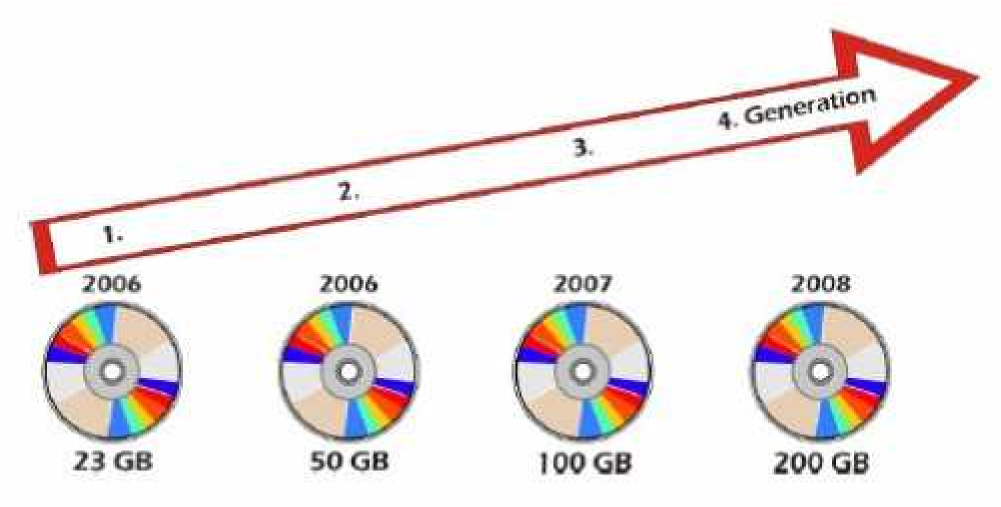
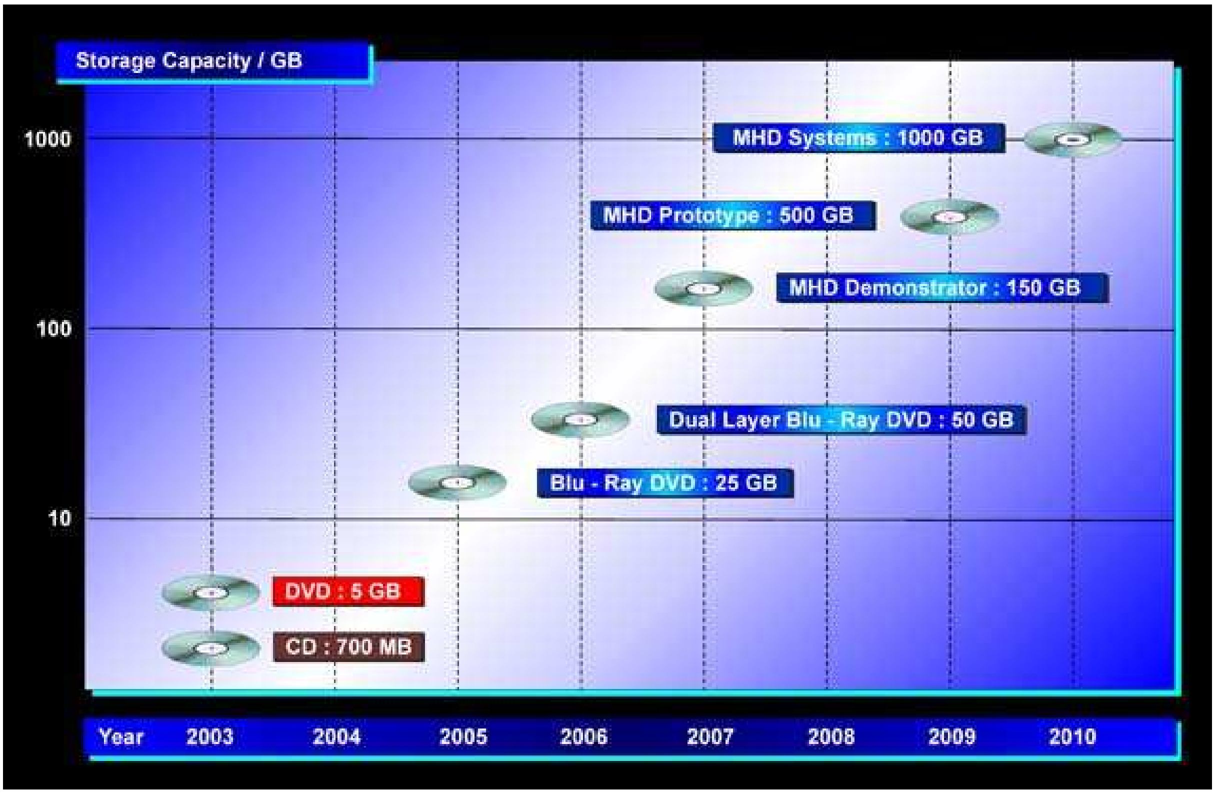
[29] http://www.sps.ele.tue.nl/members/L.Huang (geraadpleegd op 15-07-2009).
[30] http://www.bright.nl/op-de-opvolger-van-blu-ray-past-bijna-vier-keer-zoveel-data (geraadpleegd op 15-07-2009).
[31] http://en.wikipedia.org/wiki/LS-R (geraadpleegd op 15-07-2009).
[32] Deze holografische disc werkt met een in tweeën gesplitste laserstraal, waarvan één helft door een halfdoorzichtig materiaal wordt geleid. Op dat materiaal bevindt zich een raster waar de informatie in is gecodeerd. Door samenvoegen van beide stralen kan de informatie worden uitgelezen. De grote capaciteit komt door het gebruik van driedimensionale structuren, dit in tegenstelling tot de voorgangers, die zich beperkten tot tweedimensionale. De capaciteit loopt op tot maximaal 1,6Terabyte. Zie ook http://tweakers.net/nieuws/40097/holografisch-geheugen-kan-blu-ray-en-hd-dvd-bedreigen.html, http://tweakers.net/nieuws/53063/inphase-levering-holografische-opslagschijven-start-in-mei.html, http://en.wikipedia.org/wiki/Holographic_Versatile_Disc en http://www.hvd-forum.org/abouthvd/technology.html (geraadpleegd op 15-07-2009).
[33] http://en.wikipedia.org/wiki/Protein-coated_disc en http://www.abc.net.au/science/news/stories/s1680304.htm (geraadpleegd op 15-07-2009).
[34] http://en.wikipedia.org/wiki/3D_optical_data_storage (geraadpleegd op 15-07-2009). Zie ook http://en.wikipedia.org/wiki/Holographic_data_storage en http://www.wtec.org/loyola/opto/c3_s5.htm (geraadpleegd op 15-07-2009).

Optische illusie?



Afbeelding7: toename capaciteit Blu-Ray
Bron: http://www.incom-storage.nl/uploads/media/Voordelen-optical-storage-als-alternatief_03.pdf
(geraadpleegd op 16-07-2009).

De toekomstige generatie optische schijven kan een veelvoud aan data bevatten dan de vorige- en de huidige generaties schijven. Op afbeelding 10 is een weergave in een tijdlijn zichtbaar.



Afbeelding 8: tijdlijn van de grootte van optische schijven
Bron: http://www.technama.com/wp-content/uploads/2009/04/discs-timeline.jpg
(geraadpleegd op 16-07-2009).

3 Randvoorwaarden bewaarbeleid optische schijven en toegankelijkheid op lange termijn

Om de toegankelijkheid van een optische schijf op lange termijn te kunnen garanderen, moet aan vele voorwaarden en condities zijn voldaan. Omdat de ontwikkeling van een optische schijf nog steeds gaande is, zijn de hier beschreven voorwaarden gebaseerd op de huidige stand der techniek en daarom per definitie aan verandering onderhevig. Het is een eerste poging tot een verantwoord beheer en onderhoud van optische schijven, om de toegankelijkheid op lange termijn te kunnen garanderen.

Series optische schijven

Zorg voor meerdere kopieën van series optische schijven. Een serie moederexemplaren moet in een speciaal hiervoor gemaakte archiefruimte of archiefkluis worden bewaard, waar een constante temperatuur en relatieve luchtvochtigheidsgraad geldt. Deze moederexemplaren worden alleen gebruikt als een optische schijf uit een andere serie moet worden vervangen.
Een tweede serie schijven wordt gebruikt om dagelijks te worden geraadpleegd, bijv. Op een studiezaal van een archiefdienst. Deze serie gebruikersexemplaren worden op een andere plaats bewaard dan de serie moederexemplaren. Een derde serie wordt als back-up in een ander gebouw opgeslagen. Zodat bij een eventuele calamiteit (brand, overstroming) het risico wordt gespreid en men altijd een of twee serie(s) schijven beschikbaar heeft.

Omgevingsfactoren

Optische schijven gedijen het beste in een geklimatiseerde ruimte. Bij voorkeur een aparte archiefruimte, los van de ruimte waar papieren archieven zijn opgeslagen. Want de bewaartemperatuur en de relatieve vochtigheidsgraad voor papieren archieven verschilt nogal met die voor optische schijven[35]. Als een geklimatiseerde ruimte niet mogelijk is, dan geniet een geklimatiseerde kluis in een archiefruimte de voorkeur. De ideale bewaartemperatuur voor optische schijven ligt tussen de 5° en 20° Celsius. De ideale relatieve luchtvochtigheidsgraad ligt tussen de 20% en 50%[36]. Om te voorkomen dat stof in een archiefruimte komt, wordt aangeraden een antistatische mat te plaatsen. De mat moet voldoen aan ISO-TR 6356[37].

Bewaarcondities

Jewel case

Bewaar een optische schijf in een jewel case. "*Een jewel case bestaat meestal uit een doorzichtige plastic bodem en deksel. In de bodem is een (meestal ondoorzichtige) cd-houder geklemd. Die houder wordt 'tray' genoemd. Tussen de bodem en de tray is ruimte voor een informatievel ('inlay'), dat door de doorzichtige bodem leesbaar is. Aan dit vel zitten ook de rugtitels. Bij normaal gebruik worden tray en bodem niet van elkaar gescheiden en blijft het informatievel daartussen buiten bereik. In het deksel is plaats voor een boekje met informatie over de cd. Het boekje kan uitgenomen worden om het te lezen*"[38].

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[35] De ideale bewaartemperatuur voor papier is tussen de 16° en 18° Celsius, de ideale relatieve luchtvochtigheidsgraad is tussen de 30% en 55% bron: http://www.st-ab.nl/wettennr01/0036-004_Regeling_bouw_en_inrichting_archiefruimten_en_archiefbewaarplaatsen.htm (geraadpleegd op 20-07-2009).
[36] Voor meer informatie over bewaartemperatuur en relatieve luchtvochtigheid van optische schijven, zie: Byers, F. Care and Handling of CDs and DVDs – A Guide For Librarians and Archivists. Council on Library and Information Resources, National Institute of Standards and Technology (NIST), Washington DC, 2003, p. 16. Vindbaar op http://www.clir.org/pubs/reports/pub121/pub121.pdf; (geraadpleegd op 20-07-2009).
[37] Describes a method of evaluating the electrostatic propensity of all types of textile floor coverings under controlled conditions bron: http://www2.nen.nl/nen/servlet/dispatcher.Dispatcher?id=BIBLIOGRAFISCHEGEGEVENS&contentID=132811 (geraadpleegd op 20-07-2009).
[38] http://nl.wikipedia.org/wiki/Jewelcase; (geraadpleegd op 20-07-2009).

Bewaar het boekje niet in de jewel case want papier kan vocht aantrekken en zorgt voor een hogere vochtconcentratie in de jewel case. Het vocht kan in contact komen met de optische schijf waardoor de datalaag van organisch materiaal kan worden aangetast. Dit kan uiteindelijk leiden tot het onleesbaar worden van de schijf. "*Een normale jewel case meet 142 x 124 x 10,5 mm. Het boekje aan de voorkant meet precies 120x120 mm. De inlay aan de achterkant is 138 x 120 mm, met aan beide zijden een rugtitel van 6 x 120 mm*"[39]. Afbeelding 9 laat u een jewel case zien.

Afbeelding 9: een jewel case voor een optische schijf
Bron: http://www.megadiscstore.com/images/10mm_Single_Black__CD_Jewel_Case.jpg
(geraadpleegd op 20-07-2009).

Tyvek®
Een andere archiveermethode is optische schijven te bewaren in hoesjes die zijn gemaakt van Tyvek. Tyvek is een synthetisch materiaal dat bestaat uit vezels van HDPE (hoge-dichtheid-polyetheen). Het materiaal is door het bedrijf DuPont ontwikkeld. Tyvek lijkt op papier en is gewoon te beschrijven, maar scheurt niet en is vloeistofdicht en waterdampdoorlatend. Het materiaal is knipbaar en snijdbaar[40].

Brandproces

Naast de machinaal vervaardigde (geperste) optische schijven, is het ook mogelijk om zelf optische schijven te branden. "*Het branden van cd-r is een bijzonder complex proces waarbij vele factoren een rol spelen. De manier waarop een cd-r wordt gebrand bepaalt dus mede de houdbaarheid van de optische schijf*"[41]. Of zoals Dana J. Parker schrijft ""*CD recordable technology is a complex and convoluted subject. There are many factors that come into play when recording a disc: the rate of spin, the formula of the dye, the ambient temperature, the internal temperature, the age of the media, the power and wavelength of the laser, the spacing and size of the marks on the media relative to the speed of the disc, to name but a very few*"[42].

Er zijn twee methodes om optische schijven te branden:

- Het branden van bestanden vanaf een harde schijf naar een optische schijf
- Het branden van kopieën van optische schijven op een andere optische schijf.

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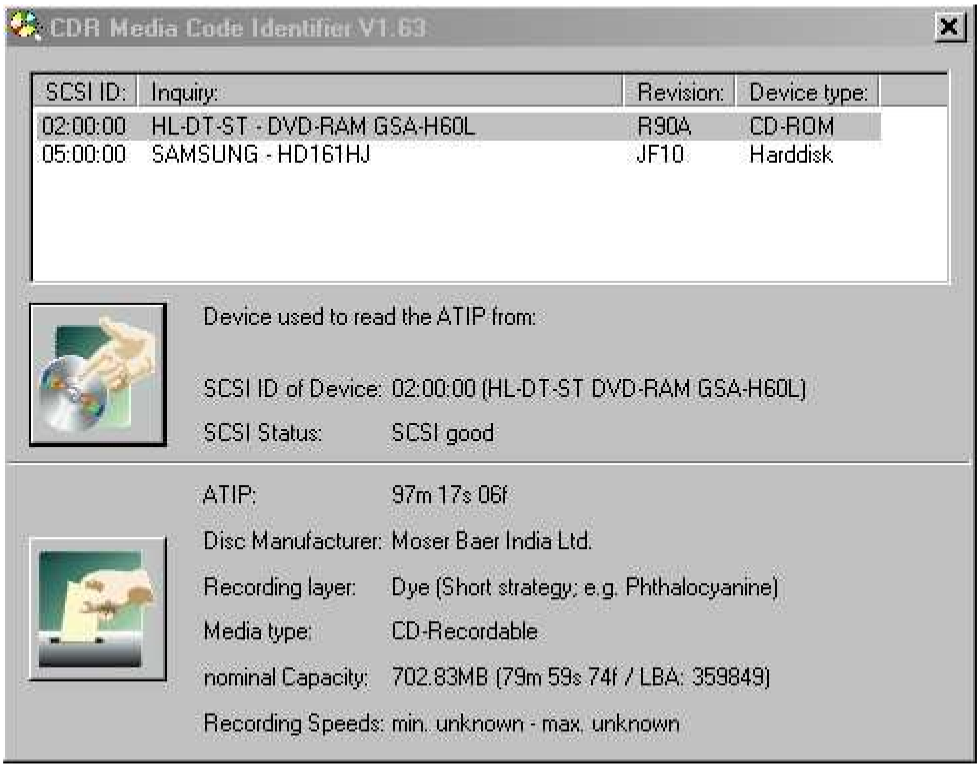
[39] http://nl.wikipedia.org/wiki/Jewelcase; (geraadpleegd op 20-07-2009).
[40] http://nl.wikipedia.org/wiki/Tyvek;
Zie ook: http://www2.dupont.com/Tyvek/en_US/products/product_landing.html (geraadpleegd op 20-07-2009).
[41] http://persons.kb.nl/rgillesse/cdrot/langetermijncdr.html; (geraadpleegd op 20-07-2009).
[42] The Rest of the Rest of the Story: Shedding Some Coherent Light on CD-R, te vinden op http://www.cd-info.com/CDIC/History/Commentary/Parker/stcroix.html; (geraadpleegd op 20-07-2009).

Soort optische schijf

Gebruik altijd professionele beschrijfbare optische schijven van een A-merk[43]. Deze schijven zijn duurder dan de merken optische schijven in de detailhandel maar ze zijn speciaal gefabriceerd voor lange termijn bewaring[44]. Er zijn voor een CDR twee varianten: een opnamecapaciteit van 650MB (74 minuten) en 700 MB (80 minuten). Een CDR met een grotere capaciteit (800MB of hoger) wordt niet aangeraden[45].

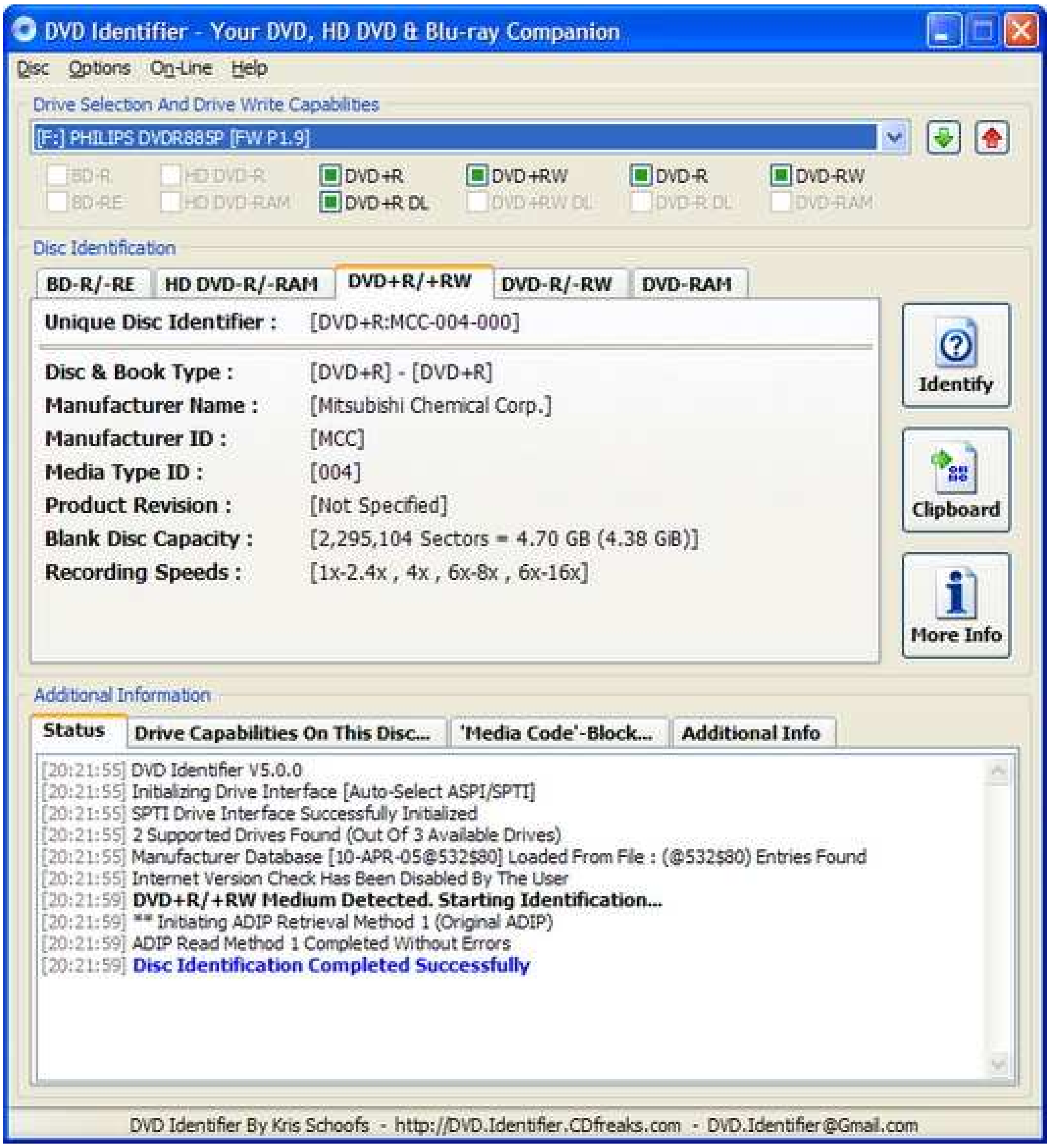
Absolute Time in Pre-groove (ATIP)

De levensduur van een optische schijf wordt in grote mate bepaald door het merk van beschrijfbare optische schijven. Om deze keuze te vereenvoudigen is het mogelijk om bepaalde informatie in de Absolute Time in Pre-groove (ATIP) van een lege schijf te achterhalen. Hierin staat bijvoorbeeld vermeld uit welke fabriek de schijf afkomstig is en welk type dye is gebruikt. "*Het dye van een cd-r is een organische laag die de data opneemt*"[46]. Er zijn twee softwareprogramma's die deze ATIP kunnen lezen: CDR Identifier (versie 1.63) en DVD Identifier (versie 5.20)[47].



Afbeelding 10: schermafdruk CDR Identifier (bron: schrijver dezes).

[43] Er zijn wereldwijd ongeveer 20 fabrieken waar beschrijfbare optische schijven worden gefabriceerd. Voor een compleet overzicht zie http://www.cdmediaworld.com/hardware/cdrom/cd_factories.shtml (geraadpleegd op 22-07-2009). Voor alle schijven zonder aanduidbaar merk zie een test op http://www.cdmediaworld.com/hardware/cdrom/cd_quality.shtml (geraadpleegd op 22-07-2009).
[44] Voor een compleet overzicht van alle beschikbare beschrijfbare optische schijven zie http://www.globalsources.com/gsol/I/CD-R-manufacturers/b/2000000003844/3000000171703/16976.htm?items_per_page=60 en http://www.instantinfo.de/showcdrhersteller_e.php; zie ook: http://www.yuden.co.jp/ut/product/disks/disks01.html; (geraadpleegd op 22-07-2009).
[45] Een testmethode van CDR is te vinden op http://ixbtlabs.com/articles/cdrdisktest/index2.html (geraadpleegd op 22-07-2009).
[46] http://cdduplicator.nl/uitleg/cdr-dye.html; (geraadpleegd op 22-07-2009). Extra achtergrondinformatie over soorten dye is te vinden op http://www.cdmediaworld.com/hardware/cdrom/cd_dye.shtml (geraadpleegd op 22-07-2009).
[47] CDR Identifier is te downloaden op http://download.chip.eu/nl/download_nl_778415.html en DVD Identifier kan worden gedownload op http://download.chip.eu/nl/DVD-Identifier-5.0.1_787349.html; (geraadpleegd op 22-07-2009).



Afbeelding 11: schermafdruk DVD- Identifier Bron: http://dvd.identifier.cdfreaks.com (geraadpleegd op 22-07-2009).

Kopie naar harde schijf

Bij het kopiëren van een optische schijf is het raadzaam eerst een kopie van de moederschijf te kopiëren naar een harde schijf. Daarna worden de data vanaf de harde schijf gebrand op een, nieuwe, lege optische schijf. Dit brandproces is weliswaar langzamer dan het "*on-the-fly*"[48] branden maar het voorkomt beschadiging van data en "bufferunderrun" waardoor het eindresultaat beter is.

Soort (re)writer

Een (re)writer is een apparaat waarmee informatie op een beschrijfbare optische schijf kan worden gebrand. Tevens kunnen er schijven mee worden gelezen. De kosten voor een (re)writer zijn maximaal 100 euro, de kosten voor een Blu-Ray (re)writer kan oplopen tot 900 euro[49].

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[48] "*Het kopiëren van CD's waarbij de kopie zonder tussenkomst van de harde schijf direct vanaf de bron wordt gekopieerd*. Bron: http://www.computerwoorden.nl/direct--14984--On-the-fly%20branden.htm (geraadpleegd op 22-07-2009).

[49] Een uitgebreide test van DVD-(re)writers is te vinden op http://compreviews.about.com/od/cddvd/tp/SATADVDBurners.htm (geraadpleegd op 23-07-2009).

Brandmethode

Er zijn twee manieren om informatie op optische schijven te branden: disc-at-once en track-at-once. Bij de 'disc-at-once' methode wordt in één keer gebrand. De laserstraal wordt pas uitgezet wanneer de schijf helemaal is beschreven. Bij de andere schrijfmethode, de 'track-at-once', wordt de laserstraal voortdurend aan- en uitgezet. Hierdoor worden soms onvolledige sectoren geschreven, waardoor E-32 fouten (= onherstelbare fouten na foutcorrectie) ontstaan[50]. "*De brandsoftware moet zo worden ingesteld dat de optische schijf volgens de methode 'disc-at-once' wordt gebrand. Deze schrijfwijze benadert het beste de kwaliteit van de geperste optische schijf*"[51].
Overburning ofwel het beschrijven van een lege optische schijf boven zijn aangegeven capaciteit wordt te allen tijde afgeraden. Om het beste resultaat te verkrijgen is het raadzaam niet meer dan 600MB (ongeveer 60 minuten) te branden.

Brandsnelheid

Hoe langzamer de brandsnelheid, hoe beter het eindresultaat. De maximumsnelheid om een optische schijf te branden is 16-speed, ook al kunnen (re)writers een veelvoud van deze snelheid aan.

Buffer Underrun

Een van de grootste problemen bij het branden van een optische schijf, is een "buffer underrun". Buffer underruns doen zich voor wanneer de data niet snel genoeg wordt aangevoerd tijdens het branden. Om dit op te vangen moet de (re)writer vanaf het begin een zekere hoeveelheid data in de buffer inladen. Deze buffer fungeert dan als een soort brug ten opzichte van enerzijds de datatoevoersnelheid en anderzijds de datauitvoersnelheid. De nieuwste (re)writers gebruiken de meest recente technologische ontwikkeling om deze buffer-underrun problemen teniet te doen. Deze technologie wordt de Burn-Proof (Buffer Under RuN Proof) technologie genoemd[52].

Computerverbinding

Branden van optische schijven moet altijd gebeuren op een PC die niet is aangesloten op een netwerk. Elke invloed op het brandproces (denk aan antivirussoftware bij een internetverbinding, met een constante in- en uitvoer van data) moet worden voorkomen. Ook een schermbeveiliging wordt niet aanbevolen. Alle processorkracht moet kunnen worden aangewend voor het brandproces.

Brandprogramma

Er zijn gratis brandprogramma's[53] als programma's waarvoor moet worden betaald[54], om optische schijven te kunnen branden. Er zijn echter twee programma's die meer aandacht besteden aan het brandproces:

- Exact Audio Copy (EAC)[55];
- Accuburn-R CD Data Protector[56].

EAC is gemaakt om de best mogelijke kopie van een audiocd te maken.

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[50] Meer info over E32 fouten op: http://www.mscience.com/faq16.html (geraadpleegd op 23-07-2009).
[51] Zie ook http://en.wikipedia.org/wiki/Optical_disc_recording_modes (geraadpleegd op 23-07-2009).
[52] http://cdduplicator.nl/uitleg/burnproof.html (geraadpleegd op 23-07-2009).
[53] Voor een overzicht van gratis brandprogramma's zie http://download.cnet.com/windows/cd-burners/?&filter=licenseName="Free"|&tag=ltcol;narrow, http://download.chip.eu/nl/Brandprogramma_s_713088.html, http://www.snapfiles.com/Freeware/gmm/fwcdburn.html en http://www.freeprogrammingresources.com/cd-burning-freeware.html (geraadpleegd 03-09-2009)
[54] Voor een overzicht zie http://en.wikipedia.org/wiki/List_of_optical_disc_authoring_software (geraadpleegd op 23-07-2009).
[55] http://www.exactaudiocopy.de/ en een handleiding op http://www.snelrennen.nl/eac.php (geraadpleegd op 23-07-2009).
[56] http://www.infinadyne.com/accuburn-r.html; (geraadpleegd op 23-07-2009).

Optische illusie?

Accuburn is ontwikkeld om data op een optische schijf voor een langere termijn te archiveren. Het voert na het brandproces een controle uit tussen het gebrande bestand en het originele bestand.

Het programma maakt bovendien onderscheid tussen drie verschillende brandmethodes:

- *"Archival – Storing data for long term preservation;*
- *Backup – Storing data for short-term emergencies;*
- *Data transport – Moving data on CDS and DVDs between computers"*[57].

"AccuBurn-R can be used in a variety of ways, depending on the needs of the user. There are several different ways to configure AccuBurn-R to most effectively use it and the information presented here will help you to choose the right configuration. The first step is to choose how you are planning on using AccuBurn-R. If there is any doubt about how this works, it is recommended to follow all of the links and read all of the descriptions. Select one of the techniques below.
It is important to understand that unlike all other CD and DVD writing software, AccuBurn-R's mission is data reliability. When you write to a CD or DVD there is no automatic verification by the drive - it just writes. No checking whatsoever is done automatically. AccuBurn-R changes that and checks everything by default. The result is more reliable storage for backups and archives.
A side effect of this reliability is that it will leave some of the disc unused for the possibility of writing corrections to improperly written data. This can result in AccuBurn-R not using all of the space on a disc in some circumstances. If you absolutely must use all of the space on a disc, turn off verification"[58].

Beschrijven van optische schijven

Elke methode om optische schijven te voorzien van tekst wordt afgeraden omdat zelfklevende etiketten en ook CDR-pennen organisch materiaal bevatten, die de reflectielaag van een schijf kan aantasten. Ook de methode om tekst in een optische schijf te etsen, Lightscribe[59], wordt afgeraden want de reflectielaag kan worden aangetast, waardoor data ontoegankelijk kan worden.

Periodieke controles van optische schijven

Om de toegankelijkheid van optische schijven op langere termijn te kunnen garanderen is periodieke controle noodzakelijk. Dit kan door alle schijven af te spelen en/of door ze uit het doosje te halen en te controleren op beschadigingen (fysieke controle). Het wordt aangeraden minimaal één keer per jaar zowel een fysieke controle te doen, als alle schijven af te spelen. Een extra mogelijkheid is het gebruik van een analyseapparaat, zoals een DVD-Analyzer[60].

Mochten er beschadigde optische schijven zijn, dan zijn er softwareprogramma's die beschadigde bestanden kunnen herstellen. In bijlage 5 vindt u een overzicht van deze software.

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[57] Handleiding Accuburn-R, (geraadpleegd op 23-07-2009).

[58] Handleiding Accuburn-R, (geraadpleegd op 23-07-2009).

[59] LightScribe is een optische schrijftechniek die gebruik maakt van speciaal gecoate, cd's en dvd's om lasergeëtste labels te maken. Het oppervlak van LightScribe schijf is bedekt met een reactief laagje dat van kleur verandert wanneer het licht absorbeert van een 780nm infrarood laser. Deze labels blijven jaren goed als je ze in gewoon daglicht zou leggen, maar meestal worden optische media in het donker bewaard zodat de labels zeker meer dan een paar jaar stand houden, zie http://nl.wikipedia.org/wiki/LightScribe; (geraadpleegd op 23-07-2009).

[60] Een aantal DVD-Analyzers is te vinden op: http://www.datarius.com/products/measure/Pre-recordedDVDAnalysisTestingwithDaTAVIEWCS-5.html; http://www.mediatechnics.com/pages/cda.htm; http://www.miteklab.com.tw/eng/expert.htm; http://www.audiodev.com/?id=5672; http://www.opticalmediacorp.com/index.php/exe/cms/name/shuttleplex; http://www.cloversystems.com/DVX.htm; (geraadpleegd op 23-07-2009).
Voor een uitvoerige uitleg van een DVD-Analyzer, zie bijlage 2 - Keulemans, E.J. *To burn or not to burn? That's the question! Een onderzoek naar een doeltreffend en doelgericht bewaarbeleid voor optische gegevensdragers – succes- en faalfactoren bij Zeeuwse archiefdiensten.* Provincie Zeeland; Middelburg, 2009, p. 18.

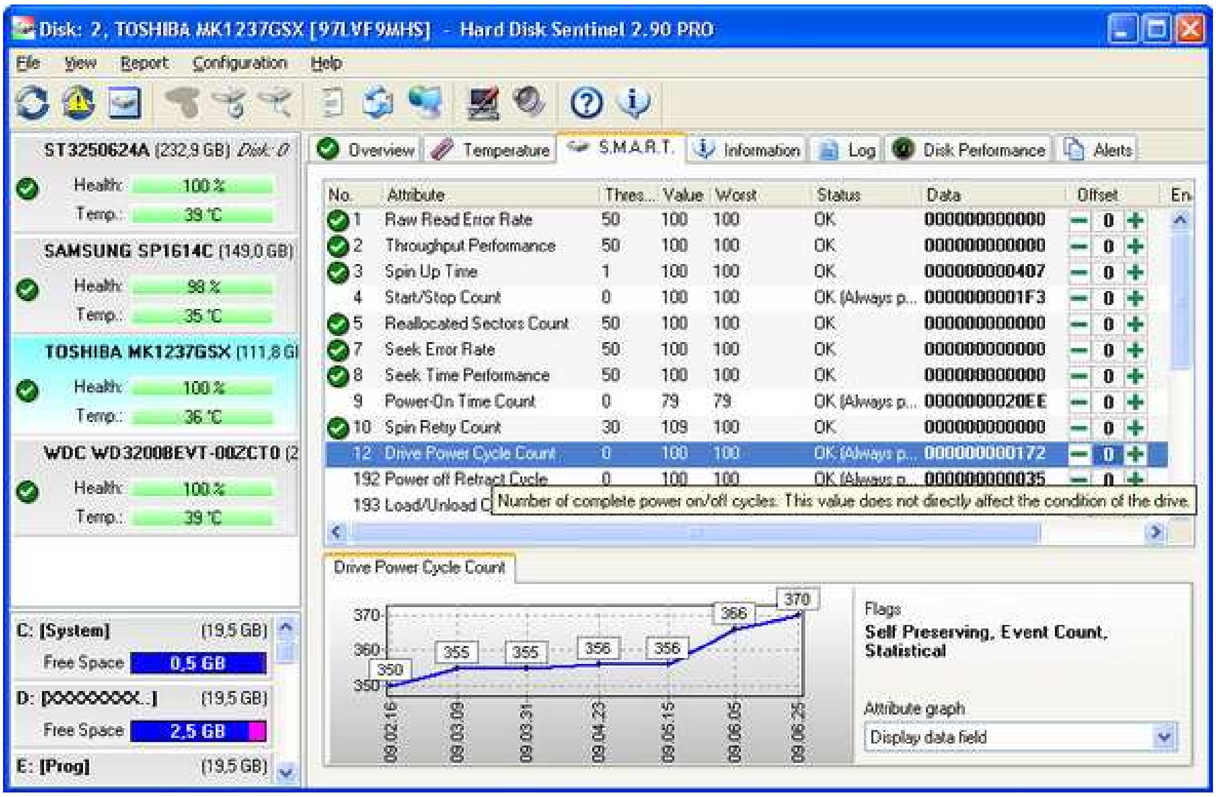
4 Alternatieve opslagmedia

Zes Zeeuwse archiefdiensten overwegen om de data van optische schijven over te zetten naar alternatieve opslagmedia[61]. Wat zijn de alternatieven voor opslag van data voor lange termijn?

Harde schijf

Een harde schijf is een vorm van geheugen, een computeronderdeel waarop gegevens bewaard kunnen worden. Er zijn in- en externe harde schijven. Een interne harde schijf zit in de computer en is niet te verplaatsen, terwijl een externe harde schijf wel eenvoudig te verplaatsen is en dus op een andere computer kan worden aangesloten.
Gegevens die op de harde schijf zijn opgeslagen, blijven over het algemeen minstens 10 jaar intact. De levensduur van een harde schijf hangt af van de temperatuur en mechanische schokken. Bij de desktopcomputer die stil staat hoeft alleen op de temperatuur gelet te worden. Een vuistregel is dat bij iedere 10 graden hogere temperatuur de levensduur halveert[62].

Om de levensduur van een harde schijf te kunnen controleren heeft het bedrijf Compaq de S.M.A.R.T methode ontwikkeld. "***S.M.A.R.T.*** *oftewel* ***S****elf-****M****onitoring,* ***A****nalysis, and* ***R****eporting* ***T****echnology is een monitoringsysteem voor harde schijven, ontwikkeld om indicatoren voor betrouwbaarheid in de gaten te houden in de hoop defecten aan de schijven te kunnen anticiperen*[63]. Op afbeelding 12 is een schermafdruk van een programma met S.M.A.R.T. zichtbaar.



Afbeelding 12: Softwareprogramma Hard Disk Sentinel met S.M.A.R.T. Bron: http://www.hdsentinel.com/screenshots.php (geraadpleegd 01-09-2009).

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[61] Zie bijlage 2: Keulemans, E.J. *To burn or not to burn? That's the question! Een onderzoek naar een doeltreffend en doelgericht bewaarbeleid voor optische gegevensdragers – succes- en faalfactoren bij Zeeuwse archiefdiensten.* Provincie Zeeland; Middelburg, 2009, p. 13.
[62] http://nl.wikipedia.org/wiki/Harddisk (geraadpleegd op 15-08-2009).
[63] http://nl.wikipedia.org/wiki/S.M.A.R.T. (geraadpleegd op 01-09-2009).

Het is ook mogelijk een server[64] te gebruiken. Er zijn vele soorten servers, afhankelijk van het doel waarvoor de data op de harde schijven in die servers worden gebruikt. Om gegevensverlies bij een falende harde schijf te beperken, is het mogelijk om meerdere schijven 'aan elkaar te koppelen' in een server. Dit noemt men Redundant Array of Independent Disks (RAID). Het is "*een set methodieken voor fysieke data-opslag op harde schijven waarbij de gegevens over meer schijven verdeeld worden, op meer dan 1 schijf worden opgeslagen, of beide, ten behoeve van snelheidswinst en/of beveiliging tegen gegevensverlies*". Men onderscheidt verschillende Raidconfiguraties. In bijlage 10 staan alle Raidconfiguraties met plus- en minpunten vermeld.

Solid State Drive

Een solid state drive (SSD), zoals een USB-stick, is een apparaat om gegevens te bewaren met behulp van niet-vluchtig geheugen zoals flash of vluchtig geheugen zoals SDRAM. Een SSD wordt gebruikt in een computer waar normaliter een harde schijf werd gebruikt. Voordeel aan een SSD is, dat het geen bewegende onderdelen heeft waardoor de toegangstijd zeer klein is, en zich geen mechanische problemen kunnen voordoen. De opslagcapaciteit wordt steeds groter: de eerste USB-stick uit 2000 kon 8 MB aan data bevatten, het meest recente exemplaar heeft een capaciteit van 256Gb[65].

Magneetband

Een magneetband bestaat uit een band van kunststof waarop een dunne laag magnetiseerbaar materiaal is aangebracht en waarvan de magnetische deeltjes met een magneet (de schrijfkop) in een bepaalde richting gemagnetiseerd kunnen worden. Er ontstaat op de band een heel klein magnetisch veld. Door een leeskop kan het magnetische veld van de deeltjes later worden gelezen en worden vertaald in elektrische stroom. Op deze manier kan informatie worden opgeslagen in de magnetische polarisatie van de deeltjes, en later worden teruggelezen. De informatie kan zowel analoog als digitaal worden opgeslagen.

Tapedrive

Een tapedrive is een apparaat dat vaak wordt gebruikt om back-ups op magneetband te kunnen maken. De huidige magneetband zit in een cassette die gemakkelijk kan worden verwisseld en een hogere opslagcapaciteit heeft dan een beschrijfbare OS. Het is daarom een veelgebruikt medium voor het veiligstellen en archiveren van grote hoeveelheden data. Magneetbanden en tapedrives zijn er in vele soorten en maten. De data worden bij de huidige systemen digitaal op de band opgeslagen.

Verschillen bestaan in de manier van beschrijven en lezen van de band:

- lineair: de band wordt langs een stilstaande kop getrokken (MLR, Travan, DLT, LTO en ADR)
- helical scan: de band loopt langs een trommel waarin een kop ronddraait (DAT/DDS, AIT, VXA en Exabyte).

Drie soorten tape worden gebruikt:

- Advanced Intelligent Tape (AIT)[66], grootte van 25Gb – 800Gb.
- Lineair Tape Open (LTO)[67], grootte van 100Gb tot 800Gb.
- Digital Linear Tape (DLT)[68], grootte van 10Gb – 40Gb.

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[64] http://nl.wikipedia.org/wiki/Server (geraadpleegd op 16-08-2009).
[65] "*Nadat Kingston eerder al een 128GB USB stick had uitgebracht komen ze nu met een USB stick met 256GB opslagruimte. De USB stick zal de naam DataTraveler 300 met zich mee dragen, heeft een USB 2.0 aansluiting en is 70,68x22,37x16,45mm groot. Door het slide mechanisme is er geen beschermkapje nodig. De USB maakt gebruik van Windows ReadyBoost en heeft een lees snelheid van 20MB/s en een schrijf snelheid van 10MB/s. Bij de USB stick wordt Password Traveler software bijgeleverd waardoor je je USB stick kunt beveiligen met een wachtwoord*" Bron: http://www.bouweenpc.nl/nieuws/2667 (geraadpleegd op 16-08-2009).
[66] http://www.tech-faq.com/ait.shtml; (geraadpleegd op 16-08-2009).
[67] http://www.tech-faq.com/lto-tape.shtml; (geraadpleegd op 16-08-2009).
[68] http://www.tech-faq.com/dlt.shtml; (geraadpleegd op 16-08-2009).

Hoewel op de grootste tapes dus 800 GB kan worden opgeslagen, is dit zelden genoeg voor grote datahoeveelheden van honderden terabytes. Om dit probleem op te lossen worden tapeloaders en taperobots ingezet, apparaten waarin één of meer tapedrives gecombineerd zijn met een mechanisme om de cassettes uit een houder of rek in de eigenlijke tapedrive, en na gebruik weer terug, te plaatsen. Grote zgn. tape libraries kunnen tot wel 70.000 tapes bevatten[69].

Silicon Carbide

Mitsubishi heeft een technologie ontwikkeld die het mogelijk maakt om data te graveren op plaatjes van 10 x 10 cm van zgn. Silicon Carbide (SiC). Deze SiC-plaatjes zijn geschikt om belangrijke informatie langdurig te bewaren en zonder hulpmiddelen te raadplegen. Het zijn een soort keramische informatiedragers waarop inscripties zijn aangebracht. Silicon Carbide is na diamant een van de hardste materialen en heeft een sterke weerstand tegen hitte, slijtage en chemische invloeden. De informatiedragers worden gegraveerd door middel van lasertechniek. Bij een lettertype met 2-punts characters kunnen in totaal zes A4-tjes worden weggeschreven op één SiC-plaatje van 10 x 10 cm. De aan beide zijden gegraveerde plaatjes zien er uit als een moderne variant van de vroegere kleitabletten. Of deze informatiedrager een duurzame toekomst heeft moet worden bezien[70].

[69] Zie pagina 25 voor een uitgebreide beschrijving van het grootste formaat tapedrive: een tape library.
[70] Voor meer informatie zie http://www.vhic.nl/default.asp?A1PID=1326PTMC&A1SID=249020079&FOLDER=323BTMC (geraadpleegd op 16-08-2009).

5 Casestudy: Onderzoek naar bewaarbeleid in de praktijk

In de maanden juli en augustus 2009 zijn vijf organisaties (hierna **O1, O2, O3, O4 en** O5) uitgenodigd voor een interview over het beheer, het onderhoud, de toegankelijkheid en bewaarbeleid van optische schijven. Met deze organisaties is afgesproken dat de onderzoeksgegevens volledig geanonimiseerd zullen worden verwerkt. O1, O2, O4 en O5 hebben optische schijven in hun collectie, O3 heeft geen optische schijven maar bewaart haar data op een alternatief opslagmedium. O5 heeft naast optische schijven ook nog een alternatief opslagmedium voor haar data.

Aantal OS

O1 heeft ongeveer 1200 optische schijven in haar collectie, het grootste gedeelte is gerelateerd aan een papieren dossier uit het dynamisch of het semi-statisch archief.
O2 bewaart ruim 6800 optische schijven (audio-cd's) en ca. 2200 data-cd's in haar collectie dus totaal circa 9000 optische schijven. De audio-cd's zijn radio-opnamen van lokale radiostations.
O4 heeft 638 UDO-schijven[71] in een E-depot, waarop 13 miljoen (wetenschappelijke) publicaties (10Tb), 20 miljoen krantenpagina's en 3000 complete websites uit het .nl-domein zijn gearchiveerd. Deze UDO-schijven hebben een totale grootte van 30 Terabyte, met een maximale uitbreiding naar 500Tb.
O5 heeft een paar duizend optische schijven waarop allerlei verschillende soorten data is gearchiveerd.

Bewaarcondities

O1 heeft haar optische schijven in twee, afgesloten kasten (zie pagina 15), in de archiefkelder staan. Alle schijven zitten in plastic doosjes, jewelcases[72] genaamd, met het papieren hoesje erbij gevoegd. Op de buitenkant van de jewelcase is een stuk papier bevestigd met additionele informatie. Alle schijven worden in dezelfde kelder bewaard als de papieren archieven, waar een bewaartemperatuur tussen 15° en 17° Celsius en een relatieve luchtvochtigheidsgraad van ca. 55% heerst. Daarnaast heeft men nog ca. vijftig gouden optische schijven voor langdurige bewaring, waarop planologische tekeningen en waterstaatstekeningen zijn gebrand. Per jaar worden ca. 400 á 500 optische schijven tezamen met papieren dossiers ten behoeve van archivering aangeleverd.
De schijven van **O2** staan in diverse kelders, waar tevens de papieren archieven zijn gearchiveerd, alle schijven zijn opgeborgen in een hoesje van TYVEK[73]. De bewaarcondities zijn ook hier een bewaartemperatuur tussen 15° en 17° Celsius en een relatieve luchtvochtigheidsgraad van ca. 55%.
O4 heeft alle data op UDO-schijven staan in een E-depot, waarin het 19° Celsius is en een relatieve luchtvochtigheidsgraad heerst van 40% - 45%.
Van **O5** zijn geen specifieke bewaarcondities bekend.

Meerdere series optische schijven

O1 heeft geen series kopieën van haar optische schijven maar slechts 1 unieke schijf bij elk papieren dossier. **O2** heeft meerdere series kopieën optische schijven in haar collectie. De data van O2 staat ook op een andere locatie. Dit doet men om de kwetsbaarheid van de data te verminderen. Daarnaast heeft O2 een back-up[74] en wordt databeveiliging toegepast. De bewaarkopieën staan in het depot, de gebruikerskopieën staan op de studiezaal.
O4 heeft een identieke serie op tape (back-up) die in hetzelfde gebouw staat. Daarnaast heeft men een zgn. offside back-up op tape die op een andere locatie staat.
O5 heeft soms identieke series van haar OS of deze data op een alternatief opslagmedium gearchiveerd.

[71] Zie p. 10 voor beschrijving van deze speciale Blu-Ray schijf.
[72] Zie p. 15 voor uitleg over dit plastic doosje.
[73] Zie p. 15 voor uitleg over TYVEK.
[74] http://nl.wikipedia.org/wiki/Back-up; (geraadpleegd op 18-07-2009).

Optische illusie?

Onderhoud en controle

Aan het onderhoud en de controle van optische schijven wordt door zowel **O1** als **O2** nagenoeg geen aandacht besteed. O1 maakt wel kopieën van oudere schijven maar een intensieve controle hiervan ontbreekt. **O2** heeft wel de intentie om een controle uit te voeren voor de optische schijven die blijvend moeten worden bewaard. Maar hieraan wordt momenteel geen prioriteit gegeven. **O4** houdt periodieke controles van haar optische schijven. **O5** voert geen enkel onderhoud uit naar de optische schijven in haar collectie maar men is wel bezig met het overzetten van data op andere opslagmedia.

Alternatieve opslagmedia

O1 heeft geen behoefte aan het overzetten van de data van een optische schijf naar een alternatief opslagmedium. De door hen beheerde optische schijven zijn meestal gerelateerd aan een papieren dossier uit het dynamisch- of semi-statisch archief. Volgens de vigerende selectielijst[75] kan een groot gedeelte van deze dossiers op termijn worden vernietigd, waardoor het overzetten van de data op een alternatief opslagmedium niet noodzakelijk is. De voor blijvende bewaring in aanmerking komende optische schijven wil men te zijner tijd overdragen aan een archiefdienst. **O2** is van plan om alle data die nu op optische schijf wordt bewaard, binnen enkele jaren over te zetten op servers[76] voor intranet, internet en E-depot[77]. **O4** heeft de back-up van haar data op tape staan en geeft aan dat haar data om de circa 3 jaar moeten worden gemigreerd[78] naar een ander opslagmedium. **O5** heeft data op interne netwerkschijven staan, in de toekomst worden alle data overgezet naar een opslagmedium in een nog te bouwen E-depot.

Afbeelding 13: kasten waarin de OS van O1 worden bewaard (bron: foto gemaakt door medewerker van O1).

[75] http://www.lopai.nl/pdf/selectielijst_provinciale_organen_2005.pdf; (geraadpleegd op 18-07-2009).
[76] http://nl.wikipedia.org/wiki/Server; (geraadpleegd op 18-07-2009).
[77] www.gemeentearchief.rotterdam.nl/content/index.php?option=com_content&task=view&id=281&Itemid=304; (geraadpleegd op 18-07-2009).
[78] Migreren is het overzetten van data van het ene opslagmedium naar het andere opslagmedium.

Optische illusie?

O3

O3 heeft geen optische schijven in haar collectie meer[79] maar zij heeft alle data op een alternatief opslagmedium gearchiveerd. Dit is een digitale datatape; een magnesiumband[80] waarop, afhankelijk van de gekozen standaard, 200Gb - 1600Gb kan worden opgeslagen. Deze datatapes staan in zgn. tape libraries (bibliotheek van banden) van Storagetek[81], waarin duizenden tapes liggen opgeslagen. Robotarmen in de tape library zorgen er automatisch voor dat een bepaalde tape uit een houder wordt gehaald en in een afspeelapparaat wordt geplaatst. Daarna kan het video- of radiosignaal via een glasvezelverbinding worden uitgezonden. Er is plaats voor maximaal 70.000 tapes; momenteel is 2 petabyte[82] aan data beschikbaar en heeft men ruimte voor nog eens 6 petabyte.

O3 heeft als wettelijke taak het, in opdracht van alle 24 publieke omroepen, uitzenden van radio- en televisieprogramma's. Per jaar 9000 uur televisie- en 30.000 uur radio-uitzendingen. Alle programma's worden opgeslagen op digitale datatape. Men slaat geen gegevens op optische schijven op, omdat dit volgens hen te kostbaar is en te moeilijk in beheer, toegankelijkheid en onderhoud.
Het probleem voor O3 is het ontbreken van een wereldstandaard om grote hoeveelheden data op te slaan. Daarom kiest men voor een oplossing die kostenbesparend en gebruikersvriendelijk is: een digitale magnesiumband met daarop digitale data. Volgens O3 is dit goedkoper dan de data opslaan op harddisks in servers. Bovendien verbruikt deze digitale datatape-methode minder stroom.

Afbeelding14: tapelibrary van O3 waarin duizenden digitale datatapes zijn opgeslagen.
(Bron: foto gemaakt door medewerker van O3).

[79] Men heeft in het verleden wel gegevens opgeslagen op optische schijf: een 2 jaar durende proef tussen 1998-2000, in opdracht van een telecombedrijf, waarbij al het internetdataverkeer van 1000 gebruikers in zgn. jukeboxen werd opgeslagen (een paar duizend optische schijven). Deze optische schijven zijn na 5 jaar weggegooid want er werd niets meer mee gedaan.
[80] http://nl.wikipedia.org/wiki/Magneetband; (geraadpleegd op 18-07-2009).
[81] http://en.wikipedia.org/wiki/Storage_Technology_Corporation; (geraadpleegd op 18-07-2009).
[82] "*Een petabyte, afgekort PB, is 1000 terabytes ofwel 1.000.000.000.000.000 bytes (1015 B). Een petabyte aan informatie komt ongeveer overeen met een toren van 1,8 km hoog van gestapelde cd-romschijven zonder doosje*" bron: http://nl.wikipedia.org/wiki/Petabyte; (geraadpleegd op 18-07-2009).

Toegankelijk houden van data voor toekomst

O1 blijft optische schijven als drager gebruiken omdat de meeste optische schijven onderdeel uitmaken van een papieren dossier. Wel wil men meer aandacht gaan besteden aan de optische schijvendie, tezamen met het papieren dossier, voor blijvende bewaring in aanmerking komen. Men overweegt om, naast een periodieke fysieke controle, een DVD-Analyzer aan te schaffen.

O2 blijft optische schijven als drager gebruiken maar binnen een paar jaar moeten alle data zijn overgezet naar een alternatief opslagmedium. De uitgangspunten daarbij zijn: standaard en open bestandsformaat en eenvoudig toegankelijk. Men wil meerdere servers aanschaffen voor intranet, internet en E-depot. Een 3-jaarlijkse migratie naar een ander medium wordt ingecalculeerd.

O3 gebruikt magnetische datatapes als opslagmedium en is voornemens dat ook te blijven doen. Optische schijven zijn voor hen geen optie vanwege de grote hoeveelheden data die moeten worden gearchiveerd, gecombineerd met de frequente uitleen van data. Men realiseert zich dat magnetische banden weliswaar ook aan slijtage onderhevig zijn. Maar men prefereert dit opslagmedium boven optische schijven vanwege het gebruikersgemak en de grotere opslagcapaciteit.

O4 gebruikt UDO-schijven in een E-depot en houdt rekening met regelmatige migratie naar andere opslagmedia.

O5 heeft het grootste gedeelte van haar data op interne netwerkschijven of externe harde schijven staan. Dit is geen bewuste maar een pragmatische keuze. De kosten spelen een rol maar ook het gebruikersgemak en het referentiekader: iedereen doet het. O5 kiest voor een NAS[83] en een E-depot omdat andere opslagmedia een beperkte opslagcapaciteit hebben en teveel onderhoud vergen Uiteindelijk worden alle data toegankelijk via E-depot waarin alle werkprocessen, afspraken en strategieën samenkomen. En men heeft een Digitaal Restauratie Atelier in voorbereiding, met als doel het opsporen van allerlei (optische) dragers van digitaal materiaal die, indien nodig, worden opgelapt en uiteindelijk worden opgenomen in het E-depot.

[83] "*NAS is een Network-attached storage en staat voor een opslagmedium dat op het netwerk aangesloten is. Dit systeem maakt gebruik van het TCP/IP protocol voor de dataoverdracht. NAS-apparaten zijn in feite volwaardige fileservers. Bij NAS wordt het bestandssysteem beheerd vanuit het NAS-systeem zelf, in tegenstelling tot SAN, waarbij het bestandssysteem beheerd wordt door servers. NAS is ontwikkeld door storage leverancier NetApp. NAS-systemen kunnen gebruikmaken van meerdere harde schijven die vaak in RAID staan. Tegenwoordig (2006) zijn er NAS-systemen in de handel die qua opbouw nauwelijks verschillen van externe USB-schijven. Met behulp van eenvoudige PC-hardware en een pakket als FreeNAS kan zelf een NAS-systeem opgebouwd worden. Grotere NAS-systemen zijn vaak servers die speciaal voor deze taak ontworpen zijn en een voor opslag geoptimaliseerde variant van een Operating system als Windows of Linux draaien. Bij dergelijke grote NAS-systemen zijn vaak ook voorzieningen voor het maken van back-ups ingebouwd. De alternatieven voor NAS zijn Direct-attached storage (DAS), waarbij het opslagmedium direct aangesloten is op een computersysteem, en Storage area network (SAN) systemen, waarbij de opslag (net zoals NAS) in een extern opslagsysteem gebeurt dat via een netwerk benaderd kan worden*" Bron: http://nl.wikipedia.org/wiki/Network-attached_storage (geraadpleegd op 20-07-2009).

6 Conclusies en aanbevelingen

Conclusies

1. Goed beheer begint bij vastgesteld bewaarbeleid, waarin de uitgangspunten van het beheer en het onderhoud van optische schijven worden beschreven en waarin de risico's van mogelijk informatieverlies worden benoemd. Ook moet bewaarbeleid voorzien in een regelmatige migratie naar een ander opslagmedium en moet aandacht worden besteed aan de kwaliteit van de digitale data, door regelmatige controle van de bitstream.

2. De "*randvoorwaarden bewaarbeleid optische schijven en toegankelijkheid op lange termijn*" hebben zichtbaar gemaakt dat aan bewaarbeleid van optische schijven vele voorwaarden en eisen zijn verbonden. Het is de combinatie van deze factoren die bepalend zijn voor de uiteindelijke levensduur van de optische schijf en de toegankelijkheid van de data op lange termijn. Een cruciale factor is het brandproces en een lege beschrijfbare optische schijf van goede kwaliteit. Ook is het noodzakelijk dat optische schijven in meerdere identieke series op diverse locaties worden bewaard, zodat bij een eventuele calamiteit het risico op dataverlies tot een minimum wordt beperkt.

3. Ondanks de aanwezigheid van alternatieve opslagmedia, geniet de optische schijf nog steeds de voorkeur om data voor langere termijn op te slaan. Een optische schijf is goedkoop in aanschaf, eenvoudig te gebruiken en heeft relatief een lange levensduur. Als bovendien aan de "*randvoorwaarden bewaarbeleid optische schijven en toegankelijkheid op lange termijn*" wordt voldaan en aandacht wordt geschonken aan bewaarbeleid voor optische schijven, kan de optische schijf als opslagmedium voor data nog vele jaren mee.

4. De technische ontwikkeling van de optische schijf is nog in volle gang. Toekomstige generaties hebben een grotere opslagcapaciteit en haar componenten worden steeds geavanceerder. De meest recente optische schijf bevat geen datalaag van organisch materiaal maar heeft een opnamelaag van glas waarin de data worden geëtst, waardoor de toegankelijkheid van de data op lange termijn aanzienlijk kan toenemen.

5. In een digitaal tijdperk hebben digitale opslagmedia een constante zorg nodig. Dit begint bij een weloverwogen keuze voor het soort opslagmedium en de ingecalculeerde risico's op mogelijk dataverlies in de toekomst. Maar welk opslagmedium men ook kiest, ieder opslagmedium is aan slijtage onderhevig en periodieke controle van zowel het medium zelf, als van de hierop aanwezige data (bitstream) is noodzakelijk. En een regelmatige migratie naar een nieuw opslagmedium is onvermijdelijk.

6. Bij aanvang van dit onderzoek werd verondersteld dat alle organisaties een bepaalde hoeveelheid optische schijven in hun archiefcollecties zouden hebben. Ook bestond het vermoeden dat men meerdere series schijven zou hebben. Dat echter alle optische schijven aan een periodieke controle zouden worden onderworpen, om de toegankelijkheid van de data op langere termijn te kunnen garanderen, is voor de meeste organisaties nog een toekomstig scenario.

7. De uitkomsten van de interviews in hoofdstuk 3 baren zorgen. Optische schijven worden te weinig periodiek gecontroleerd en er is geen bewaarbeleid voor optische schijven. Meerdere identieke series van optische schijven ontbreken. Hoopgevend is echter dat bij een aantal organisaties deze data op een ander opslagmedium als back-up zijn gearchiveerd. Maar het algemene beeld dat aan optische schijven onvoldoende aandacht wordt besteed is verontrustend.

8. Het vertrouwen dat men al te vaak heeft in een technische geavanceerd ogende optische schijf als informatiedrager is dan ook gezichtsbedrog. Het lijkt alsof alle informatie op termijn nog aanwezig is, maar na een paar jaar blijkt alles volledig te zijn opgelost.

Aanbevelingen

1. Om een weloverwogen keuze te kunnen maken voor een opslagmedium en de toegankelijkheid van data op lange termijn, is het noodzakelijk om vooraf te bepalen:

Doel opslag

- Zijn de data unieke gegevens die voor langere tijd worden gearchiveerd?
- Zijn de data tijdelijk en kunnen ze na een bepaalde tijd kunnen worden vernietigd?
- Dienen de data als back-up van andere data die, eventueel op een ander opslagmedium, op een andere locatie zijn gearchiveerd?

Gebruik en toegankelijkheid

- Worden de data regelmatig gebruikt, waardoor de kans op snellere slijtage van het opslagmedium groter is?
- Zijn de data ook beschikbaar op een ander opslagmedium, waardoor de kans op slijtage kan worden geminimaliseerd?
- Moeten de data online beschikbaar zijn of is toegankelijkheid "lokaal" voldoende?

Houdbaarheid opslagmedium

- Wat is bekend over de levensduur van het opslagmedium?
- Is er (onafhankelijk) onderzoek gedaan naar de levensduur van dit opslagmedium?
- Kan de fabrikant garanties geven over de houdbaarheid en de toegankelijkheid van het medium en de hierop gearchiveerde data op lange termijn?

Migratie

- Welke garanties kunnen door fabrikant worden gegeven als data moeten worden gemigreerd van het opslagmedium naar een ander opslagmedium?
- Welke kosten zijn aan deze migratie verbonden?
- Welke mogelijkheden heeft het opslagmedium als het in een omgeving wordt geplaatst, waarin verschillende opslagmedia naast elkaar figureren?

Financiële consequenties

- Wat zijn de aanschafkosten van het opslagmedium, voor zowel hard- en software?
- Wat zijn de te verwachten kosten voor het beheer en het onderhoud van het gekozen opslagmedium?
- Zijn er additionele kosten te verwachten door bijv. aanpassing van hard- en software?

2. Optische schijven kunnen mogelijk nog actuele, politiek vitale, informatie bevatten. Als deze informatie verloren gaat, ontstaat voor de overheid een enorm probleem. De mogelijkheid om het overheidshandelen te kunnen reconstrueren komt ernstig in gevaar en de overheid is niet in staat om haar handelen juridisch te verantwoorden. Om informatieverlies te voorkomen is het van belang dat bij overheidsinstanties het bewustzijn wordt bevorderd dat digitale opslagmedia vergankelijk zijn, dat ze periodiek moeten worden gecontroleerd en dat data na verloop van tijd moeten worden gemigreerd naar een ander opslagmedium.

3. Goed beleid begint met het benoemen van het probleem en het nadenken over oplossingen. De grootste uitdaging is het ontwikkelen van een strategie voor identificatie, opslag, migratie en beleid voor het gebruik en vooral de toegankelijkheid van de data. Digitale producten vereisen een voortdurende zorg. Digitale data slijt immers niet langzaam en stukje bij beetje, maar is toegankelijk of niet. Een beetje toegankelijk bestaat niet!

Literatuur

Boudrez, F. *CD's voor het archief*. Antwerpen, 2001.

Bradley, K. *Risks Associated with the Use of Recordable CDs and DVDs as Reliable Storage Media in Archival Collections – Strategies and Alternatives.* Memory of the World Program, Sub-Committee on Technology. Unesco, Paris, 2006.

Byers, F. *Care and Handling of CDs and DVDs – A Guide For Librarians and Archivists.*
Council on Library and Information Resources, National Institute of Standards and Technology (NIST). Washington DC, 2003.

Bouwhuis, Gijs, et. al. *Principles of Optical Disc Systems*. Bristol, 1985.

Buckley, Jonathan W., *New Life for Dead Storage Technologies; Consumer-driven Optical Storage in the Data Center*. z.p., 2006.

Byers, F. *Care and Handling of CDs and DVDs – A Guide For Librarians and Archivists.*
Council on Library and Information Resources, National Institute of Standards and Technology (NIST), Washington DC, 2003.

Chambers, Mark L. *Hewlett-Packard Official Recordable CD Handbook*. Foster City: IDG Books, 2000.

Keulemans, E.J. *To burn or not to burn? That's the question! Een onderzoek naar een doeltreffend en doelgericht bewaarbeleid voor optische gegevensdragers – succes- en faalfactoren bij Zeeuwse archiefdiensten.* Provincie Zeeland; Middelburg, 2009.

Navale, V., *Predicting the Life Expectancy of Modern Tape and Optical Media*, National Archives and Records Administration (US), z.p, z.j.

National Institute of Standards and Technology (NIST)/Library of Congress (LoC),
Optical Disc Longevity Testing Procedure, NIST Special Publication 500-263.
Washington DC, 2005.

Purcell, Lee, and David Martin. *The Complete Recordable-CD Guide*. Alameda: Sybex, 1997.

Rothenberg, J. Avoiding *Technological Quicksand: Finding a Viable Technical Foundation for Digital Preservation*. Washington DC, 1999.

Rijksarchiefinspectie, *Een dementerende overheid? De risico's van digitaal beheer van Verantwoordingsinformatie bij de centrale overheid*. Den Haag, 2005.

Tanaka, K. and Keisuke Fujiwara, *Application of Polynomial Regression and re-sampling method to estimate Life Time of Optical Disk.* Ichihara, 2008.

The National Archives. Digital Preservation Guidance Note 3. *Care, Handling and Storage of Removable Media.* z.p., 2003

Zondag, M. *De CD: Mogelijkheden en beperkingen*, in Archievenblad; uitgave van Koninklijke Vereniging van Archivarissen in Nederland; jaargang 108, nr. 5, juni 2004.

Internet (Alle URL's zijn geraadpleegd op 01-09-2009)

Standaarden
http://www.iso.org/iso/home.htm
http://www.osta.org/technology/cdqa.htm
http://www.ecma-international.org/

CDR, DVDR
http://www.cdrfaq.org/
http://www.dvddemystified.com/dvdfaq.html
http://www.cdrinfo.com/
http://www.cdfreaks.com/
http://en.wikipedia.org/wiki/Cd-r
http://www.brennmeister.com/
http://www.mrichter.com/cdr/primer/blanks.htm
http://www.laserfaq.org/sam/cdfaq.htm
http://www.millenniata.com/index.html

Blu-Ray
http://www.blu-ray.com/faq/
http://www.plasmon.com
http://www.incom-storage.nl/fastsilentcubelongtermarchiving.html
http://www.fast-lta.com/en/fast/index.php

Dye
http://cdduplicator.nl/uitleg/cdr-dye.html
http://www.cdmediaworld.com/hardware/cdrom/cd_dye.shtml

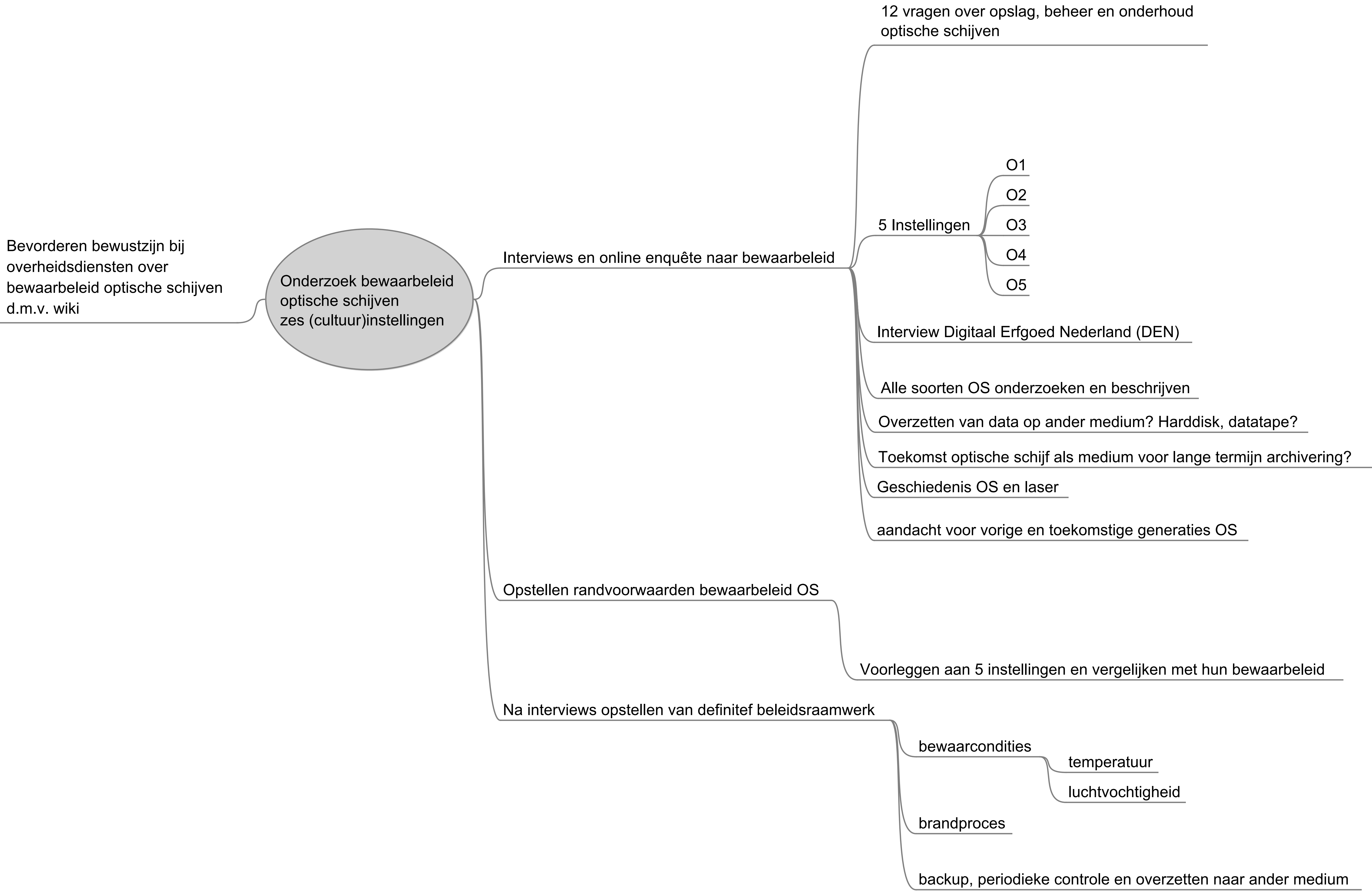
Fabrikanten beschrijfbare OS
http://www.globalsources.com/gsol/I/CD-R-manufacturers/b/2000000003844/3000000171703/16976.htm?items_per_page=60
http://www.instantinfo.de/showcdrhersteller_e.php
http://www.cdmediaworld.nl/hardware/cdrom/cd_cdr_info_abc.shtml
http://www.mam-a.com/technology/quality/longevity.htm
http://www.yuden.co.jp/ut/product/pdf_html/index.html#footer

Brandprogramma's
http://en.wikipedia.org/wiki/List_of_optical_disc_authoring_software
http://www.exactaudiocopy.de/
http://www.infinadyne.com/accuburn-r.html

Naslag
http://persons.kb.nl/rgillesse/cdrot/langetermijncdr.html
http://www.den.nl/docs/20050808095810
http://www.digitaleduurzaamheid.nl/index.cfm?paginakeuze=271#p3
http://www.dans.knaw.nl/nl/
http://www.minatica.be/showthread.php?t=23218
http://www.pc-active.nl/component/content/article/10508
http://www.cdfreaks.com/news/6450-CD-Recordable-discs-unreadable-in-less-than-two-years.html

Bijlagen

Bijlage 1: Mindmap


Bevorderen bewustzijn bij overheidsdiensten over bewaarbeleid optische schijven d.m.v. wiki
Onderzoek bewaarbeleid optische schijven zes (cultuur)instellingen
Interviews en online enquête naar bewaarbeleid
12 vragen over opslag, beheer en onderhoud optische schijven
5 Instellingen
O1
O2
O3
O4
O5
Interview Digitaal Erfgoed Nederland (DEN)
Alle soorten OS onderzoeken en beschrijven
Overzetten van data op ander medium? Harddisk, datatape?
Toekomst optische schijf als medium voor lange termijn archivering?
Geschiedenis OS en laser
aandacht voor vorige en toekomstige generaties OS
Opstellen randvoorwaarden bewaarbeleid OS
Voorleggen aan 5 instellingen en vergelijken met hun bewaarbeleid
Na interviews opstellen van definitef beleidsraamwerk
bewaarcondities
temperatuur
luchtvochtigheid
brandproces
backup, periodieke controle en overzetten naar ander medium

Bijlage 2: To Burn Or Not To Burn, That's The Question
(IDM 2008-2009, essay module 2, E.J. Keulemans)

To burn or not to burn?
That’s the question!

Een onderzoek naar een doeltreffend en doelgericht bewaarbeleid voor optische gegevensdragers – succes- en faalfactoren bij Zeeuwse archiefdiensten.

Erasmus Universiteit, Informatie- en Documentmanagement (IDM) 2008-2009, module 2, Eric-Jan Keulemans, 2009-04-16, begeleider ir. A. (Ad) C. van der Kolk

Inhoudsopgave

Samenvatting

In 1988 werd de cd-recordable (cd-r) geïntroduceerd waarna ze een opmerkelijke opmars heeft doorgemaakt. Deze drager is al vele jaren een favoriet medium van Zeeuwse archiefdiensten om kwetsbare data voor lange termijn te archiveren.

Veelal wordt aangenomen dat cd-r's op z'n minst tien jaar houdbaar zijn. Sommige fabrikanten claimen zelfs een houdbaarheid van een eeuw. De afgelopen jaren is echter gebleken dat cd-r's aan slijtage onderhevig zijn en dat data op een cd-r binnen twee jaar onleesbaar kunnen worden.

Omdat de cd-r vele varianten kent, wordt in dit onderzoek de term optische gegevensdrager (OGD) gebruikt, tenzij in de literatuur specifiek wordt verwezen naar de term cd-r.

De onderzoeksvraag luidt*: "Aan welke voorwaarden moet worden voldaan om de toegankelijkheid van een OGD op lange termijn te kunnen garanderen?".*

Om de onderzoeksvraag te kunnen beantwoorden is gebruik gemaakt van drie complementaire onderzoeksmethodieken:

- Literatuuronderzoek;
- Online-enquête;
- Onderzoek DVD-Analyzer.

Twee onderzoeken uit de periode 2003-2006 naar bewaarcondities van OGD worden besproken. Ook wordt ingegaan op een aantal ISO-normen en de Regeling duurzaamheid archiefbescheiden.

Alle tien Zeeuwse archiefdiensten zijn uitgenodigd voor een (online) enquête naar het bewaarbeleid van OGD, negen organisaties hebben hierop positief gereageerd. Het doel van de enquête is te achterhalen of archiefdiensten OGD's in hun collectie hebben, of zij een specifiek bewaarbeleid voor OGD's hebben, of zij dat bewaarbeleid in de praktijk ook toepassen en of zij zelf OGD's branden.

Tenslotte wordt aandacht besteed aan de DVD-Analyzer (DVX), waarmee OGD's kunnen worden getest. De provincie Zeeland heeft, na een uitgebreide marktverkenning, dit apparaat in 2006 aangeschaft ten behoeve van de controle van OGD's bij Zeeuwse archiefdiensten.
De DVX meet de kwaliteit van een disc door het zoeken naar fouten tijdens het afspeelproces. Zowel de hoeveelheid fouten als de ernst ervan wordt onderzocht. Om OGD's te testen wordt gebruik gemaakt van een foutopsporings- en correctiemethode, beter bekend als Cross-interleaved Reed-Solomon Coding (CIRC).

In het onderzoek komen de voorwaarden om de toegankelijkheid van OGD's op lange termijn te kunnen garanderen, uitgebreid aan bod. Naast de zgn. omgevingsfactoren (de soort OGD, de kwaliteit van de fabricage, de archivering, de temperatuur en relatieve luchtvochtigheidsgraad, de bewaar- en gebruiksomgeving), wordt ook aandacht besteed aan het opgenomen digitale signaal, de interactie tussen brander, merk en soort OGD en het afspeelapparaat, het brandproces, de brandmethode, de verpakking van OGD's en de levensduur van de overige hard- en software.

Het onderzoek laat zien dat veel factoren een rol spelen om de toegankelijkheid van OGD's op lange termijn te garanderen. Daarom wordt in de aanbevelingen voorgesteld om uitvoeriger onderzoek hiernaar te doen. Dit onderzoek moet resulteren in een beleidsraamwerk "bewaring van OGD's en toegankelijkheid op lange termijn".

Speciale dank gaat uit naar mijn begeleider Ad van der Kolk. Ondanks zijn drukke bestaan is het hem gelukt scherpe analyses en waardevolle suggesties te doen.

Ad, bedankt!

Eric-Jan Keulemans,
Kleverskerke,
16 april 2009.

1 Onderzoeksvraag en onderzoeksmethodieken

Inleiding

Sinds de introductie in 1988[1], heeft de cd-recordable (cd-r) een opmerkelijke opmars doorgemaakt. Deze door Philips en Sony uitgevonden optische gegevensdrager, waarop door middel van een laserstraal digitale informatie wordt gebrand, is al vele jaren een favoriet medium van archiefdiensten. Zij gebruiken de cd-r om informatie voor een langere termijn te archiveren (vijf tot tien jaar). "*Veelal wordt aangenomen dat cd-r's op z'n minst tien jaar houdbaar zijn. Sommige fabrikanten claimen zelfs een houdbaarheid van een eeuw*"[2]. "*De afgelopen jaren is echter gebleken dat cd-r's aan slijtage onderhevig zijn en dat data op een cd-r binnen twee jaar onleesbaar kunnen worden*"[3].

De oorzaak van deze slijtage is tweeledig: enerzijds moeten tijdens het brandproces van de data op een cd-r de meest ideale condities worden geschapen[4], anderzijds zijn de bewaarcondities van gebrande cd-r's van belang om de toegankelijkheid van cd-r's op lange termijn te kunnen garanderen. De termen cd-r, dvd-r en alle varianten hierop, worden in de literatuur door elkaar gebruikt. In dit onderzoek wordt de term optische gegevensdrager (OGD) gebruikt, tenzij in de literatuur specifiek wordt verwezen naar de term cd-r.

Onderzoeksvraag

Aan welke voorwaarden moet worden voldaan om de toegankelijkheid van een OGD op lange termijn te kunnen garanderen?

Onderzoeksmethodieken

Om de onderzoeksvraag te kunnen beantwoorden en om het onderzoek vanuit diverse invalshoeken te kunnen benaderen, is gekozen voor drie complementaire methodieken:
Literatuuronderzoek: Twee onderzoeken uit de periode 2003-2006 naar bewaarcondities van OGD worden besproken. Ook wordt ingegaan op een aantal ISO-normen en de Regeling duurzaamheid archiefbescheiden.
Enquête: Alle tien Zeeuwse archiefdiensten zijn uitgenodigd voor een (online) enquête naar het bewaarbeleid van OGD, negen daarvan hebben positief gereageerd. De enquête bestaat uit 15 vragen; de enquêtevragen treft u aan in bijlage 1. Het doel van de enquête is te achterhalen of archiefdiensten OGD's in hun collectie hebben, of zij een specifiek bewaarbeleid voor OGD's hebben, of ze dat beleid ook toepassen en of zij zelf OGD's branden.
Onderzoek DVD-Analyzer (DVX): De DVX van Clover Systems is een apparaat om een OGD te testen. De provincie Zeeland heeft, na een uitgebreide marktverkenning, dit apparaat in 2006 aangeschaft ten behoeve van controle van OGD's bij Zeeuwse archiefdiensten. De DVX meet de kwaliteit van een disc door het zoeken naar fouten tijdens het afspeelproces. Zowel de hoeveelheid fouten als de ernst ervan wordt onderzocht. Om OGD's te testen gebruikt de DVX een bekende foutopsporings- en correctiemethode, beter bekend als Cross-interleaved Reed-Solomon Coding (CIRC).

Opbouw document en beoogde doelgroep

Hoofdstuk 1 behandelt de onderzoeksvraag en de onderzoeksmethodieken. Hoofdstuk 2 gaat in op de oorsprong en werking van de OGD, de ISO-standaarden en de Regeling duurzaamheid archiefbescheiden. In hoofdstuk 3 worden de resultaten van de onderzoeksmethodieken gepresenteerd. Dit onderzoek wordt afgesloten met hoofdstuk 4 waarin de conclusies worden getrokken en aanbevelingen worden gedaan. Het onderzoek en de resultaten daarvan zijn in eerste instantie gericht op de Zeeuwse archiefdiensten, opdat zij inzicht krijgen in de eisen voor een optimaal bewaarbeleid van OGD's. Het onderzoek is uitgevoerd in het kader van module 2 "Documentmanagement en Nieuwe Media" van de postacademische opleiding Informatie- en Documentmanagement, jaargang 2008-2009, aan de Erasmus Universiteit in Rotterdam.

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[1] The CD-R, originally named CD **W**rite-**O**nce (WO), specification was first published in 1988 by Philips and Sony in the 'Orange Book'. Bron: http://en.wikipedia.org/wiki/Cd-r; 2009-04-16.
[2] http://www.pc-active.nl/component/content/article/10508; 2009-04-16.
[3] http://www.cdfreaks.com/news/6450-CD-Recordable-discs-unreadable-in-less-than-two-years.html 2009-04-16.
[4] Het samenspel tussen PC, brander, brandprogramma, brandmethode, brandsnelheid en soort OGD.

2 Oorsprong, werking en standaarden van een OGD

Oorsprong en werking van een OGD

De specificaties voor een CD-R zijn in 1988 door Philips en Sony vastgelegd en gepubliceerd in het "*Orange Book*"[5]. Het was echter Yamaha's *"Programmable Disc System*" dat als eerste opneembare OGD in 1988 op de markt werd geïntroduceerd[6].

Standaarden

De fysieke standaard voor de CD-R is: "*ISO-10149*"[7]. Deze standaard maakt gebruik van een heel nauwkeurige foutopsporings- en verbeteringsmethode. Een dermate hoge nauwkeurigheid is voor OGD's onontbeerlijk. De bestandsysteemstandaard zorgt er voor dat de mappenstructuur en de bestanden kunnen worden uitgelezen. De "*ISO-9660 standaard*"[8] zorgt ervoor dat dit onafhankelijk van het besturingssysteem van een computer (Windows, Apple enzovoorts) gebeurt. "cd-r's *hebben een diameter van 120 mm en een dikte van 1,2 mm*"[9].

"*Een belangrijke mogelijkheid die de ISO 9660 standaard biedt is dat er metadata aan de CD-R kunnen worden toegevoegd. Hier kunnen gegevens ingevuld worden als auteur, archiefnummer, label, copyright informatie, datum, enzovoorts. Joliet is een uitbreiding van Microsoft op de ISO 9660 standaard en maakt het onder meer mogelijk om langere bestands- en directorynamen te gebruiken (maximaal 64 karakters)*"[10].

Werking

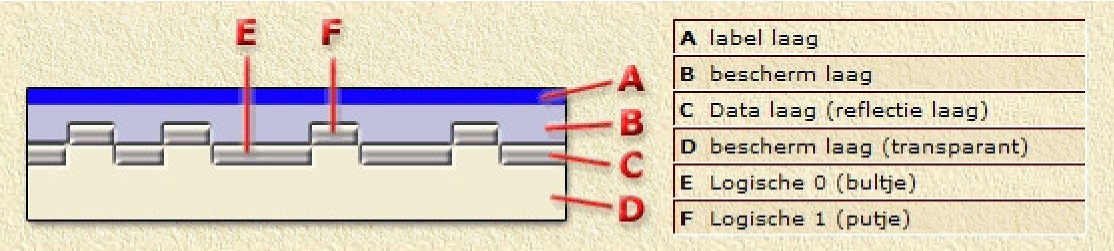
"*Een OGD bestaat uit verschillende lagen, van boven naar beneden: het optionele etiket, de laklaag, de reflectielaag van aluminium, zilver, goud of platinum, de dye (kleur) of datalaag en tot slot de beschermende plastic laag (polycarbonaat). In de datalaag bevindt zich de werkelijk gebrande informatie in de vorm van zogenoemde 'pits' en 'lands'. In tegenstelling tot fabrieksmatig geperste cd's (bijvoorbeeld audio cd's) waarin de informatie letterlijk is gestanst in de policarbonaat, bestaat de datalaag van de zelf gebrande cd uit lichtgevoelig, organisch materiaal*"[11].
"*De laser brandt ondoorzichtige data pits die het laserlicht absorberen en die normalerwijze de door de reader uitgezonden laserstraal terug laten reflecteren. De reflective layer (weerkaatsende laag) is de laag die de laserstraal terug naar de optische sensor stuurt die vervolgens de pulsen in nullen en enen veranderd*"[12]. Figuur 1 toont de samenstelling en structuur van een OGD.

Figuur 1: De samenstelling en structuur van een OGD[13].

[5] http://searchstorage.techtarget.com/sDefinition/0,,sid5_gci503648,00.html; 2009-04-16.
[6] Bradley, K. Risks Associated with the Use of Recordable CDs and DVDs as Reliable Storage Media in Archival Collections – Strategies and Alternatives. UNESCO, Paris, 2006. p. 5.
[7] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=25869; 2009-04-16.
[8] http://bmrc.berkeley.edu/people/chaffee/jolspec.html; 2009-04-16.
[9] Boudrez, F. CD's voor het archief. Antwerpen, 2001. p.1-2.
[10] http://www.den.nl/docs/20050808095810; 2009-04-16.
[11] http://www.digitaleduurzaamheid.nl/index.cfm?paginakeuze=271#p3; 2009-04-16.
[12] http://www.dvdduplicator.nl/frameset.html; 2009-04-16.
[13] Boudrez, F. CD's voor het archief. Antwerpen, 2001. p. 2.

To burn or not to burn? That's the question!

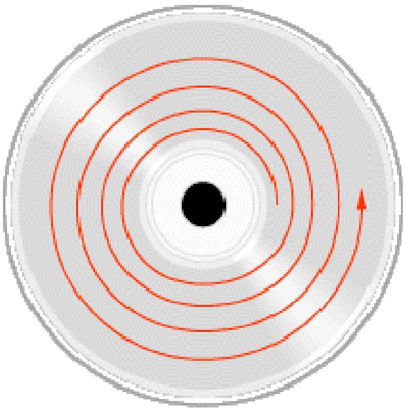
"Het digitaal opslaan van informatie op een OGD is eigenlijk heel simpel. De enige mogelijke waarden zijn "0" of "1". Als er "0" moet staan gebeurt er niks, als er "1" moet staan zit er een klein putje, een kuiltje in de schijf. De putjes worden "pits" genoemd, de bergen "lands".[14] Figuur 2 toont de weergave van de pits en lands van een OGD.



Figuur 2: een dwarsdoorsnede van een OGD met pits en lands[15]

"*De informatie op de OGD wordt waarneembaar gemaakt door middel van een laserstraal, die microscopisch kleine gaatjes in het metaalfolie aftast.*
OGD's worden in steeds grotere mate ook gebruikt voor de opslag van langdurig te bewaren gegevens. Op het moment is de capaciteit van de minst dicht beschreven optische schijven 700 MB. Omdat onduidelijk is hoe lang deze leverbaar zullen zijn, is afgezien van een absolute maximering van de capaciteit. Echter, hoe minder dicht beschreven hoe minder kans op fouten. Een absolute maximum snelheid voor het wegschijven van gegevens is niet te geven om dezelfde reden als het ontbreken van een absoluut maximum aan de capaciteit. Dat komt door de onvoorspelbaarheid van de technische en commerciële ontwikkelingen"[16].

"Als een OGD wordt afgespeeld, straalt een laser op de pits en lands terwijl die langskomen. De pits en lands worden als een doorlopende spiraal geschreven die bij het gat begint en 32 mm naar buiten doorloopt. Als de spiraal recht gebogen zou worden, heeft ie een lengte van 5,6 km"[17]. Figuur 3 laat de doorlopende spiraal zien, vanuit het centrum van de OGD naar de rand.



Figuur 3: de spiraal vanuit het centrum naar de rand van een OGD[18]

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[14] "*Wat meer uitleg over de pits and lands: "Er bestaan negen variaties in de lengte van de "pits". De ruimte tussen de "pits" wordt "lands" genoemd. [..] De data op een CD worden ingelezen door een laseroog, waardoor er geen direct contact tussen de schijf en het leesapparaat is. Het laseroog neemt de intensiteit van de reflectie op. Een "land" (90 %) wordt meer gereflecteerd dan een "pit" (20 %). Eén "pit" of "land" staat niet voor een 1 of een 0. De binaire waarden worden voorgesteld door de overgangen tussen "pit" en "land" en de padlengte tussen de transities*". (Bron: Boudrez, F. CD's voor het archief. Antwerpen, 2001. p.1-2.).
[15] http://www.weethet.nl/dutch/cdrw_howitworks.php; 2009-04-16.
[16] http://www.den.nl/docs/20050808095810; 2009-04-16.
[17] Tanenbaum, A. (vertaald door L. Geurts). Gestructureerde computerarchitectuur, Pearson Education, 2005. p. 94.
[18] Figuur afkomstig uit Handleiding DVX (E.J. Keulemans), Middelburg, 2007, p. 6.

3 Onderzoeksmethodieken

Resultaten literatuuronderzoek

Er worden twee baanbrekende onderzoeken naar de lange termijn bewaring van OGD's besproken. Het onderzoek van Byers uit 2003 kijkt vooral naar de omgevingsfactoren bij de bewaring van OGD's, terwijl het onderzoek van Bradley ingaat op de kwaliteit van het opgenomen signaal op een OGD en wordt aandacht besteed aan de interactie tussen de diverse componenten gedurende het brandproces.

Byers, F. *Care and Handling of CDs and DVDs – A Guide For Librarians and Archivists.* Council on Library and Information Resources, National Institute of Standards and Technology (NIST), Washington DC, 2003[19].

Dit is een gids voor bibliothecarissen en archivarissen die optische gegevensdragers in hun collectie hebben. Het rapport geeft tips hoe men OGD's dient te behandelen en aan welke voorwaarden moet worden voldaan om een lange levensduur van OGD's te garanderen.

Volgens Byers wordt de levensduur van OGD's beïnvloed door een aantal factoren: soort OGD, kwaliteit van fabricage, conditie van een OGD vóór opname, archivering en opslag, omgang in gebruik en omgevingsomstandigheden (temperatuur en luchtvochtigheidsgraad).

Eerst moet de term levensduur worden gedefinieerd. Een beproefde methode is gebaseerd op het aantal fouten op een OGD vóórdat de foutcorrectie inwerking treedt. Elke OGD bevat fouten, daarom heeft ieder afspeelapparaat de beschikking over een foutopsporings- en correctiemethode, beter bekend als "*Cross-interleaved Reed-Solomon Coding*"[20].
De kans dat een OGD niet kan worden afgespeeld, neemt toe naarmate er meer fouten optreden. Maar het is onmogelijk om het exacte aantal fouten te definiëren die leiden tot het niet kunnen lezen van een OGD, omdat het afhangt van de fouten die optreden ná foutcorrectie. Als het aantal fouten (vóór foutcorrectie) op een OGD dusdanig toeneemt dat het niet meer door de foutcorrectie kan worden hersteld, neemt de kans op onleesbaarheid toe. En kan uiteindelijk leiden tot volledige onleesbaarheid van een OGD en dus het einde van de levensduur.

Als OGD's in een koude, minder vochtige omgeving worden bewaard, hebben ze een langere levensduur. Byers maakt hierbij onderscheid tussen de bewaar- en gebruiksomgeving. In twee door hem aangehaalde "*rapporten*"[21], blijkt dat de ideale bewaartemperatuur voor OGD's ligt tussen de 5 en 20 graden Celsius. De relatieve vochtigheidsgraad voor OGD's in een bewaaromgeving ligt tussen de 20% en 50%. Abrupte temperatuurswisselingen hebben een groter nadelig effect op de kwaliteit van een OGD dan een gelijkmatige temperatuurswisseling[22].

Een OGD moet worden bewaard in een individuele "*jewel case*"[23]. Voor lange termijnarchivering is het raadzaam om het papieren boekje uit de jewel case te halen. Papier kan vocht aantrekken, zorgt voor een hogere vochtconcentratie in de jewel case en het vocht kan in contact komen met de OGD.
Voor het beschrijven van OGD's zijn pennen beschikbaar op waterbasis, alchoholbasis en chemische basis. Om elk risico uit te sluiten adviseert Byers om voor het beschrijven van OGD's gebruik te maken van een pen op waterbasis.
Voor OGD's die langer dan 5 jaar bewaard moeten worden, wordt het gebruik van zelfklevende stickers afgeraden. Deze stickers bevatten organisch materiaal, dat de reflectielaag van een OGD kan aantasten en wat kan leiden tot verkorting van de levensduur.

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[19] http://www.clir.org/pubs/reports/pub121/pub121.pdf; 2009-04-16.
[20] http://en.wikipedia.org/wiki/Cross-interleaved_Reed-Solomon_coding; 2009-04-16.
[21] ISO TC 171/SC, January 2002 **en** Hartke, J.L., Measures of CD-R Longevity. Media Sciences, Inc. July 2001. (http://www.mscience.com/longev.html#METHOD); 2009-04-16.
[22] Het bewaren van OGD's beneden het vriespunt wordt niet aanbevolen omdat tot op heden niet duidelijk is wat de gevolgen zijn van het ontdooien van OGD's. Verder onderzocht moeten worden de ISO normen "*ISO 18925:2002 Imaging materials - Optical disc media - Storage practices" en " ISO 18921:2002 Imaging materials -- Compact discs (CD-ROM) -- Method for estimating the life expectancy based on the effects of temperature and relative humidity".*
[23] http://nl.wikipedia.org/wiki/Jewelcase ; 2009-04-16.

Bradley, K. *Risks Associated with the Use of Recordable CDs and DVDs as Reliable Storage Media in Archival Collections – Strategies and Alternatives.* Memory of the World Program, Sub-Committee on Technology. Unesco, Paris 2006[24].

Bradley stelt dat de kwaliteit van het opgenomen digitale signaal een belangrijke factor is voor de levensduur van een OGD voor lange termijnarchivering. Deze kwaliteit is afhankelijk van de interactie tussen de brander, merk en soort OGD, en het afspeelapparaat. Omdat hiervoor nog geen standaard is ontwikkeld, is de kwaliteit van de opgenomen data en de levensduur van een OGD onvoorspelbaar. Het is mogelijk om een OGD te testen maar (semi)-professionele testapparatuur is kostbaar en betrouwbaar testen kost veel tijd.

Dit onderzoek legt de complexiteit van het gebruik van opneembare OGD's uit en behandelt de gevaren voor het gebruik van OGD's als het enige opneembare medium voor lange termijnarchivering.

Digitale archiveringsexperts stellen dat geen enkele drager permanent is.

Een geïntegreerd digitaal archiveringssysteem met een digitale bibliotheek (repository), wordt gezien als de meest geschikte drager voor lange termijnarchivering van kwetsbare data. Dat is een kostbaar systeem maar betrouwbaar en relatief eenvoudig te migreren naar een ander archiveringsformaat, met een minimum aan menselijke interventie en behoud van de (structuur en inhoud van) data.

Nadat data op een OGD zijn vastgelegd, is compatibiliteit tussen OGD en leesapparaat noodzakelijk. Het komt regelmatig voor dat een OGD, welke is gebrand op apparaat A, niet kan worden gelezen door apparaat B. De internationale organisatie voor standaarden (ISO) is daarom een "*project*"[25] gestart om dit probleem te ondervangen.

Het branden van data op een OGD kan verschillende resultaten geven. Het is sterk afhankelijk van elk onderdeel van het brandproces. Het op een objectieve manier branden van data is mogelijk door vooraf de foutmarge te bepalen. De onderdelen van het brandproces zijn de lege OGD, de computer en software, de brander en het apparaat om OGD's te testen.

Er zijn drie soorten dye (opnamelaag) die worden toegepast bij een OGD:

- "C*yanine*"[26]: De eerste OGD's bevatte een dye van cyanine en hebben een groene kleur. De eerste exemplaren konden slecht tegen direct zonlicht, waren binnen een paar jaar onleesbaar en daarom niet geschikt voor lange termijnarchivering.
- "*Phthalocyanine*"[27]: OGD's met een dye van phthalocyanine zijn veelal zilver, goud of lichtgroen van kleur. Ze kunnen zonlicht goed verdragen en hebben een geschatte levensduur van honderd jaar.
- "*Azo*"[28]: Tenslotte zijn er OGD's met de dye azo, welke direct zonlicht zeer goed kunnen verdragen en een geschatte levensduur hebben van enkele tientallen jaren.

Een niet te onderschatten onderdeel van het brandproces is de brandsnelheid en de brandmethode. Voor het beste resultaat wordt aangeraden om een OGD te branden op een lage snelheid (max. X8) en te kiezen voor de brandmethode disc-at-once[29].

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[24] http://unesdoc.unesco.org/images/0014/001477/147782E.pdf ; 2009-04-16.
[25] ISO N178 Electronic Imaging – Classification and verification of information stored on optical media.
[26] http://en.wikipedia.org/wiki/CD-R en http://en.wikipedia.org/wiki/Cyanine; 2009-04-16.
[27] http://en.wikipedia.org/wiki/CD-R en http://en.wikipedia.org/wiki/Phthalocyanine; 2009-04-16.
[28] http://en.wikipedia.org/wiki/CD-R en http://en.wikipedia.org/wiki/Azo_compound; 2009-04-16.
[29] "*Er zijn twee manieren om informatie op cd's te branden. Bij de 'disc-at-once' methode wordt de cd in één keer gebrand. De laserstraal wordt pas uitgezet wanneer de cd helemaal is beschreven. Bij de andere schrijfmethode, de 'track-at-once', wordt de laserstraal voortdurend aan en uit gezet. Hierdoor worden soms onvolledige sectoren geschreven, waardoor E-32 fouten (= onherstelbare fouten na foutcorrectie) ontstaan. Het wordt aanbevolen de brandsoftware zo in te stellen dat de cd volgens de methode 'disc-at-once' wordt gebrand. Deze schrijfwijze benadert het beste de kwaliteit van de geperste cd*" (Bron: http://www.digitaleduurzaamheid.nl/index.cfm?paginakeuze=271#p3; 2009-04-16.

Regeling duurzaamheid archiefbescheiden (Stcrt. 2002, 180)[30]

In deze regeling worden kwaliteitseisen gedefinieerd waaraan archiefbescheiden van de overheid moeten voldoen die voor permanente bewaring in aanmerking komen.

"*Optische schijven moeten voldoen aan ISO 9660 en ISO 10149*"[31]. "*De verpakking van optische schijven bevat geen polyvinylchloride, is stofvrij en bestaat uit kunststof, waaruit geen stoffen kunnen vrijkomen die reacties kunnen aangaan met de verpakte optische schijven*"[32]

"*De normen voor digitale media in het algemeen, optische schijven in het bijzonder, gaan niet zozeer over de eigenschappen van het materiaal, als wel over de wijze waarop de gegevens zijn gestructureerd. Materieel is eigenlijk alleen het verpakkingsvoorschrift van belang. Omdat bij alle digitale media niet zozeer de kwaliteit en de potentiële levensduur van de drager maar ook de levensduur van de overige hard- en software van doorslaggevend belang is, kan men zich afvragen of het stellen van voorschriften eigenlijk wel zinvol is. De theoretische levensduur van een eerste klas OGD is 500 jaar maar het is de vraag of een OGD over 15 jaar nog wel bruikbaar is, omdat de afspeelapparatuur noch de hiervoor noodzakelijke software niet meer voorhanden is. Mede daarom is artikel 8 van de Regeling (een conversie- en migratieopdracht) ook van toepassing is op materieel duurzame CD's*"[33].

Het literatuuronderzoek laat zien dat vele factoren een rol spelen bij lange termijn bewaring van OGD's.
Byer vindt vooral de omgevingsfactoren als soort OGD, kwaliteit van fabricage, conditie van een OGD vóór opname, archivering en opslag, omgang in gebruik en temperatuur en luchtvochtigheidsgraad van belang.
Bradley stelt dat juist de kwaliteit van het opgenomen digitale signaal een belangrijke factor is voor de levensduur van een OGD. Deze kwaliteit is echter afhankelijk van de interactie tussen de brander, merk en soort OGD, en het afspeelapparaat.
De Regeling duurzaamheid archiefbescheiden vindt dat OGD's moeten voldoen aan ISO 9660 en ISO 10149. Het commentaar[34] op deze regeling door het Landelijk overleg van provinciale archiefinspecteurs (LOPAI) behandelt niet zozeer de omgevingsfactoren, de kwaliteit en de potentiële levensduur van de drager maar vindt juist de levensduur van de overige hard- en software van belang.

Resultaat enquête bewaarbeleid

Alle tien Zeeuwse archiefdiensten zijn uitgenodigd voor een (online) enquête naar het bewaarbeleid van OGD's. Negen archiefdiensten hebben gereageerd op deze uitnodiging. Deze enquête bestaat uit 15 vragen en heeft plaatsgevonden in de periode 1 – 17 maart 2009. Het doel van de enquête is te onderzoeken of archiefdiensten OGD's in hun collectie hebben, of zij een specifiek bewaarbeleid voor OGD's hebben en of ze dat ook uitvoeren, en of zij zelf OGD's branden[35]. De belangrijkste resultaten van de enquête worden hieronder weergegeven.

Aantal OGD's in collectie	Aantal archiefdiensten	Percentage
< 100	5	55,6%
100-250	-	-
> 250	4	44,4%

Ouderdom OGD's	Aantal archiefdiensten	Percentage
0-5 jaar	6	66.7%
5-10 jaar	3	33,3%
Ouder dan 10 jaar	-	-

[30] http://wetten.overheid.nl/BWBR0012804/geldigheidsdatum_15-03-2009; 2009-04-16.
[31] Artikel 7, eerste lid, van de Regeling duurzaamheid archiefbescheiden, p. 21.
[32] Artikel 7, tweede lid, van de Regeling duurzaamheid archiefbescheiden, p. 21.
[33] Duurzaamheid van gegevensdragers in overheidsarchieven. Landelijk overleg van provinciale archiefinspecteurs (LOPAI), z.p. 2005, pag. 14-15.
[34] Duurzaamheid van gegevensdragers in overheidsarchieven. Landelijk overleg van provinciale archiefinspecteurs (LOPAI), z.p. 2005
[35] In bijlage 1 treft u de enquêtevragen aan.

Opslag OGD's	Aantal archiefdiensten	Percentage
Archiefkluis waar ook papieren archieven zijn opgeslagen	7	77,8%
Andere plaats	2	22,2%
Aparte archiefkluis met eigen lucht/temperatuurbehandeling	-	-
Afgesloten ruimte in archiefkluis, met eigen lucht/temperatuurbehandeling	-	-
Afgesloten ruimte in archiefkluis, zonder eigen lucht/temperatuurbehandeling	-	-

Soort OGD	Aantal archiefdiensten	Percentage
Machinaal (CD-ROM)	1	11,1%
Gebrand	3	33,3%
Machinaal + gebrand	4	44,4%
Weet niet	1	11,1%

Zelf branden OGD's	Aantal archiefdiensten	Percentage
Ja	6	66,7%
Nee	3	33,3%

Brandmethode	Aantal archiefdiensten	Percentage
Disc-at-once (DAO)	5	55,6%
Track-at-once (TAO)	1	11,1%
Niet van toepassing	3	33,3%

Gebruik stickers/CDR-pen om informatie op bovenkant OGD aan te brengen	Aantal archiefdiensten	Percentage
Stickers	-	-
CDR-pen	5	55,6%
Stickers én CDR-pen	-	-
Geen stickers noch CDR-pen	3	33,3%
Weet niet	1	11,1%

Extra drager als back-up	Aantal archiefdiensten	Percentage
Ja, back-up op andere drager	8	88,9%
Nee, geen back-up	1	11,1%

Opslag back-up	Aantal archiefdiensten	Percentage
Andere plaats dan originele OGD maar zelfde gebouw	2	22,2%
Andere plaats dan originele OGD maar ander gebouw	5	55,6%
Zelfde plaats en zelfde gebouw als originele OGD	1	11,1%
Niet van toepassing	1	11,1%

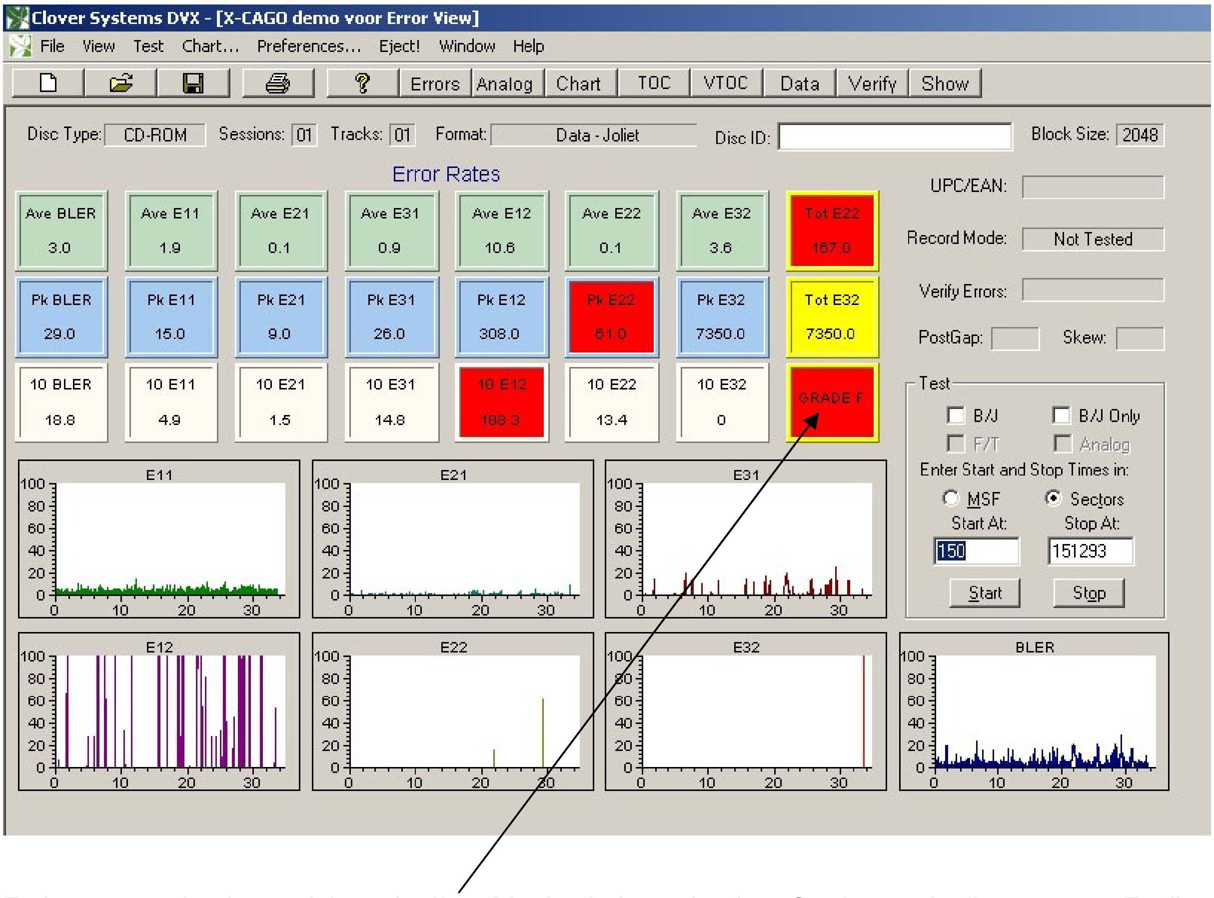
Periodieke controle OGD's	Aantal archiefdiensten	Percentage
Ja, door afspelen	2	22,2%
Ja, fysieke controle	1	11,1%
Ja, afspelen en fysieke controle	-	-
Geen controle	6	66,7%

Controle door DVD-Analyzer	Aantal archiefdiensten	Percentage
Ja, controle DVD-Analyzer	3	33,3%
Nee, geen controle DVD-Analyzer	6	66,7%

Overzetten op andere drager	Aantal archiefdiensten	Percentage
Ja, overweging om data van OGD over te zetten naar ander medium	6	66,7%
Nee, data blijft op OGD	2	22,2%
Nog niet over nagedacht	1	11,1%

Werking DVD-Analyzer

De DVD-Analyzer van Clover Systems (hierna DVX), is een apparaat om OGD's te testen. De DVX meet de kwaliteit van een disc door het zoeken naar fouten tijdens het afspeelproces. Een fout op een disc kan een fysieke fout zijn maar ook een fout die zich openbaart als een disc wordt afgespeeld. Het zegt dus iets over het samenwerkingsproces tussen OGD en speler. Zowel de hoeveelheid fouten, als de ernst van deze fouten wordt onderzocht. De standaardwaarden van de DVX zijn gemiddelde waarden, die door de fabrikant zijn ingesteld. Als een vakje, tijdens of na een test, haar originele kleur behoudt (groen, blauw of wit), blijft de testwaarde binnen de door de fabrikant ingestelde standaard. Als tijdens een test een standaardwaarde wordt overschreden, wordt een vakje **rood** gekleurd.



Zodra een test is afgerond, komt in **dit vakje** de eindwaarde ofwel Grade van de disc te staan. Er zijn 5 verschillende eindwaarden: **A** is de beste kwaliteit; **B** is nog steeds een goede kwaliteit maar niet geheel perfect; **C en D** vertekenen al verval. **F** is een onacceptabele disc. Bij de waarden **C**, **D** en **F** is het raadzaam om een kopie te maken om verder verval tegen te gaan.

In bijlage 2 wordt een uitgebreide beschrijving gegeven van de testmethode van de DVX.

4 Conclusies en aanbevelingen

Conclusies literatuuronderzoek

Het literatuuronderzoek, waarin twee onderzoeken uit respectievelijk 2003 en 2006, evenals de Regeling duurzaamheid archiefbescheiden (Stcrt. 2002, 180) zijn behandeld, laat zien dat voor lange termijnarchivering van OGD's vele factoren een rol spelen. Om de toegankelijkheid van een OGD op lange termijn te kunnen garanderen moet aan een groot aantal voorwaarden zijn voldaan.

Het onderzoek van **Byers** stelt dat vooral de soort OGD, de kwaliteit van de fabricage, de (manier van) archivering en de temperatuur en relatieve luchtvochtigheidsgraad van belang zijn. Er zijn tientallen soorten en merken OGD's verkrijgbaar[36]. Het is veelal *trial and error* om de juiste OGD te vinden.

In het onderzoek van **Bradley** is juist de kwaliteit van het opgenomen digitale signaal en de interactie tussen brander, merk en soort OGD en afspeelapparaat van belang. Hierbij wordt veel aandacht besteed aan het brandproces en de brandmethode. Bradley breekt ook een lans voor het migreren van data naar een ander, minder kwetsbaar, medium.

De Regeling duurzaamheid archiefbescheiden wil dat OGD's voldoen aan ISO 9660 en ISO 10149 en stelt eisen aan de verpakking van OGD's. Het commentaar op de Regeling, van het landelijk overleg van provinciale archiefinspecteurs, gaat vooral in op de levensduur van de overige hard- en software. Je kunt wel aandacht besteden aan allerlei omgevingsfactoren, het is nog maar de vraag of een OGD over 15 jaar nog wel bruikbaar is, omdat de afspeelapparatuur noch de hiervoor noodzakelijke software niet meer voorhanden is.

De OGD is een kwetsbaar maar effectief medium, ook al moet aan vele voorwaarden worden voldaan om de toegankelijkheid op lange termijn te kunnen garanderen. Toen de OGD begin jaren negentig werd geïntroduceerd, was de aanschafprijs en het eenvoudig gebruik ervan voor veel Zeeuwse archiefdiensten van doorslaggevend belang, om het als opslagmedium voor lange termijnarchivering toe te passen. De ontwikkeling van OGD's gaat nog steeds door. In 1995 werd de "*Blu-Ray disk*"[37] geïntroduceerd, waarop vier keer zoveel informatie als een OGD past. En de "*opvolgers*"[38] staan al in de steigers, waarop tot wel 4 "*Terabyte*"[39] aan data kan worden opgeslagen.

Conclusies enquête

Archivering van OGD's

Zeven diensten hebben hun OGD's opgeslagen in de archiefkluis, waar ook de papieren archieven zijn gearchiveerd. De overige twee diensten hebben de OGD's opgeslagen op een andere plaats. De ideale bewaarcondities voor OGD's bestaan uit een temperatuur tussen de 5 en 20 graden Celsius en een relatieve luchtvochtigheidsgraad die tussen de 20% en 50% ligt[40]. Deze waarden voor papieren archieven liggen tussen de 16 en 18 graden Celsius respectievelijk 50% en 55%[41]. Als men OGD's in dezelfde ruimte als de papieren archieven opslaat, kan dit op termijn leiden tot ontoegankelijke OGD's.

Branden van OGD's en back-up

Zes archiefdiensten branden zelf OGD's. Men gebruikt hiervoor een regulier merk in plaats van een OGD, die speciaal voor lange termijnarchivering wordt gefabriceerd[42] en een gegarandeerde levensduur heeft van tenminste 100 jaar. Dit is een aandachtspunt maar nog geen onoverkomelijk bezwaar, want bij acht archiefdiensten wordt de informatie op een OGD ook op een andere drager als

36 http://www.instantinfo.de/showcdrhersteller_e.php; 2009-04-16.
37 http://nl.wikipedia.org/wiki/Blu-ray; 2009-04-16.
38 http://www.bright.nl/op-de-opvolger-van-blu-ray-past-bijna-vier-keer-zoveel-data **en** http://en.wikipedia.org/wiki/Holographic_Versatile_Disc; 2009-04-16.
39 http://nl.wikipedia.org/wiki/Terabyte; 2009-04-16.
40 Zie de rapporten die door F. Byers in het literatuuronderzoek worden genoemd: ISO TC 171/SC, January 2002 **en** Hartke, J.L., Measures of CD-R Longevity. Media Sciences, Inc. July 2001. (http://www.mscience.com/longev.html#METHOD); 2009-04-16.
41 http://www.kb.nl/cons/smit/2004%20tegen%20de%20zure%20lucht%20van%20verval.pdf; 2009-04-16.
42 http://www.mam-a.com/technology/quality/longevity.htm; 2009-04-16.

back-up opgeslagen. Mocht de OGD op termijn niet meer toegankelijk zijn, dan kan men de informatie ook nog achterhalen via de back-up. Eén dienst vertrouwt volledig op de OGD als primaire drager want zij maakt geen gebruik van een andere drager als back-up.

Periodieke controle OGD's
Twee archiefdiensten doen een periodieke controle van hun OGD's door ze af te spelen, één dienst doet een periodieke fysieke controle en zes diensten voeren geen enkele controle uit. Slechts drie van negen archiefdiensten controleren hun OGD's met behulp van een DVD-Analyzer. Weliswaar is dit controleapparaat niet zaligmakend en moet het worden gezien als een extra hulpmiddel om de toegankelijkheid van OGD's op lange termijn te garanderen, echter het helemaal niet controleren van OGD's is zeer alarmerend. Zowel het literatuuronderzoek in dit onderzoek als informatie van diverse websites[43] heeft aangetoond, dat OGD's aan slijtage onderhevig zijn en dat data op een OGD al binnen twee jaar onleesbaar kunnen worden.

Overzetten naar ander medium
Twee archiefdiensten blijven hun informatie bewaren op OGD's, één dienst heeft hierover nog niet nagedacht maar de resterende zes archiefdiensten overweegt de informatie op OGD's over te zetten naar een ander medium.
Er is een nieuwe generatie OGD[44] verkrijgbaar die stabieler is en een grotere opslagcapaciteit heeft. Maar het is nog onduidelijk of deze Blue-ray disk geschikt is voor de lange termijnarchivering van kwetsbare data. Nader onderzoek hiernaar verdient aanbeveling.

Bovendien is het door het toenemend aanbod van online opslagruimte onbekend hoe lang OGD's nog blijven bestaan. "*Volgens elektronicagigant Samsung zal het Blu-ray disc-formaat nog slechts vijf jaar bestaan. "Director of consumer Andy Griffiths zegt dat digitale distributie hierna het stokje zal overnemen. Als de visie van Samsung blijkt te kloppen is het Blu-ray formaat dus uitgestorven voordat het tienjarenplan van Sony's PlayStation 3 is verstreken. "Het PS3 disc-formaat zal zeker een winnaar zijn, alleen niet voor lang", zegt Griffiths van Samsung UK. "Ik geef Blu-ray nog vijf jaar, maar zeker geen tien. Het zal zeker groot worden en ik weet zeker dat 2008 het jaar van Blu-ray gaat worden." Griffiths zegt verder dat aan de ontwikkeling van Steam en Xbox Live te zien is dat digitale distributie de toekomst is*"[45].

Daarnaast zijn er andere opslagmedia voorhanden: "*SAN*"[46], "*NAS*"[47], "*DAS*[48]" of een "*externe harde schijf*"[49]. Het migreren van data van een OGD naar dit type opslagmedium heeft als voordeel dat alle data op één of meerdere harde schijven staan en dat dit medium niet intensief hoeft te worden gecontroleerd. Nadeel is echter dat een harde schijf slechts drie tot vijf jaar meegaat[50], waarna migratie van data naar een nieuwe harde schijf of een ander opslagmedium noodzakelijk is.

Elk type opslagmedium kent voor- en nadelen, het ideale systeem bestaat niet en het is nog onduidelijk welke ontwikkelingen ons op dit gebied nog te wachten staan.

Gebruik DVD-Analyzer (DVX)
De DVX is een extra hulpmiddel en moet worden gezien als een aanvulling op de periodieke controle van OGD's door ze af te spelen of door een fysieke controle, om de toegankelijkheid van OGD's op lange termijn te kunnen garanderen. Het is raadzaam om de OGD's minimaal één keer per jaar te controleren met behulp van de DVX. De testmethode van één OGD neemt gemiddeld een half uur in beslag. Als uit de test blijkt dat het maken van een kopie van een OGD raadzaam is, moet ook deze kopie weer met behulp van de DVX worden getest. Hierdoor kan het totale testproces per OGD ruim één uur belopen. Aangezien vijf archiefdiensten 0-100 exemplaren en de overige vier diensten zelfs meer dan 250 OGD's in hun collectie hebben, is het een zeer tijdrovende bezigheid. Maar het biedt

[43] http://www.cdfreaks.com/news/6450-CD-Recordable-discs-unreadable-in-less-than-two-years.html en http://www.pc-active.nl/component/content/article/10508; 2009-04-16.
[44] http://nl.wikipedia.org/wiki/Blu-ray; 2009-04-16.
[45] http://www.vmv.nl/nieuws.aspx; 2009-04-16.
[46] http://nl.wikipedia.org/wiki/Storage_Area_Network; 2009-04-16.
[47] http://nl.wikipedia.org/wiki/Network-attached_storage; 2009-04-16.
[48] http://nl.wikipedia.org/wiki/Direct-attached_storage; 2009-04-16.
[49] http://nl.wikipedia.org/wiki/Externe_Harde_schijf; 2009-04-16.
[50] http://computertaal.info/2009/03/25/beperkte-levensduur-van-externe-opslagmedia/; 2009-04-16.

een extra mogelijkheid om de toegankelijkheid van data op een OGD op lange termijn te kunnen garanderen.

Alle negen Zeeuwse archiefdiensten hebben OGD's in hun collectie maar opmerkelijk genoeg heeft geen van hen een specifiek bewaarbeleid voor OGD's. Bovendien schenkt men onvoldoende aandacht aan de fysieke archivering van OGD's. Vooral het ontbreken van een periodieke fysieke controle of een controle door middel van de DVX is verontrustend.

Aanbevelingen

1. De onderzoeksresultaten uit het literatuuronderzoek hebben aangetoond dat voor de toegankelijkheid van OGD's op lange termijn aan vele voorwaarden moet zijn voldaan en waarin vele factoren een rol spelen. **Om ervoor te zorgen dat de toegankelijkheid van OGD's op lange termijn wordt gegarandeerd, stel ik voor om uitvoeriger onderzoek te doen naar alle genoemde factoren. Dit onderzoek wil ik doen voor het referaat van de opleiding IDM 2008-2009, welke moet resulteren in een beleidsraamwerk "bewaring van OGD's en toegankelijkheid op lange termijn"**.

2. De enquête onder Zeeuwse archiefdiensten naar het bewaarbeleid van OGD's laat zien dat geen enkele dienst een specifiek bewaarbeleid voor OGD's heeft, maar elke dienst heeft wel OGD's in haar collectie. Bovendien bewaart men deze OGD's veelal in dezelfde ruimte als de papieren archieven, terwijl voor beide dragers een andere temperatuur en luchtvochtigheidsgraad wordt aanbevolen. **Daarom stel ik voor dat iedere archiefdienst een aparte ruimte reserveert voor de bewaring van OGD's, om de toegankelijkheid op lange termijn te kunnen garanderen**.

3. Uit de enquête komt naar voren dat zes van de negen diensten de OGD's uit hun collectie noch op een fysieke manier noch met behulp van de DVX controleert. Weliswaar hebben acht diensten de informatie op een OGD ook op een andere drager als back-up opgeslagen, het verdient aanbeveling om OGD's met enige regelmaat te controleren**. Ik raad aan dat alle Zeeuwse archiefdiensten hun OGD's minimaal één keer per jaar controleren, zowel door middel van een fysieke controle als door middel van een test met behulp van de DVX.**

4. De enquête laat zien dat een aantal archiefdiensten overweegt de informatie op OGD's over te zetten naar een ander medium. Er zijn alternatieve opslagmedia voorhanden maar ook deze zijn aan slijtage onderhevig. Er is inmiddels een nieuwe generatie OGD verkrijgbaar die stabieler is en een grotere opslagcapaciteit heeft. Maar het is nog onduidelijk of deze OGD geschikt is voor de lange termijnarchivering van data. **Ik stel daarom voor om deze OGD aan een nader onderzoek te onderwerpen en de resultaten hiervan mee te nemen in het beleidsraamwerk "bewaring van OGD's en toegankelijkheid op lange termijn".**

Literatuur

Boudrez, F. *CD's voor het archief.* Antwerpen, 2001.

Boudrez, F. *Duurzame CD's*. Richtlijn nr. 2. Stadsarchief Antwerpen, z.j.

Bradley, K. *Risks Associated with the Use of Recordable CDs and DVDs as Reliable Storage Media in Archival Collections – Strategies and Alternatives.* Memory of the World Program, Sub-Committee on Technology. Unesco, Paris, 2006.

Byers, F. *Care and Handling of CDs and DVDs – A Guide For Librarians and Archivists.* Council on Library and Information Resources, National Institute of Standards and Technology (NIST), Washington DC, 2003.

Duurzaamheid van gegevensdragers in overheidsarchieven. Landelijk overleg van provinciale archiefinspecteurs (LOPAI), z.p., 2005.

Keulemans, E.J. *Handleiding DVX*, Provincie Zeeland. Middelburg, 2007.

National Institute of Standards and Technology (NIST)/Library of Congress (LoC), *Optical Disc Longevity Testing Procedure*, NIST Special Publication 500-263. Washington DC, 2005.

Regeling duurzaamheid archiefbescheiden (Stcrt. 2002, 180)

Sony DADC, *Environmental Chamber Tests for CD-R/ DVD-R at Sony DADC*, z.p., z.j.

Tanenbaum, A. (vertaald door L. Geurts). *Gestructureerde computerarchitectuur*, Pearson Education, z.p., 2005.

The National Archives. Digital Preservation Guidance Note 3. *Care, Handling and Storage of Removable Media*, z.p., 2003

Zondag, M. *De CD: Mogelijkheden en beperkingen*, in Archievenblad; uitgave van Koninklijke Vereniging van Archivarissen in Nederland; jaargang 108, nr. 5, juni 2004.

Internet

http://persons.kb.nl/rgillesse/cdrot/langetermijncdr.html

http://www.den.nl/docs/20050808095810

http://www.digitaleduurzaamheid.nl/index.cfm?paginakeuze=271#p3

http://www.iso.org/iso/home.htm

http://www.instantinfo.de/showcdrhersteller_e.php

http://www.pc-active.nl/component/content/article/10508

http://www.cdfreaks.com/news/6450-CD-Recordable-discs-unreadable-in-less-than-two-years.html

http://en.wikipedia.org/wiki/Cd-r

http://wetten.overheid.nl/BWBR0012804/geldigheidsdatum_15-03-2009

http://www.cdrinfo.com/

http://www.cdfreaks.com/

Bijlagen

Bijlage 1: Enquêtevragen Bewaarbeleid optische gegevensdragers

Hoeveelheid en ouderdom OGD

1. Hebt u optische gegevensdragers (OGD) in uw collectie?
Ja, ik heb OGD in mijn collectie.
Nee, ik heb geen OGD in mijn collectie.
Weet niet.

2. Hoeveel OGD bevat uw collectie?
0-100 exemplaren.
100-250 exemplaren.
Meer dan 250 exemplaren.
Weet niet.

3. Hoe oud zijn de meeste OGD in uw collectie?
0-5 jaar.
5-10 jaar.
Ouder dan 10 jaar.
Weet niet.

Bewaarcondities OGD

4. Zijn de OGD in uw collectie machinaal gefabriceerd (CD-ROM) of zijn ze gebrand?
Machinaal (CD-ROM).
Gebrand.
Machinaal (CD-ROM) en gebrand.
Weet niet.

5. Waar zijn de OGD uit uw collectie opgeslagen?
In een aparte archiefkluis met eigen lucht- en temperatuurbehandeling.
In een afgesloten ruimte in de archiefkluis, met eigen lucht- en temperatuurbehandeling.
In een afgesloten ruimte in de archiefkluis, zonder eigen lucht- en temperatuurbehandeling.
In de archiefkluis waar ook de papieren archieven liggen opgeslagen

Brandproces OGD

6. Brandt u zelf OGD?
Ja, ik brand OGD.
Nee, ik brand geen OGD.
Weet niet.
Let op! Als u kiest voor Nee, ga dan verder naar vraag 11.

7. Welk brandprogramma gebruikt u hiervoor?
AccuBurn.
Roxio Media Creator.
Nero.
Weet niet.

8. Welke brandmethode wordt door u gebruikt?
Methode disc-at-once.
Methode track-at-once.
Weet niet.

9. Welk merk (CD-R of DVD+/-R) wordt voor het branden van OGD gebruikt?
Regulier merk (TDK, Maxell, Philips), verkrijgbaar in computerwinkel.
Speciaal merk (Sony Double Gold, MAM, Taiyo Yuden), verkrijgbaar bij speciaalzaak.
Ander merk.
Weet niet.

10: Worden OGD voorzien van plastic stickers of gebruikt u een CDR-pen om informatie op de OGD aan te brengen?
Ja, ik gebruik stickers.
Ja, ik gebruik CDR-pen
Ja, ik gebruik stickers én een CDR-pen.
Nee, ik gebruik geen stickers noch CDR-pen.
Weet niet.

Back-up, fysieke controle OGD en overzetten naar ander medium

11. Is de informatie op een OGD, ook op één of meerdere extra dragers (back-up) opgeslagen?
Ja, informatie is ook op één of meerdere dragers opgeslagen.
Nee, informatie is niet op een andere drager opgeslagen.
Weet niet.
Let op! Als u hier kiest voor Nee, ga dan verder naar vraag 13

12. Ligt deze back-up op een andere plaats en/of in een ander gebouw, dan het originele moederexemplaar van de OGD?
Ja, de back-up ligt op een andere plaats maar in hetzelfde gebouw.
Ja, de back-up ligt op een andere plaats én in een ander gebouw.
Nee, de back-up ligt op dezelfde plaats en in hetzelfde gebouw als de originele OGD.
Weet niet.

13. Worden de OGD in uw collectie periodiek gecontroleerd, bijv. door ze af te spelen en/of door middel van een fysieke controle?
Ja, periodieke controle door afspelen.
Ja, periodieke fysieke controle.
Ja, periodieke controle door afspelen en fysieke controle.
Nee, geen controle.

14. Worden de OGD uit uw collectie periodiek gecontroleerd met behulp van de DVD-Analyzer?
Ja, OGD worden periodiek gecontroleerd met behulp van een DVD-Analyzer.
Nee, OGD worden niet met behulp van DVD-Analyzer gecontroleerd.
Wat is de DVD-Analyzer?
Weet niet.

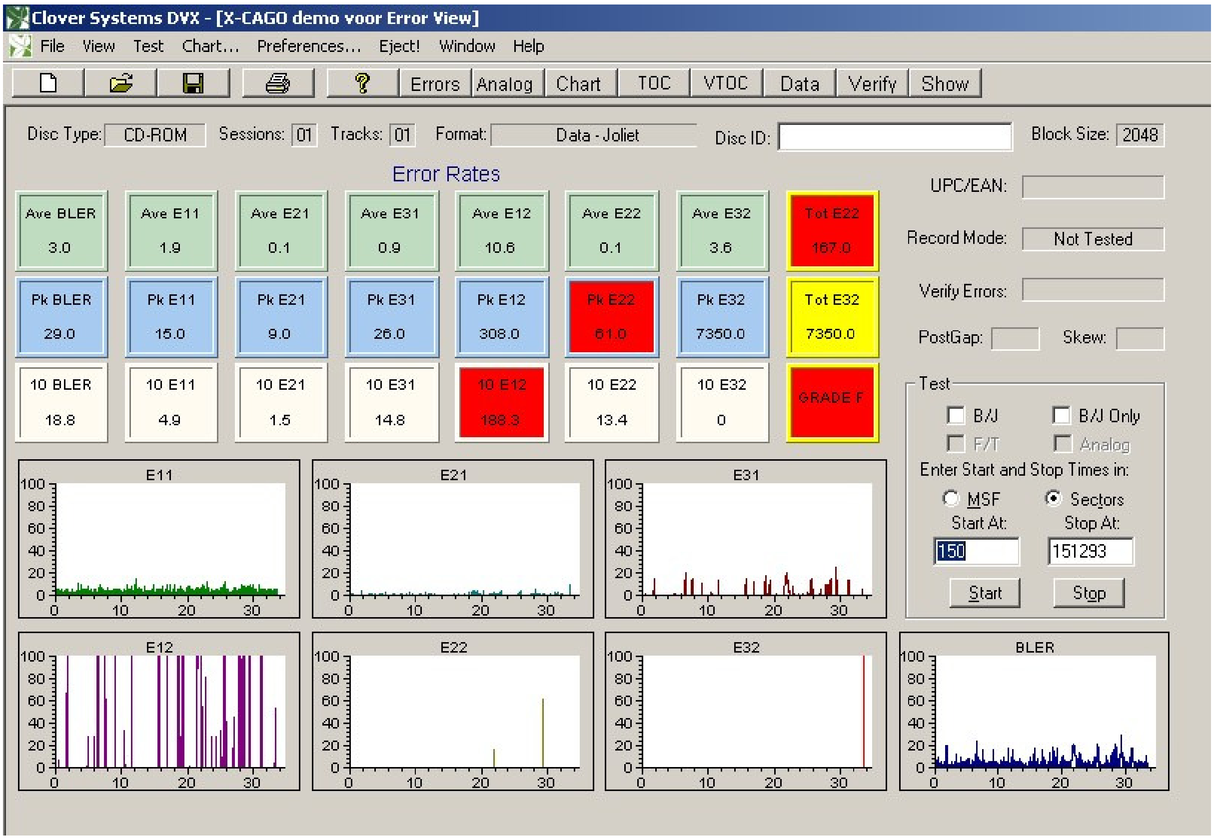
15. Overweegt u OGD op een ander medium te zetten, bijv. (in- of externe) harddisk?
Ja, ik overweeg de OGD over te zetten op een ander medium.
Nee, ik blijf informatie bewaren op OGD en overweeg geen ander medium
Nog niet over nagedacht.

Bijlage 2: Gedetailleerde uitleg werking DVX

Cross-interleaved Reed-Solomon Code (CIRC)
Om CD's te testen wordt gebruik gemaakt van een foutopsporings- en correctiemethode, die ook in alle "normale" (muziek)cd-spelers wordt gebruikt. **CIRC** staat voor Cross-interleaved Reed-Solomon Code. CIRC gebruikt twee methoden om fouten op te sporen en deze fouten te corrigeren gedurende het afspeelproces:

Redundantie: Dit betekent dat extra informatie tijdens het brandproces aan een disc wordt toegevoegd. Redundantie geeft u de mogelijkheid om deze extra informatie te lezen. CIRC heeft een redundantie van 25%, dit betekent dat 25% extra informatie wordt toegevoegd. Dit is informatie over de originele data (dus de metadata), waardoor u de mogelijkheid krijgt om de oorsprong van de originele informatie te achterhalen. M.a.w. welke informatie dit had *moeten* zijn.

Interleaving: Dit betekent dat data wordt verdeeld over een relatief groot gebied. Met CIRC worden de bits voor het brandproces "verspreid" en tijdens het afspeelproces weer teruggezet. De bits van individuele data worden door elkaar gegooid en worden verspreid over vele andere data. Om een enkele byte te kunnen uitwissen moet je een groot gebied verwijderen. Door deze testmethode worden alleen kleine gedeelten van vele data vernietigd. Er is altijd genoeg informatie over van elke sample om alle informatie te reconstrueren. Om een geheel blok van data te verwijderen, moet men een gat van 2mm doorsnee in de CD boren!



De CIRC-methode maakt gebruik van twee fasen van foutcorrectie tijdens het afspeelproces, getiteld **C1** en **C2**. De (lees)foutcorrectie chip kan 2 slechte bytes per blok in fase één (**C1**) en wel 4 slechte bytes per blok in fase twee (**C2**) herstellen.

Voor C1 zijn dat de foutmeldingen E11, E21 en E31:

E11= 1 slechte byte in een raamwerk in de C1-fase, welke werd gecorrigeerd.

E21= 2 slechte bytes in een raamwerk in de C1-fase, welke werden gecorrigeerd.

E31= 3 of meer slechte bytes in de C1-fase, welke <u>niet</u> werden gecorrigeerd. Dit blok is niet te corrigeren in de C1-fase en wordt doorgegeven aan de C2-fase.

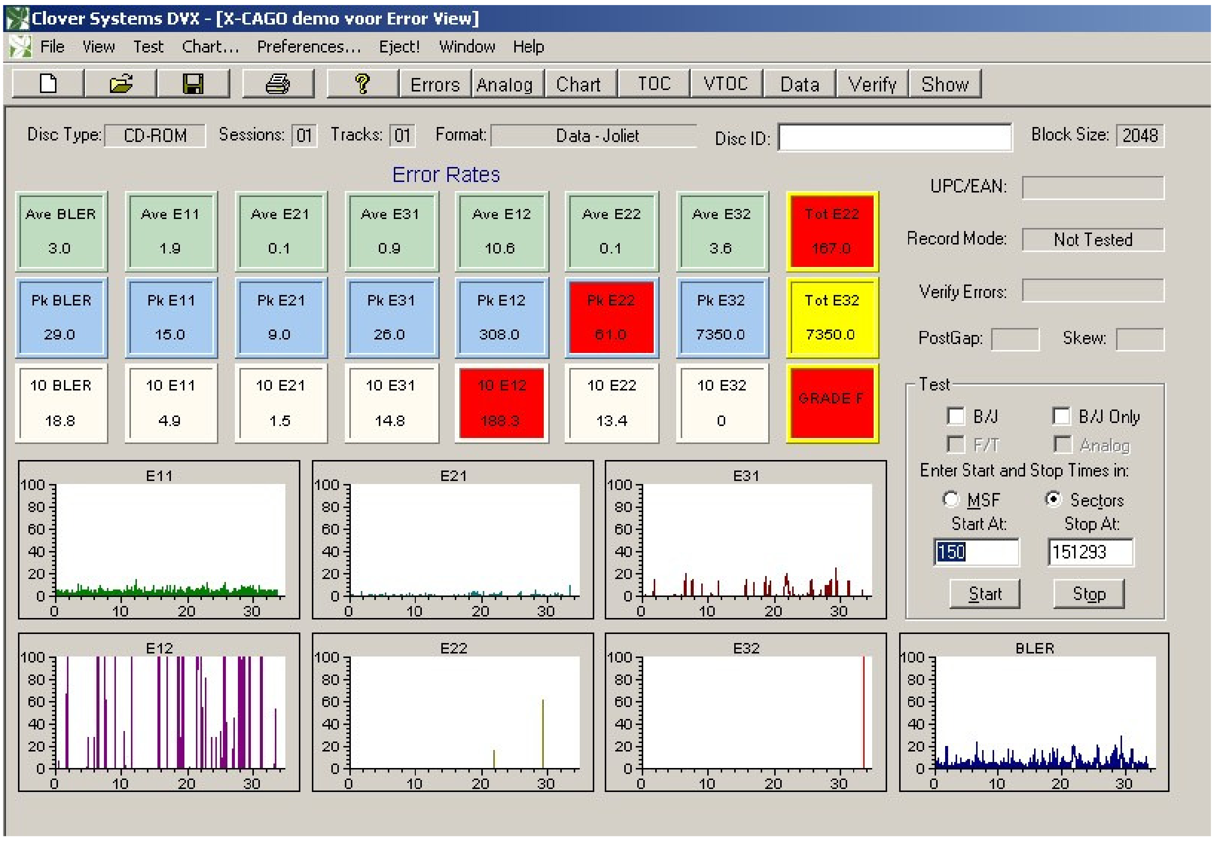
Vanwege het de-interleaving proces van de data tussen de C1-fase en de C2-fase, bevinden 3 of meer slechte bytes uit de C1-fase (=**E31**), zich in aparte blokken. Deze blokken worden ter correctie aangeboden aan de C2-fase, waar zij kunnen worden gecorrigeerd.

Voor C2 zijn dat de foutmeldingen E12, E22 en E32:

E12= 1 slechte byte in een raamwerk in de C2-fase, welke werd gecorrigeerd.
E22= 2 slechte bytes in een raamwerk in de C2-fase, welke werd gecorrigeerd.
E32= 3 of meer slechte bytes in de C2-fase, welke <u>niet</u> werden gecorrigeerd. Deze fouten worden als onherstelbare fouten aangemerkt.
*Fouten op een disc worden weergegeven voor elke "1-seconden gemiddelden". Aangezien er **7350** dataframes per seconde worden getest, is het maximum aantal fouten per seconde **7350**.*

Block Error Rate (BLER)
Tevens wordt de Block Error Rate (**BLER**) gemeten. BLER is het totaal aantal geconstateerde fouten per seconde in de C1-fase (**E11+E21+E31**). De specificaties van de Red Book standaard gaat uit van een maximale BLER van 220 fouten per seconde, gemeten over gemiddeld 10 seconden. Maar BLER telt alleen de hoeveelheid fouten. Het zegt echter niets over de ernst van deze fouten.

1–seconde en 10-seconden gemiddelden (alleen bij CD's)
Als een test is gestart, stuurt de programmatuur gemiddeld 1 keer per seconde alle foutparameters naar de DVX. De gepresenteerde data zijn "1-seconde gemiddelden". De Red Book standaard gaat uit van 10-seconden gemiddelden. De gemiddelde waarden zijn echter voor "1 en 10-seconden gemiddelden" gelijk. Het DVX-scherm laat zowel de "1-seonde gemiddelden" als de "10-seconden gemiddelden" zien. Daarom heeft de "1-seconde gemiddelden" hogere pieken en lagere dalen.



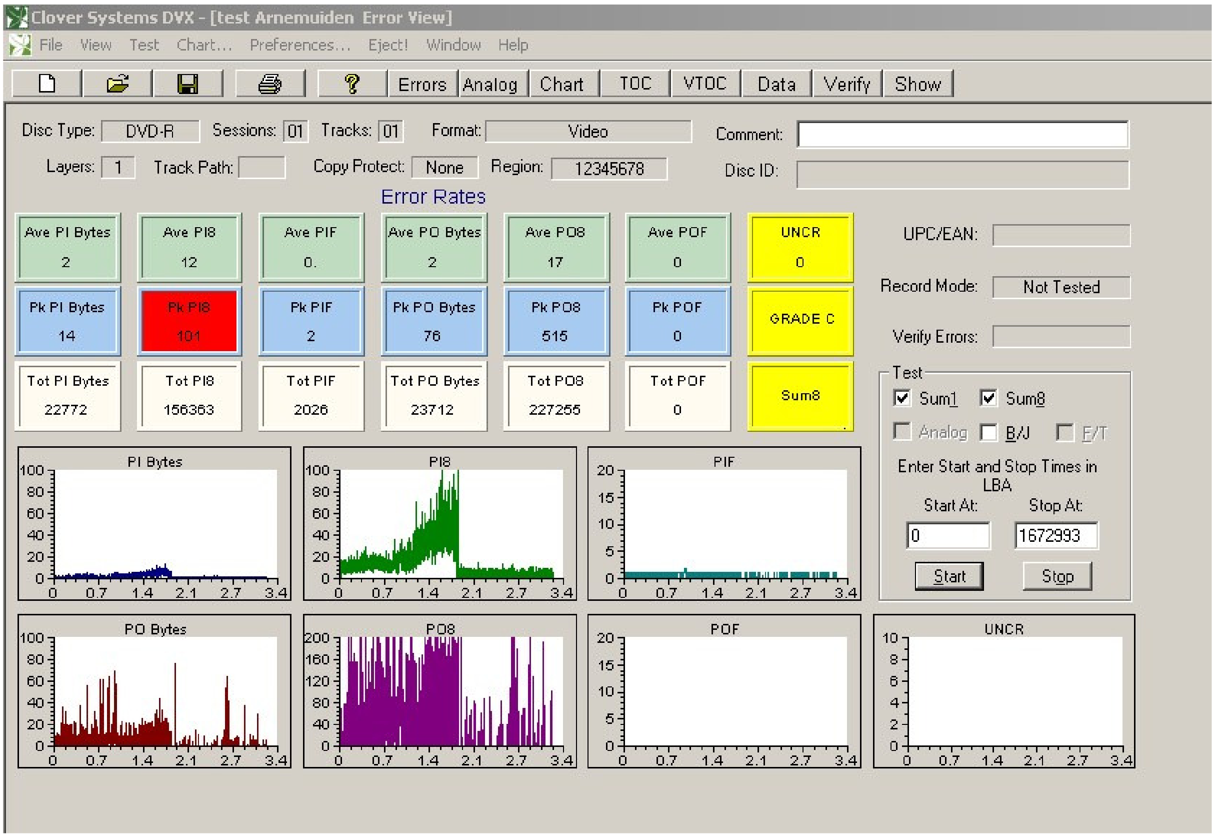
U ziet in de schermafdruk hierboven drie horizontale rijen met VAKJES. Van boven naar beneden:
Ave : gemiddelde BLER, E11, E21, E31, E12, E22, E32

Pk : piekwaarde BLER, E11, E21, E31, E12, E22, E32
10 : 10-seconden gemiddelden BLER, E11, E21, E31, E12, E22, E32

De laatste kolom bevat **totalen** (van boven naar onder): E22, E32, eindwaarde

Gedetailleerde uitleg van de testmethode: DVD-test

Een DVD-test maakt ook gebruik van een Reed-Solomon methode voor foutcontrole. Het grootste verschil met een CD is de grootte van het te corrigeren datablok en het ontbreken van het interleaving-proces. Een DVD heeft maar één spoor plus de leadout per sessie. De starttijd wordt weergegeven als Logical Block Adresses (LBA).



U ziet in de schermafdruk hierboven 3 horizontale rijen met vakjes. Van boven naar beneden:
Ave : gemiddelde PI Bytes, PI8, PIF, PO, PO8, POF
Pk : piekwaarde PI Bytes, PI8, PIF, PO, PO8, POF
Tot : totaalwaarde PI Bytes PI8, PIF, PO, PO8, POF

De laatste kolom bevat **totalen** (van boven naar onder): **UNCR** (=onherstelbare fouten), **Grade** dus eindwaarde, **Sum8**.

De foutcorrectie van een DVD-test maakt gebruik van een foutcorrectieblok van 32 Kb (bij een CD wordt een foutcorrectieblok toegepast van 24Kb). Het blijkt dat de foutcorrectie van de Reed-Solomon methode toeneemt, naarmate het te corrigeren datablok groter wordt. Daarom is de foutcorrectie bij een DVD veel nauwkeuriger. Dit is noodzakelijk omdat de grootte van de putjes en bultjes van een DVD veel kleiner zijn dan die van een CD.

Tijdens het afspeelproces worden kleine leesfouten gecorrigeerd door middel van PI. PO wordt gebruikt voor grote leesfouten.

DVD-fouten worden getest per **1 ECC-blok**, terwijl andere fouten getest per 8 ECC-blokken. **ECC** betekent Error Correction Code. Dit is extra informatie die tijdens het brandproces aan data wordt toegevoegd, om, tijdens het afspeelproces van een DVD, fouten op te sporen en waar mogelijk te corrigeren.

PI bytes en PO bytes worden altijd getest per 1 ECC-blok (**Sum1**) maar PI8-, PIF- en P08-fouten worden altijd geteld per 8 ECC-blokken (**Sum8**).

1 ECC blok = 16 sectoren = 32768 bytes.

PI bytes = het aantal slechte bytes in alle rijen van 1 ECC blok, welke werden gecorrigeerd.

PI8 bytes = het aantal rijen in 8 ECC blokken met slechte bytes, geconstateerd door de binnenste pariteit, welke werden gecorrigeerd.

PIF = het aantal rijen in 1 ECC blok met slechte bytes dat niet door de binnenste pariteit kon worden gecorrigeerd.

PO Bytes = het aantal slechte bytes in alle kolommen van 1 ECC blok, welke werden gecorrigeerd.

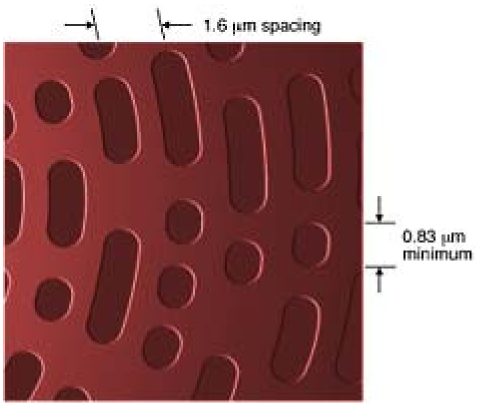
PO8 = het aantal kolommen in 8 ECC blokken, geconstateerd door de buitenste pariteit.

POF = het aantal kolommen in 1 ECC blok welke niet door de binnenste pariteit konden worden gecorrigeerd.

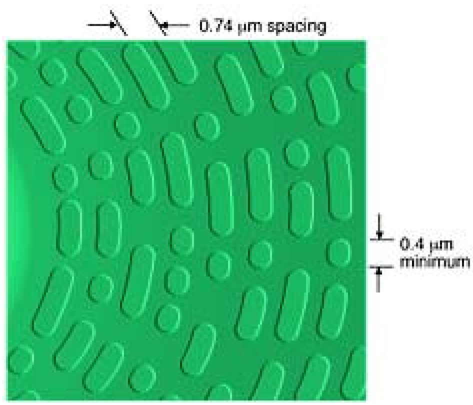
UNCR = het totaal aantal niet-corrigeerbare ECC blokken op een hele disc.

PK = de grootste waarden die zijn waargenomen op een hele disc tijdens een test.

TOT = het totaal aantal fouten op een hele disc.



putjes en bultjes van een CD

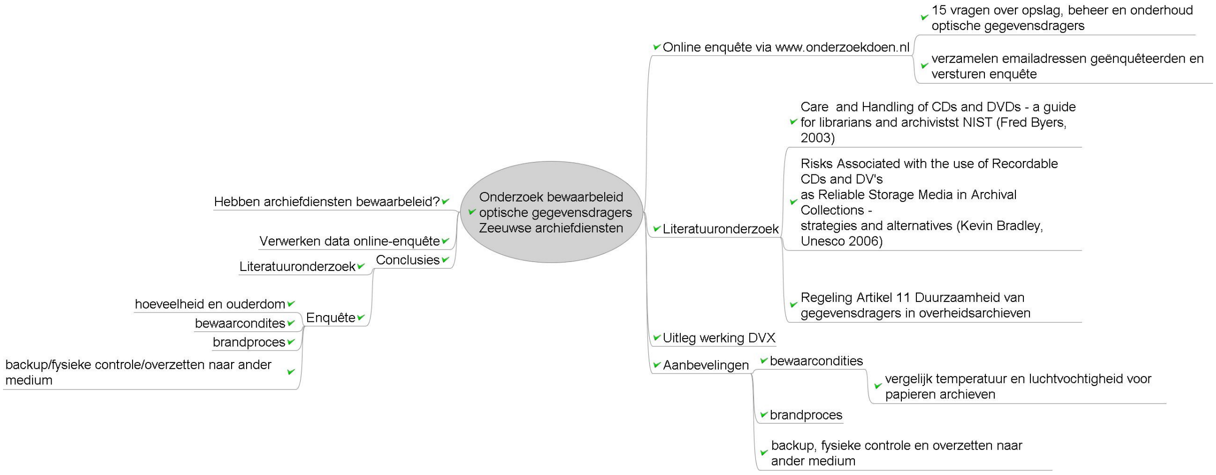


putjes en bultjes van een DVD

In plaats van twee fasen bij de foutcorrectie van een CD, zet de foutcorrectietest van een DVD de gecorrigeerde data in rijen en kolommen. Elke rij en elke kolom hebben haar eigen pariteiten bytes. Correctie van de rij wordt weergegeven als binnenste pariteit (Inner Parity of **PI**). Correctie van de kolom wordt weergegeven als buitenste pariteit (Outer Parity of **PO**).

Pariteit is een procedure voor foutcontrole, waarbij het aantal enen altijd hetzelfde moet zijn (oneven of even) voor elke groep bits.
De rij (=**PI**) wordt als eerste gecontroleerd én gecorrigeerd dus bytes die niet konden worden gecorrigeerd in een rij, kunnen altijd nog in een kolom door de buitenste pariteit (=**PO**) worden gecorrigeerd. PI fouten (**PIF**) zijn daarom niet fataal. Maar PO fouten (**POF**) kunnen niet meer worden gecorrigeerd. De Reed-Solomon methode voor foutcontrole kan 5 bytes per rij en 8 bytes per kolom corrigeren. Tijdens het afspeelproces meet de DVX de foutmeldingen in de rij (=binnenste pariteit of **PI**) en de foutmeldingen in de kolom (=buitenste pariteit of **PO**).

Bijlage 3: Mindmap



Bijlage 3: Standaardvragen voor interviews met (cultuur)instellingen

1. Hebt u optische schijven (hierna OS) in uw collectie?
2. Hoeveel OS bevat uw collectie?
3. Hoe oud zijn de meeste OS in uw collectie?
4. Waar zijn de OS opgeslagen?
5. Zijn dit meerdere series identieke OS?
6. Waar zijn deze series opgeslagen?
7. Welk onderhoud pleegt u aan uw OS?
8. Is er een periodieke controle?
9. Brandt u zelf OS?
10. Welke alternatieve opslagmedia heeft u in gebruik?
11. Waarom hebt u juist voor deze opslagmedia gekozen?
12. Hoe denkt u data toegankelijk te houden voor de toekomst?

Bijlage 4: Standaarden

The Red Book (1980)
In 1980 publiceerden Sony en Philips The Red Book[84], de Compact Disc-standaard, dat alle details beschreef om een compact disc, -plaat en -speler, te fabriceren.

The Yellow Book (1983)
The Yellow Book[85] is de standaard dat het bestandsformaat van CD-ROM beschrijft. Het is de eerste uitbreiding van Red Book. Yellow Book is gelijk aan ECMA-130.

The Green Book (1986)
The Green Book[86] is de specificatie van CD-I, een multimediasysteem van Philips dat in 1991 werd uitgebracht. Het werd aangesloten op een tv. Naast de speciale CD-I's konden ook audio-cd's, foto-cd's en, in combinatie met een videocassette, video-cd's (VCD) worden afgespeeld.

The Orange Book (1990)
De specificaties van de CD-R zijn voor het eerst gepubliceerd door Philips en Sony in het Orange Book[87], waarin de standaarden van CD-Recordables worden opgesomd.
De eerste beschrijfbare optische schijf werd in 1988 geïntroduceerd door Taiyo Yuden onder de naam That's CD-R maar de ontwikkeling ervan was al gestart in 1985[88]. Dit is een optische schijf met de eigenschap Write Once Read Many (WORM), d.w.z. eenmalig te beschrijven en vele malen te lezen.

The White Book (1992)
Het White Book[89] refereert aan een compact disc waarop geluid, stilstaande beelden en bewegende videobeelden staan.

The Beige Book (1992)
The Beige Book[90] beschrijft de specificaties voor de Photo-CD.

The Blue Book (1995)
Blue Book[91] is een supplement van het Orange Book waarin de specificaties staan beschreven voor een multisessie CD. De officiële naam is CD Plus, soms ook CD-Extra of E-CD.

The Scarlet Book (1999)
The Scarlet Book[92] beschrijft de specificaties van de Super Audio CD, die drie verschillende versies van hetzelfde materiaal kan bevatten.

The Purple Book (2000)
The Purple Book[93] beschrijft de door SONY ontwikkelde technologie van een OS met een dubbele opslagcapaciteit.

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[84] Een uitgebreide beschrijving van alle specificaties van The Red Book standaard voor de Compact Disc Digital Audio is te vinden op http://en.wikipedia.org/wiki/Red_Book_(audio_CD_standard) (geraadpleegd op 20-08-2009).
[85] http://en.wikipedia.org/wiki/Yellow_Book_%28CD_standard%29 (geraadpleegd op 20-08-2009).
[86] http://en.wikipedia.org/wiki/Green_Book_%28CD-interactive_standard%29 (geraadpleegd op 20-08-2009).
[87] Een volledige uitleg van deze standaard is te vinden op http://www.osta.org/technology/cdqa2.htm (geraadpleegd op 20-08-2009).
[88] http://en.wikipedia.org/wiki/Taiyo_Yuden; (geraadpleegd op 20-08-2009).
[89] http://en.wikipedia.org/wiki/White_Book_%28CD_standard%29 (geraadpleegd op 20-08-2009).
[90] http://en.wikipedia.org/wiki/Photo_CD (geraadpleegd op 20-08-2009).
[91] http://searchstorage.techtarget.com/sDefinition/0,,sid5_gci508910,00.html (geraadpleegd op 20-08-2009).
[92] http://whatis.techtarget.com/definition/0,,sid9_gci514000,00.html (geraadpleegd op 20-08-2009).
[93] http://en.wikipedia.org/wiki/DDCD en http://tweakers.mobi/nieuws/16084 (DDCD) (geraadpleegd op 20-08-2009).

Optische illusie?

De **International Organisation for Standardization** (ISO) ontwikkelt en publiceert internationale standaarden[94]. Voor alle standaarden moet worden betaald.

De **International Association dedicated to the standardization of Information and Communication Technology (ICT) and Consumer Electronics** (ECMA) heeft tot doel om, samen met nationale, Europese en internationale organisaties standaarden te ontwikkelen en vast te stellen op het gebied van Informatie- en Communicatietechnologie en Consumentenelektronica[95]. In tegenstelling tot de ISO-standaarden zijn een groot aantal ECMA-standaarden, hoewel inhoudelijk identiek aan ISO-standaarden, gratis te downloaden via de website van ECMA.

De belangrijkste standaarden voor optische schijven worden vermeld.

<u>ISO 9660/ECMA-119</u>
ISO 9660 is een standaard met betrekking tot een bestandssysteem voor cd-rom. De bedoeling van de standaard is ondersteuning door- en data-uitwisseling tussen besturingssystemen. ISO-9660 zorgt ervoor dat dit op een platform onafhankelijke manier gebeurd. ECMA-119 is hieraan identiek[96].

<u>Joliet</u>
Joliet is een uitbreiding van Microsoft op ISO 9660 en maakt het onder andere mogelijk om langere bestands- en directorynamen te gebruiken (maximaal 64 karakters)[97].

<u>ISO 13346/Universal Disk Format (UDF)</u>
ISO 13346 is een verdere uitwerking van ISO 9660. De UDF-gegevensindeling[98] is gebaseerd op een norm die is ontwikkeld door de Optical Storage Technology Association (OSTA) en een specificatie voor een bestandssysteem, bedoeld voor het bewaren van bestanden op media waarop je kunt opnemen. Gelijk aan UDF is ECMA-167[99] .

<u>ISO 10149</u>
ISO 10149 is de fysieke standaard voor een data-cdrom. Deze standaard maakt gebruik van een heel nauwkeurige foutopsporings- en verbeteringsmethode. Een zo hoge nauwkeurigheid is voor data cd's onontbeerlijk. De bestandsysteemsstandaard zorgt er voor dat de mappenstructuur en de bestanden kan worden uitgelezen.

<u>ISO 10995</u>
Voor de gebruiker van optische schijven heeft de ISO een test, waarmee bepaald kan worden hoelang optische media hun gegevens kunnen vasthouden, tot standaard verklaard. "*De goedkeuring van deze wereldwijde standaard is een belangrijke mijlpaal; de standaard zal gebruikers in staat stellen om gemakkelijker schijven voor archivering te herkennen", aldus Osta-voorzitter David Bunzel"*[100].

<u>ISO 12024</u>
ISO 12024 is een standaard voor het testen van lege optische schijven.

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[94] http://www.iso.org/iso/home.htm (geraadpleegd 21-08-2009).
[95] http://www.ecma-international.org/ (geraadpleegd op 21-08-2009).
[96] Deze standaard is te downloaden op http://www.ecma-international.org/publications/standards/Ecma-119.htm (geraadpleegd 21-08-2009).
[97] De Joliet-specificatie is te vinden op http://bmrc.berkeley.edu/people/chaffee/jolspec.html (21-08-2009).
[98] De UDF is te downloaden op http://www.osta.org/specs/pdf/SecureUDF_1_00.pdf (geraadpleegd op 21-08-2009).
[99] Te downloaden op http://www.ecma-international.org/publications/files/ECMA-ST/Ecma-167.pdf (geraadpleegd op 21-08-2009).
[100] http://tweakers.net/nieuws/51698/test-voor-levensduur-optische-media-krijgt-iso-stempel.html; (geraadpleegd op 21-08-2009).

Optische illusie?

ISO 12142
Standaard voor het monitoren en vastleggen van fouten ter controle van gearchiveerde data op een optische schijf.

ISO 18921
ISO 18921 is een standaard om de levensduur van een optische schijf te schatten op basis van de effecten van temperatuur en relatieve vochtigheid.

ISO 18925
ISO 18925 is een standaard voor lange termijn archivering van optische schijven en bevat aanbevelingen voor bewaaromstandigheden, bewaarfaciliteiten en de controle van optische schijven.

ISO 18938
ISO 18938 is een standaard voor behandelings- en bewaaromstandigheden van diverse soorten optische schijven: compact disc (CD), digital versatile disc (DVD), high definition digital versatile disc (HD DVD), Blu-ray disc (BD), en alle hybride varianten van deze soorten én de soorten optische schijven waarbij een organische opnamelaag (dye) is gebruikt: beschrijfbare en herschrijfbare optische schijven.

Bijlage 5: Overzicht softwareprogramma's om data op een optische schijf te herstellen

CD / DVD Diagnostic 3.0
Met het programma CD/DVD Diagnostic kunnen bestanden van gebrekkige media worden hersteld door de beschadigde sector verschillende keren te laten lezen en er ondertussen een foutcorrectie op los te laten.
Meer informatie op http://www.infinadyne.com/cddvd_diagnostic.html

Stellar Phoenix CDRom Data Recovery 2.0
Het herstellen van data door middel van een krachtig, eenvoudig te gebruiken programma. Kan gegevens herstellen van beschadigde of gebrekkige optische schijven.
Meer informatie op http://www.stellarinfo.com/cd-data-recovery.htm

ISO Buster 2.5
Met IsoBuster is het mogelijk verloren gewaande data van beschadigde cd's, dvd's, HD DVD's en Blu-Ray-schijven te lezen.
Meer informatie op http://www.isobuster.com/isobuster.php

Retro Burner CD/DVD Recovery
Herstelt data van elke optische schijf door gebruik van geavanceerde algoritmes die berekenen hoe data is gebrand op een optische schijf.
Meer informatie op http://www.dtidata.com/cd_dvd_recovery.htm

CDRoller 8.50
CDRoller is een krachtig programma om beschadigde gegevens van CD's en DVD's te redden.
Als gegevens op optische schijven worden opgeslagen, is het onzeker of ze over enkele jaren nog leesbaar zijn. CDRoller kan helpen bij het terughalen van verloren data van CD's en DVD's, die krassen hebben of niet meer zijn af te lezen.
Meer informatie op http://www.cdroller.com/

Quick Recovery for CD
Is een "do-it-yourself" CD recovery softwarepakket.
Meer informatie op http://www.recoveryourdata.com/cd-recovery.html

Unstoppable Copier 4.0
Met Unstoppable Copier is het mogelijk om bestanden te kopiëren van een (optische) schijf met problemen als gevolg van krassen of stof. Het programma zal proberen om ieder stuk van het bestand te lezen en deze stukken weer aan elkaar te zetten.
Meer informatie op http://www.roadkil.net/program.php?ProgramID=29

Bijlage 6: Understanding CD-R and CD-RW

Understanding CD-R & CD-RW

-OSTA.org-
Optical Storage
Technology Association

Revision 1.00
January 2003

Optical Storage Technology Association (OSTA)
Market Development Committee

Author's Notes

It's often said that the only constant in the computer and consumer electronics industries is change. Nonetheless, CD-R and CD-RW have remained a constant and trusted companion for many. CD-R and CD-RW technologies have, of course, evolved over the years but change here has come in practical and tangible improvements to quality, performance and ease of use. Unique compatibility and affordability, at the same time, have made CD-R and CD-RW the popular storage choice of industry and consumers alike.

This paper replaces OSTA's earlier "CD-R & CD-RW Questions & Answers" document. Like its predecessor, it seeks to answer basic questions about CD-R and CD-RW product technology in an understandable and accessible way and to provide a compass pointing to sources of further information.

If you have suggestions to improve the effectiveness of this paper, please feel free to contact the author by email: hugh_bennett@compuserve.com.

Sincerely,

Hugh Bennett, President
Forget Me Not Information Systems Inc.

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PHYSICAL, LOGICAL AND FILE SYSTEM STANDARDS

What is the Orange Book?

Orange Book is the set of specifications created by Philips and Sony to define the optical signal characteristics, physical arrangement, writing methods and testing conditions for CD-R (Orange Book Part II) and CD-RW (Orange Book Part III) discs. First released in 1990, Orange Book originally dealt with only single speed CD-R recording but, with rapid advances since made in hardware and media technology, the specification grew to include CD-RW in 1996. Higher writing speeds continue to be incorporated as the industry evolves.

What are the different sections of CD-R and CD-RW discs?

Orange Book organizes CD-R and CD-RW discs into various sections serving distinct purposes. The Information Area is most fundamental and consists of a shallow spiral groove (pregroove) extending from the discs' inside to outside diameter. Encoded in the structure of this pregroove are speed control and Absolute Time In Pregroove (ATIP) time code information as well as other parameters critical for recorders to correctly write a disc. Several regions within this pregroove are reserved exclusively for recorder use.

The first is the Power Calibration Area (PCA), located in the inner portion of the disc, which is employed while determining the correct power level for the writing laser. Due to physical and practical design limitations on rotational velocity it is, generally speaking, not possible to conduct power calibrations at the inner diameter of the disc at speeds above 16x. A process of extrapolation is therefore used to determine suitable writing power for those higher speeds. Recently, Orange Book has designated the addition of another PCA located in the Lead-Out Area at the outer portion of the disc to provide the space necessary to conduct actual high speed write power calibrations.

Following the first PCA is the Program Memory Area (PMA) which is used as intermediate storage to record track information for all sessions written to the disc. Typically, the PMA is first followed by the Lead-In Area, containing table of contents information, followed by the Program Area which holds the written data tracks and finally the Lead-Out Area which indicates to a reading device that the end of the data has been reached.

What is a Multisession CD-R or CD-RW disc?

Multisession recording allows additional data to be written to a previously partially recorded CD-R or CD-RW disc. Each session on the multisession disc has its own Lead-In Area, Program Area and Lead-Out Area and may be connected to other sessions to function as a single volume (linked) or operate independently (multi-volume). In addition to being written by a recorder the first session of a multisession disc can be, alternatively, prerecorded (stamped) at the factory.

What is the difference between fixation and finalization?

Fixation is the process of completing a CD-R or CD-RW disc session by writing Lead-In (table of contents) and Lead-Out information. Once a disc is fixated it can then be played back in CD and DVD-ROM drives and recorders and consumer electronics devices compatible with the particular disc type and format. It is also possible to record additional information later to create a multisession disc. Finalization, on the other hand, completely closes the disc so no further material can be added.

What are the different writing modes?

CD-R and CD-R/RW recorders employ several different writing modes including Disc-At-Once (DAO), Track-At-Once (TAO), Session-At-Once (SAO), and packet writing. Be aware that not all recorders and software support all writing modes. If in doubt, consult with the product manufacturer.

During DAO recording the Lead-In Area, Program Area and Lead-Out Area of a CD-R or CD-RW disc are consecutively written in a single uninterrupted operation. DAO recording is only possible using a blank disc and, after recording is completed, no additional information can be written. Typically, DAO is used to write CD audio, CD-Text and discs destined for mass replication.

In contrast to DAO, TAO operates by turning the writing laser on and off at the beginning and end of each track and writes the Program Area of a disc before its Lead-In and Lead-Out Areas. It is possible to use a recorder to read from (or write additional tracks to) a TAO disc before a session is fixated. All TAO discs contain 2 to 3 second gaps between tracks (run-in, run-out and link blocks) but some recorders have the ability to vary the size of the gaps.

SAO is much like DAO in that the Lead-In Area, Program Area and Lead-Out Area are consecutively written in a single uninterrupted operation. However, the first session is not finalized so additional sessions can be added. Typically, SAO is used to write CD Extra (Enhanced Music CD) discs where the first session contains one or multiple audio tracks and the second session consists of multimedia computer data.

Packet writing records variable (CD-R) or fixed (CD-RW) sized chunks or "packets" of data to the disc for as many times as is needed to complete the writing of the user's files. In the case of a CD-R disc (which is not erasable) data may be added incrementally until the disc becomes full. CD-RW discs, on the other hand, are completely rewritable and thus are a little different from their CD-R cousins in that files can be added and deleted as needed.

What is ISO 9660?

The ISO 9660 standard was introduced in 1988 and is the most widely used file format for data (CD-ROM) discs. ISO 9660 defines a common logical format for files and directories so discs written to ISO 9660 specifications can be read by a wide array of computer operating systems (MS-DOS, Windows, Mac OS, UNIX, etc.) as well as consumer electronics devices. Due to the vast differences which exist among native file systems ISO 9660 takes a lowest common denominator approach resulting in a variety of restrictions upon the nature and attributes of files and directories. Three levels of interchange define these restrictions with level one being the most constraining and level three is the least (at the cost of compatibility with some operating systems). Various protocols are available to extend ISO 9660 to accommodate file system features specific to individual operating systems (longer file names, deeper directory structures, more character types, etc.) while preserving ISO 9660 compatibility with other platforms. These protocols include Joliet (Windows 95 and higher), Apple Extensions (Mac OS) and Rock Ridge (UNIX).

What is The Universal Disc Format (UDF)?

The Universal Disc Format (UDF) specification was first released by OSTA in 1995 and is designed to be a common logical file system for all removable optical storage media. Over the years various updates to UDF have been introduced to add new capabilities. For example, UDF 1.02 is the standard file system used for prerecorded and recordable DVD discs while UDF 1.5 is commonly employed for packet writing CD-R and CD-RW media. Most recently, UDF 2.0 has added full support for Windows NT, enhanced data security and improved CD-R functions while defining backward read capabilities between discs created with the new UDF 2.0 format and discs created with earlier versions of UDF.

What is a hybrid disc?

The term "hybrid" is popularly used to describe several different types of discs. The first kind of hybrid disc is one that contains multiple file systems, such as ISO 9660 and HFS (Mac OS). A second type of hybrid is a CD that contains applications designed to interact with the Internet so static data resides on the disc and live information is downloaded as needed from the Web. These discs are sometimes called "connected CDs." A third kind of hybrid is defined by Orange Book as a CD-R or CD-RW disc with a prerecorded (stamped) first session with the ability to potentially hold additional written sessions.

What is Running OPC?

Running Optimum Power Control (Running OPC) is a special technique used in many newer CD-R and CD-R/RW recorders that monitors and maintains the quality of the disc writing and ensures the accuracy of all the marks and lands lengths across the disc. The term Running OPC actually describes the general process that may be known by several trade names. Some differences in execution may be present to give some of these implementations competitive advantages over others.

RECORDING HARDWARE

What types of devices write CD-R and CD-RW discs?

All CD-R and CD-R/RW recorders write CD-R discs but only CD-R/RW recorders write both CD-R and CD-RW discs. Many DVD recorders also come combined with CD-R and CD-RW writing functions but be aware that there are exceptions. If in doubt, consult with the hardware manufacturer.

Are there audio CD recorders available that connect to stereo systems?

Several manufacturers offer consumer and professional audio CD recorders that connect, like cassette decks, to conventional stereo systems. Typically, they will record to CD-R or CD-R and CD-RW discs from either digital (CD, DAT, MD, etc.) or analog (cassette, vinyl record, radio, etc.) sources.

What do the numbers describing a CD-R or CD-R/RW recorder mean?

Manufacturers typically use a sequence of two, three or four numbers to express the maximum writing and reading speeds of a recorder. The generally accepted industry convention for a CD-R recorder has been for the first figure to indicate CD-R writing speed followed by CD reading speed for CD-R and prerecorded (pressed) data CDs. For a CD-R/RW recorder the first number usually indicates CD-R writing speed followed by CD-RW writing speed and then by the CD reading speed. In the case of a combination recorder a fourth number is included to indicate DVD reading speed. As examples, 8x12 usually means 8x CD-R write and 12x CD read while 48x12x48 typically indicates 48x CD-R write, 12x CD-RW write and 48x CD read. And for a combination recorder 24x10x40x12 denotes 24x CD-R write, 10x CD-RW write, 40x CD read, and 12x DVD read.

What types of CD-R and CD-R/RW recorder configurations are available?

Whether for PC, Mac or UNIX computers in desktop, laptop or notebook form, CD-R and CD-R/RW recorders are available in a wide variety of configurations to suit most needs. Several industry standard interfaces are available including SCSI, EIDE/ATAPI, Parallel, USB and IEEE 1394 for either internal or external recorder connection.

EIDE/ATAPI
The Enhanced Integrated Drive Electronics/ATA Packet Interface (EIDE/ATAPI) is the most popular method for connecting CD and DVD-ROM drives and hard disks as well as CD-R and CD-R/RW recorders to a computer. Since most computers already have EIDE/ATAPI built-into their motherboards no additional interface card is necessary. These devices are normally installed internally but many external recorders are actually EIDE/ATAPI models that use bridge technology to convert them to SCSI, USB or IEEE 1394 interfaces.

SCSI
The Small Computer Systems Interface (SCSI) or "scuzzy" interface is a high performance and flexible method of connecting to a computer many peripherals including scanners, CD and DVD-ROM and hard drives as well as CD-R and CD-R/RW recorders. In addition to long cable lengths, SCSI allows for both internal and external attachments. Some computers already have SCSI built-into their motherboards, but, more often than not, a SCSI interface card is required. Depending upon the specific product, a SCSI card may or may not be included with the CD-R/RW recorder bundle.

Parallel
CD-R/RW recorders that make use of a parallel interface connect to the computer using the same parallel port used by a printer and can only be installed externally. Depending upon the product, some recorders have pass-through arrangements allowing both a printer and recorder to be connected to the computer at the same time.

USB
The Universal Serial Bus (USB) is used to connect many types of peripherals to a computer including joysticks, mice, keyboards, printers, scanners and external CD-R and CD-R/RW recorders. Since USB is a plug and play interface computers do not have to be rebooted when a recorder is attached as these devices are automatically recognized by the system. And USB has been updated several times to accommodate the demands of increasingly faster peripherals. USB 1.1 interfaces are built into the motherboards of many systems and generally permit up to 4x CD-R/RW writing and 6x reading speeds. USB version 2.0 is an updated version of the specification allowing greater performance but typically requires an additional interface card. Most USB 2.0 CD-R/RW recorders are backward compatible and can operate at reduced speed when connected to older USB 1.1 systems.

IEEE 1394
Popularly known by trade names such as FireWire and i.LINK, IEEE 1394 is a high performance plug and play interface commonly used to connect computers to external hard disk drives and CD-R and CD-R/RW recorders as well as consumer electronics devices like digital camcorders, televisions and game consoles. IEEE 1394 interfaces come standard on many Macintosh systems and on some brands of PCs but, more often than not, an interface card is required.

What is buffer underrun?

An important point to remember about CD-R and CD-RW recording is that information must be written to a blank disc in a continuous stream. To help smooth out the flow in the data transfer rate from the computer, the recorder employs a memory buffer which, like a reservoir storing water for use when it is needed, caches data for when it is required by the recorder. As with a water reservoir, the key is to always have enough data in the buffer to satisfy the demands of the recorder, even if, from time to time, the computer can't supply the needed amount of information. If the buffer runs dry (a "buffer underrun") the disc is ruined.

How can buffer underrun be prevented?

Most current computer recorders incorporate advanced buffer underrun protection technology to eliminate buffer underruns but for units not so equipped there are a variety of common sense techniques that can be used to help minimize the possibility. These include ensuring that the recorder and writing software are properly configured, defragmenting the operating system and data source hard disk partitions, disconnecting from any networks, closing all other programs and disabling background tasks such as power managers and anti-virus software. In more stubborn cases additional measures to be considered include reducing writing speed as well as enabling the recording software to build a temporary image on the hard disk drive before recording.

What is buffer underrun protection?

In order to keep pace with the demands of ultra speed writing, recorder manufacturers have created new technologies for preventing buffer underruns. A recent innovation now known by a multitude of different trade names, buffer underrun protection utilizes a combination of recorder hardware, firmware and writing software to accomplish its task.

Buffer underrun protection functions by constantly monitoring the amount of data in the recorder's buffer during the writing of a disc and suspends recording if the amount available falls below a predetermined threshold. Once the buffer again accumulates sufficient data the recorder resumes writing precisely where it left off. Obviously, it's critical to leave as small a gap as possible between the previous and newly recorded sections so as to avoid producing an unreadable segment on the disc. Generally speaking, the gap length has been found to be well within the error correction capabilities of CD and DVD-ROM drives and players. As the technology matures the gap will continue to shrink.

RECORDING SOFTWARE

Is special software needed to use CD-R and CD-R/RW recorders?

The two main types of software needed to operate CD-R and CD-R/RW recorders, namely packet writing software and CD recording software (sometimes called premastering software), are available for most major operating systems. The majority of CD-R and CD-R/RW recorders include either one or both types as part of their purchase bundles. Be aware, however, that software from competing publishers may offer a different range of features. In addition, some current operating systems and standalone application software have built-in CD-R and CD-RW recording capabilities.

CD Recording Software
Unlike many removable storage solutions that are restricted to just housing and retrieving data, CD-R and CD-R/RW recorders are also used as powerful multimedia devices. In addition to providing the means to store, backup and distribute data on CD-R and CD-RW discs, many CD recording software packages also include the tools necessary to write or edit different content on CDs such as music, photos and video.

Taking the form of standalone applications, many recording software packages have the capability to create discs in different physical formats (eg. data, audio, video, hybrid, etc.) using various file systems (eg. UDF, ISO 9660, HFS, etc.) and support different file naming conventions (eg. Joliet, Rock Ridge, Apple extensions, etc.). Some can actually clean up clicks, pops, scratches and hiss from old music LPs or cassettes and lay out and print labels and jewel case inserts to personalize and identify discs after they are written. Depending upon the package, other capabilities may include the ability to duplicate CDs, assemble Red Book CD-DA or compressed digital audio compilation CDs a track at a time from different sources and even create photo and video albums.

Packet Writing Software
Packet writing software installs at the driver level and makes a CD-R or CD-R/RW recorder seem to the user as just another removable drive. Appearing the same as a floppy or hard disk, users write files to a CD-R or CD-RW disc by simply dragging and dropping the files over the recorder's icon or saving from within an application.

As with all removable storage systems, the first step in operating a CD-R or CD-R/RW recorder using packet writing software is to initialize the disc to prepare it to receive the user's data. After inserting a blank disc into the recorder the user is prompted by the computer to initialize the disc which is then ready to go after an automatic formatting procedure. Some products conduct background formatting where the disc is available to write shortly after initiating the process but others require formatting to complete before data can be written.

Packet writing records variable (CD-R) or fixed (CD-RW) sized chunks or "packets" of data to the disc for as many times as is needed to complete the writing of the user's files. In the case of a CD-R disc (which is not erasable) data may be added incrementally until the disc becomes full. CD-RW discs, on the other hand, are completely rewritable and thus are a little different from their CD-R cousins in that files can be added and deleted as needed. Typically, packet writing software records CD-R and CD-RW discs in OSTA's Universal Disc Format (UDF).

What is the storage capacity of CD-R and CD-RW discs formatted for packet writing?

After being formatted for packet writing use the storage capacity of CD-R and CD-RW discs is somewhat less than their unprepared state. For example, a 74 minute/650 MB (12 cm) CD-R disc has an initial formatted capacity of roughly 620 MB while an equivalent CD-RW disc stores approximately 530 MB after being formatted for random rewriting. Due to increased defect management overhead, a Mount Rainier formatted CD-RW disc is able to store roughly 30 MB less than its conventionally packet written counterpart.

Are CD-RW discs created using packet writing software from different publishers compatible with each other?

Generally speaking, it is possible to format a CD-RW disc using one publisher's packet writing software and write to the same disc using software offered from a different publisher. However, once data has been written to the disc only the software that was used to write the information can be used to append or rewrite other data. Greater writing interchangeability for CD-RW discs is, however, one of the primary goals of the new Mount Rainier format. It is advisable to consult with the appropriate software publisher for specific compatibility details.

What is Mount Rainier?

The Mount Rainier specification was developed in 2001 to provide the framework necessary for computer operating systems to seamlessly rewrite data CD-RW discs in a drag and drop fashion without the use of additional drivers or software. Through enhancements over the abilities of conventional packet writing software, including background formatting, recorder-based defect management, improved interchangeability and greater ease of use, Mount Rainier's goal is to make 3.5" floppy diskettes obsolete by replacing them with CD-RW discs for everyday data storage and interchange.

What is required to read and write Mount Rainier CD-RW discs?

Mount Rainier formatted CD-RW discs are rewritten on Mount Rainier-enabled CD-R/RW recorders. Since this specification is a recent innovation it is supported by only some of the latest recorders but it is expected that, over time, an increasing number of new units will incorporate Mount Rainier capability. In cases where the operating system being used does not offer Mount Rainier functions it will be necessary to employ additional software to format and rewrite discs. Typically, this comes as modified conventional packet writing software to allow the rewriting of Mount Rainier formatted CD-RW discs.

Mount Rainier formatted CD-RW discs are read on MultiRead-compliant CD-ROM drives, CD-R/RW recorders and MultiRead-compliant DVD-ROM drives and recorders. In situations where the operating system used does not offer Mount Rainier functions it is necessary to employ an additional software driver to read the discs. It is therefore advisable to consult with the appropriate hardware manufacturers and software publishers to verify the specific capabilities of your recorder, operating system and writing software.

RECORDING SPEED

How long does it take to write a CD-R or CD-RW disc?

The amount of time taken to write a disc depends upon the speed of the recorder, the writing method used by the recorder and the amount of information required to be written. Recording speed is measured the same as the reading speed of ordinary CD-ROM drives and players. At single speed (1x) a recorder writes 150 KB (153,600 bytes) of data (CD-ROM Mode 1) per second and at a multiple of that figure at each speed increment above 1x.

CD Read and Write Average Data Transfer Rates
(transfer rates indicated in bytes)

Read/Write Speed (CLV)	Audio (2,352 Bytes/Block)	CD-ROM Mode 1 (2,048 Bytes/Block)	CD-ROM Mode 2 (2,336 Bytes/Block)	CD-i/XA Form 1 (2,048 Bytes/Block)	CD-i/XA Form 2 (2,324 Bytes/Block)
1x	176,000	153,600	175,200	153,600	174,300
2x	352,800	307,200	350,400	307,200	348,600
4x	705,600	614,400	700,800	614,400	697,200
6x	1,058,400	921,600	1,051,200	921,600	1,045,800
8x	1,411,200	1,228,800	1,401,600	1,228,800	1,394,400
12x	2,112,000	1,843,200	2,102,400	1,843,200	2,091,600
16x	2,816,000	2,457,600	2,803,200	2,457,600	2,788,800
20x	3,520,000	3,072,000	3,504,000	3,072,000	3,486,000

Writing Modes
As the market for CD-R and CD-RW products came into its own writing speed accelerated due to rapid advances made in hardware and media technology. One breakthrough came in writing modes which permitted recorders to reliably operate beyond 20x speed. Available units now employ a variety of writing modes including Constant Linear Velocity (CLV), Zone Constant Linear Velocity (ZCLV), Partial Constant Angular Velocity (PCAV) and Constant Angular Velocity (CAV).

Constant Linear Velocity (CLV)
CDs were originally designed for consumer audio applications and initially operated using a CLV mode to maintain a constant data transfer rate across the entire disc. The CLV mode sets the disc's rotation at 500 RPM decreasing to 200 RPM (1x CLV) as the optical head of the player or recorder reads or writes from the inner to outer diameter. Since the entire disc is written at a uniform transfer rate it takes, for example, roughly 76 minutes to complete a full 74 minute/650 MB disc at 1x CLV. As recording speed increases the transfer rate increases correspondingly so that at 8x CLV writing an entire disc takes 9 minutes and at 16x 5 minutes. Recording time as well is directly related to the amount of information to be written so partial discs are completed in proportionally less time. But writing at higher speeds requires rotating the disc faster and faster (eg. 10,000 to 4,000 RPM at 20x CLV which places escalating physical demands upon both

media and hardware. Manufacturers have met this challenge by moving beyond the original CLV mode to obtain even higher performance.

Zone Constant Linear Velocity (ZCLV)
In contrast to CLV which maintains a constant data transfer rate throughout the recording process, ZCLV divides the disc into regions or zones and employs progressively faster CLV writing speeds in each. For example, a 40x ZCLV recorder might write the first 10 minutes of the disc at 20x CLV, the next 15 minutes at 24x CLV, the following 30 minutes at 32x CLV and the remainder at 40x CLV speed.

Partial Constant Angular Velocity (PCAV)
Some recorders make use of the PCAV mode which spins the disc at a lower fixed RPM when the optical head is writing near the inner diameter but then shifts to CLV part way further out on the disc. As a result, the data transfer rate progressively increases until a predetermined point is reached and thereafter remains constant. For example, a 24x PCAV recorder might accelerate from 18x to 24x speed over the first 14 minutes of the disc then maintain 24x CLV writing for the remainder of the disc.

Constant Angular Velocity (CAV)
The CAV mode spins the disc at a constant RPM throughout the entire writing process. Consequently, the data transfer rate continuously increases as the optical head writes from the inner to outer diameter of the disc. For example, a 48x CAV recorder might begin writing at 22x at the inner diameter of the disc accelerating to 48x by the outer diameter of the disc.

What is the difference between low and high speed CD-RW discs?

CD-RW media present additional problems in that it is not possible for one kind of CD-RW disc to support all recording speeds. Low speed discs are compatible with all CD-RW recorders and can only be written from 1x to 4x speeds. High speed discs, on the other hand, can be written from 4x to 10x but only on recorders bearing the high speed CD-RW logo.

Can CD-R and CD-RW discs written at different speeds be read back at any speed?

The speed at which a disc is written has nothing to do with the speed at which it can be read back in a recorder, CD-ROM or DVD-ROM drive.

Do some CD-R recording speeds produce better results than others?

Recorder and media manufacturers carefully tune their products to operate with each other across a wide range of speeds. As a result, equally high quality CDs are created when recording at almost all speeds. However, 1x presents a minor exception. Generally speaking, the physics and chemistry involved in the CD recording process seem to produce more consistent and readable marks in CD-R discs at 2x and greater speeds.

Can any CD-R disc be recorded at any speed?

In order to accommodate progressively higher recording speeds CD-R disc design and manufacturing has continued to evolve. Consequently, reliable operation is best achieved by following disc manufacturers' guidance with respect to the range of writing speeds formally supported by their respective discs, while acknowledging that this can change as recording specifications change. Additionally, new media companies and products continually enter the market and some recorder companies may test particular brands of discs more extensively than others. Thus it may be advisable to inquire of the recorder manufacturer for specific media recommendations.

Is there any way to prevent a recorder from writing a CD-R disc at too high a speed?

CD writing speed can be set at an appropriate level manually in all premastering software to correspond with the recommendations of the recorder and disc manufacturers. Beyond this, some of the latest recorders also employ systems to actively monitor the writing process and automatically adjust recording speed in order to achieve the optimum results.

PHYSICAL COMPATIBILITY

What types of devices read CD-R discs?

Once written, CD-R discs closely mimic the optical characteristics of prerecorded (pressed) CDs. As a result, they can be read on almost any computer CD-ROM drive, CD-R or CD-R/RW recorder or MultiRead-compliant DVD-ROM drive or recorder. Additionally, CD-R discs are compatible with most consumer electronics devices including portable, car and set-top CD audio players and MultiPlay-compliant DVD-Video players and recorders. All DVD devices that read CD-R discs do not necessarily display the MultiRead or MultiPlay logos. If in doubt, consult with the hardware manufacturer.

What types of devices read CD-RW discs?

Written CD-RW discs have slightly different optical characteristics (lower reflectivity and signal modulation) than prerecorded (pressed) and written CD-R discs and therefore are not as widely compatible. They can be read only on MultiRead-compliant CD-ROM drives, CD-R/RW recorders and MultiRead-compliant DVD-ROM drives and recorders. CD-RW discs are, in addition, compatible with some consumer electronics devices including MultiPlay-compliant portable, car and set-top CD audio players and MultiPlay-compliant DVD-Video players and recorders. Again, all CD and DVD devices that read CD-RW discs do not necessarily display the MultiRead or MultiPlay logos. If in doubt, consult with the hardware manufacturer.

What is MultiRead?

The MultiRead specification was created by OSTA in 1997 to provide hardware manufacturers with the requirements necessary to make CD-ROM drives and recorders read CD-RW discs. MultiRead also bridges the differences between CD and DVD technologies and provides the framework for DVD-ROM drives and recorders to read CD-R and CD-RW discs. Specifically, MultiRead requires that compatible drives read Red Book CD audio and CD-ROM information contained on prerecorded (pressed), CD-R and CD-RW discs.

Examples of Discs Readable by MultiRead-Compliant Drives and Recorders

Type of Disc	CD-ROM Drive	CD-R Recorder	CD-R/RW Recorder	DVD-ROM Drive	DVD-R/-RW Recorder	DVD-RAM Recorder	DVD+R/+RW Recorder
CD-DA disc	yes	yes	yes	yes	yes	yes	yes
CD-ROM disc	yes	yes	yes	yes	yes	yes	yes
CD-R disc	yes	yes	yes	yes	yes	yes	yes
CD-RW disc	yes	yes	yes	yes	yes	yes	yes

What is MultiPlay?

The MultiPlay specification was created by OSTA in 2000 to provide hardware manufacturers with the requirements necessary to make CD and DVD consumer electronics devices play CD-R and CD-RW discs. Specifically, MultiPlay requires that all compatible devices play prerecorded (pressed), CD-R and CD-RW discs in Red Book audio format. As well, devices with CD-Text and VideoCD capabilities must also play these formats when written on CD-R and CD-RW discs.

Why can't all DVD devices read CD-R and CD-RW discs?

DVD format specifications deal with elements of disc design and not the hardware that reads them. As a result, DVD device manufacturers are free to incorporate whatever features they like into their products, including deciding which types of discs are supported. Consumer demand and cost considerations are taken into account by manufacturers who then construct their products and marketing accordingly.

In addition to these market forces a number of technical issues come into play. Despite appearances to the contrary, a CD and a DVD are distinctively different physically from each other. For example, a DVD disc uses a substrate half as thick as does a CD (0.6 mm vs. 1.2 mm) as well as smaller pit and lands and has less distance between the coils of the data track. A DVD is also read using a shorter wavelength laser (650 nm red vs. 780 nm infra-red) through an optical lens with a larger numerical aperture (0.60 vs. 0.45). Thus, DVD devices which also read prerecorded (pressed) CDs employ a number of tactics to accommodate these differences. However, a CD-R disc has its own unique construction so reading it requires additional hardware components.

Unlike the molded plastic pits of a prerecorded disc the optical responses of the organic dyes used in the recording layer of a CD-R disc are carefully designed to function in the 780 nm range used by CD drives and recorders. Consequently, when a CD-R disc is read using the shorter 650 nm DVD laser wavelength the signals returned from the disc are greatly diminished and may not be read reliably. DVD devices that are designed to read DVD and CD-R discs (such as those compliant with MultiRead and MultiPlay specifications) compensate for this problem by incorporating dual laser optical pickups to generate both 650 nm and 780 nm wavelengths.

A CD-RW disc is a little different. The optical response of the phase change material used in its recording layer is not as wavelength dependent as organic dye in a CD-R and can be read using a 650 nm laser. However, because a CD-RW disc has relatively low reflectivity and signal modulation the optical systems of some DVD devices may not be sensitive enough to read it.

DISC SIZE AND CAPACITY

What are the physical sizes of CD-R and CD-RW discs?

CD-R and CD-RW discs come in standard 12 cm (120 mm) and 8 cm (80 mm) sizes. The most popular is the larger 12 cm type which has the same physical dimension as most commercial audio CDs and computer software CD-ROMs. 8 cm discs are less common but, thanks to their smaller size, are gaining popularity for use in consumer electronic devices such as portable compressed digital audio players, digital still image cameras and data storage products like miniature CD recorders.

What about business card CD-R and CD-RW discs?

Beyond the conventional 8 cm and 12 cm sizes some manufacturers offer discs shaped like business and credit cards or in other novelty forms. These do not conform with Orange Book specifications and, as a result, may not write and play back in all recorders or reading devices. Following manufacturer instructions is always the best course.

What capacities of blank CD-R and CD-RW discs are available?

Manufacturers commonly express disc capacity in terms of how much Red Book digital audio (in minutes) and computer data (in megabytes) a disc can contain. Historically, 63 minute/550 MB (12 cm) and 18 minute/158 MB (8 cm) discs were once available but are now rendered obsolete by advances in recording technology. Currently, 74 minute/650 MB, 80 minute/700 MB (12 cm) and 21 minute/185 MB (8 cm) discs are the market standards.

What about 34, 90 and 99 minute CD-R discs?

A few media manufacturers have recently introduced 34 minute/300 MB (8 cm), 90 minute/790 MB and 99 minute/870 MB (12 cm) CD-R discs. To achieve these higher capacities such discs do not conform to Orange Book specifications and, as a result, may not write in all recorders, be accessible to all software or readable in all players and drives. Using 34, 90 and 99 minute CD-R discs is therefore not recommended.

How much information can actually be stored on CD-R and CD-RW discs?

The amount of information that can be written is determined by the disc's recording capacity as well as the physical and logical formats used.

Each of the five main CD physical formats devotes a different amount of space to user data (audio = 2,352 bytes/block, CD-ROM Mode 1 = 2,048 bytes/block, CD-ROM Mode 2 = 2,336/bytes/block, XA Form 1 = 2,048 bytes/block, XA Form 2 = 2,324 bytes/block). For any given data format disc capacity can be calculated by multiplying the appropriate user data area size by the CD data transfer rate of 75 blocks per second by 60 seconds by the minute size of disc. For example, a 80 minute disc written in CD-ROM Mode 1 format: user data area of 2048 bytes/block x 75 blocks/second = 153,600 bytes/second x 60 seconds = 9,216,000 bytes/minute x 80 minutes = 737,280,000 bytes. This rounds to roughly 700 MB (dividing by 1,024 to convert into KB and again by 1,024 to convert into MB). It should be noted, however, that in the real world capacity can vary slightly among discs from different media manufacturers.

For discs written with computer data the logical format used also consumes space available for user information. For example, the overhead for the first session of a multisession disc consumes 22 MB of space and each subsequent session thereafter uses 13 MB. And in the case of CD-RW discs which are formatted for random packet-writing, usable capacity is reduced by roughly 23%.

CD-R and CD-RW Disc Capacities

(capacities indicated in bytes)

Disc Size	Playing Time	Audio (2,352 Bytes/Block)	CD-ROM Mode 1 (2,048 Bytes/Block)	CD-ROM Mode 2 (2,336 Bytes/Block)	CD-i/XA Form 1 (2,048 Bytes/Block)	CD-i/XA Form 2 (2,324 Bytes/Block)
8 cm	18 min	190,512,000	165,888,000	189,216,000	165,888,000	188,244,000
8 cm	21 min	222,264,000	193,536,000	220,752,000	193,536,000	219,618,000
12 cm	63 min	666,792,000	580,608,000	662,256,000	580,608,000	658,854,000
12 cm	74 min	783,216,000	681,984,000	777,888,000	681,984,000	773,892,000
12 cm	80 min	846,720,000	737,280,000	840,960,000	737,280,000	836,640,000

What is the difference between 74 and 80 minute discs?

The only meaningful difference between most 74 and 80 minute discs is their storage capacity. Typically, this increase in usable space is achieved by tightening the coils of the pregroove (track pitch). This allows the disc to accommodate a longer pregroove and therefore a larger recordable area.

Are there any compatibility issues when using 80 minute instead of 74 minute discs?

Originally, 80 minute discs were specialized products for use in audio premastering studios but now have become commonplace and compatible with most software, recorders, readers and players. In some instances, however, older recorders and premastering software must be upgraded to accommodate 80 minute discs. It is, therefore, advisable to check with the manufacturers of your products and ensure that the latest versions of software and firmware are being used.

What is overburning?

Overburning (sometimes called oversizing) is the ability to write beyond the manufacturer's declared capacity on a CD-R or CD-RW disc. This is accomplished by using the disc's Lead-Out Area (reserved to indicate to a reading device that the end of the data has been reached) to store the additional user information. Although some recorders and premastering software packages have the ability to overburn a disc the practice is not permitted by Orange Book standards. Overburning might affect product warranties and result in lost data so it is not recommended.

AUDIO RECORDING

What is the Red Book?

Red Book is the set of specifications created by Philips and Sony to define the essential parameters for Compact Disc-Digital Audio (CD-DA). First released in 1980, Red Book has been adopted an international standard (IEC 60908:1999, Audio Recording — compact disc digital audio system) and forms the foundation for all other compact disc standards.

What types of audio CDs can CD-R and CD-R/RW recorders write?

CDs were originally designed for audio so it's only natural that CD-R and CD-R/RW recorders write discs in the official Compact Disc-Digital Audio (CD-DA) Red Book format for use in any CD audio compatible player. Just like their mass produced prerecorded (pressed) cousins, CD-R and CD-RW discs can hold up to 80 minutes of CD quality audio (44.1 Khz, 16 bit) using as many as 99 separate tracks. In addition to Red Book discs, recorders also write compressed digital audio CDs which, instead of holding conventional tracks, contain MP3, WMA or other compressed audio files. Depending upon the scheme used, one compressed CD-R or CD-RW disc holds as much as ten to twenty ordinary audio CDs and can be played back in devices enhanced for compressed digital audio listening such as compatible computers, personal, home and car CD players as well as many DVD-Video players.

What types of material can be used as sources for audio CD recording?

Depending upon the capabilities of the recorders and software used, CD-R and CD-RW audio discs can be written from either digital or analog sources. Digital material such as existing MP3 files or CDs are conveniently read directly from the hard drive, recorder or from a separate CD or DVD-ROM drive. To record analog sources such as LP records, cassette tapes, microphone or radio tuner inputs connected to a home stereo, signals are first digitized through the computer's sound card.

Digital
Digital audio material comes in many forms including compressed and uncompressed computer files such as MP3s, WMAs and WAVs, Compact Discs (CD), MiniDiscs (MD), Digital Audio Tapes (DAT), Digital Compact Cassettes (DCC) and Alesis ADAT. How they are handled by the computer for writing to CD varies depending upon the capabilities the individual recording system.

Digital Files
A popular way to create audio discs is to use uncompressed (WAV, PCM, etc.) and compressed (MP3, WMA, etc.) computer files as the recording sources. When producing a compressed digital audio CD these files are written to disc just as they come and, depending upon the recording software used, may be accompanied by MultiAudio or other navigational information. In the case of a Red Book audio CD, compressed files must first be uncompressed and translated into the correct format before recording. Historically, this had to be accomplished manually but most recording software now performs the conversion process automatically during the writing process. As with any audio recording it's important to remember that the sound quality of a written disc will be no better than the source material used. Higher resolution digital audio files obviously will produce better results.

CD
Recording CD to CD is much simpler than recording from analog sources since most CD and DVD-ROM drives are capable of transferring audio directly (Digital Audio Extraction) without the necessity of converting from analog to digital. As a result, CDs can often be recorded disc to disc using a CD or DVD-ROM drive as the audio source. Where a suitable drive is not available the recorder itself can be used as the audio source. In this case, the audio is read using the recorder and stored temporarily on the computer's hard drive until written out again.

DAT, MD, DCC, ADAT
Although the contents of DATs, MDs, DCCs and ADATs are already in digital form, most computers lack the proper connections for directly importing digital material. As a result the analog outputs from the source must be connected to the computer's sound card and the audio re-digitized. Since there is always a loss of quality in the conversion process, some manufacturers offer special sound cards that connect to the digital outputs of the source deck to transfer the audio to the computer while keeping it in quality digital form.

Analog
Analog audio equipment such as LP record players, cassette tape recorders, microphones and radio tuners use continuous electrical signals of varying voltages to record and play sound. Computers, on the other hand operate, in the digital world where everything is represented in binary form. Thus, before the computer can manipulate or record analog audio sources to a hard drive or a CD-R/RW disc, the sounds must be converted into digital form through the computer's sound card. Higher quality sound cards will produce better results but most cards are capable of recording at the 44.1 kHz frequency, 16 bit resolution used by audio CDs. Some recording software automates the conversion and writing processes into a few simple steps by performing time saving tasks such as detecting the silences between songs to automatically split the music into separate tracks.

What is MultiAudio?

The MultiAudio specification was created by OSTA in 2001 to provide a standardized structure for compressed digital audio files (MP3, WMA, etc.) written onto removable optical media, such as CD-R and CD-RW discs. This uniformity allows these discs to be played back in the same way on any compatible device including MultiAudio-compliant computer software media players and consumer electronics devices such as CD and DVD audio and video players. To accomplish this goal MultiAudio requires that, in addition to compressed digital audio files, an appropriately formatted disc also must contain a defined table of contents which the playing device will use for file navigation. In addition, the specification allows playlists to be created to organize material so it can be accessed by categories such as genre, album, artist or even in custom groupings created by the user. MultiAudio formatted discs are created by standard recording software packages and CD-R/RW recording-enabled audio jukebox applications which support the MultiAudio specification. Written discs can then be played back in MultiAudio compliant devices and even in compressed digital audio units not supporting the specification, albeit in a more limited fashion. Since MultiAudio is simply an organizing system it's important to remember that the types of discs and specific compressed digital audio file formats supported depend upon the individual capabilities of the particular devices or software employed.

Can consumer compact disc audio recorders write to any CD-R or CD-RW media or are special discs required?

Even though general purpose CD-R and CD-RW discs and their consumer audio versions appear for all practical purposes identical, only blank media bearing the "Compact Disc Digital Audio Recordable" (CD-DA Recordable) and "Compact Disc Digital Audio Rewritable" (CD-DA Rewritable) logos can be written in consumer audio recorders. The reason for this restriction is to comply with international copyright agreements. A special Disc Application Code present in the ATIP information of a CD-DA Recordable/Rewritable disc's pregroove wobble identifies it specifically for audio use. Consumer audio recorders are programmed to reject discs not containing the correct code. By adopting this safeguard various countries and other authorizing jurisdictions may selectively apply copyright levies to the price of blank discs intended for consumer audio use while exempting those destined for computer or professional applications.

Does using lower CD-R recording speeds and lower capacity media produce better sounding discs?

High speed CD-R writing often creates discs with low I3 and I11 signal amplitudes (optical signals generated from the smallest and largest marks) and 80 minute discs achieve their capacity by packing marks and lands more tightly together. These result in reduced recording and playing margins and sometimes lead to perceptible sound degradation, especially in older CD audio players which may not employ equalization (signal boosting). Consequently, many high speed recorder manufacturers recommend creating audio discs at reduced writing speeds while some recorders even limit their maximum speed to 24x when writing audio discs. In addition to slower recording speeds, some manufacturers also suggest using 74 minute instead of 80 minute discs. Several of the latest recorders even offer special writing modes which record audio discs with longer marks and lands than would normally be the case, albeit at the expense of some capacity. For example, an 80 minute disc written with longer marks and lands might only hold 74 minutes of audio and a 74 minute disc just 68 minutes of material.

DIGITAL PICTURES ON CD

What are the differences between Photo CD and Kodak Picture CD?

Eastman Kodak developed Photo CD and Picture CD to deliver and store high quality digital image files of pictures taken with conventional cameras and film. Photo CD was introduced in 1992 and is intended for professional and commercial applications while Picture CD came to market in 1999 aimed at the average consumer. Generally speaking, Photo CD discs store images using a proprietary file format (Image Pac) in, depending upon the version, five to six levels of resolution (128 x 192 to 2048 x 3072 or 4096 x 6144 pixels). Picture CD, on the other hand, employs the more common JPEG format in one resolution (1024 x 1536 pixels). In terms of capacity, Photo CD discs hold approximately 100 images and additional pictures can be added at later times. With Picture CD, however, images from a single roll of film are written at the time of original processing only. In addition, Photo CD compatible computer software is required to view and use Photo CD images but Picture CDs include on the discs a range of Windows and Macintosh applications to display, organize, enhance and email images.

What hardware is required to view images on Photo CD and Kodak Picture CD discs?

Both Photo CD and Kodak Picture CD discs are written in industry standard multisession (Mode 2, Form 1) format and are therefore playable on most computer CD-ROM drives and MultiRead-compliant (or other CD-R compatible) DVD-ROM drives and recorders. Historically, Photo CD images could be displayed on TV sets connected to dedicated Photo CD and multi-purpose Compact Disc Interactive (CD-i) players. These devices, however, are no longer available. Most recently, a few DVD-Video player models have come along incorporating Picture CD viewing capability.

Can DVD-Video players display digital still images written on CD-R and CD-RW discs?

In addition to select DVD-Video player models which are compatible with commercially produced Kodak Picture CDs some devices display JPEG images written to standard ISO 9660 formatted CD-R and CD-RW discs. It is anticipated that once OSTA's MultiPhoto/Video specification is released more manufacturers will incorporate digital image viewing capabilities into their DVD-Video and even, perhaps, other consumer electronic devices. It is also possible to use a CD-R or CD-R/RW recorder and software to create Video CD 2.0 formatted discs containing slideshows of digital images which can be played back on many MultiPlay-compliant (or other CD-R or CD-RW compatible) DVD-Video players. Be aware, however, that not all DVD-Video players support the Video CD format and not all recording software creates Video CD slideshow discs.

What is MultiPhoto/Video?

The MultiPhoto/Video (MPV) specification is a collaborative effort between OSTA and the International Imaging Industry Association (I3A) and is currently under development. This specification will provide a standardized structure for still image digital photographs (JPEG, etc.) and video (eg. MPEG, AVI, etc.) stored on fixed and removable storage media, such as writable CD and DVD discs, flash memory cards and hard disk drives. This uniformity enables computer software and consumer electronics devices to more easily process collections of digital photographs and video and to play them back in the same way on any compatible device. To accomplish this goal MPV requires that, in addition to digital image files or video, an appropriately formatted storage medium must contain a defined table of contents and descriptive information (metadata) which the playing device will use for file navigation. In addition, MPV can also act as a protocol for exchanging information between software applications and services. It is expected that MultiPhoto/Video formatted CD-R and CD-RW discs will be created by a broad range of software including CD recording packages as well as digital camera, scanning, imaging and multimedia authoring software which support the MPV specification. Written discs could then be played back in MPV compliant devices and even in systems not supporting the specification, albeit in a more limited fashion. Since MultiPhoto/Video is simply an organizing system it is important to remember that the types of storage media and specific image and video file formats supported depend upon the individual capabilities of the particular devices or software employed.

DUPLICATION, REPLICATION AND PUBLISHING

What alternatives are available to copy CDs?

There are several different methods available to make one or multiple copies of existing CDs ranging from single CD-R and CD-R/RW recorders to specialized devices that automatically duplicate and label discs and, for large runs, commercial mass replication. Options are distinguished by cost, speed, convenience and capability. When dealing with commercial software and audio discs keep in mind copyright laws and that copy protection systems may be employed to hinder straightforward duplication.

Computer CD-R and CD-R/RW Recorders
By far the quickest and least expensive way to duplicate a disc is to simply copy it using a computer outfitted with a CD-R or CD-R/RW recorder combined with off the shelf writing software. In addition to creating discs from scratch many basic writing software packages duplicate most standard CD formats. Specialized copying software is also available with more sophisticated capabilities such as the ability to make backups of copy protected discs and even the power to simultaneous duplicate to multiple recorders. But remember that the ability of a system to copy specific disc formats depends upon the individual capabilities of the software, reader and recorder used. It is therefore advisable to check with the respective manufacturers for specific information.

Typically, discs are duplicated CD to CD by using the computer's CD-ROM or DVD-ROM drive as the master source feeding the copying recorder. In cases where a separate reading drive is not available the master is first downloaded to the computer hard drive using the reading ability of the recorder and later written back to a blank disc using the same recorder. Employing the hard disk as an intermediate copying step is also a common tactic used when dealing with poor quality source discs or other situations where computer systems are not fast enough to keep up to the speed set on the recorder.

CD Duplication Systems
For copying larger numbers of discs various dedicated CD duplication solutions are available including machines that function by themselves or with the assistance of an operator. These configurations can either sit as standalone units or may be attached as computer peripherals. The most common devices are hand-fed tower systems which employ a number of CD-R or CD-R/RW recorders chained together for simultaneous duplication from either a master CD or from a hard drive. Also widely used are automated products incorporating robotic disc handling systems which mechanically load and unload one or more recorders. Sometimes disc label printers are included to produce a handful or even hundreds of finished discs per hour. Historically large and expensive, many CD duplication systems are now compact and affordable and within reach of many for personal and office use. A number of companies also offer commercial CD duplication services to perform short run work in quick turnaround times.

CD Mass Replication
In contrast to CD duplication which is usually performed on a small scale at the desktop level, CD mass replication is typically used to make huge quantities of discs such as commercial audio CDs and software CD-ROMs. These prerecorded (pressed) discs are manufactured from a mold in a factory setting and are created using a series of industrial processes including premastering, mastering, electroplating, injection molding, metallization, spin coating, printing and advanced quality control. In addition to manufacturing discs many replication companies offer companion services including packaging, printing, distribution and fulfillment.

What is CD publishing?

Somewhat like CD duplication equipment, CD publishing systems employ CD-R or CD-R/RW recorders but are used to create quantities of unique discs from different computer files rather than just to make multiple copies of a single master disc. Employing robotic disc handling systems and integrated label printers, many of these devices can be accessed over computer networks and shared much like office laser printers. Examples of CD publishing applications include retail audio CD vending kiosks, creating CD-Rs containing cheque images or monthly banking records, archiving computer-generated billing records to disc in place of microfilm and accepting conventional 35 mm film resulting in digital pictures on CD-R discs.

Can CD-R and CD-RW discs be protected against copying?

Historically, copy protection technologies were only available to protect prerecorded (pressed) discs but a variety of methods are now available to deter copying the contents of CD-Rs and CD-RWs, to authenticate media and even to forensically trace the origin of discs. Such capabilities are included in some CD-R and CD-R/RW recorders or may be offered as features in software tools as well as duplication and publishing systems.

DISC LABELING

What alternatives are available to label CD-R and CD-RW discs?

There are several different labeling methods available for CD-R and CD-RW discs ranging from hand writing, to adhesive labels, specialized devices that print directly onto the disc surface and ultimately the various commercial printing solutions. Each option is distinguished by cost, speed and convenience as well as by durability and the visual quality of the result. But keep in mind that applying any kind of label modifies the disc in a significant way. Thus, product warranties can be affected and unforeseen consequences may arise. It is, therefore, advisable to always follow manufacturer directions.

Hand Writing
By far the quickest and least expensive way to label a disc is to simply write on its top surface. Using a soft fiber or felt-tipped permanent marker is preferable but be aware that the solvents in some types of inks can migrate through the disc surface and potentially damage the reflective and dye layers beneath. The part of the disc least vulnerable to injury is the center clamping or hub area. Beware ballpoint pens or other sharp writing instruments as they may deform the disc substrate and delaminate the disc layers thereby causing information to become unreadable. Some discs are specially coated to accommodate handwritten labels and even some special markers are available and intended for such use.

Adhesive Labels
A more attractive way to label a disc is to apply an adhesive label. Several manufacturers offer inkjet and laser printer compatible products specifically designed for labeling discs as well as positioning devices to help with centering. Full surface or "donut-style" labels are preferable to partial stickers but be aware that any adhesive label can potentially upset the balance of a disc when playing back, especially at high speeds, causing excessive noise, vibration and data retrieval problems. Heat, humidity, handling and the passage of time can also compromise the stability of adhesive labels causing separation from the disc surface and even interfere with the drive. Sticky labels may not be the best choice when archiving important data as some types of label adhesives can react with and compromise the disc over time. Remember too that, once applied, labels should never be removed or repositioned. Even smoothing air bubbles can concentrate physical stresses in a small area and delaminate the disc.

Specialized Disc Printers
A range of specialized disc printing devices is also available to label discs in larger numbers and for imparting a more polished appearance. Currently, desktop products employing inkjet, thermal transfer and re-transfer technologies are available for directly labeling on the disc surface.

Inkjet
Inkjet printing technology has been available for many years and has proven extremely popular with consumers due to its high quality and cost effectiveness. Inkjet printers function by ejecting liquid ink from a print head onto the surface of a specially coated "inkjet-printable" disc. These special discs have an extra coating, called an Ink Absorption Layer (IAL), which receives the ink from the printer and allows it to stay in place long enough to dissipate its solvents and properly dry. Inkjet printers produce high-resolution full color images but there is a downside in that resulting labels can be smudged by high humidity or damp fingers. Inkjet printed discs should not be stored or shipped in form-fitting soft plastic envelopes as the chemicals used to keep the package materials supple can soften the inks causing the label to stick to the sleeve and potentially delaminate the disc when removed. Using jewelcases or other containers that do not come into direct contact with the printed surface is best.

Thermal Transfer
Unlike inkjet printers which spray liquid ink, thermal transfer printers convey solid pigment from a coated ribbon onto the surface of a disc through a combination of heat and pressure. Typically used to produce monochrome and spot color labels, thermal transfer printing does not require specially coated discs to accept the ink from the printing process. The results are, as well, reasonably durable. However, some disc surfaces give better results than others and offer more protection from potential damage during the printing process. Consequently, discs are available which feature special coatings optimized for thermal transfer printing. For labeling situations where discs share a largely common background appearance but vary slightly from disc to disc or among groups of discs some thermal transfer solutions can align and overprint their output onto partial images already screen printed onto the surface of the disc.

Re-transfer
More recently, re-transfer printers have come to market and function by applying heat and pressure to convey solid resins from an ink ribbon to a compliant intermediate film and then to the surface of the disc. Typically re-transfer systems produce photo-realistic color labels which are smooth and highly durable. Only certain types of disc surfaces are suitable for re-transfer printing including those optimized for thermal transfer use as well as some inkjet-printable surfaces and "crystal" protective coatings.

Commercial Printing
Various methods are used to commercially decorate discs including screen, offset, pad and flexographic printing. These are large-scale industrial processes typically used to label large numbers of discs with the same pattern or in situations when precise color matching is required for critical items such as company logos. In addition to desktop disc labeling, many duplication companies and replicators offer commercial printing services.

DISC HANDLING, STORAGE AND DISPOSAL

What is the best way to handle and store a CD-R or CD-RW disc?

A disc should always be handled by grasping its outer edges, center hole or center hub clamping area. Avoid flexing the disc, exposing it to direct sunlight, excessive heat and/or humidity, handle it only when being used and do not eat, drink and smoke near it. Discs should be stored in jewel cases rather than sleeves as cases do not contact the discs' surfaces and generally provide better protection again scratches, dust, light and rapid humidity changes. Once placed in their cases discs can be further protected by keeping them in a closed box, drawer or cabinet. For long-term storage and archival situations it is advisable to follow manufacturer instructions. For further information consult the international standards for preserving optical media (ISO 18925:2002, Imaging materials — optical disc media — storage practices).

Should fingerprints and dust be cleaned off a CD-R or CD-RW disc?

CD technology is robust and employs several design elements to minimize the effects of fingerprints and minor scratches on data integrity. The first line of defense comes from the physical structure of the disc and the location of the data-bearing marks and lands. The reading laser beam shines through the disc's substrate focusing beyond the contaminated surface and directly on the marks and lands beneath. In concert with advanced error detection and correction capabilities minor debris and abrasions are largely ignored. That said, handling care should be taken as above and a dusty disc should be blown off so that the dust does not enter the drive mechanism and accumulate on the lens or other optical components. It should also be noted that fingerprints, dust and scratches have a greater impact on recording than is the case with reading since the contaminants reduce the effectiveness of the writing laser by obscuring its beam from the disc's recording layer.

What is the best way to clean a CD-R or CD-RW disc?

Dirty discs should be carefully cleaned using a soft dry lint-free cloth or camera lens tissue. Holding the disc by its outer edges or center hole gently wipe outward from the center hub toward the outside edge of the disc (just like the spokes of a bicycle wheel). Do not wipe the disc using circular motions as any scratches created will do the least damage if they cut across the track of marks and lands. More stubborn fingerprints or stains can be removed using a soft dry lint-free cloth lightly moistened with water or a commercially available CD cleaning fluid. Do not use vinyl record cleaners, lacquer thinner, gasoline, kerosene, benzene or other solvents, as they may damage the disc. Manufacturer directions should always be followed.

Can scratched and damaged CD-R and CD-RW discs be restored?

Often it is less expensive and makes more sense to transfer the data from a damaged disc onto a new one rather than to try to restore the problem disc. For dealing with more badly damaged situations consumer disc repair kits are available while several companies offer CD restoration and resurfacing equipment and services. See the resource listing in the appendix for contact information.

Is it possible to recover data from damaged CD-R and CD-RW discs?

Several software packages are currently available which diagnose disc problems and help recover deleted, unreadable or otherwise inaccessible information. A number of companies also offer commercial CD data recovery services. See the resource listing in the appendix for contact information.

What is the best way to destroy unwanted CD-R and CD-RW discs?

For office and high volume production situations various CD destruction options are available including mechanical shredders, desktop devices which employ heat and pressure to make disc unreadable and grinders which abrasively remove the disc's reflective and data-bearing recording layers. A number of companies also offer commercial CD destruction services and deal with classified or other sensitive materials. See the resource listing in the appendix for contact information.

Can unwanted CD-R and CD-RW discs be recycled?

A number of companies offer CD recycling services and are able to reclaim some of the materials used in the disc's construction. See the resource listing in the appendix for contact information.

DISC LONGEVITY

How many times can a CD-RW disc be rewritten?

As is the case with all optical storage media using phase change technology there is a limit to the number of times the recording layer in a CD-RW disc can be reliably switched between its crystalline and amorphous states. Currently, CD-RW discs can be rewritten approximately 1000 times.

What is the shelf life of unrecorded CD-R and CD-RW discs?

The unrecorded shelf life of a CD-R or CD-RW disc is conservatively estimated to be between 5 and 10 years.

How long will data recorded on CD-R and CD-RW discs remain readable?

The life span of a written disc depends upon a number of factors including such things as the intrinsic properties of the materials used in the disc's construction, its manufactured quality, how well it is recorded and its physical handing and storage. As a result, the life span of a recorded disc is extremely difficult to estimate reliably. However, to calculate disc life spans within some practical timeframe blank media manufacturers do conduct accelerated age testing by subjecting samples of their discs to environments much beyond those experienced under normal storage conditions. Generally speaking, only the effects of varying temperature and humidity are considered. These test results are then used to predict how long a disc will remain readable under more normal storage conditions. Since questionable testing and measurement procedures can seriously impact upon and compromise these estimates several international standards have been developed which specify procedures to be used conducting accelerated testing and analyzing the resulting data from prerecorded (pressed) and recordable CDs:

ISO 18921:2002, Imaging materials — Compact discs (CD-ROM) — method for estimating the life expectancy based on the effects of temperature and relative humidity

ISO 18927:2002, Imaging materials — Recordable compact disc systems — method for estimating the life expectancy based on the effects of temperature and relative humidity

For years now many media manufacturers have performed their own lifetime evaluations using these or a variety of other homegrown tests and mathematical modeling techniques. Historically, manufacturers have claimed life-spans ranging from 50 to 200 years for CD-R discs and 20 to 100 years for CD-RW. Be aware, however, that disc producers, manufacturing methods and materials change over time as do applications and cost imperatives. Consequently, those concerned with disc longevity should consult the appropriate international standards and their media manufacturer for more particular information.

It is important to remember, however, that nothing lasts forever and that technologies inevitably change. Well-designed products, such as CD-R and CD-RW, allow for seamless transition to the next generation and ultimately, since they embody digital information, contents can be transferred to future storage systems as becomes necessary to preserve whatever has been stored on the discs.

DISC TESTING AND VERIFICATION

Is it necessary to verify a CD-R or CD-RW disc after recording?

Verifying discs after writing helps maintain an appropriate quality level. The amount of ongoing integrity checking and data verification that may be necessary is really a question of acceptable risks for any particular application. For example, letting recording software conduct data comparisons immediately after writing is usually sufficient in casual settings but critical data archiving and large-scale duplication may call for more comprehensive testing. This is due to the differences that often exist among recorders, drives and players. For example, recorders typically incorporate higher quality optical systems and lenses with slightly larger numerical apertures than do reading devices. Consequently, successfully verifying a written disc on a recorder does not guarantee broad playing compatibility, especially in cases where disc jitter is marginal.

How can the quality of a written CD-R or CD-RW disc be assessed?

Several methods can be used to assess the quality of a written disc. These include measuring its optical signals, examining the integrity of its physical and logical formats, performing interchange testing and conducting data verification. Each method is a piece of the quality testing puzzle. The extent to which a disc needs to be tested depends, of course, upon the imperatives of the application.

At a basic level it is possible to confirm that information has been correctly written to a disc by comparing it against the source material using the verification features found in many off the shelf writing software packages. When somewhat more detailed analysis is warranted, interchange testing can be performed to provide some practical indication of real-world compatibility. To accomplish this, audio CDs are played back in a number of consumer audio players to check for quality issues while data discs are checked in a variety of CD-ROM and DVD-ROM drives to make sure that recorded information is completely recoverable and at speeds established by the manufacturers. Specialized computer software controlling everyday CD-ROM drives can also be used to read a disc at a lower level of organization to verify that its physical and logical formats conform to industry specifications.

For situations which require appraising the more fundamental physical characteristics, a number of commercial analysis tools are available to examine the optical signal characteristics of a recorded disc and thus identify low-level errors. Typically, these devices are standalone or computer-attached and employ CD audio or CD-ROM drives specially modified to measure various disc parameters and provide descriptive reports. As is the case in testing generally, results can vary significantly among inspection systems so, to maintain continuity, discs should always be evaluated on the same pieces of equipment. Commercial CD testing companies offering quality verification services using such devices are also widely available.

An important question which has always existed for compact disc testing is the uncertainty of the relationship between the results derived from evaluating discs on low-level analyzers and real world disc performance in the installed population of reading and playing devices. Over the years a succession of groups and companies have labored to reconcile these two product classes through the use of various multi-point calibration discs and other vehicles. However, given the extremely rapid technological evolution of reading and playing devices it is impossible to conclusively establish any definitive link between measured and actual performance, especially for marginal discs.

When assessing disc quality keep in mind the huge number of variables involved. These include such things as the discs with their different types, batches and manufacturers, recording software and hardware in their many varieties and versions, diverse recording conditions encountered, different test equipment employed, operators of differing experience and even the handling of the discs themselves. Consequently, judgements should be made on a relative rather than absolute basis.

DISC CONSTRUCTION AND MANUFACTURING

What is the construction of a CD-R disc?

Just like all kinds of CDs a CD-R disc is a sandwich of a number of layers. First comes a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside diameter of the disc. On top of this substrate is an organic dye recording layer (cyanine, phthalocyanine or azo) followed by a thin metal reflective layer (gold, silver alloy or silver) and finally an outer protective lacquer coating. Some discs are also topped with additional layers that improve scratch resistance, increase handling durability or provide surfaces suitable for labeling by inkjet or thermal transfer printers.

How are CD-R discs made?

Current CD-R disc manufacturing lines are extremely efficient, incorporating all major production elements to produce a staggering number of discs. The first step in producing a CD-R disc is to create the polycarbonate plastic substrate using an injection molding process. The dye layer is applied using spin coating and the reflective layer by means of cold planar magnetron sputtering. The lacquer overcoat is then applied by another spin coating procedure followed by ultraviolet curing. Additional durability or printable layers are typically applied using screen printing methods.

Why are the recording surfaces of various kinds of CD-R discs different colors?

Due to the intrinsic absorption spectrums of the various dyes, the thickness of the layers and the type of reflector materials used the recording side of a CD-R disc can appear many different colors including shades of green, yellow and blue. For many years the color of a disc was incidental in its design but some manufacturers now intentionally aim for specific visual effects. For example, CD-R discs are now available which mimic the look of prerecorded (pressed) CDs and tinted substrates are sometimes even used to make discs appear black or exotic colors. Keep in mind, however, that disc operation is not affected by its visual appearance. While the human eye perceives a rainbow of colors, all of the discs function the same way when illuminated by the 780 nm laser of a CD-ROM drive or recorder.

What are the differences between the dyes - cyanine, phthalocyanine and azo?

The recording layer of a CD-R disc is composed of one of cyanine, phthalocyanine or azo dye and, although each has its own recording and longevity characteristics, they all serve the same purpose. Over time, there has even been a steady convergence in their properties.

Information is written to a CD-R disc by means of a laser to heat and alter the dye sufficient to create a pattern of marks and thereby mimic the pits of a molded CD. Although each dye is tuned to absorb light in the range of 780 nm, they all respond differently to the writing laser. Some dyes become bleached from exposure to the beam while the others create permanent features and deform the underlying substrate. In addition, each dye requires a different laser intensity and duration to properly form marks.

Early CD-R discs employed cyanine-based dye exclusively and recording conditions defined in Orange Book Part II standards were tuned around cyanine characteristics. As the market evolved discs using phthalocyanine and azo dyes emerged and specifications changed to reflect the new reality. Since then, recorders select write strategies appropriate for the type of dye and carefully control the laser beam as required to achieve the best results with all types of media.

In terms of their composition, quenchers (metal dithiochelates, benzenaminium salts, etc.) are normally added to cyanine dyes to increase light stability while phthalocyanine and azo dyes are intrinsically less sensitive to light exposure after recording.

Remember that CD-R discs are complex engineering marvels so when it comes to choosing among them keep in mind the importance of selecting products based on your particular requirements rather than focusing on any one characteristic.

What is the construction of a CD-RW disc?

To allow information to not only be written but also re-written many times over, CD-RW disc construction is more complex than that of CD-R. A CD-RW disc uses a six-layer design beginning with a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside edge of the disc. Next comes a dielectric layer (zinc sulfide and silicon dioxide), followed by a phase change alloy recording layer (indium, silver, tellurium, and antimony), another dielectric layer, a thin metal reflective layer (aluminum) and finally a protective lacquer overcoat.

How are CD-RW discs made?

As with CD-R, producing CD-RW discs involves using multiple manufacturing stages including injection molding, sputtering, spin coating, ultraviolet curing and quality inspection. The first step is to create the substrate by injection molding. The dielectric layers, phase change recording and reflective layers are applied to the substrate using cold planar magnetron sputtering. Spin coating and ultraviolet curing are then used to apply the protective lacquer coating. Since the sputtering process lays down the phase change alloy in its amorphous condition powerful lasers are used to initialize the disc and return the recording layer back to its crystalline state.

Are there any meaningful differences among blank discs produced by different manufacturers?

As with all products, discs produced by competing companies are distinct from one another because they may employ different designs, use materials from various suppliers and are manufactured by different factories, equipment and workers. However, all blank discs conform to Orange Book Part II (CD-R) or Part III (CD-RW) specifications and should work in all recorders. Discs are differentiated based on brand names, quality and consistency, features, price and packaging. Some recorder companies may test particular brands of discs more extensively than others so it may be advisable to inquire of the recorder manufacturer for specific recommendations depending on particular applications.

APPENDIX A — SUGGESTED FURTHER READING AND RESOURCES

BOOKS

Apple Computer, Inc. *The Apple CD-ROM Handbook: A Guide to Planning, Creating, and Producing a CD-ROM.* Reading: Addison-Wesley, 1992.

Bouwhuis, Gijs, et. al. *Principles of Optical Disc Systems.* Bristol: Adam Hilger, 1985.

Brown, Martin C. *CD Recordable Solutions.* Cincinnati: Muska and Lipman, 2001.

Caffarelli, Fabrizio, and Deirdre Straughan. *Publish Yourself on CD-ROM: Mastering CDs for Multimedia.* New York: Random House, 1992.

Chambers, Mark L. *Hewlett-Packard Official Recordable CD Handbook.* Foster City: IDG Books, 2000.

Chambers, Mark L. *Recordable CD Bible.* Foster City: IDG Books, 1997.

Chambers, Mark L. *CD and DVD Recording for Dummies.* New York: Hungry Minds, 2001.

Marchant, Alan B. *Optical Recording: A Technical Overview.* Reading: Addison-Wesley, 1990.

Ogletree, Terry William, and Todd Brakke. *The Complete Idiot's Guide to Creating Your Own CDs.* 2nd ed. Indianapolis: Macmillian, 2002.

Pahwa, Ash. *The CD-Recordable Bible: An Essential Guide for Any Business.* Wilton: Eight Bit Books, 1994.

Purcell, Lee. *CD-R/DVD: Disc Recording Demystified.* New York: McGraw-Hill, 2000.

Purcell, Lee, and David Martin. *The Complete Recordable-CD Guide.* Alameda: Sybex, 1997.

Pohlmann, Ken C. *The Compact Disc Handbook.* 2nd ed. Madison: A-R Editions, 1992.

Pohlmann, Ken C. *Principles of Digital Audio.* 4th ed. New York: McGraw-Hill, 2000.

WHITE PAPERS

Bennett, Hugh. *Running Optimum Power Control: Data Integrity in CD-Recording.* Santa Barbara: Optical Storage Technology Association, 1998.

Busk, Philip J. et. al. *Compact Disc Terminology.* 2nd ed. Wilmington: Disc Manufacturing, Inc., 1993.

Busk, Philip J. *Integrating Mixed-Mode CD-ROM.* Wilmington: Disc Manufacturing, Inc., 1992.

DeMoulin, Robert, Toshi Iizuka, and Rod Volturno. *CD Recordable Handbook: A Guide to Choosing the Right CD Recorder for You.* 2nd ed. San Jose: Ricoh Corporation, 1995.

Disc Manufacturing, Inc. *A Glossary of CD and CD-ROM Terms.* Wilmington: DMI, 1993.

Disc Manufacturing, Inc. *An Overview to Multimedia CD-ROM Production.* Wilmington: DMI, 1992.

Eastman Kodak Company. *Data Integrity on CDs.* Rochester: Eastman Kodak Company, 1995.

Eastman Kodak Company. *Permanence, Care, and Handling of CDs: Including CD-ROM, Writable CD, and Kodak Photo CD.* Rochester: Eastman Kodak Company, 1995.

Eastman Kodak Company. *Why Kodak Writable CD Media with Infoguard Protection System?* Rochester: Eastman Kodak Company, 1995.

Hamelinck, Dirk, Bob Ijtsma, and Eggert Gudmundsson. *Mount Rainier: Drag and Drop Data on CD-RW.* Eindhoven: Royal Philips Electronics, 2000.

Multi Media Masters and Machinery. *A 'Revolution' in CD-R and DVD-R Spin Coating.* Yverdon-les-Bains: Multi Media Masters and Machinery, 1999.

Multi Media Masters and Machinery. *CD-R and DVD-R: Ready for the Present, Prepared for the Future.* Yverdon-les-Bains: Multi Media Masters and Machinery, 2000.

Multi Media Masters and Machinery. *The Next Wave in Optical Storage: CD-RW and Rewritable DVD.* Yverdon-les-Bains: Multi Media Masters and Machinery, 2000.

Philips Electronics. *Basic Principles of CD-Recordable/Rewritable Digital Audio.* Eindhoven: Philips Electronics, 1998.

Philips Electronics. *CD-ReWritable: How it Works.* Eindhoven: Philips Electronics, 1997.

Plextor Europe. *The Process of Writing.* version 1.0. Zaventem: Plextor S.A./N.V., 2002.

Royal Philips Electronics. *Thermo-Balanced Writing.* Eindhoven: Philips Electronics, 2001.

Roohi, Misty. *More than CD: Enhanced CD Formats.* Wilmington: Disc Manufacturing, Inc., 1996.

Summers, Clayton. *Introduction to ISO 9660.* Wilmington: Disc Manufacturing, Inc., 1995.

Warner, Josh. *The Enhanced CD Fact Book Version 1.01.* Cupertino: Apple Computer, 1995.

STUDIES

Doculabs, Inc. *Compatibility of CD-R Media, Readers, and Writers.* Chicago: Doculabs, 1997.

Hartke, Jerome L. *CD-R Media Survey.* Marlborough: Media Sciences, 2000.

Optical Disc Manufacturing Association. *Variation of Measurement.* Milford: ODMA, 1995.

Optical Storage Technology Association. *CD-R/DVD-ROM Compatibility Study.* Santa Barbara: OSTA, 1998.

Optical Storage Technology Association. *CD-R Compatibility Study Phase 1.* Santa Barbara: OSTA, 1997.

Optical Storage Technology Association. *CD-R Compatibility Study Phase 2.* Santa Barbara: OSTA, 1998.

Stinson, Douglas, Fred Amell, and Nick Zaino. "Lifetime of Kodak Writable CD and Photo CD Media." *SIGCAT DISCourse* 9.1 (1995): 1+.

PERIODICALS

Computer Technology Review	www.wwpi.com
EMedia, the Digital Studio Magazine	www.emedialive.com
Medialine	www.medialinenews.com
One to One	www.oto-online.com
Optical Disc Systems	www.opticaldisc-systems.com
Software Business Magazine	www.softwarebusinessonline.com
Tape Disc Business	www.tapedisc.com

PRINT DIRECTORIES

Billboard International Disc/Tape Directory	www.billboard.com
EMedia, the Digital Studio Magazine Buyer's Guide	www.emedialive.com
The Gold Book	www.oto-online.com
The International DVD and CD Plant Directory	www.oto-online.com

EXHIBITIONS AND TRADE SHOWS

AES	www.aes.org
CeBIT	www.cebit.de
COMDEX	www.comdex.com
Digital Content Delivery Expo	www.dcdexpo.com
International Consumer Electronics Show	www.cesweb.org
Media-Tech Expo	www.media-tech.net
NAB	www.nab.org
PC Expo	www.techxny.com
Replication Asia	www.replicationasia.com

GENERAL INFORMATION WEB SITES

Andy McFadden's CD-Recordable FAQ	www.cdrfaq.org
BurnWorld	www.burnworld.com
CD Freaks	www.cdfreaks.com
CD Media World	www.cdmediaworld.com
CDR Zone	www.cdr-zone.com
CDR-Info	www.cdrinfo.com
CDRLabs	www.cdrlabs.com
CDROM-Guide	www.cdrom-guide.com
CD-RW Central	www.cdrwcentral.com
cd-rw.org	www.cd-rw.org
Digital Drives	www.digitaldrives.com

GENERAL INFORMATION INTERNET NEWSGROUPS

comp.publish.cdrom.hardware
comp.publish.cdrom.software
comp.publish.cdrom.multimedia
alt.comp.periphs.cdr

INDUSTRY ASSOCIATIONS AND ORGANIZATIONS

1394 Trade Association	www.1394ta.org
CDs21 Solutions	www.cds21solutions.org
Consumer Electronics Association (CEA)	www.ce.org
Industrial Technology Research Institute (ITRI)	www.itri.org.tw
International Disc Duplicating Association (IDDA)	www.discdupe.org
International Federation of the Phonographic Industry (IFPI)	www.ifpi.org
International Optical Disc Replicators Association (iODRA)	www.iodra.com
International Recording Media Association (IRMA)	www.recordingmedia.org
Optical Disc Manufacturing Association (ODMA)	www.odma.com
Optical Storage Technology Association (OSTA)	www.osta.org
Orange Forum	www.orangeforum.or.jp
SCSI Trade Association	www.scsita.org
USB Implementers Forum	www.usb.org

LICENSING AND STANDARDS ORGANIZATIONS

American National Standards Institute (ANSI)	www.ansi.org
ECMA International	www.ecma.ch
International Committee for Information Technology Standards	www.ncits.org
International Electrotechnical Commission (IEC)	www.iec.ch
International Organization for Standardization (ISO)	www.iso.org
Optical Storage Technology Association (OSTA)	www.osta.org
Philips Intellectual Property and Standards	www.licensing.philips.com

APPENDIX B — INDUSTRY AND PRODUCT CONTACTS

MARKET RESEARCH AND CONSULTING FIRMS

Cahners In-Stat Group	www.instat.com
Forget Me Not Information Systems Inc.	73144.1631@compuserve.com
Gartner, Inc.	www.gartner.com
IDC	www.idcresearch.com
InfoTech, Incorporation	www.infotechresearch.com
Magnetic Media Information Services (MMIS)	www.mmislueck.com
Santa Clara Consulting Group	sccg@pacbell.net
Strategic Marketing Decisions (SMD)	www.smdcorp.com
Techno Systems Research Co., Ltd. (TSR)	phone: 03-3866-4505
Understanding and Solutions	www.uands.com

DUPLICATION AND PUBLISHING SYSTEMS

Alea Systems, Inc.	www.alea.com
Alera Technologies, LLC.	www.aleratec.com
An Chen Computer Co. Ltd.	www.copystar.com.tw
Ashby Industries, Inc.	www.ashbyindustries.com
Bernardini SRL	www.bernardini-srl.com
CopyPro, Inc.	www.copypro.com
Copytrax Technologies	www.copytrax.com
Cyclone USA	www.cdcyclone.com
Discmatic	www.discmatic.com
DixxPli USA	www.dixxpli.com
Hoei Sangyo Co., Ltd.	www.hoei.co.jp
ILY Enterprise Inc.	www.ily.com
Imedia Technologies (IMT)	www.imt-sa.com
Interactive Media Corporation	www.interactivemediacorp.com
JukeBox Information Systems	www.jbis.com
LSK Data Systems GmbH	www.lskdata.de
Luminex Software, Inc.	www.luminex.com
MediaFORM, Inc.	www.mediaform.com
Mediatechnics Systems	www.mediatechnics.com
Microboards Technology	www.microboards.com
Microsynergy	www.idt-microsynergy.com
Microtech Systems	www.microtech.com
Niscoa, Inc.	www.niscoa.com
Nistec Corporation	www.nistec.co.jp
Odixion USA	www.odixionusa.com
OptoMedia Storage Solutions Limited	www.optomedia.co.uk
Orient Instrument Computer Co., Ltd.	www.orient-computer.co.jp
Otari, Inc.	www.otari.com
Primera Technology	www.primeratechnology.com
Rimage Corporation	www.rimage.com
Rimax International	www.rimax.net
R-Quest Technologies, LLC	www.r-quest.com
Terra Computer Systems	www.terra.cz
The Logical Company	www.u-master.com
T.S. Solutions	www.ts-solutions.com

Telex Communications, Inc.	www.telex.com
Verity Systems	www.veritysystems.com
Young Minds, Inc.	www.ymi.com
Wytron Technology Co. Ltd.	www.wytron.com.tw

DISC LABELS AND PRINTERS

Alera Technologies, LLC.	www.aleratec.com
Avery Dennison Corporation	www.avery.com
Burlington Paper	www.burlingtonpaper.com
CopyPro, Inc.	www.copypro.com
Fellowes	www.fellowes.com
Kyso Inc.	www.kyso.com
MediaFORM, Inc.	www.mediaform.com
Memorex Products	www.memorex.com
Neato	www.neato.com
Odixion USA	www.odixionusa.com
Primera Technology	www.primeratechnology.com
Rimage Corporation	www.rimage.com
Verity Systems	www.veritysystems.com

DISC MANUFACTURERS/BRANDS

Alera Technologies, LLC.	www.aleratec.com
CDA Datenträger Albrechts GmbH	www.cda.de
CMC Magnetics Corp.	www.cmcdisc.com
Daxon Technology Inc.	www.daxontech.com
Doremi Media Co., Ltd.	www.doremi4u.co.kr
Emtec-Multimedia Inc.	www.datastoremedia.com
Fujifilm Computer Products	www.fujifilmmediasource.com
Gigastorage Corporation	www.gigastorage.com
Imation Corp.	www.imation.com
KDG Mediatech AG	www.kdg-mt.com
Lead Data Inc.	www.leaddata.com.tw
Maxell Corporation	www.maxell.com
Memorex Products	www.memorex.com
Mitsui Advanced Media, Inc.	www.mitsuicdr.com
Moser Baer India Ltd. (MBI)	www.glyphicsmedia.com
Moulage Plastique de L'Ouest (MPO)	www.hi-space.com
PNY Technologies	www.pny.com
Prodisc Technology Inc.	www.prodisc.com.tw
Quantegy, Inc.	www.quantegy.com
Ritek Corporation	www.ritek.com.tw
Sony Electronics Inc.	www.mediabysony.com
Summit Hi-Tech Pte Ltd.	www.smsummit.com.sg
Taiyo Yuden Co. Ltd.	www.yuden.co.jp
TDK Electronics Corp.	www.tdk.com
Techo Plus Digital Disc	www.technoplus.it
Verbatim Corporation	www.verbatim.com
Viva Magnetics Limited	www.viva.com.hk

RECORDER MANUFACTURERS/BRANDS

Actima Technology Corporation	www.actima.com.tw
Alera Technologies, LLC.	www.aleratec.com
AOpen Inc.	www.aopen.com
Behavior Tech Computer Corp.	www.btc.com.tw
BenQ Corporation	www.benq.com
CenDyne Inc.	www.cendyne.com
CyberDrive	www.cyberdrive
Digital Research Technologies	www.dr-tech.com
Hewlett-Packard Company	www.hp.com
Hi-Val	www.hival.com
I/O Magic Corporation	www.iomagic.com
Imation Corp.	www.imation.com
Infinite Data Storage (IDS)	www.infinitedtastorage.com
Iomega Corporation	www.iomega.com
LG Electronics Inc.	www.lge.com
Lite-On IT	www.liteonit.com
Matsushita Kotobuki Electronics Industries, Ltd.	www.mke.panasonic.co.jp
Micro Solutions Inc.	www.microsolutions.com
Mitsumi Electric Co., Ltd.	www.mitsumi.com
Philips Electronics	www.philips.com
Pioneer Electronics	www.pioneerelectronics.com
Plextor Corp.	www.plextor.com
Ricoh Company	www.ricoh.com
Samsung Electronics Co., Ltd.	www.samsung.com
Sanyo Electric Co., Ltd.	www.burn-proof.com
Sony Corporation	www.sony.com
TDK Electronics Corp.	www.tdk.com
Teac Corporation	www.teac.com
Toshiba	www.toshiba.com
Ultima Electronics Corp.	www.ultima.com.tw
Yamaha Corp.	www.yamaha.com

RECORDING SOFTWARE PUBLISHERS

Ahead Software	www.nero.com
Aplix Corporation	www.aplix.com
B.H.A. Software Corporation	www.bhacorp.com
Charismac Engineering	www.charismac.com
Elaborate Bytes	www.elby.ch
Fangmeier Sytemprogrammierung	www.feurio.com
Gear Software	www.gear.com
Golden Hawk Technology	www.goldenhawk.com
HyCD, Inc.	www.hycd.com
NewTech Infosystems	www.ntius.com
Oak Technology	www.oaktech.com
Padus, Inc.	www.padus.com
PoINT Software and Systems	www.pointsoft.de
Roxio, Inc.	www.roxio.com
Software Architects, Inc.	www.softarch.com
Veritas Software	www.veritas.com
VOB Computersysteme GmbH	www.vob.de

JUKEBOXES AND NETWORK STORAGE

ASACA Corporation	www.asaca.com
ASM GmbH & Co. KG	www.asm-jukebox.de
DAX Archiving Solutions	www.smartdax.com
DISC, Inc.	www.disc-storage.com
JVC Professional Products Company	pro.jvc.com
Kubik Enterprises Inc.	www.kubikjukebox.com
Luminex Software, Inc.	www.luminex.com
Pioneer Electronics	www.pioneerelectronics.com
Plasmon	www.plasmon.com
PowerFile, Inc.	www.powerfile.com
Procom Technology, Inc.	www.procom.com

DISC QUALITY ANALYSIS AND TESTING

Adivan High Tech AG	www.adivan.com
aeco NV	www.aecogroup.com
AudioDev	www.audiodev.com
CD Associates, Inc.	www.cdassociates.com
Cube Technologies GmbH	www.cube-tec.com
Clover Systems	www.cloversystems.com
DaTARIUS Technologies GmbH	www.datarius.com
Eclipse Data Technologies	www.eclipsedata.com
Efocus International Ltd.	www.efocus.co.uk
Quantized Systems	www.quantized.com
Sony Precision Technology, Inc	www.sonypt.com
StageTech Developments AB	www.stagetech.se

DISC REPAIR, RESTORATION AND DATA RECOVERY

Action Front Data Recovery Labs, Inc.	www.actionfront.com
Acodisc	www.acodisc.com
ArrowKey, Inc.	www.cdrom-prod.com
AuralTech	www.auratech.com
CD Data Guys	www.cddataguys.com
CD Recovery Services	www.cdrecovery.com
Compact Disc Repairman, Inc.	www.cdrepairman.com
Digital Innovations	www.digitalinnovations.com
ESS Data Recovery	www.savemyfiles.com
Naltech	www.naltech.com
Ontrack Data International	www.ontrack.com
Skippy Disc	www.skippydisc.com

DISC DESTRUCTION AND RECLYCLING

Alera Technologies, LLC.	www.aleratec.com
CD ROM Incorporated	www.cdrominc.com
Ecodisk	www.ecodisk.com
EcoMedia	www.ecomedia.com
GBC ModiCorp Limited	www.gbcmodi.com
Greendisk	www.greendisk.com
Hammacher Schlemmer and Company	www.hammacher.com
Hetzel Elektronik-Recycling GmbH	www.her-online.de
Intimus Business Systems	www.intimus.com
Lacerta Group, Inc.	www.lacerta.com
MBA Polymers, Inc.	www.mbapolymers.com
MRC Polymers	www.mrcpolmers.com
Niscoa, Inc.	www.niscoa.com
Sony Disc Manufacturing	www.sdm.sony.com

ABOUT OSTA

The Optical Storage Technology Association (OSTA) was incorporated as an international trade association in 1992 to promote the use of writable optical technologies and products. The organization's membership includes manufacturers and resellers from three continents, representing more than 85 percent of worldwide writable optical product shipments, working together to educate consumers and shape the future of the optical storage industry. Included among OSTA's many accomplishments are its groundbreaking CD-R compatibility efforts, development of the Universal Disc Format (UDF) as well as the MultiRead, MultiPlay, MultiAudio and MultiPhoto/Video (MPV) specifications.

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Bijlage 7: Understanding Recordable and Rewritable DVD

Understanding Recordable & Rewritable DVD

-OSTA.org-
Optical Storage
Technology Association

First Edition
April 2004

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Optical Storage Technology Association (OSTA)
Market Development Committee

Author's Notes

In the continuing evolution of writable optical storage beyond CD-R and CD-RW, recordable and rewritable DVD meet the expanded demands of personal and professional video as well as still uncharted applications.

This document is a compliment to my earlier "Understanding CD-R & CD-RW" white paper. Thus, explanations are provided to satisfy essential questions about DVD-R, DVD+R, DVD-RW, DVD+RW and DVD-RAM product technology and offer direction to sources of further information.

Suggestions to improve the accuracy, completeness or effectiveness of this paper are welcomed by the author who can be contacted by email: hugh_bennett@compuserve.com.

Sincerely,

Hugh Bennett, President
Forget Me Not Information Systems Inc.

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PHYSICAL, LOGICAL AND APPLICATION SPECIFICATIONS

What writable DVD formats are available?

There are five kinds of writable DVD technology (DVD-R, DVD+R, DVD-RW, DVD+RW and DVD-RAM). Similar to CD-Recordable (CD-R), DVD-R and DVD+R discs are write-once incorporating a dye recording layer to which information is irreversibly written by means of a laser heating and altering it to create a pattern of marks mimicking the pits of a prerecorded (pressed/molded) DVD. DVD-RW and DVD+RW, on the other hand, closely resemble CD-ReWritable (CD-RW) by employing a phase-change recording layer that can be repeatedly changed and restored by the writing laser (approximately 1000 times). DVD-RAM also uses phase-change technology but can be rewritten roughly 100,000 times. With its hard sectors, random access capabilities and optional cartridge, DVD-RAM more closely resembles traditional disc-based storage media than do DVD-RW and DVD+RW. This separates DVD-RAM somewhat from the prerecorded DVD format that provides the basis for most DVD discs.

Due to technological limitations when it was introduced in 1997, DVD-R employed 635 nm wavelength laser technology to store 3.95 GB per 12 cm disc (DVD-R version 1.0). Capacity was increased to 4.7 GB per disc in 1999 (DVD-R version 1.9). In 2000, DVD-R was split (DVD-R for Authoring version 2.0 and DVD-R for General version 2.0). DVD-R (Authoring) continues to use a 635 nm laser and remains available in limited form as do 3.95 GB discs for some highly specialized applications while the less expensive DVD-R (General) is more widely used and employs the same 650 nm laser wavelength as other DVD formats.

In 1999 DVD-RW was introduced only in Japan (version 1.0) with 4.7 GB 12 cm discs incorporating an embossed information area (for content protection) unreadable by nearly all DVD devices. This was changed in 2000 (version 1.1) to make discs broadly compatible.

DVD-RAM first appeared in 1998 offering 2.6 GB of storage per 12 cm disc (version 1.0) growing to 4.7 GB in 1999 (version 2.0). A 1.46 GB 8 cm disc was introduced in 2000 (version 2.1).

Originally, a 3.0 GB version of DVD+RW was proposed but no products were ever released. DVD+RW came to market in 2001 with a capacity of 4.7 GB per 12 cm disc while DVD+R arrived in 2002.

What specifications govern writable DVD discs?

As is the case with CD-R and CD-RW, all DVD disc formats are governed by a variety of industry specifications or "books" defining their mechanical properties, optical signal characteristics, physical arrangement, writing methods and testing conditions. In addition, various documents also deal with file systems as well as applications.

Specifications for DVD physical formats (DVD-ROM, DVD-R, DVD-RW, DVD-RAM) and applications (DVD-Video, DVD-Audio, DVD-ENAV, DVD-VR, DVD-AR, DVD-SR) were established and are continually updated (increases in writing speed, etc.) by the DVD Forum (originally DVD Consortium), an association of manufacturers founded in 1995 by Hitachi, Matsushita Electric, Mitsubishi Electric, Pioneer, Philips Electronics, Sony, Thomson, Time Warner, Toshiba and JVC.

DVD+R, DVD+RW and DVD+MRW (Mount Rainier) format specifications were created and are maintained by the DVD+RW Alliance, a separate group of manufacturers established in 1997 by Philips Electronics, Hewlett-Packard, Mitsubishi Chemical, Ricoh, Sony and Yamaha. The DVD+VR and DVD+R Video application formats are the creation and responsibility of Philips Electronics.

Over the years many DVD physical formats have also developed into ECMA International and ISO/IEC standards. The composition of these manufacturer groups and standards bodies continues to change and expand.

DVD Physical Format Standards
(ECMA International and ISO/IEC)

Format	Description	ECMA Standard	ISO/IEC Standard
DVD-ROM	80 mm disc	268 (Apr. 01)	16449:2002 (Apr. 02)
DVD-ROM	120 mm disc	267 (Apr. 01)	16448:2002 (Apr. 02)
DVD-R (G)	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	NA	NA
DVD-R (A)	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	NA	NA
DVD-R	120 mm & 80 mm disc (3.95 GB & 1.23 GB)	279 (Dec. 98)	20563:2001 (July 01)
DVD+R	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	349 (Dec. 03)	DIS 17344
DVD-RW	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	338 (Dec. 02)	DIS 17342
DVD+RW	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	337 (Dec. 03)	DIS 17341
DVD-RAM	120 mm & 80 mm disc case	331 (Dec. 01)	DIS 17594
DVD-RAM	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	330 (June 02)	DIS 17592
DVD-RAM	120 mm disc case	273 (Feb. 98)	16825:1999 (May 99)
DVD-RAM	120 mm disc (2.6 GB)	272 (June 99)	16824:1999 (May 99)

What is the DVD-Video format?

DVD-Video (DVD-V) is an application format released by the DVD Forum in 1996. Originally designed to meet the requirements of the film industry for distributing commercial movies on prerecorded (pressed) discs, the DVD-Video format applies equally to writable DVD. Updates were undertaken in 2000 to officially accommodate DVD-R (General) and DVD-RW and again in 2001 for DVD-RAM. DVD-Video format can also be used with DVD+R and DVD+RW.

Typically, discs written in DVD-Video format can be played back using any DVD video player or computer DVD-ROM drive employing appropriate software (subject to that device's physical compatibility with the specific type of disc). Among its features, the DVD-Video format supports one main stream of video (MPEG-1, MPEG-2) with up to nine separate camera angles, as many as eight audio streams (Dolby Digital, MPEG-1, MPEG-2, LPCM, DTS), a maximum of 32 subpicture streams (graphic overlay) together with navigation menus, still images, simple interactivity, random accessibility plus many other extras.

Depending upon the capabilities of the computer installed DVD recorder, hardware and software used, DVD-Video format discs can be written using material transferred from either digital or analog sources. Digital material (such as video from a DV or writable DVD camcorder) is typically read directly from that device using an IEEE 1394 (FireWire/i.LINK) or USB interface and computer files (such as WMA, QuickTime, AVI, MPEG) from a hard drive. To record analog sources (such as VHS tapes, laserdiscs and cable broadcasts) signals are first digitized through a video capture card or similar IEEE 1394/USB unit. By using authoring software supporting the DVD-Video format, transferred material can sometimes be simply written to disc or processed into a more involved title employing creative tools and by adding further material.

Writable DVD camcorders as well as professional and consumer electronics (CE) recorders are all-in-one systems incorporating video and audio capture combined with authoring and disc writing. Typically, DVD-R and DVD-RW capable devices offer a "Video mode" selection to write those discs in DVD-Video format. Keep in mind that not all products exploit the full range of DVD-Video features and that there may be additional restrictions to consider. For example, it is generally not possible to partially write discs on one recorder and "finalize" them or add new material using a different recorder. Check with the manufacturer for specific details.

What are the DVD Video Recording, DVD+RW Video and DVD+R Video formats?

The DVD-Video format was initially designed to place static material on disc and not to seamlessly manage successive real time recording and editing from cable, satellite and other live video sources (like a VCR). To address this, several additional application formats were developed for use by consumer devices including writable DVD camcorders and consumer electronics (CE) recorders. The first of these is the DVD

Video Recording (DVD-VR) format released by the DVD Forum in 1999 for DVD-RW and DVD-RAM and later updated in 2000 to accommodate DVD-R (General). Philips Electronics then followed in 2001 and 2002 with its own DVD+RW Video (DVD+VR) and DVD+R Video formats for DVD+RW and DVD+R discs. Since many DVD-Video format features are not required for home recording applications, these formats offer an abridged selection of capabilities while adding some of their own.

Typically, DVD-RW and DVD-RAM capable recorders offer a "VR mode" selection to write those discs in DVD-VR format while DVD+RW and DVD+R recorders automatically write DVD+RW and DVD+R discs in the appropriate DVD+VR and DVD+R Video format. However, DVD-VR differs significantly from the original DVD-Video format. As a result, only devices specifically designed to be DVD-VR compatible (for example, units marked "RW compatible" and "DVD Multi") can play DVD-VR recorded discs. DVD+VR and DVD+R Video closely resemble the DVD-Video format and, as such, maintain playback compatibility with most DVD devices. Keep in mind that not all products exploit the full range of features offered by these formats and that there may be additional restrictions to consider. Check with the manufacturer for specific details.

What is The Universal Disc Format (UDF)?

The Universal Disc Format (UDF) specification was first released by the Optical Storage Technology Association (OSTA) in 1995 and is designed to be a common logical file system for all removable optical storage media. Over the years various updates to UDF have been introduced to add new capabilities. So with DVD, UDF 1.02 is the standard file system used for DVD-Video, DVD-Audio and DVD-ROM prerecorded and writable discs. UDF 1.5 is frequently employed for incremental writing while UDF 2.0 applies to DVD-RW and DVD-RAM discs written in the DVD Video Recording (DVD-VR) format.

RECORDING HARDWARE

What types of devices record writable DVD discs?

The business, marketing and technology of writable DVDs have evolved over the years. There is now a wide variety of computer and consumer electronics (CE) devices available that record various versions and combinations of writable DVD disc formats (DVD-R, DVD-RW, DVD+R, DVD+RW, DVD-RAM). Product capabilities as well as marketing language and terminology vary widely so be careful to check with the manufacturer for specific details.

Examples of DVD Discs Writable by DVD Recorders

Recorder Type	DVD-R (Authoring)	DVD-R (General)	DVD-RW	DVD+R	DVD+RW	DVD-RAM
DVD+RW recorder	no	no	no	no	yes	no
DVD+R/+RW recorder	no	no	no	yes	yes	no
DVD±R/±RW recorder	no	yes	yes	yes*	yes	no
DVD-R (A) recorder	yes	no	no	no	no	no
DVD-R/-RW recorder	no	yes	yes	no	no	no
DVD-RAM recorder	no	no	no	no	no	yes** ***
DVD-RAM/-R recorder	no	yes	no	no	no	yes***
DVD Multi recorder	no	yes	yes	no	no	yes***
DVD Super Multi recorder	no	yes	yes	yes	yes	yes

* Some "Dual RW" recorders are not compatible with DVD+R discs.
** 2.6/5.2 GB DVD-RAM recorders are not compatible with 4.7/9.4 GB DVD-RAM discs.
*** Consumer electronics (CE) DVD-RAM, DVD-RAM/-R and DVD Multi recorders are not compatible with 2.6/5.2 GB DVD-RAM discs.

Are DVD video recorders available that connect to home theater systems?

A number of manufacturers offer consumer electronics (CE) and professional DVD video recorders that connect, like VCRs, to conventional video systems. Typically, they will only record to DVD from un-copy protected digital and analog sources (VCR, camcorder, internal hard disk drive, cable, satellite, laserdisc etc.).

Are writable DVD camcorders available?

Several manufacturers offer consumer digital camcorders that record video and still pictures directly to writable DVD discs. These units employ the smaller 8 cm disc size and can often be connected to a computer (typically using an IEEE 1394 or USB interface) to transfer material for editing as well as to be used as an external DVD recorder.

What do the numbers describing a DVD recorder mean?

Manufacturers typically use a sequence of numbers to express the maximum DVD and CD-R/RW writing and reading speeds of a recorder. Given the wide variety of possible format combinations and marketing approaches there are no established conventions as to the order of their presentation.

What types of computer DVD recorder configurations are available?

Whether for PC, Mac or UNIX systems in desktop, laptop or notebook form, computer DVD recorders are available in a wide variety of configurations to suit most needs. Several industry standard interfaces are available or forthcoming including SCSI, EIDE/ATAPI, USB, IEEE 1394 and Serial ATA for either internal or external recorder connection.

EIDE/ATAPI
The Enhanced Integrated Drive Electronics/ATA Packet Interface (EIDE/ATAPI) is the most popular method for connecting internal CD and DVD-ROM drives, hard disks as well as CD-R/RW and DVD recorders to a computer. Since most computers already have EIDE/ATAPI built-into their motherboards no additional interface card is necessary. These devices are normally installed internally but many external recorders are actually EIDE/ATAPI models employing bridge technology to convert them to SCSI, USB or IEEE 1394 interfaces.

SCSI
The Small Computer Systems Interface (SCSI) or “scuzzy” interface is a high performance and flexible method of connecting to a computer many peripherals including scanners, CD and DVD-ROM, hard drives as well as CD-R/RW and DVD recorders. In addition to long cable lengths, SCSI allows for both internal and external attachments. Some computers already have SCSI built into their motherboards, but, more often than not, a SCSI interface card is required. Some early DVD recorders made use of SCSI but most current units employ EIDE, USB or IEEE 1394 connections.

USB
The Universal Serial Bus (USB) is used to connect many types of peripherals to a computer including joysticks, mice, keyboards, printers, scanners, flash memory and external CD-R/RW and DVD recorders. Since USB is a plug and play interface computers do not have to be rebooted when a recorder is attached as these devices are automatically recognized by the system. USB has been updated several times to accommodate the demands of increasingly faster peripherals. While adequate for low speed CD-R/RW units the earlier USB 1.1 interface is not fast enough to keep up with DVD recording so that USB 2.0 is typically recommended. USB 2.0 interfaces are now built into the motherboards of most current systems but older computers may require an additional interface card.

IEEE 1394

Popularly known by trade names such as FireWire and i.LINK, IEEE 1394 is a high performance plug and play interface commonly used to connect computers to external hard disk drives, CD-R/RW and DVD recorders as well as consumer electronics (CE) devices like digital camcorders, game consoles and digital televisions. IEEE 1394 interfaces come standard on many Macintosh systems and on some brands of PCs but, more often than not, an interface card is required.

Serial ATA

Serial Advanced Technology Attachment (Serial ATA) is a new interface for connecting computers to internal storage devices such as hard disks, DVD-ROM drives and CD/DVD recorders. It is intended to eventually replace the current parallel ATA (EIDE/ATAPI) interface and will offer several advantages including longer and thinner cables with fewer pins, hot-plug capability, point-to-point connection (i.e. no master/slave relationship between devices) and a technology roadmap for future performance increases. Serial ATA interfaces are now built into the motherboards of many up to date systems but older computers may require an additional interface card.

Do computer DVD recorders write CD-R and CD-RW discs?

With near universal playback compatibility and low cost, CD-R and CD-RW discs are still excellent choices for a wide variety of data, audio and video applications. Consequently, in addition to writable DVDs, most current computer DVD recorders conveniently write CD-R and CD-RW discs (some older recorders may not be compatible with high, ultra and ultra speed plus CD-RW discs). However, this has not always been the case so, if in doubt, check with the hardware manufacturer.

RECORDING SPEED

How long does it take to record a writable DVD disc?

The amount of time taken to write a disc depends upon the writing speed of the recorder, the writing mode used by the recorder, the amount of information to be written and if verification or defect management is employed. Recording speed is measured the same as the reading speed of ordinary DVD-ROM drives and DVD players. At single speed (1x) a recorder writes 1.32 MB (1,385,000 bytes) of data per second and a multiple of that figure at each speed increment above 1x.

DVD Read and Write Average Data Transfer Rates
(transfer rates indicated in binary notation)

DVD Read/Write Speed	Transfer Rate bytes/sec	Transfer Rate KB/sec	Transfer Rate MB/sec	Equivalent CD-R/CD-RW read/ write speed
1x	1,385,000	1,352.54	1.32	9x
2x	2,770,000	2,705.08	2.64	18x
3x	4,155,000	4,057.62	3.96	27x
4x	5,540,000	5,410.16	5.28	36x
5x	6,925,000	6,762.70	6.60	45x
6x	8,310,000	8,115.23	7.93	54x
8x	11,080,000	10,820.31	10.57	—
10x	13,850,000	13,525.39	13.21	—
12x	16,620,000	16,230.47	15.85	—
16x	22,160,000	21,640.63	21.13	—

Writing Modes
Building upon the advances made in CD-R and CD-RW technology writable DVD performance has progressed rapidly in a relatively short time. DVD recording speeds (data transfer rates) now surpass even their quickest CD-R and CD-RW counterparts. And, as with CD-R and CD-RW, DVD recorders employ a variety of writing modes to operate reliably and efficiently at both low and high speeds including Constant Linear Velocity (CLV), Zoned Constant Linear Velocity (ZCLV) and Constant Angular Velocity (CAV).

Constant Linear Velocity (CLV)
DVDs initially operated using a CLV mode to maintain a constant data transfer rate across the entire disc. The CLV mode sets the disc's rotation at roughly 1400 RPM decreasing to 580 RPM (1x CLV) as the optical head of the player or recorder reads or writes from the inner to outer diameter (ID to OD). Since the entire disc is written at a uniform transfer rate it takes, for example, roughly 57 minutes (excluding lead-in/lead-out) to complete a full 4.7 GB disc at 1x CLV. As recording speed increases the transfer rate increases correspondingly so that at 4x CLV writing a disc takes approximately 14 minutes. Recording time as well is directly related to the amount of information to be

written so partial discs will be completed in proportionally less time. But writing at higher speeds requires rotating the disc faster and faster (e.g. ID 8400 to OD 3480 RPM at 6x CLV) which places escalating physical demands upon both media and hardware. Manufacturers meet this challenge by moving beyond the CLV mode to obtain even higher performance.

Zoned Constant Linear Velocity (ZCLV)
In contrast to CLV which maintains a constant data transfer rate throughout the recording process, ZCLV divides the disc into regions or zones and employs progressively faster CLV writing speeds in each. For example, an 8x ZCLV DVD+R/+RW recorder might write the first 800 MB of the disc at 6x CLV and the remainder at 8x CLV speed. DVD-RAM (1x, 2x, 3x), on the other hand, uses a different form of ZCLV that divides the disc into many more regions (1.46 GB disc/14 zones, 2.6 GB disc/24 zones, 4.7 GB disc/34 zones). Here, rotational speed is kept constant within each zone but varies from zone to zone resulting in a roughly constant data transfer rate throughout the entire recording process.

Constant Angular Velocity (CAV)
The CAV mode spins the disc at a constant RPM throughout the entire writing process. Consequently, the data transfer rate continuously increases as the optical head writes from the inner to outer diameter of the disc. For example, a 5x CAV DVD-RAM recorder begins writing at 2x at the inner diameter of the disc accelerating to 5x by the outer diameter of the disc.

Verification and Defect Management
In addition to simply writing data, some recording software and hardware perform data verification or employ sophisticated defect management techniques, which can double the total amount of time to write the disc. Typically, data verification takes place after all data is written while defect management occurs during writing, actively verifying sectors and skipping over or relocating problems to a spare area of the disc. Data verification, a feature found in some recording software, works with most disc formats and often can be switched on or off. Both hardware (DVD-RAM, DVD+MRW) and software (UDF 2.0 formatted DVD-RW, DVD+RW and DVD-RAM) defect management is available and typically cannot be deactivated (consumer electronics DVD-RAM recorders typically do not implement defect management while, under certain circumstances, some computer DVD-RAM recorders may be able to partially disable this function).

Can writable DVD discs written at different speeds be read back at any speed?

The speed at which a disc is written has nothing to do with the speed at which it can be read back in a recorder, player or DVD-ROM drive.

How might DVD recording speeds increase in the future?

Product manufacturers have publicly discussed plans to increase DVD recording speeds to as high as 16x CAV. Achieving data transfer rates beyond this may be possible but is generally thought not to be practical given the technical challenges and cost considerations involved for minimal increases in real world performance. This is analogous to what happened with CD-R recording which, facing similar design (rotational speed capabilities of commercially available spindle motors) and market issues (high vibration and sound levels), effectively peaked at 52x/54x CAV speed.

PHYSICAL COMPATIBILITY

What types of devices read DVD-R and DVD+R discs?

Once written, single-layer (SL) DVD-R and DVD+R discs closely mimic the optical characteristics of single-layer (SL) prerecorded (pressed) DVDs. Thus, they can be read on the majority of computer DVD-ROM drives and DVD recorders. In addition, DVD-R and DVD+R discs are compatible with most consumer electronics (CE) DVD devices including portable, car and DVD players and recorders. Compatibility continues to evolve so newer devices are generally more able to play written discs. For example, some early DVD video players were released before the DVD-R specifications were completed so they do not recognize DVD-R discs. Some manufacturers suggest that under certain circumstances DVD+R can work around this issue by having the recorder write the disc using the prerecorded disc identification code thereby allowing the player to treat it as a pressed disc (see "DVD disc category" below). If in doubt, consult with the hardware manufacturer.

What types of devices read DVD-RW and DVD+RW discs?

Written DVD-RW and DVD+RW discs can be read on the majority of computer DVD-ROM drives and DVD recorders as well as consumer electronics (CE) DVD devices including portable, car and DVD players and recorders. However, DVD-RW and DVD+RW discs have optical signal characteristics (lower reflectivity) closer to those of dual-layer (DL) prerecorded (pressed) DVDs which sometimes contributes to incompatibilities (see "DVD disc category" below). As with DVD-R and DVD+R, compatibility continues to evolve so some devices (typically older) may not be able to play written discs. If in doubt, consult with the hardware manufacturer.

What types of devices read DVD-RAM discs?

DVD-RAM discs are significantly different from prerecorded DVDs (data in land and groove areas, embossed sector headers, lower reflectivity and signal modulation, hardware-based defect management, optional cartridge, etc.). As a result, only devices specifically designed to be DVD-RAM compatible can read DVD-RAM discs. These include DVD Multi-compliant computer and consumer electronics (CE) drives, players and recorders as well as other DVD-RAM recorders and DVD-ROM drives expressly supporting DVD-RAM. Keep in mind that not all devices accommodate cartridged discs. As well, there have been several generations of DVD-RAM technology so previous and current versions of discs and devices may not be compatible with one other. Specifically, early DVD-RAM recorders and DVD-RAM compatible DVD-ROM drives read only 2.6 GB single-sided (SS) and 5.2 GB double-sided (DS) discs. In addition, DVD Multi-compliant and DVD-RAM consumer electronics (CE) recorders and players cannot read 2.6 GB (SS) and 5.2 GB (DS) discs. If in doubt, consult with the hardware manufacturer.

What is DVD Multi?

The DVD Forum created the DVD Multi specification in 2001 to provide hardware manufacturers with the requirements necessary to make computer and consumer electronics (CE) DVD devices read or read and write most DVD disc formats sanctioned by the DVD Forum. Specifically, the DVD Multi specification requires that DVD Multi Players read DVD-ROM (prerecorded), DVD-R (General), DVD-RW and DVD-RAM discs and DVD Multi Recorders read and write those same formats. Be aware that DVD Multi does not prescribe that devices should accommodate DVD-RAM cartridges or 8 cm discs. If in doubt, consult with the hardware manufacturer.

Examples of Discs Readable and Writable by DVD Multi Compliant Drives, Players and Recorders

Type of Disc	DVD Multi Player	DVD Multi Recorder
DVD-ROM (prerecorded)	read	read
DVD-R (General)	read	read/write
DVD-RW	read	read/write
DVD-RAM	read*	read/write*

* DVD Multi consumer electronics (CE) devices are not compatible with 2.6/5.2GB DVD-RAM discs.

What is the "DVD disc category" and how can it affect playback compatibility?

Contained within the Lead-In Area of a DVD disc is information about its physical format including its "disc category" (also known as "book type"). This refers to the kind of disc it is as defined by one of the many DVD Forum specifications or "books". Currently, there are four categories — prerecorded (pressed) DVD, DVD-RAM, DVD-R and DVD-RW. DVD Forum specifications do not govern DVD+R and DVD+RW therefore these discs use other categories.

Playback problems can arise (typically in some older devices) if the playing unit is programmed to ignore the category information or to accept only prerecorded discs or the four DVD Forum defined types. To potentially improve the playback compatibility of DVD+R and DVD+RW discs in such devices some DVD recorders are designed to write, or optionally write, these discs with the prerecorded (pressed) category code. Since DVD+RW discs are rewritable various routines (for consumer electronics recorders) or software (for computer recorders) are sometimes made available that can rewrite the disc category code in both its native DVD+RW and the prerecorded setting.

Not all DVD+R/+RW compatible recorders support making these changes and, in general, manufacturers advise against changing a disc's category setting unless this specific playback problem is encountered and others recommend against this practice entirely.

DVD Disc Categories

Disc Format	Disc Category	Disc Specification Source
Prerecorded (pressed) DVD	0	DVD Forum
DVD-RAM	1	DVD Forum
DVD-R	2	DVD Forum
DVD-RW	3	DVD Forum
DVD+RW	9	DVD+RW Alliance
DVD+R	10	DVD+RW Alliance

DISC SIZE, CONFIGURATION AND CAPACITY

What are the physical sizes of writable DVD discs?

Generally, writable DVD discs come in 12 cm (120 mm) and 8 cm (80 mm) diameter sizes. The most commonly used is the larger 12 cm type which has the same physical dimension as most commercial video, audio, computer software and game console DVDs. 8 cm discs are less common and are typically used in portable consumer electronic devices such as digital video camcorders.

What configurations of writable DVD discs are available?

Currently, writable DVD discs are single-layer (SL) products which can either be single (SS) or double-sided (DS). Single-sided discs are used in everyday data and video applications while double-sided discs are more specialized (largely due to the lack of a convenient labeling surface) and are typically employed in automated storage jukeboxes and in writable DVD camcorders. In addition, DVD-RAM discs come as bare or can be enclosed in protective "cartridges". Some types of these cartridges may be opened to allow the discs to be removed while others come permanently sealed. Be aware that not all DVD-RAM compatible drives, players and recorders accommodate cartridged discs.

DVD-RAM Disc Cartridge Configurations

	Sealed Cartridge		Removable Disc		Empty Cartridge	
Size	**Single-sided**	**Double-sided**	**Single-sided**	**Double-sided**	**Single-sided**	**Double-sided**
8 cm	—	—	Type 7 (1.46 GB)	Type 6 (2.92 GB)	Type 9 (1.46 GB)	Type 8 (2.92 GB)
12 cm	Type 1 (2.6 GB, 4.7 GB)	Type 1 (5.2 GB, 9.4 GB)	Type 2 (2.6 GB, 4.7 GB)	Type 4 (5.2 GB, 9.4 GB)	Type 3 (2.6 GB, 4.7 GB)	Type 5 (9.4 GB)

Are dual-layer writable DVD discs available?

Manufacturers are developing 8.5 GB single-sided (SS) dual-layer (DL) DVD+R and DVD-R discs for release sometime in 2004 or 2005. Although they approximate dual-layer prerecorded DVD-9 discs be aware that, due to various technical issues, such writable discs may not be read compatible with some older computer DVD-ROM drives and DVD players and they will not be write-compatible with older recorders. If in doubt, check with the hardware manufacturer.

What capacities of blank writable discs are available?

Manufacturers express disc capacity in terms of how much computer data a disc can contain. DVD-R (General), DVD-R (Authoring), DVD+R, DVD+RW and DVD-RAM discs come in 4.7 GB single and 9.4 GB double-sided (12 cm) and 1.46 GB single and 2.92 GB double-sided (8 cm) sizes.

This has not always been the case for DVD-RAM and DVD-R. DVD-RAM discs designed for use in early recorders (version 1.0) come in 2.6 GB single-sided and 5.2 GB double-sided (12 cm) sizes. DVD-R discs compatible with first generation recorders (version 1.0) come in 3.95 GB single-sided and 7.9 GB double-sided (12 cm) and 1.23 GB single-sided and 2.46 GB double-sided (8 cm) sizes.

Keep in mind that manufacturers quote the capacity of a writable DVD disc in decimal (base 10) rather than binary (base 2) notation so a 4.7 GB disc stores 4.7 billion bytes [4,700,000,000 bytes ÷ 1000 = 4,700,000 KB ÷ 1000 = 4,700 MB ÷ 1000 = 4.7 GB]. Expressed in binary notation (as is typical with CD-R, CD-RW and most operating systems) the same disc has a capacity of roughly 4.38 GB [4,700,000,000 bytes ÷ 1024 = 4,589,844 KB ÷ 1024 = 4,482.27 MB ÷ 1024 = 4.38 GB].

How much information can actually be stored on writable DVD discs?

The amount of information that can be written is determined by the disc's recording capacity as well as the physical and logical formats used.

All writable DVD formats devote the same amount of usable space to data (2,048 bytes per sector). DVD+R, DVD+RW and DVD-RAM specify the number of sectors available for user information (1.46 GB DVD+R/+RW 714,544 sectors, 4.7 GB DVD+R/+RW 2,295,104 sectors, 1.46 GB DVD-RAM 714,480 sectors, 2.6 GB DVD-RAM 1,218,960 sectors, 4.7 GB DVD-RAM 2,295,072 sectors) so disc capacity can be calculated by multiplying the user data area size by the number of disc sectors. For example, a 4.7 GB DVD+R disc: 2,048 bytes/sector x 2,295,104 sectors = 4,700,372,992 bytes. This rounds to roughly 4.7 GB (decimal notation).

DVD-R and DVD-RW, on the other hand, do not stipulate the number of sectors that are dedicated to user information but simply that a minimum capacity must be available on the disc. In the case of DVD-R (version 1.0) this is 3.95 (12 cm) and 1.23 (8 cm) billion bytes and for DVD-R (Authoring), DVD-R (General) and DVD-RW 4.7 (12 cm) and 1.46 (8 cm) billion bytes. Consequently, real world capacity can vary slightly among discs from different media manufacturers although many have informally settled on 2,298,496 sectors (4,707,319,808 bytes) for a DVD-R (General) 4.7 GB disc.

Writable DVD Disc Capacities
(Unformatted Single-Sided, Single-Layer Discs)

Disc Format	Specification Version	Disc Size	Number of User Data Sectors Per Side	Gross Capacity (bytes)
DVD+R	1.2	8 cm	714,544	1,463,386,112
		12 cm	2,295,104	4,700,372,992
DVD+RW	1.2	8 cm	714,544	1,463,386,112
		12 cm	2,295,104	4,700,372,992
DVD-R	1.0	8 cm	600,586	1,230,000,000
		12 cm	1,928,711	3,950,000,000
	Authoring 2.0	8 cm	712,891	1,460,000,000
		12 cm	2,294,922	4,700,000,000
	General 2.0	8 cm	712,891	1,460,000,000
		12 cm	2,294,922	4,700,000,000
DVD-RW	1.1	8 cm	712,891	1,460,000,000
		12 cm	2,294,922	4,700,000,000
DVD-RAM	1.0	12 cm	1,218,960	2,496,430,080
	2.0	12 cm	2,295,072	4,700,307,456
	2.1	8 cm	714,480	1,463,255,040

Be aware, however, that the logical format (UDF, FAT, HFS etc.) as well as any defect management system employed consume space otherwise available for user information. For example, DVD-RAM can dedicate as much as 184 MB (192,937,984 bytes) on a 1.46 GB disc, 126.86 MB (133,022,816 bytes) on a 2.6 GB disc and 216 MB (226,492,416 bytes) on a 4.7 GB disc for defect management while Mount Rainier formatted DVD+RW (DVD+MRW) can allocate up to 128.75 MB (135,000,000 bytes) on a 1.46 GB disc and 515.94 MB (541,000,000 bytes) on a 4.7 GB disc.

How many minutes of video can be stored on writable DVD discs?

In contrast to CD technology where Red Book audio or Video CD specifications rigidly prescribe the amount, type and quality of material a disc contains, the DVD-Video format is flexible, permitting content to be housed in different forms and levels of quality. Consequently, the number of minutes of audio and video that can be stored on a writable DVD disc varies considerably.

In terms of its basic capabilities, the DVD-Video format supports one main stream of video (MPEG-1, MPEG-2) with up to nine separate camera angles, as many as eight streams of audio (Dolby Digital, MPEG-1, MPEG-2, LPCM, DTS, SDDS), a maximum of 32 subpicture streams (graphic overlay) as well as navigation menus and other extras. Each of these occupy space so the amount of material that can be recorded depends upon the number of features incorporated, the type and degree of audio and video compression used and the capacity of the disc. For example, a single-sided 4.7 GB disc holds roughly one hour of straightforward audio and video at maximum DVD quality and a 1.46 GB disc approximately 18 minutes. At the other end of the spectrum, the same discs might accommodate as much as nine hours and three hours respectively of VHS quality material.

Not all computer video and audio encoding systems, authoring software and consumer electronics (CE) recorders offer access to all DVD-Video features or support all degrees of compression. Thus, in practice, different products offer a range of possible recording times. For example, an entry-level DVD-Video authoring software package might support only limited features and permit only one hour of recording (using as little compression as possible) to keep the quality of the final result as high as possible. Mid-range and professional hardware and software tools provide the greatest degree of freedom while consumer products generally offer the least.

Generally speaking, consumer electronics (CE) recorders have a variety of automatic or manual recording modes typically ranging from one to four hours (occasionally six to eight hours) per 4.7 GB disc while writable DVD camcorders usually offer between 20 minutes to one hour per 1.46 GB disc. Although manufacturers sometimes use language such as High Quality (HQ), Standard Play (SP), Long Play (LP) and others to describe the recording time of their products, be aware that there are no broadly accepted industry standards for the use of such terminology.

COPYING DETERRENTS AND CONTENT PROTECTION

Can commercial DVD-Video and DVD-Audio discs be copied onto writable DVDs?

To deter users from making disc-to-disc and other direct digital copies of commercial movies and audio albums, most prerecorded DVD-Video and DVD-Audio format discs are protected at the factory using (respectively) the Content Scrambling System (CSS) and Content Protection for Prerecorded Media (CPPM).

CSS and CPPM selectively encrypt disc sectors that can only be decrypted during playback by licensed products (DVD players, computer DVD playback software and others). Critical information (decryption keys, album identifiers) required to unlock content is located in protected regions of these discs (Control Data Zone of Lead-in Area and sector headers) accessible to the player or drive and under only carefully regulated circumstances. Without these keys the encrypted video or audio is unusable. Performing bit-for-bit duplication or simply copying files from the disc to a writable DVD, hard drive or other storage medium will not yield a useful reproduction.

As a further defense, writable DVD products employ several safeguards to prevent valid CSS decryption keys and CPPM album identifiers from ever being written to these discs. For example, blank writable DVD discs come from the factory with the Control Data Zone of their Lead-in Areas already "prewritten" (DVD-R General) or embossed (DVD-RW, DVD-RAM) with dummy information. And, in the case of DVD-R (version 1.0), DVD-R (Authoring), DVD+R and DVD+RW, recorders are designed to write only dummy information in the same disc area (and sector headers). This also inhibits CSS or CPPM protection being conferred on content recorded on writable DVD discs for professional or other applications.

Nevertheless, over the years various computer software tools have emerged to allow the making of copies of CSS protected DVD-Video discs.

COPYRIGHT LAW must always be respected whenever dealing with content of any type. Products that bypass protection systems are not permitted in most jurisdictions. And even if a disc lacks content protection it does not mean that copying is permitted. OSTA does not support the use of writable DVD products for any unlawful purpose.

What is region management?

In addition to employing technology to discourage copying, CSS-encrypted DVD-Video discs may optionally contain region management information to allow commercial movie publishers to control the distribution of their products throughout the world. Discs (so enabled) and players contain information that specifies the geographic areas where they are to be marketed. To prevent discs intended for sale in one part of the world being distributed and used elsewhere all devices automatically check discs for region codes and only play titles for which they are authorized.

For computer DVD-ROM drives and recorders this task is accomplished through Regional Playback Control (RPC) of which there have been two phases. Phase I implementations were used prior to the end of 1999 and function through the computer's video playing software, decoding system or operating system to manage region control. In this case, the region code could be set only once and, for some decoders, the region was sometimes even preset at the factory. Phase II implementations have been in use since 2000 and hand-off responsibility for region management exclusively to the drives and recorders implementing the necessary functions in their firmware. Generally speaking, the user can change the region code up to five times with the manufacturer having the additional ability to then service the unit and reset this counter (up to four times).

Assorted workarounds to region management exist in the marketplace (typically outside North America) including "multi-region" DVD players that read discs regardless of region codes. As well, altered computer DVD-ROM drive and DVD recorder firmware is sometimes circulated to achieve the same effect. Be aware, however, that such modifications can invalidate product warranties.

DVD-Video Region Codes
(Simplified)

Region Code	Geographic Region
1	United States, Canada
2	Japan, Europe, Middle East, South Africa
3	South East Asia (including Hong Kong)
4	Australia, New Zealand, Mexico, Central and South America
5	Northwest Asia, North Africa
6	China
7	Unassigned
8	Special purpose (aircraft, cruise ships, hotels)

What is Content Protection for Recordable Media?

Sometimes analog or digital broadcasts (typically in Japan) are identified to allow only one copy to be made by a viewer and by using the Content Protection for Recordable Media (CPRM) system, such material can be encrypted and recorded once to a writable DVD disc. As it is currently marketed, CPRM is an option found only in some consumer electronics (CE) DVD recorders that write DVD-RW and DVD-RAM discs using the DVD Video Recording format (DVD-VR). This allows material specifically flagged "copy once" to be written to a single disc but prevents that disc from then being further duplicated. This is accomplished by binding the content to the particular disc through encryption employing, among other things, a code (media identifier) unique to each writable disc compliant with the CPRM system. This one-off code is inserted at the factory into the special Narrow Burst Cutting Area (NBCA) of a DVD-RW or Burst Cutting Area (BCA) of a DVD-RAM disc and, as such, cannot be duplicated by a DVD recorder.

Be aware that not all DVD players, drives and recorders that play or write DVD Video Recording formatted (DVD-VR) discs are compatible with CPRM and that not all blank DVD-RW and DVD-RAM discs are equipped with the NBCA or BCA necessary to handle CPRM content. If in doubt, consult with the hardware or disc manufacturer.

DUPLICATION, REPLICATION AND PUBLISHING

What alternatives are available to duplicate DVDs?

There are several different methods available to make one or multiple copies of existing DVDs ranging from single DVD recorders to specialized devices that automatically duplicate and label discs and, for large runs, commercial mass replication. Options are distinguished by cost, speed, convenience and capability. Some of the many applications include reproducing previously created DVD home movies, circulating in-house corporate software, updates and training videos, making backup copies for off-site storage and even commercially distributing software, audio and DVD-Video titles.

As previously stated in this white paper, it is essential to always investigate and obey COPYRIGHT LAWS whenever dealing with content of any type and be aware that products that bypass content protection systems are not permitted in most jurisdictions. Also keep in mind that one is not necessarily authorized to copy a disc even if it lacks content protection measures. OSTA does not support the use of writable DVD for any unlawful purpose and that all DVD products should be used only for legal purposes.

Computer DVD Recorders
By far the quickest and least expensive way to duplicate a disc is to copy it using a computer outfitted with a DVD recorder combined with off the shelf writing software. In addition to creating discs from scratch, many basic writing software packages will duplicate most standard DVD formats. Specialized copying software is also available with more sophisticated capabilities such as the ability to simultaneous duplicate to multiple recorders. But remember that the ability of a system to copy specific disc formats depends upon the individual capabilities of the software, reader and recorder used. It is therefore advisable to check with the respective manufacturers for specific information.

Typically, discs are duplicated DVD to DVD by using the computer's DVD-ROM drive as the master source feeding the copying recorder. In cases where a separate reading drive is not available the master is first downloaded to the computer hard drive using the reading ability of the recorder and later written back to a blank disc using the same recorder. Employing the computer's hard disk as an intermediate copying step is also a common tactic used when dealing with poor quality source discs or other situations where computer systems are not fast enough to keep up to the speed set on the recorder.

DVD Duplication Systems
For copying larger numbers of discs various dedicated DVD duplication solutions are available including machines that function by themselves or with the assistance of operators. These configurations can either sit as standalone units or may be attached as computer peripherals. The most common devices are hand-fed tower systems that employ a number of DVD recorders linked together for simultaneous duplication from

either a master DVD or from a hard drive. Also widely used are automated products incorporating robotic disc handling systems that mechanically load and unload one or more recorders. Sometimes disc label printers are included to produce a handful or even dozens of finished discs per hour. In addition to large commercial solutions many DVD duplication systems are compact and affordable and within reach for personal and office use. A number of companies also offer commercial DVD duplication services to perform short run work in quick turnaround times.

DVD Mass Replication
In contrast to DVD duplication which is usually performed on a small scale at the desktop level, DVD mass replication is typically used to make huge quantities of discs such as commercial DVD movies and software DVD-ROMs. These prerecorded (pressed) discs are manufactured from a mold in a factory setting and are created using a complete series of industrial processes including premastering, mastering, electroplating, injection molding, metallization, bonding, spin coating, printing and advanced quality control. In addition to manufacturing discs, many replication companies offer companion services including packaging, printing, distribution and fulfillment.

What is DVD publishing?

Somewhat like DVD duplication equipment, DVD publishing systems employ DVD recorders but are used to create quantities of unique discs from different computer files rather than just to make multiple copies of a single master disc. Employing robotic disc handling systems and integrated label printers, many of these devices can be accessed over computer networks and shared much like office laser printers. Examples of DVD publishing applications include creating writable DVDs containing medical images or monthly banking records, archiving computer-generated billing records to disc in place of microfilm and accepting conventional analog video tapes resulting in DVD video on writable DVD discs.

Is it possible to transfer the contents of a DVD-9 video disc onto a writable DVD?

Writable DVD discs are currently single-layer (SL) products that accommodate a maximum of 4.7 GB of information per side. Prerecorded (pressed) DVD discs, on the other hand, can contain up to 8.5 GB of data on one side by using dual layers (known as DVD-9). Several techniques can be used to place the larger contents of a DVD-9 DVD-Video format disc onto writable DVDs. These include splitting the material onto two discs or re-authoring it to fit onto one. For example, by using various software programs disc content can be broken into pieces or supplementary material deleted so only the main video segment remains to fit onto a single writable DVD disc. Such software can sometimes recompress the video content to a lower bit rate to fit onto one disc. In this case excluding extraneous material lessens the required amount of recompression to maintain higher video quality. As stated earlier in this white paper, COPYRIGHT LAW must always be respected.

Is it possible to copy one writable DVD disc type onto another?

Depending upon the capabilities of the hardware and software used it is possible to copy one writable DVD disc type onto another (for example, copying the contents of a DVD+RW disc to a DVD-R disc). Be aware, however, that there are slight capacity differences among the various types that might make the contents of one disc too large to fit onto a disc of another type. As well, some application formats may be untested or inappropriate for use with certain types of discs.

DISC LABELING

What alternatives are available to label writable DVD discs?

There are several different labeling methods available for writable DVD discs ranging from hand writing, to adhesive labels, specialized devices that print directly onto the disc surface and ultimately the various commercial printing solutions. Options are distinguished by cost, speed and convenience as well as by durability and the visual quality of the result. But keep in mind that applying any kind of label modifies the disc in some significant way. Thus, product warranties can be invalidated and unforeseen consequences may arise. It is, therefore, advisable to always follow disc, recorder, drive and player manufacturer directions.

Hand Writing
By far the quickest and least expensive way to label a disc is to simply write on its top surface. Using a soft fiber or felt-tipped permanent marker is preferable but be aware that the solvents in some types of inks can potentially damage the disc and, even though the plastic dummy substrate of a single-sided writable DVD disc affords some protection, caution is still in order. Avoid using ballpoint pens, pencils or other sharp writing instruments. As with CD-R and CD-RW the part of the disc least vulnerable to injury is the center clamping or hub area. Double-sided writable DVD discs can be marked only in this region. Some discs are specially coated to accommodate handwritten labels and even special markers are available and intended for such use.

Adhesive Labels
A more attractive way to label a disc is to apply an adhesive label. Several manufacturers offer permanent marker, inkjet, solid ink and laser printer compatible products specifically designed for labeling discs as well as positioning devices to help with centering. Other options include various surface colors and finishes including matte, glossy, foil, holographic and glow in the dark as well as special coatings that can be repeatedly written on with permanent marker and dry erased. Full surface or “donut-style” labels are preferable to partial stickers but be careful as any adhesive label can potentially upset the balance of a disc when playing back. This is especially true at high speeds, resulting in excessive noise, vibration and data retrieval problems. Heat, humidity, sunlight, handling and the passage of time can also compromise the stability of adhesive labels resulting in separation from the disc surface and even interference with the drive. Sticky labels may not be the best choice when archiving important data as some types of label adhesives can react with and undermine the disc over time. Remember too that, once applied, labels should never be removed or repositioned. Even smoothing air bubbles can concentrate physical stresses in a small area and potentially damage the disc.

Specialized Disc Printers

Specialized disc printing devices are available to label discs in larger numbers and for imparting a more polished appearance. Currently, desktop products employing inkjet, thermal transfer and re-transfer technologies are available for directly labeling on the disc surface.

Inkjet

Inkjet printing technology has been available for many years and has proven extremely popular with consumers due to its high quality and cost effectiveness. Inkjet printers function by ejecting liquid ink from a print head onto the surface of a specially coated "inkjet-printable" disc. These special discs have an extra coating, called an Ink Absorption Layer (IAL), which receives the ink from the printer and allows it to stay in place long enough to properly dry. Some discs are even available decorated with screen printed images and areas left blank for desktop inkjet labeling. Inkjet printers produce high-resolution full color images but there is a downside in that resulting labels are subject to being smudged by high humidity or damp fingers and thus are not suitable for use in automotive or other harsh environments. Inkjet printed discs should not be stored or shipped in flexible plastic envelopes as the chemicals used to keep the package materials supple can interact with the inks and cause the label to stick to the sleeve resulting in additional physical stresses upon disc removal. Using jewel cases or other containers that do not directly contact the printed surface is best.

Thermal Transfer

Unlike inkjet printers that spray liquid ink, thermal transfer printers convey solid pigment from a coated ribbon onto the surface of a disc through a combination of heat and pressure. Typically used to produce monochrome and spot color labels, thermal transfer printing does not require specially coated discs to accept the ink from the printing process. The results are, as well, reasonably durable. However, some disc surfaces give better results than others. Consequently, discs are available which feature special coatings optimized for thermal transfer printing. But be aware that writable DVD discs often have a raised ring in their center hub or clamping area that interferes with and can damage the printer's labeling head. It is possible to print above and below this area to avoid the difficulty and there are some discs specially manufactured without this ring to provide an unobstructed surface. For labeling situations where discs share a largely common background appearance but vary slightly from disc to disc or among groups of discs some thermal transfer solutions can align and overprint their output onto partial images already printed onto the surface of the disc.

Re-transfer

More recently, re-transfer printers have come to market and function by applying heat and pressure to convey solid resins from an ink ribbon to an intermediate film and then to the surface of the disc. Typically re-transfer systems produce photo-realistic color labels that are smooth and highly durable. Only certain types of disc surfaces are suitable for re-transfer printing including those optimized for thermal transfer use as well as some inkjet-printable surfaces and "crystal" protective coatings. Some additionally offer coated center hubs that allow for full surface printing.

Commercial Printing
Various methods are used to commercially decorate discs including screen, offset, pad and flexographic printing. These are large-scale industrial processes typically used to label large numbers of discs with the same pattern or in situations when precise color matching is required for critical items such as company logos. In addition to desktop disc labeling, many duplication companies and replicators offer commercial printing services.

Can labels produced on inkjet-printable discs be made more water resistant?

Several different methods can be used to improve the durability of labels produced on inkjet-printable discs. Various products are available which apply materials to coat or seal the surface of the disc to provide a more robust barrier against moisture and handling. In addition, such solutions can impart different finishes (such as gloss or matte) and, in the case of overlaminates, possibly attach a stock or custom hologram to enhance label appearance and authenticate a disc to help deter counterfeiting.

DISC HANDLING, STORAGE AND DISPOSAL

What is the best way to handle and store a writable DVD disc?

A disc should always be handled by grasping its outer edges, center hole or center hub clamping area. Avoid flexing or dropping the disc and exposing it to direct sunlight, excessive cold, heat or humidity. Handle only when being used and do not eat, drink or smoke close by. Discs should be stored in DVD jewel cases or video boxes rather than sleeves because cases will not contact the discs' surfaces and generally provide better protection again scratches, dust, light and rapid humidity changes. CD jewel cases can stress DVDs by gripping them too tightly resulting in discs being difficult to remove from CD cases without excessive flexing. As a result, use only containers specifically designed for DVDs and discs should always be removed carefully. Once placed in their cases discs can be further protected by keeping them in a closed box, drawer or cabinet. For long-term storage and archival situations it is advisable to follow manufacturer instructions. For further information consult the international standards for preserving optical media (ISO 18925:2002, Imaging materials — optical disc media — storage practices).

Should fingerprints and dust be cleaned off a writable DVD disc?

Like CD, DVD technology is robust and employs several design elements to minimize the effects of fingerprints and minor scratches on data integrity. The first line of defense comes from the physical structure of the disc and the location of the data-bearing marks and lands. The reading laser beam shines through the disc's substrate focusing beyond the contaminated surface directly onto the marks and lands beneath. In concert with advanced error detection and correction capabilities minor debris and abrasions are largely ignored. That said, handling care should always be taken as above. A dusty disc should be blown off so that the dust does not enter the drive mechanism and accumulate on the lens or other optical components. It should be noted as well that fingerprints, dust and scratches have a greater impact on recording than is the case with reading a disc since contaminants reduce the effectiveness of the writing laser by obscuring its beam from the disc's recording layer.

What is the best way to clean a writable DVD disc?

Dirty discs should be carefully cleaned using a soft dry lint-free cloth or camera lens tissue. Holding the disc by its outer edges or center hole gently wipe outward from the center hub toward the outside edge of the disc (just like the spokes of a bicycle wheel). Do not wipe the disc using circular motions, as any scratches created will do the least damage if they cut across the track of marks and lands. More stubborn fingerprints or stains can be removed using a soft lint-free cloth lightly moistened with water or a commercially available DVD/CD cleaning fluid. Do not use vinyl record cleaners, lacquer thinner, gasoline, kerosene, benzene or other solvents, as these may damage the disc. Manufacturer directions should always be followed.

Can scratched and damaged writable DVD discs be restored?

Often it is less expensive and makes more sense to transfer the data from a damaged disc onto a new one rather than to try to restore the problem disc. For dealing with more badly damaged situations consumer disc repair kits are available and several companies offer DVD restoration and resurfacing equipment and services. See the resource listing in the appendix for contact information.

Is it possible to recover data from damaged writable DVD discs?

Several software packages are currently available to diagnose disc problems and help recover deleted, unreadable or otherwise inaccessible information. A number of companies also offer commercial DVD data recovery services. See the resource listing in the appendix for contact information.

What is the best way to destroy unwanted writable DVD discs?

For office and high volume production situations various DVD destruction options are available including mechanical shredders, desktop devices that employ heat and pressure to make a disc unreadable and grinders that abrasively remove the disc's reflective and data-bearing recording layers. Unlike a CD where data is physically located close to the disc's top or label side, information recorded on a DVD resides in its interior. Consequently, not all devices that destroy CD-R and CD-RW discs are capable of properly dealing with writable DVDs. A number of companies offer commercial destruction services and deal with classified or other sensitive materials. See the resource listing in the appendix for contact information.

Can unwanted writable DVD discs be recycled?

A number of companies offer DVD recycling services and are able to reclaim some of the materials used in the disc's construction. See the resource listing in the appendix for contact information.

DISC LONGEVITY

How many times can a DVD-RW, DVD+RW and DVD-RAM disc be rewritten?

As is the case with other optical storage media using phase-change technology there is a limit to the number of times the recording layer in a DVD-RW, DVD+RW and DVD-RAM disc can be reliably switched between its crystalline and amorphous states. It is estimated that a DVD-RW or DVD+RW disc can be rewritten approximately 1000 times and a DVD-RAM 100,000 times. In addition, these formats (under certain circumstances) employ defect management schemes to actively verify data and skip over or relocate problems to a spare area of the disc.

How long will data recorded on writable DVD discs remain readable?

The life span of a written disc depends upon a number of factors including such things as the intrinsic properties of the materials used in the disc's construction, the quality of its manufacture, how well it is recorded and the way it has been handled and stored. As a result, the life span of a recorded disc is extremely difficult to estimate reliably. However, to calculate disc life spans within some practical timeframe blank media manufacturers conduct accelerated age testing by subjecting samples of their discs to environments much beyond those experienced under normal storage conditions. Generally speaking, these tests only consider the effects of varying temperature and humidity. Results are then used to predict how long a disc will remain readable under more normal storage conditions. Questionable testing and measurement procedures can seriously impact upon and compromise these estimates so keep in mind that unlike prerecorded (pressed) CD and CD-R discs there are currently no international standards for conducting writable DVD accelerated testing. Writable DVDs and CDs may appear similar, but their construction and underlying design differ significantly so what applies to the one does not necessarily apply to the other.

As with CD-R and CD-RW discs media manufacturers have performed their own lifetime evaluations using a variety of homegrown tests and mathematical modeling techniques. Generally speaking, manufacturers claim life spans ranging from 30 to 100 years for DVD-R and DVD+R discs and up to 30 years for DVD-RW, DVD+RW and DVD-RAM. Be aware, however, that disc producers, manufacturing methods and materials change over time as do applications and cost imperatives. Consequently, those concerned with disc longevity should consult their media manufacturer for more particular information.

One thing is sure — nothing lasts forever and technologies inevitably change. Ultimately, since writable DVDs embody digital information, contents may be transferred to future storage systems as becomes necessary to preserve whatever has been stored on the discs.

DISC TESTING AND VERIFICATION

Is it necessary to verify a writable DVD disc after recording?

Verifying a disc after recording helps to maintain an appropriate quality level. The amount of ongoing integrity checking and data verification that may be prudent is really a question of acceptable risk for any particular application. For example, letting recording software conduct data comparisons immediately after writing is usually sufficient in casual situations but critical data archiving and large-scale duplication may call for more comprehensive testing. This is due to the differences that often exist among recorders, drives and players. Consequently, successfully verifying a written disc on only a recorder does not guarantee broad playing compatibility, especially in cases where a disc is of marginal quality.

How can the quality of a recorded DVD disc be assessed?

Several methods can be used to assess the quality of a written disc. These include measuring its optical signals, examining the integrity of its physical and logical formats, performing interchange testing and conducting data verification. Each method is a piece of the quality testing puzzle. The extent to which a disc needs to be tested depends, of course, upon the imperatives of the application.

At a basic level it is possible to confirm that information has been correctly written to a disc by comparing it against the source material using the verification features found in many off-the-shelf writing software packages. When more detailed analysis is warranted, interchange testing can be performed to provide some practical indication of real-world compatibility. To accomplish this, DVD-Video discs are played back in a number of consumer electronics (CE) DVD video players and computer DVD-ROM drives to check for quality issues while data discs are checked in a variety of DVD-ROM drives to make sure that recorded information is completely recoverable and at speeds established by the manufacturers. Specialized computer software controlling everyday DVD-ROM drives can also be used to read a disc at a lower level of organization to verify that its physical and logical formats conform to industry specifications. In all cases it is assumed that the testing tool used broadly represents the behavior of the general population of reading and playing devices in the market. However, this may or may not be a valid assumption given the wide variety of readout optical systems and the error detection and correction (EDAC) circuitry and strategies in use.

For situations that require appraising more fundamental physical characteristics, a number of commercial analysis tools are available to examine the optical signal characteristics of a recorded disc and thus identify low-level errors. Typically, these devices are standalone or computer-attached and employ DVD-Video or DVD-ROM drives specially modified to measure various disc parameters and provide descriptive reports. As is the case in testing generally, results can vary significantly among inspection systems. To maintain continuity, therefore, discs should always be evaluated on the same piece of equipment. Commercial DVD testing companies offering quality verification services using such devices are also widely available. The accuracy and usefulness of commercially available test platforms (other than those produced by a few semi-officially sanctioned manufacturers) are often debated in technical circles. Consequently, the results such systems generate should be viewed cautiously as it is unclear what they mean in the larger context of reliability and in determining conformance to established specifications.

An important question that has always existed for optical disc testing is the uncertainty of the relationship between the results derived from evaluating discs on low-level analyzers and real world disc performance in the installed population of reading and playing devices. Given the extremely rapid technological evolution of reading and playing devices it is impossible to conclusively establish any definitive link between measured and actual performance, especially for marginal discs.

The DVD Forum has established numerous verification laboratories around the world charged with determining and certifying the conformance of the various types of DVD discs and devices to their respective specifications. Philips Electronics, Ricoh and Sony deal with DVD+R and DVD+RW. While these labs are considered to be the last word in verifying disc conformance to specifications and quality testing they are unable to provide any guidance regarding the reading or writing performance of discs with the already installed population of recorders, drives or players. This is one of the many functions served by several ad hoc industry groups such as the DVD+RW Compatibility and Convergence Group (DCCG), Recordable DVD Council (RDVDC), RW Products Promotion Initiative (RWPPI) and the Optical Storage Technology Association (OSTA).

When assessing disc quality keep in mind the huge number of variables involved. These include such things as discs with their different types, batches and manufacturers, recording software and hardware in their many varieties and versions, diverse recording conditions encountered, different test equipment employed, operators of differing experience and even by the physical handling of the discs themselves. Consequently, judgments should be made on a relative rather than absolute basis.

DISC CONSTRUCTION AND MANUFACTURING

What is the construction of DVD-R and DVD+R discs?

DVD-R and DVD+R discs can be either single or double-sided. A single-sided (SS) disc is composed of a recording side and a dummy side while a double-sided (DS) disc consists of two recording sides. The recording side of a DVD-R and DVD+R disc is a sandwich of a number of layers. First comes a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside diameter of the disc. A DVD-R disc additionally includes pits and lands on the areas between the coils of the groove (land pre-pits). Added to this substrate is an organic dye recording layer (azo, cyanine, dipyrromethene or others) followed by a metal reflective layer (silver, silver alloy, gold). The dummy side of a single-sided disc consists of an additional flat polycarbonate plastic substrate (sometimes with an additional metal layer to obscure the bonding layer from view for aesthetic purposes). An adhesive then bonds two recording sides (for a double-sided) or a recording and dummy side (for a single-sided) together into the final disc. Some single-sided discs are also topped on the dummy side with decorations or additional layers that provide surfaces suitable for labeling by inkjet, thermal transfer or re-transfer printers.

How are DVD-R and DVD+R discs made?

The first step in manufacturing a DVD-R or DVD+R disc is to fabricate the polycarbonate plastic substrates (incorporating the spiral groove and land pre-pits) using an injection molding process. The dye is then applied using spin coating and the metal layers by means of DC sputtering. After both sides of the disc are completed they are bonded together using a hot melt, UV cationic or free radical process. Additional decoration or printable layers are typically applied using screen printing methods. A DVD-R (General) disc undergoes a further manufacturing step in which a specialized computer DVD recorder is used to "prewrite" information in the Control Data Zone of its Lead-in Area to inhibit direct copying of prerecorded DVD-Video discs encrypted with the Content Scrambling System (CSS). Apart from this, and some minor differences in the configuration of the molding stamper used to create the substrates, the process for manufacturing DVD-R and DVD+R discs is virtually identical.

What is the construction of DVD-RW, DVD+RW and DVD-RAM discs?

To allow information to not only be written but also re-written many times over, DVD-RW, DVD+RW and DVD-RAM (rewritable) disc construction is more complex than that of DVD-R and DVD+R (recordable). Just like a recordable disc, a rewritable disc can be either single or double-sided. The recording side of a rewritable disc also uses multiple layers beginning with a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside diameter of the disc. A DVD-RW disc additionally includes pits and lands on the areas between the coils of the groove (land pre-pits) and a DVD-RAM disc also inside the groove itself (land and groove). Next comes a dielectric layer (zinc sulfide and silicon dioxide), followed by a phase-change alloy recording layer (either indium, silver, tellurium and antimony or germanium, tellurium and antimony), another dielectric layer and a metal reflective layer (silver, silver alloy, aluminum). Additional layers may also be incorporated above or below the dielectric layers (germanium nitride, silicon carbide, silicon dioxide, silicon nitride, zinc sulfide, antimony telluride and others). The dummy side consists of a flat polycarbonate plastic substrate sometimes with an additional metal layer. An adhesive then bonds the sides together into a single disc. The exterior of the recording side may also be "hard coated" with a transparent material (indium tin oxide, silicon-based lacquer and others) designed to repel dust and resist fingerprints and scratches. Similar to a barcode in appearance, a DVD-RAM or DVD-RW disc can also contain near its inner diameter an optional Burst Cutting Area (BCA) or Narrow Burst Cutting Area (NBCA) to supply information required to implement Content Protection for Recordable Media (CPRM).

How are DVD-RW, DVD+RW and DVD-RAM discs made?

As with DVD-R and DVD+R, producing DVD-RW, DVD+RW or DVD-RAM discs involves using multiple manufacturing stages. The first step is to fabricate the substrates (incorporating the spiral groove, land pre-pits and embossed areas) by injection molding. The dielectric layers, phase-change recording, reflective and any additional layers are applied to the substrate using DC, RF and reactive sputtering. After both sides of the disc are completed they are bonded together using a hot melt, UV cationic or free radical process. Since the sputtering process lays down the phase-change alloy in its amorphous condition a special device using powerful lasers (initializer) returns the recording layer back to its crystalline state. Subsequent recording then results in less reflective (dark) areas being written against a more reflective (bright) background. The Burst Cutting Area (BCA) or Narrow Burst Cutting Area (NBCA) is marked into the disc using the initializer or a dedicated device outfitted with a YAG (yttrium aluminum garnet) laser. Hard coating can be applied to the substrates at different stages in disc manufacturing using a variety of processes such as spin coating, vacuum deposition and screen printing. A DVD-RAM disc can optionally undergo a further manufacturing step in which it is physically formatted by a conventional computer recorder (to detect and map any defective sectors). Apart from some minor differences in the configuration of the molding stamper used to create the substrates the process for manufacturing DVD-RW and DVD+RW discs is virtually identical while DVD-RAM fabrication is more involved.

How does writable DVD and CD disc manufacturing differ?

Apart from the thinner substrates and tighter manufacturing tolerances, the most significant difference between writable DVD and CD manufacturing is the need to perfectly bond two DVD halves together to create a disc that is the same thickness as a CD (1.2 mm). It is imperative that the two disc halves have the same long-term mechanical behavior to ensure that the resulting disc maintains its thermo-mechanical stability. This is particularly important for high-speed discs where flatness and uniformity are paramount. Writable DVD disc manufacturing equipment and production steps (with the addition of the bonding stage) closely resemble those used to fabricate their CD counterparts. In fact, many media manufacturers have simply modified their existing CD-R and CD-RW equipment to produce writable DVD discs although it is generally expected to become less feasible to do so (for productivity and product quality demands) as the technology and business evolves.

APPENDIX A — SUGGESTED FURTHER READING AND RESOURCES

BOOKS

Bouwhuis, Gijs, et. al. *Principles of Optical Disc Systems.* Bristol: Adam Hilger, 1985.

Brakke, Todd. *The Complete Idiot's Guide to Creating CDs and DVDs.* 3rd ed. Indianapolis: Alpha Books, 2003.

Bunzel, Tom. *Easy Creating CDs & DVDs.* Indianapolis: Que Publishing, 2003.

Chambers, Mark L. *CD and DVD Recording for Dummies.* New York: Hungry Minds, 2001.

Chambers, Mark L. *Creating Your Own Great DVDs & CDs: The Official HP Guide.* Upper Saddle River: Prentice Hall PTR, 2003.

De Lancie, Philip and Mark Ely. *DVD Production: A Practical Resource for DVD Publishers.* Oxford: Focal Press, 2001.

Dixon, Douglas. *Desktop DVD Authoring.* Indianapolis: New Riders, 2003.

LaBarge, Ralph. *DVD Authoring & Production.* Lawrence: CMP Books, 2001.

Marchant, Alan B. *Optical Recording: A Technical Overview.* Reading: Addison-Wesley, 1990.

Purcell, Lee. *CD-R/DVD: Disc Recording Demystified.* New York: McGraw-Hill, 2000.

Taylor, Jim. *DVD Demystified.* 2nd ed. New York: McGraw-Hill, 2001.

Underdahl, Brian. *Create Your Own DVDs.* Berkeley: McGraw-Hill/Osborne, 2003.

Watkinson, John. *The MPEG Handbook.* Oxford: Focal Press, 2001.

TECHNICAL AND WHITE PAPERS

Aldridge, Kenny and Pamela Matheney. *DVD in Detail.* Toronto: Cinram, 1999.

Bennett, Hugh. *Understanding CD-R & CD-RW.* Cupertino: Optical Storage Technology Association, Jan. 2003.

Bennett, Hugh. *Running Optimum Power Control: Data Integrity in CD-Recording.* Santa Barbara: Optical Storage Technology Association, 1998.

Byers, Fred R. *Care and Handling for the Preservation of CDs and DVDs: A Guide for Librarians and Archivists.* Gaithersburg: National Institute of Standards and Technology, May 2003.

Dr. Schenk GmbH. *Inspection and Measurement Solutions for CD-RW, DVD-RW and DVD+RW: Technical White Paper.* Munich: Dr. Schenk GmbH, Mar. 2003.

Dr. Schenk GmbH. *Inspection and Measurement Solutions for DVD-RAM: Technical White Paper.* Munich: Dr. Schenk GmbH, Mar. 2003.

DVD Recordable Special Interest Group. *Rewritable DVD Benefits and Technologies.* DVD Recordable Special Interest Group, Mar. 6, 2003.

Eastman Kodak Company. *Permanence, Care, and Handling of CDs: Including CD-ROM, Writable CD, and Kodak Photo CD.* Rochester: Eastman Kodak Company, 1995.

Ely, Mark and Dave Block. *Publishing in the Age of DVD: A Primer for Creating Content for DVD.* 2nd ed. Novato: Sonic Solutions, 1998.

Godfrey, Stephen E. *Making Your Own DVDs.* Yorba Linda: DV Studio Technologies, 2000.

Hitachi America. *An Introduction to DVD-RAM.* Brisbane: Hitachi America, 2000.

Hitachi America. *DVD-RAM Defining Storage Convergence: A Review of 4.7 GB DVD-RAM Format Enhancements.* Brisbane: Hitachi America, 2000.

Macrovision Corporation. *Preserving An Effective DVD Copy Protection System.* Santa Clara: Macrovision Corporation, Mar. 3, 2003.

Miyamoto, H. *DVD-RAM - Designed for Data Storage: A Review of the DVD-RAM Format Specification.* Brisbane: Hitachi Amercia, 1998.

Multi Media Masters and Machinery. *A 'Revolution' in CD-R and DVD-R Spin Coating.* Yverdon-les-Bains: Multi Media Masters and Machinery, 1999.

Multi Media Masters and Machinery. *CD-R and DVD-R: Ready for the Present, Prepared for the Future*. Yverdon-les-Bains: Multi Media Masters and Machinery, 2000.

Multi Media Masters and Machinery. *Focus on DVD Bonding*. Yverdon-les-Bains: Multi Media Masters and Machinery, 2000.

Multi Media Masters and Machinery. *The Next Wave in Optical Storage: CD-RW and Rewritable DVD*. Yverdon-les-Bains: Multi Media Masters and Machinery, 2000.

Philips Components B.V. *Rollout of Mount Rainier and its EasyWrite Validation Suite*. Philips Components B.V., 2003.

Pioneer Electronics. *Dual Layer Technology for DVD-R (8.5 GB).* Pioneer Electronics, Jan. 2004.

Pioneer New Media Technologies. *An Introduction to DVD Recordable (DVD-R).* Long Beach: Pioneer New Media Technologies, 2001.

Pioneer New Media Technologies. *An Introduction to DVD-RW.* Long Beach: Pioneer New Media Technologies, 2001.

Pioneer New Media Technologies. *DVD-R Authoring vs. General Media: What's the Difference?* Long Beach: Pioneer New Media Technologies, 2001.

Plextor Corp. *Mount Rainier on Plextor Drives: Drag and Drop Files to ReWritable DVD and CD Media*. Fremont: Plextor Corp., Sept. 2003.

Plextor Corp. *Why You Need PowerRec*. 2nd ed. Fremont: Plextor Corp., Dec. 2003.

Royal Philips Electronics N.V. *Dual Layer DVD+R: Doubling the Data Storage Capacity of Recordable DVD to 8.5 Gbyte*. Eindhoven: Royal Philips Electronics N.V., Oct. 2003.

Royal Philips Electronics N.V. *DVD+ReWritable: How it Works*. Eindhoven: Royal Philips Electronics N.V., 1999.

Royal Philips Electronics N.V. *DVD+RW Video: Compatibility and Convergence*. Eindhoven: Royal Philips Electronics N.V., 2000.

Sharpless, Graham. *An Introduction to DVD Formats.* Dallas: Disctronics, July 2003.

Sharpless, Graham. *CD and DVD Glossary.* Dallas: Disctronics, July 2003.

Sharpless, Graham. *CD and DVD Manufacturing.* Dallas: Disctronics, July 2003.

Sharpless, Graham. *DVD-ROM Format & Applications.* Dallas: Disctronics, July 2003.

Sharpless, Graham. *DVD-Video: Format & Features.* Dallas: Disctronics, July 2003.

Sharpless, Graham. *New Formats for Music: DVD & SACD.* Dallas: Disctronics, July 2003.

Software Architects Inc. *The Universal Disk Format: UDF.* Bothell: Software Architects Inc., Aug. 1998.

Sonic Solutions. *Sonic cDVD: DVD Content on CD Media.* Novato: Sonic Solutions, 2000.

Sonic Solutions. *Sonic eDVD: Where DVD Meets the Internet.* Novato: Sonic Solutions, 2000

Sonic Solutions. *Understanding DVD Audio.* Novato: Sonic Solutions, 2000.

Sony Corporation. *DVD Handycam Technology Handbook.* Sony Corporation, 2003.

Sony Electronics. *DVD: The Inside Story.* Park Ridge: Sony Electronics, 1995.

3M Data Storage Optical Technology Division. *Plain Talk: Dual-Layer Compact Disc.* St. Paul: 3M Data Storage Optical Technology Division, 1995.

Verhoeven, J.A.Th. et. al. *High Density CD: An Industrial Approach.* Veldhoven: Optical Disc Manufacturing Equipment, 1995.

STUDIES

Intellikey Labs. *DVD Recordable Media Test.* Burbank: Intellikey Labs, Sept. 19, 2002.

LaBarge, Ralph. "DVD Compatibility Test." *DV Magazine* July 2002: 20+.

Optical Storage Technology Association. *CD-R/DVD-ROM Compatibility Study.* Santa Barbara: OSTA, 1998.

Optical Storage Technology Association. *DVD Compatibility Committee Phase 1 Findings.* Cupertino: OSTA, 2004.

MAGAZINES AND NEWSLETTERS

AV Video Multimedia Producer	www.avvideo.com
Camcorder & ComputerVideo	www.candcv.com
Computer Technology Review	www.wwpi.com
Computer Video	www.computervideo.net
DV Magazine	www.dv.com
EMedia, the Digital Studio Magazine	www.emedialive.com
Film & Video	www.filmandvideomagazine.com
Government Video	www.governmentvideo.com
Medialine	www.medialinenews.com
Mediaware	www.recordingmedia.org
Millimeter	www.millimeter.com
One to One	www.oto-online.com
Optical Disc Systems	www.opticaldisc-systems.com
TapeDisc Business	www.tapedisc.com
Videomaker Magazine	www.videomaker.com
Video Systems	www.videosystems.com

DIRECTORIES AND BUYER'S GUIDES

Billboard International Buyer's Guide	www.billboard.com
DVD Directory	www.newmediainfo.com
EMedia, the Digital Studio Magazine Buyer's Guide	www.emedialive.com
Gold Book	www.oto-online.com
International DVD and CD Plant Directory	www.oto-online.com
Production Services Buyers Guide	www.newmediainfo.com

EXHIBITIONS, TRADE SHOWS AND CONFERENCES

AES	www.aes.org
CEATEC Japan	www.ceatec.com
CeBIT	www.cebit.de
COMDEX	www.comdex.com
DS Expo: Data Storage Expo & Conference Tokyo	www.reedexpo.co.jp
DV Expo	www.dvexpo.com
DVD Entertainment Conference & Showcase	www.recordingmedia.org
DVD Europe	www.dvdeurope2004.com
DVD International Conference & Exhibition	www.itl.nist.gov
Government Video Technology Expo	www.gvexpo.com
IFA	www.ifa-berlin.de
International Consumer Electronics Show	www.cesweb.org
LA DV Show	www.ladvshow.com
Macworld Conference & Expo	www.macworldexpo.com
Media-Tech Expo	www.media-tech.net
NAB	www.nab.org
Optical Storage Symposium (OSS)	www.osta.org
Replication Asia	www.replicationasia.com
Replication Expo	www.howellexpo.com

GENERAL INFORMATION WEB SITES

CD Freaks	www.cdfreaks.com
CDR-Info	www.cdrinfo.com
CDRLabs	www.cdrlabs.com
CD-RW Central	www.cdrwcentral.com
cd-rw.org	www.cd-rw.org
Dvdoctor	www.dvdoctor.net
DVD FAQ	www dvddemystified.com
DVDplusRW.org	www.dvdplusrw.org
DVD-Recordable.org	www.dvd-recordable.org
DVDRhelp	www.dvdrhelp.com
Mpeg.org	www.mpeg.org
Optical Storage Technology Association (OSTA)	www.osta.org

GENERAL INFORMATION NEWSGROUPS AND LISTS

alt.dvd.video
alt.video.dvd
alt.video.dvdr
rec.video.dvd
rec.video.desktop
www.tully.com/dvdlist
http://lists.apple.com/mailman/listinfo/dvdlist

INDUSTRY ASSOCIATIONS AND ORGANIZATIONS

CDs21 Solutions (CDs21)	www.cds21solutions.org
Consumer Electronics Association (CEA)	www.ce.org
Copy Protection Technical Working Group (CPTWG)	www.cptwg.org
DVD Application Group	www.dvdapplicationgroup.com
DVD Association (DVDA)	www.dvda.org
DVD Forum	www.dvdforum.com
DVD+RW Alliance	www.dvdrw.com
Industrial Technology Research Institute (ITRI)	www.itri.org.tw
International Disc Duplicating Association (IDDA)	www.discdupe.org
International Federation of the Phonographic Industry (IFPI)	www.ifpi.org
International Optical Disc Replicators Association (iODRA)	www.iodra.com
International Recording Media Association (IRMA)	www.recordingmedia.org
Japan Recording Media Industries Association	www.jria.org
Optical Storage Technology Association (OSTA)	www.osta.org
Recordable DVD Council (RDVDC)	www.rdvdc.org
RAM Promotion Group (RAMPRG)	www.ramprg.com
RW Products Promotion Initiative (RWPPI)	www.rwppi.com
SCSI Trade Association	www.scsita.org
Serial ATA Working Group	www.serialata.org
Society of Motion Picture and Television Engineers	www.smpte.org
1394 Trade Association	www.1394ta.org
USB Implementers Forum	www.usb.org

LICENSING, SPECIFICATIONS AND STANDARDS ORGANIZATIONS

American National Standards Institute (ANSI)	www.ansi.org
Dolby Laboratories	www.dolby.com
Discovision Associates (DVA)	www.discovision.com
DVD 6C Licensing Agency	www.dvd6cla.com
DVD Copy Control Association (DVD CCA)	www.dvdcca.org
DVD Format Logo Licensing Corporation (DVD FLLC)	www.dvdfllc.co.jp
ECMA International	www.ecma-international.org
4C Entity	www.4centity.com
International Committee for Information Technology Standards	www.incits.org
International Electrotechnical Commission (IEC)	www.iec.ch
International Organization for Standardization (ISO)	www.iso.org
Macrovision Corporation	www.macrovision.com
MPEG LA, LLC.	www.mpegla.com
Optical Storage Technology Association (OSTA)	www.osta.org
Philips Intellectual Property & Standards	www.licensing.philips.com
Small Form Factor Committee (SFFC)	www.sffcommittee.org
Verance Corporation	www.verance.com

APPENDIX B — INDUSTRY AND PRODUCT CONTACTS

MARKET RESEARCH AND CONSULTING FIRMS

Cahners In-Stat Group	www.instat.com
Forget Me Not Information Systems Inc.	73144.1631@compuserve.com
Gartner, Inc.	www.gartner.com
IDC	www.idcresearch.com
InfoTech, Incorporation	www.infotechresearch.com
Jon Peddie Research	www.jonpeddie.com
Magnetic Media Information Services (MMIS)	www.mmislueck.com
Santa Clara Consulting Group	www.sccg.com
Strategic Marketing Decisions (SMD)	www.smdcorp.com
Techno Systems Research Co., Ltd. (TSR)	www.t-s-r.co.jp
Understanding and Solutions	www.uands.com

DUPLICATION AND PUBLISHING SYSTEMS

ACARD Technology Corp.	www.acard.com
Alea Systems, Inc.	www.alea.com
Alera Technologies, LLC.	www.aleratec.com
An Chen Computer Co. Ltd.	www.copystar.com.tw
CopyPro, Inc.	www.copypro.com
Copytrax Technologies	www.copytrax.com
Cyclone USA	www.cdcyclone.com
Discmatic	www.discmatic.com
DixxPli USA	www.dixxpli.com
Hoei Sangyo Co., Ltd.	www.hoei.co.jp
ILY Enterprise Inc.	www.ily.com
Imedia Technologies (IMT)	www.imt-sa.com
Interactive Media Corporation	www.interactivemediacorp.com
JukeBox Information Systems	www.jbis.com
LSK Data Systems GmbH	www.lskdata.de
Luminex Software, Inc.	www.luminex.com
Mediatechnics Systems	www.mediatechnics.com
MF Digital	www.mfdigital.com
Microboards Technology	www.microboards.com
Microsynergy	www.idt-microsynergy.com
Microtech Systems	www.microtech.com
Niscoa, Inc.	www.niscoa.com
Nistec Corporation	www.nistec.co.jp
Odixion	www.odixion.com
OptoMedia Storage Solutions Limited	www.optomedia.co.uk
Orient Instrument Computer Co., Ltd.	www.orient-computer.co.jp
Otari, Inc.	www.otari.com
Pengo Technologies	www.pengo.com
Primera Technology, Inc.	www.primera.com
Rimage Corporation	www.rimage.com
Rimax International Ltd.	www.rimax.net
R-Quest Technologics, LLC	www.r-quest.com
Terra Computer Systems	www.terra.cz
The Logical Company	www.u-master.com

T.S. Solutions	www.ts-solutions.com
Telex Communications, Inc.	www.telex.com
Verity Systems	www.veritysystems.com
Young Minds, Inc.	www.ymi.com
Wytron Technology Co. Ltd.	www.wytron.com.tw

DISC LABELS AND PRINTERS

Avery Dennison Corporation	www.avery.com
Burlington Paper	www.burlingtonpaper.com
Casio Computer Co., Ltd.	www.casio.com
CopyPro, Inc.	www.copypro.com
Epson America, Inc.	www.epson.com
Fellowes/Neato	www.fellowes.com
Imation Corp.	www.imation.com
Intenso GmbH	www.intenso.de
Kyso Inc.	www.kyso.com
LSK Data Systems GmbH	www.lskdata.de
Memorex Products, Inc.	www.memorex.com
MicroVision Development, Inc.	www.surething.com
MF Digital	www.mfdigital.com
Primera Technology	www.primeratechnology.com
Rimage Corporation	www.rimage.com
TDK Electronics Corp.	www.tdk.com
Verbatim Corporation	www.verbatim.com
Verity Systems	www.veritysystems.com

DISC MANUFACTURERS/BRANDS

Advanced Optical Disc Holland B.V.	www.aodgroup.com
Alera Technologies, LLC.	www.aleratec.com
BeAll Developers, Inc.	www.bealldev.com
CMC Magnetics Corp.	www.cmcdisc.com
Daxon Technology Inc.	www.daxontech.com
Digital Data Technologies Sdn Bhd	www.ddt.com.my
Digital Disc Dessau GmbH	www.digital-disc.de
Emtec-Multimedia Inc.	www.datastoremedia.com
Euro Digital Disc Productions GmbH	www.euro-digital-disc.de
Fuji Photo Film	www.fujifilm.com
Gigastorage Corporation	www.gigastorage.com
Imation Corp.	www.imation.com
Infodisc Technology	www.infodisc.com.tw
Info Smart Technology Limited	www.infosmart.com.hk
Intenso GmbH	www.intenso.de
Inter Media Co., Ltd.	www.intermedia.jp
JVC Company of America	www.jvc.com
Khypermedia Corporation	www.khypermediaco.com
KMP Inc.	www.kmpmedia.com
Lead Data Inc.	www.leaddata.com.tw
MAM-A Inc.	www.mam-a.com
Manufacturing Advanced Media Europe (MAM-E)	www.mam-e.com
Maxell Corporation	www.maxell.com
MDA Technology Limited	www.mda.com.hk

Megan Media Holdings	www.meganmedia.com.my
Memorex Products, Inc.	www.memorex.com
MJC Singapore Pte Ltd.	www.mjc.com.sg
Moser Baer India Ltd. (MBI)	www.moserbaer.net
Moulage Plastique de L'Ouest (MPO)	www.hi-space.com
Nashua Media Products	www.nashuamedia.com
Piodata Inc.	www.piodata.com
PrimeDisc Technologies GmbH	www.primedisc.com
Prodisc Technology Inc.	www.prodisc.com.tw
Optodisc Technology Corporation	www.optodisc.com
Pengo Technologies	www.pengo.com
Philips Electronics	www.philips.com
Quantegy, Inc.	www.quantegy.com
Ricoh Corporation	www.ricoh.co.jp
Ritek Corporation	www.ritek.com.tw
Sentinel N.V.	www.sentinel.be
Sony Electronics Inc.	www.mediabysony.com
Taiyo Yuden Co. Ltd.	www.t-yuden.com
Traxdata/Conrexx Technology B.V.	www.traxdata.com
TDK Electronics Corp.	www.tdk.com
Ul Tran Technology & Service Co.	www.ultran.com.tw
UmeDisc Ltd.	www.umedisc.com
Verbatim Corporation	www.verbatim.com
Wing Shing Optical Disc Co. Ltd.	www.wing-shing.com

RECORDER MANUFACTURERS/BRANDS

Accesstek Inc.	www.accesstek.com.tw
Actima Technology Corporation	www.actima.com.tw
Alera Technologies, LLC.	www.aleratec.com
AOpen Inc.	www.aopen.com
ASUSTek Computer Inc.	www.asus.com
Behavior Tech Computer Corp.	www.btc.com.tw
BenQ Corporation	www.benq.com
BUSlink USA Inc.	www.buslink.com
CIS Technology, Inc.	www.cis.com.tw
Digital Research Technologies	www.dr-tech.com
Fantom Drives	www.fantomdrives.com
Hewlett-Packard Company	www.hp.com
I/O Magic Corporation	www.iomagic.com
Iomega Corporation	www.iomega.com
Kanguru Solutions	www.kanguru.com
Khypermedia Corporation	www.khypermediaco.com
LaCie	www.lacie.com
LG Electronics Inc.	www.lge.com
Lite-On IT	www.liteonit.com
Matsushita Electric Industrial Co. Ltd./Panasonic	www.panasonic.com
Memorex Products, Inc.	www.memorex.com
Micro Solutions Inc.	www.micro-solutions.com
Mitsumi Electric Co., Ltd.	www.mitsumi.com
NEC Corporation	www.nec.co.jp
Norcent Technology Inc.	www.norcent.com
Nu Technology Inc.	www.nu-global.com
OptoRite	www.optorite.com

Pacific Digital	www.pacificdigitalcorp.com
Philips Electronics	www.philips.com
Pine Technology	www.pinegroup.com
Pioneer Corporation	www.pioneerelectronics.com
Plextor Corp.	www.plextor.com
Ricoh Company	www.ricoh.co.jp
Sanyo Electric Co., Ltd.	www.burn-proof.com
Sony Corporation	www.sony.com
TDK Electronics Corp.	www.tdk.com
Teac Corporation	www.teac.com
Toshiba	www.toshiba.com

DVD-VIDEO RECORDERS AND CAMCORDERS

Afreey Inc.	www.afreey.com.tw
Apex Digital Inc.	www.apexdigitalinc.com
CyberHome Entertainment, Inc.	www.cyberhome.com
Daewoo Electronics	www.e-daewoo.com
Daytek Electronics Corp.	www.daytek.ca
Ellion Digital	www.elliondigital.com
Gateway, Inc.	www.gateway.com
Hitachi, Ltd.	www.hitachi.com
Lite-On IT	www.liteonit.com
Magnavox Consumer Electronics	www.magnavox.com
Matsushita Electric Corporation/Panasonic	www.panasonic.com
Mico Electric Ltd.	www.micoelectric.com
Mustek, Inc.	www.mustek.com
Philips Electronics N.V.	www.dvdrecorder.philips.com
Pioneer Corporation	www.pioneerelectronics.com
Polaroid (The Petters Group, LLC)	www.polaroidelectronics.com
Sampo Corporation	www.sampo.com.tw
Samsung	www.samsung.com
Samwin Hong Kong Limited	www.samwin.com.hk
Sharp Electronics Corp.	www.sharp-usa.com
Sony Electronics	www.sony.com
Tae-Young Telstar Co. Ltd.	www.tytelstar.com
Thomson/RCA	www.rca.com
Toshiba Corporation	www.toshiba.com
Victor Company of Japan/JVC	www.jvc.com
Yamaha Corporation	www.yamaha.com
Zenith Electronics Corporation	www.zenith.com

DVD-VIDEO AUTHORING AND ENCODING

Adaptec, Inc.	www.adaptec.com
Adobe Systems Inc.	www.adobe.com
ADS Technologies	www.adstech.com
Ahead Software	www.nero.com
Apple Computer, Inc.	www.apple.com
AVerMedia Inc.	www.aver.com
Canopus Corporation	www.canopus.com
Custom Technology Corporation	www.cinemacraft.com
CyberLink Corp.	www.gocyberlink.com

Darim Vision Co., Ltd.	www.darim.com
Dazzle Multimedia	www.dazzle.com
Digigami, Inc.	www.digigami.com
Digital Ventures Diversified	www.dvdcomposer.com
DV Studio Technologies, LLC	www.dv-studio.com
Globalstor Data Corporation	www.globalstor.com
Heuris Logic Inc.	www.heuris.com
InterVideo, Inc.	www.intervideo.com
Ligos Corporation	www.ligos.com
Margi Systems	www.margi.com
Magix	www.magix.com
Matrox Electronic Systems Ltd.	www.matrox.com
Mediostream, Inc.	www.mediostream.com
Nanocosmos GmbH	www.nanocosmos.de
NewSoft Inc.	www.newsoftinc.com
Optibase, Inc.	www.optibase.com
Pinnacle Systems, Inc.	www.pinnaclesys.com
PixelTools Corporation	www.pixeltools.com
Plextor Corp.	www.plextor.com
Roxio, Inc.	www.roxio.com
Sonic Foundry, Inc.	www.sonicfoundry.com
Sonic Solutions	www.sonic.com
Sony BSSC	bssc.sel.sony.com
321 Studios	www.321studios.com
Ulead Systems, Inc.	www.ulead.com
Vitec Multimedia	www.vitecmm.com
Wired Inc.	www.wiredinc.com
Zapex Technologies, Inc.	www.zapex.com

DVD-AUDIO AUTHORING AND ENCODING

Cube Technologies GmbH	www.cube-tec.com
Minnetonka Audio Software, Inc.	www.minnetonkaaudio.com
SADiE	www.sadie.com
Sonic Solutions	www.sonic.com

RECORDING SOFTWARE

Ahead Software	www.nero.com
Aplix Corporation	www.aplix.co.jp
B.H.A. Software Corporation	www.bhacorp.com
Charismac Engineering	www.charismac.com
Gear Software	www.gear.com
Golden Hawk Technology	www.goldenhawk.com
NewTech Infosystems	www.ntius.com
Padus, Inc.	www.padus.com
Pinnacle Systems, Inc.	www.pinnaclesys.com
PoINT Software and Systems	www.pointsoft.de
Roxio, Inc.	www.roxio.com
Software Architects, Inc.	www.softarch.com
Sonic Solutions	www.sonic.com
ValuSoft	www.valusoft.com

JUKEBOXES AND NETWORK STORAGE

ASACA Corporation	www.asaca.com
ASM GmbH & Co. KG	www.asm-jukebox.de
DAX Archiving Solutions	www.smartdax.com
DISC, Inc.	www.disc-storage.com
JVC Professional Products Company	pro.jvc.com
Kubik Enterprises Inc.	www.kubikjukebox.com
Luminex Software, Inc.	www.luminex.com
Pioneer Corporation	www.pioneerelectronics.com
Plasmon	www.plasmon.com
PowerFile, Inc.	www.powerfile.com
Procom Technology, Inc.	www.procom.com
QStar Technologies	www.qstar.com

DISC AND DRIVE QUALITY ANALYSIS AND TESTING

Adivan High Tech AG	www.adivan.com
Almedio Inc.	www.almedio.co.jp
AudioDev	www.audiodev.com
DaTARIUS Technologies GmbH	www.datarius.com
Dr. Schwab Inspection Technology GmbH	www.schwabinspection.com
Eclipse Data Technologies	www.eclipsedata.com
Efocus International Ltd.	www.efocus.co.uk
Expert Magnetics Corp.	www.expertmg.co.jp
Intellikey Labs	www.intellikeylabs.com
Kenwood TMI Corporation	www.kenwoodtmi.co.jp
Katano Matsushita Co., Ltd.	www.panasonic.co.jp/kmc
Philips Intellectual Property & Standards	www.licensing.philips.com
Pioneer Corporation R&D	www.pioneer.co.jp
Professional Multimedia Test Centre	www.pmtctest.com
Pulstec Industrial Co., Ltd.	www.pulstec.co.jp
Quantized Systems	www.quantized.com
Sony Precision Technology, Inc	www.sonypt.com
Teac Corporation	www.teac.co.jp
Testronic Laboratories	www.testroniclaboratories.com
Victor Company of Japan, Ltd.	www.jvc-victor.co.jp

DISC REPAIR, RESTORATION AND DATA RECOVERY

Action Front Data Recovery Labs, Inc.	www.actionfront.com
Acodisc	www.acodisc.com
Alera Technologies, LLC.	www.aleratec.com
ArrowKey, Inc.	www.cdrom-prod.com
AuralTech	www.auraltech.com
CD Data Guys	www.cddataguys.com
Compact Disc Repairman, Inc.	www.cdrepairman.com
Digital Innovations	www.digitalinnovations.com
Doctor Disc Company	www.drdiscoompany.com
ESS Data Recovery	www.savemyfiles.com
Ontrack Data International	www.ontrack.com
Skippy Disc	www.skippydisc.com

DISC DESTRUCTION AND RECLYCLING

Alera Technologies, LLC.	www.aleratec.com
CD ROM Incorporated	www.cdrominc.com
Ecodisk	www.ecodisk.com
EcoMedia	www.ecomedia.com
Fellowes, Inc.	www.fellowes.com
GBC ModiCorp Limited	www.gbcmodi.com
Geo-Tech Polymers	www.geo-tech.com
Greendisk	www.greendisk.com
Hammacher Schlemmer and Company	www.hammacher.com
Hetzel Elektronik-Recycling GmbH	www.her-online.de
Intimus Business Systems	www.intimus.com
Lacerta Group, Inc.	www.lacerta.com
MBA Polymers, Inc.	www.mbapolymers.com
MRC Polymers	www.mrcpolmers.com
Niscoa, Inc.	www.niscoa.com
Olympia Business Systems, Inc.	www.olympia.to
Security Engineered Machinery	www.semshred.com
Sony Disc Manufacturing	www.sdm.sony.com

ABOUT OSTA

The Optical Storage Technology Association (OSTA) was incorporated as an international trade association in 1992 to promote the use of writable optical technologies and products. The organization's membership includes manufacturers and resellers from three continents, representing more than 85 percent of worldwide writable optical product shipments, working together to educate consumers and shape the future of the optical storage industry. Included among OSTA's many accomplishments are its groundbreaking CD-R and recordable DVD compatibility efforts, development of the Universal Disc Format (UDF) as well as the MultiRead, MultiPlay, MultiAudio and MusicPhotoVideo (MPV) specifications.

ABOUT THE AUTHOR

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Bijlage 8: Primer on CDR

Primer on CD-R

The following is intended to be parts of a primer on recordable Compact Disc formats. I have favored simple expression over technical detail. For that, I urge you to check other resources, as found in the URLs. In particular, the information from vendors is authoritative, where the following is **not.** The focus is on PC's and Windows; those with Unix or Mac systems are welcome to translate to the extent possible. (I try not to write about things I don't know.)

Inputs are invited for corrections and for additional topics. Best of all would be a draft for posting here; it will get you a byline and international exposure. (Great for the resume, you know.)

MEDIA

AUDIO RECORDING

VIDEO

FILE TYPES

UDF - PACKET WRITING

OTHER ISSUES

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Return to Mike's home page

Before you Begin

If you have already begun to use CD-R, you know all of this. It is not for you. Please skip it.

If you want to argue with any of this material, please do it somewhere else.

In short, the following is all so obvious that I'm embarassed to write it down. Still ...

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1. General

1. Most of what you 'hear' about CD-R is false.
2. A CD-ROM reader cannot write to CD-Recordable (CD-R) media.
3. A CD-R writer cannot write an erasable (CD-RW) blank unless it is designed to do so.
4. Any writer can read any type of disc which it can write. That does not mean that it can read any particular disc which it has written. The ability to read depends on the medium and its contents.
5. No CD-ROM device can read any form of DVD or DVD-ROM.
6. No CD-R device can write any form of DVD or DVD-ROM.
7. Any kind of file which can be stored on your hard drive can be copied to a CD-R.
8. A file which is too big to be written to a given blank cannot be written to that blank.
9. Certain types of information on a CD-ROM must be written in particular ways. Those include the files of Video CD (VCD) and CD Digital Audio (CD-DA).
10. An image of the contents of any drive is not the same as the contents themselves. To recreate a CD-ROM from its image, the image must be transformed by software, not simply copied, to the CD-R.

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2. Packet writing

1. Packet writing (using UDF) requires a drive designed to write packets and packet-writing software supporting that drive.
2. Fixed-length packets can only be written to an erasable blank in a writer designed to write packets and to write erasables - and requires software made for the purpose.
3. If a drive is not supported for a given function by a given program, it cannot be used to do that job with that program. Exception: In some cases, a drive can be made to look like another; that will almost certainly void any warranty and may lead to unexpected and even unsolvable problems.
4. Packet writing cannot be used to create a CD-DA or to create an exact copy of a pressed disc.
5. If two programs require contradictory values for a parameter (such as Auto Insert Notification), they cannot both be active in a single operating system at one time. Similarly, if they require different versions of a single DLL or other component, they cannot both be active at the same time.

3. Media

1. 'Media' is a plural noun. Its singular is 'medium'.
2. Two blanks which have the same coloring may or may not behave the same way.
3. There are no absolute rules for what medium is best for any specific purpose.
4. The manufacturers and distributors of media are under no obligation to tell you what they put into their packages or to tell you when they change those contents.
5. Erasable (RW) and write-once media work in entirely different ways.
6. The upper (non-recordable) surface of a CD-R is delicate and must be handled with care.
7. Never use a pencil or a ball-point or other hard-tipped pen to write onto a CD-R.
8. In the present state of the art, two write-once media which meet the specifications may behave very differently in a recorder.
9. The various colors of write-once media indicate differences in manufacture but do not qualify one as generally 'better' than another.

4. Readers

1. Any device designed to read a CD, CD-ROM or CD-R is a reader. Every CD-R writer is a reader.
2. There is no known way to write to a specific medium with a specific writer and be sure that it can be read on all readers.
3. A reader designated MultiRead should be able to read an erasable; some which are not so designated may be able to do so as well.
4. Some readers will not read CD-R at all.
5. While there are reasons to prefer a reader using either SCSI or EIDE, each can perform all functions of the other.
6. A given reader has the right to reject any given CD-R.
7. A reader which is not a writer normally will read only a closed session.*
8. An audio player will normally read only the first closed audio session on any disc.*

5. Writers

1. While there are reasons to prefer a writer using either EIDE or SCSI, each can perform all functions of the other.
2. Many features supported by some writers may not be supported by others. Some are precluded by hardware, some by firmware. In general, a feature not supported by your hardware cannot be implemented on your hardware.

3. A hardware manufacturer may claim capability requiring software or media not supplied with the product.
4. Not all writers are manufactured by the company whose name appears on their packaging.
5. A writer not designed to write erasable media will not write erasable media.
6. A writer not designed to write packets (UDF) will not write packets.
7. In general, any modification of the hardware or firmware of a writer not sanctioned by the manufacturer will void any warranty and may result in unexpected and even unrecoverable problems.

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6. Audio

1. There are no files on an audio CD.
2. The apparent .CDA files are a fiction of the operating system.
3. If you see an audio CD as having WAV files, you have an artificial environment which is likely to cause problems when you work with that disc unless you know what is going on.
4. Compact Disc - Digital Audio (CD-DA) is the fixed and inviolate format for sound which will play on a conventional stereo. It is 44.1 Ksps, two-channel, 16 bits, uncompressed PCM. With trivial exceptions, no flexibility is allowed and you cannot put more onto the disc and still play it back in a conventional machine.
5. WAV is a file type which mastering software will convert to CD-DA when writing a CD-DA.
6. MP3 is a file type which some mastering software will convert to CD-DA when writing a CD-DA.
7. Whether WAV or MP3, a file which your software will not convert (e.g., at an incommensurate sampling rate) cannot be written by that software to CD-DA.
8. Performance of a reader on audio is usually not the same as its performance on data.
9. Converting a 44.1 Ksps WAV file to CD-DA introduces no noise, distortion or coloration to the sound. Any differences you hear are due to your ears and your hardware.

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7. Summary

1. When in doubt, **read.** Sources include this site, the FAQ and other sites linked from the URLS page here.
2. CD-R technology is evolving rapidly. What was true yesterday may be false today; what is scheduled for tomorrow may never happen.
3. The more you understand about an immature technology such as CD-R, the more likely you are to recover from any problem.
4. CD-R problems may arise from hardware, software, firmware or procedures. Some derive from the motherboard, the adapter, reader, writer, operating system and other hardware and software on the system. Many arise from interactions of components.

5. The most common cause of failure in writing CDs is the action or inaction of the operator.

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* This condition is true by specification. It is possible for a manufacturer to create an exception so it may be false for a specific piece of hardware.

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Make Your Own CD's

In slightly modified form, this article was published in ***User Friendly*** *the journal of the Los Angeles Computer Society in October 1997.*

A quiet revolution in technology began near the end of 1995 with the release of the first practical consumer CD recorders. That revolution has been continuing as both hardware and software have evolved. By now (late 1997), do-it-yourself CDs and CD-ROMs are quite reasonable goals for the home user and are routine tools for many small offices.

The recording process

A CD-Recordable (CD-R) disc differs fundamentally from a CD or CD-ROM. A 'pressed' disc is made from a glass master with the information stored as pits and lands. That master is pressed against a softened plastic aluminized to give a shiny, metallic surface which reflects the reading laser. The signal generated is very strong and unambiguous. In a CD-R, a flat plastic substrate is plated with gold and covered with a dye layer. The dye, which may be gold, green or blue, has the property that when exposed to an appropriate, strong laser light, it changes state. In one state, it is nearly transparent to infrared; in the other, it is more nearly opaque. The reading laser passes through the dye layer twice: once on the way to the gold layer, once on the way back. The resulting signal does not show as great a difference between a zero and a one as does the pressed CD, but it is still enough for most readers to decipher. The quality of the signal from a CD-R depends on the medium used, the writing laser and the reader. As a result, there is no 'best' CD-R blank or 'best' writer.

Compact Disc audio

A Compact Disc Digital Audio (CDDA or CD for short) consists of a continuous stream of bits translated in a CD player into a digitized waveform which is then converted to analog for listening. Also on that disc is a Table of Contents (TOC) which consists of tiny files describing the start point and the length of the recording. They are specified in terms of recording 'blocks' on the disc; each block is 2K long and there are about 330,000 of them on a normal CD or CD-ROM. It is not important when listening to the music, but is very important when creating a CDDA to remember that the sound is not stored in files at all, but in that stream of bits. (The book of specifications for CDDA was originally bound in red and is now universally known as The Red Book; other colors apply to standards for other formats.) A redbook sound must fit the standards in detail and be recorded at 44.1 KHz sampling at sixteen bits' resolution and two channels.

CD-ROM

A CD-ROM differs fundamentally from a CDDA in that its information is stored in conventional files of the sort familiar to computer users. One of the jobs of CD recording software is to translate a redbook bit stream into WAV files and back. Using any standard CD-R package, that conversion is transparent to the user, but for technical reasons is very important. The process of retrieving the digital bit stream from a

CDDA is called Digital Audio Extraction (DAE). Not all CD-ROM readers can do DAE; some do it only very slowly, very poorly, or both; and some do it quickly and well. Therefore, not all readers are equally good at supplying information for subsequent recording if you want to make a CD-R of favorite selections from your CD library. Incidentally, the directory to the information on a CD-ROM is not stored in a FAT (File Allocation Table) or other familiar file system; it's in the TOC. One key job of the Microsoft Extensions in MSCDEX is to make the CD-ROM's TOC look like a FAT to the operating system. That's why drivers are loaded either in DOS or in Windows (or both) to enable your computer to 'see' your CD-ROM drive.

Variations on the themes

As if CDDA and CD-ROM were not enough, there are variants which mix sound and data, CD Video interactive, Photo Discs and more. Different programs support more or fewer of those formats; if you have special needs in these areas, you must find the recording package which does the job you need. There are also two major innovations in recording which may lead to new uses of CD-R when they are fully integrated in software. Packet writing allows you to dump a collection of files onto a disc when you wish but to delay building the TOC until you are ready. The other major change is the rewritable CD-R. A packet writer using a read/write (RW) will have software to mount the drive as though it were a removable hard drive or large Zip. The next step is already sampling: DVD-RAM. With that, a rewritable packet system will hold gigabytes of data!

A final warning: At this writing (September, 1997), CD-R is not a science or a solid technology. It is essentially an art form, with the advantage that once you have the formula for what you're trying to do, it tends to work repeatedly. However, the tools of that art are changing at remarkable speed. New hardware and new software emerge monthly and the truths of today will be questionable or false in a few months. However, so far it has worked well enough for me to have seen five titles pressed into 4,000 CD-ROMs - and to have at least five more projects in active development.

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Getting Started in CD Recording

This is a personal set of recommendations on starting with your new CD Recorder. The fundamental idea is K.I.S.S. - Keep It Simple, Stupid.

1. Install your system - follow instructions.
No, you don't have to do it this way. You can hang the drive wherever convenient on the bus, run other software, terminate in ways that are not recommended. And all of that **may** work. But just for the heck of it, start off by following the instructions. Then, if it doesn't work, you call up the manufacturer and get useful information on fixing it.

2. Prepare your system to burn a CD-R.
If the software that comes with your drive does not run in your preferred OS, don't run it there. Clear out enough space on your HD to be sure you can burn a CD-R. To be certain, use a drive (IDE or SCSI/AV) with 1,000 MB free. Ideally, use a separate drive from that on which your temporary files are stored. Make certain that all drives that may be used are fully defragmented.

3. Burn a simple data disc first.
Even though you will ultimately be doing much more difficult things, start out with the easy case: All data, Mode 1, files on the hard drive. For example, back up all of your C: drive files that will fit and that are not open while you burn. That means, exclude your CD-writing software folder/directory and the Windows and system directories. It's useful to have that backup disc anyway, but the main reason for this is to be sure that you **can** burn a disc.

While you're at it, make that first disc Disk At Once (DAO). Again, when you can do that, you can use Track At Once (TAO) and multiple sessions to see what they do. Try Digital Audio Extraction (DAE) from your CD-ROM reader or from your CD-R; play with copying a CD-ROM, then a CD; make an ISO file on the HD and burn that; and otherwise check the bells and whistles. But do those one at a time, **after** you know that the basic setup works.

4. One at a time, add functions and modify configuration to make the system work as you wish.
You will probably be able to run a SCSI CD-R on the same adapter that manages your other devices, even those (Jaz drive, HD, CD-ROM) that will be in use with your CD-R. You probably will succeed with various positions on the chain for the reader and with various terminations. But to attempt a complex installation first would mean that any error messages you get will be unique to your system - and none of the manufacturers involved will be willing or able to help you solve the problem. If you make the system work in the manufacturer's configuration, then move one step at a time, you can find out why one of them fails and fix it. If you do three at a time ... forget it!

The same rule holds with other modes, mixed formats, audio files compiled from multiple sources and the other sources of flexibility you will ultimately want for full exploitation of your hardware. Going one step at a time will cost you a few blanks, but will save you endless hours of frustration and save the people who are willing to help you even more.

5. Don't use untried shortcuts.
It would be wonderful if your 12x IDE CD reader fed digital data to your CD-R, but it probably won't. You will want a good CD-ROM to do extract digital audio quickly and cleanly instead of beating your

head against an uncooperative manufacturer's wall of stubbornness. Or use your CD-R as a reader and make an image. Sure, it takes a little longer, but it works. And if you're going to write at 4x, it doesn't matter whether your reader will run at 8x or 48x - it won't read files any faster than they can be written. (Note, too, that the fact that your reader will work at high speed for other functions does not mean that it can do DAE comparably quickly. An 8x reader may not be able to extract digital audio at all; if it does, it may only do so at 2x, or even at 1x. If you **must** do high-speed DAE, ask around to find a reader that may do it, optimize your system - and hope.)

The same rule applies to your hard drive. It may well be possible to use a single, multi-gigabyte drive for CD-R and the rest of the things you want of your system, but why? A second drive will set you back $100 or so, and that's a bargain. So is getting enough RAM.

Without buffer-underrun protection, the fundamental requirement for a successful burn on a CD-R is maintaining a steady flow of data. Anything that interrupts that flow will create a coaster instead of a usable disc. If you are getting coasters, turn off anything you can on your computer that is not needed to burn the disc: screen savers, AV monitors, fax receivers. A defragged hard drive won't waste time while the heads seek the next data item. If you're copying a lot of small files, you will want to make an ISO file for the same reason. Again, you **may** get away with violating those rules, but until you know your system and its capabilities, don't take the chance.

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Getting Smart(er)

There are many ways to get information about CD Recording - or almost anything else - on the Internet. This note is intended to list some of them with indications of when and how to use them. It provides guidelines, not rules, but you are probably here for guidance, so take them for what they're worth.

Accountability

Accountability means that the information you get is reliable and that the source is responsible for its accuracy. The highest level of accountability is the **statement of the manufacturer** or the publisher of a product. If the company says: "This drive works with that software" and it doesn't, you can recover damages. That's real accountability and the reason that many manufacturers of hardware and publishers of software are circumspect about what they assert and careful to post disclaimers.

The next level of accountability is information posted at a **WWW site** by responsible third parties. Clearly, a FAQ such as Andy's excellent one for CD-R at http://www.cdrfaq.org/ is near the top of the list. My CD-R site at http://www.mrichter.com/ (where this page is posted) is also accountable because I make the effort to keep it accurate and I respond to corrections and suggestions. In other words, the sites are accountable because Andy, his colleagues and I are. You have to judge whether other pages are reliable or not - there's no official imprimatur to say: this is truth and that is opinion. I recommend three WWW sites for general CD-R information: the FAQ for a reference book (I use it all the time); Adaptec's site for the best information on their products and their use; and this primer for information on why things work as they do.

A lower level of accountability, but one still of great value, is the **Adaptec mailing list.** As with the WWW pages, its virtue is in its persistence. In general, neither Adaptec nor those who post to the list vouch for the correctness of what's there, but because the list is persistent over time and because its archives are presented in searchable form, any error is likely to be caught and corrected. Along the same lines, much misinformation is trapped by the listowners before it reaches your inbox.

One step above mere rumor and surmise are the **newsgroups.** There is one primary newsgroup for CD recording: alt.comp.periphs.cdr. Two others, comp.publish.cdrom.hardware and .software, have much less traffic and seem to be havens for newbies and people with nothing useful to do. Nevertheless, there are sometimes good questions and useful answers in the comp.publish groups. However, before using any newsgroup, please take a look at the section below for guidelines.

Finally, there is private **e-mail.** Those of us who publish our real e-mail addresses are inviting questions and follow-ups, so feel free to post. Please try to use a bit of judgement when you do. I have received e-mails (I kid you not) saying: I just bought a bare drive - how do I use it? If your question requires a lengthy answer, I am much more likely to post it to this primer than anywhere else, so look for the answer here first. Scan the Adaptec site for their writeup and for the archives of the list. It doesn't hurt to check the FAQ, either. For some strange reason, I get perturbed when a question with answers readily available is asked of me for the thirty-fifth time in a week. "What's the best medium?" is likely to inspire a very uninspiring response.

Newsgroups

On-topic and cross-posting

Make way for my gripe line.

There is so much overlap among the three major CD-R newsgroups that there's no point in complaining about a software question being asked in the .hardware group. However, as you wander farther off-topic - into DVD recording, hard drive optimization, spread-sheet software and so on, you are ever less likely to get a useful answer and ever more likely to generate resentment among the people who want to help. (The people with nothing better to do are happy to discuss matters about which they know nothing.) To find out what's relevant to a newsgroup, *read it.* Scan through the current posts to see if they focus on your concerns - it is not enough to have one post in forty peripherally related to your issue.

Cross-posting is seldom appropriate for a question and must be done correctly (the easy way). It makes sense to cross-post an announcement, but usually one appropriate newsgroup is the place to post a question. If it's as urgent as smoke coming out of your floppy drive, crossposting makes sense; otherwise, pick one spot and if you don't get a reply in a few days, try another.

Correct crossposting is easy: compose one message and post it to all the newsgroups you feel **must** get it. That way, all replies will thread together and can be correlated with one another. If you write separate posts to each of your victims ... er ... target groups, then each will have its own thread and no one will know how to relate them to one another. In addition, someone who wants to help - particularly to correct an error in your problem statement - would have a difficult and ultimately impossible task. She would have to know all the newsgroups to which you posted and would have to subscribe to each in order to make the correction.

When I see an off-topic post, I either ignore it or say: "The question is off-topic - this group is for CD recording as indicated in its name. If you post to a relevant group, you should include [some specifics missing in the original post.]" When I encounter an improper cross-post, I reply "If you must crosspost, please do it correctly. Reply posted to ..."

I am routinely accused of being a "netcop" for those observations. The most interesting thing about that accusation is that those protecting others' right to misuse the resources never provide any useful input - even of as limited use as mine. They will discourse on my motivation and ancestry, but somehow never address the question at hand. I suppose it makes them feel good, so I don't complain.

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Terms of Art

This is a selective list of terms relevant to CD-R with explanations rather than definitions. Organized and authoritative information may be found (as usual) in the FAQ at http://www.cdrfaq.org/ and at Roxio's site. Much of this information is controlled by standards; many of those standards are controlled by the International Standards Organization (ISO). Those pertaining to Compact Disc are in the evolving document, ISO 9660.

NOTE: I look forward to getting information to correct any errors and will consider suggestions or requests for additional entries. I am not interested in arguments about facts, particularly if 'somone' told you ... If you read the INet long enough, someone will tell you whatever you want to hear. You will 'hear' that a CD-ROM can write CD-R, that LaserDiscs are digital, and that Saddam Hussein and Benjamin Netanyahu are lovers. I am not interested in rumor, wishful thinking or anything but traceable fact.

Not Relevant - LaserDisc and CD-V

LaserDiscs and CD-V's are analogue, not digital. Their video and audio data are not read or written on a computer. Digital data on a LD are encoded into analogue to be recorded. Regardless, these media are not readable or writable with CD-ROM or CD-R.

Slightly Relevant - DVD

DVD used to stand for Digital Video Disc or for Digital Versatile Disc. It now stands for DVD. It is a medium with great potential for entertainment and for data storage - and is important in the development of CD-R. However, DVD is in flux right now and what it will become is TBD.

DVD-Video

The DVD players in your local electronics superstore are the video counterpart of CD players. The format used on DVD movies is MPEG 2. First, that is not the same as MP2 - MPEG 1 Level 2 - which is an audio format. MPEG 2 is implemented in hardware, not software. Creating an MPEG 2 file at this point takes a workstation, hardware and software that would buy a small house in most parts of the world. This is a job for a powerful PC and for many purposes is better handled in specialized hardware.

DVD-ROM

A single DVD can hold over 5 GB of data and a few applications see value in exploiting it. While this is not the place to go into technical depth, it is worth pointing out some important technical differences between DVD-ROM and CD-ROM. Maybe it's enough to say that DVD's may hold two or more tracks on each side and may be written on both sides of the disc.

DVD-ROM readers can read DVD movies, DVD-ROMs and pressed CD formats. The first generation cannot read CD-R of any flavor, but later generations are Multiread and will read CD-R and CD-RW. Please note (again) that additional hardware - an MPEG 2 decoder - is required to play a DVD movie on a DVD-ROM.

DVD-R

There is a DVD-R on the market It writes DVD movies (built on a workstation) and DVD-ROMs.. It is commercially available for about $17,000. If you're interested in buying or using one, find an expert; I can't afford even to think about it.

DVD-RAM

There are two competing formats for DVD-RAM and first production units (under $1K) are on the market now. It is logical that at most one will win out eventually, but no one knows which format - or whether it will be another mechanism altogether. As I understand the standard format, it will read DVD movies and DVD-ROMs. A 2.6-GB blank (which may be readable in DVD-ROM) costs about $20 today; a 5.2-GB blank, which is not readable in other hardware, is double-sided and costs about $40.

DVD-RW

Logically, DVD-RW should include DVD-R - but it doesn't. It should be a variation of DVD-RAM - but it isn't. And it should have a single standard - but guess what? Fortunately, the competitive units are not yet available; if you want to learn about it at this stage, please look somewhere else. I have all I can do to keep up with commercial products.

Compact Disc

Now we get into the real world. Some of these things have been around long enough to be pretty well understood and even to be in regular use. The first topic is formats - in particular, those used on pressed discs. Note that discs are pressed from glass masters. The masters are made from tapes. The tapes **may** come from CD-R's or from other sources; the pros are not limited to starting with CD-R any more than cassettes have to come from cassette masters or video tapes from VHS tape masters. Therefore, the pros can break the 'rules' we follow in CD-R.

CD Audio

Properly called CD-DA (Compact Disc - Digital Audio), this is the sort of thing you drop into your Discman. Information about it is defined in the Red Book - a formal standard which is explicit and (largely) followed. The Red Book (named for the color of its cover) calls for a standard format which is not subject to argument; for convenience, I use redbook as a word for that format: uncompressed Pulse-Code Modulated (PCM) data sampled 44,100 times per second in two channels of 16 bits each and ordered and interleaved in a particular manner. With reordering, that format becomes RAW or SND on a computer. Wrapping appropriate header and footer information around a RAW or SND file produces an AU or WAV file. As discussed elsewhere in this primer, software which extracts digital audio produces WAV files; authoring software writes CD-DA from WAV files. It is worth repeating here that a conventional CD player reads exactly one closed session on a CD; anything recorded after the first session is invisible to it and if that first session is not closed or is not audio, it will not be read at all.

CD-ROM

CD-ROM (Compact Disc - Read-Only Memory) is used to describe any CD format in which data (rather than audio tracks) are written. Hybrid modes incorporate both data and audio and are discussed below. A data track is a session and consists of a Table of Contents (TOC) and data. The TOC is translated into a FAT16 file system by the CD Extensions (such as MSCDEX). The files are any flavor of computer file. More information elsewhere in this primer addresses multiple data sessions and related matters.

Hybrid Modes

On a CD-Xtra disc, a CD-DA session is followed by one or more data sessions. Since the first session is audio and closed, it will play on an ordinary CD machine. The subsequent sessions read as they would on any data CD-ROM. To satisfy the standard for CD-Xtra, the audio session and first data session must be written at once and some additional folders and data must be recorded; however, for many purposes it is sufficient simply to record a closed CD-DA session, leave the disc open, then add one or more data sessions which do not import the first. Mixed Mode is similar to CD-Xtra except that the data session(s) is written first and the resulting disc plays only in a CD-ROM or special player. NOTE: The standard requires that the audio of a hybrid mode be written TAO; some software violates the standard to support emulating pressed discs.

CD Recording

Home recording of CD's in various formats has been practical since about 1995. The technology is evolving rapidly, various packages of hardware and of software implement different features more or less in compliance with the standards - and confusion is increasing even faster than brands and models.

CD-R

Compact-Disc Recordable (CD-R) uses a blank consisting of a polycarbonate base with a layer of dye under a metallized surface covered with a lacquer. Clear and blue dyes may be used, resulting in gold or green appearance; the metal layer is gold with those dyes. A different blue dye is overlaid with aluminum, giving a silver/blue disc. When exposed to intense laser light, the dye changes opacity to the less-intense illumination used to read a disc.

CD-RW

Compact Disc - Rewritable uses a different mechanism for recording. The sensitive layer is a silver-colored alloy which changes state (crystalline to amorphous) when exposed to intense laser light and which changes back to some extent when exposed to different illumination. Those state changes cannot be repeated indefinitely; the specified number of cycles for successful operation is currently 1,000. Although an erasable blank is fundamentally different from the kind used to write once, a CD-RW recorder will write CD-R without penalty.

Only some players - CD audio or CD-ROM - can read erasable blanks. CD-ROMs designated Multiread should read them reliably; others may or may not. Some audio players which read write-once CD-R media will also read erasables; some will not.

Packet Writing

Where CD-R and CD-RW were designed to make a disc which behave like a pressed CD or CD-ROM, packet writing is designed to allow writing comparatively small amounts of data in the way that one writes to a floppy drive. Two different systems are used, one for erasable blanks, the other for write-once; they are discussed in this primer under Packet Writing. However, it is important to note the following, which apply to reading in drives other than the writer.

1. CD-DA cannot be written in packets; a packet disc cannot be read in an audio player.
2. A packet-written disc may be finalized to a format readable under Win95 or Win NT, but cannot be read at all in DOS or Win3.x.
3. A write-once packet disc may be readable without finalizing in Windows 98 and an imminent Apple system.
4. An erasable packet disc requires a driver to be read. It cannot be finalized.

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Compact Disc - Digital Audio

Someone wrote to me with questions about commercial CDs (technically, Compact Disc - Digital Audio or CD-DA). Responding to her made it obvious that I have again taken for granted information which is hard to gather from the variuos Internet sources, so I will summarize it here.

The format for CD-DA was defined in a formal specification commonly called the red book (for the color of its cover). It is maintained by Philips and is available at a substantial price as are other specifications known as the orange and yellow books for other formats. The red book specifies that an audio CD may carry the CD logo if and only if it complies with the specification. In particular, the contents must be as follows. Let me note that there are some conventions in acronyms: k means a thousand, K means 1024; b means bits, B means eight-bit bytes.

1. A continuous stream of audio bits organized in a particular way with a Table of Contents (TOC) indicating the start of each "track" in a particular fashion.
2. The audio stream uses Pulse Code Modulation (PCM) which is equivalent to a reordering of a WAV or AIFF file minus any header or footer.
3. The sample rate is 44,100 bits per second (kbps), which is sometimes (erroneously) written 44.1 KHz.
4. Each sample consists of two channels of audio.
5. Each channel has two, eight-bit bytes per sample for 16 bits of encoding.
6. Subchannels are available for specialized purposes. These provide CD Text and other capabilities more complex than needed here.

What about higher sample rates?
44.1 ksps provides audio response beyond 22 kHz, therefore beyond the capability of ordinary playback equipment to reproduce or most users to hear as pure tones. In fact, there are audible losses due to that sampling when real music is offered, but that was the compromise selected in the 1970s when the technology was developing. Higher sampling rates would have meant much more expensive equipment for relatively little return. In addition, that technology would have meant shorter recording time.When DVD-Video came along, 48 ksps was selected; the practical difference between them is negligible. However, mastering and some audio sources justified still higher rates and has led to standards beyond that of CD-DA such as 96 and 192 ksps.

What about more bits per sample
In one sense, that is provided in the spec: it allows for four-channel (quad) recording and playback. That halved the recording time and never caught on. But 16 bits corresponds to more than 90 db of signal-to-noise ratio (SNR). Since good tape sources provided only about 60 db SNR, more bits per channel would mean only improved encoding of the noise, which was already encoded in the last several bits. Among the many options for DVD-Audio, more bits per sample are supported.

What length can a CD-DA offer?
The specification for the timing on a CD-DA and other CD formats is based on a spiral along which the read laser tracks. That spiral had a nominal length for writing the full disc which corresponds to 74 minutes. Tolerance was established so that the actual pitch of the spiral would fill the disc at no less than

63 nor more than 80 minutes (actually, 79 minutes, 59 74/75 seconds - written 79:59:74). While it has always been clear that a steeper pitch, providing longer recording time, meant more errors than a shallower one, the payoff in playing time was deemed more important by the mass market so gradually shorter blanks for CD recording (CD-R) lost market. At this writing (2006), general-use CD-R blanks are available only at "80" minutes with 74-minute media sold only for archival use. Still longer discs have been marketed - up to 99 minutes - but they have high error rates and are seldom employed. It is worth noting that the largest 'length' number which can be written to the disc is 79:59:74; longer discs cannot tell the truth about their length and later track starts are not specifiable in the TOC.

What's the difference between CD-R, CD-RW and pressed (commercial) discs?
There are three technologies involved: CD-R uses a dye to record information; it can be written only once. CD-RW uses the change of state of an alloy and can be erased and rewritten. These are discussed elsewhere in this primer. A pressed disc is, in fact, pressed. The information of the audio stream and the TOC is prepared by a special program to create a glass master. That master is used to make one or more metal stampers. A stamper is pressed into a fluid plastic layer of the blank disc to impress the information. Once set, that disc is given an aluminum coat from which the read laser is reflected. At any point in that process, a speck of dust means a flaw in reproduction, so pressing requires a clean room and special operations to avoid contamination. Fortunately, CD-R and CD-RW are more tolerant and small amounts of contamination are seldom detected.

Errors in digital recording? Is that for real?
Unfortunately, it is. CDs of all sorts are read by analogue mechanisms and digitized by gating. The raw error rate is surprisingly high and both encoding and error correction are used on all CDs and DVDs to bring it to a manageable level. A data disc has an extra layer of error correcting code (ECC) which uses about 13% of the space; that is not used for audio so the player provides error concealment to reduce the effect of misreading. The subject rapidly becomes complicated; it is discussed throughout this primer and in the CD-R FAQ.

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Media - Design and Durability

Let's take a look at how CD media are made and at what that means for their durability. There are darned few hard data available on many of these matters and even fewer reliable numbers, so apply a substantial fudge factor - and give me better numbers if you can find them. Please remember in what follows that the light used to read a CD is infrared and not visible to the human eye. What you see is not what the reader sees, so do not be misled. I am also neglecting here the whole business of the grooves pressed into all discs and containing both positioning information and code for the type of medium.

To begin with, we should examine a pressed disc. Essentially, it begins with a fairly thick layer of tough, clear plastic. The top surface of the plastic has been inscribed with pits and is covered with a very thin layer of metal. On top of that is a thin layer of that plastic, then the graphics which are silk-screened on the very top. Going back to that inscribed top of the bottom piece of plastic, it is usually created by pressing a metal stamper made from a glass master into the surface. Where the result is flat (parallel to the face of the disc), the reflection from the metallized layer is strong; where there is a slant to the plastic, the illumination is scattered and there is no significant return signal. Thus, the maximum brightness is high and the minimum is quite low.

An erasable disc (CD-RW) is similar in some ways to the pressed disc. The top and bottom layers are the same, but the plastic is smooth. The big difference is that instead of a metallized layer which simply reflects the light uniformly, the erasable uses an alloy which changes state when illuminated strongly. In the crystalline state, the alloy reflects light quite well. But it can also be switched to an amorphous state in which its reflectance is substantially lower. The frequency of illumination for reliable reading of an erasable is different from that for a pressed disc or for a CD-R, so special hardware is needed in a reader to allow it to get the signal back. It is also significant that the change of state is not completely reversible. After a number of cycles, the alloy becomes stubborn at a spot and insists on being either crystalline or amorphous, ignoring all the urging that the writing laser may offer. As a result, the disc will gradually develop errors over repeated erasures; eventually, they will be too numerous for error correction to deal with and the disc will be a coaster.

A write-once disc (CD-R) uses yet another arrangement. The layers are similar: thick plastic, smooth surface, metallized reflecting layer, thin plastic over the top. The essential difference is that the thick plastic layer has a dye in it which changes color when illuminated by the writing laser. Before illumination, it may be relatively opaque to the reading frequency; after illumination, it will lighten. The dye is deliberately unstable (otherwise, it would not change transparency) in two different senses. One is that it is able to be written - to respond to the writing laser by changing color - only for about five years; the other is that over time and depending on handling, the dye can fade. When working right, the dye absorbs some of the light when it would ideally be clear and allows some through when we want it to be opaque, so it does not offer the contrast of a pressed disc.

Writing and labelling the disc

The top plastic layer on a pressed disc is pretty sturdy - not as durable as the thicker bottom layer, but pretty good especially when it has a nice coat of silk-screen ink on it. An erasable is usually pretty good in this respect as well; not as resistant to mistreatment as a pressed disc, but a lot better than a typical CD-R. A write-once blank may have a durable top surface added or not. A durable surface, like one advertised for 'long life' or used to support ink-jet printing, is still much more vulnerable to scratches than is the top of a pressed disc, but the least expensive blanks, with no additional protection or surface printing, are the most fragile of all.

In general, if you want to write onto an uncoated disc, you should use a pen made for the purpose. TDK has one available for about $3. Many uncoated discs will take writing from the felt-tip (**not** the metal-sheathed ultra-fine) Sharpie, but there is a slight risk that the solvent in the Sharpie's ink can etch some plastics which may be used. Other pens may well be safe, but why not hedge your bets and either find out from your medium's manufacturer or stick with something made for the purpose? As for pencils and ballpoints: you might as well use a dentist's drill or a sandblaster.

Another option is to apply an adhesive-coated paper label such as are available from Avery, Neato, Stomper and others. That's a fine solution, but there are some risks. Obviously, the label needs to be pretty well centered to avoid problems in high-speed readers. Also obviously, you don't want loose adhesive to foul up your reader or its optics. However, the biggest problem is the adhesive used. It must not let go. If it does, the label will peel away in part, snag in the drive and potentially peel some of the adjacent plastic layer. And that is disaster. If you scratch the thick layer moderately, there will probably be no effect at all. But an uncoated disc has a remarkably thin upper layer and even a tiny scratch or hole will disrupt the metal layer below; a disturbed reflecting layer means no reflections, which means no data - dead disc.

Lifetime

Okay, now you're prepared to handle the disc with due respect for the ultrathin lacquer layer on top. How long will the disc last if you don't sandblast it? If it's a pressed disc, the answer is likely to be 'forever'. That is, there is no decay mechanism known for the CD's sandwich of plastic and metal if it is made well. We may learn better some day, but for now when we find a CD that has gone bad, we suspect that it was made badly, that something led to oxygen reaching the metallizing layer or some extraordinary event - like a fission bomb - turned the plastic opaque.

Write-once media are another story and one which is less understood. Remember, that dye which holds the information is unstable. Time alone will cause the dye to fade or to grow opaque. Either way, it will mask the data. From accelerated tests, manfuacturers will claim life expectancy of 100 or 200 years, but they don't know. On top of that, the real life depends on how you store the disc. Intense light - sunlight or most other forms - will change the dye. After all, the only difference between the sun and the writing laser is that the laser concentrates its light much more finely. How much exposure does how much damage is ... unspecified. Even worse is uncertainty about storage temperature. Life tests are accelerated by holding the disc at a higher temperature than normal; no one seems to be willing to speculate on what happens to that 100-200 year estimate if the disc is not held at 20 C (or whatever).

The erasable disc's decay is probably something like that of the write-once. There have been reports that intense illumination (in one case, with an ultraviolet PROM eraser) will erase an RW and that seems quite likely. My guess is that cosmic rays will also lock the alloy in one state, but I have found no data from manufacturers or others on the matter. But the real killer is that 1,000-cycle estimated life. Well, I certainly don't expect to write and erase the blank a thousand times - come on, be sensible! Unfortunately, you may be doing more erasing than you think. In particular, if you are writing fixed-length packets, the area which holds the directory (think of it as a FAT, though it isn't) is written and rewritten each time you modify a file. It does not take a lot of scrubbing of that part of the disc to reach a thousand cycles to become unreliable. By now, you probably will not be surprised to know that we don't know how to assess that vulnerability, to predict how much use of a disc written in fixed-length packets will kill it.

De Beers claims that 'A diamond is forever.' But diamond is an unstable form of carbon under normal conditions and degrades from the time it is mined. A CD-R or CD-RW treated well may last effectively 'forever', too - as long as we will care about it (though not as long as a diamond). Mishandled, 'forever' for a CD-R may be measured in minutes.

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A Happy Medium

While I do not mean to shock you (prepare yourself, please): the CD-Record process is not perfect.

Now that you have recovered, let's take a look at what is imperfect and what can be done to minimize at least part of the risk. A commercial (pressed) CD or CD-ROM consists of a thin layer of aluminum inside a block of plastic. That aluminum has pits and flat areas; the flats reflect the laser light to provide the signal. That signal is normally very strong because the aluminum reflects almost all of the laser light shining on it, the pits reflect almost none, and almost anything will read the difference quite easily.

In contrast, a CD-R has less contrast. Recording a CD-R means subjecting a layer of dye to enough laser energy to make it change its state. If you leave a color photograph in the sun long enough, it will change color. Its dyes have changed state. The same sort of thing (though much better controlled) is going on in the CD-R. The dye then allows more of the light of a reading laser to pass through the area where it has been written. That light is reflected by the layer of metal behind the dye and passes through again. As a result, most of the reader's light is passed by the area which has been written and most of it is blocked by the area which has not had a state change . Even under the best conditions, the bright spots are less bright and the dark ones less dark than on a pressed disc. Reliable reading then becomes more difficult on a CD-R than it is on a commercial disc.

How well a blank will record in **your** CD-R depends on several factors. How well it plays back depends on others. Essentially, if a medium is 'right' for your recorder, it will change state very effectively when it has been written as you intend. However, if you write at a different speed, it may not work as well - it may no longer be as well tuned to the energy the laser lays down. (Perhaps you are recording more slowly; if the areas that should have changed state did so effectively at a higher speed, they can't change more when hit with extra energy. However, the parts that should have stayed opaque might get enough spilled energy at the lower speed to change a little - perhaps enough to make them a little less black when read out. Change to a less sensitive medium and you may have better results.)

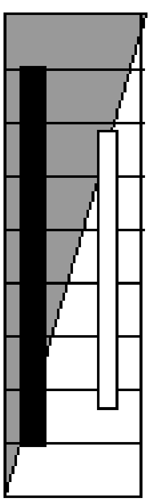
Figure 1

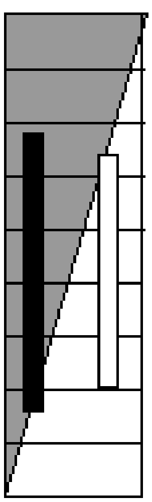
Figure 2

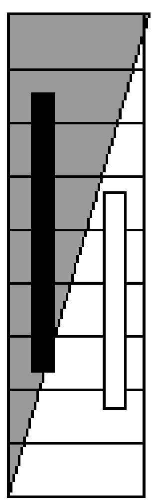
Figure 3

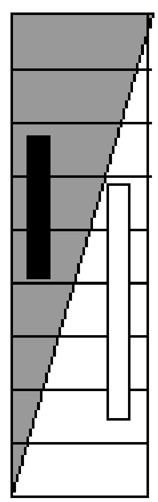
Figure 4

The pictures above are supposed to show the range of laser signal received from the disc when illuminated for reading. Perfect reflection would be the solid white at the bottom of each Figure; perfect absorption would be the solid gray at the top. The signal available in each case is the black bar on the left within each Figure; the detection ability of the reader is the white bar on the right. Figure 1 represents a good, pressed CD and a good reader. The maximum signal is much more than is needed for a the reader to see a one; the minimum signal is much less than that needed to be recognized as a zero. Figure 2 suggests what happens with CD-R: the signals are closer to the thresholds of the reader, but still unambiguous.

In Figure 3, a less sensitive reader (needing more light) is looking at a CD-R which produces less signal at both ends. Notice that here a one is ambiguous; it lies between what the reader would call a zero and a one, so that there is a significant chance that a bit will be misread.If you are reading a megabyte file, there will be about 4 million ones and about 4 million zeros. If the chance that a one is misread is only one in a million, there will be about four errors in reading the file. That means that four times, there will have to be a reread; it's unlikely that the reread will be wrong again, but the reading process has been slowed a great deal. Of course, if the one is even weaker or the reader needs a little more signal, the chance of error goes up until the reread also has a significant chance of failure. Especially if the disc is imperfect - perhaps a spot of dust - it can become completely unreadable.

Figure 4 represents what happens with an erasable (RW) disc. Notice that the signal level for a one becomes much lower; the dye is never as nearly transparent as it is for a CD-R. As a result, a conventional reader cannot make sense of the disc at all. In order to read both RW and conventional discs, the reader must adjust its parameters based on the signals it receives. Such dual-mode readers are becoming available at this time (Fall 1997), but few are on the market. If RW discs become common, the demand for dual-mode readers will be significant and they will become the standard for new drives.

Finding a happy medium

Now that we can see **why** it is the combination of writer, medium and recorder that makes a difference, we can look at how to determine what combinations will make you happy. If you have a writer, a reader and some blanks, you are ready to burn them and try them. If the result leaves you unhappy - reading is slow, audio is noisy or whatever - clearly, any of the three components can be changed. A writer costs less than $100; a good reader will set you back less than $20; blank media run well under $1. Which one would **you** change first?

There are three major kinds of media with substantial variations in two of them. Relatively few companies make blanks, but many sell them; those who do not make their own buy them from one of the manufacturers. The major differences in formulation are indicated by the color of the writing surface: gold, green or blue. There is more variation among the different varieties of gold or of green than between different colors on average, but at least you can be sure that you have a different formulation if you change colors. Because that is what you will want to do: try different media until you get what you want.

Let's assume that you're going to go with one of the major brands - perhaps one that you expect to find available consistently and at low cost. Buy a few blanks for your first runs. If you expect to copy audio CD's on the fly from your reader, do one of them. If you often write data-only CD-Rs from your hard disc, do one of them. Then check out how the discs perform on the different readers you may want to use. For example, check your audio CD-R in your car player if you expect to use it there. The mobile units tend to be more fussy about CD-Rs than good home audio players or computer CD-ROMs. If everything works well in all of your expected applications, lock in on that brand and variety (if you can tell the variety from the package). Buy a supply of blanks and keep a few in reserve so that even if a new batch turns out to be bad, you still have some that you can rely on.

There are many ways to determine how good a copy is. There are thorough tests which are tedious and simple ones which go quickly. One of the simplest takes advantage of the fact that a poor track will often need to be reread. The rate at which errors occur in blocks of data (called BLER) is what you want to determine. When you insert a disc into a reader, the activity light goes on while the Table of Contents (TOC) is being read. If the BLER is high, even reading the TOC will take some time; if the TOC cannot be read reliably, the drive will take a long time to determine the problem and then may spit the disc out. Suppose that you have just made a copy of a disc that you own. When you put the original into the drive on which you plan to read, the drive light turns on for five seconds. Put in your copy; if the light goes on for five seconds, the BLER is very low and the combination is good. If it is on for, say, nine seconds the combination is marginal, but not hopeless - look for something better.If it's on for thirty seconds (even if eventually it goes out), the combination is useless and you need to scrap that medium and look for something else for that job. Remember, too, that because one medium works best for you at one speed for one purpose and in one reader, you can't be sure that it will be the best choice when any of those changes.

Wrapup

If you have gotten to this point, you should know the answers to questions often asked in the newsgroups and elsewhere:
1. What's the best medium (variations: for my drive, for audio, for mixed modes)
2. What's the best writer (or reader) - sometimes specifically for audio or data or mixed format
3. Why won't this reader work on discs that work elsewhere? Is it broken?
4. Why won't my writer read discs that it writes?

Since you can answer all of those and many more, you are an expert. Just as I am. It doesn't take much to become an expert, but let's not spread the word. :-)

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Media

The medium - the blank onto which the recorder writes - is one key to successful CD-R. Unfortunately, there is not the consistency one would wish among the various types. Several different forms are available at this writing (March 1999), distinguishable by the color of the active surface - the one that goes down and onto which the laser writes. They are gold, green and blue. None of them is 'best', and the gold and green vary greatly among brands. Even a single brand may have different product, depending on the actual manufacturer. There are also two different colors of metallizing layer: silver and gold. (The silver may either be silver or platinum.) The active color which seems to be green is actually blue, but made to look green by reflection from the gold metallizing.

It is the combination of medium and recorder that determines how well your discs come out. If someone finds that Brand X makes great audio discs, you may find them terrible because your recorder does not use them as well. Thus, you may want either to stay with the hardware manufacturer's recommendation or with the results reported on the newsgroups or the mail list. Note, too, that an audio disc that plays well in some CD machines may not be acceptable in others and that what works best for data may not handle audio as well.

Most media on the general market are of essentially the same length. There are slight variations, but whether the package is marked 650 MB, 680 MB or something else, it is almost certainly about the same size as any other with similar markings, as attested by the claim of 74 minutes. The longer discs (80 minutes), shorter ones (63 minutes) and shortest ones (smaller diameter, about 15 minutes) have been hard to find and often disproportionately expensive; the 80-minute discs are also reported to be harder to write successfully. Otherwise, the apparent difference in capacity is largely a marketing difference in counting megabytes and is of no practical interest. There is slight variation in actual length - a matter of a few seconds - but that is seldom important and may not be consistent even within a brand. There is a page on this in the Files section of this site with some measured lengths and a link to another such table.

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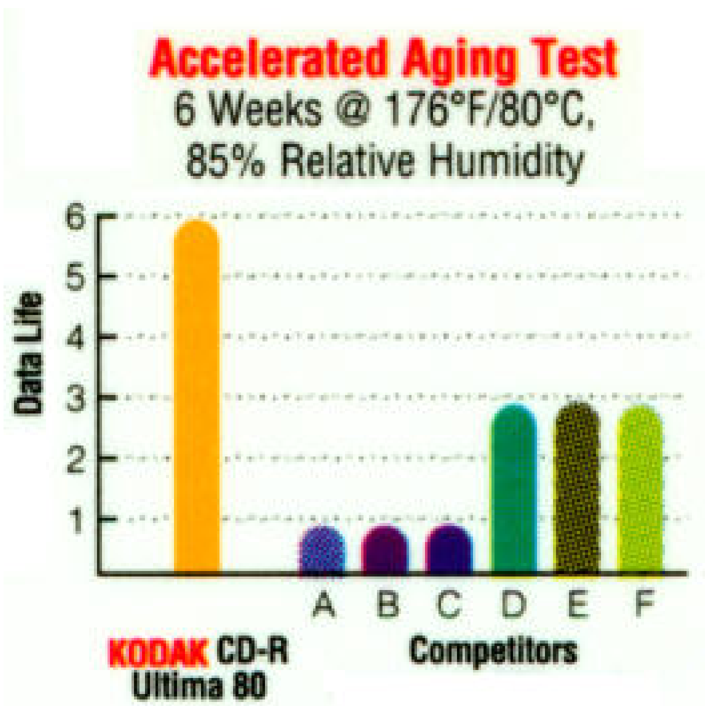
Longevity

One of the key questions about CD recording is: how long will it last - where 'it' is a write-once or erasable blank either before or after recording. There is a little information about write-once blanks which I am trying to summarize below and a lot less about erasables.

A write-once blank uses a dye which is not entirely stable over time either before or after it is written. Using accelerated life tests, manufacturers estimate that a type of disc will remain writable for between five and ten years after manufacture. After that, the probability of write errors will increase - I suspect because the power requirement will become non-uniform and regions will not record properly. After being written, the areas which have been written should hold well, but the unwritten areas will effectively be hardened and the disc will develop excessive errors if you write another session years later.

Some comments are critical. One is that there are assumptions about handling of the discs which can be significant. If you expose any blank to intense sunlight for a period of time - whether written or not - you will find that it changes visibly and functionally. That does not mean that you need to keep the discs in the dark, but that exposure to heat or light will accelerate the breakdown. With normal handling, a written disc will probably outlast you and certainly your interest. A related point is that poor labelling - a bad adhesive, leeching ink or solvent - can destroy a disc over time. Finally, accelerated life tests are performed by overloading the medium with the forces which are **believed** to cause the decay. Needless to say, none of the media we use today has had a century or even a decade of storage to validate the tests that are reported.



The Technology Advantage of Kodak

Our silver+gold alloy makes all the difference! Even under the harshest test conditions, CD-Rs from Kodak surpass competitors for disc stability and data life-up to 6 times more life than leading competitors!

The information above is from Kodak Ultima discs and is of interest because it indicates the way in which manufacturers support their claims. Accelerated life test is necessary because decades are not available for testing. The problem is, no one knows how closely the results match real conditions. The fact that Kodak's discs would last longer in a jar with water on the surface of Venus doesn't say much about how they'll last where humans can survive - which does include summer in Texas, despite the impression of Houstonians.

Erasables work quite differently and are subject to different forms of decay. I have been able to find neither claims for life expectancy nor accelerated life tests on them. It is clear that the story is more complex than for write-once if only because we know that erasables lose reliability when put through erase cycles. My guess is that the distinction in bit-sized regions between crystalline and amorphous becomes lost, that the regions become more or less locked in one state or the other when written repeatedly. If that's true, then the same effect will presumably limit the life when the disc is exposed to heat, light or cosmic rays. Does that mean that erasables will last longer than write-once or not? Yes, it does. It means that their expected life is longer or shorter, but I cannot determine which. So far, experience suggests that high-speed erasables have much shorter lives than write-once.

A final comment seems appropriate. The failure modes known and hypothesized here do not lead to the disc suddenly 'breaking' in any sense. Reading a CD entails correcting errors. As the disc degrades, the rate of errors increases. An unwritten blank may become gradually less consistent in reacting to the write process so that regions are not written uniformly. Regardless, you are not likely to find that a spindle becomes suddenly useless the day after its tenth birthday or that an erasable which has worked beautifully for 999 erase cycles turns transparent on the 1000th. Instead, there will be a gradual increase in the risk of a faulty data read or a gradual degradation in audio quality.

Let's put it all together to see what we can do for long life of write-once media:
1. Use a line of discs with a good reputation to minimize the risk of systematic failure
2. Treat the discs well, especially with regard to labelling.
3. Take manufacturers' data for what they are: well-intentioned, self-serving guidance.

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Labelling

Now that you have produced your shiny silvery or golden disc, how do you mark it? By this time, you are probably not surprised to learn that that is not a simple question. Before going into the specifics, some words of warning are needed. **DO NOT** use ball point, Post-It notes, or any conventional glue or tape.

Construction

The bottom of the disc seems intuitively to be the sensitive part, but 'tain't so. The reflective layer just below the upper surface is far more delicate than the thick plastic on the bottom. Your reader will make quick work of a scratch or dust speck on the bottom, but anything which disturbs the metal foil will make the disc usesless.

In the least expensive discs, the upper layer is little more than an acrylic varnish over the foil. Solvents used to suspend ink and hard tips used to lay the ink down can wreak havoc. Some discs have a more durable coating applied to the top - various names are used to suggest that they are less vulnerable to damage. They are still fragile, but not to the extent of the bare discs. In general, a printed surface suggests a stronger one and one designed for you to write on the disc (underlined spaces for date, etc.) is a pretty sure bet. Still, a soft nib and water-soluble ink are desirable. Finally, there are discs made for ink-jet printers. They have thick, usually painted surfaces and can be written much more freely. A perfectionst such as found at Media Sciences will tell you that you should only write on the clear, inner ring of a disc; that any inscription on the working surface increases error rate. No doubt, they're correct.

Pens

By now, this is easy, right? You want a soft-tipped pen with water-soluble ink for complete safety. The TDK version is available from several suppliers of bulk discs for about $3; Apogee has another at a similar price. An art supply store can probably provide you with a range of altenatives in various colors and line widths.

It's inevitable that people ask about the excellent Sanford Sharpie line. Simply put, there have been few reports of failure from the use of Sharpies, but the ink is not water-soluble so there's a chance that it's a problem waiting to happen. I use the standard Sharpie all the time on coated discs. For the others, I figure that the TDK costs me a tenth of a cent or so per disc and at that rate I can afford to splurge. <G>

I will offer one warning on the Sharpie and others: be aware of the tip and its potential for problems. Sanford's Ultra Fine Point is surrounded by a metal collar with at least the potential to scratch the lacquer. If I want a fine line, I use the TDK with its semi-rigid tip. Perhaps I'm being overcautious, but I see no point in risking data loss for something as simple as this.

Labels

There are several manufacturers of labels and of positioning devices for CD-R. Avery's 5824 are unique in two respects: they have an ingenious positioning scheme which means you have high reliability without an additional hardware; and you can get them from any competent stationer. They are expensive so I recommend them for those who only want to use labels on rare occasion. They are also a good starting point for beginners since Avery provides templates for many programs and supports the 5824 with their Label Pro software.

There are also branded labels from Neato, Stomper and others plus unbranded ones from independent sources. There are two essential issues in selecting such labels - but only one can be determined easily. That is whether the printing surface is suitable for your printer and purposes. If you want to print photographic quality with an inkjet, you may have real problems finding suitable stock. The other problem is the adhesive. You would think you can use some sort of super glue - but the adhesive, like ink, must not contain any solvent which would attack the plastic or seep through to damage the reflective layer.

The adhesive bonds the paper label to the disc's upper surface - the one that's so vulnerable to damage. If it does not hold tightly enough, the label can begin to peel. You cannot remove it (that would pull off some of the lacquer layer and probably destroy the reflector and the disc); you cannot press or glue it back down again; and you cannot use the disc with the label pulling off. The best choice is to try to stick it down long enough to make a copy.

If the label is not well centered and reasonably flat, it will unbalance the disc - particularly in a high-speed reader. You get one and only one chance to position the label and if your eye or your hand is off, you may turn a perfectly good recorded disc into a coaster. For that reason, the major makers of labels sell positioning devices. Once you have graduated from Avery and have selected the brand of label stock you want to use, the positioner is a wise choice. Note, too, that labels vary widely among manufacturers and even from a single source. As a result, you may need to find the right label stock for your needs.

A final point on labels: they may be too thick. Slot-loading drives are particularly sensitive to disc thickness and some high-quality labels can be thick enough to cause problems.

Direct printing

There are several vendors with printers adapted from low-cost inkjet models. I have not used any of them, but the reports are consistent: they work well for a while, then critical parts wear out from the heavy load of a CD-R where the design is intended for paper. For some time, Epson has offered inexpensive printers in Japan with direct capability, but information is available only in Japan and they must be ordered as gray-market (unwarranted) product from importers.

There are at least three quality direct inkjet printers. Primera (formerly Fargo) and Rimage have been in the business for some time and Marcam has recently appeared as a contender. However, these devices are costly ($1300-$4000 list).

Manufacturers of bulk CD-R systems seem to prefer the Primera Signature (relatively low cost) for high-volume applications. It uses standard ink-jet cartridges and delivers modest resolution on the disc. Note that the silk screening used on pressed discs offers only about 150 dpi; while 300 dpi may be marginal for a letter, it looks good on a CD-R. The Primera prints onto special discs for which a premium of the order of ten cents is typical; that means that they are desirable for both cost and quality when volume is high enough. Primera and Rimage offer more costly printers that use wax transfer and can print on any disc surface.

If you are patient and watch carefully, you may be able to get a good deal on a CD-R printer. For example, when Primera upgraded their products, they offered refurbished units at a substantial discount from their list prices. Nevertheless, it takes a substantial printing load to justify $1,000 or more to replace a $3 pen or a package of labels.

Software

Check out DISCUS at http://www.magicmouse.com/ for an attractive and inexpensive program for writing to the disc, labels and inserts. To capture the titles or tracks, your choice of mastering program is the best starting point.

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Rebadging - Who Made This?

There are only a few manufacturers of CD-ROM and CD-R(W) drives - far fewer than there are brands on the market. Many of even the biggest names, such as Hewlett-Packard, do not make drives at all. Rather, they contract with manufacturers to deliver drives branded with their names. We speak of the process as "rebadging". In the process, they may have specific features built in for their purposes or they may use off-the-shelf product with a new faceplate.

The information needed to write a disc depends on the features you want to use. A program with limited application, such as one which writes only audio or which only copies a CD or CD-ROM, is not sensitive to many of those features. One which needs to create CD-Text **and** to write data from a HD in DAO **and** to create a VCD **and** to do all the other things a full-function program sets out to accomplish must know the specific properties of the hardware it is to use. Therefore it needs the specific drive string and that means that a rebadged Plextor is not a Plextor, but an HP, IOmega or whatever.

Further complicating the matter is that the rebadgers may have different drives under the same "hood" at the same or different times. One may be bought from Plextor, another from Ricoh and so on. They are different drives to the mastering program, but the user has no way to know that. Neither, in fact, does the software publisher until the drive or at least the essential information comes to them. If the manufacturer cooperates, the information may be there before the drive hits the market; if not, they have to find a way to get that particular drive (in the sense of "under the hood") from commercial sources. There is no way that a programmer can support a drive he does not know. Some programs with less capability can get away with less - whether the mechanism came from Plextor or Ricoh may make no difference for the limited application. So when a publisher says that Drive X is supported by Version N, they mean that the drive version(s) they know are supported. They do not mean that the one you buy this week is supported unless its the same mechanism that bore that name last week.

Incidentally, you will see evidence of this problem even with limited-function software. In the newsgroups, you will find arguments over whether the FlyByNight model 12 supports a feature. One person says it doesn't; another says it does. Of course, they're likely to be right. Both of them. They have different drives with no external indication of the difference.

Before you ask: the same holds true with blank media. The package of RitesAll 16x media you buy at your neighborhood feed store today may have the same discs inside as the next one on the shelf or the package you buy tomorrow - or it may not. The only external indication you have **may** be the country of origin, usually on a sticker attached to the outside. That alone is a good indicator: this discs are from Taiwan, those are from Malaysia - they're not likely to be the same formulation. You cannot judge by the appearance of the blank except in a negative sense. That is, if they look different in color or surface finish, they will almost certainly perform differently, but if they look the same, they may or may not be equivalent.

Now, a CD-R(W) reports itself to the operating system as a "drive string" - a set of characters which identifies it so that its features can be known and exploited. Two drives which look the same to the user but are different inside will report different drive strings. So the unsupported unit which shares a model number with a supported one differs where the computer sees it - in the drive string. The computer cannot see the writing on the box or even on the drive itself; it knows the drive by its string and supports it or not based on what's in that string.

Similarly, the recorder recognizes the blank not by what the packager wrote onto the disc or its package but by what is written into the disc itself in the ATIP. For further discussion of that, please see the page A Blank is not Blank. In this case, the ATIP limits what can be done with the blank, but two different formulations may have identical information in their ATIPs.

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A Blank is not Blank

No - this is not a trick. The fact is that although a blank has nothing written on the medium, it does contain information - information which can be very important to its use.

A brief recap on the construction of a writable disc. From bottom to top, the three layers are a polycarbonate plastic; a metal; and a lacquer (plastic) top coat which may be overcoated or printed. A write-once blank has a dye in the polycarbonate; the dye changes its infrared transmissivity when written with a high-power laser. An erasable uses an alloy for the metal layer; that alloy changes state between crystalline and amorphous when written, thereby changing its reflectivity.

That polycarbonate slice of the sandwich has a spiral groove pressed into the plastic with a stamper. The laser beam is servoed to stay in the groove as it writes. The tighter the spiral, the greater the total length along the spiral and the longer the disc can record and play. Unfortunately, a tighter groove is harder to follow accurately, so both writing and reading an 80-minute blank are more demanding than the same operations on a 74.

The spiral is not plain; it is modulated with a wobble to give the laser tick marks to locate its place along the spiral. That regular modulation or jitter is further modulated with digital information in what's called the ATIP. Specifically, information in the ATIP includes

- Manufacturer
- Writable/Rewritable
- Dye type
- Spiral length in blocks
- Rated speed
- Audio

Since the length of the spiral is pressed by the same stamper which encodes the ATIP, that information **must** be correct. Everything else is true or not depending on whether the stamper is used by the manufacturer who had it made to press the intended medium. Ideally, the stamper is tuned to exactly the material of the blank - but there's no guarantee of that or of the manufacturer of the blank being the one who had the stamper made.

Only a writer can read the ATIP because only a writer cares about what's in it. If the disc is so badly corrupted that it cannot stabilize in the drive, the ATIP cannot be read, so the writer doesn't even know whether the disc is erasable. Obviously, competent software won't attempt to erase a write-once disc, so that's one way to kill a rewritable medium. Dye type is of little practical interest; whatever is encoded there is overruled by the result of power calibration when the burn begins.

Rated speed is important when specified. If there is no specification, an erasable is always written at 2x; otherwise it may be rated for 4x, so erasable discs not coded to permit 4x writing will not allow it. Similarly, only discs encoded for "audio" can be written in the standalone writers (otherwise, they are identical with that manufacturer's conventional blanks). It is not clear what happens when a standard, write-once disc without a speed specification is to be written; at least in general, it appears that whatever you try will be attempted, but that does not mean that it will work.

Finally, we come back to groove length. The minimum inner and maximum outer radii for a CD are specified in the standard. The manufacturer's rated number of blocks in the ATIP is the amount that can be written in that space, allowing for the runout (leadout) track. In practice, the spiral goes beyond the maximum radius, so there is more room than the manufacturer allows - but it is room at the expense of the design maximum of travel on the writer and the reader.

Writing beyond the rated number of blocks is called **overburning.** It is a somewhat risky operation for reading and for writing. If the disc is fully written with overburning, then the runout track goes beyond the maximum radius. Then the reader, which needs the runout track for operation, may not be able to read it and may be unable to sync on the disc. That's one way that a disc can work in one reader but fail in another. At least theoretically, it's possible for overburning to damage a writer by forcing it to travel farther than its design permits. In short, overburning is risky; it can pay off in some cases, but if you use it, you're on your own.

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Erasable Media

Erasable (RW) blanks are fundamentally different from write-once media. They may look similar, but that is misleading.

A write-once blank (CD-R) uses a dye which changes composition when exposed to strong light of the right frequency. That change is not reversible; the new form is stable and absorbs the reading laser differently from the original. An erasable disc (CD-RW) uses an alloy instead of a dye. When exposed to light of the right properties, it changes from crystalline to amorphous; another form of exposure switches it back to crystalline. The **reflectance** of the alloy depends on its form. Essentially, as a crystal it reflects the read laser as though it were a dull mirror; in amorphous form, it scatters the illumination. Instead of getting white and black (like a pressed disc) or near-white and near-black (like a write-once), an erasable provides light and dark gray and needs more sensitivity in reading.

As a result, only drives marked MultiRead are able to read your erasable reliably. Very few audio CD players will read RW discs. Otherwise, you can use mastering software on an erasable exactly as you would on write-once and expect the same results. That makes erasable media valuable for a couple of reasons. If you're trying something you have not done before, your failures will not fill the trash with non-recyclable plastic. More to the point, the variation in erasable blanks is much less than that in write-once. Therefore, if you cannot tell whether a failure is due to your system or your medium, try an erasable.

UDF is implemented quite differently on erasable and write-once media. For details on that, please see the pages on packet writing. In summary, a CD-RW written in fixed-length packets cannot be finalized to ISO 9660 Level 3, but it can be read in a MultiRead drive with an appropriate driver installed.

Erasing

When an area of the disc is erased, it is converted to be all crystalline - or at least, as nearly so as possible. In practice, there is always some amorphous material (as there is some crystalline material left when written to be amorphous). With each write/erase cycle, a bit or a region of bits becomes more nearly balanced between amorphous and crystalline. As a result, after a number of cycles, the two states become less distinct to the reader and the ones and zeroes approach 'halves'. Nominally, a disc will survive 1000 such cycles, but individual regions may fail sooner. During formatting for fixed-length packets, the software can determine that a region is failing and mark it to be bypassed when writing. However, there are some critical regions - such as where the TOC begins - which cannot be bypassed. Without packet writing, bypassing is not possible.

When any disc is to be recognized by a drive, either by being inserted with AIN on or by being selected by software, the drive attempts to find out what sort of beasty it's dealing with. To do that, it must find the start of the TOC and read data from it. If it gets nothing at all, then a writer assumes that it has a blank; a reader keeps trying indefinitely. Let's assume that we have inserted an erasable with a bad TOC into the drive so that we can erase it. If the TOC is bad enough, even a writer will not be able to make sense of it and will keep reading indefinitely. It gets enough to know that the disc is not blank, but not enough to figure out what it has. That disc defies erasing because erasure cannot start until the TOC is read.

If the TOC can be read well enough to let the drive stop, but not so well that it can be deciphered, you have an 'Unrecognizable Format'. It needs to be recognized so that a quick erase is possible - one which clears the TOC to allow writing without clearing the whole disc. You may not intend to use quick erase, but the software is not psychic, so it will not let you start doing anything until it knows how to do what you might intend. It **could** accept the condition and simply gray out the quick option, but I have found no program which does that. Fortunately, that problem disc may be erasable with a program such as Super Blank (linked from this site) which offers no option but always does a full erase.

Is all hope lost for the disc which will not stabilize? Perhaps not. There are three options, none of which is certain but each of which has been reported to succeed occasionally.

- **Fool the drive** Start with a good disc, prepare to do a full erase, but just before you hit the last OK, swap it for the faulty one.
- **Give it a sunburn** Expose the disc to strong sunlight for some hours.
- **Treat it like an EPROM** Expose the disc to a PROM burner.

When (if?) quantitative data are accumulated, I'll be happy to post them. When erasable blanks cost $5-10 each, recovering them was worth the effort and I had some success with the first two methods. Now that $2 will buy an erasable blank, I'm more likely to discard a flaky one.

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Erasing

Let's get the obvious out of the way first: you cannot erase a write-once (non-erasable) disc. That does not mean you need special hardware or non-commercial software or a secret trick. It means that the changes in the dyes of a write-once blank are not reversible.

Restricting ourselves to erasable (CD-RW) media, we can look at how erasing is done. In first approximation, it works just as we write to those discs. A region corresponding to a bit is heated with a laser until it (more or less) melts, then refreezes in either mostly crystalline or mostly amorphous state depending on the heat/cool cycle used. The result is more or less reflective, hence a one or a zero.

In quick erasure, the TOC is reset to suggest that the disc is blank, but in fact the rest of the disc still has its information. This is not simply resetting one byte of the filename as on a hard drive, so recovery tools will not work to restore the information. Neither is it such complete erasure that a backup program, such as TakeTwo, will be able to use the disc. In short, Quick erase is great for routine use, but if it does not work, a Full erase is needed.

In full erasure, the whole surface is cycled and the information is really, really (honest-to-gosh) gone. A disc which was used for packets may not switch happily to mastering if you use Quick Erase - but Full Erase will probably do the trick. (I would be happy to tell you when one works and when you need the other, but I haven't figured it out yet. It seems to depend on the medium, it may depend on the recorder, but it definitely depends on more information than I've been able to collect so far. Watch this space; some day it may have the answers.)

Finally, there are two more levels of erasure - one that is likely to work and one that should not, but sometimes does. Super Blank is linked from this site. It is made to erase a batch of blanks at once on multiple SCSI drives. However, it will work on only one drive at a time if you wish and it does support most ATAPI (EIDE) drives - so try it. If the disc is sufficiently fouled up, it may report serious errors and start flashing at you. If you ignore that and let it proceed for forty minutes or so, it usually does erase the disc. Super Blank does only Full erase and theoretically does it no better than any other full-erase program. In practice, it seems to work where others do not.

Another solution that should not work - but may - is solar assist. When you put a disc into a drive, job number one is to determine what the disc is. To do that, the TOC is read and the runout track is checked. If the drive is a reader, it does not need a runout track, but in any drive, there must either be a TOC or no TOC at all. If there's a part of a TOC or a faulty one, the drive will keep looking... Forever. If a disc won't stop spinning in a reader, try it in your writer; if there's no runout track (blank, open session, etc.), it will settle down there. But if the TOC is fouled, it will not stabilize even in the writer and violent means are called for.

On occasion, a 'dead' erasable - one which would not stabilize - can be made to look blank enough to be erased by exposing it to strong sunlight for a few hours. Whether it's heat, ultraviolet or black magic, it sometimes works. No sun? Try an EPROM programmer or other intense UV source. No guarantee, nothing but hope that something might save that scrap of metallized plastic.

A final note on Adaptec; the story may be similar with products of other publishers. There are two ways to erase in Easy CD Creator 4. A separate CD Eraser is included with Direct CD; it only offers Quick erase. For the option of Full or Quick, you need to use the Erase function on the CD menu of the ECDC core program. Since Full erasure is needed primarily for DCD functions (including the DCD-related TakeTwo), this is characteristic forgetfulness. You have Full capability where you don't need it, but not where you do.

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Disc Speed and Rating

There are three distinct parts to this note: some words on terminology, information on write-once media and critical data on erasable blanks. Terminology first: What's with this business of "erasable" and "write-once"; aren't "CD-RW" and "CD-R" good enough. Frankly, no, they're not.

The terms "CD-R" and "CD-RW" are applied to both the drives and the media that they write. In itself, that ambiguity is confusing, but even worse is the fact that it leads to a set of misunderstandings, particularly by newbies. I believe it's the reason that some do not recognize that you can master an erasable. There have even been some who don't know you can burn a write-once disc in a CD-RW drive. So, live with it: I use "erasable" and "write-once" for media, "CD-R" and "CD-RW" only for writers.

Write-Once Media

As noted elsewhere in this primer, there is a place in the ATIP of every blank for specifying the maximum and minimum write speeds. However, that is a capability, not a requirement. No manufacturer of media is required to fill in those data and many do not. If the blank does not establish a minimum, you are free to write - or to try to write - at 1x. If it does not specify a maximum, then you can run your drive at its max speed. The problem is that that may not produce a valid burn.

There is an optimum speed for writing any blank in any burner. Fortunately, that will tend to be a broad optimum and not to be very sensitive to the burner used. So if the optimum speed in your Yamaha is 8x then that medium will probably burn well at 4x and 12x and I'm likely to get good results in my Plextor at those speeds as well. However, that disc may not write well at 2x, might not work at all at 1x, may have high error rates at 16x and be prohibitively bad at a higher speed.

The result is that there is no blanket answer to the question of whether a blank certified for 12x will work at 16x (or 20x or ...). If it is not limited in the ATIP, you need to find out its performance for yourself or trust the reports in the newsgroups. Remembering that there are errors on every disc (though most are correctable), you can see that someone else saying it's (not) good enough for his needs doesn't promise you anything about your criteria.

Erasable Media

When erasable discs came along, they could be written at only one speed: 2x. So the rule for writing the ATIP was different from that for write-once. If there is no value specified for minimum, the lowest write speed is 2x; if none for maximum, the highest speed is 2x. So far so good, but when the manufacturers wanted to get practical speeds on erasables, they came up with a new alloy. The dynamics of melting and freezing this metal are quite different from those for the 2x or 1x-4x media and the new stuff simply won't work below 4x. These blanks are termed "HS" for High Speed and drives suitable for writing them are similarly marked "HS". At this writing, HS media and drives are typically rated 4x-10x. Non-HS media and drives operate at 1x-4x.

Here comes the fun: the two types overlap at 4x. So someone with a non-HS writer may believe he can use HS media at 4x. Nice thought, but it's wrong. They simply won't work and if he's lucky, his software will tell him that when he tries. If he's not lucky, he may write or format without getting anything written or formatted. Even that's not as bad as using a non-HS disc in an HS drive. Typically, that does work, but only for a little while. All erasable media seem to be forgetful and to lose their data after some period of storage. The old 2x-only blanks seem to hold the information for many years; 1x-4x are less reliable; HS are pretty sad in this respect, but still should work for testing over a few months. But if you write an HS disc in a non-HS drive, you have a good chance that it will have forgotten most of that information the next day, perhaps on the next insertion.

The conclusion is that most experienced users of CD-RWs are very selective about where they use erasable media. Even more, they make sure that they use a tested brand of the right type: HS or not. Erasing is a good thing; forgetting is not.

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How Many Bits??!!

In a discussion of error protection, Guy G. Sotomayor, Jr ggs@shiresoft.com explained how playing back a CD-ROM at 1x requires reading the disc at more than 4 megabits per second. If you are concerned about matters such as making copies accurate to the bit level or if you want to understand some of the reasons behind the imperfections of CD-R, this section is worth the time it takes. Before going into his text, let me note that a 'symbol' is a character or a value - basically, just an 8-bit byte. Each sample of a redbook waveform consists of sixteen bits for each of two channels: 32 bits, 4 bytes or 4 symbols.

> The first thing to remember is that the data on the CD is stored as 14 bits/symbol rather than just 8. There are several reasons for this, but it makes reading the bits easier. Here are the criteria for selecting which patterns can actually be used:
> 1. 11 is not allowed
> 2. 1001 is as close as two 1s are allowed to get
> 3. 100000000001 is as distant as two 1s are allowed to get (ten 0s).
>
> Each 14-bit symbol is separated from its neighbor by 3 bits, called merging bits, coupling bits, connecting bits or packing bits. They allow the 3 rules above to be applied continuously. Remember at this point we just have a string of bits -- there is still nothing indicating where bytes start and stop. To recap, 8 bits is represented by 17 bits - a little over 2x.
>
> Now, we look at how data is actually stored on the CD. Everything depends upon a 588-bit frame. The 588 bits are organized as follows:

Description	Bits/each	Total bits
Sync Word	24 bits + 3 padding bits=27	27
Control Word	17	17
Audio Samples	6 samples, 2 symbols ea	17 x 12=204
Error Correction Q	17	17 x 4=68
Audio Samples	6 samples, 2 symbols ea	17 x 12=204
Error Correction P	17	17 x 4=68

> Total 588.
>
> To figure out how many 588-bit frames per second we're dealing with we go back to what we see on the output of the CD (namely 176400 bytes per second). A stereo "frame" is 24 bytes, so if we take 176400 / 24 we get 7350 frames per second. Now take 7350 x 588 and you get 4321800 bits per second. Q.E.D.
>
> BTW, the P, Q, G, etc channels are derived from "stacking" the control words (98 of them to be exact) to get the encoded data. As you will no doubt notice, audio data has ECC applied to it. This is the CIRC that I spoke of previously. This is **always** there. Data because of its more exacting nature has an additional layer of ECC applied to it to further reduce the chance of an error. Hope this clears it up!

Footnote from Mike:
There are additional issues including the nature of that 'additional layer of ECC' and the numeric values for error rates in audio and in data. Since ECC discussed by Guy is always imposed, I usually do not consider it in the discussions in this primer. The only specifications I have found for accuracy on CD-R suggest a bit error rate of one in a million for audio and one in a billion for data. Both appear to be worse than we experience in practice, particularly the one for data; that extra layer of ECC should cut the rate by a lot more than a factor of a thousand. Error rates for pressed discs are **much** lower than those for CD-R.

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It's not all Ones and Zeroes

One of the usual responses to questions about quality of CD recording is "It's all ones and zeroes; quality doesn't matter". Some of this is discussed on a page here about media. The message there about indeterminacy of reading is the same here, but now with different implications.

When a CD is read, light from a read laser passes through the plastic, bounces from the metal reflecting layer, and is returned to the detector. On a pressed disc, pits and lands in the metal cause the light to be reflected well or poorly. On an erasable, the metal alloy's crystal structure makes the spot shiny or dull. On a write-once disc, the dye in the plastic causes the (infrared) illumination to be transmitted more or less well. In all of these, the distinction is not between zero and one, perfect reflection and perfect scattering, perfect transmission and perfect blocking. It is between less and more grayness. Somewhere in the continuum of grayness, the detector has a threshold: above that, call it a one; below, call it a zero.

Most of the time, the one-ness or zero-ness of the signal is correct. When it is uncertain or incorrect, Error Correction Code (ECC) is called on to fix it. With ECC, some of the available bits of storage are used to record information about blocks of bits so that if there are few enough errors in the block, they can be corrected. More error correction is provided on a data disc than on an audio disc since a glitch (a highly techncial term for an uncorrectable error) in audio will either be suppressed by the player or little noticed by the listener. But a glitch on a data disc may mean a program that doesn't work at all. (Video is comparable in this respect to audio so that for a VCD, the video file [DAT] is similarly given less correction code than a data file.)

Clearly, as the fuzziness of data reading increases, more and more correction is needed and the chance of uncorrectable error increases. If error correction can handle four mistakes in 2048 bytes, then if fuzziness gets up to an average of one in 2K, there will be a fair number of such sectors - there are over 300,000 of 'em on a full CD-R - with more than four, hence too many to correct. That data disc will not read correctly or reliably. "Reliably" because fuzziness varies with time of day, phase of the moon and supply of apples to the ancient gods - it varies unpredictably as the disc is read. When an uncorrectable error is first encountered, the drive will reread the sector in the hope that the next time is more propitious and valid data can be read. Of course, rereading means stopping the usual forward progress of reading, backing up the optical assembly and synchronizing again; in short, it really slows things down. When a disc has enough errors, reading slows substantially, sometimes to *less* than 1x.

Two significant things occur here. First, you can guesstimate the quality of a recording by the speed with which your drive reads it. Note that in a different drive, the threshhold will be different, the fuzziness will vary and the read will go at a different speed. Thus, you can't really say that it's a bad disc; all you can say honestly is that you cannot read it well in a given drive.

The second implication of rereading is that if matters get **really** bad, the drive may keep trying 'forever'. That is, the system may hang while the drive tries in vain to get valid data. It is a property of the basic -86 chip design and its interrupts that only one basic I/O command will be recognized at a time. While waiting for a read to be acknowledged, the chip will not 'see' a keyboard request. If the read is repeated in the hardware until a good signal is found and that signal never arrives, the keyboard is locked out. Only power-down or the equivalent reset will get through to stop the fruitless effort to read a disc that's bad enough.

The bottom line on all of this is that errors happen. They are not extraordinary, diabolical or traumatic; in reasonable numbers, they are expected and corrected, but that correction comes at a price. The more fuzziness in the data, the greater the chance that an error will escape correction, that the disc will read slowly or even that it will hang up. Thus, our objective is not only to write with no uncorrectable errors - the only ones which will be caught automatically - but to write with as few correctable ones as practical. If a signal level of 0 is a perfect zero and 1 is a perfect one, we want to have mostly .1, .2 and .8, .9 values detected and very few in the .4-.6 region. As noted in the page on media, those detection levels vary with the reader, but if you write consistently strong signals, the disc is likely to work well on all drives which are reasonably compatible with your medium. (That is not to say that an old Hitachi drive will read phthalocyanate media well; it won't regardless of how well it is written. But you can do nothing about that except change medium.)

If you're writing audio, fuzziness in writing - high error rate - degrades performance but usually does not cause failure. In playback, some drives compensate (see the page on Losses) by reducing expectations. All will provide at the analogue output error concealment which can cost high-end response to avoid noises which would be objectionable. That sort of correction is **not** applied on digital output, so for easy listening you may want to use analogue signal through your sound card even though many modern applications let you play back the more accurate digital signal. Most significantly, if you are extracting digitally, you will find spikes corresponding to uncorrected error - very annoying clicks due to a misread and uncorrected bit. A happy result of all this is that if you have a batch of media which you cannot record with low error rates, you may still be able to get rid of them for low-fidelity audio discs which are intended for listening, not for extracting. Since error rates tend to go up on the outer portions of a disc, they are especially useful when used for short, low-fi audio. So even a poor purchase can eventually be disposed of, though only with care.

Whether writing audio or data, you want to minimize the risk of poor reading. To do that, you want to minimize the number of correctable errors in what you write. You can do nothing about the range of readers that will be used other than choose media which are recognized as being of high quality, but among those choices you can select those which have the fewest errors when written by **your** drive of choice at the speed you use. Unfortunately, the quality of writing varies with the speed at which bits are written and in modern drives that speed varies over the disc. Every writer calibrates the power of the write laser at the beginning of a recording and good ones recalibrate during the write, but there is an optimum speed at which the fuzziness of bits is least and writing is best and no recalibration will keep the system at that optimum throughout.

Clearly, then, we want to find a way to test our writes to determine how good they are - how many correctable errors they have. To get an idea of how difficult that is to do thoroughly, drop by Media Sciences at http://www.mscience.com/ and read up on it. The tests that they perform are thorough and demanding - and far beyond the hardware and software available to the home user. Even a lower level of testing, Block Level Error Rate or BLER, requires special drives and equipment. On the other hand, simple pass/fail tests with your mastering software provide no information on correctable errors. In between, there are tools which will help. Since a crude test of the number of re-reads provides insight, you can judge qualitatively by the speed of extraction (audio) or copying (data). Far better is the measurement provided by programs such as Exact Audio Copy and CDSpeed. My own choice is for the Arrowkey products CD/DVD Diagnostic and Inspector which are explicit and, for Inspector, graphic. (Links are on the page of URLs, of course.)

Finally, I note that how well you need to write is up to you and to your application. If I'm spending $1000 to have a disc pressed, I'm willing to measure my master before I send it off, even though a thorough test will take ten minutes or so. When I restock my media, I buy enough to make testing worthwhile and check out a few samples at different speeds in my drives. Those which give zero errors - correctable and not - are used for archiving. Any with even low error rates are used for less critical applications. But in no case would I trust my data to a medium I had not calibrated for my purposes.

You may want to do something similar.

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Audio Losses - pressed vs. CD-R

At first glance, there should be no reason for loss of fidelity between an original disc and a CD-R copy. In practice, there are often reports of such degradation. For example, Philips reports at their WWW site in cddd3610e.pdf that you can expect the following differences at the analogue line output, with similar values for headphone.

Line Out	On pressed CD	On recordable CD
Amplitude Linearity	1.5 dB (20 Hz - 20 kHz)	2.5 dB (20 Hz - 16 kHz)
S/N-ratio	81 dB (84 dB A-wtg)	80 dB (82 dB A-wtg)
Total Harmonic Distortion + Noise	65 dB (1kHz)	55 dB (1kHz)
Channel separation min.	70 dB (20 kHz) min.	65 dB (16 kHz)

They also state - emphatically

THE SOMEWHAT REDUCED AUDIO QUALITY WHEN PLAYING BACK AUDIO TRACKS ON CD-R DISCS HAS NO RELATION TO THE DIGITAL QUALITY OF THE AUDIO TRACKS AS THEY HAVE BEEN RECORDED ONTO THE CD-R DISC.

Those numbers are pretty good, but why don't they match? Why is CD-R playback inferior to that from a pressed disc? I have no proof, but offer the following guess. If someone has information about it, please let me know.

The signal read from a CD-R is inferior to that from a pressed disc. Either the maximum brightness is less or the minimum blackness is brighter - or both. As we know, a layer of error correction is saved by using Mode 2 Form 2 for CD-DA. So we have a weaker signal and less correction, hence more errors. That means that the circuitry on the analogue side - the part that feeds line out and headphones - will be making more corrections. Those corrections will have exactly the kind of impact in the table. My guess is that Philips recognizes the losses and adjusts the circuitry so that it does not attempt to pass an inferior signal.

Regardless of why or how it happens, it's clear that Philips acknowledges that pressed discs deliver better performance on the analogue output - sound better - than recordables. Even though other manufacturers may not be explicit about it, you can bet that they, too, cannot deliver the same performance from recordable and pressed discs. Does that mean that the digital signal is better and that you will get better response from SPDIF or from DAE? Probably not; the cause is still there - errors in the read signal. The effects should be the same in the sense that there will be uncorrected extraction errors. It seems likely that some drives will have fewer than others, just as some do DAE faster or with fewer audible errors than others.

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What's this DAE stuff, anyway?

There may be nothing about CD-Recordables more confusing than Digital Audio Extraction. So, let me try to explain what it's all about and why it is an issue. As usual, corrections are invited; I am not an expert in this field and can be accused of sharing my ignorance, not my knowledge.

In the beginning, the compact disc format was defined for digital audio - CDDA. The rules for CDDA are defined in a standard called The Red Book (not the Little Red Book - that's the one with Chairman Mao's wisdom). CDDA says that there's a small file (in the computer sense) on the disc which identifies the tracks that follow. Then there are the tracks with a precisely specified sequence of bits in which two channels of audio at 16 bits per channel and 44,100 samples per second are interleaved. Those tracks are not files - they are simply tracks with strings of bits. The only files on the disc are those little pointers which tell the laser where to go to get a track, how long it is, etc.; they could hold a bit more information, but since few CD players would use it, few publishers bother to put it in.

The difference between a track and a file is worth looking at. After all, a WAV file may be an interleaved pair of strings with the same properties as the track. But the WAV file contains information about its contents, for example, the fact that it's sampled at 44.1 KHz; it also has an associated CRC (cyclic redundancy check) which lets the retrieving software determine whether it has been read correctly. When stored on a CD-ROM, it has an extra layer of error correction; the track has a minimal level in the hardware that we'll discuss later. In short, the WAV file carries overhead, 'wasted' space, with information not in the CDDA track.

When a CD player recognizes an audio track, it routes the bit stream to its DAC - digital-to-analogue converter. There the minimal layer of error correction is applied to patch up some errors in a disc that's in good shape (it cannot do much more) and the analogue sound output is generated. Since an error is usually in a single sample and a sample lasts less than 25 microseconds, you're not supposed to notice it. However, we would like to capture that digital data stream to our system in order to record it onto a CD-R and perhaps even to edit it. That means we wish to take raw data extracted from the audio track and convert them into a file that can be stored, modified and written with a computer. To do that, the reader must feed the digital data to an output that the computer can read. If the drive will provide that information, it is giving you Digital Audio Extraction, DAE. Not all CD-ROM readers do that, so some simply cannot provide the signal that's needed. You can run any software you wish, if it won't provide the output, the output won't be there.

In some cases, the firmware of the reader can be changed to provide DAE; in others, it's a hardware problem - period. In addition, something must tell the drive that the computer wants the DAE output - that the signal should be diverted from the DAC to the digital output. It can also tell the reader how fast to try to read the CDDA stream. Another critical need when the computer is trying to convert the stream of bits into a file is that they come through on time and in sequence. Again, if there's a bit of inconsistency in the audio stream, we probably won't hear it; but the computer is not as forgiving as the human ear and it wants each sample to be meaningful, not just 90% or 99% or even 99.9%. So where a sample or two can be dropped every so often while listening to a CD, none can be lost if the data are to go into a file.

Thanks to all the error correction on digital data, a CD-ROM reader may run at 4 or 8 or 20 times the speed that a CDDA is supposed to play. But without that correction, the audio stream may not be able to run at full speed. In fact, on some supposedly high-speed CD-ROM drives, CDDA may not even extract at 1x - 150 KB/sec. In other cases, there are so many errors that the resulting file is unacceptable. Again, the problem is not the software but the reader's hardware and/or firmware. All that the software has done so far is to command that particular reader to read CDDA as digital data to the appropriate output port, receive the data stream, and slow down the reader if the data are not usable to build a file.

Finally, the software comes into play to do a bit more. It takes the received data stream of a track, converts it to a WAV file and writes it to the hard drive if that is being used as an intermediate. By writing to the HD, the DAE is allowed to be slower than would be needed to write directly to the CD-R. If you do not go to the HD, then noise or something else may slow the reader enough to underrun the buffer on the writer (it is not getting data fast enough to keep writing) and your CD-R is another coaster. Writing the data to the HD buffers the information so that varying read speed is acceptable. In addition, you can listen to the WAV file that the software records to confirm that it's good enough to write to your valuable blank. Of course, if you are sure that the reader and the CD-ROM are good, or if you are in more of a hurry to get a copy than you are in need of a good one, you are free to burn 'on the fly' - directly from the reader to the writer.

Most readers do not use even the little error correction available when performing DAE. Only the Plextor family consistently corrects the data stream on the way to the digital port. And few drives but the Plextors extract CDDA as quickly as they do digital data. Those using Plextors for DAE are not praising them because Plextor is paying them; they are simply sharing with you their best advice on saving money and time. You are free to ignore their (our) recommendations, but don't expect a whole lot of sympathy when you do. And I am sure that they/we will be happy to let you know when another vendor delivers quality signals from a quality product. Until then, we will have to restrain ourselves from saying: 'I told you so' when you find that you spent more for your 24x EIDE than you would have four a 4+ and cannot get decent DAE even at 1x.

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Counting on Errors

A fundamental difference between storage on CD-R and on a hard drive is that the CD-R or CD-ROM has a much higher error rate than we are accustomed to. Without substantial error correction, CD-R would either be much less attractive - slower and offering less storage - or not usable at all. There is a low-level of ECC (Error Correction Code) built into CD recording which is below the horizon of any test equipment and which we will ignore for that reason.

BLER - BLock Error Rate - is specified for CD recording. Essentially, it is the probability that a bit which is to be written to the disc is read back incorrectly. If you send a master in to be pressed, the BLER will be determined; if it is too high, you will be asked for a replacement master to ensure that the master made from your disc is accurate. About 13% of the space on a data disc is consumed by block-level error correction bits. Because both video and audio playback can tolerate an occasional glitch which would be unacceptable in a program, block-level is skipped for CD-DA and VCD. Those formats then get about a 13% boost in storage space.

It is possible to read and write raw data to a CD-R - data in which the block-level bits are seen separately. In normal operation, the hardware processes those bits with the 2K data block to deliver only corrected information, but some readers will deal with raw bytes on command. That capability has been exploited for some time in copy protection, where a block is deliberately made bad by altering the block-level correction bits. Some consumer recorders and readers allow you to do the same thing. That can be exploited to circumvent that form of copy protection or to create your own.

In normal copying operations, each block is corrected in the reader and fresh correction bits are generated in the writer. When you create a disc image, the bits are generated in your software; that's why an image of 650 MB of data occupies 750 MB. (It is also why you cannot simply copy an image to a disc and have it run; in that case, another set of ECC bits would be created.) In raw copying, the disc is read as though Form 2 and error handling is left to the software. Any reader which can do DAE can supply raw data, but not all support the software commands that make it practical for data. Clearly, any writer will allow raw write since it will write CD-DA or an image, neither of which has block-level ECC added in the writer.

The question then arises: When should I use raw copy and when 'cooked' (error-corrected)? For normal operations, cooked is the answer. When you copy raw, any errors are propagated to the next generation - and any new ones are added. As a result, the chance of an undesired, uncorrectable error goes up. However, if you are trying to copy a disc protected through deliberate errors, raw mode is the only practical choice. (An expert - such as the one who created the protection in the first place - can hex-edit an image. That is a game the novice will lose.)

There are programs such as CD-R Diagnosis, Exact Audio Copy and CD Speed (all linked here) which will report error rates of CD-DA discs. In order to choose the best medium for your purposes, a starting point is to write CD-DA on each line of blanks at each speed and to see which gives the best results. That doesn't make much sense if you bought a special deal on ten CD-Rs, but it may be worthwhile when planning to buy a spindle of fifty or more. The test is simple: start with a clean audio CD, make copies at each speed you want to try, then run one of the programs on each test disc in each reader for your computer. A few hours of testing can save a lot of grief downstream.

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Writing Speed

One of the more common questions in CD-R is: What's the best writing speed? The answer is, again, the one that works best for you. This page is intended to provide insight into why that is so.

First, having the laser work 'faster' or 'harder' is not the issue. It is designed to work in a specific fashion and its capabilities for speed and power are within its designed use. The issue on the laser is akin to that of a CPU: if the computer is on, it is spending its cycles doing either useful work or nothing. The computer will not last longer by having it spend more time doing nothing. The laser will not work better by being used more gently - assuming that the drive is not overheating, etc. In what follows, I write of dye, but the same sort of thing is true for the alloy in an erasable (with extra complications due to heat transfer).

Think of the old Memorex "Is it live" commercial in which the glass was shattered by a sound. That 'demonstration' had the note matching the glass' resonant frequency. (At least in principle; it was an ad, after all, not reality.) If the note had been a little higher or a little lower, it would have had to be much louder to shatter the glass, but it could still have been done. The dye in a CD-R is akin to the glass. It is designed to work best with the write laser energy supplied in a particular way. If it is provided faster or slower, it will still do the job, but less efficiently. That lack of efficiency will show up as a dark area being less dark (because the energy was not used efficiently) or a light area being darker (because of scatter from an adjacent dark area). To a significant extent, that is corrected by power calibration, but a given type of disc will still write better at one speed than at any other in a given recorder. If the optimal speed is 4x, it will probably still be very good at 2x and 6x, but may not work as well at 1x and 8x.

An erasable disc works by heating a tiny area of an alloy until it melts, then allowing it to harden either as a crystalline or an amorphous material. Since the alloy conducts heat, the cycle of heating and cooling depends on how much energy is dumped into it how quickly and how the heat is conducted away. In order for the melting to be localized and for the cooling to be controlled, early erasable media could be written **only** at 2x. Recently, media have been developed which can be written at from 1x-4x and the range may be increased with time. Even so, there is a best writing speed for that heat/cool cycle in any given writer.

The limitations of write-once media are different so that media which work over speed ranges of 8-to-1 or even 12-to-1 are available. Even so, there is a best speed and the farther one operates away from that speed, the higher the error rate. At first thought, it would appear that the dye would react based on the total energy, not the speed with which it is applied, but that's not the way the process operates - at least, not completely. If you are familiar with Silly Putty, you know that you can apply a lot of force to it slowly and it will simply deform - ooze out of the way. Apply the same force quickly, perhaps by dropping it onto a hard surface, and it will bounce. But hit it with a hammer and it will shatter. The resilience of the chemical bonds is similar in some ways to that of the Silly Putty; the changes depend both on how much energy is applied and how quickly.

Unfortunately, home recorders do not let us get a handle on the BLER (bit-level error rate), so we cannot read the uncorrected errors. Therefore the only way we know how well the writer, speed and medium combine is by looking for cases when the errors are so many that they get through the ECC. Since we only see those errors when we read the disc, uncertainties due to the reader enter as well. Please see the pages on media in this primer for some illustrations (of a sort). In summary, some readers are better tuned to a darker recording and some to a lighter one, so different readers will have different error rates from a single disc.

This is *not* an exact science - it's closer to psychology than to rocketry, at least at this stage of its evolution.

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Burning Faster and Better

In ancient days, writing speed was not a problem. The first burners wrote at 1x and the media obliged. As higher speeds became available, it gradually became clear that the best blanks for writing at 1x were not necessarily the best for "high speeds" such as 2x, 4x, even (wow! Ferraris!!) 6x. In fact, each formulation is optimized for a specific speed and maintains quality for a range of write speeds above and below that. Higher is not better - at least, not in the sense that it will write better at low speed than a blank made for lower speed.

As we have moved to ever-faster drives and media, we have lost the ability to write at low speed. That's seldom a problem; the usual reason one wants to write slowly is to write better, for example so that the disc will play in a reluctant reader. However, there are times when one does want to write at 1x. For example, if you need to capture audio in real time. (If you want to capture as data, then you can use packet writing.) That simply cannot be done with most available blanks. Fortunately, there is a solution. Standalone recorders are designed for real-time audio writing, so the media destined for them (and bearing the Digital Audio logo) will record at 1x. Of course, you need a drive which will write at that speed, and they are also becoming less common as max speeds rise. And, of course, you will have to pay the royaty premium for the "Digital Audio" blanks.

It is worth noting that the highest constant write speed on the market now (September 2002) is 16x. All faster drives begin at about 16x and offer higher speeds only as they approach the end of the disc. So a "40x" blank must write well at speeds from 16x to 40x, which imposes quite a demand on the formulation. In my own tests, I've found that such a blank gives poor results if written at 8x or below - but YMMV, Your Mileage May Vary, which is the bottom line for all the questions about speed of recording media. "Can I use 8x blanks in my 24x writer?" Yes, if they work well in your drive. "Can I use 32x blanks in my 12x writer?" Yes, if they work well in your drive. "These 16x blanks work well in my faster drive, but those don't - why?" Because they don't write well at the higher speed.

The situation with erasable media is a little more complicated, but there is a saving grace, a logo. Rather, it is a line on the logo of your drive - on the right side, reading bottom to top. A drive designed for high-speed erasable media will read "High Speed". The reason that this is so important is that the alloy used to record information is different for High Speed writing (4x and above) from that used for low speeds (4x and below). If you use the wrong kind of blank for your drive even at 4x, you may not write at all; you may write but it won't read back; or you may write but it fades away in a short time. You are welcome to try, but be aware that the odds are very much against you.

From the Philips licensing site:

> **News June 30, 2002**
> Orange book Part III CD-RW Volume 3, Ultra Speed tentative version 0.9, dated: June 2002.
>
> Released for distribution: tentative version of Part III CD-RW Volume 3, Ultra Speed. This book describing CD-RW discs with recording speeds in the range 8x up to 24x or 32x nominal CD speed.

Which, being interpreted, means that there will be a new class of erasable medium which cannot be written at a speed lower than 8x and which will demand yet another burn strategy from the drive. Note that where the original (Part I) media and High Speed (Part II) overlap only at 4x, High Speed and Ultra Speed (Part III) will overlap at several speeds, increasing confusion as well as efficiency.

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Reading Errors

We like to think of the computer reading and writing information perfectly. In fact, we seldom even think about that at all because perfect operation is so common. Unfortunately, perfection is not achievable by man. In Islam, that reality is recognized by requiring that a flaw be woven into each 'Persian' rug. In computers, real hardware provides all the errors we need.

According to the specification, CD-R errors start out as being not more than one in a million. Sounds good, right? 99.9999% accuracy should satisfy even the most critical person - but it won't do for computers. There may be 8*650*1024*1024 bits on a CD-ROM. If so, 5,000 of them may be faulty and reading that disc will be a **major** problem. So almost 15% of the space on the disc is 'wasted' in coding which helps automatic error correction - ECC or Error Correction Code. With ECC, the specified error level is cut by a factor of 1,000 so that there would be only five bits wrong on a disc. Even those may be transient so that when an uncorrectable error is found the sector is reread in the hope that good information can be retrieved. In addition, most discs will exceed the specification significantly. Even so, if rereading is necessary the data flow is reduced substantially. The read mechanism must stop its rapid progress, back up and start the sector over.

That saving ECC layer is not applied to audio. If it were, the longest playing time on a CD-DA would be about 64 minutes instead of 74. Similarly, on a VCD there's no ECC on the video files. The idea is that the extra playing time costs only slight errors on playback and that you won't notice the ones that sneak through any error correction applied on the analogue side. For video, the fault is usually a momentary spot in the picture and no correction is used. For audio, the player has some limited ECC of its own, but if it is used there can be a loss of brilliance in the sound.

Another key factor in the quality of information read from a CD-ROM or CD-R is the quality of reading. Some errors derive from the way the track is formed on the disc and are related to the term 'jitter'. Even more significant is that, in general. the faster the data fly past the pickup, the greater the chance that a bit will be misinterpreted. With a pressed disc and ECC, that is not significant. Listening to a CD-DA or watching a VCD occurs at 1x regardless of the drive, so again speed errors don't matter. However, when you extract digital data through DAE or in raw form from a VCD, the story becomes less happy. All other terms being equal, the faster you run DAE, the greater the number of ticks and pops - bit errors - you will encounter.

There is also a quality issue here - and in this, I am providing personal opinion, not objective data. With the increasing pressure from the marketplace for faster and faster drives, other things are being sacrificed. The general public neither knows nor cares about DAE, so the ability to get a good signal without ECC is not a selling point on CD-ROM readers. Therefore the manufacturer will work to find a way to claim 24x for a poorly made drive which might work well if designed for, say, 12x and provide competent DAE at 1x or 2x. In practice, the 24x will be slowed by the need to reread even data and may deliver very little more in effective speed than a 12x, while being unable to provide satisfactory DAE even at 1x. Even a pressed CD-DA may sound dull on that drive, though typical computer speakers are unlikely to show that since they, too, seem aimed at bass boom instead of clean high-end response. And as has been reported elsewhere, running a disc at high speed increases vibration and mechanical noise.

Finally, a CD-R is not a pressed disc and it does not perform as well. In particular, a pressed disc has great contrast between its strongest reflection and its maximum scattering of the reader's light. A CD-R or CD-RW has a much lower maximum signal and a much higher minimum signal for the reading diode. As a result, the chances of reading errors from a CD-R or CD-RW are higher than for a pressed disc and a copy of a CD-DA copy (especially audio) is likely to sound noticeably worse than the original. Of course, the better the hardware, firmware and software are for the job, the better the results are likely to be. But there is no free lunch, there is no guarantee of perfect writing or reading, and if you do not take that into account as you choose your reader and test your CD-Rs, you may regret it.

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Isolating Errors

When a burn goes bad, especially when it fails repeatedly, the question arises: is it hardware, firmware, software, operating system, configuration or medium? Or is it something else?

That question cannot be answered simply and often requires extended analysis. Unfortunately, that analysis is very difficult by remote control - if your hands are not on the system, the job reduces to judging a beauty contest blindfolded. (Come to think of it ... no, you know what I mean.)

Using an erasable

Assuming that your problem is with mastering and your drive will write erasable discs, get a few of a good brand. Burn something to each disc to be sure that it works well in your system, then do a full erase and file the discs away.

When you have a problem burn, pull out one of the erasables and repeat the burn there. (You'll erase it later, so nothing will be lost except some time.) If the problem does not appear on those discs which you know are good, it's almost certainly the medium or the speed. If the problem occurs with a write-once at the speed you used for the erasable - it's your medium.

Yes, that test is too easy, but it works. Why not use another write-once blank and forget the erasable? Because it wastes a disc (no big deal at current prices) and because the other line may have other problems. This way, you know the disc is good.

Using CD-R Diagnostic

When you analyze a disc with CD-R Diagnostic at its most detailed level (Complete Scan), it comes as close to measuring BLER (Block Level Error Rate) as your hardware allows. In many cases, it actually gets down to that point. It reports the total errors it found and those which are not corrected. That is a very powerful set of data. The total error count is a measure of the quality of the burn. It takes a pretty poor burn or a physically damaged disc to get an uncorrected data error, but the total shows you how hard your drive has to work to get good results. Note that comparing bytes does not tell you how much error correction was done. As a result, it doesn't let you know how close you are to problems.

Try using different media and different speeds to see how error rates vary. You probably have two readers since a writer is also a reader. Try the same disc in both to see how dependent the writer/speed/medium combination is on the reader you use. When you try a new medium, don't just assume that if it works, it's good or even that if the files match with WINDIFF or another program you can count on the disc. Get below the level of corrected errors to see the best way to use that line of blanks.

CD Speed and Exact Audio Copy

These two programs work somewhat differently and report differently in extracting audio from your drives. Like CD-R Diagnostic, they provide insight into how well your readers work on any particular writer/speed/medium combination. Running either program, you will quickly discover that the quality of

DAE can vary a great deal with the nature of the original disc. Very few readers will deliver the same results on a CD-R that they do on a pressed disc. When you change any of the parameters of your CD-R burn, the performance of your reader(s) is likely to change as well.

Before the problems arise

Don't wait until a critical operation fails to find out that you have a problem. Get what you need to do the analysis when everything is working right. Check out the erasables and learn the software you will need. When the crisis comes, you will be ready to deal with it. The same idea leads to another conclusion: don't wait until you run out of blanks to pick up more. Make sure you have enough on hand for any anticipated project when you order or buy your next batch. Otherwise, when you must get XYZ gold/green 80's for the job, they will be unavailable - and you'll be stuck. That's not the time to research other lines to see what you can substitute.

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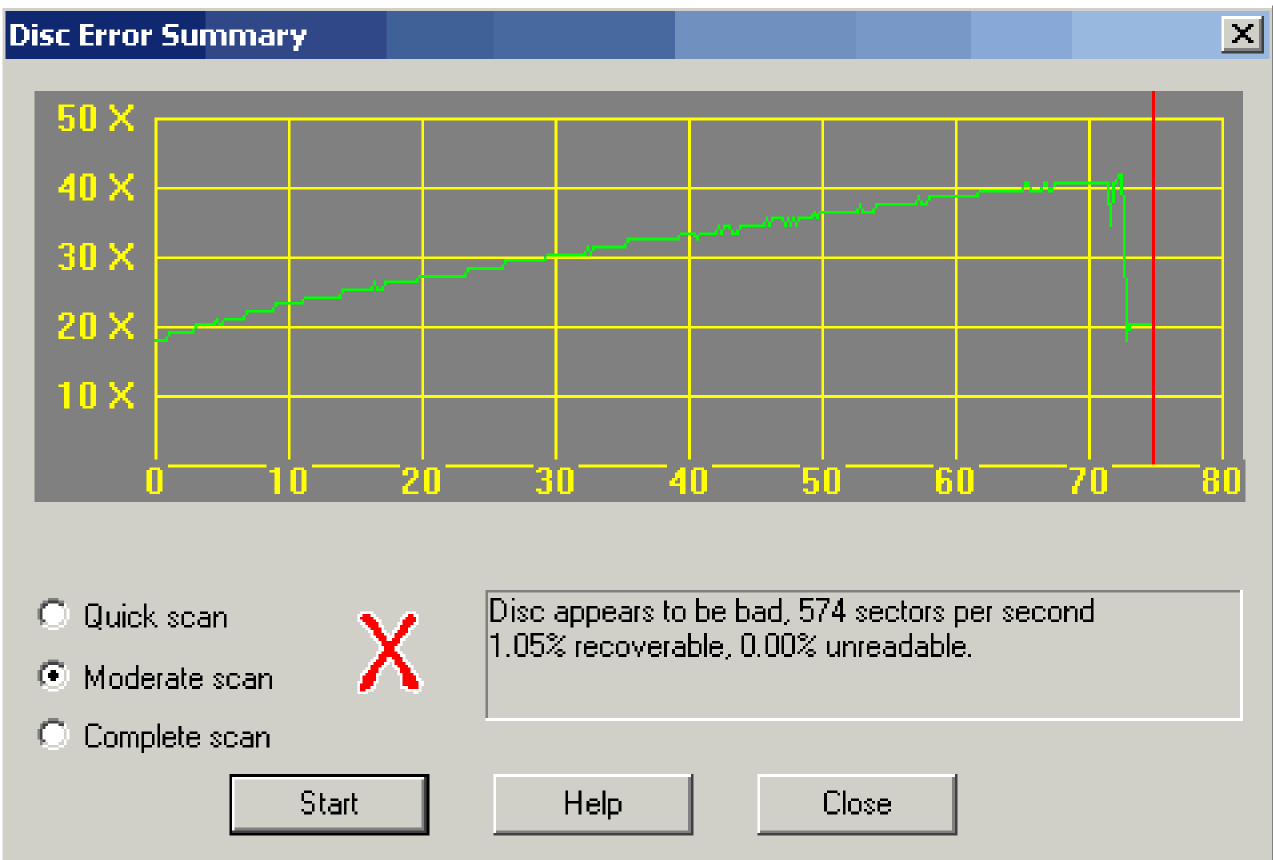
Interpreting Tests

Before beginning, I will admit that I have cheated a little. First, I used a disc with properties I know from previous samples. It's a "BrandX" 700-MB which writes well at 12x and 8x to about 650 MB, then picks up soft errors. The point at which errors appear varies from one disc to another and there are occasional "hard" errors which show up in the first blocks, but as you'll see they're all invisible to the simple "go/nogo" tests most people use. The second way I cheated is to use the big brother of CD-R Diagnostic, CD-R Inspector. I chose that because it provides a graphic output which is easier to see and use than Diagnostic, but everything you see below can be done with Diagnostic if you watch what's going on as you test. The disc had about 658 MB of data and it reads just fine in all my drives - a little slow in some, but without serious complaint.

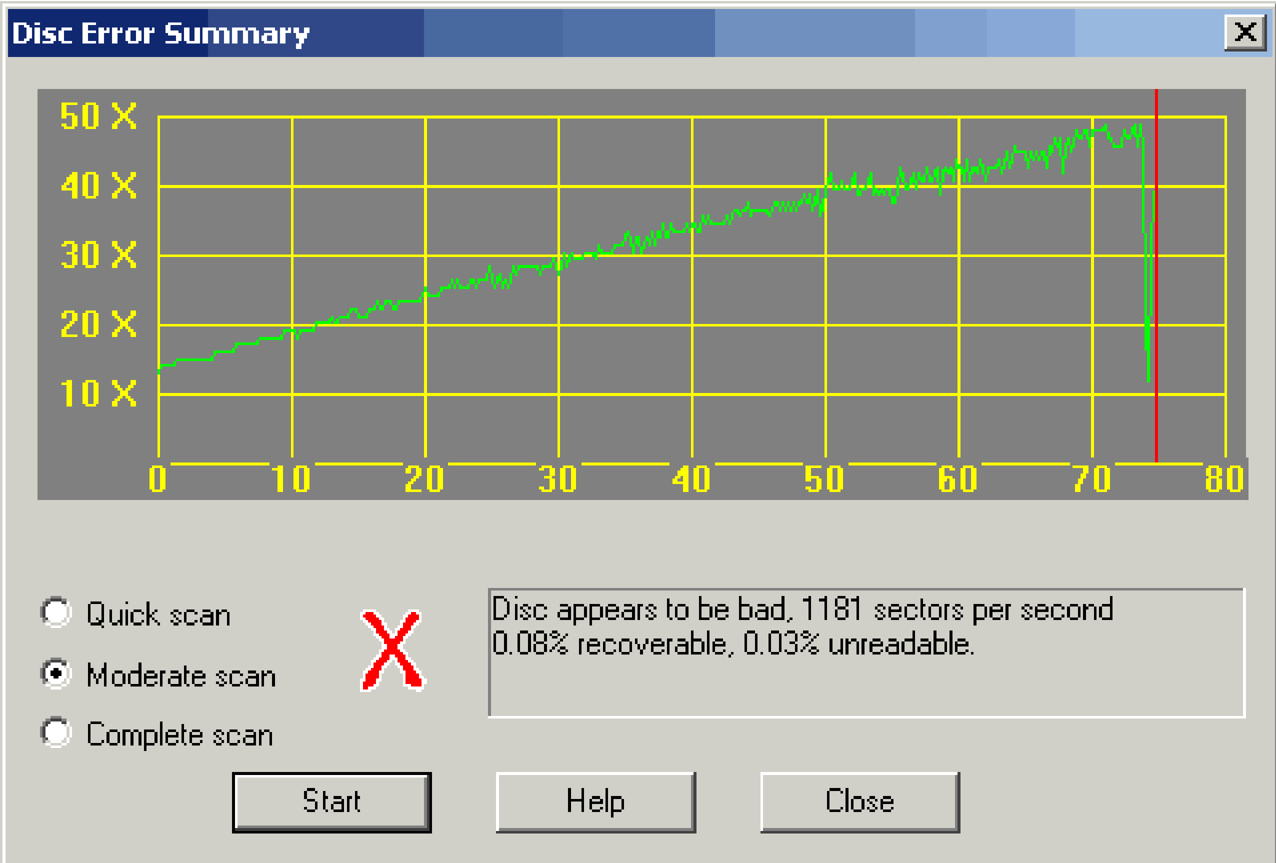
Plextor 40Max



Let's begin at the end: 0.00% unreadable. That's gratifying. There are no fatal errors; all that were detected were corrected by the error-correction code. The bad news came just before that. 1.05% recoverable errors means that the ECC was needed on 1% of the sectors read. We got through - but would we have been so lucky on another reader?

There's more information here. When the soft errors show up, the drive slows down. Those flaky blocks are reread to verify the ECC. In fact, the drive has a maximum speed a bit over 40x, but that's lost on this disc because of rereading. Incidentally, the test was repeated after the others were run and the results were identical.

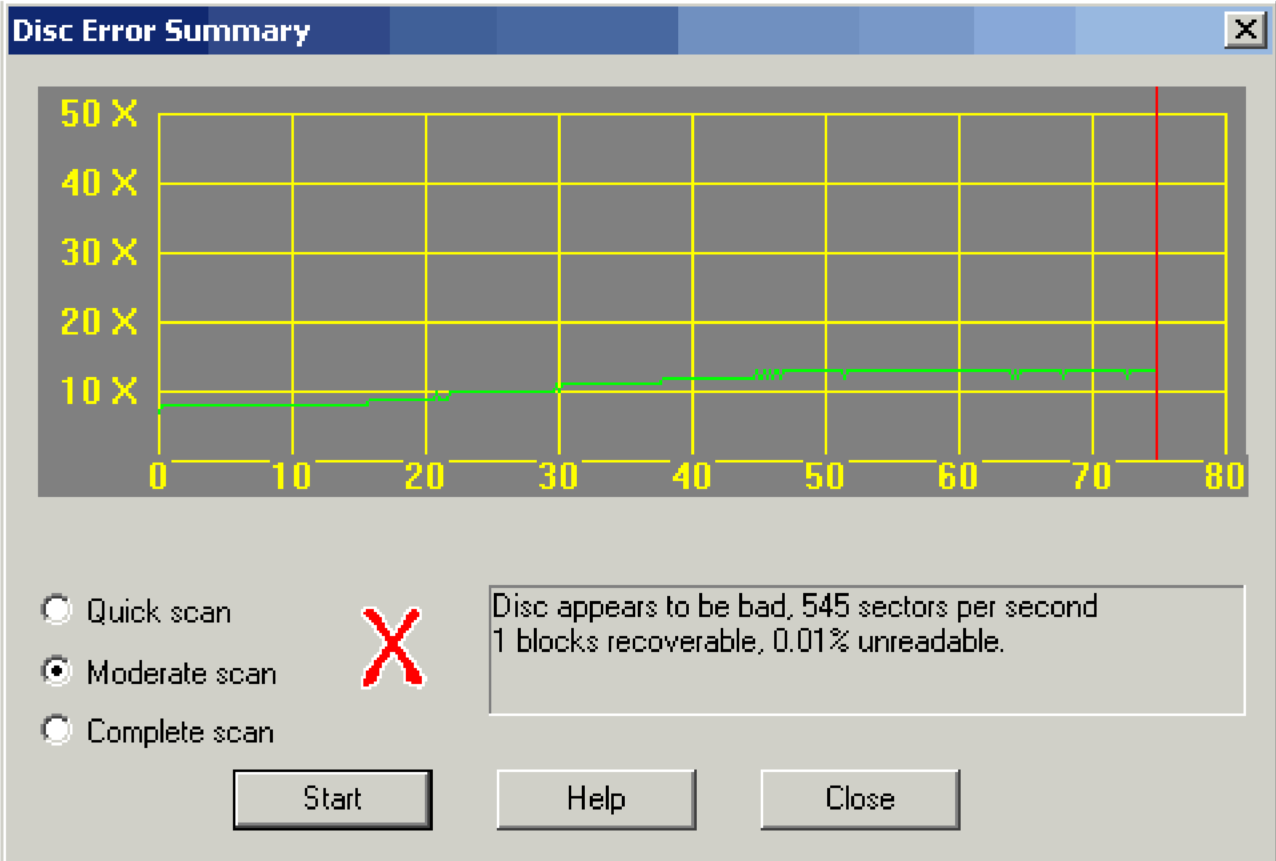
Plextor 12/10/32



Now we're getting 0.03% unreadable - errors which are not corrected. In fact, those occurred in reading the TOC and turned out not to affect the ability to recover the files. How do I know? I checked the data against the source files with WINDIFF (free from Microsoft). WINDIFF found **no** differences at the byte level. The errors were there, but it was possible to get past them - in this reader. There were fewer recoverable errors with this reader on the same disc used in the 40Max. Which, in my interpretation, means that this reader has slightly different sensitivity in reading a burned disc. As it happens, it's better tuned to the particular way the disc was written.

Note that this drive, which supposedly has maximum read speed of 32x, actually reaches well over 40x before the soft errors slow it down. Overall, it's twice as fast as the 40x. It starts at a lower speed but ramps up more quickly and doesn't hit those soft errors (which make it slow down) until later in the burn.

Plextor 412



With this drive, we get the best results of all - except for the "unreadable" (i.e., uncorrectable) errors. Again, they did not interfere with WINDIFF ultimately recovering all the bytes correctly, but that was good luck. The errors are not really unrecoverable, but too difficult to read reliably for CD-R Inspector to regard them as valid. Again, the "unrecoverable" errors were in the first blocks, which probably explains the slow start.

Conclusion

There should be no surprise here. This disc is not well matched to the writer; in fact, it is probably not well matched to any of my writers from the tests I've run on them. For critical use, it's a "bad" line of blanks. However, simplistic tests - checking that the files are readable - would indicate no errors at all. If it had been recorded with audio instead of data, it would sound fine on any of the drives. However, the errors would be there and concealed by the electronics. On another reader - perhaps a car CD player - it might well fail in several ways. It might not track well; it might produce noise or sound dull; it might not progress correctly from track to track.

Does all that matter to you? Maybe not. If you know that the line works well when written in your drive and read in your players, you may not care. But the quality is missing and if you're relying on this disc to carry information to someone with a reader you don't know or to behave in someone else's CD player, you're running a major risk.

With the low price of quality discs today, I can't justify using these 700-MB blanks for anything that matters. I have others which cost about fifty cents each and check out free of all errors in all of my readers. They are well matched to my writers and at 14 MB per penny, they're less expensive than these "free" ones.

YMMV - Your Mileage May Vary.

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Keep It Clean

This note has nothing to do with X ratings. Put whatever information you wish onto your discs, but it won't get there unless the laser can see to write it.

Most of us have encountered a pressed disc - CD or CD-ROM - which would not play. On examination, it may disclose the reason: a gouge, a smear of grease, a blob of dirt or something else which keeps the laser from focussing on the pits. A simple rule: if the laser cannot see the information, it cannot read it. If it cannot read it, your stereo or your computer cannot make use of it.

The solution is usually simple enough: polish out the gouge or clean off the disc, then try again. Voila! It's fine.

Unfortunately, life is not so easy when you're writing instead of reading. If the laser encounters that blob or smear when writing the disc, the information is lost. The name for the result is: coaster. There are hundreds of millions of bytes on a CD-R. If all are good, it's a disc. If a few are bad, it may be a coaster.

If you're lucky, the coaster isn't all bad. Maybe just one faulty file, maybe a few. Or perhaps the glitch is in the TOC and nothing can be read - or it's detected in trying to work with a UDF disc and it can't be finalized. At worst, it becomes an unreadable mess and everything is lost.

That doesn't happen to me!

True - most of the time, it doesn't. You remove the shrinkwrap and take a dust-free blank from a jewel case. You burn it and - no problem. Or you take the blank from a spindle and drop the cover back on. After burning, if you get a speck of dirt, you wipe it off. So, no problem - right?

Maybe.

There's that disc you wrote with 200 MB and now you want a second session. Or the packet disc to which you add a few MB of downloads each week. Hey, it's been in the almost-closed jewel case over by the ash tray; what's the problem?

Oh.

Well, maybe you can keep it dust-free. In the real world, the best way to keep the disc free of dust and dirt is to clean it before **each** burn. Remember, you don't get to clean it after you find the problem, as you do when reading. Well, that's not true; you can clean the coaster so that it's bright and shiny in your mobile. You just don't get to clean it off and then use it as though nothing had happened - as you do when reading it.

What to do about it

First, let no coaster go undiagnosed. The first thing to do is to look at the writing surface under a strong light with magnification if needed. Look at the circle where the area you've written ends. Look closely for the bit of a hair that came at just the wrong spot. You may not find it - it could have fallen off or slipped to another spot on the disc. Or there may be another cause this time. But if you don't know what made **this** coaster, then whatever it was will be ready to create more for you.

Another move - highly recommended - is to look before you burn. Keep a can of 'compressed air' and a clean, lint-free cloth handy. Examine the writing side before you insert the disc to be sure there is nothing that can be blown away or wiped off. It makes sense to blow the surface clean before you look; it will get most of the schmutz (a term of art; see any good computer dictionary) so there will be less to see and less to miss. And even though the cloth was clean and lint-free, if you use it, examine and blow the disc afterward.

Note that these precautions are far more important when you are reusing a disc than when you are burning a new one. Even if dirt got under the shrinkwrap, all you lose is that blank. If this is a second session, you risk the first; if a UDF, you risk it all. In fact, I speculate that one reason UDF discs mysteriously go bad is that in one of the writes or one of the reads of the directory, a bit or two was lost. That's all it would take to make a directory unreadable and a data disc into a coaster.

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Tick - It's the TOC

The Table of Contents (TOC) on a CD-R is the repository of all the information required for your OS to understand the pattern of bytes on the disc. Essentially, it contains everything needed for your system to figure out what information is where and in what format, so that your request to receive information can be satisfied.

For example, on an audio disc the data are not stored in files, but in a continuous stream. The TOC informs the OS (or the player) that a specific block is the beginning of a track. When you play a track, a command is given to go to that block and to begin to retrieve the bit stream which follows. Note that the track itself - in the audio sense - need not begin where the TOC says it does, but that is irrelevant to the player. There are also subcodes which can be used to interpret how to backspace and so on - but they are beyond the present scope. (And if you want to read that as meaning that I don't understand them, I couldn't argue.)

When you go to write a Disc At Once (DAO), all the information needed for the job is available when you start. Mastering software assembles that information and decides what is to be in the TOC. When everything is ready, the laser is positioned and turned on and writing begins. The **first** thing written is the TOC which says: this is a closed disc of a single session and here is the information on what you will find where among the following bytes. The laser then proceeds to write those bytes in sequence and in accordance with the information saved to the TOC. When the last byte is written, the laser turns off and you have a good disc. If that burn is interrupted after the TOC is written but before the end, everything is accessible up to the failure. An audio disc which fails when track 5 is being written will be usable for tracks 1-4 and maybe for the written part of 5 - but what happens when the track runs out depends on the player.

When you write Track At Once (TAO), the procedure is quite different. The writer begins by inscribing a special area on the blank called the Program Memory Area with information needed to close the session later. Then it records track information and writes the track itself. When it's time to close the session, the writing laser turns off, the mechanism returns to the PMA and the information inscribed there is read back to close things up, record how many tracks there are in all and, in general, to complete the TOC. So if the burn fails before the PMA is read (or if the PMA cannot be read at all), the TOC is not complete and a reader cannot make sense out of it. However, not all is lost! Although the reader needs a complete TOC to do its job, a writer is prepared to make do with less and, in fact, has what it needs in the part of the TOC which is complete to retrieve the valid data.

Suppose that you have written your disc - and the software reports errors. If the error has to do with reading, then it is almost certainly the inability to read the PMA when it came time to close the session. The disc is trash, but you **can** retrieve the information from it in a writer. That information may not include what was on the last track, so if it was a data session you're in trouble. But if it was an audio session, you should be able to recover all the tracks but the last. Note that the particular error message you get is critical here. If it says buffer underrun, the data are not there so they can't be read and (in TAO) the TOC was not written, so you couldn't find them if they were. If it reports a communication error, it might well have occurred when seeking for the PMA; in that case, your writer may actually be able to read everything on a TAO disc. Finally, if a communication error came at the end of a DAO burn, it may mean only that the runout track was incomplete. Since most modern readers need very little runout, the disc may work perfectly for you although it is 'too long'.

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Backup

There are three distinct types of backup to CD-R:

- Copy selected files from a computer system to disc
- Duplicate a CD-DA or CD-ROM
- System backup for restoration if needed

Copy selected files

There's not much to say about backing up your current working files from your HDD to a CD-R. There are basically two approaches, used by different programs. CDRWin typifies one: replicate a folder on the CD-R with fully qualified paths to each file. The other approach, used by ECDC and others, is to organize the CD-R like a separate drive, with its own folders (invented by you or dragged from the source) and with files pulled from various places at your pleasure. You might replicate a folder if you want to remove it from the drive and be able to restore exactly as it had been. You might mix and match with ECDC in order to organize scattered files into a single project.

Duplicate a disc

Of course, there are the easy ones which simply copy with a mastering program. Slightly more difficult to handle are those which appear to be oversize because of a distorted TOC (see the page on Oversize discs); those can usually be duplicated through a disc image. But there is another whole world of 'protected' software which cannot be duplicated in a straightforward way. Unfortunately, I cannot help with that.

There are moral issues of piracy, right to maintain an archival copy, licensing for use relative to ownership, and so on. They are important to me and I don't know how I'd deal with them if I were able to cover this subject at all. But I do not play computer games and very rarely copy any disc except those I create, so I simply have nothing to share. Hunt around the newsgroups for the pirates' dens - look for alt.binaries and warez - if you wish to learn about this subject.

System backup

Again, I plead ignorance: I do not know enough about Mac OS or Linux to offer anything of value. So this deals only with backup of DOS/Windows - and even then, DOS and Win 3.x are simply assumed to go along when the backup is being made. For that, there are two different approaches to backup: file level and disc image.

File-level backup transcribes each file with its fully qualified name. It operates in a manner similar to XCOPY - and XCOPY can do it. So can PKZIP, which will also compress the files and reduce the number of entries needed for the final TOC. Where position of the file on the disc does not matter, that's all that you need. Unfortunately, a full system backup includes some files whose position **is** critical. The system files with which your computer boots and certain files used in copy protection are characteristic of position-sensitive information.

Drive imaging means compressing the information on a drive so as to preserve positioning as well as all data. It is also needed to capture certain files which are opened when you enter 32-bit Windows and are therefore inaccessible to ordinary programs.

There are two approaches to imaging a drive or a system: capturing directly to CD-R or capturing to a conventional drive (hard disc or removable) for mastering later to CD-R. Direct capture requires some form of packet writing. It is slow but convenient; it requires a writer which supports the type of packet writing the backup program uses. There are many programs which use one or both of those approaches, including Ghost from Symantec, Veritas' Backup Executive and PowerQuest's Drive Image. The most flexible program I have seen and the one I use routinely is TakeTwo, part of Adaptec's Easy CD Creator 4 and above. For that reason, I use it here as an example of the options and their uses. Other programs provide subsets of its features which may be sufficient for your needs and desirable for other reasons - such as being bundled with your drive or having a user interface which you find easier to navigate.

TakeTwo backs up from within Windows either directly to a supported CD writer or to any partition - even the one which is being backed up. Writing directly, it automatically spans discs and formats them if required during the backup. Writing to another device, it permits you to specify the size of each constituent file, so you may use it to write to Zip cartridges or to HDD files which will later be mastered to CD-R.

TakeTwo restores a drive from a cold boot, using a single floppy which it creates for you. While that disc works 'as is' on most systems, it may not on yours, so test it before relying on it. If you need a driver to access your storage medium it may not be supplied on the disc; then you will have to add it yourself. Since the drivers included handle all Adaptec SCSI interfaces and most ATAPI devices, the odds are that they will be sufficient. The program also supports simple retrieval of files and folders from within Windows, allowing you to recover them to any location you choose.

Again, the above is not intended to be an endorsement of any specific program. TakeTwo is my choice because of the way I have configured my system and the drives and devices I employ. Other people prefer other software for reasons which make sense to me. You may well be one of those "other people."

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Oversize Discs

The capacity of a 'normal' CD-R, like that of a normal CD or CD-ROM, is 650 MB of data or 74 minutes of audio. Sometimes, one runs across a source disc that seems to be larger or a CD-R that claims to have more recording capacity. Those phenomena may be real or illusory and they can be handled in various ways. This note is intended to provide guidance in copying the uncopy-able and similar issues. One suggestion I do make is: Don't break the law. Backing up a disc you own is apparently legal. Saving your own files onto CD-R is certainly OK. Otherwise, please be careful; I don't want to be an accessory to theft.

Estimating size

First, capacity of a disc is measured in megabytes - but how large is a megabyte? Is it a million bytes? a thousand kilobytes? or 2^20 bytes? A thousand kilobytes is 1,024,000 bytes or about 2.5% more than a million bytes; a true megabyte (1,048,576 bytes) is about 5% more than a million bytes. Since there is no enforcable standard for the word 'megabyte', manufacturers of CD-R's get away with claiming almost 5% more capacity than is 'really' there. It's an accounting trick that will not let you store one extra character on the disc.

There are CD-R's with more than 74 minutes' recording capacity. The maximum possible is a shade under 80 minutes. There are also 63-minute discs, but while they are said to be more reliable than 74's, they are again hard to find and no less expensive than the longer ones. Even the 80-mm blanks with about 15 minutes' capacity may reappear. (There are also recordable minidiscs, but this is complicated enough already!) The result is that under all reasonable circumstances, you will be recording on a 74-minute, 650-megabyte CD-R. If you need an 80-minute blank, you will need to hunt it down.

Where did the megabytes go?

A data CD-R gives the impression that it is written with a FAT and structure just like that of a hard drive, but it isn't. As a result, there is information stored on the CD-R that takes away capacity in hidden ways. The amount 'wasted' depends on the type of recording being made. More to the point, CD-R software does not usually estimate the capacity of the disc precisely. A similar phenomenon occurs with audio CD-R's. As a result, you may be 'cheated' out of some tens of megabytes. Even worse, you may not know about it until you have burned the disc - and find that it cannot be closed.

The size of the Table of Contents (TOC) which consumes CD-R capacity depends on parameters you set when recording. To minimize the wasted space, record DAO. If that doesn't solve the problem, try writing an image to your HD. That image is a byte-level preview of what will be written to the CD-R, so the software need not estimate whether or not it will fit but can actually count bytes and sectors to prove it. Another test (not a perfect one) is to do a test write. Most cases of trying to write more than the disc will hold will be caught in the process and all you will have wasted is the time for the test. You may even run a test on an ISO - just to be certain. As usual, different writing software has different ways to do these things, so check your manual.

When you are preparing to write a CD-R, your software may estimate that you do not have enough room. Some programs simply refuse to proceed. Others inform you and blithely try to do the impossible when you tell them to. If you are near capacity, write the image, then test writing it to the disc you want to use. If that works, cross your fingers over a rabbit's foot and burn your copy. And remember what happened to the rabbit.

Disc length and Overburning

Although standard discs are marked 650 MB and 74 minutes, in fact they vary significantly in actual length. The true size the manufacturer designed in - as blocks or another measure - can be found with appropriate software such as the Disc Information of Easy CD Creator 3.x and CD Information of ECDC 4.x.

Overburning refers to stealing some of the space beyond the manufacturer's intent to hold data. The leadout/runout track is standardized at about 13 MB, but not all readers need the full length. With some hardware and software, you may use that space for data or audio - but you should be aware that that may leave the disc unreadable in some drives. This procedure is risky because it leads to apparent success and works often, then can let you down when the disc is most critical to you. I suggest that you look into other choices - such as an 80-minute blank - before overburning even if your system has the capability. Still, if you are in a critical situation and *must* find an extra couple of megabytes, it may be worth trying.

The manufacturer specifies in the ATIP the number of blocks which the disc is prepared to hold. Given the parameters of the spiral, that should take the write laser to the specification limit. In fact, the spiral probably goes somewhat farther than that and you can probably get away with a shorter runout track than specified - so it is possible to overburn.

Overburning has nothing to do with SCSI or EIDE. As I understand the limitation, some drives use the ATIP information to refuse burns beyond the block count and others leave enforcement to the writing software. There is no command to "overburn".

The software commands the drive to write specific information to specific blocks of the disc. That is not on a block-by-block basis because of positioning, but in principle, the software says: put this there - and the hardware does it. There are several cases of interest for a standard (650-MB) blank.

1. The software says: write in a block within the ATIP count and the hardware does it
2. The software says: write in a block beyond the ATIP and the hardware refuses
3. The software sees that the write would be beyond the ATIP and does not command it
4. The software commands a write beyond the ATIP and the hardware tries to do it

Case 1 is not overburning at all - it is the normal condition. Case 2 means that the hardware precludes overburning Case 3 means that the software precludes overburning Case 4 means that overburning is attempted - leading to four additional cases:

- 4a) Everything goes fine, the burn completes and the disc is successful
- 4b) The burn goes beyond the available spiral and part of the write does not occur

- 4c) The carriage hits a stop and part of the write does not occur
- 4d) The burn runs out of spiral **and** hits a stop

4b-d may also be successful burns since most readers will be happy with less than a full runout track. Any of them is more likely to have created a coaster and, depending on the design of the drive, 4c and 4d may do physical damage.

There are two situations of interest to add to the above when the ATIP indicates a blank longer than 74 minutes. Obviously, no drive will accept an arbitrarily large block number - the maximum value will certainly correspond to a blank shorter than 7400 minutes. There are old drives which were designed with a 74-minute maximum; they will not burn 80-minute blanks at all and the software will not - or, at least, should not - allow you to write beyond that limit. A special case is one group of Sony designs used in some Sony and HP drives. They simply ignore commands beyond a certain point, corresponding to about 78:30 on an audio disc.

In all of this, you need to remember that the reader has only a very limited vocabulary when talking to the computer. It does not shake hands on each transaction or report regularly on the status of its operation. When it knows that something specific has failed, it says so; otherwise, it runs open-loop, trying to implement the commands it receives. It does not report the power calibration it achieved, only that it failed to find one. It does not report the level of its internal buffer, only the fact that it has emptied. And so on.

Oversize source

There are two distinct cases here: a source CD or CD-ROM which is too big to copy, and a set of files under your control which exceeds the capacity of the CD-R. In fact, there's a middle ground of considerable interest.

First, some CD-ROMs are effectively copy protected and cannot be copied at all. (More precisely, some can be copied but the copy won't run.) The mechanisms include physically altering the medium as well as creating software conditions that some or all CD-R software will not handle. If you wish to backup such a CD-ROM and if you have reason to believe that the protection is effected only in the data (not by the physical medium), try other writing software to see if it can do what your preferred program won't. That may cost you some coasters, but you must expect to pay a price for circumventing the vendor's efforts. (Incidentally, there may be information in a newsgroup or mailing list that will be of assistance.)

Next, there are tricks that may be played by the CD-ROM publisher with files and directories that make the amount stored appear to be larger than it is - sometimes by a factor of two or more. If you make an image of the source disc and find that it fits onto your CD-R, you're home free. Incidentally, those tricks may be used for purposes other than to inhibit copying, so paranoia may not be appropriate.

In the category of files under your control, the solution is obvious: Control the files. Save some for another disc. If you are archiving, consider zipping text, database and other low-density types. Resize images or use a bit more compression. For audio, drop a verse or a chorus or repitch the selection. 10 MB is about 1.5% of the capacity of a CD-R. If everything you did were 98.5% efficient, you wouldn't be likely to complain. So, don't do it here, either.

Finally, if you have a disc that is stubbornly just a bit too big to copy, don't waste your time trying to figure out how the publisher did it. Retrieve all the files to your HD and remove the read-only attribute on the data. Now you have control and can apply the same tricks you would if you had created the files in the beginning. Perhaps there's a directory full of information for a platform or OS you don't use; kill it. There may be 500 graphics files you don't care about; scan for any worth having and dump the rest. Use your imagination and your good judgement. (One useful trick if you have a Jaz drive or a blank HD partition: create your reduced disc on that drive and run it. If it works, burn it; if not, make the appropriate adjustments.)

A Note on Microsoft's Way

It should not be a surprise to you that Microsoft knows their operating systems - and how to break the rules that they impose.

Much of MS's software is cross-platform: it runs on different systems with only moderate changes depending on the host and its configuration. An easy way to develop that code is to have the common elements in one set of folders developed by one group and have the parts particular to a specific platform developed by a group of specialists in that platform. For ease of control, the platform developers are probably given read-only access to the common code in folders that appear to belong to them. In effect, the developer for a DEC system builds her own CD-ROM using the common code and her own interface to the Alpha. She can then create a CD-R for the Alpha and test it. However, before release the Alpha and Intel (I386) packages need to be combined onto a single CD-ROM for distribution.

It is easiest to keep all the references to common code in the platform-dependent parts unchanged. To accomplish that, MS can and apparently does fake the references in the TOC. That is, the common code appears to be in both the Alpha and the I386 folders. It is actually present only once, but the table which references it gives the appearance of providing two copies. In many cases, that results in a disc which seems to have much more than 650 MB on it. Note that this illusion is developed as a programming convenience, not to provide 'copy protection'. You can probably back up a MS disc which appears to be oversize either by dropping unneeded platforms from your copy or by making an image and burning from there.

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What the Manufacturers Say

The vendors of blank media do not care how good the product is; they only care about our willingness to buy it. If quality sells, they provide quality. If price sells, they provide price incentive. If it's packaging or reputation or buzz words or a tin whistle in every jewel case, they know it and exploit it. That behaviour is part of the free market and it is neither good nor bad - it is just true.

Kodak used to make CD media. In fact, their blanks were considered among the best available. They no longer produce media; their market shrank because of price and there are not enough customers for quality. One of Kodak's selling points was the greater life of their discs. In fact, they printed a graphic on their "Ultima" media showing that at 80 C and 85% r.h., they lasted twice as long as three competitors and six times as long as three others. That's about as good as it gets.

Unfortunately, it's not good enough.

Which are the six against which "Ultima" was compared? Are there others which are better than "Ultima" but were not reported? What's the relationship between life at 175 degrees F and at 75 degrees F? What happens at reasonable humidity? How usable is a disc which has passed its "data life"?

And if all the inferences they suggest are true, does it make any difference? Suppose that the poorest blanks would last untouched at room temperature for 200 years where Kodak's would be good for 1200 - would you care? In the real world, do discs usually go bad because they have been stored too long or because they were scratched, baked, soaked or otherwise mishandled?

I am not saying that the information or the discs would be bad, only that we cannot know from what the manufacturer says. Suppose that the vendor is less reputable than Kodak and claims: "Specially formulated for audio" or "Ultra-durable" or even "Lifetime guaranteed". None of those claims means anything. Neither does the name. "Super Premium Eternal Disc" may be inferior to another manufacturer's "Standard". We already know that most brands as sold are not made by the company whose name is on the package. That vendor buys them from a manufacturer and if another maker offers a disc for a tenth of a cent less, the vendor will switch in a minute. You, of course, will have no outward indication, no marking on the package or information on the disc. The last batch worked just great, but my drive must be broken since the new batch is making coasters.

Watch out for those "guarantees", too. If you prove to the vendor's satisfaction that the disc was faulty, he will replace the bad one with another of the same type. Right. You are going to negotiate with the vendor, then pay for packaging and postage to send in a forty-cent disc that didn't work to get one back that probably won't work either. (And don't forget to copy that sales slip from when you bought 'em.) Did you lose priceless data? Not warranted! Did you incur extra expense because the faulty disc was mailed to Basutoland? Not warranted! Any vendor can offer such a warranty at negligible risk - and many do.

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You are old, CD-R ...

I trust that it is not news to anyone that CDs of any flavor can be damaged. Scratches, chips and dirt on the bottom layer lead to misreading and in the worst cases failure. Total failure usually comes from the top side, though, where anything which gets through to the metal layer is likely to turn the CD into a small and leaky coaster. Whatever is put on the top of the disc has a chance of seeping through the protective layer (which may be only a thin wash of acrylic lacquer) to damage the metal and demolish the data.

Such disaster aside, pressed discs are pretty nearly invulnerable to degradation. Handled with reasonable care, they will outlast the users and probably the technology unless they were defective in manufacture. Erasables ought to be similar - but they're not. For whatever reasons (and I've found nothing but anecdotal documentation), they seem to have a tendency to grow forgetful over time. Without systematic assessment and tests against specifications, the only safe course is to reserve erasable media for testing and for short-term use. From here on, then, we'll talk about write-once media, a.k.a., CD-R.

A CD-R consists of several layers with different 'responsibilities'. We begin at the bottom with clear polycarbonate to provide spacing and refraction for the illumination. (Note that "clear" applies to the wavelength - color - of interest and not necessarily to the appearance to the human eye. Pigment can be in that layer to provide a colorful disc which is still essentially clear to the lasers used. In all of what follows, optical properties are those for the dye not the eye.) Next comes a layer with a photosensitive dye. Above that is a metal reflector and on top of that is an acrylic lacquer topped by any paint, printing or label which may be used. Of all of those, the one of interest for life of the disc is the layer with the dye.

There are two operation points of interest for the dye. At one intensity and wavelength, the transmissivity - transparency - of the dye can be read. At another point, it can be changed. That means that a write laser can hit a spot of dye at one wavelength and intensity to make it dark to a wavelength and intensity used by a read laser. The process is not reversible in the usual sense; you can't undo writing, just as you cannot unexpose film once light has struck it. In fact, there is a useful analogy with old photographic film, the sort which was sensitive only to blue light. Once it was exposed, it could be processed under another color - usually red - without damage. That's still true for monochrome photographic paper which is processed in a darkroom illuminated in colors to which it is insensitive. So you may think of the dye in a CD-R as sensitive only to one color but visible (readable) in another.

Staying with the analogy, we know from experience that over a long enough period, a photo will fade. Properly processed, stored and handled, that takes decades or centuries. The same is believed to be true for CD-R. Once written, the information will remain for decades when handled properly. However, mistreatment will damage any such medium. In the case of CD-R, that means exposure to intense light or to an environment which leaks corrosive material to the metal. It is not easy to see the damage done by ordinary light on some media, but if you have an old CD-R with an azo (blue) dye, you can try a simple test. Lay the disc in bright sunlight, blue (or green) side up. Block a portion of the disc with something opaque. Give it some hours of exposure, bring it into ordinary light and notice that the unblocked area has been bleached to a lighter shade. While the blueness itself does not indicate sensitivity, its fading means that the dye has degraded and the former ones and zeroes are no longer readily distinguished from one another.

In normal operation (not intense light), the time for a CD-R to degrade is supposed to be a century or more. That assessment comes from "accelerated life test" where unfavorable conditions for a short time are extrapolated to normal conditions for a longer time. No doubt, there is validity to those tests and manufacturers have no better way to determine how long information will last, but the multiplier from days of test to years of use is far from proved. Still, as long as we expect the disc to remember what was written for decades, that's probably good enough.

Photographic film has a second sort of lifetime as indicated by its expiration date. Over time and as a function of storage, an unexposed area will acquire some exposure, if only due to cosmic rays. The silver halide also changes sensitivity to exposure so the speed rating will vary. In all, after a while it becomes less able to record the exposure. The same sort of thing happens to the dye in a CD-R. After a few years on the shelf, the dye breaks down, gets 'tired', and is less able to record a clear signal when exposed to the write laser. That can be corrected to some extent by calibration at the start of writing, but gray is still gray and age will reduce the quality of a recording. (See the page on "It's not all Ones and Zeroes".)

These effects of aging are not simple go/no-go distinctions. For each type of aging, the difference is an increase in error rate, not complete inability to record anything or to playback anything. Audio becomes dull as error concealment kicks in; data reading becomes slower. Eventually, good information can no longer be recovered - a CRC fails or a track will not advance. Nothing can be done to stop or to reverse the ravages of time. Preventive measures are needed if your information is to last on CD-R.

Step one is to buy enough good media to use up in reasonable time. With the demand on media today, what you buy is likely to be no more than a few months old. My rule of thumb is to use blanks within three years of purchase, though usually I run out much sooner than that. I have been able to measure degradation in a very good line of media (Mitsui silver) over four years and reluctantly trashed my last hundred blanks when they exceeded my threshhold for quality of recording. I have some slow media (Kodak 4x) that are even older and still write acceptably; when they give up, I'll have no way to record for an old laptop and will probably have to retire it.

Step two is to copy an archived disc before it fails. This does not apply to ordinary home use, where the lifetime of a recorded disc will appear infinite to those with normal human life expectancy. However, if you have a vital record on CD-R, it is wise to make at least two copies on different media and to check them every few years. When one begins to show correctable errors, use the clean copy to make some fresh ones. That's overkill for most purposes, but you may have some cases where it's worth the effort just to be sure that that ambertype of your great-grandparents survives to be seen by your great-grandchildren.

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Audio Basics for CD-Recording

One of the functions many people seek with CD-R is creating audio CD's. Software for creating CD-ROM's supports that desire, but each product varies in the ways in which the job is done. For information on your software - **read the manual.** This note is intended to cover the basics of audio file formats and problems.

Jump to Recording with D/A/D conversion
Editing a WAV file
Recording on the fly

CD Audio and WAV files

A selection on an audio CD is very nearly in WAV format. It is a variant of a specific type (redbook) of WAV file: 44.1 KHz sampling, stereo, 16 bits depth. Unlike an ordinary data file on a CD-ROM, the sound file does not contain error correcting codes (ECC) within it to handle data lost in transfer. Instead, a layer of ECC is provided on the disc. One of the ways in which CD players vary in sound quality is that they are more or less effective in using ECC to repair errors in reading the audio.

NOTE that an audio player is required to read only the first closed audio session on a disc. To avoid problems of poor readability, mysterious noises and so on, the beginner should not try to leave the disc open when closing the first audio session. You may write the disc in DAO, write the whole session at once in TAO, or write repeatedly *leaving the session open* until the last track, when you should close the disc. When you understand CD Extra and are willing to experiment, multisession can be fun.

Getting a WAV file

There are two different ways to create a file on a CD-ROM: an audio CD track or a WAV file. Only the former will play in a CD player. However, CD-R software will convert a WAV file (CD Creator will take one at less than redbook standard) into the necessary format and will read the audio file from a CD into a redbook WAV file on your hard disc. In that process, your reader may run at anywhere from 1x to its maximum speed. The higher the speed of reading, the more chance that some information will be lost. Since there is no effective error correction, those faults will show up in the WAV file. Fortunately, that file is on your hard disc and you can listen to it. If it sounds good there, it should sound good when converted to the CD format and recorded. If the copy on your disc has clicks or other problems - don't give up.

The first step is to persuade your software to read the CD at a lower speed. First, you need a player which supports Digital Audio Extraction (DAE). Your CD-R certainly will do that; a CD-ROM reader may or may not. Most SCSI readers provide DAE; very few IDE readers do, and then only with the right software. If your reader does not support DAE, you can use D/A/D conversion or your CD-R. Let's assume we have DAE. Using whatever tools your software provides, cut the read speed down until you get a clean WAV file. That tells you how fast you can run with that CD. Now check with other CD's to find out whether your first one was unusually good (or bad). Ultimately, you will decide that you can use a particular speed reliably. Don't try to cheat on it: If your reader won't give you a good signal at 4x, no software or CD-R media or whatever will improve on that.

Note that you are now beginning to understand why some 8x CD-ROM readers are slower than some 4x. They may run at 8x under ideal conditions, but if they aren't able to retrieve information reliably, even error correction may not be enough to get a good file. So the system rereads that file until it comes out right. There's no standard around to say what 8x (or any other speed) means - except that under some circumstances as many as 8x150 KB/sec will come from the drive. Whoopee!

D/A/D

The information on a CD or CD-ROM is stored in digital format. To listen to that signal, it must be converted to analog (a.k.a. analogue to us old-timer purists). The conversion is done in the reader and uses the ECC of the disc to a greater or lesser extent. If you have put an appropriate jumper from your reader to your sound card (so you can listen to a CD while you 'work'), you can record from that with controls on your mixer. If not, any CD player can be connected to the Line In jack on your sound card - as can any other appropriate source of analog audio. The quality of the signal going into your sound card then depends on the quality of the CD reader/player you are using.

On the sound card, an analog signal is converted to digital - and with that comes a set of problems. Essentially, converting between analog and digital signals is a matter of approximation. D/A is hard enough, but A/D is tougher still. The result is that only very good and very costly equipment will do first-rate D/A/D. Is your present sound card good enough for you? No one can answer that but you. Would the BrandX SuperSound do enough better to be worth the cost? 'Better' depends in part on your taste, and 'enough' is meaningless to anyone but you. Perhaps someone on the mailing list or in a newsgroup can give you insight, but don't expect easy answers. There aren't any.

At least, if you do use A/D/A instead of DAE, you will use the CD's ECC. If a CD you want to use insists on crackling on DAE at 1x, you may have no other choice.

Editing a WAV file

One of the advantages of making a WAV file through DAE or D/A/D is that you can edit it. Tools for that purpose are included in the audio section of the links at this site. Those editors will let you modify the sound in many ways: denoising, adding effects, repitching, cloning, ...

There are some tricks to this operation. One is that some software figures that whatever's tucked onto the end of the file for its own purposes won't do any harm. As far as the computer is concerned, that's so. However, on a CD those bytes become a 'click', and for some strange reason most people don't like extra clicks and pops on their recordings. Here, the solution is easy: don't end your editing with such a program. If you want to use an editor which you know leaves the click behind, do it. Then open the file in another editor that you know doesn't make popcorn (such as GoldWave) and save it. The click will be left behind.

Recording on the fly

"On the fly" means writing the CD-R from the source (here, a CD reader) without going through the extra step of writing to the hard drive. Let's dispose of the obvious first (not that you don't already know it, but for the benefit of those who don't). You cannot read from the CD-R while you are writing to it; therefore, you need a separate CD reader to record on the fly. Recording on the fly requires that the data being read are digital, so your separate reader must support DAE. If you don't want to use a second, DAE-capable reader, you cannot record audio on the fly. Given current prices for a SCSI CD reader under $100, it doesn't take many coasters to pay for a second drive - and you have a SCSI adapter already for your CD-R, so you probably don't need to buy one of those.

When you go to record on the fly, your software assumes that you can run at full writing speed without a problem. So you're tempted to think that your CD-R that writes at 2x will work fine with a reader that runs at 2x or above. You may be disappointed. For audio, you should already have determined with the WAV tests above that your reader is only reliable at 1x - even though the box says 2x, 4x, or 45.7x. The same thing that keeps a WAV file from sounding good will guarantee ticks and pops when you record on the fly. Therefore, you must slow down on-the-fly recording to the highest speed at which your reader will work. Of course, if that speed is faster than your CD-R can write, you can't beat the CD-R hardware by getting a faster reader. There's still no free lunch.

All the other stuff

Recording a CD is much like recording a CD-ROM. Some combinations of media, hardware, firmware and software work better than others. If gold/gold media work better for you for CD-ROM, they will probably be better for CD, too. Just because your hardware vendor's bundled software has a good interface for CD-ROM does not mean that you will find it ideal for audio (or *vice versa*). There are at least three choices of CD-R software on each major platform and each does every part of the job differently from every other.

There is no 'best' hardware, software or medium. The mailing list and newsgroups will provide you with unauthoritative, inaccurate, contradictory, incomplete and irrelevant information. Still, it's better than buying and learning all those products.

At least I think it's better.

From someone who knows: Pauses in Audio

From: Bart Lynn - blynn@eng.jvcdiscusa.com

As an Engineer for a CD manufacturer, I feel that I can try to explain the differences in the pause times on CDs. Red Book (the Compact Disc Specification for Audio) states that the Pflag must be 2 ~ 3 seconds. Therefore, since Absolute time starts at 00:00:00, the start of track 1 can be from 00:02:00 to 00:03:00. Of course, there can be silence after that point, so there can be in essence a lot of pause.

Most PC/Mac software sets the start of track 1 at Atime 00:02:00, since Yellow Book (Compact Disc

Specification for normal CD-ROM discs) specifies that the pause be just 2 sec. At JVC, we start at 2 seconds Atime, then we offset the first track 1 second, prior to the start of the music (CD-ROMs start at exactly 00:02:00). Each additional track is offset 5 frames (30 SMTPE frames to 1 second). The end time of the last track is moved forward 1 second. The reason is that many old CD players (from like 1985, up to the triple beam ones) search for the start of the track by the Pflag, not the absolute time. The new players can be extremely accurate in searching, where the older ones cannot. As a manufacturer, we have to try and supoort all makes and models, so we have to provide a slight tolerance for them. Additionally, the record label/artist sometimes requests that we provide additional pauses, especially for classical music, or live recordings.

Bart Lynn
JVC Disc America

Extensive additional material is available at http://www.westnet.com/~gsmith/ - but let me caution the unwary that the subject is complex. Those pages may be difficult to digest, but can be worth the effort.

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Analogue Audio

Let's start with the basics. Sound is a pattern of pressure that we sense - usually thought of as sound waves in the air. The usual way to deal with sound waves in electronics is to create an electrical analogue by exposing the sound waves to a microphone. The signal from the microphone can be amplified and recorded - still in analogue form - on audio tape or on a vinyl disc. It can also pass through an Analogue-to-Digital Converter (ADC) to become a digital signal. One of the functions of a sound card is to provide an ADC to deliver a digital signal corresponding to an original pattern of pressure. Another function is to synthesize a digital signal from instructions in the form of a MIDI or similar file. On the other side, the sound card provides Digital-to-Analogue Conversion (DAC) which is then used to drive tape recorders, speakers or other analogue devices. The inputs used for the purpose may be WAV files, MIDI synthesis or other **digital** signals the card accepts. Finally, the sound card allows mixing of its various analogue signals on input and/or on output. So the card will allow you to mix the analogue signal provided from its CD input with a synthesized sound from a MIDI file to drive your speakers with the combination. And a "full-duplex:" card allows such an analogue signal to be digitized while being played.

There are two ways to get sound from your CD reader. First, there's a headphone output with a volume control. Run a cable from that output to line in on your sound card, and you're ready to go just as you would be if the source was a tape deck. Even better (especially on internal drives) is to connect a special, analogue cable from the reader's plug to one marked CD on your sound card. The sound is the same at the two outputs, but with the internal connection you don't have to remember to twiddle the headphone volume control and you don't have that cable hanging outside the case. Finally, most CD readers support Digital Audio Extraction - DAE - which gets a page of its own in this primer. Recording from the CD as analogue uses the DAC of the reader to generate the signal, then the ADC of the sound card to convert back to digital. Each of those processes is imperfect and can degrade the sound. However, if your DAE is not perfect, the analogue connection may sound better to you - so, use it! Only the purists will insist that you should put up with what you don't like because It's the Right Way. One more point: if you have two CD sources, such as a reader and a writer, do **not** try to connect them both to the same jack on your sound card. Either get a card with dual stereo inputs or run that cable from headphone out to line in. (Connecting them both to the same input **may** work or may appear to, but can have unfortunate consequences.)

Let's look more deeply into the question of recording from CD-DA. Since you are likely to have both options, should you use DAE or analogue recording? The answer already given is: use what works for you. But there is more to it than that. Assuming that you **do** have the choice (good DAE and an analogue connection), when should you use analogue? First, some recordings have an extra bit set for preemphasis. That is a shift in the frequency response away from flat. Under some circumstances, it can let the producer record a **LOUDER** signal. If it's set, then DAE from the disc will sound too bright and lacking in bass. If all you're going to do is write that extracted file back to a CD-R, you can live with preemphasis as long as your software allows you to set the bit when you record. (Adaptec's PC programs do not.) If you want to edit the WAV file, you will definitely want to correct the preemphasis first; for that, you will find it easier to record analogue instead of ripping the track with DAE.

Another factor is error correction, which in general is beyond the scope of this page. The important thing about it is that errors recorded onto a CD-R or read from a CD-DA track will get through DAE without correction. But when the reader sends the signal to one of its analogue outputs, it passes it through filtering circuits which clean up some of those errors. The more cleanup the circuits do, the more they alter the sound quality. One reason that a copy of a CD-DA track may differ from the original is that the filters have more to do (CD-R has more audio errors than a pressed disc) and therefore change the sound more. Should you use analogue or DAE on a CD-R? Whichever sounds better to you - but be aware that they will have some differences in sound.

There's a lot of good material at http://homepages.nildram.co.uk/~abcomp/lp-cdr.htm with details not covered in this low-level page; stop by for more when you're ready.

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Recording from an Analogue Source

Okay, folks - here we go on how to record your favorite LP's, cassettes, 45's, DAT's, 78's and so on to CD. These notes end with getting a clean WAV file. From there, you use advice elsewhere in this primer or wherever to make your CD-DA, MP2 or MP3, or???

Sources

Most analogue audio sources deliver about one volt output. One important exception is a turntable; most cartridges for vinyl or shellac put out less than a hundredth of that level. If your cartridge is crystal or ceramic (few are), you may be able to connect your turntable as though it were a tape deck. However, in general you need to **preamplify** the output of your cartridge in order to record it on your computer. (**NOTE:** the preamp also corrects the frequency response of a cartridge.) You can buy a separate preamplifier at Radio Shack or any other general-purpose electronics store or build one with a circuit from my Files page. If you can't find one for a turntable, one made for a microphone may do. Even better is to use a receiver or a high-fidelity preamplifier. They may show up at a pawn shop or a swap meet. If you have a choice on a stereo unit (receiver or preamp), get one with two sets of tape input/output connectors. The output to use is one pair of connectors marked to go to TAPE REC. Output from your sound card goes to the corresponding TAPE MONITOR inputs to the preamp. In my setup, I have two high-level sources (open-reel decks) connected to TUNER and AUXILIARY, a cassette deck on TAPE 2 (REC and MONITOR), the sound card LINE IN connected to TAPE1 RECORD, the sound OUTPUT connected to TAPE 1 MONITOR, and the amplified speakers connected to the preamp OUTPUT. I can record from either open-reel deck or the cassette or phono to the sound card or from phono, an open-reel deck or the computer to the cassette deck. Just one warning: watch out for feedback loops when you're using the cassette deck.

For some purposes, it's sufficient and more convenient to record the turntable output to tape, then to feed the tape signal into your sound card. There are some other sources to discuss: Digital Audio Tape (DAT), MiniDisc (MD) and turntable. DAT and MD provide analogue outputs and can be connected just as tape decks are. Some also provide digital output; those can be connected digitally if your sound card has SPDIF interface and if the signals are (or can be made) compatible. But that's 'way, 'way beyond the level of a primer (which translates into: Mike doesn't know about that stuff).

Getting ready

Now that we have some sound going into the sound card, we need to look at getting it recorded. The first step is telling the card what input to read and to set its level. Unfortunately, most people are stuck with the absurd Voyetra mixer that comes free with Windows. If you have a better one, use it. (If you're a programmer who wants to do a service for humanity, how about making a freeware replacement?) Start the mixer - usually with a right-click on the speaker icon in the tray; otherwise, it's Volume Control in Accessories. Now, go to the Options menu and select Preferences. Click on Record and make sure that all the inputs are checked before you click OK. Now you have sliders for each input available to you. Pick the input you want. (CD is for the analogue connection of your reader or writer; unless you want that, you should probably select Auxiliary - which is their substitute for LINE IN.) Now, set the slider near the top of its range. You have just told the sound card to record from the selected channel at about the right level. DO NOT close the mixer - you're going to need it again.

Now the sound card is ready to go - but something has to tell it what to do with the selected signal. The Windows applet called Sound Recorder will do for starters, but it records to RAM. When it runs out of RAM (which usually doesn't take long), it's done. So you will probably want another program - such as Adaptec's Spin Doctor, one of the WAV editors or CDWAV (see the URLs page). Each package works differently from the others, but all are similar. Select the Record function, set mono/stereo, bit depth (usually 8 or 16) and the sampling rate (options are usually spelled out). If you are going to make a CD-DA, it's best to capture directly to redbook format: stereo, 16 bits and 44.1 KHz. If you record with other settings, you must convert with some program, which is slow and inconvenient - and very slow if conversion is done well. Most programs default to redbook; Spin Doctor only works that way.

You're not yet ready to record, though. Your recorder s/w has three choices: it can use only memory (as the applet does), it can use a TEMP file (either in the Windows default directory or one you select in the program), or it can write directly to your output file. Check that program for the way it works. Now, you have to set the recording level. If you overrecord, the result is painful even if it only lasts for a short time. The analogue signal is fed to the ADC (Analogue to Digital Converter) on the sound card. The ADC can only provide its maximum signal - all 1's. The result is that any excess signal is clipped, hard and brutally. Don't do it! If you record at lower level, you can leave it there or you can use a WAV editor or Spin Doctor to correct the level. Before you start recording, put your recording s/w and the mixer in non-overlapping windows on your screen. Find a passage in your source which is as loud as it gets. Activate the indicator of your s/w - sometimes it can be done without starting to record; sometimes, you will have to start some form of recording (which you will later throw away). Adjust the level on the mixer so that the level indicator on your s/w is always below maximum. If it's only 80% or 90% of maximum, that will be fine; those correspond to two and one db loss, respectively, which is not significant (and which will still give you much more signal-to-noise ratio than your system needs.)

Recording and processing

Now you're ready to record. Hit the record button (specify your capture file if necessary), then start your source. I strongly recommend that if you want more than one selection from a side of a tape or an LP, you record the whole side at once. You can always split and edit the selections later with a WAV editor; for splitting a long file, CDWAV can't be beat. These operations use a lot of space on your hard drive and may take a lot of time. Most editors will require at least twice as much space as the file you're editing. If you've captured a 30-minute side, you will need a spare 700 MB or so to hold redbook-format WAV files for editing. As you will discover quickly, lots of RAM and a fast CPU will help a lot, too.

When the file needs to be cleaned, still more time is needed. Removing clicks and hiss can be handled more or less automatically by programs such as CoolEdit and DART Pro, but that work takes a lot of processing. Even light treatment can take longer than playing the file. Different programs and different settings take varying time and give varying results. I use many different programs for my sources, depending on the initial quality and the importance of the recording. For example, I like the way that DART Pro removes clicks, the way CoolEdit handles hiss and noise, and GoldWave supports manual editing. I have spent hours correcting a single, four-minute cut. (No, I'm not rational about that, either.)

Along the way, some programs may complain about the headers produced by others. For safety's sake, I strongly suggest that you have StripWave (see the URLs page) available.

I can't tell you how to process your files - that's up to you and your source material. Anything you do to the signal will degrade it; if what you do is more important than what you lose, you come out ahead. The least damage is done by manual editing, but that is excruciatingly slow and painful. (Literally painful; an hour or two of editing will teach you more than you want to know about tense arm muscles.) The tools available today can be used with care to produce minimum loss and satisfying results. Misused, they can turn a favorite recording into mush.

Spin Doctor

In many ways, the easiest program for analogue recording is Spin Doctor. Select the source, select the target, set the cleaning options, and let it go. Still, there are some things you need to take into account to get the best results.

First, all the analogue sources are the same, regardless of the different lines from which you select. You still have to specify the source with the mixer. The different options give you different icons on the screen and may let Adaptec (some day) tune the cleaning operations to the kind of source being used. Next, if you select any of the options - cleaning or equalizing volume - the program will record the signal to the HD, then process it, then produce the output WAV file. It is designed to be allowed to do its 'thing' without interruption; let it have its way. I strongly recommend that you do any processing in a separate operation. First, record the tracks to HD without processing. Then do some cleaning, balancing or whatever by running Spin Doctor from one HD file to another. Finally, burn the finished WAVs to CD-R. Spin Doctor permits you to go from analogue source directly to CD-R, but that simple step often fails. The problem is that any tiny speed error, any hitch in the process will create a coaster. That's because the source is (by definition) running at 1x - real time. The recorder needs a steady stream of data and has a limited buffer. So if there is any difference between the speeds, or if you use an erasable blank (which must be written at 2x), you will have a coaster. It may work for you; if you want to try it, feel free. But safety and flexibility (opportunity to split tracks, edit, whatever) suggest that you go through your HD. Remember, you have to cue perfectly, cannot correct a mistake and cannot adjust levels (or anything else) except where it will be heard forever after.

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It doesn't sound good!

Okay, now that you've burned a Compact Disc Digital Audio (CDDA) - why doesn't it sound good? We have to begin with how the information is recorded to understand how it can go wrong.

There is a directory of sorts on each CDDA which identifies and locates the individual tracks. A track is located by its starting block and its length. There are about 330,000 blocks of 2K each on a standard blank; each one represents somewhat more than 10 milliseconds of sound. If you start a CD without specifying a track, it begins to play at the first byte of the first block and keeps on playing through to the last. There is no information on the track about the track - for that reason, it is not a 'file'. It's just a sequence of bytes.

If you write a track to the disc that is not an integer number of blocks, there are bytes to be written which don't come from your source (WAV) file. Most modern WAV editors will fix that by making sure that the number of bytes is a multiple of the block size (2K). If yours does not, there will be a click at the track transition for the random bytes that fill the last block. Solution: break the tracks on block boundary using appropriate software. (CDWAV from Mike Looijmans is linked from this site. It will split a long track into short ones on block boundaries.)

If you write a disc using Track at Once (TAO), the laser is turned off between tracks. When it is turned on, it writes a gap of two seconds before the start of the next track - that is dictated by the standard but there is software which allows you to violate the standard. You can also avoid that gap by recording in DAO - Disc at Once - where the laser burns continuously through the full set of tracks. Not all CD-R's support DAO, some do not support it well, and some which do support it are not implemented for DAO by some software. In general, if you have DAO problems, check the software from Goldenhawk; it does whatever can be done along those lines on any hardware yet manufactured. Or if you are really hard up, check the DAO page in this primer.

That covers getting a WAV file onto the CD-R in good shape. How about creating the WAV file or copying directly (on the fly) from a source disc? If you are having problems copying on the fly, first extract the files to your hard drive as WAVs and check them there. If the files sound bad, the problem is in your reader, not in your writer. (If you have problems with the last tracks of a CD, don't judge by extracting only the first ones.) You should look at the extracted files in a WAV editor to see if there are sharp spikes which you might not hear easily - they are the clicks and pops. In that case, please turn the 'page' in this primer and go to Snap, Crackle and Pop. Then you can get into the **really** complicated parts by reading about the complexity of WAV Files.

Skips and repeats

The CD writer needs a continuous supply of data. If something interrupts that flow for a significant time, the buffers can empty and underrun. If the interruption is shorter, a buffer - particularly that in the reader - may not cause an immediate underrun but may supply either zeroes or a repeat of the last information. In that case, you get a silence (zeroes) or a repeat lasting a fraction of a second.

Of course, the right way to fix such a problem is to ensure that the buffers do not empty. If you are writing on the fly from a reader, check the lights for regular operation. If you see a significant inactivity, then a burst you may have spun down (typically, between tracks) and if spinup is not fast enough the flow is interrupted. Another cause is a slightly damaged source disc which must be reread on the fly. If the problem arises when writing from the HD (very rare, indeed), then something is interrupting HD access and you should check for the usual villains: FastFind, anti-virus monitoring or another concurrent program.

If the problem occurs when writing on the fly and you have no remedy for the cause, extract the files to the HD and burn from there.

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DAO - SAO - TAO

Most of us are familiar with audio CD's and the tracks of music which they contain. When mastering a CD, those tracks may either be laid down separately, with the laser turning off between each pair; or in a continuous flow. If the laser writes **Track at Once** (TAO), a gap of two seconds is introduced (set by the Redbook standard) to ensure proper synchronization. If the tracks are written continuously in **Disc at Once** (DAO), no gap is required. There are schemes for approximating DAO by adjusting the gap in spite of the standard; the results may or may not be satisfactory depending on the player used and there is always a small gap with that approach.

DAO also has a role in data recording: masters for mass production are required to be in that format. Jerry Hartke, President of Media Sciences, Inc. http://www.mscience.com/ has provided the following on why pressing plants require DAO masters. Note that going through the 8-mm intermediate adds to the cost of mastering and that it will also (slightly) change the size of the disc being pressed.

> Mastering facilities must have perfect source data or their laser beam recorder will abort and ruin an expensive glass master. Track-at-once recording leaves "link-blocks" at the end of lead-in and at the beginning of lead-out. These are read as defects, or errors, by the LBR. Disk-at-once recording has no link blocks. Many mastering houses have learned from a rather gruesome history, and transfer information from a CD-R to 8-mm tape using methods that remove problems such as link blocks. Mastering is then conducted from the perfect image on the 8-mm tape, not from the "bad" CD-R.

Not all CD-Recorders are capable of DAO and not all software supports even those that can do it. The best information on DAO recording is provided by Jeff Arnold at http://www.goldenhawk.com/ If you believe that you will want DAO either for mastering pressed discs or for making CD-DA's without gaps, check there **before** you pick your recorder.

SAO - Session at Once

Session at once is a relatively new capability used on some CD Extra discs. With SAO, an audio session is written without intertrack gaps, just as though it were DAO. The difference is that only the **session** is closed, so one or more additional sessions can be written. Since an audio player can only see the first session of a disc, it makes no sense to write audio after SAO (unless you want to play the disc only on your computer).

Not all software supports SAO; Easy CD Creator 4.0 and above does, but earlier versions did not. Similarly, not all writers support this mode. Many which handle DAO, such as the Ricoh 62xx, are not compatible with SAO. Of course, that may be changed with firmware and new drives are almost certain to support SAO.

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Snap, Crackle and Pop - noisy CD's

You have just 'backed up' your favorite CD to a CD-R. You go to play it and - it's full of noise. Snaps, pops and crackles all over the place. Must be bad software or a faulty blank, right?

Wrong. There's a chance that it comes from a dirty or noisy CD; if that's the case, clean it or change it. But the most probable cause is your hardware and its Digital Audio Extraction or DAE. There's a page on the subject of DAE here. This page is devoted to how to tell whether that's your problem and what to do if it is.

The telltale symptoms of faulty DAE are that the noise is in an extracted WAV file and that the amount of noise varies over the disc (usually worse as the track number goes up). There are three ways around the problem: read at alower speed; change the reader; or transfer through analogue. Note that a drive may extract digital audio at higher than rated speed, at rating, only at 1x or even at less than 1x, the speed at which it plays CDDA. And if your preferred reader does not do acceptable DAE (or doesn't do it at all), you should try your writer as a source.

Control of reader speed depends on the extraction software. Some programs, such as Plextor Manager, give you substantial control and let you select from 1x to the drive's maximum. Most do not and automatically select the highest possible speed. On many drives, that speed is too high for the sound to be free of noise. (Why is it that Plextor - all of whose readers except the 6x do DAE at maximum speed essentially without error - is the company that helps you use the lower speed you don't need on their drives. Unfortunately, the drives that need such a Manager can't be used with Plextor's and their manufacturers offer no equivalent.)

Replacing the reader is costly, but it is the best solution. No, you do not need to use a Plextor. There are many other good drives out there and you may be able to find one that costs less and is good enough for you. However, I have seen many posts that said: *I finally gave up and bought a Plextor; I should have done it months ago.* And in case you wondered: I get no kickback from any of the manufacturers I name. They've never offered, so I haven't even been tempted.

Finally, you can try recording a WAV with your sound card instead of DAE. Just make sure that you use the CD Player as the input by selecting it in the mixer and setting an appropriate level. (Alternative: run a cable from the player's headphone out to the sound card's line in.) If you have no appropriate s/w, you can try the Windows applet, but it will only record to memory so you may not get much music unless you have a lot of RAM on your system. Any of the WAV editors (links to several are on the URLs page) will do better for you. There are several reasons why you may be unhappy doing it this way. The most serious is that your are using digital-to-analogue conversion (DAC) in your reader and ADC (guess!) on your sound card. Each of those is imperfect and the artifacts that they create compound one another. A less important difficulty is that the sampling rate you get depends on your PC's clock, so the playing speed may be slightly higher or slightly lower than the original. However, because of the interaction of similar frequencies in non-linear processes (boy, he knows big words), resampling can produce artifacts such as subtle beats or recurrent noise. Still, it costs nothing to try this approach and if it works, don't fix it.

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WAV Files

Let me begin by assuring you that computers are simple. The people who set standards and write programs for them are not.

A WAV file consists of three elements: a header, audio data, and a footer. The header is mandatory and contains the specifications for the file - information on interpreting the audio data - and optional material including copyright. The audio data are - um - audio data in the format specified by the header. The footer is optional and, if present, contains other annotation. I like to call the combination of header and footer the 'envelope' of the data. Usually, the data in a WAV file take the form of PCM bit streams. A simple one would be 8-bit samples taken 11,025 times per second from a single (monaural) channel. Then within the envelope would be a RAW file - the sequence of those 8-bit bytes in order and ready to be fed to a sound card's Digital to Analogue Converter (DAC) to play on your speakers. There is a well-defined way to put the other formats into the RAW file, which then goes into the envelope containing the information about how to make sense of the bytes which follow. What gets written to a CD-R is very much like the RAW file, with one important modification: the order of bits in each byte is reversed. So your CD-R authoring program can take a 44.1-KHz, 16-bit, stereo WAV file (i.e., in redbook format) out of its envelope, switch the order of bits, and write it to your disc.

Other formats can be stored in a WAV file. Apart from changing the PCM parameters, you can put a compressed stream into the envelope. Whatever is in the WAV file, your CD-R program must convert it to redbook in order to write CD-DA (Compact Disc, Digital Audio); and if the disc is not in CD-DA, it won't play on an ordinary audio CD machine. In many cases, converting from another format to CD-DA will require substantial processing. As a result, you may not be able to keep up with the writing speed of your CD-R. Since the program does not know how fast your computer is or how much processing will be needed, ECDC (at least) always converts a non-redbook WAV to redbook in a temporary file before writing it to your disc. ECDC also doesn't want to run out of disc space during that conversion, so it converts one file at a time, writes it to the CD-R, then converts the next. Writing one track at a time, it obviously cannot write DAO.

Now we get to the messy part. Not all programs follow all the rules all the time. As a result, the envelope may not be quite what it should be to make a valid WAV file. When that difference confuses the next program reading the file, it may refuse to open the WAV file or it may need to be told the format of the audio data, or it may just interpret some of the envelope information as audio data. For example, the 16-bit version of DART Pro appears to convert a valid header with annotation to an invalid one and does not recognize footers at all. If you feed it a WAV file from a program like GoldWave, which creates an envelope with valid annotation in the header and footer, it produces an output file which is almost unreadable. Fortunately, GoldWave will open it - when you tell it what format it has. Unfortunately, the envelope information DART Pro did not respect are still present - as data within the audio file. Those can be heard as initial and final clicks and can be seen in the first and last milliseconds of the file. If you snip those data out of the file, you can now Save As WAV and get a proper file again. Another option is to run StripWave. That program will strip the footer (it is unnecessary) before you start the offending program. Run it after that program has mishandled the header and it will strip out the excess audio - the initial click. NOTE: DART Pro is not the only offender and the 32-bit version appears to leave annotation where it is.

Another problem program is Plextor Manager. It also fails to put the right information into the header so that data appear in the audio stream. Again, StripWave will fix it easily - but you may not need to do so. The effect of the faulty envelope varies depending on the next program to see it. Some authoring programs are able to strip the faulty data the same way that StripWave does, so the simple error will not show up on your disc. Or, if it does, it may be lost when it is read from the disc. So once you have a bad envelope, you may or may not get an initial click or a final click. And you may get it on DAE but not when you listen to the disc, or hear it when you play the disc but not see it on DAE. If you do have the faulty file and process it before writing it to CD-R, the processing (WAV editing) program may refuse to open the file, may embed the data in the audio stream so that the click is guaranteed to show up later, or may correct the problem for you.

The bottom line is that you either set up a procedure which you know works for your software and your needs, or you figure out for yourself when and how you strip the faults from the WAV files. Note that StripWave is shareware and links to it and to other interesting tools are in the URLs at this site.

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Block Boundaries

Now to zero crossings and splitting on block boundaries. Sit back - this is not a ten-word issue. And in all this, remember that what you are hearing is a bitstream, not distinct tracks. One more caveat: I know Sound Forge and many other WAV editors only by reputation. The ones I use regularly are GoldWave and CoolEdit Pro.

A track is a collection of sequential blocks of that bitstream and is designated in the TOC. Tracks must be split on block boundaries. Addressing in the TOC is in terms of blocks and you cannot split more finely than that. Each block on an audio CD is 1/75th second. For SMPTE, it's 1/30th, for other purposes, it's other sizes, but we're talking CD-DA, so it's 1/75th.

If the split occurs on a block boundary and if you burn DAO, then the sound is continuous across the split and there is no click or silence or other artifact - the bitstream is continuous and the sound is uninterrupted. If your split is not on the block boundary, then the block has to be filled with something.

By splitting at a zero crossing, the program presumably fills the rest of the block with zeroes for you. That's fine - if you want a silence which may be as long as (almost) 1/75 second. Sound Forge is right that you won't get a click, but you will get a momentary dropout, sort of an inverted click, if the zero crossing did not occur during an extended silence. The advantage of splitting at a zero crossing is not for writing to CD-R but for listening to the WAV. If you pick a high-amplitude signal to end a block (on the screen), then play it, you will hear a distinct noise at the end. The signal has dropped abruptly to zero. If you do the same thing at a zero crossing, you do not hear the click. Again, this is for listening to the WAV directly, not for recording in CD-DA where the block must be filled.

If you use a program which does not split on a block boundary, *something* must be used for the missing bytes and now there is no supply of zeroes for the job. I am told (I haven't verified it) that the program may pick up whatever debris is around from the stream of data from your source. It might even be the next few milliseconds of the audio - but in that case, they will be repeated. At best, it might fill with zeroes (see the issue above), but regardless you will not have continuous sound across the split. So the way to get a clean split for continuous play is to split the track at the block boundary. CDWAV and GoldWave force you to do that. In allowing for alternate frame rates, CoolEdit gives you the option to vary it. My understanding is that Sound Forge provides the option as well. And zero crossing has nothing to do with block (frame) boundaries.

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Cleaning Audio

The following is representative of the way that I clean up audio source files. It is intended simply as a guideline for those new to the process; many other programs and approaches can be used and different sorts of faults on the original call for different tools and techniques. Programs referred to in the text are generally available from links here.

Capturing

If the source is monaural, begin by recording it monaurally. If it has limited frequency range, do not sample at too high a rate. Many of the steps which follow are disproportionately difficult in redbook format (44.1 KHz, stereo); if you can work at 22.05 KHz monaural, life will be much easier. I usually record with CDWAV (linked here). It permits me to capture as I wish and to split the tracks from a tape or LP while saving them. I also use CoolEdit for the purpose since I like its level indicator or GoldWave for quick manual editing. I rarely use Spin Doctor for poor sources because it permits recording only in redbook.

If my source does require full fidelity and stereo, then Spin Doctor lets me pre-clean the file during capture. That is usually good enough to eliminate the need for denoising and declicking the whole recording, but manual intervention is likely still to be necessary for an LP source. Because of the nature of the work I will be doing, automatic splitting is rarely useful. In addition, if a single source tape or LP has several tracks, it is usually easier and better to do the automated denoising and declicking before splitting the tracks. In that way, the general sound will not vary from one track to the next.

First pass - Outliers

The audio should be captured at a low enough level so that overload is not a threat. In general, if you are going to clean the source, it starts out poor enough so that capturing a few db low will not harm the result after normalization. If the source has a serious problem - such as a scratch - I like to remove the extreme spikes by hand before running anything else. Without question, GoldWave is the best way to manipulate the waveform by hand. Where CoolEdit requires moving each sample or very brutal treatment (snipping or zeroing), GoldWave allows you to redraw the waveform with the mouse. Another advantage of GoldWave (especially Versions 4 and above, in beta as I prepare this) is that it will open virtually any file and provide you with access to edit any header and footer which sneaks into the audio stream. Those are the usual sources for clicks at the beginning or end of a track and various programs will introduce or eliminate them. Note that even StripWave will not necessarily handle footers if they prove to be a problem. However, I use Strip Wave when one program's output will not immediately load into another - as when a CDWAV file is to be read by DART Pro.

Ticks and pops

Step two is to remove the clicks, ticks and pops of modest amplitude. Having tried several programs for the purpose, I have settled on DART Pro as the most effective and easiest to use. In particular, the Test option in DART Pro 32 is consistent and very informative. The similar capability in CoolEdit is available only in some of its restoration tools and is much more awkward to use. Do not overclean your track! In general, if you try to eliminate all the transient noise, you will distort the music. Any automated denoising should be adjusted to leave the music at nearly full quality even if that means some noise is left behind. In particular, count on removing some leftover ticks after a noisy track is passed through DART Pro. Again, GoldWave is the way to smooth out those residuals.

Hiss, fixed tones and equalization

My choice for these operations is CoolEdit. If there is a persistent tone in the track, spectrum analysis will identify it and a notch filter will cut it down to size. But before beginning any track-level operation, I like to normalize it - again, in CoolEdit. Many tracks are normalized to 100% so that the peak level is just 0 db - maximum signal. However, I usually normalize a highly compressed track to only 80-90% so that its average level balances well with a fully normalized track that has a wide dynamic range. Similarly, I cut the level for a track which is quiet by its nature; I don't want a serenade and a march to play back at the same level.

After reducing fixed tones - whines, hums and the like - I listen to the track for frequency balance and for hiss. In general, I am willing to put up with more hiss than others prefer, but if I must cut it I use previews in CoolEdit to be sure I don't take out too much sound in the process. Then I judge the frequency balance of the result and decide on any general curve I want to apply. Again, I tend to change the signal as little as possible and I use the very flexible options in CoolEdit for that job. (GoldWave is similarly powerful and flexible.)

Preparation for recording

CoolEdit offers excellent tools for resampling, mixing and splitting tracks and similar manipulations. In general, I finish off the track in that program and use the Edit menu option to change the file parameters. For example, I may produce a redbook WAV for CD-DA; a 22KHz, stereo, 16-bit track for MP3; and a sample at 11 KHz, monaural and 8 bits for posting at my WWW site. GoldWave will reformat for me, but not as well and without all the flexibility of CoolEdit.

This process sounds tedious and for best results from poor sources, it is. However, it can also be quite rewarding. It may take an hour or more to extract a listenable result from a well-worn disc recorded in 1903, but it may then become a valuable resource not only for my pleasure but also for scholars and music lovers for generations to come.

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Sound Balancing

Your perception of the loudness of an audio track depends on several factors. One is the absolute loudness, another is the dynamic range, a third is the kind of material.

The maximum signal you can record on a digital system is fixed by the number of bits available. If an analogue system is overdriven, the result is a gradual increase in distortion; digitally, saturation is a wall and even a slight step beyond it is highly disturbing. (There are, of course, some kinds of 'music' which are designed to be distorted; I have nothing to contribute for them.) So the maximum level you want to set is something which does not go beyond maximum loudness.

The second factor is dynamic range - the range from the loudest to the quietest passage in the program. At a symphonic concert, that can be as high as about 100 db - for a very quiet audience and some very loud passages. CD recording at 16 bits offers 96 db range. A very good tape deck can deliver about 60 db. But in many environments, use of wide dynamic range is undesirable, so the actual dynamic range on a recording may be compressed to 40 db or less. Different recordings will vary in the amount of compression used - and the average sound level depends more on that than on the absolute maximum you have to keep to 100% (16 bits).

The third factor is the program content. I don't know about you, but I want a march to sound louder than a lullaby. So even after you set the maximum and mean levels by normalizing and compressing, you have to consider how loud you want the result to be.

All is not as bad as this sounds. In general, a given label will be pretty consistent across its recordings of a single group or even of a single kind of music. But as you try to mix a greater variety, you face the problem that the software doesn't know what compression makes sense (or how best to implement it) - and it certainly does not determine how loud **you** want a given track to seem on a given compilation. The automatic level setters do what they can, but they are basically limited to setting the maximum level. The rest must be done to your taste by you. A good WAV editor, such as CoolEdit Pro will let you shape the compression on a track-by-track basis as well as permitting you to adjust level and keep from hitting saturation. It will also denoise, alter channel and frequency balance, and do many wonders - with a lot of time and effort on your part. To avoid that, choose the tracks for your compilation with some care and take what you get with automatic balancing.

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Clicks - a Recap

This section is essentially redundant with information in three other parts of this primer: Digital Audio Extraction (DAE), Disc At Once (DAO), Snap, Crackle and Pop and It Doesn't Sound Good. The purpose is not to beat the message into you, but to indicate the **process** by which a problem is analyzed.

Clicks throughout the tracks

These noises usually arise on tracks extracted digitally (ripped) from a CD-DA. They come from faulty DAE or occasionally from a damaged source disc. While a better reader is the right answer, other choices include reading from your writer, slowing down DAE, and recording through an analogue connection. You can hear such clicks on a WAV file extracted to your hard drive. Note that the low signals generated by CD-R compared with pressed discs make some sources of clicks more likely; as a result, a setup you find acceptable with commercial originals may be too noisy for you if you are ripping from a CD-R.

Click at the beginning of a track

The source here is usually data being read as audio. There are different ways that the WAV envelope can be written and some software assumes that some of those options are not in use. In that case, they pick up some bytes of data as though they were audio and encode them into the CD-DA. If you look at the first milliseconds of the WAV (from whatever source) in one or two WAV editors (linked from my page of URLs) you can see the noise as a spike; some editors will give you a strange error message in this case because they think that the WAV file is a raw format. In that case, they may or may not show the glitch. If you get that message, that editor will save the file without the click. In any event, some audio players should reproduce that click if you listen carefully to a WAV file.

Click at the end of a track

A track must begin at a block boundary, where each block is 1/75th of a second. If the last block of a track is incomplete, it will be filled in by something else. Depending on the software, it may be filled with zeroes or with whatever bytes happen to lie next on the disc from which you are writing. In the latter case, you are likely to get a click. A click from this cause will **not** be audible on the WAV file you are going to write since the block limitation is encountered only when writing to the CD-R. Most good tools for splitting tracks enforce the block boundary, but the more powerful ones (such as CoolEdit and Sound Forge) let you choose a size different from the nominal. If you do not use 1/75th second for the sector size, you can produce this problem with even the best software.

A second cause is similar to that of a click at the beginning. The WAV envelope around an audio track may include a footer as well as the header and that footer may be read as audio data. If so, you may again be able to hear the click in some WAV players.

The third source for a click at the end of a track comes from a click at the beginning: if some bytes of header are read as audio and if the audio data started as an integral number of blocks, then the last block being written has only as much audio as got pushed out of the first block by the unwanted data. The result may be a click or may be silence; you can identify it easily in a WAV editor by the fact that it usually lasts for 100 milliseconds or more where other sources are usually much less than a millisecond.

Click between tracks

This is an oddity that occurs only when you record a continuous program without using DAO. Some software allows you to violate the spec requirement of two seconds between TAO tracks. You may even be able to run it down to what appears to be zero - but it isn't. In the short intertrack gap which is produced, the signal is zero. If the continuous program had sound at the track split, the brief, sudden silence may be audible and may seem to be a click. If you tried a 'zero' intertrack gap, this is a likely cause and can be fixed only by writing in true DAO.

Analyzing your problem

So you get clicks - and want to know what to do about them. The first step is to listen to them to find out where they occur. The second is to use information such as that above to identify the cause. If that fails, ask in the Adaptec mailing list or the newsgroups for assistance - but be sure to report what you learned from your own analysis.

Once you find the cause, what do you do about it? The best choice is to eliminate the cause, not the effect. If your mastering software does not like the header from your WAV editor, change one of the programs until you have a compatible pair; if your reader doesn't do good DAE, use a different reader or a different speed. Another choice is to clean up the results. Many of the sources can be fixed with a program like StripWave, which eliminates most problems with the envelope. You can use a WAV editor to remove those clicks manually. You can do generalized cleaning in powerful WAV editors or standalone programs such as WAVClean, DART Pro and DCART. Spin Doctor (part of Easy CD Creator) has a simplified cleaning capability as well.

Are there other causes? Sure, but I don't know enough about them to write them up here. Fortunately, they are also uncommon. Frankly, the specifics of dealing with clicks is less important to me here than exposing the process used to track down errors. If you post - to tech support, the mailing list, the newsgroups or by e-mail - that you have clicks on your tracks, you haven't said enough for anyone to help. The same is true when you report that you can't burn a data disc. You must do your homework before you can get any help. Unless you bring in a personal consultant, you're the only one who can isolate the cause - or at least reduce the possible causes to one or a few of the many potential sources.

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MP3 to CD-DA what's going wrong?

This note is a synthesis of some basics and some material elsewhere in this primer to see what may go wrong when you make a conventional audio disc from MP3s. There's nothing new here, but putting it together may be worthwhile. We will walk through the whole process even though you may only deal with a small portion; imperfections can come from others' contributions. Some other starting notes: different programs deal with deviations in different ways so something that works when you listen with WinAmp may fail when you burn with MusicMatch - or vice versa.

Let's say we start with a cassette of a concert. We digitize it first at the redbook standard of 44.1 Ksps, 16 bits, stereo, uncompressed PCM. Then we split it into tracks and encode it to MP3. (Some programs hide the PCM, some write it out as a WAV, but all which allow splitting or editing go to PCM along the way. If you doubt that, watch how much storage is used while you're recording.) Now you take those MP3s, make an audio layout and burn the disc in DAO so there are no gaps.

But there are. And maybe there are noises in them. And some of those files were not accepted in the layout. Some were accepted, but turn out to be only four seconds long. Others have glitches or bits chopped off the end. What's going on?

We avoided one error: sampling at the wrong rate. Still, when you get a file from the Internet or from a friend, it might have been created at a different sampling rate. If it came from a DAT, it may be at 48 Ksps. Regardless, some programs demand 44.1 Ksps stereo at 16 bits while others are more tolerant, but none will buy 48 Ksps (or 16 or 32) because they cannot resample on the fly. As with other operations which come up later, they might be able to do a competent job for writing at 1x on the fly, but they don't know how fast you'll want to write or how much CPU power will be available, so they avoid the issue by making you do the resampling. But we were smart; we bypassed that problem by recording right in the beginning.

When we split the PCM/WAV file, where did we do it? With most programs - CDWAV, GoldWave, CoolEdit - you split on block boundaries. Other programs are more flexible; with CoolEdit Pro, for example, you can redefine a block (frame) from its nominal audio value of 1/75th of a second to handle film and other rates. Some simply cut where you tell them to, ignoring blocks. If the track ultimately going to the CD does not end on a block boundary, the software will fill it in so it does. Needless to say, it doesn't fill it with music - just silence.

There's another trap when that PCM is made into a WAV. That is adding non-audio data. Like MP3, WAV can carry additional information. However, when you put that in for other purposes, your later programs may not recognize it as a chunk of data and make it into audio. That will not only mean the wrong length of track (not ending on a block boundary), but will also make a very noticable click.

Now we compress the tracks to MP3 and get ready to use them. Along the way, we added the information we'll want in our MP3 player - artist, selection, that sort of thing. Out comes just the thing - a 128-Kbps file that sounds close enough to the tape to suit our needs. Well - maybe. First, it's not really **at** 128 Kbps. When you told the program to encode for that rate, it set some parameters so that it would get close, then charged ahead. Depending on your encoder, you'll be off by a little. That doesn't matter in most ways and not at all when you listen, but it does mean that the size of the file is not exactly 128 Kbits per second (plus overehad). That becomes more significant still if you encoded with VBR - Variable Bit Rate - which squeezes a little more quality from the compressor.

Now let's make that layout and let's include this introduction your friend sent over. Oops, wrong sample rate, have to resample in an editor. Okay, now why does this extra track seem to be only four seconds long? Oh, it was encoded with VBR which our mastering software won't convert - back to the audio editor or a separate decoder to make it a PCM (WAV) for the layout. We start the burn and the program stops on another file; back to the editor to find the data dropout (just a bit or two - what difference does it make? I can't even hear it) and snip it out. Now it burns and what am I hearing instead of a nice continuous concert? Gaps where the MP3s decoded to incomplete blocks thanks to the losses in compression, bit rate deviation and the like. Clicks from misplaced ID3 information (courtesy of some compressors) or from having silence where sound ought to be. (Huh? Howcum? Well, suppose you have a steady tone and introduce a very short silence. You hear it turn off, then on again - a click.)

One more 'goodie' is that some tracks may be cut off and others may have noticeable silence added. That comes from another "feature" of some encoders: poor reporting of the playing time. Remember, the mastering program cannot play the file to determine how long it really is and the compression is only approximate, so the only way the program knows that this track is 03:24:12 (minutes : seconds : frames) is by reading it from the header. The program has to believe the header whether it wants to or not.

If you've gotten this far, I trust that you will understand why **you** are the only one who can determine why the disc doesn't sound good and pin down the actual source(s) of your trouble instead of blaming your writer, your mastering software, or any other single component of the process. You should also have a good idea of some of the inaudible differences among mastering and encoding programs.

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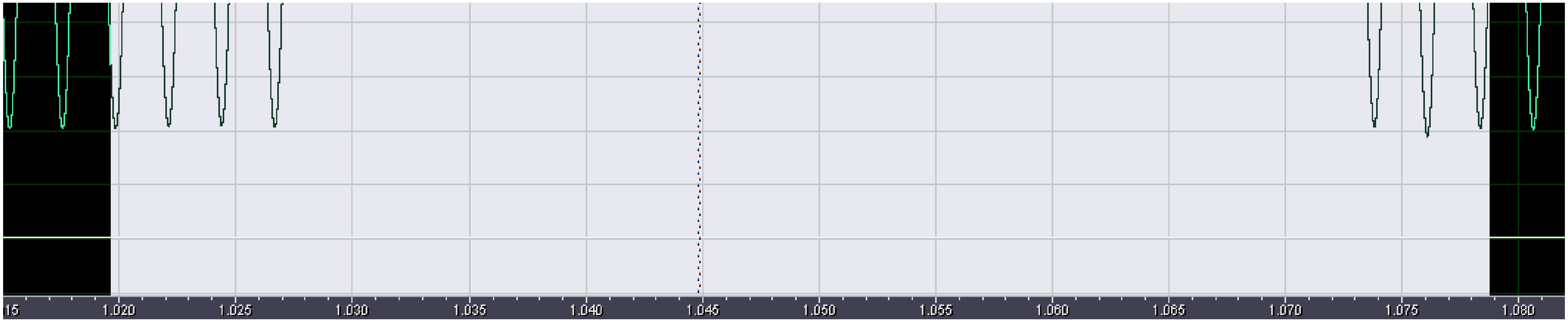
MP3 Test

A rather basic test was conducted using Adobe Audition and its Fraunhofer MPEG Level 3 compressor. The signal consisted of a one-second, 440-Hz sine wave sandwiched between two 0.5-second silences. The tests were made with redbook paramaters and 11:1 compression to 64 Kbps. The saved split files were then appended to provide the images below. Checking with splits and joins of WAV files showed no anomalies; repeated with lossless compression (APE) and decompression also showed flawless joins. Other compressors, both alternatives for MP3 and other formats such as WMA, can be tested similarly. I would be interested in reports on those and may include them in the primer if you permit.

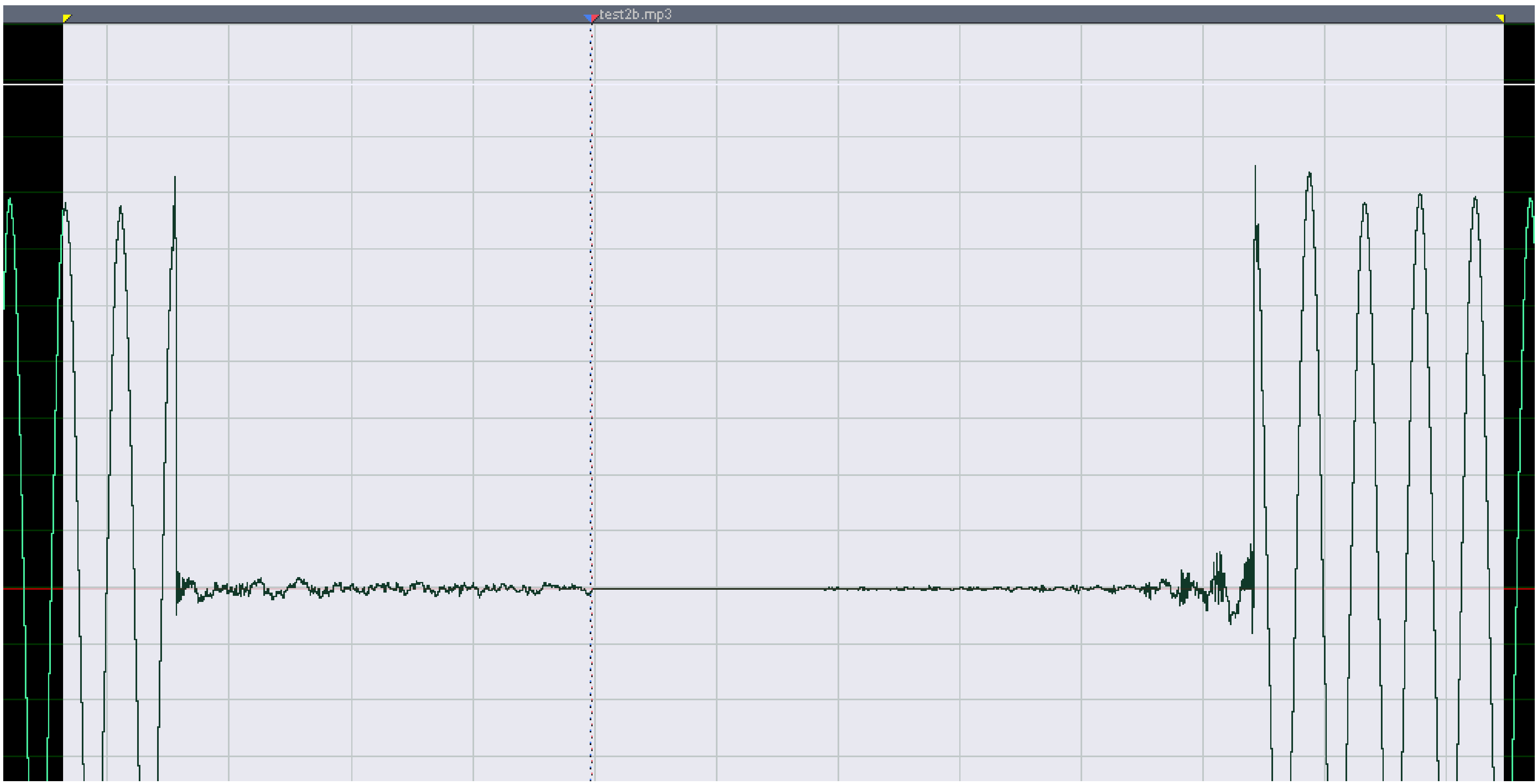
The question of the gap arose from those trying to reassemble a waveform from several pieces in MP3 format. For example, they may take a concert in the form of an MP3 file for each number and burn a CD-DA in DAO. The result can be annoying clicks between tracks or even a perceived silence where the sound should be continuous. MP3 compression adds a (nominal) silence before and after each file's audio content. If there is silence or near-silence at the split, any introduced silence simply adds time and is not noticed on listening. However, if there is significant sound at the split, introducing silence has the same effect as adding a pop. The transitions to and from sound at the edges of the gap are audible. The significance varies with the loudness, the nature of the audio and the duration of the silence, but it is not unimportant for most listeners most of the time. A representative signal in MP3 is here (though not in the PDF), from Test 1.

Test 1



This demonstration spilts at a null. The introduced gap is 44 msec; that is consistent across the tests and is quite audible. The transients are slight and negligible in practice, but the gap is not. The shortest found to date (other compressors, other rates) is 20 msec; the longest, nearly 100 msec.

Test 2

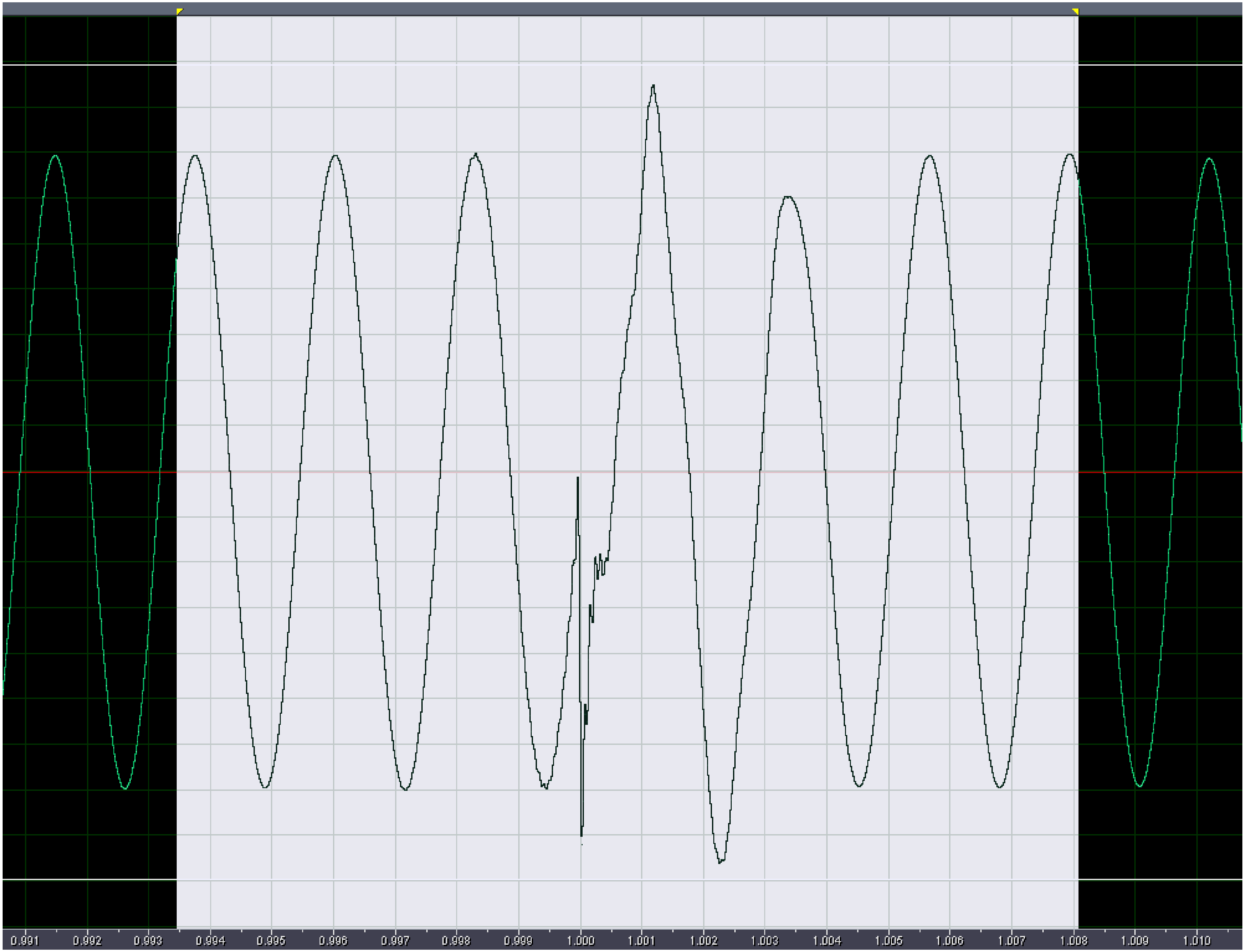


This test splits at a peak of the 440-Hz tone. Note that the level exceeds that of the original; for that reason, compression of a maximum signal may result in clipping. Here, the transients nearly fill the gap between sound segments and have significant high-frequency components. If the segments are to be rejoined, ensuring minimum perception of the operation would require discarding a cycle of the test tone.

Test 3

The results here are intermediate between those of Tests 1 and 2. Simply eliminating the gap by hand is probably sufficient for most listeners.

Test 1 - WMA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1.002
1.003
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1.005
1.006
1.007
1.008
1.009
1.010

Adobe Audition's WMA compressor was used just as Test 1 used MP3s. While there is no gap *per se*, the introduced changes are evident. That is consistent with my determination that WMA generates substantial artifacts on complex audio; for that reason and despite its apparent saving of file size, it is not a format I recommend.

Inferences

It is strongly recommended that track splits be at near-silence if there is a possibility that the separate MP3s will be rejoined either as files or through conversion (e.g., to CD-R). To create a CD-DA, it would make sense to have a single MP3 for the entire disc and a CUE sheet to split the tracks. While that has not been tested thoroughly, it seems to solve the problem of gaps and clicks. A convenient tool to generate the CUE sheet is CDWAV, found among the URLs at this site.

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Archiving Audio

First, let's be clear: this is about saving audio files **you** have worked on. Where and how you archive a copy of that CD you bought on eBay is a whole other subject. This is about that surreptitious concert tape you spent half a day rebalancing and de-hissing; the rare LP you spent hours de-clicking and selectively compressing. Now you have a batch of WAV files and an audio CD, maybe a spare CD just in case. That's not necessarily good enough, though; what are the options for making a copy that will last and will give you the same quality CD-DA next year that you burned today?

Saving as CD-DA

Hey, you've got that spare audio (CD-DA) disc; you can just run a copy from that. Right?

You can, but that may not be your best choice. The potential problem is that there may be slight errors on that disc, noise you do not hear when you listen to it but that will show up on a copy. Even if there are none now, they may develop over time or with handling and they may show up when you upgrade to a drive that doesn't like the medium you used. The key here is that when you save as audio, you gain about 13% in capacity but pay for that by dropping a layer of error correction. The odds are that you'll be okay, but you can hedge your bet with one of the other options.

Saving the WAVs

Okay, if you save the WAV files, you get back that blessed layer of error correction and gain extra confidence. Unfortunately, you lose 13% of capacity, so that if you started with a 74-minute disc, you need to store about 740 MB and ECC or not, it won't fit onto one disc. You could write it to two discs, which makes re-creating the CD-DA tedious; you could use a "99-minute" blank, but that will run the risk of failure 'way up. So if your home-made disc is less than about 65 minutes, you're home free, but otherwise you have your choice of poor options if you want to save as WAV.

Saving an image

It turns out that this has the same size problem as saving WAVs with little advantage. For example, if you decided you wanted to touch up a track, you would have to extract all the tracks to WAV, modify one, then make your new CD-DA and a new image to save. Extracting those tracks can mean burning a fresh CD-DA and running DAE or running a program such as CD-R Diagnostic or ISOBuster. The one advantage of archiving as an image is that it lets you make additional CD-DAs very easy: just double-click the saved image to fire up the appropriate mastering program, ready to burn.

Saving with lossy compression

Compressing to MP3 or one of the other formats using perceptual encoding can give you back that 13% - and a lot more. Many people are happy with redbook audio compressed to 128 Kbps - a factor of eleven or so. Some want to cut their losses and use 256 or even 384 Kbps. Even so, there are losses and at the least, they may leave you wondering whether you've thrown away something you will want some day. It's also worth noting that high-quality compression, such as high-rate with LAME, are far from speedy.

Saving with lossless compression

"Lossless" compression? What's that about?

We know that the usual compressors - ZIP, RAR and the like - do little or nothing to save space in a WAV file. But there are compressors for audio which cost neither quality nor money. The one I've run is Monkey's Audio, which is quick, simple and provably lossless. That is, you can take your favorite WAV file, compress it to APE, then decompress it and you will have a bit-for-bit match to the original. Because lossless compression throws nothing away, it does not shrink files as much as MP3 does, but it will save more than enough space to put even an 80-minute CD-DA onto a 650-MB disc. The one drawback is that you must decompress back to WAV to use the file. If one of the schemes becomes popular, perhaps the CD-mastering programs will accept it for direct writing.

The medium that holds the message

The time you spent creating this audio masterpiece is worth a fair amount to you; don't sacrifice it for a few pennies of medium. Testing labs which have the equipment and no bias will tell you that the longer the blank, the higher the error rate. That doesn't mean that you will hear the difference - even if CD-DA loses one layer of error correction, there are others beneath it. What it does mean is that a 90 or even an 80 is less reliable than a 74 and that you run a higher risk of having an error when you need that file. This is also a case where you may want to invest the extra dime or dollar in a Taiyo-Yuden or Mitsui disc - the best you have found for your writer - just to be sure.

Links to the programs in this page are here at this site.

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Correcting Pitch

In most cases, the pitch of your source is correct - that is, the recording is at the pitch and has the duration intended by the performers. However, the farther back the original was made, the more likely that it is now at the wrong pitch regardless of the form in which you find it. In the first three decades of sound recording, a '78' would be recorded (usually) somewhere between 60 and 95 rpm! Later, errors became less frequent and less extreme, but they still occurred. The best way to solve the problem for transfer to your computer (and to your CD-R) is to change the pitch at the source - with a variable-speed turntable or tape player. There are also variable-speed CD players, but they offer control only at their analogue outputs; whether you would prefer to record from a corrected analogue signal or from off-pitch DAE is up to you. If you are using a variable-speed player, then, you simply adjust it until the pitch is right to you and record through the line input of your sound card. So from here on I assume you're starting from a fixed-speed source and you have to correct pitch digitally. For convenience, all sampling rates below are in KHz.

Determining pitch

Well, this should be easy, right? Maybe so, maybe not. It depends on your source and on your ear. First, we assume that whatever pitch error exists, it is constant through the recording. That was not strictly true in the earliest days, but correction for changes during the recording is beyond the scope of this primer (i.e., I don't know how I would do it if I had to).

Step one is to record a short selection in which the pitch can easily be determined. I recommend doing that in monaural at a reduced sample rate, perhaps 22.05. It makes handling the file easier and should serve your purposes as well as working with a file four times the size. That file is loaded into your favorite WAV editor. For this purpose, I find GoldWave the best choice because its speed controls are the most comfortable for me. All you need to do in GoldWave is to adjust the playback speed until the pitch on your test file checks with your pitchpipe or other reference. Now note the error - the difference between the playback speed and that at which you recorded. For reference, a semitone is about 6% in speed; half an octave is about 40%.

Resampling

One way to correct pitch is to record at the nominal sampling rate you will be using, say 44.1, and then to resample to correct. For example, if your 22.05 test played back best at a rate of 23.3 KHz your WAV is about a semitone flat. In GoldWave, you can simply record the whole selection at 44.1 sampling, then transpose it down a semitone. The same thing is done slightly differently in other editors, but the effect is the same: approximately six samples are thrown away out of every hundred and the others are adjusted to fit. GoldWave gives you no control over how that adjustment is done and uses a simple, quick algorithm for the purpose. CoolEdit Pro and other WAV editors provide control in the form of pre- and post-filtering and relatively complex interpolation schemes. Since that interpolation is done 44,100 times per second per channel in this example, even a fast CPU will take substantial time to do a good job. Only you can determine how much time you want to spend processing and how important the errors are.

Off-Sampling

(Note: this term is my invention. If you have a better one, please let me know.)

Most audio capture programs allow you to pick from a few sampling rates. Typically, they are 48, 44.1, 32, 22.05 and lower. However, Mike Looijmans' CDWAV is not so choosy. In addition to its presets, you may type in any integer sample rate you would like. If the playback is best at 6% higher speed than recording, then you can record at a sampling rate 6% lower than your target and if you have a way to interpret the result as 44.1, you would be on pitch. With the right tools, that's straightforward.

Record in CDWAV at your shifted sample rate - here 41.5. Record the selection as a .PCM file. PCM is a raw format (other extensions are RAW and SND). Now, open that file as PCM in CoolEdit and lie to the program - tell it that the rate is 44.1. In this case, lying is good for you. All you need to do now is to clip off the click in the header (a real PCM doesn't have a header, but CDWAV recorded it with the WAV envelope, which has to go). Save the file as WAV - and you're done. No resampling, so no approximations or delays.

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Sound Cards

To tell the truth, this subject is peripheral to CD recording and I've been reluctant to add it. But questions come up so often that it seems to be necessary - and for many, the performance of the sound card in the PC is essential to getting good results on CD-R.

First, I shall neglect some of the factors important to users of computer audio for other purposes. The primary interest for CD-R is the ability of the sound circuitry to encode PCM - Pulse Code Modulation - from analogue. There is a special case in which the sound card serves a purely digital function - S/PDIF; it will be dealt with at the end. In addition, the focus here is on CD-DA, Compact Disc - Digital Audio.

Pulse Code Modulation

In PCM, a collection of computer bytes corresponds to a single, specific point on an analogue waveform. The frequency with which those samples is taken is the sample rate, usually designated in samples per second but written (imprecisely) as KHz (KiloHertz). Of course, one issue is whether there are one or two channels of audio involved - monaural or stereo sound. Another is how many bits are used for each sample collected; the usual values are 8 or 16. If the encoding is set up to collect 8,192 samples per second (8 KHz) from a monaural signal and to encode at 8 bits per sample, the resulting PCM stream takes 8 K bytes per second (bps). If samples are collected to be recorded in redbook format at 44.1 KHz, stereo and 16 bits, the PCM stream takes 176.4 Kbps. That rate is labelled 1x for audio. (Because of error correction, the corresponding data rate is 150 Kbps.)

Noise Floor

One key function of the sound card is to convert the analogue input signal it receives into digital data. The quality of the result depends essentially on two factors: the noise floor and the accuracy of ADC. Noise floor means the noise introduced by the card itself and the leads which provide input when there is no signal. It determines a level of hiss due to the card as opposed to what may be received from a tape or other input. For comparison, a very good cassette tape can deliver about 60 db SNR - Signal to Noise Ratio. That means that its noise floor is 60 db below its maximum signal. Because of quantization (the resolution capability of a digital signal) the SNR for 16 bits such as from a CD is about 96 db. A sound card which puts its quality into gaming and MIDI may deliver something like 50 db - in other words, it may provide more noise than a good, Dolby B cassette. A less expensive sound card which focusses on WAV quality may deliver 75 db. Where those cards typically cost less than $100, for $200-500 or so, one can buy still higher quality, up to about 82 db. Beyond that, the experts use outboard converters to avoid the electrical noise inside the computer's case.

ADC - Analogue to Digital Conversion

The input to a sound card is typically an electrical analogue of a sound wave. The card's job is to convert that signal to a digital one of the proper number of bits and at the proper rate. The conversion process is more or less accurate depending on how well the card is designed and built. Not surprisingly, the cards with low noise floor also have high-quality ADC. High-end cards may encode to 20, 24 or more bits. That allows substantial editing without losing quality before the bit depth is reduced to 16 for writing to CD-R. In general, mastering s/w will create redbook audio from 8- or 16-bit samples, but not from others.

Sample Rate

Similar to but worse than bit depth, sample rate is under your control and must be chosen with care. The highest frequency which can be captured in digital form is half the sample rate: 44.1 K samples per second cannot record more than 22.05 KHz audio. However, there are significant effects at lower frequencies, so it is desirable to work at a higher sampling rate when practical. Most DAT recording is done at 48 KHz; 16 and 32 KHz are common choices for lower-fidelity sources; professional mixing is often done at 96 KHz. However, those rates are not easy to convert to 44.1 for CD-R, so they will require processing outside the mastering software before they can be burned to CD-DA. Like adjusting for non-standard bit depth, that is a job for a WAV editor. Because the file size and the difficulty of editing increase with sample rate, processing low-fi sources at 22.05 KHz monaural is much more efficient than the same process in redbook - 44.1 KHz stereo. Fortunately, most mastering s/w will convert that to redbook without bothering you (though not on the fly).

File Formats

Rather than repeat the information elsewhere in this primer, I will simply summarize it. A PCM file may be raw or wrapped in an envelope with a specific format name. Raw files typically have extensions PCM, RAW or SND. A raw file carries no information except the stream of bytes. If you put data on that stream to specify details such as sample rate, bit depth and mono/stereo, then you must use an envelope or wrapper such as WAV, AU or AIFF. That envelope permits other information (e.g., copyright) but does not require it. Considering only the WAV file (it's all I know), the wrapper can also hold compressed files, but those are **not** PCM. ADPCM and MPEG Layer 3 are typical compressed formats.

Inputs and Outputs

For convenience and for mixing, the sound card will accept several different inputs. Typically, one comes from CD-ROM, one from Line In (an external connector) and one from Microphone (usually monaural). There may be additional CD-ROM connectors on the card, but unless there are separate sliders for them on the mixer, they probably are all shorted together and simply provide different types of plugs. You should **not** connect two signal sources to a single input of your sound card. It probably won't sound good, but it definitely will not load the sources correctly. If you want to connect both your writer and your reader to a single card, you can find a card with distinct inputs (separate sliders), install a switch for the two inputs or use a cable from an analogue output such as headphone to Line In.

In order to hear a signal from your sound card, you must enable it on your mixer. However, what you hear is not necessarily what you will record. In order to record that signal, you must enable it (and set the record level) on that same mixer. On the standard Windows mixer, you go to Options, Properties, Recording in order to reach the controls you need. The next time you boot, your settings are lost and you must go there again! Other mixers make the controls more accessible and sticky, but they are not usually available except with their corresponding sound cards. An Ensoniq mixer is available only with a Creative Ensoniq card, for example.

S/PDIF designates a direct digital connection between a device such as a MiniDisc player or a CD-ROM and your computer. It is usually implemented in a high-end sound card. Note that not all outputs of

CD-ROM drives which **say** digital or look digital will mate correctly with an S/PDIF card. Like DAE, S/PDIF avoids DAC and ADC altogether and allows you to remain in the digital domain. In addition, many sound cards implementing S/PDIF also convert from 48 to 44.1 K samples per second on command. Another advantage is that an S/PDIF input allows you to connect that second CD-ROM safely. But by now, we have gone beyond the scope of a primer. (And anyone who suggests that that means it has exhausted everything I know on the subject has been cheating!)

Recommendations

As usual, I make no comments on equipment I do not know. I have replaced three sound cards since getting into CD-R: a Creative AWE 32, an AWE 64 and a Yamaha. (The last meant replacing the motherboard on which it was located.) In all cases, I found both the noise floor and the quality of ADC insufficient; the Yamaha also proved almost impossible to control with the standard mixer. My current systems use an Ensoniq PCIAudio (no longer available) and its first cousin, the Creative Ensoniq PCIAudio. The cards and the mixers are different (and not interchangable), but both deliver high quality at low cost. I have not tried the Creative Live, a Turtle Beach, Card D, or any of the dozens or hundreds of alternatives.

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The CDDB and Protected Audio Discs

IANAL - I am not a lawyer - so please take any legal implications below to a real attorney before you act on them. Similarly, I am not a cop; I have no concern whether you are pushing on - or across - the limits of copyright. Finally, my interests are in the sort of music to which none of this applies so I am reporting inferences from what I've read far more than my own experience.

The Compact Disc Data Base (CDDB) is a database of information about Compact Discs. I trust that the rest of what you read here will not be **quite** as simplistic as that. The CDDB contains timing information about commercial audio CDs. It uses a well-defined format to store the length of each track and information about the track (title, artist, etc.) and about the disc on which it is published. It is used by having a program describe a disc to the database in terms of the duration of its tracks. The database then reports the disc and track information back to the program that asked. The duration of a track is measured in minutes, seconds and frames - seventy-fifths of a second. Looking only at the values for seconds and frames, there is pretty nearly uniform (random) distribution over 4500 possible values. If there are fifteen tracks, then there are 4500^15 patterns of values. As long as no one has set out to spoof the system, two discs with the same pattern can be relied on to have the same contents.

An obvious question is: where is that database we are referencing? As long as it has the right structure and contents, it can be anywhere - and in fact it is distributed at Internet sites and (in fragments) on personal computers. Until recently, there was a master copy referenced freely over the Internet. At this time (July 2001) there is dispute over who owns the database, who owns its information, who can access it, who can duplicate it and on and on. It seems inevitable that litigation and disputation will continue longer than this page will last, so I have to leave you to find the CDDB you want to use for your applications.

Now we get to the question of protecting audio discs. The first issue is: what is being protected? Essentially, the publishers are trying to prevent digital copies; whatever the legal situation, they tolerate analogue copies. Of course, an analogue copy goes through DAC (Digital Analogue Conversion) followed by ADC (Analogue Digital Conversion - in case you hadn't figured it out), losing quality in each step. Whatever way the publisher mungs up digital extraction to prevent piracy, he cannot keep you from making an analogue copy or the disc simply wouldn't play. You can therefore get a good - good enough? - copy of a protected disc by playing it and capturing its output with a full-duplex sound card or a program such as TotalRecorder (linked from this site).

Now let's put the pieces together. If you make an analogue copy, count on it - your disc will not be recognized confidently by the CDDB. Your capture of the duration of a track simply won't match that of the protected source. That will give you the job of entering track information, but the copy will be made and will play. Unless you're selling the result, the publishers won't call in the cops.

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Tape Recording

Admittedly, this topic is somewhat distant from recording on Compact Disc, but questions of format arise often enough that they seem to be worth addressing. The following summary simplifies the topic and gives short shrift to variant formats, particularly those which are obsolete today and which never had broad success in the marketplace. More information can be found at http://www.richardhess.com/tape/tips.htm

Modern tape recording originated in Germany just before World War II. Magnetic recording on wire antedated tape, but both mechanical and magnetic problems kept it from taking off; in practice, recordings to 78-rpm discs were used for transcription both in studios and in the home beginning in the mid-1930s and continuing into the 1950s when open-reel tape recording began to take over.

The standards for magnetic tape use English units. Standard tape speeds are 30 inches per second (ips), 15, 7.5, 3.75, 1.875 (1 7/8), 0.9375 (15/16). Tape width is quarter-inch for open reel and cartridges and 0.150-inch for cassette. Other speeds and widths have been used for professional applications and in various obsolete configurations. The original base or backing of the tape was paper, but that was soon replaced by acetate, followed by Mylar and by tensilized Mylar, which last is the onlysubstrate in common use today. The recordable medium is an iron oxide compound, though chromium dioxide had a brief heyday for high-end cassettes. The oxide is suspended in a binder which holds it firmly (one hopes) to the backing. Different oxides have different magnetic properties and three varieties are used commonly in cassettes. Note that the properties needed for digital recording differ from those for analogue; in general, digital tape is a poor medium for recording audio and audio formulations do not give good results for digital data.

The history of tape recording has been paced by the technologies of media and heads. There has been a consistent tradeoff between recorded quality and cost; in general, the wider the track and the higher the speed, the higher the fidelity and the greater the cost. For serious recording, three heads are involved, one each to erase, record and play back. Fewer heads may be used for compactness and economy, but then the performance penalty is great. The erase head must handle high currents to do its job, the record head needs precise properties for the edges of a relatively wide magnetic gap, and the playback head needs a narrow gap and high sensitivity.

Recording is done by 'permanently' magnetizing the tape as it runs across the record head. Each head is like a U-shaped electromagnet where the gap is the space between the two ends at the top of the U. The "azimuth" of the head is the angle between the gap and the path taken by the tape; ideally, the tape runs exactly perpendicular to the gap. Erase and playback heads are similarly aligned and also require control of the azimuth so that what is erased or played back is the same information that was originally recorded. Note that the heads have some properties of permanent magnets and that it is necessary occasionally to reduce persistent magnetism to minimize unwanted erasure when the tape passes over an unused head. To that end, degaussers are available in various forms. In most modern tape decks, the residual magnetism is low and degaussing is rarely needed.

Initially, the heads extended over the full width of the tape resulting in full-track recording. As technology evolved, two-track recording was introduced. The first application was half-track monaural where the head gap extended a bit less than half the width of the tape. A narrow guard band was left unrecorded so that when the second track was recorded (by flipping the tape over), there would be little chance of crosstalk between the two directions. At that stage, correct height adjustment for the head became necessary so that the full signal was read but there was no leakage from the second track.

Stereo recording was now possible using two heads for each of recording and playback. However, that required precise positioning of the pairs so that the phase relationship between the two tracks (now running in the same direction, of course) was preserved. Such "staggered" heads were needed until the technology permitted combining the two into a single "stacked" head. That is the configuration used today.

The next step was to offer four tracks on each tape to yield stereo recording in each direction. The tape was effectively divided into four strips, each a bit less than a quarter of the tape's width, again leaving a guard band. "Four-track stereo" uses the first and third tracks for stereo in each direction. Heads were then developed to record four tracks simultaneously, providing both four independent tracks for mixdown and discrete quadrophonic recording. Technology continued to advance, allowing still more tracks across the width of the tape; wider tapes were used to allow more tracks without substantial loss of signal quality.

Philips introduced and patented a format for cassettes based on open-reel but using narrower tape held in a shell. Conceptually, cassette and open-reel media are the same except that stereo cassettes have the two tracks adjacent to one another to ensure acceptable playback on a monaural machine and vice versa. One advantage of the cassette is that it is covered by patents controlling format and configuration so that any cassette is playable to some extent on any player so long as both conform to the standard. There is only one tape speed - 1 7/8 ips, one layout of tracks and one configuration of shell. Since the tape is narrower, control of azimuth and height is even more critical than on an open-reel deck, but again technologic advances made that practical.

All things being equal, a wider track and a higher transport speed produce higher audio quality: better high-frequency response and greater signal-to-noise ratio (SNR). In the real world, the generalization loses out to technology, so better tape formulations and tools such as Dolby B allow quality recording on tape which is too narrow, using too many tracks, and moving too slowly.

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A Note on Video

The two applications which drive many aspects of personal computing are video and games - and they are obviously closely related. With the availability of inexpensive capture devices such as IOmega's Buz, many are jumping into video and becoming frustrated in the process. This note is intended to address the beginning user of digital video.

Like audio, most video begins with an analogue signal. If your camera generates a digital signal directly, most of this page does not apply. For the rest of us, some capture device is required which converts the analogue information to digital as your sound card does with audio. In general, the capture is to a lightly compressed format. (Without compression, you would have to record at around 30 MB/sec. That would both load your system very heavily and rapidly use up all available space on a hard drive.) The lightly compressed format is usually compressed further offline with a codec (encoder/decoder) that limits the quality of the resulting file. One popular format is whitebook MPEG, which is used to generate VCD. In that form, the data rate is about 1x in CD-ROM terms, meaning that the signal has been compressed 200:1. In that format, a CD-R can hold about an hour of video. At 50:1 compression, a CD-ROM can hold only about 15 minutes of video. Obviously, the more compression used, the lower the resulting quality of both video and audio.

In order to play back a video, the playing computer must have the same codec installed as was used to create it. Many such are available and whenever you install one to encode, you will be able to play it back. However, the person to whom you send it may not have that codec - and in that case will need to find it and to install it before she can watch your product. Intel has several Indeo codecs and there are many others with modest advantages from one to the next. Those codecs usually generate AVI files on a PC (MOV is more common on Mac). AVI and MOV are different envelopes wrapped around the same raw data stream - as WAV and AU are envelopes for audio data. Because of the variation in AVI codecs, it may be most convenient to compress your video to MPEG, which is consistent across platforms and has a standard codec. You can produce MPEG with other products, but many find the Xing encoder most convenient and reasonably priced.

A key factor is the size of the file you generate. Since your original recording will be an AVI even if you are going to compress it to MPEG, you are limited by the specification of AVI. The definition of that format limits it to 2.1 GB total size. While that seems immense, in video terms it is quite limiting. If your original capture is compressed 50:1 (which is very high), an individual capture must be less than 45 minutes. Compression to MPEG is similar to compression to MP3 in audio - and similarly makes editing in that format almost impossible. In order to edit your video, you will need to operate with an AVI and use a tool such as Adobe Premiere or ULead MediaStudio. Editing is very demanding on your system, so be prepared to add large, fast HD's, plenty of RAM and powerful processors if you want to deal with ten minutes' worth at one time. However, it is important to recognize that a high-performance capture card is of little value for home video. If you have a very high quality digital signal, you may throw away 90% of it in compression. If you start with a half-frame source, you will 'only' throw away 60%. The results will be indistinguishable. (Obviously, the rules and the systems are very different for broadcast quality.)

No one can tell you what picture quality is good enough for your purposes. But once you know what you want, do not overbuy to achieve it. High quality in capture means major system revision; modest quality will let you know how much you are willing to invest and give you satisfying results.

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MPEG - Picture and Sound

There is a set of standards for video labelled MPEG. Some apply to video; others apply to audio. This note will cover only the basic features; for details see the usual sites as linked under URLs. Like all lossy compression schemes, the quality of the output of MPEG encoding is less than that of the original video or audio source. In general, the user has enough control to select a balance in compression between loss of quality and reduction of file size, but one should not hope for miracles. Experimentation is needed to determine what looks and sounds right for you.

Video

MPEG video was to be available in three flavors. MPEG 1 can be produced and played back (encoded and decoded) in software alone and on a fast system can provide reasonable quality at 352x240 pixels or about half of the usual minimum screen size. MPEG 2 is more efficient, supports higher resolution and requires specialized (and costly) hardware to encode and moderately priced hardware to decode; it is currently used for DVD playback. MPEG 3 is still higher quality and was intended for high-definition television (HDTV), but it has been suspended until requirements can be fully defined.

MPEG 1 is readily produced on a PC and is suitable for recording from and to VHS videotape. 'Readily' must be taken with a large grain of salt, however, since software encoding takes many times real-time. The MPEG codec is quite efficient in storage requirements and provides a high-quality picture at reasonable file sizes by video standards. A properly encoded MPEG 1 file can be turned into VCD (Video CD) with Easy CD Creator and played on a suitable set-top player. More useful for many is that it can be played on a personal computer and even accessed by a WWW browser with a suitable helper application. Many other codecs (coder/decoder) are available for video; their products are usually in the form of avi or mov files depending on whether they are packaged in Windows AVI or Mac/Windows QuickTime envelopes.

Audio

MPEG Layer 1 is a moderately compressed audio format which is used in some video to reduce decompression load. Layer 2 is usefully compressed and can be generated easily in software encoders. The usual extension for MPEG Layer 2 is .mp2. Layer 3 is still more highly compressed; the shareware program l3enc (with its companion l3dec) appears to be the most popular choice for that process. Other mp3 encoders are available or on their way.

MP2 and MP3 playback require an appropriate application; usually both are provided in a single program. One with several advantages is the inexpensive shareware WinAmp (and the companion MacAmp) from Nullsoft (http://www.nullsoft.com/) It offers a great deal of flexibility so that good results can be obtained on a slower computer; a graphic equalizer with some compression of dynamic range; and even the ability to export an MPEG file in decompressed form in the wav format. Since CD-DA is uncompressed, an MPEG file cannot be the starting point for recording an audio CD-R. An MPEG can be stored on a disc, but to make it useful in a CD player, it must be decompressed to wav before burning.

Streaming

Streaming video and audio refers to the ability to play the picture and sound as it is being received. In general, that requires special capability on the server side and is not available from a CD-R. The formats used for streaming include RealAudio, RealVideo and TrueVoice. The RealMedia capabilities are very inexpensive, but require that the user either download or buy the player program. Efficiency and quality for video are less than MPEG, but more than some video codecs; RealAudio options are quite attractive, but no converter is available to produce wav files from ra. In addition, the author of a RealMedia file may mark it so that from a streaming server it cannot be saved to disc by the user.

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Video CD

VCD is a well-defined and specific format, much like CD-DA for audio. Like audio, it requires a precise implementation of file structure so that it will play back correctly on a VCD or DVD machine which does not plug into a computer.

The VCD has one or more MPEG-compressed data streams recorded without the usual ECC of files. As with CD-DA, it is assumed that any errors will be unnoticed in the result. Unlike CD-DA, the data stream looks to be a true file and can be read (as a DAT) to your computer. However, since it does not have ECC, it can be too large to write back to a disc as a conventional file - and would not be recognizable in a VCD player if it were. Many MPEG players will play back DAT files as well as MPG's, even though they are slightly different internally.

To create a VCD, two steps are required. First, a whitebook MPG must be generated, then it must be recorded with software designed for that purpose. There may be boards or devices which create whitebook MPG's directly, but since those files are very difficult to edit, the preferred starting point is an editable AVI. The AVI from a capture device is most often edited with ULead's Media Studio or Adobe's Premiere; the latter is the choice of most serious users. The edited file can be saved with your choice of codec or those using Premiere and the Xing plugin can render directly as a fully compliant MPG. The ULead output is not fully compliant, but is acceptable to VCDC 3.5b and above. Both hardware and software encoders for MPEG are available. The Xing software implementation is relatively fast and consistently generates true whitebook code when the VCD option is selected.

The VCD format requires specific folders and files and the DAT itself must be recorded without ECC. Therefore, a dedicated program such as VCD Creator (a component of Easy CD Creator Deluxe) is required. VCDC will not record a non-compliant MPG file, so you will not waste a blank by discovering non-whitebook format after the fact. Note that relatively few VCD or DVD players will handle CD-R. Early Sony models accepted them without complaint, but later models (except the very high-end) do not. Similarly, first-generation DVD-ROM players do not read VCD's recorded on CD-R. Second- and later-generation DVD-ROM is MultiRead and should handle either CD-R or CD-RW. That is particularly advantageous in the VCD format because of the time and effort required in preparing and editing material. With audio, one can simply DAE the source to WAV files, then rearrange them and burn them to CD-DA. Theequivalent compilation capability in VCD requires a mastering program which will read DAT (as VCDC does). Otherwise, one may either generate one's own files from AVI or copy a disc in its entirety. If you are creating a VCD, it makes sense to burn an RW for evaluation before making one or more CD-R's for use. (Some standalone players which will not take write-once media will play erasable.)

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Correcting an MPEG for VCD

One question raised frequently is how to put MPEG files from various sources onto a VCD. Frequently, the answer is: you cannot - at least, not practically. That usually results in cries of protest: someone must have a simple way to 'fix' the file. The CD recording publishers are recognizing the VCD format straitjacket, so programs such as the VCD creator in Easy CD Creator are more tolerant than their predecessors and are even capable of compressing to VCD from AVI.

VCD is a strictly defined format - just as CD-DA audio is. If your original audio file is sampled at 44 Ksps instead of 44.1 Ksps, the only way you can make it into an audio disc is to resample it to 44.1. Similarly, NTSC video for VCD must be 29.97 fps. Other rates will play as MPG without a problem, but will not make a VCD. Rates that are frequently encountered on the Internet are 30 and 15 fps; 29.97 is a rare choice.

In some cases, a program such as FlasKMPEG will fix the problem; otherwise, if the original MPG does not conform, it must be opened in a suitable editor and recompressed in exactly the right format. First, there are not many editors which will do that; the best editors begin with AVI, not with MPEG. However, ULead Media Studio 5.2 will do it. Unfortunately, compression is a lossy process. In general, you begin with a file nearly conforming to the standard and end with one which has double the losses. While it is fully conforming, it looks bad. That's not because the compression process is done badly but because double compression is bad.

Returning to the audio analogy, if you download an MP3 sampled at 32 Ksps and want to convert it to CD-DA, you must first decompress it. You may do that by opening it in a WAV editor which accepts that input, such as GoldWave, or by opening it in a separate program, such as WinAmp, and saving it as a WAV. Once decompressed, the file must be resampled, typically in a WAV editor. The resampled WAV is then compressed again to MP3. Decompression is lossless. Resampling introduces problems depending on how well it is done; quick resampling can produce audible artifacts while precise conversion takes a long time. Finally, the resampled file is compressed to MP3. Whether the three steps are done in three, two or only one program, there are three stages of loss: the original compression, resampling and the second compression.

If I were forced to make a nonconforming MPEG conform, I would use two programs - in part because I prefer Xing's compression to ULead's. I would open the file in Media Studio and save it as an AVI, assuming it was not larger than 2 GB in that format. Then I would compress it with Xing. (**Note:** : Compression is *very* demanding of the computer. A 400 MHz Pentium II runs overnight on a 10-minute clip. That's another reason for using Xing - it's not as slow as Media Studio. The third reason is that Xing offers VCD settings which are absolutely compliant, where you have to set your own parameters correctly in Media Studio.

The conclusion I suggest from all of this is that the payoff for forcing conformance is too great to be worth the costs: software, learning curve to use it, time to process and quality loss. If your initial MPEG is not in whitebook format, you probably do not want to convert it to a VCD.

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Compression and Decompression

Confusion in a Bottle

In large measure, this page is a recap of primer material which has proved hard to decipher. In part, that is a natural result of poor naming and confusing concepts. Regardless, let's try again.

The purpose of compression is to use computing power to give the brain the impression of more signal than is really there. The effectiveness of compression is measured by the amount by which the rate is reduced and the loss of quality in the result. The codec (the algorithm which compresses and decompresses the signal) uses a model of human perception to deliver a given data rate from a specific input stream.

Two kinds of video compression have been standardized; another has been dropped and a fourth is on its way. MPEG 1 demands a moderately powerful computer or low-cost dedicated hardware and delivers a moderately compressed picture with acceptable sound. It is used in many home systems and fits well with CD-ROM capabilities. MPEG 2 requires enough more from the computer so that it is not practical without hardware playback support; however, it produces high-quality video, typically the best available in the home. MPEG 3 was to have been even better, but it was dropped when digital High-Definition TeleVision (HDTV) was defined. MPEG 4 is under development now and will probably emerge with digital HDTV in the next few years.

Three levels of compressed audio are defined to support compressed video. They are MPEG Level 1, Level 2 and Level 3 (abbreviated by their extensions, MP1, MP2 and MP3) - and must **not** be confused with MPEG 1 and so on. In particular, MP1 is used for low-fidelity sources, MP2 for moderate fidelity and MP3 for high fidelity. Although audio compression level may be chosen independently of video compression, MPEG 1 usually uses either MP1 or MP2 depending on the video data rate to be achieved. If the video is being compressed a lot, then audio quality will be lowered to keep the data rate down and the advantages of higher Levels are lost. In general, a video encoder will choose the 'best' amount of audio compression for the target data rate of video compression. In some cases, there are specific standards (such as those in the White Book for MPEG for VCD). In others, you may adjust the balance for yourself. MP3 is the level used for DVD and other MPEG 2 applications.

Finally, let me note that compression is much more demanding than decompression. Typically, an MPEG 1 video designed to play back on a Pentium 200 without hardware assist in real time, will encode many times slower even with an efficient software encoder. Encoding MPEG 2 requires substantial hardware to be practical at all. At this writing, MPEG 2 encoding hardware is more expensive than the computer with which it works.

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Common Files and Uninstalling

There are many complaints about the difficulty of uninstalling software of various types. This page addresses only one aspect which is particularly painful - shared files - because it affects CD-R operations. The end point is worth raising first so that those who already understand are spared the lecture. It is that some software components cannot be uninstalled because their necessary predecessors cannot be recovered. Therefore, the only practical way to get rid of them is by restoring a backup.

A program installed into Windows will typically have three groups of files: executables stored in its own folder(s); overlays, libraries, data and related files also located in dedicated folders; and common elements, often DLLs (Dynamic Link Libraries), which are located in such folders as Windows and Windows\System. The common elements are available to all applications. (There is a fourth group, elements common to programs of a family or a vendor. They share properties with the local ones and the common ones as should be apparent from what follows.)

One of the (in)famous collections of common files is the ASPI layer which translates between Windows and SCSI or SCSI-emulating devices. The separate modules form a set of which some are needed for any such communication and others only for selected jobs. The particular modules depend on your OS: NT/2K and 9x/Me use different components. Microsoft ships an outdated but functional ASPI layer with the OS - one which is sufficient for basic operations but cannot properly support CD-R.

When you install a version of ECDC prior to 4.02, an updated layer is installed with it if possible. "Possible" means that it will not overwrite a "newer" module with one which appears to be older. So if another program installed part of the ASPI layer with a later date, the update from ECDC will not replace it. The result is an inconsistent layer which can be corrected by removing the inconsistent files by hand. [Sidebar: There is another problem which arises when a program puts a version of a common file into its own folder. If that program runs before something else loads the common file, the local version will be brought into memory and will keep the system from loading the common one. In that way, your system may test fine for a consistent layer but at times have an inconsistent one - a clashing component was loaded by a 'rogue' program. Note that this is only one of the ways that ignoring programming rules can introduce problems. A more common one is a publisher modifying one of the common elements incorrectly and overwriting a valid version with its own.]

After installing a program which modifies the ASPI layer, what can be done with the files in the layer if you uninstall? They cannot be deleted because the other ASPI functions would be lost. The old ones can't be put back in because they're no longer there to restore. So the updated layer is left behind. 'Way back in the third paragraph, I mentioned that the ASPI layer interfaces for SCSI devices and for those which emulate SCSI. That emulation is used for IDE (which is why your IDE controller shows up as a SCSI device) and for many others. If you install a scanner, it may choose to update modules of the ASPI layer. Since the scanner manufacturer usually neither knows nor cares about CD-R, that "update" may kill a perfectly acceptable set of common elements. Uninstalling the scanner does not solve the problem because you can't recover the lost (valid) components with uninstall. The problems with rogue installs ulitmately reached the stage where Adaptec gave up on maintaining sanity. ECDC from 4.02 does not use the ASPI layer. The necessary communication is built into the local software and bypasses whatever is in the common files. That allows the CD-R software to run in the face of uncontrolled modifications being introduced by others. It's an unfortunate resolution since it leaves the chaos to be solved by everyone else and it wastes space on your hard drive, but it's understandable. The bottom line is that if you want to do a real uninstall, you had best restore from a backup.

You *do* make a complete image backup before any such installation, don't you? I was sure you did.

*P.S. - I'm not ignoring the partial backups of GoBack and other programs. They *may* work depending on the code and the situation. Restoring from backup *does* work - reliably and repeatedly.*

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Storage on a CD-R

Some of the following is adapted from a post to AdaptecCDR by Dick Langley, DickLTech@WWDB.org My thanks to him for permission to modify and to use his material. And since I modified it substantially, don't blame him for the mistakes - they're mine!

Let's start with an audio CD, just as the developers of CD-ROM did. CD-DA tracks are made up of blocks. There are 75 blocks per second of music. There are 588 samples per block; each has 16 bits for each of the two channels, so it takes 4 bytes for each sample or 2352 bytes per block. Now, the accuracy of reading from a CD is not nearly as high as from a hard drive or RAM. For audio, that's not much of a problem, but when the disc is used for data (as a CD-ROM), drop a bit or two and there goes the whole program. To reduce the rate of data errors and to prove that we're computer types and think in powers of two, they decided to use the same block to hold 2K (2048) bytes of data and to take the remaining 304 bytes for error correction. So a block on a CD-R is 2352 bytes long and can hold either 1/75th of a second of redbook (CD-DA) audio or 2K of data.

Audio

In documentation of audio and video processing, the word 'sector' is used for a chunk of information. By default, that chunk occupies 1/75th of a second and fits into one block. Because sector comes up later, I'll stick to blocks, thank you - and you can translate when you read about audio editors and such. And you are also now prepared to do your own arithmetic to see why 74 minutes of audio fills the same blank that holds 650 MB of data, or to understand why, when you extract a CD-DA to your hard drive, it won't fit into 650 MB. And all that neglects the cost of the header on a WAV file. On a CD-DA, there is no header. The information is in a continuous stream of bytes from one block to the next. There's a TOC to tell the player at which block each track begins, but there's no audio file on a CD-DA. (The .CDA you see with Explorer is a fiction.) To create a WAV file from the data stream, a drive capable of Digital Audio Extraction (DAE) supplies the byte stream to your software. That software converts the stream into WAV format, complete with header. DAE is done by dedicated programs (see the Files and URL pages at this site) or by your CD-R authoring program. Converting from WAV for CD-R is done by the authoring program.

If the information in a wave file is not an exact multiple of 588 samples, software pads to a complete block with nulls - silence.If you're recording a concert (for instance) and you want your selections to be addressable as different tracks via the TOC, those tracks should be multiples of a whole block. As you slam two tracks together, the sound (crowd noise for instance) should be constant when transitioning from one track to the next. If you don't have a true multiple of sectors, the last sector of a track will be padded with nulls or no sound. (In some older editors, the padding is not done with zeroes and whatever bytes were lying around will be read onto your disc). As you play your new CD and you transition from one track to the next, you may hear a click (where the sound you hear goes to nothing or to random bytes, then back again). It becomes annoying to hear these clicks between tracks. To solve this situation, software offers quantization. When you're cuttin', pastin', and slicin' tracks apart or together, it will do it in multiples of 588 samples to give you whole blocks. So if you have that concert that you've broken up in tracks, it sounds like one continuous track when played. Mike Looijmans' CDWAV (on the links page) was designed to cut on block boundaries. As you look for software that manipulates wave files, you should look for this "feature". Of course, that means your split may be moved. If you can hear the difference when it's shifted no more than 1/150th of a second, try analogue recording.

Data

Now for data blocks. Again, there is a problem stemming from the fact that there's no File Allocation Table on a CD-ROM. There **is** a TOC and most of what a FAT needs is contained in the TOC. So OS extensions are used to translate the TOC to a FAT - on a PC, to a FAT which looks like the one you would have on a 650 MB hard drive. Information on a FAT16 hard drive is stored in up to 64K sectors; the size of each sector is the total size of the drive divided by 64K, then bumped up as necessary to the nearest power of two. So a 650-MB hard drive would have sectors of 16K bytes each. Since each file must begin on a sector boundary, it will waste whatever space is left unused in the last 16K sector.

Ah, but things are better on a CD-ROM with its 2K blocks, right? No - that would be too simple. Since the OS extension must address the CD-ROM as though it had a FAT, it must look for the file to begin on a 16K-sector boundary. A 4K file wastes 12K on a 650-MB hard drive or a CD-ROM. On average, each CD-ROM file wastes half a sector or 8K. When you add up the file sizes for a disc you are about to burn, you must remember to allow for that wasted space. If you are writing from a drive which has 16K sectors - such as a Jaz or a FAT16 hard drive with at least 512 MB but less than 1 GB - you can use Explorer and Properties to determine exactly how much of your blank will be needed. If your source drive has a different sector size, you will have to do your own arithmetic or approximate using 8K wasted per file - and a little more just in case. *There's more on this subject in the page on <u>Packet writing.</u>*

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Packet Writing

As usual - but perhaps more so given my ignorance - this material is unofficial. In the hope that it's helpful, buckle up for a hard ride. Also as usual, it is aimed at Windows users; Mac users should be aware that much of it needs to be adapted to their/your needs. Note, too, that though Universal Data Format (UDF) applies only to packet writing for CD-ROM, elsewhere - notably in DVD-ROM - it has other applications.

ISO 9660, Level 1/Level 3

The International Standards Organization controls standards generated by industry. The standard for CD-R is numbered 9660 and covers the agreed rules for recording all sorts of CD's. Not all manufacturers of hardware and software look on those standards the same way: some violate them freely, some implement them in part, some try to adhere to them strictly. When a publisher like Adaptec tries to implement them fully and a hardware vendor does not (names omitted to avoid assigning guilt), problems arise. The user complains that Adaptec does not do something the drive manufacturer claims to do and everyone is likely to be both right and wrong. Adaptec says: the h/w does not implement the standard; the h/w maker says: it does what it needs to do; the user says: it's not my fault. There are many solutions available. Another software package may be used which is less stringent about the rules; a different device may be used which follows them more closely; the user may give up on the capability.

ISO 9660 Level 1 covers the formats we have known for a while. They are CD-DA, CD-ROM Mode 1, CD-ROM Mode 2, Mixed and CD-Xtra. In the first three, the disc may be written Disc At Once (DAO) if the hardware and software support the capability. CD-DA is covered in other pages of this primer under Audio. CD-ROM Mode 1 was designed for single-session recording; Mode 2 is slightly less efficient and was designed for multisession. In fact, either may be used for either single- or multi-session - the difference is that while only very old drives balk at multisession Mode 2 discs, some moderately old ones won't take multisession Mode 1. Both Mixed and CD-Xtra modes combine CD-DA and CD-ROM on a single disc. Simply put, CD-Xtra permits playing the audio on a conventional CD machine since the audio tracks come first. A similar format, Enhanced CD, may be thought of as CD-Xtra without its bonus folders and files.

On a conventional CD of any flavor, the first information the reader sees is the Table Of Contents (TOC). In CD-DA, the .CDA 'file' specifying each track is a fiction that a file manager (like Explorer) uses. In a single-session, closed disc, the TOC contains information which is interpreted by a DOS extension as being a directory. The rules for converting TOC information (including the fact that everything on the disc is read-only) are embedded in the extension, such as DOS's MSCDEX. On a multisession disc, the TOC for the first session tells the system where to find the next one - or whether the current one is the last, or whether the disc is now closed. DAO is necessarily single-session (which is why one cannot write DAO tracks in Mixed or CD-Xtra formats), but a multisession variant, SAO for Session At Once, is available on most drives.

In order to support UDF, the TOC - first information on the disc - had to change. As a result, MSCDEX and other extensions cannot read packet-written discs even after they are closed to ISO 9660 format; the information that the extension expects to see is simply not visible. The solution was to invent Level 3.

Functionally, it looks the same as Level 1 to the user, but it requires a different extension. That extension is available in Windows 9x, Windows NT, and Apple System 8, so that they can read Level 3 discs. It is not in DOS, Windows 3.x or other systems. **This has nothing to do with your hardware or application software.** Someone may write a new extension, but Microsoft may not be interested and there's not much money to be made from the effort to inspire a company to do the job. If you write one, you will be much loved by many users, but probably not well paid for it.

Universal Disk Format (UDF)

Now comes packet writing - which has two distinct flavors. The idea behind writing packets is that if one does not worry about the TOC, one can write data to a CD-R in blocks or packets. The information that goes into each packet needs to be accessible by the writer, but not necessarily by an ordinary reader. By writing an appropriate set of functions into the heart of the OS - approximately at the level of the extensions to DOS - a vendor can provide packet capability for writers with suitable hardware and firmware. However, there is no TOC in the Level 1 or Level 3 sense; that information is on the disc in other ways. That takes extra space on the disc and means that those data must be interpreted when a UDF disc is inserted into the drive.

At one time, Sony had its own format for packet writing and provided a driver to permit a UDF disc to be used in a reader; that appears to have been dropped in favor of the standard discussed below. Roxio's DirectCD implements the UDF standard and works in Win9x and NT OSs. Other publishers offer other packet-writing (UDF) implementations, but since only one UDF implementation can be in an OS at a time, the following is restricted to DCD. If someone can provide information onother realizations, I'll be glad to append it.

In the first version(s) of UDF, only conventional, non-erasable media were considered. For them, a very efficient system could be devised. At the head of each packet is the information on the file it represents including its length (which, of course, implies where the next packet begins). Each packet contains an integral number of blocks; the only space wasted is for that header and for the leftover bytes of the last 2K block. A variable-length packet can be converted to ISO 9660 Level 3 format because all the bytes of the file are in complete blocks. Those blocks may not be consecutive, however; if one writes more than one file at a time to a packet disc, the packets may be interleaved. When the session is closed to Level 3, the TOC is written in a more or less conventional fashion, but data interpretation requires that the OS ignore the old header information. In other words, the TOC is similar to that of Level 1, but both the TOC and the data are different enough to require changes that make the old extension useless. (Note that the Level 3 TOC may be written either to close a session or to close the disc. If the session is closed, another UDF session can be started and finalized/closed; when a disc is closed, the TOC indicates it and will not permit reopening.)

A note on capacity: Variable-length packet writing is very efficient. Because of the small amount of space wasted, it is possible to write more blocks than can be accomodated by a FAT16 for a 650-MB disc. If you fill a variable-length packet disc with many files of the right size, it may not be possible to close it to Level 3. That means you won't be able to read it except in your writer - the session is still open and a CD-ROM cannot read an open session.

When UDF is applied on an erasable blank, a new option is available. In addition to being able to write variable-length packets and to erase the whole disc, you can write, read and erase individual fixed-length packets. Now the CD-RW begins to resemble a conventional floppy, where the packets are the sectors, at least from the point of view of the user. That capability is reflected in DCD 2.x and beyond. However, one problem of erasable blanks is that they support a limited number of erasures - nominally, a thousand. Another problem is that when one rewrites on any drive, data may be written over previous entries. Overwriting results in 'scrubbing' or disproportionate reuse of a single region of the disc. For fixed-length packets, the consequences include high overhead to keep track of all the blocks and inability to convert the disc to any Level of ISO 9660. So an erasable blank formatted for UDF loses 20% of its capacity to overhead, forces slow access (about the equivalent of 1x) and can't make the disc readable in a conventional player.

If you think about it for a moment, that sounds much like the case for a very large floppy - which is a good analogy to keep in mind. Both a floppy and fixed-length packets waste about a lot of raw capacity on formatting; neither can be read in a device which cannot write it; each is relatively slow; and if you have a catastrophic failure during writing, you may lose the whole disc. Of course, the UDF disc is hundreds of times bigger than a floppy, but that's a (rather important) detail.

How packets are implemented - and when they're safe

When a write-once disc is formatted for variable-length packets, space is committed for the TOC, but no TOC is written. Nothing else of importance is done, so the process is quick. When a file is written to the disc, it becomes a set of packets headed by the information corresponding to what would be in its FAT entry and including its length so that the location of the next packet can be determined. At the same time, DCD holds in memory a virtual FAT (VFAT) which gives access to that file just as though it were on a conventional disc. Write another file and the VFAT is updated appropriately. When the disc is ejected, the VFAT is removed from memory and nothing is written to the disc.

If the session is closed when the disc is ejected, the information for the TOC is written to the disc from the VFAT but the packets themselves are not altered. The TOC is then accessed through the usual extension. Until the disc is closed, there is no usable TOC information on it - which is why it cannot be read conventionally. A disc with a closed session has a TOC in Level 3 format; that TOC may point to the place another TOC will be written or may say: this disc is closed. During the time that a packet is being prepared and written, a catastrophic system failure would cause the write to be incomplete and might make the disc useless; at all other times, even if the system is powered down with the disc in the drive, the information is safe. The laser is off, everything needed is already written and nothing can happen. Apply power, return to your OS, and the packets are read to form the VFAT.

With fixed-length packets, the process differs in some significant ways. The key fact is that when the disc is ejected the VFAT is written to the disc so that the location of the packets forming each file can be traced. Logically, one would ask: Why not write the VFAT each time the disc is written. The answer is, simply, that that would increase the number of writes to the space that it occupies and would kill the disc more quickly. The VFAT in memory becomes a FAT on the disc. Since the runout track was written, a suitable driver then gives access to the files. That driver is provided by the UDF Reader. Since a fixed-length-packet disc is always RW, that driver is only useful in a MultiRead drive or a writer capable of reading erasable media. A fixed-length-packet disc still in the drive after having been written must be ejected (and have the VFAT written) to give access to the new files. If power fails or the system is reset before ejecting the disc, the new information will be lost and the disc may be unreadable. Couple that vulnerability with the limited life of erasable media and you see why few serious users write fixed-length packets.

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Data in the Mix

Now that you have mastered recording data and audio separately, you are ready to tackle those great interactive discs which mix the two - and maybe other stuff as well. There seem to be many ways to do it, but what are they? how are they used? how are they written? Unfortunately, with one exception they are complicated, used with difficulty and written in various ways. Since this is a primer, not a comprehensive treatise, it will cover the easy way and give some clues to the others which you are free to research if you wish.

Before getting into that, it's important to keep in mind some properties of CD readers. First, almost all CD-ROM drives are multisession so will see the **last** session on a disc and all that link up to it. Second, audio-only players are single-session so will see only the **first** session on a disc. A player which handles multiple formats, such as a standalone DVD player, should be single-session at least for audio and will probably be single-session for everything. However, one which also handles MP3s may be mutlisession, UDF-compatible and just about anything the manufacturer makes it.

Enhanced CD / CD Extra / 'Combination' mode

In these modes, an audio session is written first with as many tracks as you wish. That session is closed but the disc is left open so that it can be followed by a data session. The two sessions are **not** linked; they are in separate volumes. When placed in a single-session reader such as an audio player only the first session (audio) is seen and the disc plays as a conventional CD-DA. The same disc in a multisession CD-ROM shows up as data and can Autorun and otherwise operate as though a pure data disc. In fact, to get to the audio session, you must use a tool such as Session Selector or ISOBuster to make the unlinked CD-DA visible to the computer.

If we stop at that point, we have an undefined but fully usable combination mode - which is what most people want to create and most drives accept without complaint. However, there are standards for two specific formats: CD Extra and Enhanced CD. Those contain specific folders and specific types of files which most users do not need or want. In early versions of ECDC, CD Extra was supported explicitly. In 5.x, the menu item for a new CD Extra generates a format close to Enhanced CD, but not quite on target. Nevertheless, it's an easy way to create the combination mode with only a small waste of disc for the unnecessary folders and files.

What if you want to access the audio from the data side? Simply put, you cannot. There is no link between the two volumes, so neither knows that the other is there, let alone what's in it. Even if you had the link, you would have no way to address the tracks from the data side. One solution is to include MP3 versions of the audio tracks on the data side; then the sound can be played as though there were a link without spending a great deal of space on it.

Other combination modes

There are many of these and only a few will even be discussed here. Further information is available in the CD-R FAQ at http://www.cdrfaq.org/ and in the excellent Technical Library of PDF files at http://www.cinram.com/ Compared with the authoritative sources in the colored books, both are easy reading - but that is only relative.

Mixed Mode

In Mixed Mode, a single session is written with a data track followed by audio tracks. Because it is a single session, the audio can be accessed from the data side with appropriate software - but that software is not generally available and involves information not accessible to the casual user. This mode is out of favor because the data track comes first. Most modern audio players will skip a data track, but some may not and the resulting sound can be catastrophic. Mixed Mode is still used for some interactive programs written by experts and intended for restricted players, not for a Discman. The data track is accessible from a CD-ROM and at least some systems will play the audio as audio in the CD-ROM drive since the data track is skipped for audio play.

Video CD

A VCD is similar to a CD Extra disc except that the audio tracks are replaced by video files (DAT) in Mode 2 Form 2. Because the folders, files and pointers are explicit in this mode, a specialized program is needed. General-purpose mastering programs such as ECDC, WinOnCD and Nero provide VCD capability; some also provide enhanced versions such as SVCD.

Writing in the pregap

The standard requires that an audio disc begin with a two-second "pregap" before the first track. The location of that first track is specified in the TOC, so it can be made longer than two seconds - the equivalent of 300 KB - without confusing most players. By setting a larger pregap, information can be stored and hidden from 'normal' operations. Conventional mastering programs do not give you access to the pregap and do not provide ways to use it if you get there.

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Arithmetic 101

This note is intended to serve two purposes: give you some idea of the limitations in recording data files and show you how simple arithmetic can be used to investigate problems you might otherwise ascribe to hardware, software, media, or an evil spell.

Problem: I have a simple layout with a lot of files to burn as data to a CD-R - and it doesn't work! Somebody said to defrag the hard drive, but why should I do that? Do I need an AV SCSI drive for this sort of simple job? No - all you need is to think about what's going on and to apply some logic.

Suppose we start with 40,000 small files. How small? first guess would be about 16K each; if we make them all just under that, they will fit onto a standard blank. In fact, how much smaller than 16K they may be makes little difference and can make the situation worse, as you will see. Let's assume that I'm writing them from a defragged drive and that I have good caching of that drive so that its directory stays in RAM. Then retrieving that file takes a check of the directory cache, one seek to the file start and 16K data transfer.

On a typical hard drive, you can transfer 3 MB/sec or more and seek time is around 10 msec. Transferring 16K will then take 10 + 16/3 or about 15 msec. If the files are smaller, the number could be as low as 10 msec - the seek time. That means that the drive will transfer 70-100 files per second and that 40,000 files will take 400-600 seconds (7-10 minutes) to write.

Now some more arithmetic. If you write a 650 MB disc at 8x, you will be writing for a bit more than 9 minutes. It takes 10 minutes to fetch the data and 9 minutes to write them without stopping - **underrun!** Suppose the files are smaller? Oh, then you will be writing less, that will take less time and **underrun!**

Now, suppose the disc with the files is fragmented. Each fragment requires a seek. If it's fragmented badly, then many fewer files will cause the same problems as a lot of files on a defragged disc. If we make an image on a defragged disc, there is only one seek required (to the start of the image) and you could write at 20x - regardless of the number of files or their fragmentation.

Please notice the following:

- This has nothing to do with your mastering software
- It has a little to do with the size of the files
- It has nothing to do with your medium
- It has a lot to do with fragmentation
- There is no maximum file count other than that of the FAT16 filesystem in which the CD-ROM is interpreted
- The recommended solutions work: defrag or make an image (or both)
- A faster drive will help a little, but not enough in most cases to pay off

We can carry this a bit further still and move from the HD to a fixed-length packet disc. Here, each packet is 32K and they are deliberately separated on the disc to reduce scrubbing when files are deleted or replaced. So each 32K read requires one seek to the start of the packet and 32K or less of data reading. On a CD-ROM, seek time is relatively long. Your assignment, should you choose to take it, is to find the seek time on your drive(s), do the arithmetic and see if you can understand why it takes so long to read a fixed-length packet disc and why the rotation speed is not the issue.

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MP3 Encoding

The need for audio compression has been apparent for some time. Even with a high-speed connection, the 10 MB/sec of redbook audio is hardly acceptable for streaming over the Internet. For some years, MP3 has been the compression scheme of choice even though it is lossy; lossless compression can rarely save more than 30% of the size of the file, where 90% reduction is common with MP3.

A bit of history first. The Motion Picture Experts Group (aha! that's where MPEG comes from!!) covers audio, video and still-image formats. The audio formats are labelled MPEG Level 1, Level 2, etc. Each is a superset of the lower ones so that MP3 includes MP2 which includes MP1. Each also uses "perceptual coding" in which less significant components of the audio are sacrificed for smaller file size. Note that as more compression is used, maintaining constant quality means more computing.

With the Fraunhofer Institute's development of L3ENC, high quality and substantial compression were realized. A serious listener with excellent source material can hear the degradation of the Fraunhofer engine even at high rates, but the penalty is not great and storage requirements are reduced in many cases by an order of magnitude - a payoff well worth the price to most users. For similar compression at low rates, other engines produce more artifacts and poorer frequency response; again, they may be acceptable to many users. In all that follows your judgement on matters of sound quality, cost and ethics should be applied; I am trying only to report the facts as I have observed them.

The Fraunhofer Institute focussed development on the MP3 encoding algorithm and owns the rights to the one in general use. (WARNING: I will **not** enter debate on the moral or legal implications of algorithm patents or of copying commercial material.) For the rates of interest to MPEG, everything up to Level 3 is handled by the high-quality Fraunhofer codec at least as well as by anything that has shown up since. When one moves to the higher sample rates and higher bitrates of Level 4 (and above?), the rules are different.

Originally, the Fraunhofer codec was licensed at a substantial fee for a higher-speed, lower-quality version and a very steep one for the full package. An individual license for general-purpose use on your computer cost of the order of $300 either directly from them or from companies which licensed it to wrap in their own shell. I signed on then, buying the AudioActive Studio Pro at a painful price. That installed the Fraunhofer codec into Windows and let me run programs such as ECDC which used it to encode audio. Along came a number of other codecs with their own algorithms. They were priced low - or free. Some were extremely fast, though not very good. Still, they satisfied many users' needs and they killed the market for the Fraunhofer.

So Fraunhofer offered a different way to use the high-quality encoder: contain it within a program. That brings the license down well under $100 and products such as CoolEdit can afford to offer an MP3 plugin and AudioActive Studio Pro can be priced competitively. Unfortunately, that means that their codec is not accessible to other programs - it is not installed into Windows. I suppose one could still license the codec directly from Fraunhofer, but it is probably still priced out of reach. So lower-quality codecs are available which may well install into Windows for you. I had some cluttering my system before my recent move to Win2K. For now I'm prepared to run CoolEdit Pro with the plugin and AudioActive Studio Pro and not compress audio in programs such as ECDC. When I get a good solution, I do not want to have to figure out how to remove garbage, even garbage I paid for in my more ignorant days.

High-quality codecs are available as freeware - both BLADE and LAME are generally regarded as superior to Fraunhofer above 128 Kbps - but I have not found an implementation which installs one into Windows. If someone has a method for Win2K, please let me know. I have both BLADE and LAME on my system for use in Exact Audio Copy, for example. Note that they demand substantial computing power; on most machines, they run far slower than real time.

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MP3 and the Perfectionist

To begin at the beginning, MPEG stands for Moving Picture Experts Group. That body establishes standards for digital video and audio. We are concerned here with the standards for the audio layer in the MPEG1 format. MPEG2 is in use today, but is not related to the MP3 files; they are MPEG1 Layer III audio. Simplifying the situation, different layers impose different loads on the decoding software - the program which converts the MPx file to uncompressed Pulse Code Modulation (PCM) audio to drive the reproducer. Layer III - MP3 - is consistent with modern low-cost dedicated packages and with Pentium-class CPU's. Layer 2 - MP2 - is less demanding; its performance is not adequate for it to be considered quality reproduction. In theory and usually in practice, system and software reproducing a given Layer will handle any lower Layer.

Simplifying again, the MPEG standard for a Layer specifies the playback of a file encoded for that Layer and leaves encoding to the developer. MPEG audio employs perceptual encoding and is lossy. That is, it compresses the data stream by throwing away information which the encoding algorithm 'believes' will affect the listener least. The decode side of the codec (code/decode algorithm) is usually pretty simply implemented from the standard; there are some differences which will be discussed below, but in general the playback algorithm is not an issue.

The encoder is a different matter altogether. There are three parameters input to any encoder to control the way it process the file: channels, sample rate and bitrate. Channels simply means monaural or stereo; in general, the encoder will provide 'stereo' channels (identical content) from a monaural original, combine two original channels into one, or leave the count unchanged. Sample rate is simply the number of samples of the data per second. Bitrate dictates the size of the encoded file. Those factors are interrelated.

Rates in common use for digital processing include 44100, 48000 and 96000 samples per second. Even though it violates convention, those are usually shortened to 44.1, 48 and 96 Ksps - which will be done here. (The standard for CD encoding is published in a book with a red cover; uncompressed, 44.1 Ksps, 16-bit, stereo signals are conveniently referred to as 'redbook' in its honor.) The more serious problem, representing Ksps as KHz, will not be accepted here. As is well known, the maximum frequency which can be encoded digitally is one half the sample rate, providing an incentive to take more samples to preserve high frequencies. In the octave below that limiting frequency, phase shift can substantially alter waveforms even though amplitude loss may be acceptable. For various reasons, it may be desirable to have the sample rate in an MP3 file different from that of the original. Many MP3 encoders will resample for the user. Some are limited to commensurate rates such as downsampling 96 Ksps to 48. Others will handle incommensurate rates and can accomplish the more difficult task of resampling 48 Ksps to 44.1. The quality of resampling may be significant here. Simply put, samples are created or destroyed in resampling and that may be done with slow, careful algorithms or quick, simple ones. Needless to say, the effects are audible if one is willing to listen.

Bitrate dictates the size of the finished MP3 file per minute of audio. CD-quality audio is defined in the standard and requires about 175 Kilobytes per second (175 KBps). MP3 bitrates are specified in Kilobits per second (Kbps - note the lower-case 'b'). The rate most often used for CD audio is 128 Kbps - which corresponds to 16 KBps or about one eleventh of the redbook rate. Other rates are frequently used, usually 64 or 256 Kbps though lower compression (higher bitrates), but 128 Kbps is usually assumed. As you would expect, throwing away 80-95% of the original information will impact the sound of the MP3. There are many encoding algorithms on the market. Some, such as BLADE, are optimized for lower compression than usual and will be neglected. Of the others, both subjective and objective tests indicate that the patented algorithm developed by the Fraunhofer Institute is the most pleasing. That is unfortunate, since it is by far the most costly to license - $300 versus $15 or less.

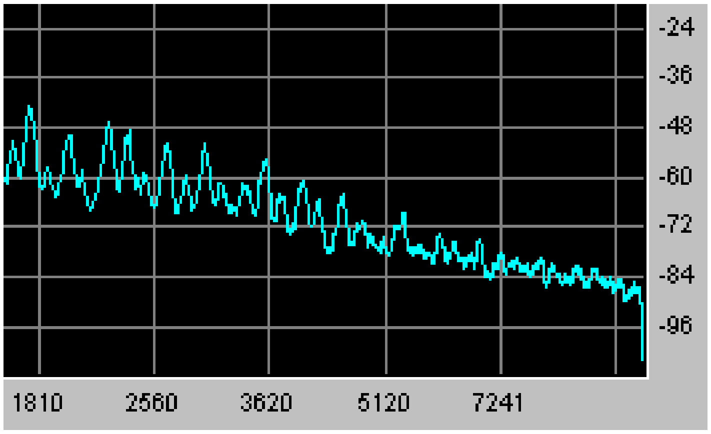

Figure 1: Original Wave

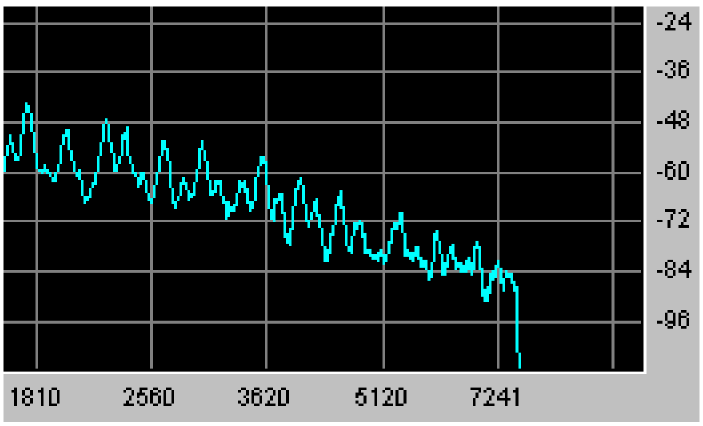

Figure 2: Fraunhofer

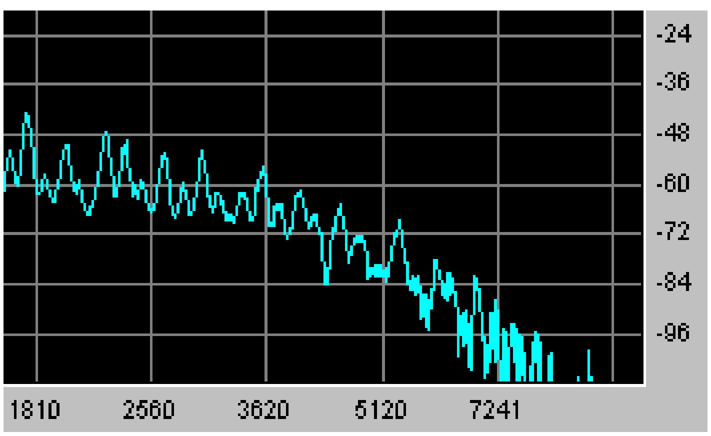

Figure 3: Encoderx

Quality is a lot easier to hear than to describe. Absent an objective measure, there are two parameters of primary interest: preservation of audio spectrum and avoiding artifacts. In practice, they go together and codecs which maintain spectrum best tend to introduce the fewest audio disturbances. The most common form of artifact is a metallic tone which includes some narrow resonances; it's one of those things you'll know when you hear it but it defies description. It appears to originate when signals near the maximum frequency are encoded differently from those near them in pitch. The Fraunhofer codec gives very nearly flat response up to a frequency at which it cuts off abruptly. Another codec may nominally extend the response another half octave, but in the process substantially distort the response curve. Figure 1 shows the spectrum of a 22.05 Ksps monaural original file. Figure 2 shows the same file after encoding with the Fraunhofer high-quality option and decoding back to PCM. Figure 3 is the same with another algorithm. Note that the spectra are quite similar up to about 1.5 octaves before the cutoff at 11.025 KHz. The Fraunhofer remains nearly flat until it falls off a cliff, making no attempt to encode the last half-octave. Another algorithm provides some output in that half-octave, but is 12 db down at 8 KHz where the Fraunhofer is within about 1 db up to its cutoff. In short, the Fraunhofer provides good encoding within its frequency range where the alternative generates artifacts amid some signal on significant overtones. Needless to say, the perception of the sound of the samples is very different even to an untrained listener.

If artifacts are audible in the encoded file, the only solution with a given algorithm is to limit the frequency response of the original. Needless to say, that limiting must be more severe, perhaps by a full octave, with an inferior encoder. Another solution is to increase the bitrate or, in the case of variable bitrate, to increase the maximum bitrate, but either of those would increase the file size.

There are listeners who find even an inferior codec's 128 Kbps file identical to a redbook source. With any audio acuity at all, a listener should be able to recognize loss in the Fraunhofer at that rate in A/B comparison with the source; she will be significantly disturbed by the artifacts of a poor encoder, though she may be unable to describe the faults in the sound.

One point in all of this is that evaluating an MP3 player as a high-fidelity device is not as simple as evaluating CD players. It is necessary to know not only the sound of the source - often, an audio CD - but also the encoding algorithm that was used. Many of us are familiar with the influence of engineering when transferring a master analogue tape to CD; the same original can sound quite different depending on the equipment used and the engineer's judgement. Fair comparison of two reproducers requires that they be loaded with the same MP3 file, not simply compared using whatever file it may have against the original. There are MP3 playback products which 'compensate' for the faults of the encoder they are intended to follow. That is a kind of inversion of the deservedly deprecated Dynagroove process in which the original was distorted to correct for faulty reproduction. As with any high-fidelity product - video, audio or otherwise - the ideal is to maximize quality of each element in the chain, not to correct in one for expected faults in another.

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Photo Facts

Contrary to popular opinion, not everyone records only games, audio, video and data onto CD-R. Some people put photos on as well. Since Kodak's proprietary PhotoCD format for discs is no longer available (but see the section on formats for word on their files), the following is generic for contnuous-tone images, not specific to CD recording. Still, it seems worth a page of exposition. Be warned, though: there's a fair amount of elementary arithmetic to follow.

Resolution

We are concerned here with printing from the computer, not by optics onto photosensitive paper. Unless you use a dye-sublimation printer (where dots and pixels are equivalent), we must begin with some treatment of pixels. A pixel here is an array of printer dots which represents a shade of a color. Since conventional printers only produce one 'shade' of dot in a given color, in order to have varying shades we must have a different number of dots considered as a group. That group is termed a 'pixel'. A pixel of 8x8 dots offers 65 shades of color (0 through 64 dots printed in the block). The extra dot is usually ignored so we speak of 64 shades for an 8x8 pixel. The original image probably has an eight-bit byte to represent that color, which means that there are 256 values available; to represent all of them, one would need a 16x16-dot pixel.

The resolution of a printer is specified in dots per inch. The manufacturers fudge a little sometimes, so a "1400-dpi" printer may only deliver that resolution on special paper with a particular sort of test pattern - but that's another story altogether. Suppose we have a true, 600-dpi printer. If its output is broken into 16x16-dot pixels, there are 37.5 pixels per inch - 600/16. That's about twice as coarse as a newspaper photo, four times worse than a good magazine's output. In short, it's too coarse to be acceptable. For a quality image, effective resolution of 150 pixels per inch (ppi) is a good target.

Photographic resolution is a somewhat different story. Photo resolution is measured in lpm: line pairs per millimeter. There are two dots in a line pair and 25.4 millimeters to the inch, so good film in a good camera can deliver 100 lpm; in computer terms, 5000 dpi! (Now you know why film scanners have such high resolution.) Incidentally, a photographic print is usually considered sharp at 7 lpm or 350 dpi. No doubt, that was a factor when laser printers came out for text (no gray scale needed) at 300 dpi. Note that a dot in photography, as in dye-sub printers, does convey shading. As a result, that 7-lpm, 350-dpi print corresponds to something like 3000 dpi in an ink-jet or laser printer.

Digital cameras make a useful reference point and it may be worth using their resolution - in megapixels (MP) with three colors each - as a reference. Here's a short table of values relating those continuous-tone pixels to performance of films, printers, computer screens and television sets.

Application	MP
35-mm frame @ 100 lpm	35
8x10 photo print @ 7 lpm	10
8x10 dye-sub print @ 300 dpi	7.5
8x10 print @ 150 ppi	1.8
4x5 print @ 150 ppi	0.45

640x480 computer screen	0.3
320x240 VHS playback	0.075

File Formats

There are two broad classes of bitmap image format: lossy and lossless. The common lossless formats include PCX, TIFF and GIF, any of which is quite usable for image storage and retrieval. GIF is usually used for images with only 256 colors, not enough for continuous-tone quality; if the 24-bit version is considered, the same rules apply as for PCX and TIFF.

In a continuous-tone image such as a typical photograph, lossless compression has little payoff. Since an uncompressed TIFF is probably the most universally recognized format, its requirement of three bytes (one per color) per pixel is a good reference point. As a result, it will take more than 100 MB to store all the information in a 35-mm film frame. Even a good 8x10 print at 150 dpi - magazine quality - is over 5 MB. Ouch!

There are now competing schemes for compression of continuous-tone images. By far the most common is JPEG. JPEG compression is quite similar to that of MP3: detail is sacrificed in ways least noticeable to the viewer in order to save storage space. The amount of compression is controllable in software. The more you save, the greater the chance of visible artifacts. The artifacts show up as pixellation of colors - regions of gradual shading turn into blocks of solid colors - and ragged diagonals. Most users seek about 10:1 compression as their compromise, but you should play with your own graphics program to see what its controls offer in price and payoff.

In general, a single compression can be chosen so its effects are acceptable. However, a second compression, even with the same settings, will result in serious image degradation. If you are delivering finished images which will need no further processing, JPEG is a good choice of format. If you are storing the images for editing later on, uncompressed files are far better. If that sounds familiar to those who have done (lossy) MP3 compression, it should.

The Kodak PhotoCD format is a modified form of JPEG with very similar properties. With appropriate software, the image can be retrieved in any of a number of sizes - a minor convenience when resizing in an inexpensive image editor is so convenient. (It made a big difference when 8 MB was a lot of RAM.) The drawbacks to that format are many: access often requires specialized software; the format is not easily displayed and is not suitable for the WWW; the file size is greater than that of a JPEG for the same maximum dimensions and compression. In short, unless you can write the nearly obsolete format for PhotoCD set-top boxes and use one, this file format has no advantage.

Storing on the CD-R

Here, the options are yours and there is no 'best' answer. On a PC, you may want to create an index with ThumbsPlus or a similar tool, though the ThumbsPlus CD writer is prohibitively expensive for personal use. Adaptec's Easy CD Creator Deluxe includes PhotoRelay with useful capabilities not only for slide shows but for video and audio as well. WinOnCD will let you write a VCD with up to 99 still photos. You can also write your own HTML for cross-platform capability.

Before you start your imaging project, clarify for yourself what the purposes will be. If you just want to have the pictures display well on the computer's screen, a 20KB JPEG will do for each and a standard CD-R will hold more than thirty thousand of them. In contrast, you'll have room for only half a dozen full-quality 35-mm frames on such a disc.

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Short File Names Long

One of the rules for using data in a computer is that fully qualified names must be unique. That is, there can be at most one file with the name D:\d1\d2\d3\filename.xyz.abc and so on. If there were more than one, when you asked for a specific file the system would not know which to give you. That's true whether it's a Short File Name (SFN - maximum of eight legal characters, a period, and maximum of three legal characters) or a Long File Name (LFN - and with too many variations in legality to provide here). "Fully qualified" means including the full path from the drive letter through all the intevening directories/files to the file name. For these purposes, note that a directory or folder looks just like a file when viewed from the folder or directory at the next higher level.

In various places on your system, you probably have several files named read.me - or readme.txt or whatever. Suppose you wanted to put two read.me files into one directory. The OS would, quite properly, refuse. It can't put the second one there with the first because the fully qualified names would be identical. That would also be true with longfilename.txt - the fully qualified LFNs would be identical. The major problem arises when one has different fully qualified LFNs but one needs to have SFNs which are visible in and acccessible on a system using 8.3 names. MS decided to write the SFN logically, as 6~k.3 where k is a single character counting 1 to 9 to a to z (and on from there to 5~10.3, etc.). Now, there is an error in that process - which you will discover if you try to retrieve file longfi~c.txt, but that's not the point here. The point is that the fully qualified SFN must be unique in any system.

The SFN is not a property attached to the file. When a file is written to a directory (folder), an SFN is created. For an 8.3 name which is unique, the SFN matches the LFN. For a non-unique 8.3, you get the usual question: Do you want to overwrite? The same is true when you have unique and non-unique LFN's. The problem comes when you have a unique LFN but there is already a file in the directory/folder with the SFN that that LFN would generate.

In folder D1, you have longfilename4.txt with SFN longfi~7.txt - don't ask why, you just do. In folder D2, you have longfilename6.txt with SFN longfi~7.txt - perfectly feasible. Now you want to put those two files into otherwise empty folder D3. If the SFN's were preserved, the OS would have to refuse to put the second file into the folder - its fully qualified SFN would be the same as the first one's. However, you would have no way to repair the problem since you can't alter the SFN without renaming the LFN. So MS did the only logical thing: they did not preserve SFN's. When you write a file to a directory, if the LFN's are unique, a new SFN is generated in which the character after the tilde is invented. It's really the only way to do it.

If you have bothered to read this far, then play with the process to see how it works. One interesting variation is to write into an empty folder longfilename.txt - and then to try to write in longfi~1.txt which would have the same SFN (since the SFN of an 8.3 file is the 8.3 name). Also notice what happens when you write the LFN's in different sequences. It's all perfectly logical - but also very inconvenient for users who want to use SFN's in an LFN environment.

I would blame Microsoft for doing it wrong if I could figure out how to do it better.

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Formats - Mastering and Packet

Settle back - this gets complicated. It is also based on my understanding not on authoritative sources. The results seem to work - the explanations you will see (and, I hope, follow) lead to the right sort of properties all around. However, anyone with authoritative information is invited to post to me privately so I can correct my errors.

As you will see, the physical properties of CD-ROM are significant in one area: there is no way to send the read head to a chosen spot on the disc. Instead, it must go to an approximate location, pick up synchronization bits, and then start writing based on that sync. Each time the head (laser beam) starts a read, it must do it from that space 'wasted' for sync.

The structure of the data and the TOC for a normal data disc (ISO 9660 Level 1) is really quite simple. Each file is written as a continuous stream of data; the TOC provides information on the start point and the size of the file. Mastering software (also called pre-mastering and authoring and typified by CDRWin and Easy CD Creator) supplies a stream of bytes to the disc for those files in sequence. To facilitate getting to each file, it needs to be tied to those sync bits; the effect is space wasted in much the same way as it is on a FAT16 - though the lost space is not really for clusters at all.

When you use variable-length packets in writing to a CD-R, two cases come up. If you write one file at a time, the packets (limited in size by the buffer of your drive) are written consecutively; if you have multiple, concurrent writes, each packet is written with a chunk of one file, but the next packet may be a chunk from another file. The packets are written consecutively - no gap between them - but they may be interleaved. Note that since you need to address packets separately, you need sync space for each. However, that's not usually critical since a variable-length packet is limited by the size of the buffer internal to your drive. If the file is small, it needs just one sync block. If it's big, the block is small enough compared with the total packet size to be negligible. Effectively, you're right back where you were in FAT16 or mastering.

When you finalize the session, the TOC is written in Level 3 format, which means that each file's pieces are properly connected. A runout track is also written during finalizing (closing) a session or the disc. So the net effect of variable-length packet writing is not very different from mastering when the disc or session has been finalized. Its advantage is, of course, that files can be written whenever you wish; you need not accumulate them between writes, though you need to pay the usual end-of-session penalty for the runout track.

When you use fixed-length packets, formatting is used to break the disc space into packet-sized chunks and a map is prepared to hold information on how the chunks make up the files. Every write to such a disc of a file larger than one packet is deliberately fragmented to help keep one area from being scrubbed (written, erased, rewritten) excessively. Those writes require separate seeks and complex bookkeeping on the map. So fixed-length packets take space for the packet delimiters and for the map. Writing them takes a lot of work in the CPU and memory (for the map) and space on the drive (for the seeks). As a result, the overhead includes bytes for each packet to sync the writing to the appropriate area of the disc. Finally, that map is not a FAT or even a TOC, so making it comprehensible requires that you install a translator (the UDF reader) if you want to read the disc on a conventional MultiRead drive. Since the runout track was written when you formatted, the disc needs no finalizing (in fact, none is possible) for it to work in a reader with that translator installed on your system.

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Multiple Sessions

Settle back, folks. This gets sort of complicated.

Track, session, volume, disc - confusion

First, let's take a crack at understanding discs, sessions and tracks, working from the bottom up.

A track is a stream of bits with a starting point identified in a Table of Contents (TOC). In audio, a track is usually a song or other identifiable chunk of music or speech. In data, one usually writes a single track with all the data of a session; the capability is there to write multiple tracks, but there is no reason to do so and it wastes space.

A session is a collection of tracks (one or more, maximum 99 per volume) with a TOC at the front and a runout track at the end. If there is more than one session on a disc, the first will point to the start of the second and so on until the last. A session is said to be 'open' if there is no runout track and the TOC still permits adding tracks. Since an open session has no runout track, it cannot be read in an ordinary CD-ROM or CD player; it can only be used in a writer. When the runout track is added, the TOC points to it and a reader can then know when to stop reading; until then, it doesn't know. Each session (after the first) takes about 13 MB - essentially for the runout track. The first session takes about 20 MB, but that is considered when the disc is designated as "650 MB" or some other length.

"Volume" is seldom used in CD recording these days, but it's a useful concept which does show up occasionally. A volume is a collection of one or more sessions, none of which is linked to a session outside of itself. Usually, a disc has a single volume. To create a second volume on a disc, add a session to a disc with one or more existing sessions - and do not link them to one another. The result is as though you had separate discs on one, but access is a problem.

Neglecting the multiple-volume issue, a disc is said to be closed if its last (or only) session has a TOC saying that the disc is closed. On modern CD-ROMs, there is no need to close a disc except to protect it from having a confusing extra session added. It is a sort of write protection against adding sessions. In addition, some older drives can be confused by an open disc, so it's wise to close the disc when you are through adding sessions to it.

Single Session and audio players

Some early CD-ROM drives and all audio players are single-session. They 'see' and use only the first session on the disc. There could be a multi-session audio player, but it is not part of the specification and all portable, mobile and home players are single-session. As a result, once you close an audio session, whatever you write after that will not be recognized except in a CD-ROM drive. That introduces a problem if you want to drop tracks onto a disc in different sittings (i.e., at different times). While the first session is open, you can play the disc only in a **writer.** But if you close the session, then any sessions you add later will not be playable in an audio unit. You may not like the situation, but those are the rules and that's all, folks!

Critical to all of this is the fact that audio players must be inexpensive. The standard is designed for the lowest common denominator of players, a brain-dead box which can read the TOC to count tracks and their lengths and nothing more. Of course there are fancier versions which can (and do) play tricks, but the design of CD-DA is built around the mindless machines.

Multisession in various forms

Given the above, there are only a few logical ways to lay out multiple sessions on a disc - and many illogical ones with special purposes. Logically, if you're going to put CD-DA onto a disc, you put it into the first session. Put it anywhere else and an audio player won't see it. Data before audio makes sense only for CD-ROM readers, and in that case the only advantage of true CD-DA tracks is that they use disc space better than would WAV files (thanks to error correction). Such arrangements and other non-logical ones can be used on game discs where all rules are made to be broken. They're off-topic here.

They are also off-topic for some programs which may not support creating or copying discs with such layouts. If you are interested in programs for "backing up" game discs and other copyrighted materials, you may find useful information here and usable programs from major publishers, but piracy is not my purpose and you should look elsewhere for expertise on those matters.

Another page in this primer deals with mixing data and other formats including CD Extra, Mixed Mode and Video CD. (Compact Disc Video [CD-V] uses analogue video as on a LaserDisc; it's not relevant here.)

Multiple data sessions

Until packet writing came along, the only useful way to write part of a data disc at a time was in separate sessions, paying the 13-MB penalty for each one after the first. Packet writing is not universal and a disc written in packets cannot be read in DOS or early Mac OS's, so multisession data discs still make sense. All modern CD-ROM drives are multisession and will read such discs without trouble. Although you should be able to mix modes and even ISO 9660 levels, safety says: don't. Data mode 2 (XA) was devised for multisession, but with today's hardware you can use either mode without penalty.

After the first session, you may either import a previous session when creating a new one or not. The simplest course when adding sessions incrementally is to import the immediately previous session automatically. That simply links the old TOC into the new one so that your resulting directory will include the old one. You may have an option at that point to delete files from the first session or to move them around among the folders. In any event, all you are moving are pointers to the data, so no significant space is wasted. Note that if you do not link the previous session, you create a new volume. The old volume (or the old session) is accessible then only with software written for the purpose, such as Adaptec's Session Selector or Nero's volume mounter.

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Packet Writing - Intermediate

Despite appearances, the following is a simplified account of storage on a DirectCD disc. For the full story, check ECMA 119 and 167 at http://www.ecma.ch - or the equivalent from ISO if you can afford their fees. I am not the source of this information, but its author is fully knowledgable and has done an admirable job of making it understandable. If you doubt that, try the ECMA documents.

In order for data to be readable on a standard CD-ROM, the disc must contain three things: a lead-in (containing the table of contents or TOC), the data area (containing the tracks), and a lead-out (containing nothing). The TOC is NOT the same as it would be used for a file system; it only describes what is in the data area - like track start and stop positions. An "open" disc or session contains only the data area since the ultimate track layout is not known (new tracks can be added) until the session is closed. These data are stored in a temporary location called the PMA. When the session is closed, the drive gets the temporary information from the PMA and writes it in the lead-in as the TOC. Again, this has nothing to do with the actual contents of the data area. Move that disc to a CD-ROM drive, and the CD-ROM will find the TOC and tracks and is able to perform reads or to play the associated audio. In a multi-session disc, you would have multiple lead-in, data, lead-out sequences with each lead-in except the last linking via some pointers to the next. The CD-ROM drive starts at the first lead-in and follows it through to the last one to locate the current data set. A CD-R/RW drive does all this, but is able to read the PMA as well so it can find the open session data. Now, when using incremental, or packet writing, the link, run-in and run-out blocks are added whenever a packet is written; they are required due to the way that data are encoded onto the disc. It also has nothing to do with the lead-in, data, lead-out business either. Do these link blocks cause problems for CD-ROM's? Some, but MultiRead is supposed to mandate the ability to deal with them.

So how does this all apply? When using CD-R, DirectCD will write into the data area of the open session, appending packets as needed. In this state there is no lead-in or lead-out so a CD-ROM cannot read the disc. When the disc is converted to ISO-9660 format, we write the ISO image to the disc and close the session. We could simply close the session and still be readable on a CD-ROM because all a CD-ROM cares about is the lead-in, data, and lead-out. Nobody could get anything useful from it without a reader, but the drive would be happy. ISO 9660 is useful because of the wide availability of ISO readers. In the case of CD-RW, we actually format for all the data and close the session right in the beginning. That is why it is readable (in theory anyway) from the start. With both CD-R and CD-RW, the file system is written into the data area of the disc, but with RW the session containing the data is closed and therefore readable on a MultiRead CD-ROM.

With DirectCD, data are written in discrete units (packets) that may be as large the recording drive's buffer. Because of the way data are encoded onto a CD, each packet is proceeded by a series of blocks (link and run-in) and followed by a couple of blocks (run-out). One way of visualizing this is to think of the packet being encased in some "insulation". The net result is that there are some additional blocks between consecutive packets of data. For example, if we have to write a 3-megabyte file on a drive with a 1-megabyte buffer, the data will likely end up written in three discrete pieces or packets, each packet being one megabyte in size and each pair being separated by the linking blocks. In order to read the data correctly, the reading software must be able to skip over the linking blocks that separate each packet. MSCDEX cannot do this. It assumes that all files will be written in one continuous extent. When it encounters files written in multiple pieces it tries to report them as multiple files. The Win95 and WinNT readers are able to skip ahead as needed. This is really the distinction between ISO level 1 and level 3. In level 3, the files can be in different pieces (multi-extent) while in level 1 the files must be single extent.

Another wrinkle added by a file system implementation is that we are able to handle multiple threads of execution writing at the same time. This means that we may have data interleaved on the disc as a result of receiving interleaved data from the operating system. This would also require multiple extents. Finally, the fixed packet size used for RW is 64K or 32 blocks (blocksize=2K). Including the link blocks and the total amount written becomes 39 blocks (1 link, 4 run-in, 32 data, 2 run-out) or 78K. This is also why there is so much overhead for direct overwrite on RW media, approximately 18% waste!

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Why Packets?

Packet writing is new, flaky and ill-supported. Why in the world would anyone need it?

In fact, practically no one **does** need it. But it may make your life easier if you use it well. It will certainly make it harder if you use it badly.

Variable-Length Packets

With variable-length packets (yes, there should be a better term), you can write arbitrarily many files to a CD-R as they become ready to write. Each day, you download from a mainframe all of your correspondence, transaction history, presentation drafts and other information to get you started fresh the next day. That information updates your HD - but drop a copy onto a CD-R for permanent record and to be sure you can start at full speed tomorrow even if the network goes down. A few megabytes - or even tens of megabytes - need to get easy, non-volatile storage in chunks: a perfect application for variable-length packets. Or you have fifty pages to scan and OCR tonight and a batch-job program which will do it and will save both images and text as it goes. Let those pages be output to a UDF CD-R; when everything looks good the next day, finalize the disc to ISO 9660 Level 3 and file the disc. I update one WWW site each week with several MB of files. Each week, I archive the site to UDF so I can return to my mistakes later and apologize appropriately.

Variable-length UDF is rarely an alternative to conventional CD-R. Basically, it's the tool for what we used to do with floppies and now might do with Zip discs or flash devices. The price of the CD-R is low, so we can feel happier about saving history with it. But when you have truly critical data or very large blocks to deal with at once, packet writing is not your best choice for primary storage. In the example of HD update, primary storage is on the HD and the UDF disc is backup. In the case of OCR, the final output on your HD is the primary product; the UDF is a way to verify what was done and to repeat the OCR even if the originals are not to be scanned again. Once closed to Level 3, the UDF disc is as reliable as any CD-R and almost as versatile, so `wasting' the 15 MB or so to finalize should be routine.

Fixed-Length Packets

Fixed-length packets are written only to erasable blanks and provide a very different sort of environment and very different potential. Think of a fixed-length UDF disc as a slow drive like a very large floppy - and try to think of its use as we used floppies before HD's became common. (That was not so long ago for Apple users.) You can install a program to such a disc and run it from there even as it updates its files. If the program is designed to be used that way, it will be CPU-intensive, not disc-intensive, and will manage DLL's and overlays differently from the way it would on a fast HD. There are few programs today written for that sort of thing, but three possibilities should be considered for CD-R use: cleaning and compressing audio and compressing video. Those are programs of modest size which write relatively little information after a lot of processing. On some computers, MP3 compression of a redbook WAV takes about as long as it does to play the WAV. The file can be read from a conventional CD-ROM (at about 150 kilobytes/sec) and execution and output can use fixed-length packets, writing 15 KB/sec. That format is written at around 2x, so the delay for slow writing does not matter much.

Using fixed-length packets where variable-length makes sense (e.g., for backups) is quite possible, but is usually a false economy. You can work that out for yourself, considering intial cost, loss of space to formatting, slow write, inability to finalize, and - most important for many - fragility and poor reliability. Fixed- and variable-length packets are good solutions for some situations, but can be frustrating or costly if used incorrectly.

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The UDF Session

Things seemed complicated enough when we were mastering a disc. Now, with UDF and packet writing, they're getting more confused. Formatting, finalizing - what's going on?

The cases are very different for write-once and erasable media - variable- and fixed-length packets. I pleaded with Adaptec to use different terms when UDF was being introduced, but I was overruled. Something about a standards committee. <G>

When you 'format' a write-once blank (CD-R), you don't really format the disc. You simply establish the directory for an unusual sort of session. Just as you can add audio tracks to an open session one at a time, you can add data files to an open UDF session one at a time. Since the session is open, it has no runout track and can be read only in a writer. Since it is not in a format known to the OS, it can be read only in a writer capable of UDF with a UDF program such as DCD operating. (In fact, a program such as Infinadyne's Diagnostic can also interpret the format, but that is because it does so the way that DCD does.)

When you add a file to a disc in variable-length packets, it goes to the UDF 'driver' part of DCD - a part you don't see but which has been installed when you boot up. That driver translates the file into one or more packets and writes them to the disc as a sort of 'track'. (Because the laser beam must be positioned for this task in a way not needed for mastering, not all drives will permit packet writing; that's why some drives do not support UDF.) After a while, you may want to make your disc readable in a CD-ROM drive, not merely in your writer. Then you close the session with a visible part of DCD. When you do that, you create a TOC similar to the one made when you master a disc - but not identical in form or content. Because closing a variable-length packet session changes the type of the directory, it is sometimes called "finalizing".

When you master a disc, a file is written in contiguous blocks - the file is read sequentially. When you write variable-length packets, the packets may *not* be in sequence. If you are copying two large files during the same period, they may be interleaved. So the format used when you close the session is ISO 9660 Level 3, not the standard Level 1 (I haven't found Level 2 yet in my reading - it may show up yet). Because it is not Level 1, it cannot be read in DOS, Win 3.x, early Mac OS's and so on. When you close a session, you have the option to close the disc. If you do, it is no longer writable. If you do not, then you can add another session by "formatting" again. That will open a fresh directory space and link the session to its predecessor. Since the earlier session is in Level 3, you are not able to master to the disc to add a Level 1 session - the TOC would become hopelessly confused.

NOTE: As you will see in the page of this primer on Psychic Software, the program does not know whether you will be closing the session or the disc and does not make allowance for it. Therefore, you can write so much to the disc that there will not be room to close the session.

Now a word on behavior with fixed-length packets. When you format an erasable blank (CD-RW), you actually do format the whole disc. You write markers to delineate the segments in which packets will be written and finish it up with a runout track at the end of the disc. As a result, the disc can be read in a CD-ROM drive - but only if that drive is MultiRead (can read an erasable) and has a translator from UDF to a format the OS will recognize. Of course, that translator takes the form of another of those 'hidden' parts of DCD. It actually reads the information about the disc's contents so that it presents the disc to the

OS as though it were a sort of oversize floppy. The translation is done in RAM - which introduces a whole set of other issues. The bottom line is that a disc in fixed-length packets is always single-session and the session is technically closed although you can still add and delete data.

Isn't it nice that this stuff is so simple?

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Compression Caution

At least two programs (PacketCD and ECDC 4.x) offer compression on fixed-length packet discs. Under the right circumstances, that can be a distinct advantage, recovering more space than UDF overhead consumes. Under other circumstances, it can be a curse.

Like any lossless compression scheme (PKZip, Drivespace), the effectiveness of compression depends on the compressiblity of the files being stored. That varies widely. Typical numbers are suggested in this table:

Filetype	Ratio
Database / spreadsheet	5-10
TXT, DOC	3-5
Executable	1.5-2
WAV	1.1
ZIP, JPG, MPx	0.9

The overhead needed for compression must be paid even on an incompressible file, so zips, JPEGs and MPEGs of all sorts (including MP3s) tend to take more space on a compressed drive than on an uncompressed one.

A minor factor on most systems is that compression and decompression take processing time. That is seldom significant compared with the time needed to store the data, but it can be noticeable in some cases. A more serious issue is that the compression scheme is not standardized. If you have one system on your computer, you may not be able to read a compressed disc from another, but you will be able to read an uncompressed one. And while you should not try writing a disc formatted by one program in another, you **must** not attempt to do so if the disc is compressed.

By far the most serious implication of compression comes up because the software is not psychic. The only way it knows how much compression will be achieved is to do it. Theoretically, it could compress everything to some work area, measure it and report back to the user before writing to the disc - but can you picture any user putting up with that? The effect of the compression program's ignorance is that an initial space estimate may say that you have a gigabyte available on the disc, but if you write 520 MB of Zips, JPEGs and MP3s, you overfill it and it will not be usable.

No one is cheating you out of anything. The program is working as well as possible. But if you ask the impossible - accurate prediction of effective compression - you won't get it. With any recording process, it is wise to be conservative, to avoid using the last few bytes or even megabytes of storage. With compressed UDF drives, even more conservatism is justified. Once you know how much compression you can achieve on your typical files, you can decide whether to use the feature or not.

If you use compression, please do so with care.

Come to think of it, care is a valuable contribution to any CD-R effort. It never hurts.

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Buffer Underruns

Most of the information here is also in other parts of the primer, some in greater detail. Still, the questions about buffer underrun - sometimes called "failure of streaming" - persist. So, let's consider it as a separate matter in order to help you diagnose it if it occurs and to cure it. Note too that buffer underrun protection, such as BURNProof, greatly reduces the risk of buffer underrun but does not eliminate it completely.

"Buffer underrun" simply means that the buffer supplying data to the writer has emptied before the data are completely written. Since mastering a disc requires that the burn of any track (at least) be continuous, interrupting the flow means - coaster time! (Because of the way that packets are written, buffer underrun cannot be a problem there.)

There are two sorts of buffer involved in CD-R: one within the writer and one which the mastering software may create from system RAM. Not all programs do it. Recent versions of CDRWin, ECDC and WinOnCD certainly do; others probably do as well, but you may want to check your preferred program. In a reasonably well configured system, the amount of buffer made from system RAM is much greater than that within the drive. Even more to the point, there is no feedback from the drive to tell the software how much buffer is being used. The result is that if you have a display of buffer level, it is reporting only the system RAM being used. That may go down to zero safely - you still have whatever is in the drive - but usually if it drops, complete underrun (which will be reported to the software) is only seconds away and unavoidable. For that reason, if you are trying to analyze the buffer underrun, it is useful to record the way the buffer behaves before the fact. Fortunately, underrun is usually found during test as well as while burning, so it can be analyzed without wasting a blank.

The normal pattern for buffer level is that it will build up quickly before the data writing begins, then hold steady - typically well over 90% - until just before the last data are to be written. Then the buffer drains to write the last information to the disc. Remember that pattern, it will be important.

One way to prevent a buffer underrun is to make the buffer so large that it cannot be emptied during the burn. Since that would mean something like a gigabyte of RAM, that's not the solution most of us choose. An alternative is to use the hard drive as a buffer - which will usually work if the problem comes when recording from another source, such as a CD-ROM - and we'll see where that is used in what follows.

Okay, if we can't put the whole disc into RAM, the objective is to keep the buffer filling more or less as fast as it is emptying. Since we're writing at between about 150 KB and 2 MB per second (1x data to 12x audio), that may be no problem at all or a severe burden on the system. If you are simply writing too fast for your source to keep up, the buffer level will ramp up to 100% initially, then gradually fall to zero - and continue to fall invisibly as the buffer in the drive is drained to produce an underrun. The solution here is either write at a lower speed or get your source to run faster. Depending on how you have configured your system, there are various ways to make the source drive run faster, but they may be more expensive or less convenient than you like. The simplest way to get your hard drive to run faster is to avoid using it for any heavy lifting while you burn. If you're close to your system's speed limit, shutting down other programs may be necessary.

What can slow down your source drive? If it's a hard drive, fragmentation will do a really good job of that; see the page on Arithmetic 101 for the effects of fragmentation and of dealing with large numbers of files. The fix in that case is simple: defrag the drive and (if you have a lot of files) write from an image. If you're reading from a CD-ROM instead of a hard drive, you need to check both the nominal speed of what you're trying to do (for example, a lot of "high-speed' drives only do DAE relatively slowly) and the actual speed given the disc you're trying to read.

Three factors typically slow the reader below the speed you expect it to deliver. One is consistently high error rates - typical of a CD-R or a scratched or dirty pressed disc. Rereading is very slow; even a modest error rate can cut the effective speed of your reader, even reduce it below 1x. That is not known to the software until the burn begins, when nothing can be done about it. If you suspect that cause, you can check the disc with CD Speed or simply make an image (where the read speed doesn't matter) and burn from that. If this is the cause of the underrun, the buffer level will fall gradually, but usually not smoothly, in a pattern similar to that of simply having too slow a source drive.

The second factor which can slow the CD-ROM reader is a severe scratch or similar localized damage which causes it to read well most of the time but to have trouble in one area. In that case, the buffer will stay up until that region is encountered, then fall rapidly as the reader re-reads to try to get valid data. You will see the read light flash as you watch the buffer drain. You can try writing from an image, but more often you will have to repair or replace the source disc.

The third cause is that the source drive simply stops for a period; when it starts up again, if it does not reach operating speed quickly enough - underrun! Most high-speed readers have a spindown time to save the bearings. If the drive is not reading information for that period, it is allowed to spin down, then when queried it will spin up. A CD-ROM being used for copying is not reading between sessions of a multisession disc. The pattern here is that the read light goes off while the buffer drains at the end of the first session - and the drive begins to spin down. You can deal with that problem in several ways: increase the spindown delay; write at higher speed (so the time to change sessions is reduced); write the second session to your hard drive and copy the first from the CD-ROM, the second from the hard drive; make the copy in separate sessions, one for each on the source; and so on. (To find out about changing spindown delay, check with the manufacturer of your reader. Using unapproved methods can damage the drive and void the warranty.)

Note that a similar condition can occur on a hard drive if its sleep time (typically, on a laptop) is set too short. There's another way that the buffer can be drained while you write from the hard drive: some other program may come along and override the high priority the mastering program set. What sort of program would do something that stupid? FastFind, some anti-virus monitors and other programs which insist on reading all your drives - including the one you're writing. Since the drive cannot read and write at the same time, if a very high priority read command is received, the writing will stop and the buffer will be drained so the read can be performed. The solution is simple and has no known alternative: kill the monitoring program.

In case you have not guessed, these are not all the ways that a buffer underrun can occur and far from the list of ways you can cure the problem. However, they should be enough to help you find out the cause of your problem and to fix it. Since you are the person who sees what's happening, you are in the best position to remedy any difficulties; fixing it by remote control through e-mail or even voice is extremely difficult.

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Firmware

Firmware is the program that's on a chip in most devices you use with your computer. It is definitely in your CD-R. Originally, such firmware was stored in Read-Only Memory (ROM) of a flavor called Programmable ROM (PROM). The information is hard-wired into the chip and can be changed only by changing the chip itself. In a later version, the chip could be burned (actually burned in the sense that metallic links could be blown out) by relatively high currents. That made it a lot cheaper to upgrade the information. Of course, by now we were writing to read-only memory, but that's computerese, not language. It got worse when people figured out how to avoid actually burning the metal and developed EPROM (Erasable PROM using ultraviolet light) and EEPROM (Electrically Erasable PROM). Still, it is a way of storing information into your hardware on how the device is to listen to and to respond to the commands it receives. It is, in a word, the sole storehouse in the device of information on what to do with inputs from its host.

The PROM in your CD-R holds firmware. If the manufacturer supports doing so, it may be written from your computer instead of needing to be done by a service center. To do it, the computer must tell the adapter how to supply the signals needed and the card must have the higher-current supplies ready to drive it. Some cards do and some don't; some manufacturers can and will let you do it, others don't. The key is that if you burn the wrong information into your device, it will lose the ability to listen to the computer to get the right information in. There is no way around it but to have it serviced and if you have burned really bad stuff, the manufacturer and service people may simply say: Tough luck - we told you not to do it and you ignored us. You voided your warranty and any implied contract, so it's your problem. Next time, follow the rules.

One brief note: there are two components to the upload you will try to use. One is the binary data which go to the device - your CD-R. The other is the loader which is the program that tells the adapter what to do and how to do it in order to get the information into the device. When the loader runs, you will see some strange stuff on your screen: a version number that has nothing to do with the firmware version, apparent error messages which are not errors, etc. None of that matters. When flashing is complete and you reboot, you will see the new firmware revision as the SCSI buss is polled. At that point, you are free to sigh with relief.

Nothing else that you do with a CD-R has the potential to do as much harm as burning firmware. If you use a program from an unsupported site, you are taking the risk. If you are very lucky, it will work. If you are reasonably lucky, it will do no harm. If you are typically lucky, you will still be able to burn the right firmware when it comes out. If your star is not in the ascendant, you may have made an expensive paperweight.

Software from an unauthorized site is the stuff of Alice in Wonderland. Eat it or drink it and something dramatic will happen. Sometimes, it isn't really bad at all.

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The ASPI Layer

In the early days of CD-ROM, every manufacturer had his own interface and connections to the host. Standard interfaces, ASPI and CAM (which will operate ASPI devices and is functionally equivalent for Windows platforms) were devised and manufacturers of SCSI devices either conformed or wandered out of the market. The situation with IDE devices was similar, but the standard that was developed for them (ATAPI) made them look to the system like SCSI and allowed them to work through ASPI. For that reason, your computer's IDE adapter and devices may show up under the SCSI controls.

The ASPI layer is a collection of programs to realize the ASPI interface. Those components work together and must be consistent and complete to avoid problems in communicating and interpreting commands. Some vendors package a subset of the layer with their products - scanners are notorious for this.Often, they will grab an old file (one that's good enough for their needs) and package that with their own software - but with the then-current date. It will then install even though a later version is on your system and it will not be removed readily, again because the date is misleading. (Okay, it's a lie!)

Note that there is an approach to interfacing the components via miniport drivers which does not require the ASPI layer; there is none in Windows 2000, for example. In general, CD-R gets along fine without an ASPI layer if the code is written appropriately to use the "miniport driver". However, code which is not fully compliant may use an ASPI layer instead. That can work - if the layer is complete and consistent. Many support programs do rely on the ASPI layer, so one is needed for them even if not for programs such as Easy CD Creator 4.02 and above.

ASPICHK.EXE from http://www.adaptec.com will analyze your system and report the consistency and version numbers of your ASPI components. If it reports a problem, you may try Adaptec's repair program - but that runs into the date problem and may not resolve inconsistency. Any ASPI layer is subject to corruption if some device is installed which replaces parts of the package.

The variety of CD-R failures due to a faulty ASPI layer is remarkable and defies detailing. Any repeating error message dealing with communications to or from your writer should trigger a verification with ASPICHK. It sometimes appears that programs that really do not need the ASPI routines install them (badly) just to be sure. With ASPICHK and the Adaptec files, ensuring a working ASPI layer is painless. To steal from an American commercial: Just do it!

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Psychic Software

One of the limitations of CD-R software is that it is not psychic - in particular, it is not able to determine what you intend to do or what you will do; it is neither ominscient nor prescient.

Suppose you are making a layout, say of data. The mastering program does not know whether you will be adding an audio layout to make a CD Extra or Mixed Mode disc. It does not know if you are going to make an image or if you plan to burn to a 74-minute blank, an 80, or to one which is already partially written. In fact, when you make up the layout, even you may not know what you will do with it; you might think you're going to burn a standard blank but then decide to add it to an unfinished disc or to use an 80.

While prescient software might decide for you, the stupid stuff we use does not. Instead, it **estimates** the amount of space required based on the most common assumption: you're making a layout which you intend to burn to its very own standard blank. Even if you already know what you're going to do with the layout, the software is not privy to that information. As a result, it only does what you have told it to do (make the layout) and informs you of what it knows (how it would fit on a standard blank).

In another situation, you might be writing fixed-length packets to a disc. The software knows how much has been written and how much you are about to write, so it can tell you if there is room enough for the files you are adding. But it has no idea of when or whether you are going to finalize the session. If it anticipates that you will finalize, then it should lie to the OS and claim to be full when it would no longer have space for the runout track. If it knows that you won't want to read the disc in a normal drive, then it should tell the OS the truth. Lacking psychic powers, it tells the truth. The result is that you can overfill the disc - write so much that you cannot finalize it. Heck, you knew all along that you wanted it to be readable in other drives; what kind of dumb program knows less than you do?

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SCSI or EIDE?

As I frequently reply to private inquiries: I use EIDE for hard drives and SCSI for everything else, so I am not able to advise those who prefer EIDE for CD-R or CD-ROM. Let me begin with an observation. Many users have switched from EIDE to SCSI for CD-R and CD-ROM. Some had a few initial problems with the move, but none has reported going back. I have seen none who went the other way and stayed with EIDE. It is not that SCSI is 'better' than EIDE, parallel port or USB. The fact is that the SCSI interface was designed for the sort of operation that CD's demand and is well suited to it.

CD-ROMs began on SCSI as did scanners, removable hard drives and tape drives. The SCSI interface manages the devices attached to it for the computer, offloading processing from the CPU and minimizing interactions among those devices. I have been asked to help people who hang scanners, printers and capture cards from a parallel port or who try to make CD-R, CD-ROM and hard drives work with EIDE. I anticipate similar questions on USB as soon as the interface becomes more popular. On occasion, there is a solution which satisfies all demands, though often it requires a high-powered EIDE adapter - and is still not as satisfying as a SCSI interface which would have cost little or no more. (In general, any PCI card will do for SCSI, though extremely high speed readers will benefit from a fast one.)

If I am asked for a recommendation on a new system, I always suggest SCSI. That's because I anticipate that a user who initially expects only to add one or two peripherals will inevitably be attracted to add others - and run into problems. Then switching to SCSI is costly (replacing existing peripherals). One complication is that the demand for cheap solutions has driven low-cost SCSI devices off the market; the products that remain are addressed to the committed user and the professional.

Many users have succeeded in running two HDD's, CD-ROM and CD-R on EIDE, but not without experimenting with primary/secondary, master/slave and DMA settings. I sit back in amazement at their willingness to spend time and effort and rejoice in knowing that my 2910 card happily supports Yamaha and Ricoh writers, an Ultraplex reader, Jaz, Zip, ScanJet and, until recently, Sony DAT.

In mathematics, there is a term for the process in which many are caught up: local optimization. At each step, with each addition to the system, the 'best' way to go is apparent. Yet after a number of such steps, if one stands back to look at the whole configuration, the result is far from optimal. It is hard to recommend that someone move to SCSI from EIDE, but those who jump to that interface always seem to wish they had done it sooner.

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All Things SCSI

The following is in response to some of the many general questions that arise from time to time on the Adaptec CD-R users list regarding SCSI. The information is not definitive and I claim no responsibility for it being 100% correct but I feel it covers most areas with sufficiently accurate information to make it interesting and therefore worth reading.

AHA2940UW. You must not use all three connectors at the same time. If you do so you will violate the SCSI spec. by turning your SCSI bus into a T. Only use two connectors at any one time.
Technical Note. The SCSI Bus is an end to end bus, i.e., it does not support branches. There is no allowance within the SCSI spec. for SCSI Bus branches (although there is a stub allowance). Therefore, as the 2940UW and other SCSI controllers utilize 3 connectors, for connectivity purposes only, you must not use all three at the same time. All three connectors are physically wired to each other, no buffering or re-clocking circuitry is present between the connectors. For the AHA2940U2W and the new AHA2940UW Pro you can use all three connectors, in fact on the U2W you can use all 4. This is due to a SCSI extender chip, the AIC3860 fitted to both cards. This little device creates an isolated extension of the main SCSI bus allowing you to use the extra connector plus electrically isolate devices between the main bus and the extended bus.
Technical Note. The SCSI bus is still one logical bus on the U2W and UW Pro, therefore you still must ensure that each device has its own SCSI ID and that each bus, primary and extended, is terminated correctly.

Termination. Only terminate the ends of the SCSI bus, not the middle or only one end but both ends of the bus. Do this either by enabling terminators on the device or by terminating the cable/external connector.
Technical Note. For single-ended SCSI there are two types of terminator, Active and Passive. Passive Terminators are to be found on older SCSI I type peripherals and can be identified as a row of three Single In Line (SIL) resistor packs, normally stamped with 220/330. This refers to the resistive value of the packs in Ohms. Due to their nature of operation, passive terminators should only be used if the speed of the SCSI bus is no greater than 5MB/s. If the speed of the bus is above this as in Fast SCSI then active terminators should be used. Active terminators give a cleaner signal on the SCSI bus and are therefore suited for use at higher bus speeds.

SCSI IDs. Try to leave 0 and 1 for disk drives. It is not strictly necessary to do this but traditionally 0 and 1 have been reserved for disk drives and it won't do you any harm if you continue this tradition.
Technical Note. SCSI IDs have a priority order; if two devices wish to gain access to the bus at the same time the device with the highest priority ID will gain access first. SCSI ID 7 has the highest priority followed by 6, 5, 4, 3, 2, 1 and 0, then by 15, 14, 13, 12, 11, 10, 9 and 8 for Wide SCSI devices.

Wide/Narrow SCSI. You can mix wide and narrow devices on the same bus but you may need to use special converters/terminators like the ones from HYPERLINK http://WWW.TMCSCSI.COM Try to convert from wide to narrow, that way is easier to implement and the wide devices can run ... well. wide. Keep the SCSI ID of the controller at ID 7, moving it above ID 7 will result in the narrow devices being unable to see the controller. Adaptec and other controllers negotiate for Wide SCSI transfers on a per device basis, the wide part only being used during actual data transfer.
Technical Note. Address lines are used on the SCSI bus, one for each ID. If you have a narrow device it

will not be equipped with the necessary address lines to see above ID 7.

Disconnect/Reconnect. This feature is normally enabled; it allows multiple devices to overlap transfers/commands on the SCSI bus and therefore maximizes the available SCSI bus bandwidth; its what makes SCSI suitable for multitasking environments. However, it can also cause a good run in coaster manufacture. Try disabling it as part of your normal trouble shooting. This setting can also be set on a per device basis on some SCSI controllers.
Technical Note. The term disconnect refers to a SCSI device's ability to disconnect **logically** from the bus. This is not a physical disconnect!. Allowing devices to logically disconnect frees up the bus to allow other devices to gain access and perform data transfers and makes more use of the available bus bandwidth. Its benefit is appreciated most in multitasking environments with multiple peripherals attached to the bus.

Synchronous Transfers. If this were a perfect world then every device ever produced would handle the request for Synchronous Transfers correctly. However, it isn't and they don't. If you are trouble shooting, then try disabling this option in the SCSI card's BIOS. CD-ROMs, CD-Rs, Tapes and Scanners have all been known to handle the controller's request for Sync. Transfers poorly. Today's hard drives are immune to this but ... well, just beware. Again this option is enabled on a per device basis so this allows devices to run at different speeds on the SCSI bus.
Technical Note. Synchronous Transfers are negotiated between devices just like Wide SCSI transfers. Different rates can be supported on the same bus at the same time. The negotiation involves a speed parameter defining a minimum period of time between the leading edge of successive REQ (request) or ACK (acknowledge) signals plus an offset parameter for the number of REQs received by a device before it has to respond with an associated ACK. Each REQ-ACK handshake defines the transfer of one byte or one word of data transfer. All Data transfers on SCSI can be performed at the full burst rate of the bus if that rate has been negotiated beforehand between devices, however command, message, status phases, etc. are performed in asynchronous mode no matter how fast the burst rate of the bus is.

Ultra SCSI & Ultra2 SCSI. Ultra SCSI is another option that can be enabled on a per device basis. Apart from increasing the speed of the bus, it has also increased the number of headaches experienced around the world by users and Tech. Support people alike! Theory goes that you can mix Ultra and non-Ultra devices on the same bus. Many people do and it all runs OK for the lucky ones. Because of the cable limitations imposed by just one device running at Ultra SCSI speeds, my suggestion if you do have issues is to A) first make sure your cable is A1 OK; B) make it as short as possible; C) separate the Ultra devices from the non-Ultra by installing another card. Ultra2 SCSI, on the other hand, is far easier to implement. It offers another step forward in SCSI speed to 80MB/s burst and also offers an electrically different signal scheme called Low Voltage Differential or LVD. This signaling scheme suffers none of the major issues seen with Ultra SCSI (short cable length vs number of supported devices, etc.) but it is electrically incompatible with Ultra SCSI devices in its native form. This becomes a non-issue as Ultra2 devices employ a scheme where they can detect if they have been installed on a non-LVD bus (Ultra or FAST) and revert to the maximum speed and electrical characteristic of that bus thus making them backward compatible with previous generations of SCSI.
Technical Note. The term Multimode I/O cell is often used when referring to LVD devices' ability to detect what type of bus they are attached to. However, since LVD devices are generally not compatible with the SCSI High Voltage Differential bus, only HVD devices should be used on a HVD bus.

Cables. Not all cables are created equal. Ultra/Wide and Fast/Wide SCSI cables are different. They have

different specifications. Make sure yours comply with whatever you are running. External cables and connectors can cause you issues if they are not up to spec. You only get what you pay for! It is asking too much when you spend $100s on the latest all singing/dancing PCI controller and expect it to drive a device via a substandard cable.
Technical Note. Ultra2 cables are essentially the same as Ultra cables. OK, they are not the same! But if you have a stable working Ultra SCSI system and wish to move to Ultra2, then the cables you currently have will work in most cases, the only reason to upgrade would be if your system was on the tolerance edge.

Bus Mastering. Bus-mastering PCI cards greatly ease the worry/pain of CD-R work. Sure they are not necessary and many people do use ISA cards and non-mastering controllers, like the early AHA2920 but at the end of the day they are affordable, like the AHA2910 / 2930 and give you that good piece of mind feeling.
Technical Note. Bus Mastering or Bus Mastering DMA (Direct Memory Access) refers to an I/O device's ability to control a data transfer directly into your computers main memory without CPU intervention. This makes better use of the available CPU bandwidth by not saturating the CPU with interrupts that a non-mastering card would generate. Today all PCI SCSI cards feature BM DMA; it is a specific requirement for the Microsoft PC99 initiative. The early Adaptec AHA2920 was a re-badged Future Domain PIO (Programmed I/O) Card but all later Adaptec cards feature BM DMA. ISA cards are to be phased out as part of the Microsoft PC99 initiative (PC99 Basic Requirements, Chapter 3, page 66 Section 3.28). This means that all new systems sold after 1 January 2000 should be sold without an ISA slot or slots if the system vendor wishes to use the PC99 logo.

Fixes. If it isn't broken then don't fix it!

If you have anything to add to the above, correct or dispute then please email me in a constructive manner at nealg@freenetname.co.uk You may distribute the above as you wish, all I ask is that you acknowledge the Author !!
Neal Gibbons

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Remembering History

This note explores some of the effects of standardization of the CD formats and the issues raised since the standards were established. If someone will supply specifics, I'll be glad to include them in an update. A very knowledgable friend has added some notes, offset here. Note that the driving force in what follows is the audio CD; CD-ROMs were forced to the same sort of parameters for compatibility.

It may be difficult to believe, but the Compact Disc did not even exist in the 19th century. In the early 1970's, Sony, Philips and a number of other companies began to plan for a commercially viable medium for digital audio. Even I had some slight input in arguing (through AES) for a higher sampling rate than the 44.1 Ksps which was standardized. Like other aspects of the design, the sampling rate was a compromise dictated by conflicting desires for maximum playing time, highest fidelity, fabrication ability, and costs on several levels. Note that at this stage, there was no concept of home recording and no prospect of the technology we use today on a routine basis.

> 44.1 Ksps was the highest sampling rate possible in mass-producible silicon in the late 70s and early 80s, when the standard was set. In fact, 16 bits of resolution turned out to be rather more difficult than was expected -- the first Philips players had oversampled 14 bit D/A converters. A sidebar: folklore says that Akio Morita, the founder and chairman of Sony, specified a 74 minute playing time so that the Beethoven Ninth could play without interruption. However, according to Kees Schouhammer-Immink, Philips' top scientist on the team of Sony and Philips engineers which designed the CD (and who is a friend of mine), that story is revisionist fiction. The diameter of the CD was originally specified to be the diagonal dimension of the compact cassette, and was then rounded to an even number. Given the sampling rate, bit depth, error correction and practical optical density at the time, the result was a playing time of 74 minutes. But that isn't particularly sexy, is it? Another sidebar: because quadrophonic equipment and software were being sold to consumers during the time that the CD specification was written, the original spec allowed for four-channel discrete audio, halving the playing time. Quad failed commercially before the CD was released, and no four-channel CDs were ever produced. [MR: The bit is still there to implement quad some day.]

The critical component in the CD was and is the laser used to read the disc. If we had solid-state lasers when the spec was being developed, I do not recall them. I believe we were still using the gas lasers which were in commercial distribution in the early LaserDisc players.Whichever sort was the target, it would operate in the near-infrared at a wavelength of about 0.8 micron. (For reference, visible light is in the range from .4-.7 micron.)

For the Compact Disc to be practical, commercial-grade manufacturing would have to be used - upgraded to some extent, but not qualitatively changed as for instrumentation in scientific laboratories. That dictated a spot size for reading of twice the wavelength - 1.6 micron. In order to position the spot, they devised the idea of a spiral pressed into the plastic. The spiral groove had a pitch not tighter than 1.6 microns and a superimposed modulation - a wiggle - to allow the laser to servo to a desired position. In order to establish the position of the laser, leadin and leadout (runin/runout) standards were set for the start (center) and end (edge) of the disc. Now the readers could be manufactured in accordance with those constraints and details such as the minimum radius for the start of the track and the maximum radius for its end. Over time, manufacturing technology advanced so that the tolerances could be held at very low cost and players that at first sold for a few hundred dollars are now available - with extra features - at a tenth the price.

Let me step back a few years to the first commercial use of a pressed optical medium, the LaserDisc (LD). In some respects, an LD is like an overgrown CD. It breaks the signal up into frames and records them around the disc in the form of pits in plastic which are read by overlaying a reflective layer. The most significant difference is that the LD is written in Pulse Width Modulation (PWM), where the length of the pit is the analogue of the signal; a CD uses Pulse Code Modulation (PCM) in which the pits embody a digitized signal. Another difference is that the twelve-inch diameter of the LD dictated enough thickness for two platters to be sandwiched together. The CD is smaller and thinner, so it cannot be double-sided.

> It could have been specified to be double-sided, but the process of bonding the two halves of a laser video disc at that time did not lend itself to efficient manufacturing and was not fully reliable. Further, the playing time was judged to be adequate without requiring manual or automated disc flipping. [MR: In the event, the choice was wise since it avoided the infamous Laser Rot.]

Part of the standard is the optical location of the reflective layer from the (physical) bottom surface. The polycarbonate medium for the disc was and is the best choice for cost, produceability and transparency; significantly, it has the highest practical index of refraction so that the optical distance was the greatest practical multiple of the physical distance between the layers. Given the properties of the plastic and the specified focal distance (from the optical path length), the thickness of the plastic is defined. Above the metallizing is a lacquer to seal it, then optional printing up to a maximum specified thickness. (The first players used top loading and could have handled arbitrary thickness, but the specification set a limit which was less than twice the thickness of the plastic.) As a result, players have evolved with other loading mechanisms that will not tolerate excessive thickness; some slot loaders will balk at a disc with a paper label applied.

That is the simplest demonstration of our limitations in exploiting advances in technology in CD. If we have a tighter pitch, the many inexpensive players in use today will be unable to maintain tracking and will balk. In fact, we have that today with discs which exploit the full specification and run up to eighty minutes of audio and some players which cannot track them. Much longer discs could be produced now by using a shorter wavelength. In fact, they **are** available. We call them DVDs. Of course, a DVD exploits other capabilities the CD does not have: two sides, multiple layers, and a variety of formats for audio, video and data among them.

Other possibilities which would be allowed by modern technology but are not in the standard are to start the spiral closer to the hub, to use shorter runin/runout tracks and to write closer to the edge. Each of those is feasible but would obsolete large groups of players old and new. In fact, with overburning, you can push the limits. Two factors come into play: the diameter of disc which is usable and the length of runout track.

Onto the wavering spiral pressed into a blank is impressed another modulation, the ATIP. On a CD-R(W), the ATIP reports the length of the spiral, the nature of the recording medium (type of dye or the alloy for an erasable), intended writing speeds and so on, including the code indicating royalty payment for the Digital Audio blanks used in standalone recorders. Except for the length of the spiral, none of the information is certain. A stamper made for one manufacturer to be used with one dye type can press blanks for another manufacturer using another dye. Even the length of the spiral is only a minimum; the actual length may be greater and the extra length may be usable - but the manufacturer does not guarantee that. The length in the ATIP is the point at which the spiral reaches the spec limit for maximum writing radius. The spiral almost certainly goes beyond that and the dye covers all the way to the edge, so why not use more? Simply, the writer mechanism is designed to go to that limit; it will go farther, but at some point it will fail, perhaps catastrophically. The reader will also reach a stop - a limit of some sort. That may simply mean that it will not read farther or it may suffer mechanical failure. Some writers and some software permit overburning - writing beyond the limit in the ATIP - and some do not. If you overburn, you now know the risks you take.

Just to wrap up, we need to look at the runout track with respect to overburn. Since a reader does not use the ATIP, the runout track provides a necessary reference for it to know where the disc ends. If a reader cannot find the runout track - it's missing or too short to be recognized - then it cannot read the disc. The runout is the last thing written; if you overburn, the runout may be eliminated, shortened or written beyond the farthest point the reader can track. Again, as you shorten the runout, you increase the risk that some reader will not be able to handle your disc.

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The Intertrack Gap - and Burn Proof

This tale must begin with a bit of CD recording history. Another aspect of the tale told under Remembering History in this primer is the effect of writer tolerances on some of the features and limitations of modern recording.

One part of the specification not addressed here is the requirement for a two-second (150-block) gap before the first track of any CD-R. Instead, we're looking at the space between two tracks, particularly (at first) on an audio disc. Why are those two seconds "wasted"? Simply because the tracks are written one at a time.

When CD-R was being defined, the problem of positioning the laser was severe. It was simply not possible to tell the laser to go to a specific point and to expect it to find that point on the inscribed wavering spiral. That's still true, but the uncertainty in positioning and the amount of information needed to get synchronization is much less with modern production techniques than it was twenty or so years ago.

The original mode of writing audio was Track At Once - TAO. A track would be written, the laser would turn off, the next track would be prepared, the write would be readied by servoing the laser to the point where the write was to begin, the laser turned on and the next track was written. To be sure that the track would begin as intended, the space from its predecessor was set to 150 blocks.

Then Disc At Once was added to the capability. In DAO, the TOC is written first to indicate where each track is to be regarded as starting. Then the laser turns on and burns all the data as a single track with no interruption where the tracks are separated and no required gap. Note that some players have more trouble finding the start of an interior track on a DAO disc than they do with TAO - the reader would like that gap for synchronization and on a disc which it does not read easily it may have to seek. That's particularly true for older audio players, but it can happen even with a new one with a poorly matched medium.

Someone then realized that a gap might still be desirable between some tracks in DAO, so an adjustable "gap" was introduced; it's not really a gap, but a specified period of silence introduced before the next track starts. Some software will also allow you to adjust the intertrack gap when writing TAO, which is useful for drives which don't support DAO, but is both imperfect (there is **always** a gap) and in violation of the specification.

So, what does this have to do with Sanyo's "burn proof" recording, since licensed by other manufacturers? First "burn proof" does not mean protected against all failures (and certainly not protecting a blank from being burned - recorded - at all). It is a means of reducing the effect of buffer underrun. If the flow of data to a recorder is interrupted long enough to empty the buffer, the recorder reports the last full block written and the software holds off until the buffer reloads. Then it begins to write from the end of the last block to complete the track. The process works because manufacturing tolerances have been improved so much that the gap between the end of one block and the start of the next can be less than the space needed for the reader to recognize a break. There is still a gap, the laser does stop writing, but it is not recognizable because the specification allowed for an even longer one to be ignored.

Back when buffer underruns were common, "burn proof" would have been a boon. Today, an underrun is rare and indicates a serious problem in system configuration which should be addressed, not simply patched over. In a sense, it may be unwise to use the "burn proof" feature because it keeps you from knowing you have a problem to fix. Of course, when the feature saves you a disc, you will feel differently.

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Readin', Writin', Speedin'

Before we get to matters of reading and writing speed, there's a bit of housecleaning to take care of.

In the old days - when a big hard drive offered 250 MB in a full-height 5.25" bay - there was a problem holding tolerances as the drive heated up with use. Those drives occasionally took time out for thermal recalibration. Drives which did contnuous recalibration were able to support continuous data streams, so were designated A/V (audio/visual). Modern drives have much tighter tolerances, so they all recalibrate continuously and don't stop working just for that. Unfortunately, the term 'A/V' has been retained to designate very high-speed drives. But what we care about is that you do **not** need an A/V drive for CD-R. However, remember that if you let your hard drive go to sleep, it will have to spin up again. Now, that's out of the way.

Writing

Okay, how fast should you write? For most users, it is not important. If you are in production, turning out copies of your own Greatest Hits album, then you care. But since modern mastering software uses only a small amount of a modern system's power and permits you to do almost anything while burning, it is no longer a big deal. If you are going to burn a half dozen discs a day or fewer, you will feel less pain waiting for a 4x burner than you will paying for a 16x. It's also a lot easier to find inexpensive media which write well at lower speeds.

Drives are getting faster all the time, so a 24x is better (quicker) than a 16x, right? Not exactly. Up to 16x, speeds do go up uniformly and as expected. But above that, the manufacturers start playing the same game they do with readers: 24x means a maximum speed of 24x, but the job won't be done in half the time a 12x takes. In fact, achieving the higher speeds requires that the laser stop and start to shift write speeds, so all such writers have buffer underrun protection. In itself, that's good, but it can also mean that you don't get the speed you expect. With a high-speed drive, your reader may not be able to keep up (see below) but you think you're being saved by underrun protection. Well, you're not likely to get a coaster, but that protection costs write speed and you may well find that your 24x writer is slower for some jobs than a 16x or even a 12x.

Reading

This primer is about CD-R. If you want a high-speed reader for some other reason, fine - but that is not of interest here. You want a CD-ROM reader to read discs for writing. In order to write "on the fly" - directly from reader to writer through mastering software - your source must supply a steady stream of data as fast as your writer will write them. The hardware provides some buffering of those data, but that is only enough to handle a short transient, typically 6-7 seconds. Modern mastering software provides additional buffering from spare system RAM. Still, eventually the buffer will be drained if the source dries up long enough.

To be sure that your source does not lag behind the demand, it must be able to supply data continuously at the needed speed. A rule of thumb is that the source should be twice as fast as the writer. In general, a CD-ROM drive rated at more than 8x does not deliver constant speed. The speed on the innermost part of the disc may be less than half that on the outermost. As a result, a drive rated at 24x may not be able to provide data fast enough to keep a high-speed writer happy. Complicating the matter further is the fact that audio extraction is often substantially slower than data transfer. Some drives do not do DAE at all; others may be rated 24x but deliver digital audio at 2x, 1x or slower.

Surprisingly, there can also be a problem with a reader which is **too fast.** A very fast reader may fill the buffer very quickly, then sit in idle while the buffer is draining. If that takes long enough, the reader may spin down. When the buffer needs to be refilled, the source starts to spin up again. If it takes too long to supply the data, the laser can be starved and the dreaded buffer underrun may appear. There are many ways to address that problem if it occurs for you: reduce the software buffer, slow the reader or increase its spindown delay. In fact, it may also be solved by slowing the write; that would give more time for the buffer to be reloaded. This problem will only occur when writing on the fly, it is detectable during test, and it can be monitored by watching buffer utilization if your software displays that information.

Emptying the cache

In a Windows system, writing to a drive is usually cached - buffered in RAM. That speeds up normal operations substantially and is necessary in practice if your system is to run well. However, it introduces a potential for disaster in some forms of CD recording. In particular, if you are writing to a packet disc, a lot of information is being held in RAM. Typically, that will include much of the information you want to store and (for fixed-length packets) the directory to all of the disc's contents. If you're in a hurry to get the disc out and eject it manually or shut down the computer without ejecting it at all, some or all of that will vanish. Needless to say, recovering what was in RAM instead of on the disc can be a problem.

When you shut down Windows, if you're smart you let the software establish equilibrium first. If you're writing packets, the same rule applies. Use the software to eject the disc; it will ensure that the pending information is written where it belongs. Save a few seconds by forcing the disc out of the drive and you may lose data, the directory or even the whole disc.

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Recording DVD's

First things first: we're speaking of DVD Movie, aka: DVD-Video. DVD-ROM is handled the same way as any other data source. DVD-Audio will be a whole other set of issues when it settles down. So the question is, essentially, how does one record a DVD Movie onto some recordable, flat medium.

Part one of the answer is that you can capture the movie in analogue or by some digital mechanisms to your hard drive. Whether that capture is AVI, MPEG1 or MPEG2, it can be processed to a form suitable for CD recording: VCD, SVCD or what have you. The result will be at best a collection of CD-Rs playing chunks of the original, usually in poorer quality and in violation of copyright. For example, a 160-minute DVD Movie will convert to three VCD's at less than VHS quality and without the supplements, alternate angles, subtitles and other goodies of the original. If that's what you're after, go to it and keep the copyright cops away.

The following material was provided by a person knowledgable in the industry and represents a snapshot as of early 2000. The industry is changing steadily and we may not be able to keep this page up to date. Still, we'll try.

The thoughts of creating, storing and reproducing long video material with high quality on a single disc are very seductive, and some consumers may be tempted to invest in this technology in order to make their own DVD-Videos. Regrettably, the state of the technology for creating one's own DVD-Videos is nowhere near the ease of use and (relatively) low cost of creating CD-Audio and CD-ROM discs.

First, there's the matter of disc standards. At present, there are four different systems for recording directly onto a DVD-format disc. One, Pioneer's DVD-R, creates discs which can be played in many standalone DVD-Video players, but both the recorder and the blank discs are expensive and are designed for use by professional DVD authoring facilities for testing purposes. The other three systems are intended for consumer use. Only one of these systems is currently available: DVD-RAM, promoted by Matsushita. This system creates discs which can be re-recorded. Two types of DVD-RAM blanks are available: single-sided discs which hold 2.6 gigabytes, and double-sided ones which hold a total of 5.2 gigabytes (2.6 gigabytes per side). DVD-RAM discs must be in a special carrier in order to be used in a DVD-RAM drive. A single-sided DVD-RAM disc can be removed from the carrier to be played in a conventional DVD or DVD-ROM unit.

There are two other systems: DVD+RW, developed by Philips, Sony and Hewlett-Packard, and DVD-RW, developed by Pioneer. Only one such, the Pioneer DVD-RW DVR-1000, is shipping at least in Japan. DVD-RW is also a re-recordable format, but the discs hold more than the DVD-RAM discs and don't require a carrier. Further, DVD-RW is not backward compatible. DVD+RW is compatible, does not use a caddy and is supported by Philips, Sony, et al.

Even with current hardware, though, one still has to capture the video and audio material, digitize it (if it is not already digital), compress the video in MPEG-2 form, and confirm that the video and audio are accurately synchronized before writing a DVD-Video disc. It is possible to make a DVD-Video disc without menus, chapter entry points and the like, and the above process results in such a disc. However, we generally want to be able to access intermediate points in a long video without having to "fast forward" to them. To accomplish this, one must create "chapter stops" at the access points, and menus which allow one to skip directly to a key moment must be created. These are not trivial issues. I am also not discussing subtitling and other features which are usually taken for granted on commercial DVD-Video discs.

Until recently, the hardware and software for the above functions cost US$40,000-$50,000 for entry-level systems, and considerable skill is required to use them. Astarte, a German software company, developed considerably less expensive DVD-Video authoring software. This software and its developers were recently acquired by Apple Computer. Sonic Solutions, one of the primary developers of professional DVD authoring software, has announced lower cost systems, as well. Perhaps it will be possible in a few years for consumers to create their own DVD-Video discs as easily as they can now create CD-Audio and CD-ROM discs. However, for at least the near term, consumer-level recordable DVD systems are only suitable for computer data storage and retrieval.

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AutoEverything

One of the most commonly asked questions about CD-R is: How do I start my CD-R automatically. The answer is simple for some cases, but can get tangled - usually in the case you want.

Auto Insert Notification (AIN)
AIN indicates to the operating system that a disc is present in a drive. If AIN is on, each drive is checked for its contents. That check is important in UDF for the system to recognize how to take control; AIN must be on for UDF software to operate reliably and stably. However, reading your drives when you are burning can be disastrous; most modern mastering software will control AIN so it may be left on safely when running those programs. AIN is necessary for Autoplay and Autorun to work; the OS cannot know to start the disc unless it knows that a disc has been inserted for it to start.

TweakUI
Microsoft offers a program called TweakUI which provides several nice features which probably should have been built into the Control Panel. One of the nicest panels in the program is Paranoia, which gives you an easy way to turn the autostart functions on and off. Since a registry hack would be needed to do the job otherwise, TweakUI is the only mechanism I recommend for controlling Autorun and Autoplay.

Autoplay
If you turn Autoplay on and insert an audio disc, your default CD player will be activated and begin to play the disc with the first track.

Autorun
This can be complicated and it's worth checking Microsoft's site if you're getting fancy or want an icon. For the simple case where you want to execute a file RUNME.EXE, you simply use a text editor such as Notepad or Wordpad to create a file, AUTORUN.INF which you place in the root of your disc. The text need only be:

```
[Autorun]
open=runme.exe
```

That's fine if the RUNME.EXE is in the root, but it also works if the program is in a folder as long as you use the fully-qualified relative pathname for the file. OUCH! No, that's not complicated, but the words are. What it means is that instead of "open=runme.exe", if runme.exe is in the folder direct\direct1 you write "open=direct\direct1\runme.exe" - whew! Similarly, if you want RUNME.EXE to start with a specific file, say START.FIL, then you write "open=runme.exe start.fil" - again using fully qualified relative pathnames as appropriate. ("Relative" means without specifying the drive letter. That's important since you want the disc to autorun in whatever drive is being used and you cannot be sure what drive letter it will have in all cases.)

Well, what do you do if you want to run whatever program may happen to be associated with a file, say FILE.FIL on the user's computer - but don't know what program that is or where it's located? Microsoft has a partial solution to that in Windows 9x:

```
[Autorun]
open=start file.fil
```

Note that you do not control the program that runs because you don't know what (if anything) the user has associated with the FIL extension. She may use MediaPlayer for RealMedia files or she may have some version of RealPlayer installed; she may use Netscape's or Microsoft's browser for .HTM.

Another problem is that your user may be running Windows NT, which does not recognize "open=start". There are several programs for doing that, including SHELLOUT.EXE at this CD-R site. There are also menu programs which give the user options on starting up once one is autoplayed from the disc. Try searching for freeware or shareware choices for "setup" or "start menu" or similar terms at your favorite source, such as www.download.com.

Where to go
For the real skinny on Autorun, search for what you want at http://msdn.microsoft.com/

If you cannot reach AIN simply by right-clicking the drive letter and looking at its properties, see your OS tips here in the primer; a link for TweakUI is there as well, though as operating systems evolve, you would do well to check your OS installation disc first. Above all, feel free to try this stuff; it is simple and demands no fancy software until you start looking at tiered menus with background sound ...

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Tips for Win 9x Users

Jeff Arnold offers:
The following tip can greatly improve CD-R performance under Windows 95. This could prevent buffer underruns and other common problems from occuring. By default, Windows 95 does excessive file caching. This is a waste of CPU time, memory, and possibly disk space, since you will never go back and use anything in the cache. To fix this problem, do the following...
1) Open the file SYSTEM.INI with a text editor (this file will usually be found in C:\WINDOWS or C:\WIN95).
2) Find the section of the file called "[vcache]".
3) Add the following lines **after** the "[vcache]" line.
minfilecache=512
maxfilecache=4096
4) Save the file changes.
5) Reboot your PC.

NOTE: If you have any problems with this setup, you can just remove the lines and reboot your system again.

NOTE: If you have changed the cache and are having problems with DCD recognizing a formatted disc, try backing out this change.

IMPORTANT: Adaptec provides valuable information consistent with Jeff's - and freeware to make things work. For example, you can and should pick up ASPICHK from them. It determines the modules in your ASPI layer and reports whether or not they need to be updated. If you need to update, you can do it with freeware from the same site.

Other thoughts to consider - and not **just** for Win95:

Where possible, put your pagiefile (swap file) on a different physical drive from the one that you are using to store your data.

Defragment your HD before you read data or build an image from a CD.

Defrag the HD from which you will be writing before starting the burn.

A friend reports:
It appears that Win95 is not shy about putting duplicate drivers here and there. You may only see this in "safe" mode, so bring Win95 up in Safe Mode, go to System Properties, and look at Device Manager. If redundant devices appear that weren't visible in regular mode, deleted *all* the hard drive devices, floppy drive devices, and redundant devices ports, etc. Then reboot several times until Win95 finds all the hardware again and installs only *one* copy of each.

Autorun and Autoplay

While packet writing needs AIN, this in itself does not enable Autorun (or Autoplay). For that purpose, I suggest using TweakUI from Microsoft's Power Toys. At this writing, it can be found at http://www.microsoft.com/NTWorkstation/downloads/PowerToys/Networking/NTTweakUI.asp

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NT Notes

Windows NT 4 provides a fine environment for CD-R. Operation is quite similar to that in Win95, but a few comments are worth noting.

NT 4 Server

To use NT Server for burning CDR's successfully you need to use regedit and change the following registry setting:

> HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control \Session Manager\Memory Management

Find a DWORD entry "LargeSystemCache=0". If the value is set to "1", file caching has higher priority than the application code in the fight for real memory. This has the nasty effect that when you handle large files, like a cd image, or a stream of files to be burnt, NT will page out the cdr-software executable (and everything else, except the kitchen sink) to the hard disk. Problem is that in the next instant NT finds that it needs to page the executable back in as it is actually running and handling these large files NT made room for... So the system will keep bouncing the program code in and out of memory, competely annihilating the system throughput, until you end up with a coaster. If I remember right, is this value set to 0 (as desired) as default on NTWS, while it is set to 1 (coaster city) as default on NTS. It is quite possible that the install (or use) of the Server resource kit caused this change to the "standard server value". This tip might be useful for anyone wanting to use NT Server when making cdrs. I run Server myself, and have no problems burning provided I do this single change to the registry.
Provided by Glenn, glennb@algonet.se

Iain Jenkins, ijenkins@btinternet.com offers the following variation on the above and additional data:

The change can be implemented using control panel as follows:
Go to control panel - network - services - server click properties
optimization change from the default "optimize for file sharing" to "maximize throughput for network applications" dismiss boxes
job done on reboot!

Another tip for setting the DMA on/off on NT for EIDE devices (it doesn't appear on the drive settings as in W9X):
Extract program DMACHECK.EXE from your service pack (3up) disk, and run it - it will give you the chance to control the DMA setting. If it doesn't give you the choice, you can still fall back on regedit to give you the desired results (it doesn't always allow DMA to be set due to incorrect device detection)
Go to: HKEY_LOCAL_MACHINE\System\CurrentControlSet\Services\Atapi\Parameters\Device X (where X is your hard disk/CD no.) look for a key DmaDetectionLevel (It may need to be created) DMA set as required:
0x0=off
0x1=on
0x2=forced

Also, check the file ATAPI.SYS for at least version dated 1/98.

Auto Insert Notification

Again, this takes editing the registry.

HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\Cdrom

Enable AIN by setting the value of Autorun to 0x00000001 (1)

NOTE: This in itself does not enable Autorun (or Autoplay). For that purpose, I suggest using TweakUI from Microsoft's Power Toys. At this writing, it can be found at http://www.microsoft.com/NTWorkstation/downloads/PowerToys/Networking/NTTweakUI.asp

ARTICLE-ID: Q168113 TITLE : Using Windows 95 PowerToys with Windows NT 4.0 Additional Information. There are two other keys that can affect this functionality:
HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Policies\Explorer
NoDriveTypeAutoRun=0x00000095
HKEY_USERS\.DEFAULT\Software\Microsoft\Windows\CurrentVersion\Policies\Explorer
NoDriveTypeAutoRun=0x00000095
The correct value for each is 0x00000095.

Making a Boot Floppy (NT4 or 3.51 workstation)

There are times when Windows NT won't start, and you know why. If this occurs, you can go through the usual procedures to restore the system, but since you know what's wrong, you can get running again more quickly if you have a boot floppy. To create one, insert a floppy disk into Drive A. Right-click on the floppy disk icon and choose Format. Format the disk using Full Format (just to be safe). Now open Windows NT Explorer and click on the root folder (usually C:\). Copy the following files to the floppy disk:
Boot.ini
Ntdetect.com
Bootsect.dos (for dual start-up installations)
NTLDR
Ntbootdd.sys (if it's in the root folder, copy it)

If you don't see these files in your root folder, choose View, Options in Windows NT Explorer. Select the radio button labeled Show All Files. Click Apply and then OK. Now you should see the files. If you don't, press F5 and look again. Using the boot floppy, you can boot into your damaged system and make the appropriate repairs.

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Standalone CD Recorders

This page was provided by a correspondent. To the extent that I have information on standalone recorders, the information is correct. I also take full responsibility for the footnote. For the rest, I am only the relay for the following.

> My experience has been with three models: Philips CDR-765, Tascam CD-RW 500 and HHb 800. The basic principle is that consumer models such as the Philips will only work with Digital Audio or "audio" discs. An audio disc is basically the same as a data disc except that it has a flag in the ID info track of the ATIP which identifies it as an "audio" CD. It carries a higher price tag because of the royalty added to consumer audio media like cassettes, VHS tapes etc. to reimburse the "industry" for copyright infringement. Data CDs are cheaper because they are not considered media for consumer use where copyright infringement is going to be a primary concern. Professional level CD-Rs can use data discs because of the anomalous law that says that assumes only consumer equipment will be used for infringement. The Philips could be tricked by swapping a conventional data disc for a Digital Audio disc at the right point in the cycle; these units are no longer on the market.
>
> Pro and consumer recorders also differ in the handling of SCMS - the "copy bit" with values of 00 for unlimited copies, 01 for one more digital copy, 11 for no more digital copies allowed. Consumer audio hardware will write 01 on the first burn, and then on a copy of anything sourced as 01 will write 11 so no more copies can be made. Pro audio gear will almost always write 00 and ignore 01 and 11 so you can make copies through optical or coax digital connections; AES/EBU digital connections don't pass SCSM info so are always ready to copy.
>
> There's also a new level of standalones, the so called "prosumer" - hybrids of consumer and pro hardware. Priced in the $500 - $700 range, you get lower cost of the initial unit, ability to use data discs, and in some cases no SCMS. The Tascam 500 is a studio unit (about $750 new) which I hooked up with a coax digital connection to my CD player for copying. Since it records in real time, a 74-minute CD takes 74 minutes to create. It syncs track IDs so the CD will be ID'd exactly like the original - very handy for letting it record and coming back an hour later to switch discs.

Footnote: There have been reports that Digital Audio media do not record correctly in some computer CD-Rs. While their higher price without payoff makes them unlikely choices when not needed, you should be aware that they may not work in your computer-based recorder.

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Standalone DVD Recorders

There is remarkable variety in the features, functions and products of the various models of DVD recorders. Whether writing DVD+R or DVD-R, not all discs which **should** play in a specific set-top box will do so. Even more surprisingly, not all will read correctly in a DVD-ROM drive. In short, at this writing, the technology is immature and consistency cannot be assured.

There are two broad categories of standalone DVD recorder: those with and those without hard drives. Without a hard drive, only very limited editing is possible and primitive titling is the most that can be expected. These units are generally stripped to the bare essentials; they can provide time-shifting for off-air recording and some limited copying from tape (the units combining VCR and DVD recorder are a little more capable). Still, if all you want to do is put a tape onto DVD for quick access, space saving and economy, any recorder will do and a hard drive is not needed.. Typically, any DVD recorder will allow you put as little as one hour or as many as eight hours onto a disc. Of course, the slower speeds give lower quality.

With an internal hard drive, the recorder has a great deal more flexibility. The capacity of the drive is seldom significant since it will surely be capable of recording more than you will ever want to store on it; typical values are 100-300 GB where 40 GB is ample in practice. Additional features, such as 1394 input and output to a computer may be of value. After trying a variety of recorders, I settled on a Panasonic DMR E-85H. What follows is based on its operation so YMMV - Your Mileage May Vary - with another model or manufacturer. Note that typical of the breed, the Panasonic uses proprietary formats except for the finalized DVD-Video. Even then, the disc may not duplicate readily since it can appear to be larger than it is - and 7 MB larger than the nominal capacity of a DVD-5 disc.

The unit will write directly to DVD-R or DVD-RAM. Going to DVD-R it has the convenience but all the limitations of a recorder without a hard drive. Writing to DVD-RAM, it can be used as though a DVD-RW but has the added advantage of being able to write to the HD digitally; from DVD-R or DVD-Video, one can only dub to the HD in analogue.

Given the quality available on a DVD and the limitations of videotape, even an excellent tape may be recorded in four-hour mode (usually designated LP) without visible loss. Even six-hour (EP) does not entail much noticeable loss. Similarly, while each passage through analogue costs some quality, it is seldom noticed; of course, digital copies are identical with the original.

Once the program is on the HD, it can be split into distinct titles and each title can have many chapters. For example, you may want to convert a tape of a play into a title for each act and a chapter for each scene. A concert may be split into a title for each group and a chapter for each number. In switching from one title to the next, there is often a brief pause; between chapters, play is continuous.

Starting with such a tape, you begin by determining the full length you will want on the resulting DVD-R. The next step is to record it to the HD. By choosing the total length as the time to be recorded, the machine will set compression to fit the material onto a standard disc. In that way, you will get very nearly as good a transfer as possible; an alternative, say choosing LP (4 hours) for a 3-hour tape will cost some quality with no advantage. Besides, when copying from a tape in variable-speed mode the recording will automatically stop at the preset time, where it will keep going in one of the specified speeds.

Because you will start the recording before you want the disc to begin and end after the end you want, step two is to shorten the total recording. During editing, you will also want to shorten it to remove any interruptions such as ads, promotions, lead-in to the next act, interruptions in the signal. So scan through to see where you want to create fresh titles, noting along the way any shortening that's needed. If there is no shortening to be done in a title, the next step is to divide the full recording to split off the first title. Repeat for the second, shortening as needed. When all titles have been defined, it's time to enter chapter stops. You also want to set the thumbnail and enter the name for each title to make the menu attractive as well as useful.

A separate menu is provided for chapter work. In it, you can divide and rejoin chapters. That contrasts with dividing and shortening titles; modifying chapter stops does not alter the files and can be redone at this stage. In practice, you may well choose to make one disc with one set of chapters, another from the same capture with a different set.

At that point, you switch over to the disc-level menu; you've been working at title level so far. The first step here is to dub the program you want from the HD to the DVD-R which will become a DVD-Video. There are two fundamental ways to do that dubbing: at high speed or at a selected lower speed. At high speed, everything you did on title level is written to the disc; at a specified speed you lose chapters and thumbnails. For example, suppose you have a long program to record, one running over three hours and divided by an intermission. You might want to create one disc for the pre-intermission period and another post-intermission (shortening to remove the intermission itself). Then you might record the two parts separately at SP to get the highest quality for each part with separate chapters set for each scene or song. But for convenience, you might then put them all together as a continuous program at LP or at a set variable-speed. For that, you still have the separate titles, but need to set the thumbnails anew and take chapter stops dropped in about every six minutes.

When the dubbing is finished (real-time for a fixed speed, about a half hour for high speed), you can adjust thumbnails in title mode on the DVD-R; if you used high speed, that's not needed. Then in the disc mode, you choose the disc setting option to give the whole disc a name, select the background for the menu page, and choose whether to start playback with the menu screen or with the first title. On the Panasonic, whenever a title completes the next is begun; after the last title, you are sent to the menu. It would be nice to have an option to go to the menu after each title, but that's not offered and you need to use the menu button on your remote. Note that this unit permits only a single-level menu.

The last step is to finalize the disc, writing the menu information and chapter stops to the DVD-R or DVD-RAM. That short operation (2-3 minutes) makes the disc playable in most set-top machines and readable in a DVD-ROM. While the total time needed can run more than twice the running time of the program, your involvement in the process will take only a few minutes (depending on how many chapter stops you want to set and the amount of shortening needed). The result can be very professional indeed.

A final note is in order on media. Recordable DVDs, like recordable CDs, are less than perfectly reliable. With a hard-drive recorder, if the copy to DVD-Video fails, another is simple. Without the hard drive, you will have lost a broadcast and at best will have to repeat the work of transferring from another source. In addition, these recorders operate at low speed; even the Panasonic writes no faster than 4x. Therefore, high-speed media may be no better and are likely to be worse in these machines than those designed for lower speeds. Note, too, that the speed marked on the package may not correspond to that encoded on the disc. The situation is similar to that on CD-R, so verification of disc properties in a computer-based DVD writer is recommended before you commit to a quantity of blanks.

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Configuring Storage

This page is about hard drives and partitions. If you already know all there is to know on the subject or if my recommendations - which are only slightly related to CD recording - are of no interest, please move on.

The current fashion in computer systems is to deliver them with a single, large drive formatted in a single partition. Simply put, that's a recipe for inefficiency and an invitation to poor practice. The first time you try to back up 40 GB or to search 20,000 files, you'll appreciate both factors - and if you decide to defrag that partition after some weeks of fragmentation, you'll be lucky to finish the job overnight.

Run two physical drives

Writing from one defragged drive to another is quick. The heads progress on each as quickly as they can and information is transferred at nearly the sustained rate of which the hardware is capable. Writing within one drive, even between two partitions, requires that the heads seek from each read sequence to the corresponding write. Seek time is **very** long compared with read and write times. For example, backing one partition up to another on a different drive is several times faster for me than backing it up to the same drive. Every time you move a large file - for example, to write the Undo for a WAV you're editing - you will see the difference.

Make partitions for use

There are three sorts of information stored on most computers:

- Operating system and essential utilities
- Applications programs
- Large-scale working data

Operating systems are getting close to a Gigabyte. Add in the utilities to support your hardware, the pagefile/swapfile (on the boot drive to handle error logs) and the like and you need a 2-GB C: partition. Some people want Gigabytes of application code, but for the most part they are simply holding applications they think they may want to consider starting to learn some day (when they'll be outdated, but who's counting?). Another way to bloat the applications partition is to throw in all the sample files and tutorials the publisher provides; just because the file is on the installation disc does not mean that it needs to be on your hard drive. If you look at the programs you use, you're likely to find that they, too, will fit into 2 GB with room to spare. (Of course, many applications use data only sparingly. Your accounting data, for example, logically stay with the programs that write them.)

Now for all those MP3s, WAVs, TIFs, JPGs, MOVs, AVIs, ... you absolutely have to have. That's cool and there's no reason not to have them accessible on your hard drive when storage is so inexpensive. The fact is that those files are not used the same way as your OS and apps. They are not searched for the same reasons and don't require the same sort of backup. Good practice says that when you've written some hundreds of MB since your last backup of those files, you write a CD-R with the new ones and mark the disc so you can find the files again. Logically, you make big - okay, **BIG** partitions for them. You don't back up those partitions, you back up their files. You don't search thousands of DLLs to find the MOV you want; you search the partition with a few dozen MOVs, AVIs and so on.

Since you're reading this primer, you are presumably also writing CDs. If your writing from a hard drive, you known that that partition should be defragged. In fact, the easy way to do it is to make one or two partitions of 1-2 GB each and to leave them empty as a rule. When it's time to write that disc, just put the source files into the empty partition - no defragging needed because the files don't fragment when you write them that way. Even if you have managed to fragment that storage, defragging such a drive is quick and sure.

My primary system

At this writing, I have two, 20-GB EIDE drives on my system. Each has three partitions: two are FAT16 (2 GB) and one is NTFS - it could be FAT32 just as well. Drive 0 has C:, E: and G:. Drive 1 has D:, F: and H:. G and H hold current backups of D: and C: respectively and can be reached from a DOS boot floppy. C: is the boot partition with OS and such; D: is the application partition. G and H have plenty of space left to hold the files to write a CD. E: and F: are the work spaces. My downloads go into a dedicated folder there and are checked for viruses regularly. Audio and video files are held there while I'm working with them and while waiting to be backed up in logical chunks to CD-R. I put my TEMP folder there as well both to speed up file transfers and to be sure I won't run out of space. And by having two such partitions on different physical drives, most of my work with large files runs at high speed.

One footnote is worth adding, I hope. The documentation will assure you that storage efficiency goes up with FAT32 and NTFS. That is certainly true - but it doesn't matter. Today, you buy Megabytes of storage for a penny; how much is it worth to save a few tens of Kilobytes per application? Like backup software, partitioning for backup is very cheap insurance. I back up C: and D: at least once a week; it takes about ten minutes total and I can burn the CD-R copy when and if I wish. I don't back up the other partitions, but I do keep CD-R copies of the important files they contain and can rebuild either easily if needed. If I have a head crash on either drive, I can be back on line in half an hour with the full system by restoring what's needed from the other drive. (Admittedly, there can be a problem with installs since the last backup, but I can reinstall anything I put in over the past few days.)

Finally (at last!), if you buy the thoughts above and want to modify your configuration along similar lines, you will find PowerQuest's Partition Magic an easy way to do the job.

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A 650-MB WWW Site

Let me begin by saying that my primary use for CD-R is not that of most others. Before I bought my first writer, I defined what I wanted to do with it and how. The result has been (through September 2000) twenty-one CD-ROMs pressed for me and distributed through the Internet to a small but appreciative 'market'. This note traces the logic leading to the selected format(s) and suggests tools for following that lead.

Format: Why and How HTML

My objective has been to make files in various formats easily accessible to users with limited computer skills. I quickly reduced the options to two: Adobe Acrobat's PDF and HyperText Markup Language - HTML, the language of the World Wide Web. Acrobat offers several distinct advantages: well-defined formatting with esthetic values such as multicolumn text, explicit placement of graphics and full-text search. It shares with HTML the ability to link elements and to operate freely across platforms. HTML won out for me for several reasons, notably the ability of the user to run a browser she already knew and the flexibility to adapt that browser to her particular needs. If she is running a monochrome display, monochrome options are at her fingertips; if she needs larger type, she may simply set her defaults. In addition, creating and editing HTML is easy with tools of moderate cost and ready availability and, perhaps most telling of all, one can easily embed a PDF into an HTML file, but not HTML into PDF. Finally, PDF would have required the user to acquire a reader and to install it onto the computer; I wanted a self-contained, machine-independent configuration.

Because I want my discs to read on as wide a range of platforms as possible and with the least limitation on personal configuration, I use only the most primitive forms of HTML. Fonts are set with H1-H6 rather than by specifying them. There are no frames and very few tables; in fact, inline and background graphics are used to supplement text instead of to replace it. As a result, a user can browse any site or CD-ROM I create with virtually any browser and retrieve from it whatever her tools support. Another plus for HTML is that if a format begins to be supported, I can add it to my 'site' and the user can get it on her own for her platform. In a word, I can deliver the product we both want without requiring the user to adapt to my means of delivery.

To create the HTML, I use HoTMetaL Pro, a powerful language processor which implements far more than I need. One of its virtues is controllable enforcement of rulesets. I can pick the flavor of HTML I want to use and have the program enforce it as I write or after the fact. You will not be surprised to find that I use the most limited ruleset available and keep it on at all times. If you prefer a less costly approach, such as the shareware HotDog, that's fine, too. However, I do **not** recommend that you use HTML export or authoring from programs not dedicated to the purpose. They tend to produce code which looks just right to you - and fails miserably when seen on another system. In fact, they throw away many of the advantages which attracted me to HTML in the first place. They often implement the specific font choices you made when you wrote instead of leaving options open for the user. I want to create an open shop with its wares laid out for all visitors to see and to use; those programs tend to organize the shop into the specific pattern you see on your screen and to force visitors to see it your way.

My Recipe - Flavor as you wish

Unlike a site on the WWW where a few megabytes are stored, the CD-ROM offers 650 MB and needs careful organization. My discs are organized with a home page that provides direct access at the top to the major components, technical and legal information as required, and advice at the bottom on special needs for configuration and helpers. Because I work on a PC and most of my customers are on PC's, I develop first for that machine and then through beta test verify operation on other hosts (both Mac and Unix). However, I do nothing that I can avoid which would keep a user out. On my latest discs (read about them here), I do require MP3, which is not built into all browsers.

I include on each disc everything needed to get up and running. For a novice on a PC (running Win 95 with Autorun ON), the disc is inserted into the reader and autoruns. I bought a royalty-free license for I-View, a compact and flexible browser designed for use off-line. I obtained permission from the authors to include freeware not only for WinAmp but also for a suitable Mac browser and helper. A Mac user can run an existing browser (or may look at a MACREAD.TXT file in the root) to install the included browser and helper on his own machine. Of course, if the user prefers another browser and is willing to add the MP3 or other helpers required, that option is also open. Again, everything is kept as simple as possible; elementary menus are used instead of frames or tables; the user is given the greatest possible flexibility.

With HTML, cross-referencing is my job before I create the disc, but that access is easily supported. Suppose I want a record of my family's history and have video clips, still photos and audio recordings prepared for inclusion. I can supply a page of Uncle John with a portrait and text and with links to sound and video clips and to scenes in which he figures prominently. I can link to that page from a page with the family tree or from each page of narrative text in which his name is mentioned. I can even take a family picture and provide a link from his area of the photo to 'his' page. Note that the same page or the same file may be linked from each point where it seems fitting to me.

Special cases and methodology

On three of my CD-ROMs, I incorporate the history of my primary WWW site. That is easily done by taking the individual pages that have been posted and linking them either chronologically or by subject. The result is a large, instantly accessible site on the CD-ROM. Note that I have to be careful because of the way most browsers operate. For example, I use playlists of MP3 files, but neither MSIE nor NN will play them from the disc. I-View has no trouble doing so because it is designed for the purpose; to make a conventional browser work, it would have to know where to find the CD-ROM. The usual browsers load the playlist into the TEMP folder, then look for the referenced files there when they are acutally on the CD-ROM. On a PC, they want the letter of the drive (which, of course, I do not know on the user's machine); on a Mac, they could use the volume label, but for some reason they do not. Only by testing can those cases be found and even there you need to be sure to use a variety of hosts and of configurations to be confident. (I goofed on one disc and some files are only playable on machines with more than 32 MB of RAM; I made a change which imposed that requirement after testing was complete and have been embarassed by the awkward workaround for the finished discs.)

My way of building the disc relies on my own system hardware and preferences; yours may vary. I start with an outline of what I want to do on that disc and an overall map of its organization. I break that down into pages and groups of pages to be written. As I prepare material for each page, I write the supporting HTML and check it on that level. I store the pages on a Jaz and periodically make a CD-R copy for backup. (Typically, I have several projects in development and dedicate a Jaz cartridge to each. Then I can work on that project simply by selecting the appropriate cartridge.) My home page for the disc is built in outline form; fleshing it out is the last step and exploits what I have from previous efforts.

Periodically, I run HTML Power Tools to verify my linkages. I skipped that step on my prototype; as a result, it has both duplicate files and broken links. When I have a viable version of a new project, I send it out to testers who are knowledgable in the computers they use and the subject matter. While they evaluate the work, I write the home page and work on other projects. As the testers feed back, I return to the job with a fresh eye and make changes as appropriate. That is also a time when I may add another cross index or additional text, but not additional files unless I'm prepared to ask for retest. I also contact the person who will press the disc and prepare the graphics and other materials needed for production. When the process is complete, I again run HTML Power Analyzer to verify the layout, then burn a couple of CD-Rs to check yet again on my PCs. Finally, I drop the discs into the mail to the pressing plant and erase the Jaz. I interact with my broker, Digital Bim, by e-mail and by telephone. About a month after mailing the masters, the finished product is delivered and ready for distribution. For your information, the cost of having discs pressed is roughly $600 for 500 copies, $850 for 1000 copies.

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Interoperability

"Interoperability" means a design supporting operation on multiple platforms or in multiple environments. In general, it means giving up features restricted to specific computers, operating systems or applications in favor of finding more users. Interoperability is seldom universal and is generally expensive: you have to give up a lot to increase your market.

If your CD recording is for your own use, interoperability is worth very little to you - and you are invited to skip the rest of this page. Or not. You know what computers and other devices you intend to have run your discs, so where's the issue? Simply put: do you know how you'll want to use them next week? Do you know you won't be installing a new OS, buying a new player or otherwise changing your base of operations?

The most nearly universal format for CD recording is Compact Disc - Digital Audio, CD-DA, redbook music. The standard is rigid and universal; there are extensions such as CD-Text, but adding them does not cost operation on equipment which does not support them. The problem with CD-DA is a consequence of its interoperability - inflexibility. If you want to play a CD of 1925 monaural 78s, you have to use the same audio parameters required to get year 2000 stereo. There's room on that disc for at least four times as much music without noticeable loss of quality (22.05 Ksps, monaural), but the standard will not permit it. If you write MP3s instead of CD-DA, you can put about 45 hours at 32 Kbps onto a CD-R which would hold only 74 minutes of redbook audio - but then you lose interoperability with all those audio CD players. That may be quite acceptable to you - you have an audio player which handles low-rate files without complaint. However, that won't help your neighbor whose MP3 portable demands 44.1 Ksps; or the guy down the block whose CD player only plays CDs - CD-DA recordings.

The problem shows up in many areas other than audio format. One is file naming. Your MP3 player, like your computer, displays information with which you can select what you want to do. Different players have different rules for that display, for the handling of folders and for tolerating multisession recording. Different operating systems on computers have varying rules for filenames as well. Fortunately, all common systems will handle strict ISO 9660 naming: 8.3 with a restricted character set (upper-case letters, numerals and the underscore). All MP3 players so far will handle a single-session disc without folders and eight-character names having an extension of MP3. As you stray from those rules - longer names, folders, additional characters, multisession - you lose platforms to play your discs.

If you want to include text and graphics on a disc, you have many ways to format it. Of course, TXT is the most readable. As with ISO 9660 filesystem, TXT is nearly universal, though very limiting. Other common formats are DOC (Microsoft Word) and PDF (Adobe Acrobat). If a sufficiently restricted set of capabilities for either one is used, free downloadable programs make those readable on most platforms. Another choice (my own preference in most cases) is HTML. But with any of those, you can write an elaborate version which is readable only with some versions of Word, with an advanced Acrobat reader or with a specific browser. It is your option whether to use features which enhance your product and restrict its use by others. For example, different browsers implement various features of HTML and supersets of HTML which others either treat differently or regard as errors. Most will handle mouseover (where the display changes when you pass your mouse over a target area), but some will not so you will lose the vision-impaired and others with graphics turned off or unavailable. On a simpler level, there is a small set of diacritical marks - accents and the like - which are handled easily in standard HTML, but go beyond them (to true single- and double-quotes, for example) and some browsers will give unintended results.

It is your choice when you design your project to build in interoperability. The point of this note is to induce you to think about the question at the beginning. Once the disc is designed, it is difficult or even impossible to extend its usability.

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A New Medium - New Ideas

CD-R technology can allow us to realize familiar things in familiar ways. We can back up CDs and CD-ROMs, we can save archives to a nearly permanent medium easily and economically. We can transcribe tapes and LPs to CD's. We can even back up our computer systems. Yet there are potentials here which are not yet being exploited - at least, not extensively - that offer new opportunities.

Browse your disc

One architecture for a CD-ROM is that of a WWW site. If that format is used, one simply browses it with one's choice of browser on any appropriate platform. The directory is not printed on the traycard - it is in the HTML with which one accesses the files. No looking up the track number or filename; just click on the link. I have been using that architecture for several published CD-ROMs, with excellent results. I am using a variety of formats - HTML, GIF, JPEG, WAV, MP3, MPG - to get a rich blend of content on a single disc.

Disc Jockey Time

We all know the virtues and the limitations of the CD: great sound limited to less than 80 minutes; continuous or selective play with the sequence predetermined on the disc or requiring programming into the player. But there is a viable alternative allowing more music to be stored on a disc and accessed in whatever order is appropriate for the job.

Suppose that the tracks are recorded on a CD-ROM, not in CD-DA format, but in WAV or MP3. Then playlists can be constructed which preselect track sequences for specific purposes: an hour of slow dancing to end an evening, twenty minutes of increasingly upbeat tracks leading to the climax of the evening, three hours of Glenn Miller for the 'mature' audience, and so on. If special needs arise, one list can be modified in real time or a new one can be constructed while another is playing. A single CD-ROM can then hold ten hours or so of music to fill a full gig.

Playback? Instead of carrying a stack of CD's and CD-R's to the party and hoping that the host's CD machine is good enough, carry one disc and a laptop you know. Connect its line out to the local sound system and you have full control right from your computer. With a program such as WinAmp from http://www.nullsoft.com/ you can call up a graphic equalizer to tone things down or to tune the sound to the local system. WinAmp and other programs for WAV and MPn also support simple scripting and both sequential and quasi-random playback.

Footnote: Two at a time!

So, does it make sense to put both of those ideas together? You bet it does! When I'm working on a disc, I write the HTML and the files - usually, MP3 and JPEG - at about the same time. I use only relative addressing and provide a folder for each logical collection with all required files. Then I can check things out with browsers on a folder level. When I'm ready, I add a home page linking to the HTML in the folders, add I-View, WinAmp and whatever else is appropriate, run some checks with analysis tools and play with it a bit - and then burn away.

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Bijlage 9: Reference Guide for Optical Media

REFERENCE GUIDE FOR OPTICAL MEDIA

Content Links

FAQs about Optical Media

There is a great deal of misinformation, hype, and misunderstanding in the field of optical media. Memorex wants to help customers make educated choices about the media and formats they choose; so we have assembled a list of Frequently Asked Questions and the Memorex Reference Guide for Optical Media covering the subject in detail. Click on the blue text to get to the answer to any question. Some answers will include additional links to the Memorex Reference Guide for Optical Media for even more information.

Digital Audio

1) There's "analogue" and there's "digital." What's the difference?
2) What's the difference between a "bit" and a "byte"?
3) How can a computer count using just 2 numbers? (The binary counting system)
4) How much data can I fit on a disc?
5) How can a computer store and play music?
6) Some people say analogue is better than digital. Others say the opposite. Which is correct?
7) What's the difference between a "medium" and a "media"?
8) How do CDs work?
9) A scratched CD can still work most of the time. How does a player correct those errors?
10) What do people mean by a Red Book specification?
11) Are CDs and CD-ROMs the same? Why is there a "Yellow Book" for CD-ROMs?
12) My computer drive won't play CDs. Why not?
13) There are a lot of abbreviations used in talking about CDs. What do these mean?
    a. ATIP
    b. BLER
    c. CAV
    d. CIRC
    e. CLV
    f. E11
    g. EFM
    h. HDTV
    i. MPEG
    j. MP3
    k. OPC

CD-R Recording

14) CD-Rs are recordable CDs. How can they record information?
15) I've heard greenish CD's are the best. Is that true or is there a better color?
16) CD-Rs used to be gold; now they're silver like CD's. What's the difference?
17) How much can a CD-R hold?
18) Are 80-minute CD-Rs better or worse than 74-minute discs?
19) What about 90-minute discs?
20) Why won't some CD-Rs work in my stereo CD-R recorder?
21) My CD-Rs won't play. Are they defective?
22) CD-Rs are called 12X, 16X, 24X, 32X, 40, 48, and even 52X. What's the difference?
23) Are faster rated discs better than slower discs?
24) Is it better to record at slow speeds or fast speeds?
25) I have an older drive that records CD-Rs at 4X. I can only get discs now rated at 40X or more but they sound terrible. Are the discs worse now than before or is something wrong with my drive?

26) I'm very careful about protecting the bottom of my CD-Rs, but someone told me the top is more fragile. Is that true?
27) How long will CD-Rs last?
28) I've heard that the colored discs are different from plain discs. Aren't they just painted CD-Rs?
29) How can a laser read through a black disc?
30) What's the best way to label CD-Rs and CD-RWs?
31) What's the best way to store CD-Rs and CD-RWs?
32) I upgraded from a 4X drive to a 24X drive. Why doesn't the new drive record 6 times faster?
33) My recordings fail due to "buffer underrun." What does that mean?
34) I have a 32X recording drive, but I can only record at 24X on Memorex discs that are labeled as 48X. Are these discs defective or mislabeled?

CD-RW

35) Now some CDs are erasable. How can they get erased?
36) What do the numbers 32/12/40 on CD drives mean?
37) I bought a 32X CD-R drive before I realized drives could go to 52X. Should I upgrade to take advantage of the time savings with the faster drive…or do I run the risk of disks blowing up in my drive?
38) I bought some 8-24X CD-RW discs that won't work with my high-speed drive. The drive can record CD-RWs rated 4-12X. What's wrong?
39) I can't format Memorex 1-4X CD-RW discs, but other brands work. That means these discs are crummy, right?
40) Will "high-speed" CD-RW drives work with any CD-RW?
41) I bought 700MB CD-RWs, but I can't put more than half a gigabyte on them. Are they defective?
42) I have a whole spindle of defective CD-RWs. Every disc fails to format. How can every disc be bad?
43) What's the difference between "ripping" and "burning"? Or are they the same?

DVD and Recordable DVD

44) How can DVDs hold more if they're the same size as CDs?
45) What's the difference in a DVD 5 versus a DVD 9? How many versions are there?
46) What's the storage capacity of a DVD?
47) My DVD player won't play CD-Rs but it plays music recorded on a CD-RWs! How can that be?
48) Now people can record on DVD, but there are 3 different types? Why?
49) What's the difference between the types?
50) I've heard that my home video cassettes will deteriorate in a few years. Which format should I pick to transfer them?
51) What's DVD-R?
52) Can I copy rented DVDs onto DVD recordable discs to build my own library?
53) What's DVD-RW? How is it different from DVD-R?
54) What's DVD-RAM?
55) What's DVD+RW? There's a DVD+R, too. Does the plus mean it's better than the minus?
56) Will any of these recordable DVDs play in my DVD player?
57) I have a 12X CD-R recorder. What speeds are there for DVD recorders?
58) I've heard that if I use the wrong speed disc in my DVD drive, it can be destroyed? Is that true?
59) I tried to record a 4.5GB file onto a 4.7GB DVD+RW but it wouldn't fit. How come?
60) My DVD drive won't record on Memorex DVDs. Is the quality that bad?
61) I have a choice of CBR or VBR in my video capture. What are they?
62) What are VR formats?
63) I captured my tapes at the highest "MPEG-2 quality." Why can't I make a DVD?

64) What is the best bit rate to choose when I capture video?
65) My DVDs don't look as good as the VHS tapes they came from. Aren't DVDs supposed to be better quality than VHS tape?
66) Once I've made DVD copies of my camcorder footage, can I throw away the tapes?
67) I tried to copy my VHS movies onto DVD, but they look terrible. Do I need better quality discs?
68) How many minutes of video can I record on a DVD recorder?
69) What do I need to record video onto DVDs?
70) Which of these formats should I buy?
71) Which is the best format?
72) I have a video DVD recorder that can record at 24X, but a friend says the fastest speed is 16X. Is he right?
73) I tried to format a DVD-RW, but I got an error. Now I can't erase the disc because my drive tells me it isn't even there! What did I do wrong?
74) Can a DVD play high-definition video?
75) I've heard that blue lasers are coming. What does that mean?

The answers to the questions follow below. Click on the link to the Memorex Optical Media Guide to get more detailed information, including pictures and charts. If you have a question not listed in our FAQs, E-mail the question to us; and we will add answers to the most frequently asked questions.

Digital Audio

1) See the Reference Guide for Optical Media section "Analogue vs. Digital."
2) A "bit" is a **b**inary **di**git; a "byte" is a digital word of eight bits. (Refence Guide)
3) The computer uses a binary counting system instead of our usual decimal system. (Reference Guide)
4) Reference Guide, Figure 1.
5) Reference Guide, "Digital Audio."
6) Digital audio sound is not perfect. Nothing is. But the distortion, noise, and mechanical concerns of CDs, for example, are far less than that of other popular media. For example:
    a. Distortion is many orders lower on a CD than on an LP or a tape.
        i. An LP has "low" distortion at only 2 points with regular tone arm geometry.
        ii. 3% Harmonic distortion or saturation defines a tape's highest record levels.
    b. Dynamic range for a CD is above 90 decibels and uniform across the disc.
        i. LP S/N ratio is low and worsens toward the end of a record.
        ii. Tape needs assistance from noise reduction circuits to overcome hiss.
    c. Noise
        i. The LP has pops, clicks from debris or damage in the groove.
        ii. Phonograph tables suffer from rumble noise.
        iii. Tape has bias noise, modulation noise, DC noise.
    d. Mechanical alignment problems and alignment issues.
        i. Wow and flutter for both LPs and tape
        ii. LP stylus height, overhang, anti-skate, tracking force, resistance/capacitance
        iii. Tape head height, zenith, and azimuth alignments and torque adjustments
    e. Wear
        i. The stylus wears the groove in the LP; the stylus itself suffers from wear.
        ii. Tape heads wear; there are magnetostrictive effects on some tape formulations that reduce high frequencies; rub-off of oxide/binder

    The CD is not a perfect medium, but it will sound more like the original recording in a far wider variety of playback systems than either a vinyl LP or a tape cassette possibly could.
7) A "medium" is the carrier **in the middle** between a source of information and its intended audience. TV is a medium. A CD-R is a medium. The word is single. More than one medium are "media," the plural of medium. TV is one news **medium**; TV, newspapers, and

the radio are news **media.** Almost no one in any media business, whether news or discs, ever uses the words correctly.

8) Reference Guide, "How a CD Works."
9) Circuits to identify and correct expected errors are built into CD players and drives. See the highlighted Reference Guide section for a detailed, but not too technical explanation.
10) The Red Book is the book published by Philips defining digital audio discs.
11) Although they look the same, the information on audio CDs and CD-ROMS is arranged differently. See Reference Guide section discussion.
12) The CD drive in the computer probably has no audio software to identify and support the playback of audio CDs. It only recognizes CD-ROMs with data. It may be necessary to add audio software and even a sound card to the computer to get it to play music.
13) Abbreviations:
    a. ATIP Absolute Time in Pre-groove
    b. BLER Block Error Rate
    c. CAV Constant Angular Velocity
    d. CLV Constant Linear Velocity
    e. CIRC Cross interleaved Reed Solomon Code
    f. E11 an Error with 1 bad byte corrected at C1 stage
    g. EFM Eight to Fourteen Modulation
    h. HDTV High Definition Television
    i. MPEG Motion Picture Experts Group
    j. MP3 Motion Picture experts group layer 3
    k. OPC Optical Power Calibration

CD-R Recording

14) See Reference Guide, "How a CD Works."
15) The color of the CD-R is a combination of the dye used and the reflective mirror layer behind it. Different dyes have different characteristics, but there are many more important factors that determine the quality of a disc than the dye and its color. See Reference Guide, "CD-R Dyes."
16) The reflective layer of a CD is aluminum. That metal would not work with the corrosive dyes of CD-Rs, so manufacturers used gold at first and then generally switched to silver or silver alloy to reduce costs. See Reference Guide, "CD-R Reflective Surfaces."
17) The maximum safe level is 80 minutes of audio or 700 MB of data (before formatting). Reference Guide, "CD-R Capacities."
18) The question is not whether one is better than the other, but whether or not the discs are more or less interchangeable with players and drives and the data are retrievable. 80-minute discs push the limit of the specifications, but that is not a problem with modern players and drives. Older CD players, car players, and older drives are more likely to have trouble with 80-minute discs than with 74-minute discs. See Reference Guide, p. 13 for more details.
19) 90-minute discs can be recorded and played in very few drives. There is little software support for this capacity, and it can actually pose a danger to drives not designed for "overburning," that is, going up to the outer edge of a CD-R. Increasing the capacity requires violating the specifications for track pitch and pit size and writing in areas intended for other information. Even if a drive could manage fitting 90 minutes of audio on a CD-R, there is no guarantee that all CD players would be able to recognize or play it.
20) Stand-alone stereo CD-R players are called "digital audio disc recorders." They require CD-Rs that have a special code in the ATIP section that identifies them as DA or "digital audio" discs that can only be recorded in these types of recorders. Computer drives can use either standard or DA media, but DA recorders can only record on DA discs. Once recorded, the DA discs will play no differently from any regular CD-R. Only the recording process is restricted, not playback.
21) If the CD-Rs won't play in the drive that burned them, there is something wrong with the medium, the drive, or the recording software. If the discs do play in that drive but not in

another player, the reason could be an incompatibility with the reading laser and the disc. Although there are tight specifications for media, there are very few specifications for drives. Older CD players sometimes have trouble reading CD-Rs for a variety of reasons including reflectivity, pit geometry, or groove shape on the disc or tracking problems in the drive. Newer players and drives have far fewer problems with compatibility.

22) The number rating of discs is a measure of how fast they can be recorded in a drive rated to be capable of that speed. A 16X disc can be recorded at 16 times normal speed ("Normal" is the playback speed of a music CD, or "1X.") in a drive rated at 16X, but at only 8X in a drive rated only for 8X maximum. A 24X drive, however, might try—and succeed—to write to a 16X disc at 24X; but if it has trouble, it will drop down to a 16X speed. See Reference Guide for some interesting details on what the speed ratings really mean.
23) Faster discs have thinner dyes that react faster to the laser light and the greater laser power used. There is no quality difference in this regard, although discs rated at the highest speeds have to have excellent balance, concentricity, and uniformity so that they do not cause problems for high speed drives. These are lesser concerns at slower speeds.
24) There are many opinions from experts who claim they can hear differences in discs recorded at 1X and those recorded at faster speeds. That is unlikely, but any measurable differences would be due to the design of the drive and the condition of the laser and their compatibility with whatever medium is being recorded. The facts are: a) recording lasers pulse at slower rates at slow speeds but act more uniformly at higher rates of speed; b) more power is required at faster speeds, but the increase in required power is not proportional to the increase in speed; there may actually be less drift in laser power at the faster 4X-12X speeds and beyond; c) lasers in drives operated at the maximum speeds all the time will age faster than if they were used at a lower power levels; d) slower speeds will cause vibrations at lower frequencies which may interfere with the transfer of data: faster speeds create vibrations at higher frequencies that may pose less of a problem; e) tests measuring error rates find little difference in results at slow speeds or high speeds, but higher speeds often slow a very slight advantage.
25) The latest discs available today are designed to be recorded at speeds of 48X to 52X. Older drives that record at slower speeds work best on CD-Rs with slow acting dyes. Unfortunately, just as computer operating systems and peripherals are always being updated in favor of the newest and fastest products, the same is true of CD-Rs. Fast reacting, high-speed CD-Rs do not work as well with the old, slow CD-R recorders. The poor sound quality is due to the drive overburning the fast acting dye and distorting the pits. Although there is nothing wrong with either your drive or the new discs, they are no longer compatible. One either has to find old CD-Rs or upgrade to a faster drive that can handle the new discs.
26) The laser looks through the bottom of the disc, a solid piece of clear polycarbonate plastic. That plastic is sturdy but should not be scratched or soiled in a way to interfere with the passage of the laser's light beam. The top of the disc, however, is only a coating of lacquer covering a thin deposit of reflective metal. It is very delicate. Never write in the top of a disc unless one is using special pens designed for CD-R writing. The wrong type of pen (a ballpoint pen, for example) can either damage the surface and the data below or use inks containing acids that will damage the lacquer protection.
27) The lifetime of a CD-R is estimated by environmental tests that try to simulate the accumulation of damage from light, heat, humidity, and exposure to the normal chemicals in the air. The "death" of a CD-R is defined as the point at which the number of errors accumulates to such a degree that simple error correction can no longer retrieve the data on the disc. Different dyes as well as different manufacturing skill and techniques have produced discs estimated to last from 70 years to over 100 years, far longer than the playback technology will last—or even the lives of the owners. The assumption is that the discs are properly handled and stored away in the dark over that time period. Real-life conditions suggest that careless handling and heedless exposure to sunlight can ruin a disc in a month or less for poor quality discs.

28) Colored discs are very often just silk-screened with ink in various shades, but Memorex's "Cool" discs are actually colored clear through. There is no difference in performance with these discs because although we humans see the full spectrum of visible colors on the discs, the laser has a much narrower vision restricted to 780 nanometers of wavelength. The only color that poses a problem for a laser is green because green can absorb the red laser light. (Experiment: put a green mark on a piece of paper and shine a red light on the paper. The paper looks green, but the mark appears black. It absorbed all the red light.)
29) Same answer as above. To human eyes the black disc appears to absorb all "visible" light, but it will not absorb the very narrow range of the red laser light.
30) The best way to label CD-Rs and CD-RW's is to use special CD marking pens whose inks do not damage the lacquer surface of the disc. An alternate method is to use adhesive paper labels designed for optical discs so that they do not peel off. Misaligned paper labels cannot be pulled off a disc without damaging the surface and the reflective layer and dye below, so be sure to use a labeling kit device for best alignment. Alignment is not as critical for audio playback as it is for high-speed audio extractions ("ripping") or data recordings for which drives read at high speed. The worst way to label discs is to use a ballpoint pen.
31) The best way to store CD-Rs and CD-RWs is to keep them in cases that protect the surface from any physical damage and the bottom from scratches. The discs should be kept away from light and heat and transient debris such as dust.
32) The "speed" of a drive is its **maximum** speed, not its average. Claimed speeds of 32X up to 52X and beyond cannot be achieved over the entire disc because of the limitations in dye reaction times, data transfer rates, and laser power. These maximum speeds are achieved only if the amount of data is enough to bring the laser head to the outer half of the disc where the disc spins the fastest--the faster the maximum claimed speed, the further from the center of the disc. See Reference Guide.
33) "Buffer underrun" occurs when the drive asks for more data to burn on a disc at a rate faster than the computer can provide. The computer's buffer memory storage can run out and interrupt the data stream. There are several ways to avoid this problem:
    a. let the computer's RAM memory concentrate only on disc burning by making sure you shut down all other applications, even those running "in the background" such as anti-virus programs
    b. defragment the hard drive so files run contiguously and the drive does not have to hunt for missing pieces
    c. record at a slower speed
    d. invest in a drive that has "new technology" to avoid buffer runs. (The new technology is chiefly more buffer memory in the drive and programming that automatically slows down the drive for you if it has to.)
34) The discs are neither mislabeled nor defective. Your drive is identifying the discs as "Memorex discs" and only allowing a maximum recording speed of 24X for them because the drive's firmware only allowed that maximum at the time it was built. It may not recognize 48X as a legitimate speed. You may be able to update the firmware by contacting the drive manufacturer so that all discs rated 32X or greater will be able to achieve at least a 32X rate on your drive.

CD-RW

35) CD-Rs and DVD-Rs use a dye to record data. The "burning" process of recording permanently alters the dye. Erasable media such as CD-RW, DVD-RW, DVD-RAM, and DVD+RW use a semi-metal alloy instead of a dye. The recording laser melts the alloy in the spots to represent pits because melting and sudden cooling dull the alloy. The laser can erase the disc by heating the alloy at lower power because heating and cooling return the alloy to its original shiny, crystalline state. See Reference Guide.
36) The series of numbers describing drives list the **maximum** possible speeds the drive is capable of reaching during: a) recording a CD-R; b) recording a CD-RW; c) reading a CD-ROM. A 32/12/40 drive can record a CD-R at a maximum speed of 32X; can record a CD-

RW at a maximum speed of 12X; and can read a CD-ROM at a maximum speed of 40X. Note that the maximum read speed may not apply to all CD-Rs or CD-RWs. If their signal to noise ratios are poor limit the drive's read speed to lower values. See Reference Guide.

37) Trading in a 24X drive for a 52X drive will save you about a minute, fourteen seconds per disc only if you record to the maximum capacity of an 80-minute disc. Recording any less will reduce any timesavings significantly. A disc can only "explode" in a drive if it has already experienced some severe damage already that the drive makes worse. Your 24X drive is almost as likely to explode such a disc as a 52X drive would since they both start up at approximately the same speed. See the section in the OMG on CD-R speeds for a graph of timesavings and speed ratings.

38) There are three different types of CD-RWs: a) the regular 1X-4X version; b) the "high-speed" 4X-16X version; and an "ultra-speed" 8X-24X version. Older drives with a maximum rating of 4X for CD-RW are limited to the 1X-4X discs. High-speed drives can use record both the regular and high-speed discs, but they cannot record "ultra-speed" discs even if the speed ratings overlap between 8X and 16X. The latest ultra-speed CD-RW drive can record all speeds of CD-RWs up to the maximum speed rating of the medium. See Reference Guide for more details.

39) That would seem logical—if there were only two variables: good discs and bad discs. However, the variables include the drive firmware and the packet-writing software. If the drive firmware does not include the proper writing strategy for the CD-RWs, the drive will produce errors on the disc that the software interprets as disc flaws. In many cases, updating the drive firmware will solve the problem if the new drive firmware includes the discs in its settings. Updating the packet-writing software may also solve the problem.

40) No. They will not be able to record the latest "ultra-speed" CD-RWs even though ratings may overlap. For example, an ultra-speed 16X disc will not be able to be recorded on a high-speed CD-RW drive with a maximum speed of 16X. The 16X high-speed rating is not the same as a 16X ultra-speed rating, or even an 12X ultra-speed rating for that matter. See the answer above. "Ultra-speed" CD-RW drives are necessary to record onto 16X-24X ultra-speed CD-RW discs; but once the discs are recorded, all CD-RW drives are able to read regular, high-speed, or ultra-speed discs.

41) No. A 700MB CD-RW truly has a blank capacity of 700MB, but 100MB are sacrificed to formatting so that data can be filed and erased. Double-sided high-density floppy diskettes have an inherent capacity of 2MB, but everyone is used to the 1.44MB capacity that remains after they have been formatted. The same applies to CD-RW.

42) It is very unlikely that a whole spindle can be defective. There are two possible reasons: 1) your drive does not have the proper write strategy for the discs (see #39), or 2) the first disc you tried could actually be defective but its errors corrupted temporary memory so that the software rejects all subsequent CD-RW discs. Rebooting will take care of the second problem, but you may have to update the drive firmware and packet-writing software to solve the first situation.

43) "Ripping" is the digital extraction of files from a CD to a computer hard drive. As the computer extracts the files, the software can turn them into .wave files for recording onto a CD-R as tracks that CD players will recognize or into compressed MP3 files or into a file format of the user's choice. "Burning" is the word describing the laser recording process in which a high-power laser "burns" the organic dye of CD-Rs or melts the metal alloy layer in CD-RWs.

DVD and Recordable DVD

44) Although the discs are the same physical size and shape, there are more tracks and smaller pit sizes on a DVD. See Reference Guide.

45) A DVD 5 is a single-sided, single layer DVD disc holding 4.7GB of information. A DVD 9 is a single-sided, double layer disc holding almost twice as much. There are four basic versions with definitions in Reference Guide.

46) The storage capacity can vary depending on the number of sides used and the number of layers on the disc. See Reference Guide for a complete listing.

47) Some newer models of DVD players follow a "multi-read" standard so that they can play most types of DVDs as well as CDs, CD-Rs, and CD-RWs. Earlier versions of DVD players were limited to DVDs, but often the circuits designed for the low reflectivity of DVDs were compatible with the low reflectivity of CD-RWs. If those types of DVD players could read CDs, they could often read CD-RWs, too. See Reference Guide.
48) There are three different types because of a combination of different design objectives and conflicting corporate interests. Reference Guide.
49) See Figure 22 on Reference Guide.
50) This is a great argument for frightening people to abandon video tape and jump into DVD recording, but it's based on misinformation. As long as the chemical formulation in the binder of the video tape is sound and the tape is stored properly, there is no cause for the tape to deteriorate over time. Playing a tape over and over can reduce the signal output by 1.5 dB, but since the signal is FM modulated, that decrease makes no difference in quality. Repeated playing can actually polish a tape surface so that a new recording might even test better than the original. (As a point of reference, modern video high quality VHS tapes are able to withstand one hour of still-frame play without deterioration. That's equivalent to 108,000 passes or repeated plays.) Over time video tapes can suffer from:
    a. Edge damage from misaligned guides or poor heads
    b. Wear from worn or damaged heads or transient debris getting between the heads and the tape surface. (Debris from the edge of the tape after slitting is a major cause of dropouts for video tape.)
    c. Damage caused by excessive humidity; for example, the condensation that occurs on the tape surface if a cold tape is brought into a warm room.
    d. Poor storage conditions that include heat, humidity, great fluctuations in temperature, and dust. Rewinding tapes periodically without stopping at any point in the cycle will relieve any stresses that build up in the tape packs from variations in temperature and humidity.
    e. Exposure to strong magnetic fields

    As long as good tape with sound chemistry is stored properly, it will not deteriorate. The real truth is the reverse: the life of optical discs is defined as the point at which slow deterioration causes the error level to reach a threshold beyond error correction. That steady deterioration can take a very long time, but it is irreversible.

    A fundamental difference between the two media is that the VCR contributes greatly to the physical quality of the tape as well as to its playback quality. Dirty heads and guides, worn head gaps, misaligned guides, improper take-up tensions, and many other alignment issues contribute to tape damage that often appears to be "degraded" tape. VCRs age at the same rate that tapes do, and an old, uncared-for VCR may be a greater contributor to poor tape playback than the aging of the tape. DVD players have no physical contact with the discs other than clamping the center hub.
51) A DVD-R is a recordable DVD similar in design to a CD-R. It is not erasable. Reference Guide.
52) No, for two reasons. First, it is wrong to take the work of others without compensating them for their efforts—and it's illegal. The second point is that there are copy protection schemes built into DVDs, drives, and software that prevent such illegal copying.
53) A DVD-RW is the erasable companion to the DVD-R. Use of a semi-metal alloy instead of a permanently altered dye makes the DVD-RW erasable. Reference Guide.
54) A DVD-RAM is a DVD designed for random access memory, for the quick and easy storage and retrieval of data. It is distinguished by its protective cartridge, but some versions come with a bare disc and without a cartridge. Reference Guide.
55) A DVD+RW is a rewritable DVD designed to work well with both video and data recording. The DVD+R is the write-once companion. The plus in their name distinguishes them from the earlier DVD-R/-RW. Reference Guide.
56) Whether a recorded DVD will work in a DVD player depends on the player. Multi-format DVD players will likely play all formats except the DVD-RAM cartridges. Older players may have

the fewest problems with DVD-R or DVD+R if they play the discs at all. The lower reflectivity of DVD-RW and DVD+RW sometimes poses problems for older players. Reference Guide.

57) DVD 1X speed is already nine times faster than a CD 1X speed; so "high-speed" DVD recording is going to be limited. All present drives can record at 1X. DVD-RAM records at a maximum of 3X; DVD-R at a maximum of 4X; DVD-RW, 2X; and both DVD+R and DVD+RW at a maximum of 4X. 8X writing is next increase in DVD recording speeds, and it will come first to DVD+R, then DVD-R, and then DVD+RW. The fastest DVD writing speed possible is 16X or just slightly faster. Reference Guide.

58) Yes, but the whole story is not quite as dramatic. The early DVD-R/-RW drives that could write at a maximum of 2X would not recognize 4X DVD-R discs and could possibly damage their laser diodes trying in vain to identify the discs unless the user intervened and stopped the drive. Pioneer provides a firmware fix to the drives so that they will recognize 4X discs and record them at 2X. See www.pioneerelectronics.com/hs/ to download the fix for their drives. In the DVD+R/+RW camp, 4X discs in early 2.4X drives will appear to behave normally, but the write strategy will create irregular marks in the discs and the discs will fail. A firmware upgrade fix for the Memorex DVD+R/+RW drive can be downloaded from www.memorex.com/service_support/software_display.php?id=456&dl=p. Memorex also provides warnings and the firmware information in all of its 4X DVD+R and DVD-R products.

59) The problem is that computers and DVD drives and media count the numbers differently. The computer counts according the base two in its binary system. The DVD camp decided to count bytes in the decimal system. A 4.7GB DVD+RW actually only holds 4.377GB in computer terms minus any capacity taken up by formatting.
    a. 1GB = 1 gigabyte = 1,073,741,824 bytes = 2^{30} in computer terms
    b. 1GB = 1 gigabyte = 1,000,000,000 bytes in DVD terms

60) There are often two reasons a disc will not record in a drive: 1) it is the wrong format, or 2) the drive lacks the firmware to recognize the disc. In the first case, a DVD-R recorder will not be able to record on a DVD+R or DVD+RW disc unless the recorder is a "dual format" recorder that can record on both. The same is true of DVD+R/RW recorders—they will not record DVD-R/-RW discs. The second case is more common, but less obvious. Drives rushed to market with the latest speed as its chief feature often limit the testing done on various discs in order to save development time. The drives work with a limited number of discs whose ID codes are in the drive memory so that the drive selects the proper write strategy—the amount of laser power required and the timing of the light pulses—to record on them. Discs whose codes and write instructions are not in the drive memory, its firmware, will not work or work very badly. In time the drive manufacturers develop new instructions for additional disc ID codes, and these are added to the drive's firmware by means of an update that is "flashed" to the drive's memory bank. Internet forum groups often make ignorant claims about discs or drives when the problems are due to incompatibilities, not any flaws in either the discs or the drives.

61) CBR stands for "constant bit rate," and VBR means "variable bit rate." The CBR means the computer assigns the same number of bits for every second of video while VBR may alter the rate depending on how complex the video is. VBR can often be more efficient and allow a little more capacity on a disc if the video is not tough to encode.

62) VR stands for Video Recording. That's the easy part—there are two incompatible VR formats: -VR and +VR. The –VR format is used by the DVD-R/–RW camp to record video in real-time onto a DVD-R or DVD-RW disc in a set-top recorder so that TV programs can be recorded from the built-in TV tuner. Unfortunately, -VR formatted discs will play only on the recording device that recorded video onto them. –VR recording allows playlists and chapter markers to be added to a recording on a DVD-RW and some editing ability. The +VR mode is used by DVD+R and DVD+RW discs for the same type of real-time recording as well as some limited editing. Unlike –VR formatted discs, +VR formatted discs will also play in DVD players that play DVD+R and DVD+RW discs.

63) MPEG-2 encoding has a number of bit rate settings, the highest of which exceed the standard for DVD-video. A DVD cannot have a bit rate higher than 9.8 Mbps (megabits per

second), including both audio and video. Some video capture/editing software allows higher rates for MPEG-2, but the higher rates will not allow DVD recording, which is what most people are trying to accomplish. Other software picks a lower rate by default. The "highest quality" for some is only 6 Mbps because it is much easier to encode and more likely to work than a higher rate. Other software limits the bit rate to 8 Mbps to offer high quality at a safer rate than the maximum of 9.8 Mbps.

64) The "best bit rate" is the one that offers the best balance between quality and disc capacity. Choose the highest rate possible—8 Mbps or higher—for "archival" quality, but that means only about 1 hour per disc. Choose lower rates if getting more information on a disc is more important than the highest video quality.

65) DVDs are capable of much better quality than that on VHS tape if: 1) the video is mastered and encoded very well, and 2) if the bit rate of encoding is sufficiently high. Capturing VHS video at too low a bit rate will produce video far worse than that on the original tape even when it is played back on a DVD player. The mastering and encoding software used by Hollywood studios costs hundreds of thousands of dollars and is far superior to anything offered to consumers today. The result is that, even at the highest bit rates, video captured from VHS tape and recorded onto DVD will not be as good as that on the original VHS tape. The best software would only be able to make it appear equal to the original, not better. The same holds true of MiniDV tape. It is encoded at a rate of 25 Mbps, but when that is transcoded to MPEG-2 video even at the maximum rate of 9.8 Mbps, the resulting video quality is less than the original if one looks very closely.

66) Throwing away the masters would be a very foolish thing to do for several reasons: A) the masters offer better quality than the DVDs made from them (see #60), and future software will reduce that difference if you want to remake them later; B) video tapes degrade with use, not with age (see #48) so they are safe if stored properly; C) DVDs do not degrade with use, but they do degrade over time as the number of errors increases; and, as digital media, at some point they may refuse to play altogether. It is a good rule of thumb never to throw away master copies.

67) The problem is probably that the capturing software did not accept a movie protected by Macrovision. Macrovision is an encoding method used to defeat copying of VHS tapes and even DVDs. Capture software will often recognize tapes protected by Macrovision and prevent the video from being seen properly.

68) The number of minutes of video a DVD recordable disc holds depends on the bit rate used to store the video: a high bit rate provides the best quality but requires a lot of data that use up time. A lower bit rate uses less data, but the video quality declines. The "standard practice" appears to be similar to that for video tape: the highest quality mode ("XP" or "HQ") allows one hour of recording; SP ("standard play") is 2 hours. At this point it becomes confusing: LP ("long play") is 3 hours for some DVD+R/+RW recorders and 4 hours for others. For DVD-RAM, LP provides 4 hours of recording time. Extended play EP is 4 hours in some DVD+R/+RW recorders but 6 hours in others and in DVD-RAM recorders. Those DVD+R/+RW recorders that designate EP as 4 hours use "EP+" for their 6-hour mode. DVD-RAM recorders will record DVD-R discs in the same modes as the DVD-RAM, but Pioneer's DVD-R/-RW recorders offer completely different nomenclature and settings. See the chart in the Reference Guide for the full details.

69) Recording video onto DVDs requires:
   a. a fast computer with a lot of RAM (>600MHz processing speed; >64MB of RAM)
   b. a method to capture the video so that the computer can accept the video data
   c. editing software to alter the program, add titles, sound tracks, etc.
   d. authoring software to arrange the edited program in a DVD format with menus
   e. a recording DVD drive
   f. lots of time and patience Reference Guide.

70) The factors in determining which format suits your purpose depend on:
   a. your reason for recording at high capacity—video or data
   b. price of the drives and the media that support them

   c. compatibility with other drives or DVD players

Memorex cannot answer the question for you. Our intent is to provide enough accurate information so that buyers can make the most educated choices.

71) Probably the one most users choose to buy, if one defines "best" as "most suited to most users." Reference Guide.
72) The fastest DVD recording speed is a bit faster than 16X, a data transfer speed that can occur only at the outer edge of the disc at the end of the recording. The speed is determined by the fastest rate of data transferred to the disc divided by the regular data transfer speed of video coming from a DVD player. There are some recorder manufacturers who are misusing the standard terminology by comparing the time it takes to play back a full disc to the time it takes to record it. Since it is possible to stuff as much as 6 hours or more on a hard drive in the Extra Play EP mode by using high compression at the sacrifice of quality, transferring the 6 hours worth of video onto a DVD disc at 4X will take the same time as transferring 1 hour of highest quality of video; but one can claim that 6 hours at 4 times the standard 1-hour speed is equal to "24X." This is misleading and incorrect. The amount of data for a 1-hour highest quality video DVD is the same as that spread over 6 hours of lowest quality video. The speed is a matter of how long it takes to transfer data, not transfer "playback time."
73) You didn't do anything wrong. When this happens, most people erroneously blame the disc or the disc quality when, in fact the real reason is most likely an incompatibility between the disc, the software, and/or the drive. If the drive or the software do not include the identification code of the particular disc so that they can set the proper write strategy for the drive (the intensity and the duration of the laser's recording pulses), the drive can end up making recording marks on the disc that are unintelligible for it to read later. The drive may inform the user that the disc is illegal, corrupted, scratched, or not even in the drive. The drive will refuse to format or erase the disc and sometimes insist that it is not a rewritable disc. In most cases the solution is to check for firmware updates for the drive that include additional discs and software updates for the recording software that also include more discs. Updates may allow users to record to the remaining DVD-RW (or DVD+RW and CD-RW discs) in a package, but the unintelligible would have to be returned to the factory to be erased by heating methods independent of drives that can no longer identify the disc.
74) High Definition video generally means a video signal with 1080 horizontal lines of video information instead of the 525 lines our NTSC television standard uses. (Of the 525 lines, only about 480 actually display picture information. The rest are used for synchronizing signals for the TV circuitry and appear in the black bands above and below the picture.) Some DVD players use special circuitry to repeat lines the way computer monitors do so that instead of showing 30 frames of picture each second, each frame composed of two fields interlaced together, these DVD players send a signal to high definition display as both fields composing a frame at the same time. This is referred to as "progressive scanning" instead of interlacing. Although more detail appears in the display, it is not true high definition. DVDs using MPEG-2 compression do not have the capacity for carrying all the data needed for HDTV. There are two ways to add high definition information to DVD discs: 1) use different compression methods to pack more information on a disc, or 2) use a laser with a smaller wavelength to pack more MPEG-2 data on the disc. Researchers are investigating both methods. The first method retains the standard laser and uses new firmware in the DVD player to distinguish regular DVDs from HD DVDs. The second method would use a blue-violet laser diode capable of much smaller wavelengths. There is a proposal for the second method to create a new DVD called a "Blu-Ray" DVD that will be capable of carrying true HDTV video signals in the MPEG-2 compression scheme and read by such a blue-violet laser. Reference Guide.
75) The lasers used in CD players and drives, CD-R/-RW burners and DVD players, drives, and burners are all ruby-red lasers with wavelengths that fall within the red light spectrum of 780 nanometers (billionths of a meter) to 622 nm. In order to create DVDs capable of high definition video, engineers have had to shrink disc pit sizes below the wavelengths of red

light, so to read the pits, a new laser had to be developed with a smaller wavelength. The laser is a blue-violet laser with a wavelength of 405 nm. Reference Guide.

REFERENCE GUIDE FOR OPTICAL MEDIA

Terence O'Kelly

Memorex has long been one of the world's foremost suppliers of media for memory storage. The very name of the company is a shortened form of "**MEMOR**y **EX**cellence" that started in 1961 with the manufacture of half-inch 9-track computer tape and progressed to audio and video cassettes, digital audio cassettes, and computer diskettes. As technology developed, Memorex expanded to optical storage media such as recordable and rewritable CDs and DVDs and has become one of the world's leading suppliers. Now, as the long-promised age of solid-state memory is beginning, Memorex is also providing a wide range of flash memory cards for computers, digital cameras, personal digital assistants, MP3 players, and cellular phones.

Today's technology is increasingly digital. The world has quickly accepted "digital" as a distinction of advanced technology and quality, often without fully understanding what it means in everyday products. CD-Rs and CD-RWs have replaced audio cassettes and floppy disks as common recording media, but few people know how they work. Newer optical storage products such as recordable and rewritable DVD are designed for greater storage capacities to challenge video tape and computer cartridges, and these media are even more complicated because of the variety of competing designs and formats available. Memorex believes that many of our customers are curious to know more about the products they are using or will be using in the near future. In our commitment to "memory excellence," we hope to explain the technology behind the products we sell. Very technical information that may be of interest only to readers with a scientific background appears in the shaded passages

ANALOGUE VS. DIGITAL

Analogue comes from two Greek words loosely meaning "word for word," as in a translation. The adjective is a way of describing information in one understandable way analogous to or similar to the actual way. The description is often applied to the use of a "picture for picture" instead of a "word for word" translation. For example, an analogue clock has hands that make a complete circuit in a minute or in an hour or in half a day, depending on which hand it is. The hands continually go around just as the earth turns completely around on its axis in a day. Analogue recordings "draw" an impression of sound waves in the squiggly groove in vinyl records or as variations of magnetic energy in cassette tape. The vinyl records and tape store these "pictures" of the sound patterns and allow them to be played back. The problem with this system is that the information gets mixed up with the flaws of the medium. A clock hand that does not keep up with the other hands gives inaccurate information. Dust in a record groove causes sounds and noises not meant to be heard. Tape imperfections cause hiss that was not part of the original sound.

Digital recording is a method that avoids these flaws. Digital recording does not try to draw or imitate the information that is being saved. Instead, it converts the information into a mathematical code that ignores the flaws of whatever medium is storing the data. To use an analogy, a canvas painting of a landscape records the landscape with all the "flaws" of canvass and paint texture (those "flaws" that make a painting an inaccurate but artistic impression). If oil is spilled on the painting, it is difficult to restore what was there because the oil becomes part of the record. If, however, someone recorded the landscape with a "paint-by-number" scheme in great detail, the oil would not matter. The oil stain had no numbers assigned to it; so the artist could reproduce the landscape by following the number code exactly. The more numbers involved, the more accurate and detailed the reproduction would be—and every copy would be almost identical to the original. *

*This example may be part of the reasoning some people use to explain why they believe analogue recordings to be artistically "musical" and digital recordings to be lifeless and "mechanical."

The word d*igital* refers to digits or numbers. It comes from the Latin word *digitus*, or “finger,” because everyone learns to count on his or her fingers. We have ten fingers, so our common numbering system is to the base 10 and uses ten digits—0 to 9. The mathematical code used in digital recordings is very intricate and needs computer chips to encode and decode; but computers don’t have fingers. They have transistors that recognize only two states: on/off (or “0/1,” “change/no change,” “+/-,” etc.). Computer engineers use the binary numbering system for computers, a numbering system to the base 2 that needs only two numbers, 0 and 1, to construct any value. Expressing the same number 3723 in both our common decimal system (10) and the binary (2) numbering system shows the differences between the two.

3,723

The decimal system uses digits 0 to 9. Each column is 10X greater than the one on its right.

1 millions	100 thousands	10 thousands	thousands	hundreds	tens	ones	
0	**0**	**0**	**3**	**7**	**2**	**3**	**= 3,723**

The binary system uses only digits 0 and 1. Each column is 2X greater than the one on its right.

2048’s	1024’s	512’s	256’s	128’s	64’s	32’s	16’s	eights	fours	twos	ones
1	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**1**

2,048 + 1,024 + 512 + 0 + 128 + 0 + 0 + 0 + 8 + 0 + 2 + 1 **= 3,723**

In our familiar decimal system, each column of digits goes up by a factor of 10. The number 3723 is represented by 3,723 with a comma often separating each of the sections worth a thousand. In the binary system that computers understand, 3723 is represented by the number 111010001011 for which each column represents a factor of 2. Each column is twice the value of the column to its right. We count by 10’s (fingers). Computers count by 2’s (on/off transistors).

The **bi**nary digi**ts** that computers use are called “bits.” These bits are organized into “words” containing eight bits called, in a fit of early computer geek humor, “bytes.” It is these words that commonly describe capacities such as a kilobyte, megabyte, gigabyte, and so forth. And because these capacities are based on a binary system, there is often confusion about the true value of the numbers. A kilobyte literally means “1,000 bytes”; but because the number base is a 2, not a 10, the closest binary number to 1,000 is 2^{10} or 1,024. A kilobyte is actually 1,024 bytes in the binary way of counting.

STORAGE MEDIA

In the earliest days of computers kilobytes meant a lot of information. That did not last long. Technological progress has made computers faster, smaller, and less expensive and has made the storage media for them capable of greater capacity while also shrinking their size and cost. Memorex’s half-inch computer tapes gave way to 8” floppy disks, then 5 ¼” diskettes, then the 3.5” diskettes that are now being replaced by CD-Rs and CD-RWs. Figure 1 shows the enormous growth in storage capacity of modern storage media, and research continues to find ways to pack more information in smaller media that cost less per gigabyte of storage capacity. Figure 2 is an example of the use of that growth in capacity. Full-color pictures, audio, and video are combining with text to make more understandable presentations than ever before. That requires more capacity.

Growth in Data Capacities

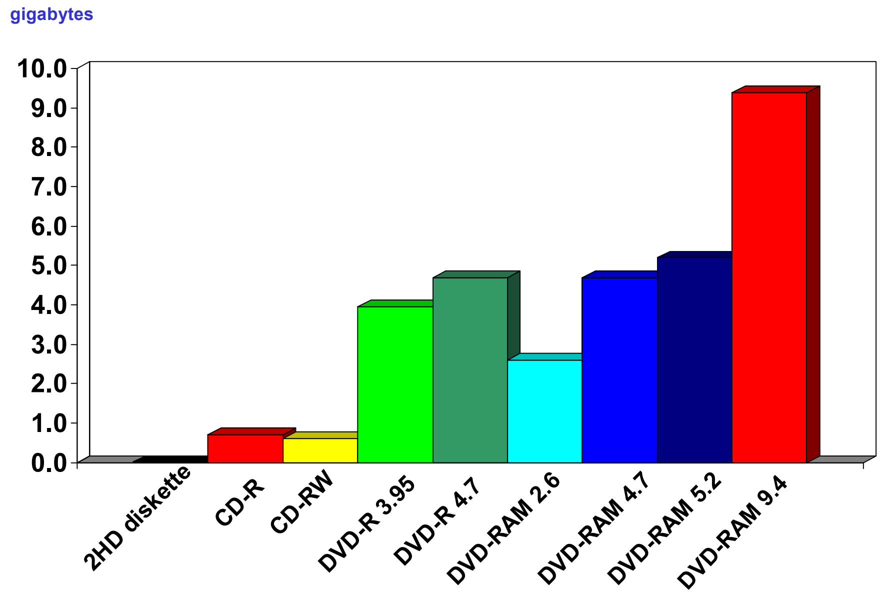


Figure 1

Growth in Data Requirements

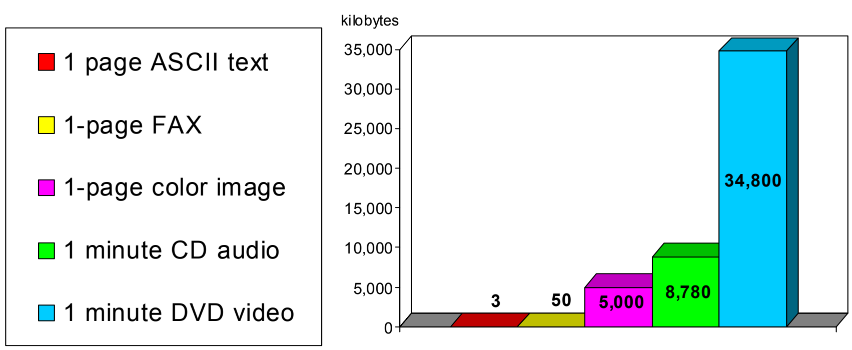


Figure 2

DIGITAL AUDIO

Mathematicians and engineers designed computers to do calculations quickly and accurately. The success of the personal computer (PC) and its growing sophistication transformed it from a desktop calculator when software engineers began to write programs that would allow it to perform all the tricks it commonly does today. One of the first tricks was to record audio. Analogue audio recordings have a fundamental problem mentioned above: they add their own inherent flaws to the recorded program. Making analogue copies of an analogue recording doubles the flaws, and this was a problem for early multi-track recordings (but a blessing for the music industry that feared people making chains of copies of just one legitimately purchased record.) "Digitizing" audio, that is, putting it into a mathematical code, avoids that fundamental flaw. Once the audio is in a binary code, that code can be recorded as +/- pulses on magnetic tape or magnetic discs, or as microscopic indentations on optical discs. As long as the code is accurately reproduced from copy to copy, any minor flaws in the recording medium can be ignored. Every copy is theoretically as good as the original. That assurance provided a solution for the multi-track problem (and opened up all the issues of copy protection for the music industry).

All sound is simply our ears' response to changes in air pressure. A whack on a drum first expands the air as the drum skin is pushed downward. Then it compresses the air as the skin bounces back. The skin moves back and forth at a relatively slow rate (or frequency) until it finally settles down. The low, bass sound of a drum creates changes in the air pressure at slow rates of change or low frequencies. Hitting a metal cymbal, however, causes the cymbal to vibrate very rapidly. Those vibrations make pressure changes in the air at a very high rate—high frequencies. Most of the sound we hear falls somewhere in between those rates of drums or cymbals. The range of human hearing typically runs from a rate of 20 cycles of up and down vibrations per second (called "20 Hertz") to a rate of 20,000 cycles/second or 20 kilohertz. *

Microphones pick up the changes in sound pressure with membranes that vibrate in response to the air hitting them. The moving membranes alter an electrical voltage signal and send it to amplifiers that increase the signal and send it to speakers (boxes with much larger moving membranes that can move enough air to recreate the original pressure changes that struck the microphone). The sound can also be stored as a recording. Analogue recordings draw the vibrations in vinyl records or as changing magnetic patterns in tape. Digital recordings take the signals and encode them before storing them.

*Earthquakes occur at about 8 Hz, too low to hear but easily felt. That's why sub-woofers are "special effects" speakers in sound systems—they are meant to create a <u>feeling</u> of low frequencies as much as a <u>hearing</u> of them. Dog whistles produce sounds beyond 20 kHz, too high a frequency for humans to hear. The human ear is most sensitive to sounds in the 3 kHz range. This happens to be the range for babies' crying, which explains adults' response depending on whether they are the parents or next-door neighbors.

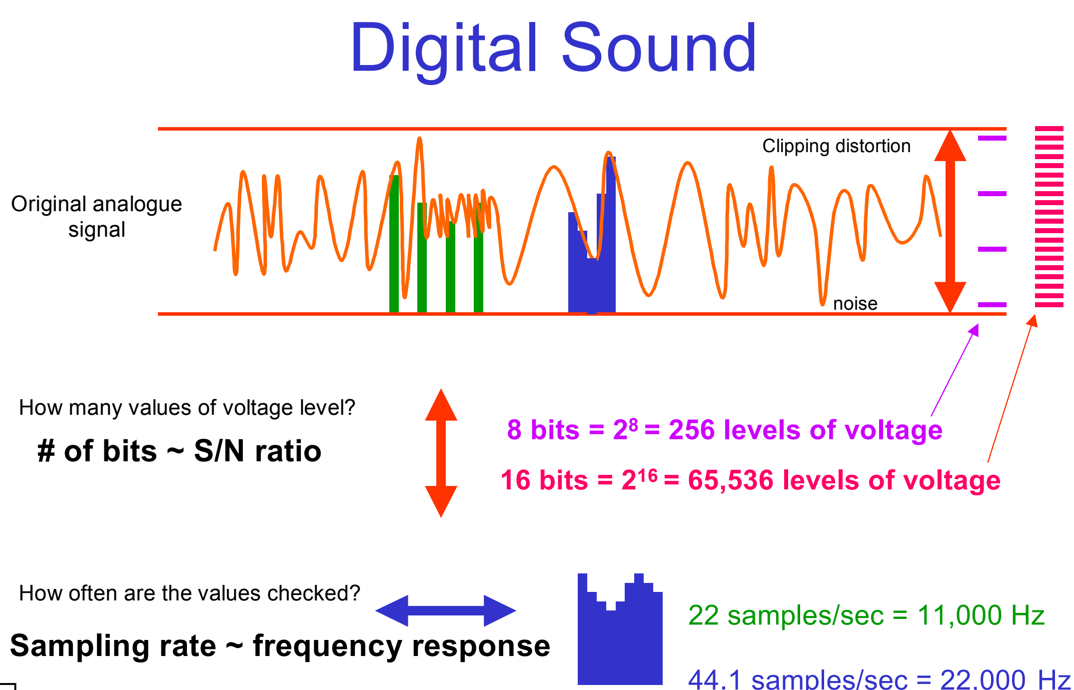


Figure 3

Digital Audio Coding

The encoding process takes the changing sound waves and treats them as a series of values of changing voltage. The wavy orange line in Figure 3 represents the changes in voltage of an electrical signal caused by the changing sound pressure. A vinyl record would have a close approximation of the orange line drawn in the groove; but a digital encoder would assign number values to each point on the line based on two judgments: 1) how high or low is the signal at any point, and 2) how often should I check it? The closer the orange line can spread to the upper limit (distortion overload) and the lower limit (the noise), the louder the signal is. The fewer the up and down patterns it has, as in the area around the blue, the lower the frequency. The more frequent the changes, as those around the green area, the higher the frequency. A digital encoder works by taking millions of samples of the electrical changes and assigning values to each sample as if it were trying to code the continuous line with a line of billions of sequential dots. The more often the encoder takes its samples, the higher the frequency it can reproduce. A mathematician by the name of Nyquist theorized that at least two samples are needed for the highest frequency to be resolved. Since audio engineers originally wanted to extend the sound a bit beyond the "human hearing limit of 20,000 Hz," they chose a sampling rate of 44,100 samples/second (the blue) to reproduce 22,050 Hz. The green lines are examples of sampling at half that rate resolving only 11,000 Hz, and it's obvious how much more gets missed in between the lines compared to the blue sampling. The sampling rate determines the frequency response of the system.

The other measure is the number of the steps up and down the orange line makes. The more values allowed (the red steps), the greater detail in defining the shape of the orange line at any one sample. The fewer values given, the less accurate the detail will be (the purple steps). This is where the binary coding comes to play. A system using 8-bit words will allow only 2^8 or 256 levels of voltage to define the shape of the orange signal. A system using 16-bit words allows 2^{16} or 65,536 levels of voltage changes for far more accurate reproduction. Each bit of information provides about 6 decibels of stronger signal; so a 16-bit system theoretically provides a signal-to-noise ration of 96 decibels, far better than the 64 decibels allowed by the best high bias cassettes (74 dB with Dolby noise reduction).

The developers of the compact disc decided on a specification for a sampling rate of 44.1 kHz and a resolution of 16 bits to provide the theoretical reproduction of music extending to 22,050 Hz at a S/N ratio of 96 dB. Some audio engineers believe that these specifications are insufficient for the best reproduction of music, and that is why they have introduced DVD-Audio using a sampling rate of 96 kHz and 24-bit words. The new specification means much more data has to fit on a disc, and that is why the DVD medium was chosen instead of the CD for high definition audio.

HOW A CD WORKS

The compact disc is an amazing design of the old and the new. Its flat, round shape mimics the LP record albums with their quick track access advantage over tape—it's much faster and easier to find the right spot on a disc than to spool through tape. Its digital design provides high quality sound that does not deteriorate over time because it is read by laser light, not by any physical contact as with record styli or tape heads. The basic design of the players is simple even if the electronics are not.

The disc rests on a drive that spins the disc at the correct speed while a laser pickup assembly moves to the inside of the disc to start reading the contents of the disc and identify its type. Information mixed in with the digital audio code tells the player what addresses the laser is reading so that the player always knows where the laser is and is supposed to go next. The tracking drive moves the pickup assembly from the inside out as the disc is being played all the way through. The disc drive and tracking drive are controlled by servo motors (motors that are constantly adjusting themselves according to information fed back to them) that keep the disc at the correct speed and keep the laser at the correct spot. The design is not much different from that of a diskette drive except that laser light reads the information instead of a head in contact with a round magnetic sheet.

The real difference is in the CD. The disc is a thin piece of optical grade polycarbonate with billions of pits molded into it in a continuous outward spiral. The arrangement of the pits is the digital code for the audio signal as well as all the information to tell the player where to move the laser pickup.

The laser shines its light up through the bottom of the disc onto the pitted spiral and follows it. The light is reflected back by a shiny layer of aluminum deposited on the disc during manufacturing. A thin coat of plastic resin protects the aluminum from oxidation and damage, and a silk-screened coated label covers the resin. The top surface of the CD that more susceptible to damage than the bottom. The bottom is solid plastic, and the laser actually sees the bottom of the pits as "bumps"

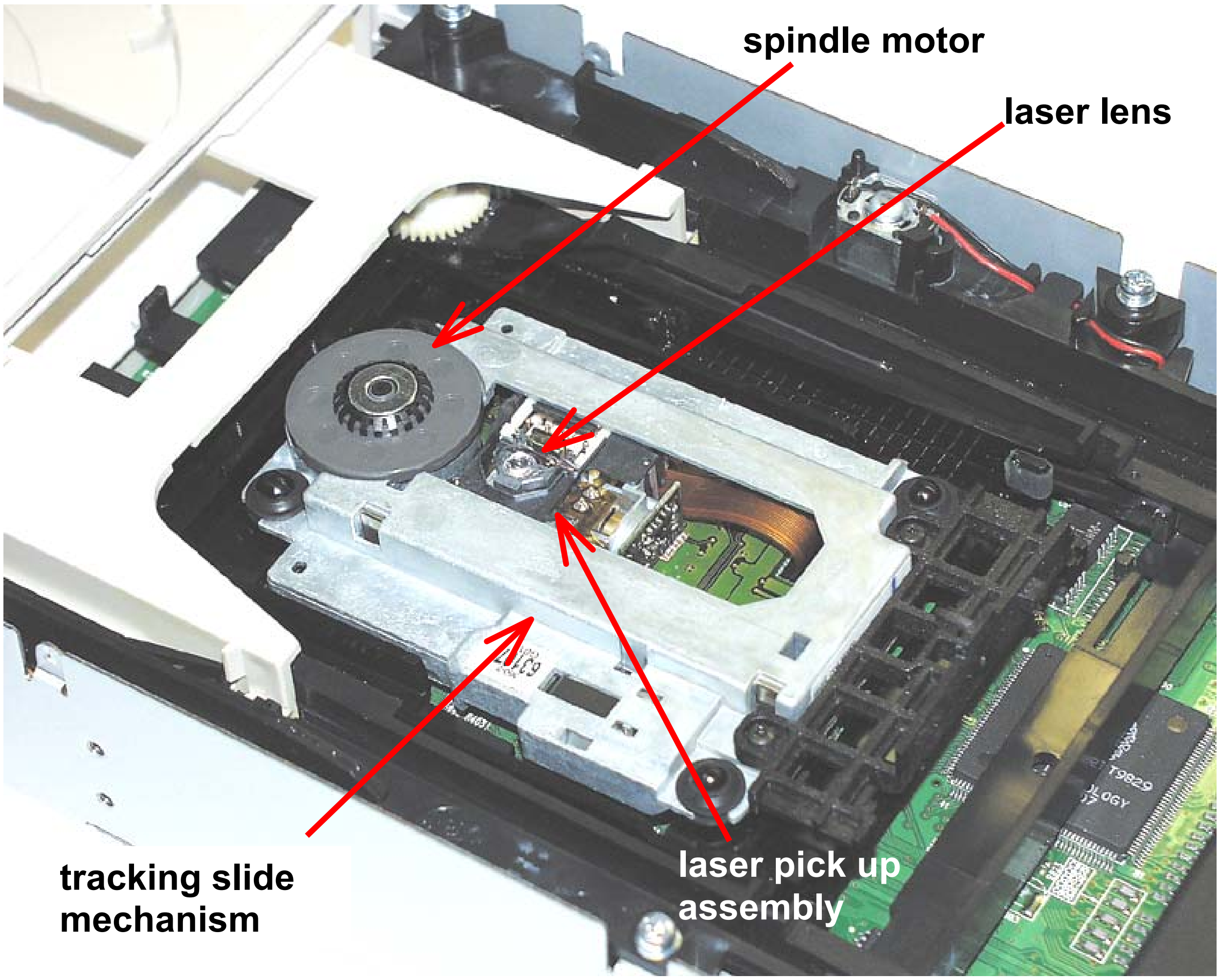


Figure 4

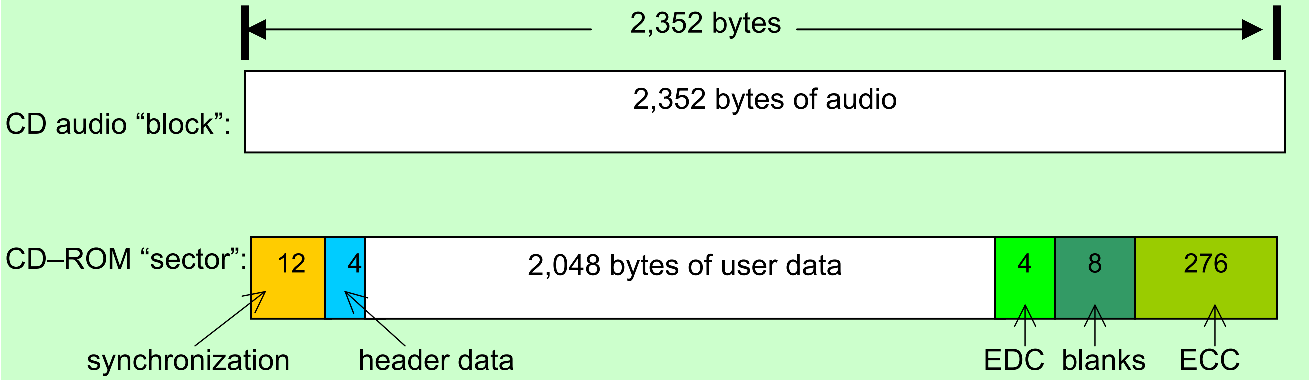
rather than pits. The laser focuses on the aluminum layer above the surface of the disc's bottom so that mild scratches or smudges on the bottom are not seen. The plastic helps in the focusing by acting as a lens and reducing the width of the laser from 0.8 millimeters as it enters the clear plastic to 0.001 millimeters at the aluminum layer. The laser light focused on the inner aluminum layer is reflected back to an optical sensor in the CD drive, and the sensor's electronics interpret the change in the angle of reflection as the laser moves over the bumps (pits) and flat areas (lands) as a "change/no change" binary digital code containing the audio and address information the drive needs. The designers knew that there was a great possibility of errors in the system due to manufacturing imperfections and slight damage from handling; so the information on the disc is scrambled and spread to different places so that a scratch, for example, does not wipe out an audible part of the sound. The electronics in the player find and reassemble the information and fix what might be missing or incorrect. Then the electronics send the corrected signal on to an amplifier.

The CD was designed with audio recording in mind, and the specifications for audio recording are published in the "Red Book" standards. In 1984 Philips and Sony introduced the Yellow Book standards for using compact discs as data media. The difference is significant and explains why software for recording audio on CD-Rs is so different from recording data. All CDs, CD-Rs, and CD-RWs have errors. An audio error is often imperceptible to a listener; but a single data error can change the value of the information or even crash a system. Extra efforts go into identifying and correcting data errors for just that reason.

Audio information is divided into frames of 24 bytes of digital audio in the form of twelve 16-bit samples, and 98 of these frames fit into one block (24 bytes x 98 frames = 2,352 bytes per block or 12 samples x 98 frames=1,176 samples per block). A block in audio terminology is the same as a sector in data terminology. The blocks are only 1/75 of a second long in time intervals; so in one second the CD player sees 1,176 samples per block x75 blocks per second=88,200 samples, half of which are devoted to one of the two stereo channels. Half of 88,200 is the 44.1k sampling rate for audio. Red Book specifications also include two methods of error detection and the correction of those errors, a system known as the Cross Interleave Reed-Solomon Code (CIRC). The first method of detection adds extra information to the audio data in the form of parity bits. Almost 25% of the total capacity of an audio disc is repeated information to account for errors: for every 24 bytes of audio data, another 8 bytes of parity information are added. The second method is interleaving, that is, spreading the bytes from one block to many others so that a major defect in one spot on a disc does not wipe out a whole block or more. The 24 bytes of one data block will end up appearing in 109 other data blocks as part of the encoding. Cross interleaving makes sure the distribution of data occurs over both short and long time intervals as a further precaution. Minor damage to a disc will end up affecting small bits of many blocks instead of wiping out blocks altogether.

A CD player's decoding system has two stages of correcting errors it finds: after audio data are reassembled in the proper order by deinterleaving (and block reconstruction using the redundant parity data, if necessary), the C1 stage corrects one or two small errors in a frame, errors such as noise in the signal. If there are three or more errors, C1 marks the whole frame as suspect and passes it back to be deinterleaved again before going on to the C2 stage. The C2 stage corrects up to 2 larger errors caused by damage to the disc or debris; but if there are 3 or more errors, the data are deinterleaved once again and passed on to the CIRC at the sector level. Test data defining errors will refer to E11 and E21 errors. That means "Errors: 1 bad byte corrected at the C1 stage" or "Errors: 2 bad bytes corrected at the C1 stage." The C1 stage cannot correct E31 errors or more; so the C2 stage is called into play after deinterleaving that redistributes the group of bad bytes into their original blocks. The C2 stage should then find fewer bad bytes to correct. E12 and E22 errors are those that the C2 stage can correct. An E32 error is uncorrectable.

An uncorrectable audio error can still be tolerated because the error correction circuitry can "guess what the byte should have been through interpolation algorithms or, as a last resort, quickly mute the output or cause a click. Uncorrectable data errors, however, are completely intolerable. No one wants a computer "guessing" what the payroll should have been or "muting" an employee because it couldn't read a Social Security number. CD-ROMs (that is, CDs, CD-Rs, or CD-RWs with data recorded on them) have all the audio error correction systems plus another system called Layered Error Detection Code and Error Correction Code that has additional parity information recorded and even more scrambling of data. The difference is apparent in the layout of the block/sectors of information for Red Book audio and Yellow Book data recording. It is also apparent in the fact that an 80-minute CD-R disc filled to capacity with audio programming holds 807 megabytes of information while the same kind of CD-R that is filled to the same capacity in a data format will hold only 702 megabytes. The difference between the two measurements of capacity is the extra error correction required for the data disc.



The addition of 12 bytes of synchronization data, 4 bytes of header information, and 288 bytes of additional error detection and correction on top of the CIRC protection that audio discs use increases the ability to correct errors. If a CD-ROM drive does find an uncorrectable error, it will make a certain number of retries to correct it. This process will slow down the data rate until the drive is able to correct the error or until it gives up and rejects the disc as defective.

BLER is a commonly used term describing Block Error Rate, the number of blocks or sectors per second that have bad bytes. The Red Book specification allows a BLER of up to 220 per second averaged over 10 seconds as the maximum allowable rate. Molded CDs fall well below that figure, and good, new CD-Rs are often even better than molded CDs in terms of errors. BLER is often offered as the "best figure" to determine good CD-Rs, but there are over fifty other important specifications that define true CD-R quality. BLER is only one of many quality characteristics. (Comparing BLER rates can be as misleading as rejecting a dinged up used car for "having had too many accidents" in favor of a car with just one mishap—one that put the engine in the back seat!)

The laser sees "bumps" instead of pits.

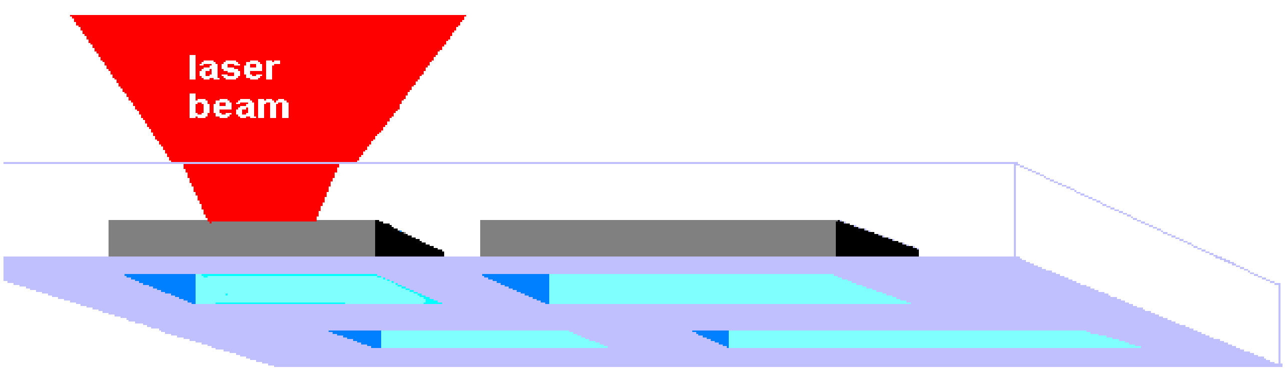


Figure 5

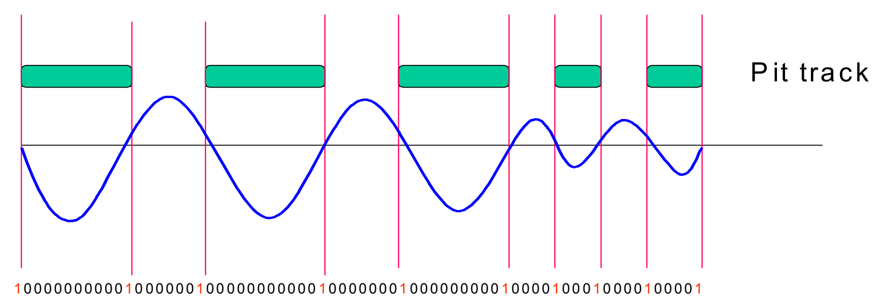
The bumps and lands on the CD do not represent the digital 1's or 0's. It's actually the **change between them**, the edges, that are the 1's. The change in the angle of laser light reflection caused when the light changes depth is what makes a binary 1 in the CD code. Therein lies a big problem, though. It's impossible to have two edges next to each other, so how can two 1's follow each other in a binary number if there can't be two edges next to each other? Engineers got around this problem by coming up with another coding system called EFM, which stands for "Eight to Fourteen

Modulation." This system makes sure that there are at least two binary 0's between any binary 1's so that the bumps or lands do not get too small. It also limits the number of 0's to no more than 10 between any two 1's. *

*This means the bumps and lands come in discrete lengths of as little as 3 bits (referred to as 3T for a 1 and two 0's) and no more than 11 bits (11T for a 1 and ten 0's). 3T is the smallest a pit or land can be; 11T is the longest. Test data for CD-Rs often refer to signal strength at 3T and 11T to define how accurately the media reproduce the proper signal from smallest bump or land to the longest bump or land.

Figure 6 shows the RF (radio frequency) signal that the optical sensor creates from the reflected light changing between the bumps and the land. Below the graph you can see the edges of the pits where the digital "ones" appear. The flow bit information coming from the RF signal undergoes even more decoding because there are error correction codes built into the system. The designers of the CD system expected errors due to scratches or dust on the CD; so they included two ways to overcome them: 1) a check code to figure out where an error might be and what the real number is supposed to be (the "Reed-Solomon code"), and 2) spreading out the information instead of keeping it sequential. The second method, called "interleaving," means that if there is a flaw on a disc, the flaw will not cause damage to all the music around it because the music information is spread out in different places. A wrinkle in cassette tape is very audible because the music around the wrinkle cannot be picked up. A scratch on a CD, however, may not be audible because the data under the scratch is from different bits of music. The CD player reassembles the scattered data in the right order and corrects what it believes to be errors in the code. CD players are actually a bit like mini-computers designed to interpret, sort out, and correct all of these codes.

RF Signal Generated from the "Pits"



The radio frequency signal is decoded into analog sound.

Figure 6

The entire system was designed to provide the best quality sound at the time it was being developed, with no physical wear to the disc and a tremendous amount of computer coding to find, fix, or hide errors. As amazed as people were when CD's first arrived and worked well, the second question after "How do they work?" was "When can we record on them?" That process took a longer time and involved the work of chemists in addition to mathematicians, engineers, and programmers. Together they developed the CD-R.

CD-RS

The recordable CD has a structure similar to that of the CD in that it is a molded piece of optical grade polycarbonate plastic with a reflective layer and a plastic resin protective layer. The differences are that instead of a spiral of pits molded into the plastic, the spiral is a groove that is nearly 3.5 miles long. This groove has a wobble in it in the form of a sine wave at the precise frequency of 22.05 kHz (half that of the 44.1 kHz sampling rate for audio CDs). The wobble is there as a way to tell a CD-R recording drive to write at the proper speed and to follow the groove precisely. Unlike a CD, the reflective layer is not deposited directly on the plastic. There is a layer of photo-sensitive organic dye that lies between the plastic and the reflective layer and fills the groove. The reflective layer lies on top of the dye (Fig. 7). The dye would corrode aluminum, so the reflective layer is silver or a silver alloy. In some cases gold is used instead of silver.

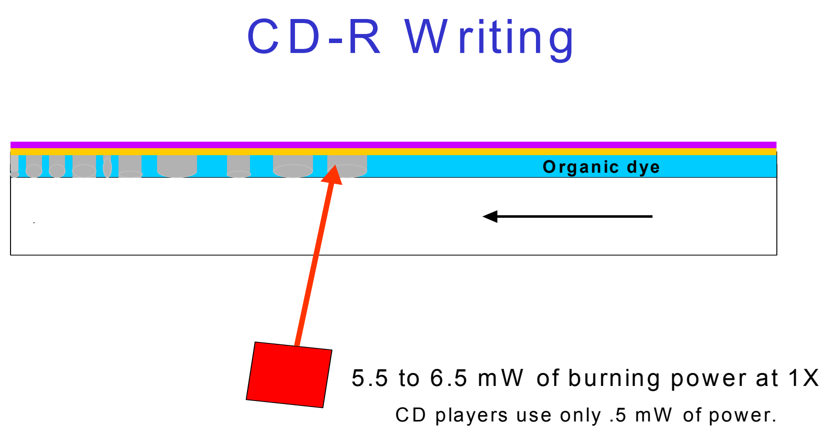


Figure 7

The protective plastic resin is coated on top of the reflective layer just as in CDs. The recording process works by using a laser with at least 10 times the power of a reading laser to "burn" the dye in a pattern resembling the 3T to 11T bumps and lands of a CD. The burning laser changes the dye so that light can no longer pass easily through these spots, and during the playback process the light of the reading laser is deflected as it crosses a burn mark in a way very similar to the deflection in a CD when the light crosses the edge of a bump. The pattern burned into the groove of the CD-R works for the playback laser just as the pattern of bumps and lands works on a CD.

CD-R DYES

There are several different types of dyes and reflective layers used in CD-Rs. The first type of dye was a cyanine dye* that has a greenish color when visible light is reflected back from the silver or gold mirror layer. A second dye called phthalocyanine** later came onto the market with different characteristics. Although it would appear as yellow against a gold layer or as slightly green/yellow or even clear against a silver layer, it, too, is a slightly blue color. This dye needs slightly less laser burning power during recording; and its burn marks leave a tiny depression in the layer that has helped give this dye a reputation for excellent stability in heat and light, two of the dangers to preserving CD-R integrity. A third dye is azo-cyanine, which has a bright blue color on CD-Rs. This is a less common dye for CD-Rs than the first two.

Cyanine dyes react to laser power more slowly than phthalocyanine dyes. The laser power is applied in what is called a "long write strategy" to make the proper pulsed burns on a CD-R. For this reason cyanine dyes work well at slow writing speeds. The phthalocyanine requires a "short write strategy" that does not work as well at the slowest speeds but does perform very well at the faster speeds. Because there is a difference in the way the dyes react to laser power and there is also a difference in recording speeds drives are capable of achieving, CD-Rs have information molded into a pre-groove section to assist the drive in determining the best settings. This section is known as the ATIP (**A**bsolute **T**ime **I**n **P**re-groove) section. Absolute time is the time counted from the very beginning of the disc to the end. Additional information tells the writing drive whether the disc is a CD-R or a rewritable CD-RW, the type of the dye used and the recommended power setting for the laser to start its testing, the spiral length in blocks (which means whether the disc is 63, 74, or 80 minutes long), the maximum rated speed for recording (up to 8X), and whether or not the disc is a regular CD-R or a digital audio CD-R ("music CD-R") that can only be recorded in drives whose purchase price includes a fee for copying. Although the disc has a recommended power setting, the drive will do its own optical power calibration ("OPC") on a reserved area of the disc to determine the best power level. This reserved section falls within the lead-in area of a disc, an area that CD-ROM

CD-R Dyes

Cyanine

- "green"
- Needs 6.5mw of laser power
- Altered region on CD-R is not much bigger than area illuminated by the laser beam
- Long write strategy
- Excellent at slow writing speeds

Phthalocyanine

- "yellow" or clear
- Needs 5.5 mw of laser power
- Altered region on CD-R is physically depressed by laser; beam affects a larger area than that illuminated by the beam
- Short write strategy
- Generally greater light and heat resistant than cyanine
- More expensive
- Excellent at high writing speeds; poor at 1X

Azo-cyanine

- "bright blue"
- Less common than other two dyes
- The standard dye for DVD-R

Figure 8

drives and audio players do not read. There are 100 testing partitions for OPC tests so that the disc can be reinserted and retested no more than 99 times after its first test, as long as the disc is not finalized after recording. The drive starts at the recommended power and then tests at seven levels below and seven levels above that recommendation. It then checks the output of the test to see

*"Cyanine" because the dye is blue. It has nothing to do with the poison cyanide.

**The ph/th is a strange combination of the Greek consonants φ and θ that should only appear together when the first is at the end of one syllable and the other at the beginning of the next sylllable, as in naphtha, the Greek word for "rock oil" (as in naphthalene and Fels Naphtha soap). Sir Patrick Linstead discovered a new class of organic dyes in 1933 and coined them phthalocyanine dyes from the words "naphtha" and "cyanine." He was a chemist, not a linguist.

what level worked the best. Some drives will then stick to that level while more sophisticated drives may perform a "running OPC" to continually monitor output and adjust power accordingly. These test steps are important because the laser's output can change as it ages, and the discs may have slight differences from the inner part of the disc to the outer edge. Once the testing is done, the drive is ready to record. The laser starts from the inside and works its way to the outside of the disc. Record players worked the opposite way, and that caused problems with vinyl discs of different diameters. The inside-out method allows recorders and players to handle discs of different sizes and dimensions without resorting to special adapters.

The official specifications for CDs are written in a book known as the "Red Book." The equivalent for CD-Rs and CD-RWs is known as the "Orange Book," first released in 1990. The Orange Book describes the various sections of a CD-R disc assigned for particular tasks. They are, in order:

1) The Information area
    a) The pre-groove area (most of which is accessible only by recorders)
        1) speed control information
        2) ATIP code—Absolute Time in Pre-groove mentioned above
        3) MID code—Manufacturer's IDentification code to assist the drive firmware in selecting the proper laser power and pulse rate. The code also identifies the type of disc
        4) PCA—Power Calibration Area, a test area for determining laser writing power. This area is suitable only for speeds up to 16X. The drive may calculate the power needed for higher speeds, but the Orange Book also added a a second PCA in the lead-out area to conduct true high speed power testing in a section of the disc that allows more physical room at the outer edge of the disc.
        5) PMA—Program Memory Area that holds track information for all sessions recorded to the disc before the final table of contents is written.
        6) Lead-In Area reserved for the final table of contents.
        7) Program Area holding all the data or music recorded on the disc. This is the largest area of the disc.
        8) Lead-Out Area that tells playback devices that the end of the disc is near.

There are two terms used to describe the completion of a recording session: "fixation" and "finalizaton." Fixating a disc means writing the table of contents (TOC) in the lead-in area and writing the lead-out areas on the CD-R disc so that the disc can be read in drives and players. CD-ROM drives and audio players look for the TOC when a disc is inserted; if it is not there, they cannot recognize the disc. If a disc is not fixated, the only drive that can handle the disc is the recording drive. That drive relies on another reserved area of the disc that lies just after the OPC area and is called the Program Memory Area or PMA. Recordings made at different times or in increments such as track-at-once or multi-session recordings store temporary TOC information in the PMA section in order to allow additional recordings to continue until the disc is full and has to be finalized. Finalizing a disc writes the final TOC and closes the disc so that no other recordings can be made to it.

Recording in the disc-at-once mode writes the lead-in with its TOC, the pre-gap, all the disc's tracks, the post-gap, and the lead-out areas in one non-stop session. It is the safer way to record CD-Rs because the recording laser operates continually and leaves no breaks in the recording that could contribute to errors. Recording in the track-at-once mode forces the laser to stop and start after each track, and the stopping and starting increase the possibility of errors. Multi-session recording also runs the risk of gaps between sessions causing errors, but modern drives seldom run into these problems today.

CD-R Reflective Surfaces

The original reflective surface for CD-Rs was gold. Gold has the advantage of being immune to oxidation. It does not tarnish or rust. The big disadvantage of gold, however, is its cost. Attempts to thin out the gold layer too much can cause some audio problems if the reflectivity varies enough to cause the signal output to waver and interfere with the servo motors in the drive. Thick gold layers do not have this problem, and the silver alloys are inexpensive enough (and more reflective than gold) that there is less need to thin them out. Figure 9 lists the advantages and disadvantages of the different types of reflective layers used for optical discs.

Reflective layers

Silver vs. Gold

	Reflective metal	Infrared reflection: alone	Infrared reflection: through medium	advantage	disadvantage
CD DVD CD-RW DVD-RAM DVD-RW	aluminum (gold/silicon for 2nd layer)	78% 18-30%	75% **18-30%** **15-20%**	•Cost	•Dyes are corrosive •Oxidizes if exposed to air
CD-R	thick Gold thin Gold	94% 84%	75% 65%	•Does not corrode or oxidize	•Cost •Reflects infrared and red well; less toward blue end of spectrum
CD-R DVD-R	Silver	96%	77% **15-20%**	•Cost •Impervious to dyes	•Oxidizes if exposed to sulfur in the air

Figure 9

CD-R Capacities

Cost was also a factor in the design of the CD system. Exacting precision is very expensive, so the designers decided to keep the expense in the mastering equipment that made the impressions (pits or wobbled groove) in the discs. Relatively inexpensive drives just have to follow the precise guides rather than duplicate them themselves. The guides for the CD-R start in the pre-groove area with the ATIP information. One of the important bits of that information is the capacity of the disc. The original CD-Rs held 63 minutes of audio or 550 MB, and 74-minute/650 MB discs soon followed. 80-minute/700 MB discs are now the most popular capacity for home recording. Greater capacity in tape means longer lengths unless the tape speed is reduced. In CD-Rs, however, the size of the disc does not change to hold more information. What changes is the speed of the drive, the distance between the grooves (track pitch) and the size of the burn marks. 80-minute CD-Rs spin more slowly than 74-minute discs to increase capacity in a manner similar to T-120 video cassettes offering 120 minutes at standard play and 360 minutes at extended play

Figure 10 lists the different speeds of the different capacity discs, and one can see how the larger capacity discs slow down to fit more information on the disc. When the disc slows down, the burn mark sizes have to get smaller to fit more information onto the disc. The older 63-minute discs had a comfortable margin to work within, and there were fewer problems with those discs in various drives than with discs of larger capacity. Old CD players may sometimes have trouble playing 80-minute capacity discs; and Figure 10 shows why: the minimum spacing between the burn marks is almost the same as the wavelength of the laser light before the polycarbonate acts as a lens to focus the beam on the mirror layer. Customers are often quick to blame a disc for poor quality when the problem may actually lie in a drive's inflexibility to "go beyond the limits" for which it was originally designed. Computer drives generally have the most flexibility in handling higher capacity discs. Older car and portable CD players and even some of the most expensive audiophile players are often the least flexible.

CD-R Capacities

- Recording area on 63-, 74-, and 80-minute discs is identical
  - 22.05 kHz wobble has a range of peak-to-peak spacing at 2% of spacing between tracks
    - 63.5 microns for 63-minute discs
    - 54.4 microns for 74-minute discs
    - 50.3 microns for 80-minute discs
  - Spindle motor locks onto wobble for precise linear velocity
    - 1.4 meters/second at 1X for 63-minute discs
    - 1.2 meters/second at 1X 74-minute discs
    - 1.1 meters/second at 1X for 80-minute discs
  - Minimum spacings for optical data marks
    - .97 microns for 63 –minute discs
    - .83 microns for 74-minute discs
    - .77 microns for 80-minute discs (the laser wavelength is .78 microns.)

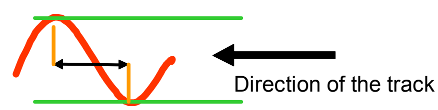


Figure 10

The red sine wave wobble in Figure 10 is not to scale. It is exaggerated to show what the "peak-to-peak" spacing is (the distance of the black arrow touching the orange lines). The built-in wobble tone guides the laser pick up drive in the recorder to follow the groove in the CD-R and tells the spindle drive to adjust its speed to keep the tone at 22.05 kHz for 1X speed or an exact multiple for higher speeds. Once the marks are burned in, they become the guides for a CD playback drive.

CD-R SPEEDS

Recording a CD-R in real time is just like recording an audio or video cassette—the recording process takes just as long as the playback. A 74-minute CD would take 74 minutes to record, frustratingly slow when a computer could process information far faster. Improvements in CD-R manufacturing and CD-R drive capabilities soon sped the recording process to 2X, then 4X, 8X, 16X, and now to 52X. The first speed increases were widely welcomed, but the latest changes have led to questions about the real benefits of faster recording times. The timesavings are most meaningful if the discs are filled to capacity because the **rated** speed is really only the **maximum** speed at which the laser records at the outer half of the disc as it fills up. Recording speed refers to the rate that the **laser records**, not to the rotational speed of the disc. See Figure 11. The fastest drives will start at just below 24X recording speeds (with the disc spinning about 10,600 rpm) at the hub area of the disc because that is the fastest rotational speed the disc can handle before encountering the physical limits of balance and wobble. As the laser moves away from the hub area toward the center on its way to the outer edge, its laser recording speed increases and the rotational speed of the disc decreases. Most users do not fill their discs to maximum capacity; so they may not allow the fastest drives to reach their fastest recording speeds. Replacing a 24X drive for a more expensive 32X drive will reduce the record time on a full 80-minute disc by fewer than 90 seconds per disc—if the computer can keep the data flowing at a speed that can keep up. If the drive is faster than the data flow, one of two things happens: 1) the data buffer that stores the information before sending it to the laser control runs out of room (a "buffer underrun" that ruins the recording), or 2) the drive slows down under the recommendation of software that prevents buffer underruns. The latest 40X, 48X, and 52X drives are more expensive because, like 16X drives, they operate at tremendous initial rotational speeds that can damage bearings of lesser drives if discs are even slightly out of balance, and they often incorporate software that slows them down if the computer cannot supply data fast enough. Most of the latest drives also incorporate greater buffer memory to reduce the problems of underruns; but unless the host computer is fairly fast, a user may find his or her expensive "super" drive smart enough to slow down to the same speed as that offered by the 12X or 16X drive it replaced.

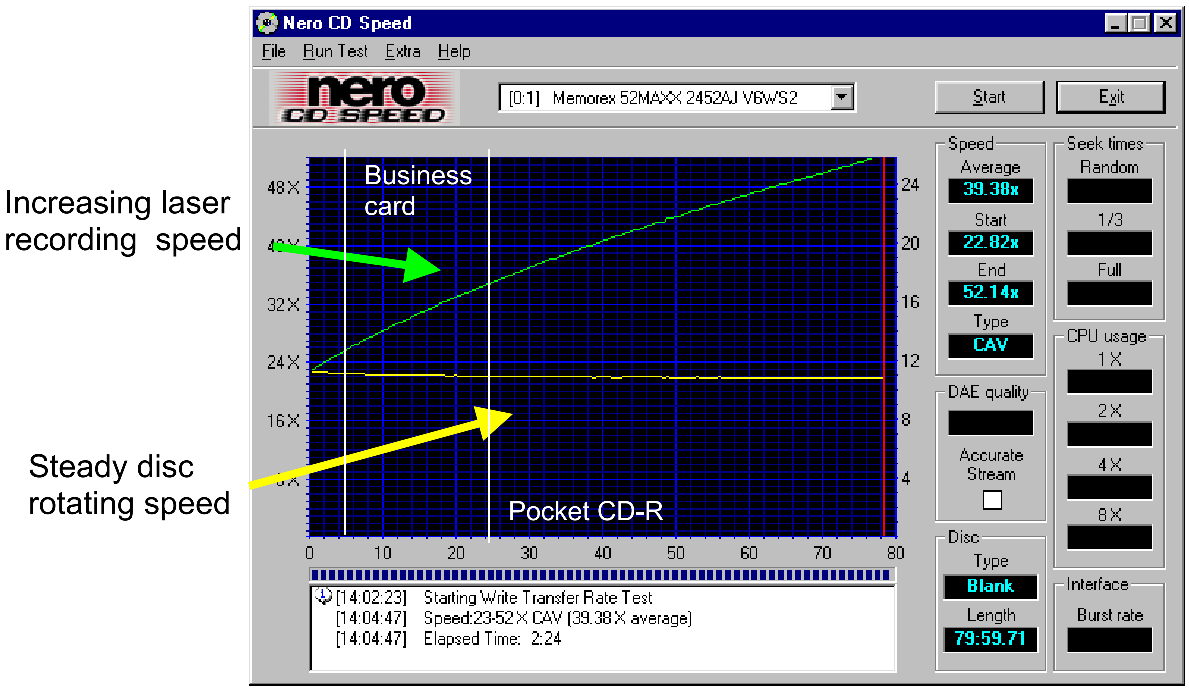


Figure 11

52X CD-R Recording Drive
Maximum Recording Speed: 52.14X
Starting Speed: 22.82X
Average Speed: 39.38X

The original design for CDs had the laser pick-up seeing the pits travel above it at a constant rate or "constant linear velocity." That means that the disc turns at a defined rate at the beginning (about 500rpm) when the laser is reading the area closest to the hub and slows down to about 200rpm as the laser moves to the outside edge so that the music data are being transferred at a steady 150 kilobytes per second. That worked perfectly for audio CDs because there was no need to go faster than the tempo at which the music was supposed to play. When CD-ROMs with data information appeared, there was an advantage to speeding them up in order to transfer data faster to the computer or to the game console. A higher fixed speed or "constant angular velocity" became the norm for CD-ROMs. In the race to produce ever-faster CD-R drives as a way to develop market differentiation, manufacturers have developed two variants of both of these methods for high-speed recording. In order to relieve drives of the stress of high rotational velocities, the "super" drives can work their way up to their highest rated speed in two different ways: 1) Zone Constant Linear Velocity (Z-CLV) and 2) Partial Constant Angular Velocity (P-CAV). See Figure 12. The result has been a general misunderstanding of the speed ratings of CD-R drives.

A 12X/4X/32X designation describes a drive that records CD-Rs at a maximum speed of 12X; records a CD-RW at a maximum speed of 4X; and plays back a CD-ROM or extracts audio from an audio CD at a maximum of 32X. A high-speed drive labeled as 24X/10X/40X can record a CD-R at a **maximum** speed of 24X, but Figure 11 shows why "24X" does not take half the time as "12X." The drives have to build up to the maximum speed; and if the disc is not even half full, the burner may never reach its maximum rating. The 80mm Pocket CD-Rs and 61mm CD-R business cards will never allow a "super" drive to reach its maximum speed. Another point worth noting is that the "40X" CD-ROM rating applies to well recorded discs. Discs with lower signal-to-noise ratios or errors will prevent the drive from reading at its maximum rating. Buyers who expect to cut their recording time in half by upgrading from 12X CD-R burners to 24X burners may be surprised at how little time is actually saved. Figure 13 shows a chart with the actual maximum time savings one can expect upgrading from one speed to another; below the graph is a chart of the actual average speed of a 52X drive at different speeds and the maximum time saved

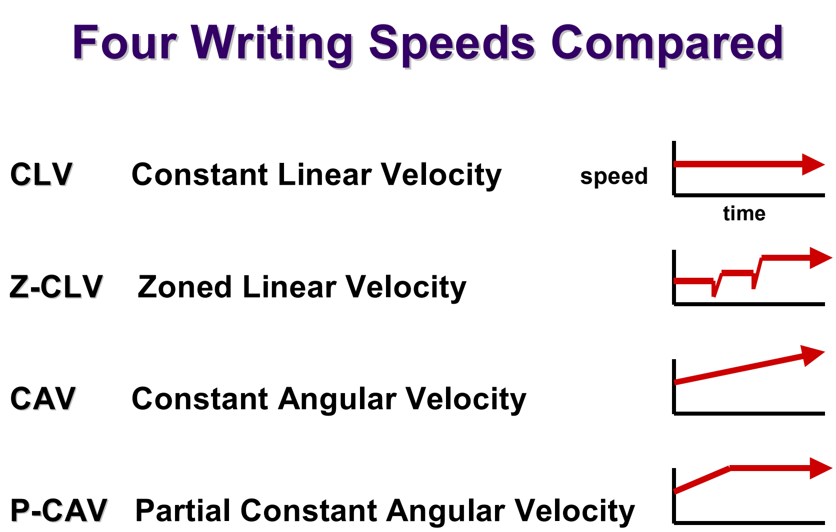


Figure 12

maximum recording speed	total time to record a full 80-minute disc	average effective speed	maximum time savings for next higher speed
4X	21:12	3.8X	
8X	10:42	7.5X	10:30
12X	7:14	11.1X	3:28
16X	5:30	14.5X	1:44
24X	3:55	20.4X	1:35
32X	3:20	24X	:35
40X	3:10	25.3X	:10
48X	2:46	28.9X	:24
52X	2:39	30.2X	:05

Figure 13

The misunderstanding of the difference between the laser writing speed and the actual drive rotational speed has promoted unnecessary concern about the integrity of CD-Rs within high-speed drives. Stories of discs "exploding" because of the high rotational forces within drives have reached the level of urban myth. Discs with damaged center hubs or badly eccentric shapes can, if improperly clamped within a drive, fracture and actually break apart. Such a situation would be due to the original disc damage increasing enough under stress to become more apparent. These "problems" existed with high-speed CD-ROM drives and even with drives rated below today's highest speed ratings. Figure 15 is a graph of the rotational speeds of a 52X high-speed drive (yellow line) and a 20X drive (red line). Both begin to spin the discs at speeds equivalent to approximately 20X although their actual rotational speeds may be 10,600 RPM versus 9,600 RPM.

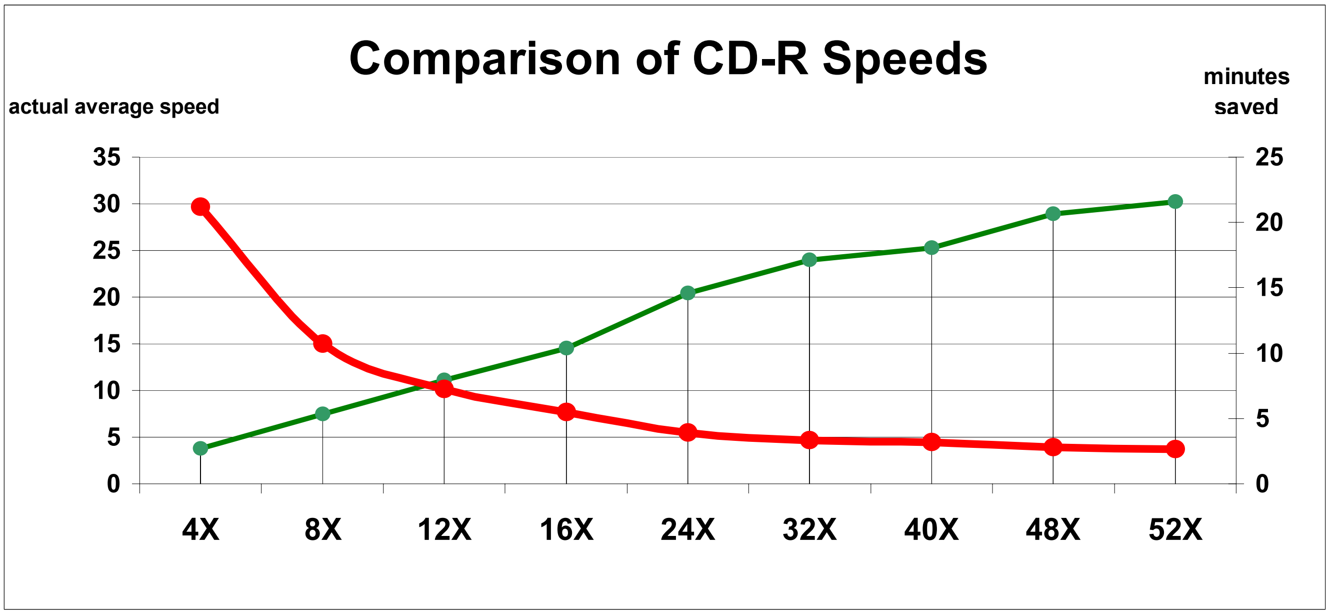


Figure 14

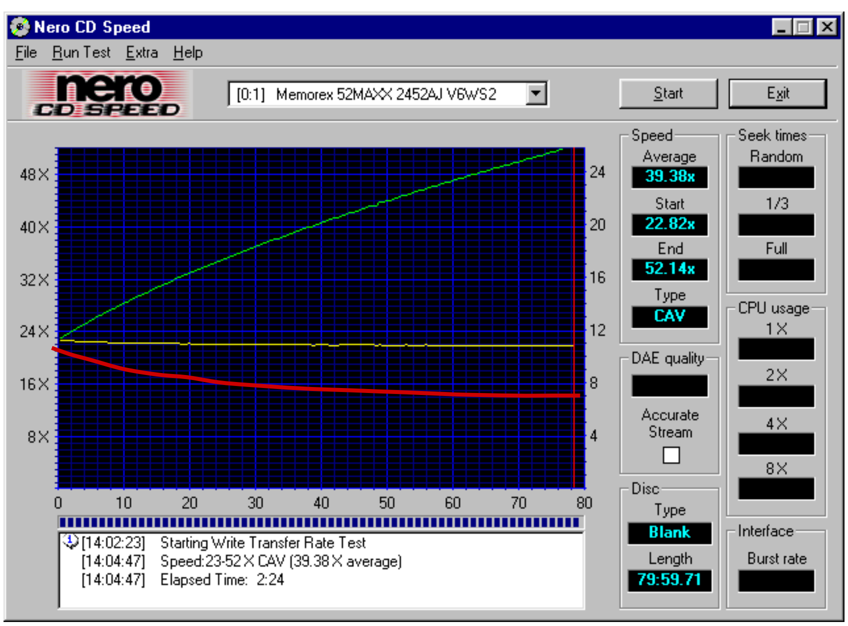
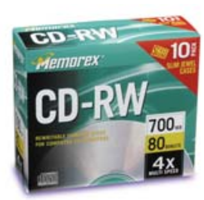


Figure 15

There is little actual rotational difference between the two, but a damaged disc that does not fracture at 9,600 RPM may not be able to keep itself together at an additional 1,000 RPM. The fault lies in the disc damage, not in "excessive" drive speeds. A badly damaged disc could also fly apart in a 20X drive. The limit of high-speed CD-R recording appears to be 52X for several reasons:

1. There are no appreciable time savings. 52X is **at best** only 5 seconds faster than 48X.
2. The flatness of a 56X would have to be perfect.
3. The mechanical problem lies in any wobble at the outer edge of a disc or in any eccentricity.
4. The cost of a 56X disc would be greater than a 52X.

These four reasons are why 52X CD-R recording speed is the limit, not a fear that discs will be exploding in users' drives.



CD-RW

The marks burned into a CD-R dye layer are permanent. They can't be changed. For users accustomed to recording over magnetic tape and magnetic floppy discs, this can be a real handicap. Researchers looked for ways to make a disc that could be erased, and they came up with the CD-RW. Instead of an organic dye layer, this disc has layers of a semi-metal alloy vacuum deposited in between two dielectric layers that act as insulation to trap the laser's heat and to prevent it from damaging the disc. The alloy has two states: a glass crystal state and an amorphous (Greek again, for "formless") state that does not reflect laser light. Heating the alloy to 200° C. (320° F.) with laser power causes it to crystallize so that it can reflect some light from the reflective mirror layer composed of a combination of titanium and aluminum (the dielectric layers contain sulfur that would tarnish silver.) Not much light comes back, only 15 to 25%; so the drive needs an automatic gain circuit to boost the light reading. (DVD players have the same circuit built into them. That's why some DVD players can read CD-RWs but not CD-Rs.) Raising the laser power to 600° C. (1,112° F.), however, melts the alloy so that when it suddenly cools afterward ("quenching") it reflects almost no light at all. This method of altering the reflectivity of the disc one way or another is called "phase change" recording and is the method used not only for CD-RW but also all the versions of recordable DVDs. The entire disc can be erased by recording over it with the lower laser power to heat the alloy enough to turn it into its crystalline state again. The fact that lower power "erases" the disc is a big advantage in phase change recording systems because the lower power can erase before higher power writes, and that allows direct overwriting of the medium without having to erase and entire disc prior to recording on it. The light reflection process is similar to that of CD-Rs with two exceptions: 1) CD-RWs, like floppy discs, need a file structure formatted on them, and that takes up to 23% of the disc's capacity; and 2) after time the alloy's ability to change its form has decreased enough that uncorrectable errors prevent its further use. The general rule is 1,000 erase cycles are the safe limit for CD-RW discs. The manufacturing process for CD-RWs is much trickier than that for CD-Rs because of the metal deposition processes (called "sputtering"); so it is unlikely that the two media will ever cost the same.

CD-RW discs have a reputation for being unstable that is undeserved. Phase change alloys are affected by extreme heat in order to change their physical state whereas CD-R dyes are affected both by lesser amounts of heat and ordinary sunlight. Chemical changes in the phase change layers due to ion migration or oxidation are potential problems for CD-RWs if they have not been manufactured properly. Both CD-Rs and CD-RWs use optical grade polycarbonate as a base material, and this type of plastic absorbs water. High levels of humidity can be a factor in reducing the storage life of optical discs if the humidity reacts with the mirror layers on the discs or the chemical stability of the phase change alloys. CD-Rs that use gold as a reflective layer are superior in this regard because gold does not oxidize. The reputation for instability may come from other factors such as packet-writing software problems. The original design intent for CD-RWs was to provide an erasable CD-R. However, the temptation to make them "optical super floppy diskettes" required a format structure written on the discs with error correction and sector addressing built in. Data would be written in "packets" with a mechanism to link blocks so that files could be altered or deleted without interfering with existing files. Unfortunately, software companies came up with mutually incompatible format systems. The "instability" of CD-RWs is very often due to conflicts or deficiencies in packet-writing format systems, not to the disc itself. Filling a CD-RW to its capacity, for example, can stifle error correction sorting of files enough that adding files causes the disc to be unreadable. It is best to leave some extra space on all rewritable media to allow room for the error correction processes to work effectively.

CD-RWs have not avoided the pressure to develop faster recording speeds. Unfortunately, there are some significant differences in the way the phase change material in CD-RWs works and the way photo-sensitive dyes in CD-Rs work. Photosensitive dyes work over a wide range of recording speeds, but the semi-metal alloys in rewritable CD-RWs have a much narrower range of compatibility for recording speeds. The original design of CD-RWs limited the fastest recording to 4X, 4 times audio playback speed. In an attempt to increase CD-RW writing speeds to keep up with the trend in increasing CD-R speeds, engineers changed both the formatting process so that some formatting was done during recording and also changed the design of the disk and recording drives to overcome earlier restrictions that limited CD-RW recording speeds. The design changes mean that older 1X-4X drives are not able to record the faster 4X-16X "high-speed" CD-RWs. Even though the older CD-RWs rated at 1X-4X and high-speed CD-RWs rated at 4X-16X share a 4X speed, it is not the "same 4X" speed. The two versions share only the speed rating; but the "write strategy," that is, the amount of laser power and the timing of the light pulses, is different. Only high-speed CD-RW drives can record high-speed CD-RWs. Because older 1-4X CD-RW drives do not have the proper write strategy to record high-speed CD-RWs, engineers have prevented their ability to write at all on these discs by shifting the Power Calibration Area in the ATIP on high-speed CD-RW discs. When an older drive looks for and cannot find the PCA where it expects it to be, the drive gives up and sends an "invalid" message to the user. There is nothing wrong with either the drive or the medium. They are just not designed for each other. High-speed drives do recognize and are able to use the older 1X-4X CD-RW discs at their maximum 4X speed.

Unfortunately, 4X-16X was not enough. In order to move to even greater CD-RW speeds, a new speed rating of "ultra-speed" has been introduced with a range of 16-32X. Once again there is a problem with overlapping but incompatible speeds: high-speed CD-RW drives cannot record onto ultra-speed CD-RW discs even if the speed range overlaps at 16X. Ultra-speed CD-RW drives can record any disc; but high-speed drives cannot write to ultra-speed discs no matter what the speed rating is. This is a cause of great confusion, and the small logos identifying the discs do not do much to clarify the limitations.

CD-RW Rewritable Discs

- Quaternary crystalline metal alloy instead of dye
    - Sputtered layers of indium-silver-antimony-tellurium
    - Crystallizes at 200° C. under 4-8 milliwatts of laser power
        - Crystalline state reflects 15-20% of the laser light during read operation
    - At 600° C. (8-14 milliwatts of power, 1X speed) the alloy melts to amorphous state
        - Sudden cooling leaves the alloy dull, with little light reflected back
    - Two zinc-sulfide and silicon dioxide dielectric layers blanket the alloy to trap heat
- Alloy's behavior deteriorates beyond 1,000 erasures; leaves uncorrectable errors

In order to offer some guidance for CD-RW users, there are three logos to distinguish the different speed ratings of CD-RW discs with barely discernable lettering on the side of the original logo. See Figure 16 below. Once any of the CD-RW discs is recorded, it can be read in all CD-RW drives that use the same packet-writing software. Reading data is not the problem. Only writing the right disc in the right drive is a concern.

INCOMPATIBLE SPEED RANGES OF CD-RW DISCS

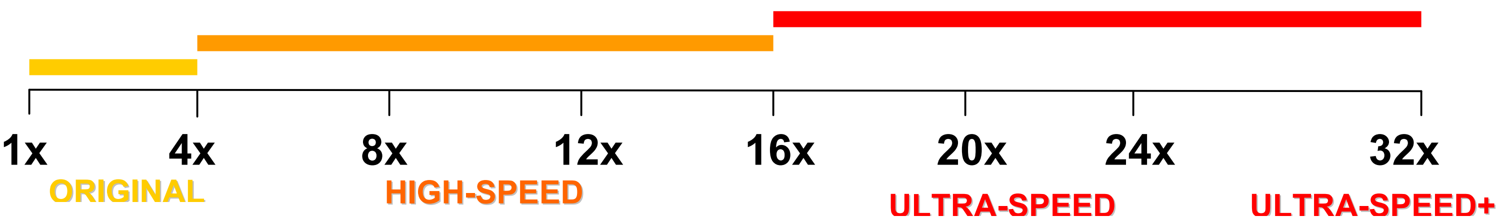


Figure 16

MINI-DISC

Sony introduced the Mini-Disc format as a recordable optical disc well before CD-Rs were available. The Mini-Disc is in the class of magneto-optical discs, discs that work on very different principles from those used in the CD-R and CD-RW discs. The Mini-Disc was a real break-through in recording technology, but its significance was overshadowed by controversies of the time: 1) the Mini-Disc was competing for public attention with a digital audio cassette known as DCC—and the public did not seem to care much about either format; 2) the Mini-Disc used heavy audio compression to store information on the disc, long before the public became comfortable with MP3 audio compression; and 3) the disc was housed in a protective cartridge. The Mini-Disc was not a recordable equivalent of a CD, and that is what consumers expected. So despite its many technological advances, the Mini-Disc was only coolly accepted, except in Japan where it became a very popular product.

The cartridge or caddy holding the MiniDisc is square with sides of 7 centimeters (2 ¾ inches) and an opening slide that makes the cartridge resemble a floppy diskette. The disc inside the cartridge could be either a molded disc like a CD or a recordable disc. In many ways, the design of the disc itself is very similar to that of CDs. The scanning velocity is the same 1.2-1.4 meters/second, and the track pitch is identical. The sampling frequencies are the same, as is the EFM (eight to fourteen) signal modulation. The audio disc holds 160 megabytes, and the data format holds 140 MB with extra error correction. The biggest differences from the CD-R, other than the cartridge and the size of the disc, is the way the disc is recorded and the audio signal compression that is used on the disc.

MiniDisc Magneto-Optical Disc

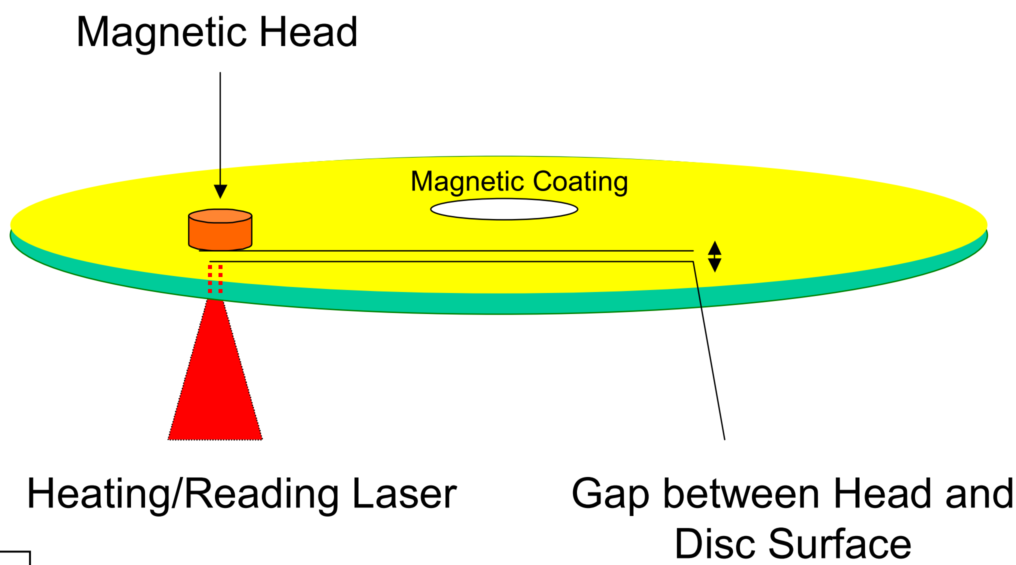


Figure 17

Unlike CD-Rs that use a layer of photo-sensitive dye and CD-RWs that use layers of semi-metal alloys that react to the laser's heat by either melting or crystallizing, the MiniDisc used a terbium-ferrite-cobalt layer that worked in combination with both a heating laser and a magnetic head. The laser heated the recording layer to the point at which it had no specific magnetic orientation (a Curie point of 185° C or 365° F). On the other side of the disc at the same radial point is an electro-magnetic head that magnetically records information to the surface of the recording just before the surface cools and retains the magnetically printed pattern (Figure 17).

This type of recording format is known as Magnetic Field Modulation. Although this seems a step backwards to the days of floppy disks, the change in magnetic patterns works in combination with a reading laser according to a phenomenon known in physics as the Kerr Effect. The differing orientation patterns of the magnetic signals on the disc will change the polarization of laser light reflected back from the disc in a way that is analogous to the pits molded into a regular CD or MiniDisc. The laser is first used in a high-power mode of 6.8 milliwatts just to heat the disc from the bottom while the magnetic head does the recording on top. During playback, the laser reads the changes in reflected light through the bottom of the disc in a way similar to that of the laser in a CD player. The combined use of both a magnetic head and a laser also applied to other forms of magneto-optical recording such as M-O discs, but the MiniDisc is the most common use of this recording technology.

The diameter of the MiniDisc is only 6.4 cm (2.5 inches). The small size meant that the audio signals had to be compressed in order to store enough music to make the format attractive. Sony introduced Adaptive Transform Acoustic Coding (ATRAC), one of the earliest forms of psycho-acoustic reduction of digital audio data that was difficult to distinguish from the original uncompressed signal. ATRAC used 16-bit stereo encoding at a sampling rate of 44.1kHz, but the rate of data is reduced to one fifth that of a CD—just 292 kilobits per second instead of the CD's 1.4

megabits per second. That data rate allowed 74 minutes of audio on the tiny disc, and further developments increased the capacity to 80 minutes. This type of compression was considered heretical to audiophiles when MiniDisc was first introduced, but it paved the way for MP3 and other forms of sophisticated psycho-acoustic compression encoding that grew in popularity with the growth of the Internet and CD-R recording. A later version of the compression scheme called ATRAC3 with a bit rate of 66 kbps allows up to 5.5 hours of recording on a standard 80-minute disc and ATRAC3plus at a rate of 48 kbps allows even more recording time.

Sony never gave up on its pioneering MiniDisc format, and continuing work has led to a 1-GB version of the disc called "Hi-MD." The Hi-MD disc competes with the miniature hard drives capable of storing 1.5 GB for use in portable audio players and digital cameras. Hi-MD recorders and playback devices are backwards compatible in that they can record and play standard 60-, 74-, and 80-minute MiniDiscs as well as the Hi-MD discs. Older MiniDisc equipment, however, will not be compatible with Hi-MD discs.

DVD—MORE IS NEVER ENOUGH

Figure 1 showed the impressive increase of storage capacity of new media. Once the CD was well established, researchers looked for ways to store high quality video onto a disc that same size. Laser discs actually preceded CDs, but they were too big and held analogue video signals, not digital. In order to fit the massive amounts of information that digital video required onto a CD-sized disc, engineers worked to: 1) decrease the pit sizes by half from a minimum of 0.83 μm to 0.4 μm); 2) increase the number of tracks (the number of rings the spiral on a disc can make) by reducing the pitch (the distance from the center of one track to the center of the next) to 0.7 μm, less than half that for CDs; and 3) decrease the amount of data required by throwing out unnecessary or repetitive information. Figure 18 shows the result of engineering efforts to fit more pits into more tracks.

Two changes had to be made to for smaller data pits: 1) the wavelength of the reading laser decreased from the 780 nanometer (billionth of a meter) wavelength used for CDs to 650 nm for DVD; and 2) the discs had to be molded in two halves to get precise pit geometry and correct focusing of the laser. The two halves are then bonded together to equal the thickness of a CD. Engineers even figured out how to make each half of the DVD hold an inner semi-transparent layer to allow the laser to focus either on the reflective surface or the semi-reflective surface in the middle. This allowed them to produce four different types: 1 side, 1 layer; 1 side, 2 layers; 2 sides, 1 layer on each; and 2 sides, 2 layers each. Each version has a number code shown in Figure 19.

Figure 20 shows the different popular optical media and the basic manufacturing steps for each. It is obvious that DVD is the most complex medium with its two bonded halves and potential semi-transparent layers. (This form, however, offers great protection for the discs because the "top" surfaces most susceptible to physical damage are glued face to face, unlike CDs and CD-Rs.) Just as complex is the encoding of the video information. Professionals from around the world worked to determine the best ways to compress video to render a high quality picture with a minimum of data. They formed a **M**otion **P**icture **E**xperts' **G**roup that issued a number of encoding schemes for different applications. MPEG 2 is the format for DVD, and an audio compression scheme in layer 3 became the popular MP3 encoding. The video encoding provides a much more detailed picture than VHS at a data rate that can fit a 2-hour movie on one CD-sized disc. DVD cannot provide HDTV or "high definition" TV at this point, but researchers are working on blue lasers with smaller wavelengths than the red lasers used in CDs, CD-Rs, and DVDs as part of the solution as well as developing new data compression schemes.

CD vs. DVD Densities

CD DVD

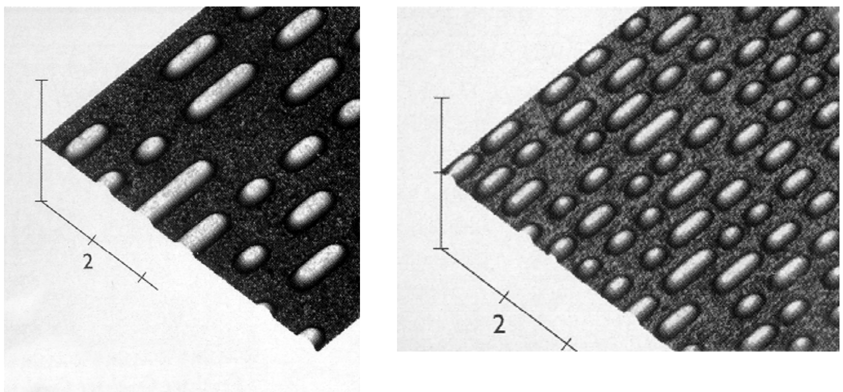


Figure 18

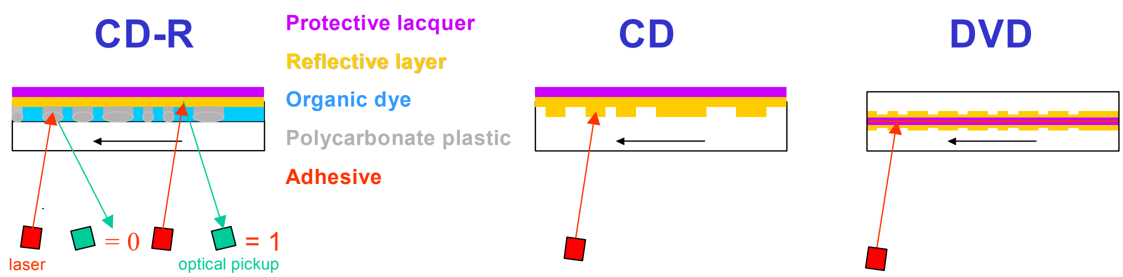
DVD Numbering

- DVD 5 4.7 GB single side single layer
- DVD 9 8.5 GB single side dual layer
- DVD 10 9.4 GB double side single layer
- DVD 18 17.0 GB double side double layer

Figure 19

The enormous capacity of the Digital Video Disc attracted CD-ROM users who wanted encyclopedias on one disc instead of 6 or more CD-ROMs and audiophiles who wanted higher resolution audio than CDs provided. So the DVD acronym was officially changed to mean "Digital Versatile Disc."

Optical Media



CD-R

1) Mold base with ATIP info & wobbled groove
2) **Spin-coat with dye**
3) Sputter reflective **silver or gold** on dye
4) Clean edges
5) Spin-coat lacquer on top of silver or gold

CD

1) Mold base with data
2) Sputter aluminum onto base
3) Spin-coat lacquer onto aluminum
4) Silk-screen surface

DVD

1) Mold **base(s)** with data
2) Sputter aluminum onto base
3) Spin-coat lacquer onto aluminum
4) Glue 2 bases together

Figure 20

DVD-RECORDABLE FORMATS—MORE THAN 1 IS TOO MANY!

The same question that followed CDs followed DVD—when can we record on them? The answer came with several competing formats offering the ability to record high-density data on a disc that may or may not be playable in a DVD player. The reasons for the competition are due to a combination of corporate pride, economics, technical arguments, and political resistance.

- Corporate pride—the developer of the "winning" format will have the reputation for ingenuity and marketing savvy. Ego drove Sony and JVC to a horrific battle over home video that JVC eventually won in the marketplace with its VHS system.
- Economics—the media industry is famous for price erosion so severe and sudden that the best chance for profit is not in manufacturing but in the royalties based on patents. Each developer is pushing for his format to provide that kind of profit protection for the future.
- Technical arguments—video generally requires a long stream of data; data storage requires fast random access. Developers of the first two systems concentrated on one requirement or the other in their designs. A third, later group was able to combine both requirements in its system.
- Political resistance—the music industry has put up a losing battle with CD-R, MP3, and copy protection. The motion picture industry has much greater firepower, and it wants to be assured that no one will be able to illegally copy and distribute movies on these new media.

At this point there is no clear answer as to which format may be the clear choice for most users or whether the formats will continue to coexist. Each of the formats is different for one or more of the reasons above.

Optical Disc Storage Capacities

	Unformatted	Formatted	Audio min.	Video min.
CD	650 MB		76 minutes	1 hr. mpeg 1
CD-R	650 MB 700 MB		74 minutes 80 minutes	1 hr. mpeg 1
CD-RW	650 MB 700 MB	533 MB 572 MB	74 minutes 80 minutes	1 hr. mpeg 1
DVD	-5 4.7 GB * -9 8.5 GB -10 9.4 GB -18 17.0 GB			133 min. mpg2
DVD-R	3.95 GB 4.7 GB*			1-6 hours**
DVD-RW	4.7 GB*	4.37 GB		1-6 hours
DVD+RW	4.7 GB*	4.37 GB		1-6 hours
DVD-RAM	2.6 GB 4.7 GB* 5.2 GB 9.4 GB	2.32 GB 4.2 GB 4.6 GB 8.4 GB		1-4+ hours

Figure 21

*This figure is actually 4.377GB because the DVD Forum defined 1 GB as a billion bytes in the decimal system instead of the conventional binary system of 1,073,741,824 bytes (2^{30}) that computers recognize.
** Windows 95 will only allow a file up to a maximum of 2.0 GB; Windows 98 allows a maximum of 4.0 GB; XP has removed limits on file sizes. These numbers generally correlate with the 4.377GB capacity of a DVD disc, but inconsistencies remain in both software and operating systems.

DVD Recordable Overview

	CD-R	DVD-R	DVD+R	DVD-RAM rewritable	DVD-RW rewritable	DVD+RW rewritable
Laser wavelength	780 nm	635/650 nm	650 nm	650 nm	650 nm	650 nm
Recording method	Organic dye	Organic dye	Organic dye	Phase change semi-metal alloy	Phase change semi-metal alloy	Phase change semi-metal alloy
Track structure	Wobbled groove	Wobbled groove	Wobbled groove with land pre-pits	Pre-molded pits along groove	Wobbled groove with land pre-pits	HF modulated wobbled groove
Recording area	In groove	In groove	In groove	In both groove and land	In groove	In groove
Number of erases	0	0	0	100,000	1,000	1,000
velocity	CLV/CAV	CLV	CLV/CAV	CLV/CAV	CLV	CLV/CAV
recording speed range	1x - 52x	1x - 16x	1x - 16x	1x - 5x	1x - 8x	1x - 4x
Design objective	audio	video	Audio/video data	data	video	Audio/video data

Figure 22

DVD-R

DVD-R is very similar to the CD-R in its design and function. The original design objective was to provide a recordable disc that could hold enough video information to compete with VHS video cassettes in terms of capacity. Like CD-Rs, information is recorded in a groove filled with an organic dye; and once the laser alters the dye, the information cannot be changed. The disc rotates at different speeds so that the data pass under the laser at a constant rate. This rate is called CLV, or "constant linear velocity," meaning that the groove travels as a steady line no matter whether it is located toward the inside of the disc or toward the outer edge. If the data are on the outer edge, the disc slows down to keep the rate of reading the data the same as the reading rate toward the center because, like a wheel, the outer edge turns faster than the inner edge around the spindle. CDs and CD-Rs also use the CLV design. Figure 23 shows a cross section of a disc groove with the laser mark fitting in the groove itself.

In order to provide copy protection for copyrighted video programs, the developers of the DVD-R offer two different versions. One is for "general" use, and it uses a 650 nm laser wavelength for recording. This wavelength is identical to that used in DVD players; so consumers who record home videos can transfer them to general use DVD-Rs and play them in their DVD players. "Authoring" DVD-Rs are those used to make video masters on sophisticated hardware unencumbered with copy protection schemes that could present software conflicts during video programming. The authoring discs use a 635 nm laser wavelength to distinguish them from the general use versions. These discs can also be played on DVD players, but they cannot be recorded in general use drives.

The first "consumer" DVD-R drives could record at 2X for only a few DVD-R discs. All others were restricted to 1X speeds. By the time 4X drives appeared, the number of disc suitable for 4X recording had increased dramatically, but these 4X discs posed a larger problem for older drives: unless the drives' firmware is updated, a 4X disc is likely to lock the drive in a recording cycle that could burn out the recording laser unless the user intervenes to stop it. Pioneer and suppliers of 4X discs warned users about the potential problem and offered a firmware update to resolve the problem. Shortly after 4X DVD-R discs appeared, most DVD-R drive manufacturers, including Pioneer, introduced "dual" DVD recorders that could record on both DVD-R/RW and DVD+R/RW.

The general purpose DVD-R discs offered in the U.S. (version 2.0*) have a pre-formatting address scheme in the form of "land pre-pits" between the grooves to identify data blocks, a pre-recorded control area that prevents bit-for-bit copying of CSS encrypted movies, Content Protection for Recordable Media (CPRM), and the possibility of double-sided discs. One reason for the use of the 650 nm laser is its lower cost so that "general" use drives do become more affordable. The latest version of the authoring DVD-Rs, version 2.0 /4.7GB, reserve space in their lead-in area for DDP (Disc Description Protocol) header information that is commonly used on DLT master tapes for DVD replication. This feature, known as CMF for cutting master format, allows the authoring DVD-R discs to become direct replacements for DLT masters. General-purpose discs cannot be recorded on authoring drives, and the authoring discs will not work on general-purpose drives. Once recorded, however, the discs can be played on each other's drives and on most recent DVD players or DVD-ROM drives.

*Version 1.0 was only 3.95GB when it first appeared in 1997. Version 1.9 in 1999 increased capacity to 4.7GB, and the next year DVD-R split into the authoring version 2.0 and the general use version 2.0 common today.

DVD-R Disc Structure

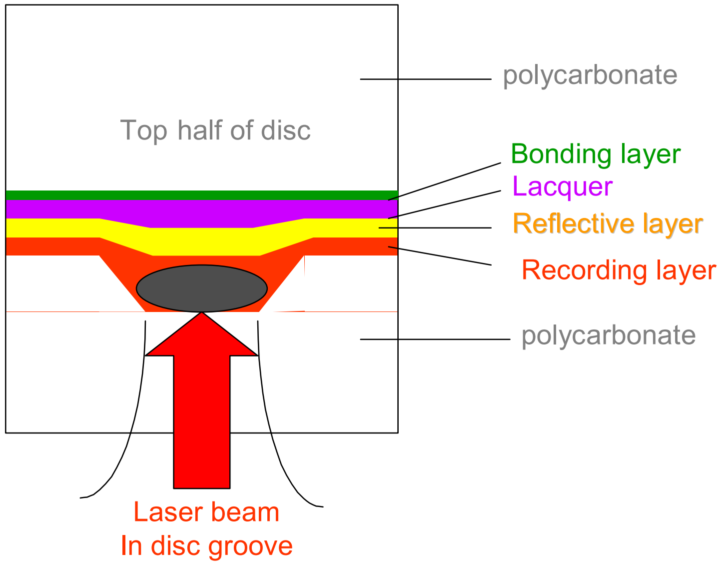


Figure 23

DVD-RW

The erasable and rewritable DVD is similar to the CD-RW version in its basic design, and its operating parameters are directly related to the DVD-R. The marks the recording laser leaves reflect the light at a different angle from the unmarked portion so that the marked reflection misses the optical sensor just as if no light came back at all. This design is known as a "phase change" of the light, and all of the rewritable DVD systems use this method. Like CD-RW alloys, the alloy used in DVD-RW may have trouble reacting predictably to the laser power after 1,000 cycles; so that figure is used as the upper limit of record/erase times. The lower reflectivity of the DVD-RW can cause confusion in some DVD players and DVD-ROM drives that mistake the disc for a dual-layer DVD and struggle to read it. Other drives may not recognize the disc format code of the DVD-RW and refuse to play it. Drives that may accept the DVD-R may not accept the DVD-RW unless their firmware can be brought up to date. The latest DVD players are becoming more compatible with DVD-R and DVD-RW discs.

The DVD-RW was introduced as a video alternative to the rewritable DVD-RAM. Video recordings on DVD-RAM cannot be played on regular DVD players even if the discs are removed from their cartridge (see below); so DVD developers wanted an erasable DVD medium that could be reused just as video tape can be. The DVD-RW works well in that role; but when used for data, its video parentage becomes a problem. Video recordings are generally sequential: new video as added at the tale end of earlier recordings. The sequential design, however, prevents data from being erased from the DVD-RW to allow more room in their place. Deleting files from a DVD-RW will not increase the disc's capacity. The only capacity available is that at the end of the last section of recorded information. This is a handicap only for data, not for video; but some DVD developers were dissatisfied with this limitation and wanted a format that worked equally well with video and data. Their solution was the DVD+RW below.

DVD-RW Disc Structure

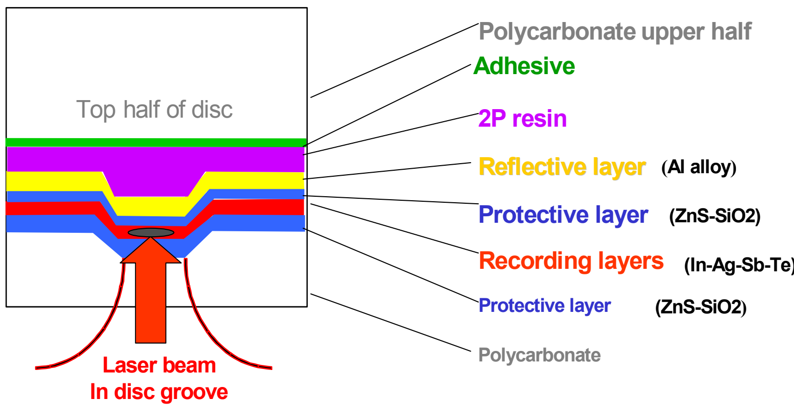


Figure 24

DVD-RAM

This DVD is the most unusual of the recordable discs. It is designed for **R**andom **A**ccess **M**emory (the RAM in the name), a way to find and get data very quickly. The design offers a great deal of memory storage capacity for data files, and its original intended use as a data storage and back-up medium got around the problems associated with video copy protection although the discs can also be used to record video. In addition to a groove molded into a slice of polycarbonate that is bonded to a second slice, there are also pits used to identify sectors for address information so that a drive can locate files very quickly. These molded addresses are visible on the DVD-RAM discs as a series of small lines perpendicular to the centering hub. Recording is done in both the groove and the land between the grooves so that the grooves can be a bit wider without reducing total recording capacity. The disc turns at the same rate of speed all the time, a rate referred to as CAV for "constant angular velocity."* This design feature also aids data access speeds because the spindle's servo motor does not have to take time to change speeds. The most unusual aspect of the DVD-RAM is that it is enclosed in a protective cartridge.

*Panasonic refers to the speed as "zoned CLV," meaning that the drive does change speeds to some degree depending on where it expects to find data addressed in a particular zone of the disc. Because the format design is to provide fast, random access for data, there is a defect management system built into the drive to avoid using areas of a disc it finds suspect. The DVD-R, because of its design objective for video, is best at linear recording. DVD-RAM allows faster access to and retrieval of data.

Figure 25

DVD-RAM Types:

Type 1: non-removable discs of all capacities
Type 2: single-sided removable discs
Type 3   single-sided bare discs
Type 4: double-sided removable discs
Type 5: double-sided bare discs
Type 6: double-sided removable 8-cm discs
Type 7: single-sided removable 8-cm discs
Type 8: double-sided 8-cm bare discs
Type 9: single-sided 8-cm bare discs

The Type 1 DVD-RAM versions cannot be removed from the cartridge, but Types 2 and 4 cartridges do allow the discs to be removed if the user is very careful. The cartridge prevents the use of DVD-RAM discs in DVD players; but since the original design objective was to provide a high capacity medium for data storage, not home video recording, the limitation may not be important in the medium's intended market. The design of DVD-RAM, however, does give it a unique advantage for video: DVD-RAM drives can simultaneously write and read from DVD-RAM media. This allows a user with a set-top video recorder to watch a program while recording it, leave to answer a phone call, then return to catch up watching the portions of the program he or she missed while the recorder continues to record without a break. DVD-RAM also offers the advantage of being able to withstand 100,000 record/erase cycles, a feature that is essential for a medium intended for frequent updates, high storage capacity, and random accessibility, or as a video recorder for time delayed viewing. The double interface layers in the coating allow the greater number of erasures and rerecordings compared to CD-RW, DVD-RW, and DVD+RW discs.

The DVD-RAM cartridge is somewhat similar to that of a micro floppy disc with a sliding shutter protecting the medium inside and a write/protect lock on the lower left side of the cartridge. The removable discs have cartridges with a knockout plug holding the hinged door in place. Once the plug is removed, the remaining hole becomes a sensor hole to tell a drive that the disc had been removed at one time. The drive firmware may then identify any errors as due to a dirty or damaged disc or may verify all data that are subsequently written to a disc that had been removed. Some DVD-RAM discs are available without cartridges.

The protective cartridge, built-in sector addresses, error management, and ability for multiple erasures and rewrites make DVD-RAM an excellent medium for reliable data back-up and retrieval. These very features, unfortunately, make the format less than ideal for exchanging video recordings on DVD players.

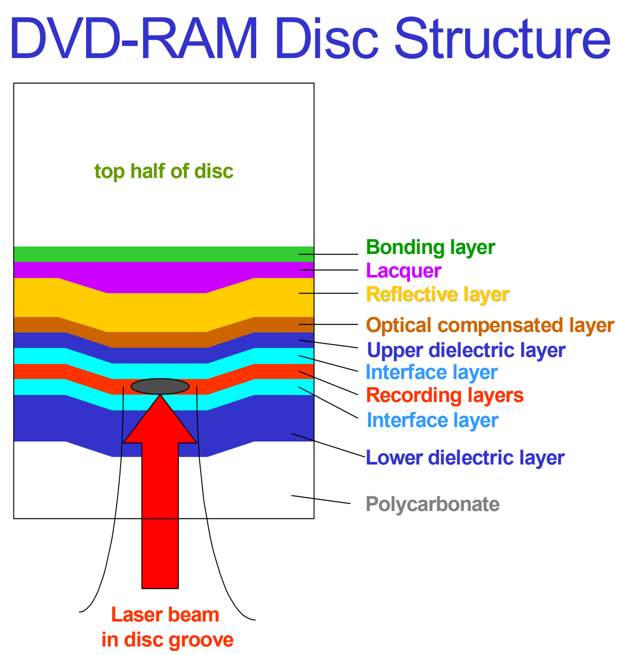


Figure 26

DVD+RW

There is an advantage in following others—one can recognize and address any of the pitfalls discovered by those who went before. The third version of recordable DVD is called DVD+RW to distinguish it from the DVD-RW that Pioneer introduced. This medium tries to provide all the features and advantages of both DVD-RW and DVD-RAM in a single disc format. (See Figure 22). It can operate at either CLV or CAV speeds, depending on whether or not the information is audio/video or data stored in the planned Mt. Rainier format. It can apply defect management systems when recording data or can leave them off when recording video so that DVD players can recognize the discs. Recorded discs can be played in about 80% of existing DVD-ROM drives and DVD players if the video is recorded in the DVD-Video format. The more recent the player, the more likely it will successfully recognize and play the disc.

DVD+RW has some significant advantages that are due to its formatting structure. The structure is based on an 817-kHz wobble incorporated into the groove molded into the polycarbonate base. This wobble is 37 times finer than the wobble in a CD-R, and the detailed waveform it provides makes aligning data blocks much easier and more accurate because it serves as the disc's addressing system. The fine detail in the signal allows "lossless linking," meaning that adding to or erasing information from a DVD+RW disc can put new data no more than a micron gap away from existing information because the ultra-high frequency wobble acts as an accurate marker guide for the recording laser (Figure 34). That built-in accuracy provides some very significant advantages for DVD+RW: 1) fully erasing and formatting the disc takes less than a minute compared to the 87 minutes required by DVD-RW with early software because DVD+RW allows "background formatting" (the formatting process continues as the computer moves on to other operations; formatting does not monopolize the computer as it does for DVD-RW); 2) it becomes very easy to make edits directly to a DVD+RW disc for video recorded in the Philips VR format or in Sonic Solutions' Open DVD architecture; and 3) the total time to record and close a disc is less.

The DVD+RW and DVD+R discs use an address system referred to as ADIP ("ADdress In Pre-groove") that is different from the DVD-R and DVD-RW discs' land-prepit address system. In CD-Rs the ATIP area contains the address information as well as information about the type of disc; the modulated groove provides tracking information as well as the correct read speed based on the frequency of the wobble in the groove. The DVD-R/-RW format also uses a groove modulated at a relatively low frequency of 140.6kHz for tracking and speed information; the LLP (land-prepit) data provide the addresses via data signal spikes as the laser reads the groove. DVD+R/+RW discs have a groove modulated at a much higher rate of 817.4kHz with address information provided by phase inversions in the signal. The phase inversion takes place over a longer section of the disc that is 32 times larger than the smallest land pre-pit signal (32T versus 1T), and that makes it easier for a high-speed device to detect the address information of a phase-inverted DVD+ signal than that for a small DVD- signal spike caused by a land pre-pit.

DVD+R

DVD+R is a dye-based version of the DVD+RW that followed the introduction of the +RW by half a year. (This presented a problem for early adopters of the DVD+RW drives who expected their drives to be able to be upgraded with simple firmware changes in order be able to write on DVD+R discs as well as DVD+RW discs. The final DVD+R design, however, meant completely new drives.) The DVD+R/+RW are very similar to the DVD-R/-RW in terms of materials and construction, except that DVD+R uses a metal chelate dye instead of the azo-cyanine used in DVD-R discs. The similarities are so strong that the pictures of DVD disc structures that appear in figures 20 and 201can apply to both DVD+R and to DVD+RW as well as to DVD-R and DVD-RW. The formats differ in terms of file structure and the design of the groove pressed into the polycarbonate substrate more than in their physical construction and materials. The dye-based DVD+R, like the dye-based DVD-R version, is more compatible with existing DVD players than their rewritable partners chiefly because the reflectivity is much greater and similar to that of pressed DVDs. The lower reflectivity of the rewritable DVDs can confuse many DVD players into treating them as dual-layer discs and not being able to read them.

There are claims and counter claims about whether or not DVD+R discs are more or less compatible with DVD players than DVD-R discs. Based on the number of claims, the best judgment is that there is little difference between the two in terms of compatibility. DVD-RAM recorders and players built by DVD-RAM supporters are more likely to play DVD-R discs than DVD+R discs, but there is little real difference between the two in terms of compatibility or capability. The real distinctions between the "plus" and "dash" camps lie in the rewritable DVD-RW and DVD+RW, not in the write-once discs.

DVD-VR AND DVD+VR

These two terms do not describe new formats but "formats within a format," or as the DVD Forum describes DVD-VR, "an application format." They have been introduced to allow set-top DVD recorders to record video in real-time, for example, from TV broadcasts received on built-in TV tuners. The original DVD specification requires certain data to precede the writing of video information. Parameters describing file lengths and navigational information such as menus—the type of information that DVD authoring software handles—is supposed to be written first on a disc. When recording data from a TV broadcast, however, the full amount of information is not known until the recording is finished. DVD-VR and DVD+VR manipulate the data in a way that allows "streamed," that is, real-time recording to continue so that the necessary "preliminary" data can be written afterwards when the disc is finalized. This data manipulation also allows some limited video editing, deletion of video segments, and modifications to the play lists on rewritable discs. The approach each application format takes is different and applies only to the like named DVD discs.

DVD-VR is designed for DVD-R and DVD-RW discs in set-top recorders. Its editing features are a bit more extensive than those for DVD+VR, but that advantage comes at a cost: DVD-R/-RW discs recorded in the DVD-VR format will not play in any other DVD player except the recorder itself. Some DVD players may be introduced to play these discs back, but the number of DVD-VR-capable players that exist now is so small that it is more reasonable to consider playback impossible.

DVD+VR applies to DVD+R and DVD+RW discs in set-top recorders. Its distinguishing feature is that it creates thumbnails for menus in the title page instead of the DVD-VR play lists, and the thumbnails can have titles applied to them. There are some other limited editing abilities that recorders may incorporate, but DVD+VR gives up sophisticated editing in favor of DVD video compatibility. Almost every DVD player that can play DVD+R/+RW discs will also play DVD+VR formatted discs. They are not restricted to the recorder that created them, unlike DVD-VR formatted discs.

CPRM (CONTENT PROTECTION FOR RECORDABLE MEDIA

CPRM is a copy protection scheme that will allow a user to make one and only one copy of an encoded analogue program. The scheme requires a recorder and disc that are both capable of interpreting the CPRM signals. CPRM-capable discs have decryption data recorded in the burst cut area including a media identification number unique to each disc. CPRM-capable recorders have device keys in their memories that combine with the CPRM disc data to allow recording of a CPRM-encoded broadcast and mark the disc as "cannot copy" once the recording is complete. No copies can be made of the encoded disc. Discs that do not have the CPRM data on them cannot be used in CPRM recorders to record any broadcast that is encoded with the CPRM signal; only CPRM-capable discs would work for such broadcasts.

CPRM decryption data are only used on DVD-RW and DVD-RAM discs and is only used for recording in the VR mode, that is, the mode used to record from analogue broadcast signals. CPRM is not used in either Europe or the Americas yet, but set-top recorders that can record either DVD-RW or DVD-RAM are already compliant with CPRM encoding.

In the U.S. the Federal Communications Commission has approved a system that by the year 2005 will include a broadcast “flag” in digital programs that restrict recordings at the option of the broadcaster. In anticipation of this change, Philips and HP have proposed a system somewhat similar to CPRM for DVD+R/+RW discs tentatively called “Vidi.” This proposal also requires information to be in place in the ADIP section of DVD+R/+RW discs as well as compliance in the circuitry of the recorders.

DVD recordable discs come with a new set of acronyms and test parameters. Some of them are similar to those used in CD-R/-RW testing, but most are descriptive of the special characteristics of DVD recording. The following list describes the most commonly used terms.

ASYM	Asymmetry
FE	Focus Error
I3/I14	The signal from the shortest pit/land distance (3T) and the longest (I14)
LPPb	Land Pre-Pit before recording
PIE	Parity Inner Error
POE	Parity Outer Error
PIF	Parity Inner Failure
POF	Parity Outer Failure
PPb DV	Push-Pull before recording Disc Variation
PWP	Phase Wobble Pre-pit
RRO	Radial RunOut

ASYM
Asymmetry is the DC offset voltage difference between the I3 and I14 signals (the shortest and the longest signals; see below). Values are measured as both an average and as a maximum. Values <3% indicate a uniform coating of the dye layer. Changes >10% indicate coating problems that vary the I3 and I14 signals enough to cause read errors when the analogue output signal is converted to a digital signal.

FE
Focus errors are the result of sectors not being addressed properly due to buffer underruns, impurities in the coating, or uneven substrate. Focus errors produce indefinite write marks that raise jitter values and the rate of read errors. Radial 2 measures radial disturbances in a frequency range of 1.1 and 10 kHz and refer to the tracking signal of a recorded DVD. Radial 2 disturbances are beyond the ability of the servo control to correct balance and are a factor in read errors.

I3/I14
The shortest pit or land has a value of 3; the longest pit or land has a value of 14. As the light from the reading laser varies according to the length of lands and pits, the signals generated from the shortest lands/pits, I3 signals, change at the highest frequency rate while the I14 signals form the longest lands and pits have the lowest frequency of changes. All the signals from I3 to I14 create an analogue signal that is converted into a digital signal representing the information on the discs. I3 signal values should be above 0.45 for a strong output. Values below 0.3 are poor signal levels. I3 has such a short distance between pit/land/pit or land/pit/land that signal levels are low and difficult to resolve. I14 Signals above 2.0 are very good while those below 1.5 are quite poor.

Jitter
The lengths of the lands and pits should be kept as exact as possible—perfect multiples of IT signals. In reality, the lengths show variations in their actual lengths that translate into timing variations referred to as jitter. DC jitter (data-to-clock jitter) is a measure of the length of each pit and land against the precise measure of a clock pulse time signal. DC jitter is measured over the entire disc and should measure below 9.5%. Bottom jitter is the value at three different points on the disc as seen by the laser. If bottom jitter is quite different from DC jitter, that is an indication that the disc has mechanical distortions.

DC jitter is also dependent on the write strategy of the burner. If the incorrect write strategy is applied, DC jitter increases as well as PI sum 8 values and the uncorrectable POF errors.

LPPb
DVD+R/+RW discs use the 817-kHz wobble signal in the groove to address sectors, but DVD-R/-RW uses land pre-pit "bridges" at the beginning of each sector. If the signal from the pre-pits is too weak, the drive cannot identify the pre-pits; if the signal is too strong, it can disturb the data signal.

PIE/POE
DVDs have double error correction. Drives put 16 sectors (sector = 2,048 bytes of usable data + 308 bytes of error correction + 4 bytes for the sector ID + 6 bytes for copyright management = 2,366 bytes) of usable data into an ECC (Error Correction Code) matrix. The rows of the matrix are checked for accuracy according to "inner parity" while the columns are checked for "outer parity." This two-dimensional error correction is nearly 10 times more efficient than that for CDs and can correct severe flaws caused by scratches or debris as large as 6 mm. The DVD specification requires that the sum of PIE in 8 sequential ECC sectors (PI sum 8) be less than 280.

DVD+R specifications require that after the first PI correction no more than 4 errors remain in the ECC sector for the sum of Parity Inner Failure. These should be corrected by the second error correction so that no errors remain for Parity Outer Failure. If POF is >0, the errors will be noticeable.

PPb DV
The push-pull signal from the drive assembly holds the laser in the track during burning. The difference between the strongest and weakest push-pull signals must be as small as possible to avoid problems following the track. These differences are measured as variations in the signal.

PWP
The land pre-pit signal must be -90º out of phase with the wobble signal. The pre-pit signal can deviate a maximum of +/- 10º for the Phase Wobble Pre-pit measurement.

RRO
Radial runout is the deviation of the pre-groove spiral in the substrate from the ideal distance from the center of the disc. It is a measure of the difference between the maximum and the minimum distance of a physical track from the axis of rotation measured over one revolution.

RECORDABLE DVD CAPACITIES

The standard DVD is capable of providing 4.7 GB of storage on one side of a disc with a single layer. One would think that this enormous capacity in a single disc would satisfy anyone used to the 1.4 MB capacity of the ubiquitous double-sided, double density floppy diskette. But even the name of that modest medium gives the story away: it was the successor of an original single-sided, standard density diskette that had replaced the 5.25-inch floppy that had replaced an 8-inch version. The design goal is always to provide more storage capacity in a smaller medium so that the cost per megabyte decreases. People will find a way to use all that storage space, and then ask for more. Figure 27 is an example of how quickly data capacity gets used. Figure 28 charts the amount of data needed to store or move information. Too much is never enough!

DVD-Recordable Capacities

4.7 GB are equal to:

- 4,700 full-color pictures (640x480 resolution; 24-bit pixels)
- 210 minutes of compressed MPEG-2 video (at DSS-satellite quality)
- 60 minutes of theater-quality MPEG-2 video
- Nearly 9 hours of CD audio
- 400,000 plus documents (filling eight 4-drawer filing cabinets)

Figure 27

Growth in Data Requirements

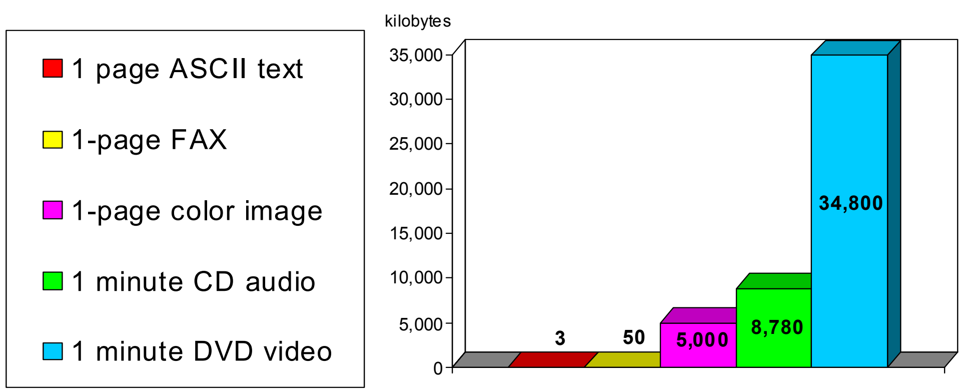


Figure 28

CAPACITY IN TERMS OF TIME

4.7GB means nothing to most people looking to record TV programs on their DVD set-top recorders. Capacity for them is the number of minutes or hours that a disc can hold. VHS tape had three time settings: SP for standard play of 120 minutes for a T-120 or 180 minutes for an E-180 in the European PAL TV system using an almost identical cassette. LP was “long play” for 4-hour recording in North America and 6-hour recording in Europe. The EP or SLP settings (“extended play” or “super long play”) increased tape capacities to 6 hours and 9 hours, respectively. The video quality, of course, declined for the longer time settings because the amount of video signal per minute of tape decreased in order to store more video on the tape. The same holds true for digital video recording on DVD discs: the amount of video data per minute of video has to be decreased in order to fit more time on a disc. The rate of data is referred to as the “bit rate.” DVD-compliant discs can hold a maximum bit-rate of 9.8Mbps (megabits per second), for both audio and video signals.

Software programs often allow users to select a bit rate from about 8mbps for “highest quality” to perhaps 4 Mbps for lower quality but increased capacity. Set-top DVD recorders do the same thing, but they refer to quality levels in terms of minutes or hours of recording time.

The good news is that the time limits are identical for the North American NTSC video system and the European PAL system. Unfortunately, the designations are not consistent from format to format or even from manufacturer to manufacturer. Figure 28 lists the different capacities for the various formats in terms used by the consumer set-top recorders.

Bit rate settings can be either a constant, unchanging rate (CBR or constant bit rate) or variable (VBR). The variable rates assign more data to complex video with lots of detail and action and less data to simpler video in order to maintain good picture quality and an efficient use of capacity.

People expect to see better quality on DVD than that from VHS tape, and that is always the case with Hollywood movie releases. Video recordings on DVDs, however, depend on the bit rate settings as well as the quality of the encoders converting video to the DVD MPEG-2 standard. Hollywood uses equipment and software that cost in the hundreds of thousands of dollars, and the quality is excellent. Home video, however, relies on far less expensive chipsets. Many people have been disappointed to see DVDs made from home VHS tapes look slightly inferior to the original tapes even when using the highest quality settings. The difference in quality is due to encoding, not to the medium. Even MiniDV digital video cassettes (encoded at 25Mbps) will look slightly inferior when converted to DVD settings of 9.8 Mbps or less. Set-top recorder settings longer than two or three hours often display the most visible forms of picture deterioration. VHS video tape suffered from lower resolution, greater noise, and more visible dropouts at the longest EP time settings; DVDs recorded in the DVD EP mode also show lower resolution and digital artifacts such as pixelation and blocking (“stair-step” edges on diagonal lines and odd rectangular shapes in the picture). Many people find the decrease in quality of DVD EP to be worse than that of VHS EP. The solution is to use the highest bit rate possible or the shortest time setting to get the best balance between video quality and time capacity.

Set-Top DVD Recorder Capacities

(NTSC and PAL)

RECORDER	TYPE OF DISC	RECORDIN FORMA	60 MIN 1 HR	120 MIN 2 HR	180 MIN 3 HR	240 MIN 4 HR	360 MIN 6 HR
DVD-RAM	DVD-	**UDF**	**XP**	**SP**		**LP**	**EP**
	DVD-	**video**	**XP**	**SP**		**LP**	**EP**
Pioneer DVD-R	DVD-R/-	**video**	**V1**	**V2**			
	DVD-	**VR**		**VR-SP**			
	DVD-	**MN-**	**level 32**	**level 21**	**level 15**	**level 9**	**level 1**
DVD+R	DVD+R/+R	**video**	**HQ**	**SP**	**LP**	**EP**	**EP+**

Incompatible with regular DVD players; playable only in the same type of recorder.

*VR means "Variable bit-Rate; MN means "manual" with 32 manual rate settings from 61 to 360 min.

Figure 29

Double-Layer DVD Recordable Discs

Capacities beyond the standard 4.7GB can be increased in one of two ways: double-sided DVD discs or double-layer discs. Despite the fact that double-sided discs are easier to manufacture (All DVD discs have two halves, and the top half is just a blank.), disc manufacturers decided to introduce double-layer discs before double-sided discs. Like double-layer DVD discs, the technique uses a semi-transparent silver alloy metal mirror layer between two layers of organic dye. This metal reflector layer has a reflectivity of 18%, similar to that of double-layer DVD discs. The middle dye layer itself (L0 in Figure 30 below) has a light transmission value of 50% to allow the laser to penetrate it to the L1 dye layer above it. L1 is much more sensitive to the laser power than L0 is because so much laser light is scattered and absorbed passing through both the semi-transparent silver layer and the first dye layer. The reflectivity of the metal layer for L1 is greater than 50%, but it ends up at about 18% also after the reflected light passes through both dye layers and the semi-reflective alloy layer. Careful tuning of the dyes, metal deposition, and groove geometry has resulted in a dual-layer disc with 8.55GB of storage capacity, but not without some tradeoffs.

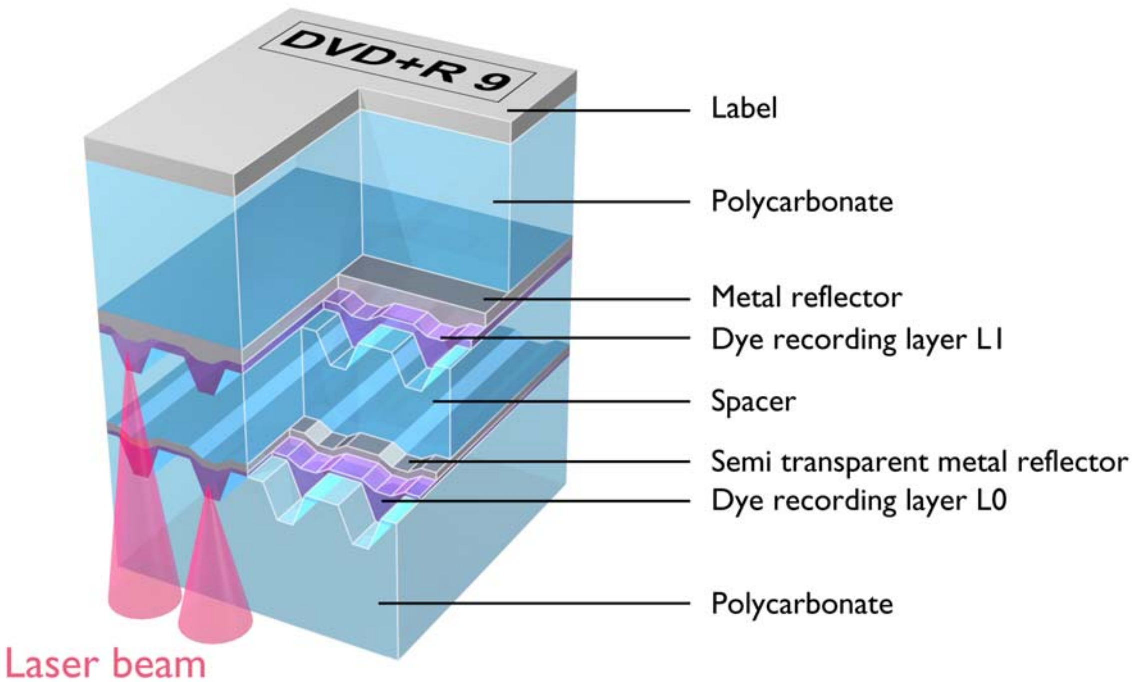


Figure 30

Picture courtesy of Philips

Double-layer discs require double-layer drives in order to be recorded, but these drives will be slower than those that write to single-layer discs. The initial double-layer drives will be 2.4X for DVD+R and 2X for DVD-R, but their lasers have power ratings equivalent to those for 8X discs because more power is required for the light to penetrate the semi-transport layer and the spacer layer. Since a laser reading or writing a dual-layer DVD starts from the inside and works outward on the "outer" layer (layer 0) to a transition point where it switches to the "inner" layer (layer 1), both layers have to have data signals matching in their total length in order to prevent DVD players from seeing errors. Dividing fixed files into two equal sizes is not a problem for computer systems, but recording video broadcasts that are not exactly defined can pose a problem for set-top recorders. One proposal is to record dummy data on the second layer to fill it to match the file size of the upper layer, but that adds time to the recording process.

The transition point of double-layer DVDs is often noticeable as a momentary freeze of the picture. The transition point of recorded double-layer DVDs poses a greater problem for DVD players because the level of reflectivity of both layers is nearly the same, unlike that of regular double-layer

DVDs where one layer is significantly more reflective than the other. Concerns about compatibility with DVD players, particularly older DVD players, are the major issue with this latest development in DVD recording.

The manufacturing process for DL discs is much more complicated than that for ordinary recordable DVDs and involves many more steps.

DVD+R Double Layer

2P Manufacturing Process

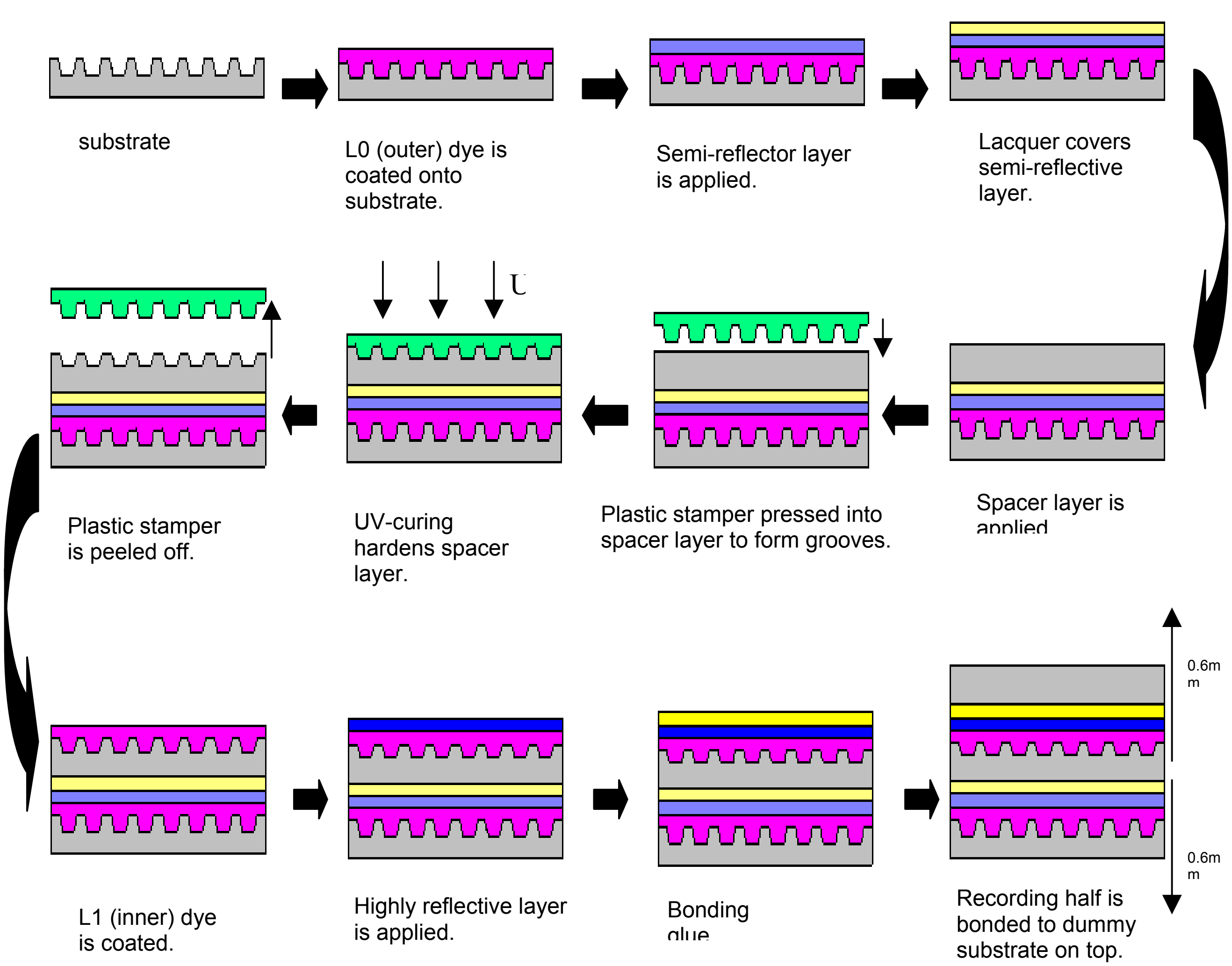


Figure 31

The first row shows how the first steps are identical to those for regular DVD+R or DVD-R discs. The main difference is the materials used. The first dye layer has to be transparent enough to allow laser light through to mark the inner dye layer. The reflective layer also has to allow laser light through it, too, to reach the inner layer. The second row shows the first new steps in manufacturing: a malleable spacer layer is applied to the first, or outer, layer; and a plastic stamper impresses this spacer with the wobbled groove for the laser to track during recording. The spacer hardens under the curing effect of an ultra-violet light and is peeled off after hardening sufficiently. The next step is coating the inner dye layer (L1) on top of the hardened stamper. A very highly reflective inner layer covers the L1 dye layer. The rest of manufacturing is similar to that for regular DVDs: the recording half is bonded to the upper dummy blank to complete what is referred to as a DVD9 disc. The critical steps in manufacturing are assuring that the dye layers and the internal spacer are as flat and even as possible with no air bubbles trapped between them.

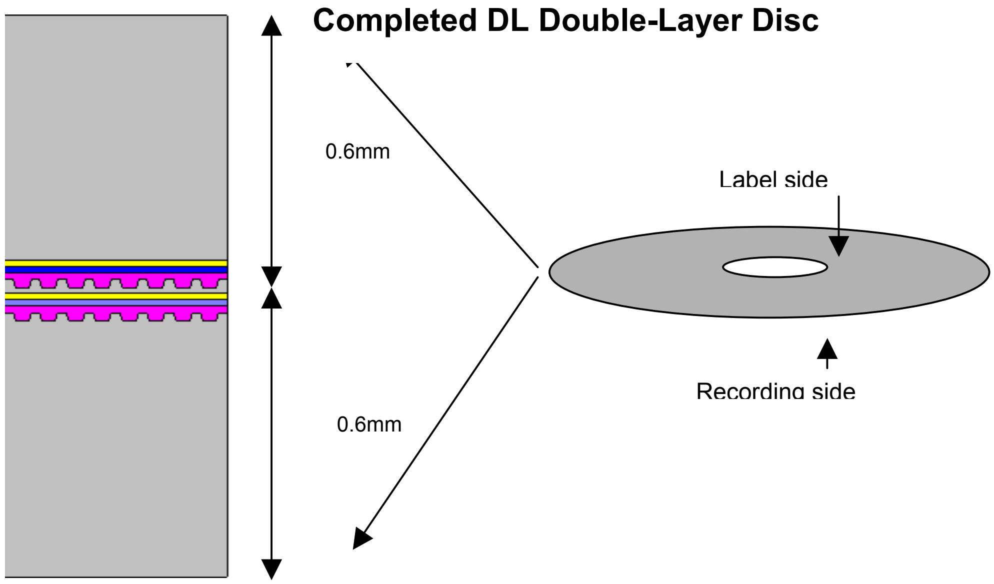


Figure 32

DVD RECORDABLE SPEEDS

The CD-user who first burns his or her DVD may likely become frustrated at the length of time it takes to complete a project. CD-Rs hold only audio information or data. DVDs also hold data, seven times more than a CD-R; but video recordings contain both audio and complex video signals that require special processing into MPEG formats that a DVD player can recognize. That takes a lot of time and processing power. One can expect to spend four to five hours of editing, authoring, processing, and recording time for every hour of recorded MPEG-2 video on a DVD recordable disc if the user is working through a computer. Some software that encodes analogue video into MPEG-2 compressed digital video can take an hour to process a minute. Software developers are aware of the complexities and have taken steps to simplify and speed up the process, but digital video recording will always remain more involved than digital audio recording. Those who choose set-top recorders have an easier time but will lack all the editing and authoring features that can personalize the final product. The frustration that comes from the length of time involved in such projects might lead a user to blame the early drives for their slow speeds. The first CD-R recorders worked only at 1X, and the latest drives claim 52X-recording speeds; and the difference is dramatic in recording times (but it is still a real-time process loading analogue signals into a computer to edit them). DVD recording drives are still in their infancy, but they are very sophisticated hardware when one considers that the pokey CD-R 1X speed was 150 kilobytes per second and recordable DVD 1X is 1.38 megabytes per second—nine times faster. The maximum transfer rate for a standard DVD is 10.08Mbps, 9.8Mbps of which are for video alone. Reducing the transfer rate of data allows longer recording times on a disc with a fixed capacity of 4.7GB, but the extra time comes at a reduction of video quality. (Recordable DVDs' 1.38MBps equals 11.08Mbps, a greater transfer rate than that for DVDs because extra data such as synchronization information are also being transferred during recording.) Recordable drives are already amazingly quick in handling huge amounts of data, and developments in building more powerful lasers now allow DVD recording speeds of 8X with 12X or even 16X soon to follow. The initial laser diodes used in DVD recording could produce 70 milliwatts of power and were restricted to a maximum of 2.4X recording speeds. More powerful 100-milliwatt lasers were used in drives capable of 4X DVD recording, and 250-milliwatt lasers for required for 16X maximum DVD recording speed. The caution about high-speed recording still remains—always recording at the maximum speed/maximum laser power shortens the laser diode's life.

The minimum acceptable laser power in milliwatts is estimated as square root of the recording speed times 50. A 4X drive requires a laser diode capable of 100 milliwatts; an 8X drive requires a minimum of 140 mW; and the final speed of 16X need 250 milliwatts. The laser itself requires a 480 MHz clock for accuracy of the timing pulses. At 200 milliwatts the operating temperature of the laser diode case can reach a temperature of 100° Celsius.

The trick in writing at 16X DVD recording speeds is to devise a write strategy that allows the dye or phase change material to cool enough after one mark/pit is made so that the trailing edge does not affect the leading edge of the next pit/mark. There are two ways to reduce this "thermal interference: 1) increasing the thermal conductivity of the mirror layer to draw off excessive heat (generally by making the metal layer thicker) and 2) thinning the dye layer. Thinning the dye runs the risk of increasing the modulation of the burn marks; so it takes a delicate balance of dye and coating parameters to optimize the recording characteristics. The precision required to make ideal marks is less than 0.05 micrometers while the disc spins at 180 revolutions per second. That is a linear speed of 56 meters per second-- over 125 mph or 200 km per hour.

Recording speed has an affect only on part of the total time required writing a DVD disc. Finalization also takes a certain amount of processing time, and it differs for the three different DVD recordable disc types. Rewritable discs also vary dramatically in the time it takes to erase and format them. These differences are due to the way in which data are arranged and addressed on the discs. DVD-RAM uses molded sectors for address information, and formatting writes the Universal Disc Format with block information for fast data erasure, storage, and retrieval. See Figure 33 below.

DVD-RAM ADDRESSES

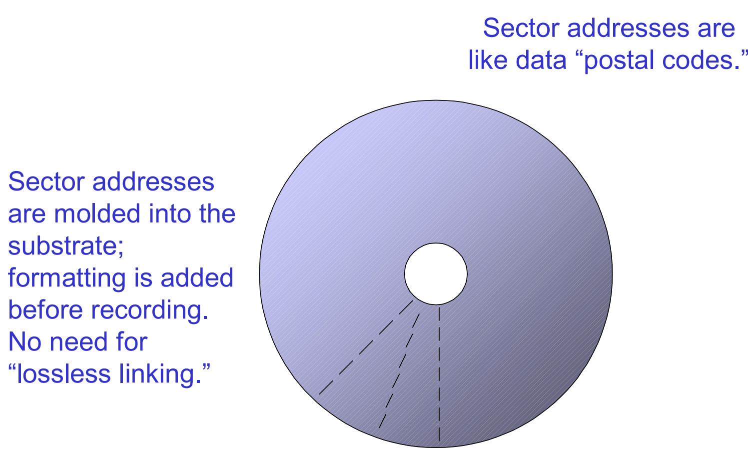


Figure 33

DVD-R and DVD-RW use molded "pre-pits" in the grooves for address information. Since this format was originally designed for sequential video recording, data are also added sequentially, as is formatting for the DVD-RW. This means, unfortunately, that formatting and erasing take much longer time than that for DVD-RAM or for DVD+R and DVD+RW because format information has to be written over the entire disc. A full erasure can take almost an hour and a half for a DVD-RW instead of a minute for a DVD+RW disc. New designs in software are being introduced to resolving this difference in formatting time, but it will likely always take longer to format and fully erase a DVD-RW than a DVD+RW. See Figure 34.

DVD-R/-RW ADDRESSES

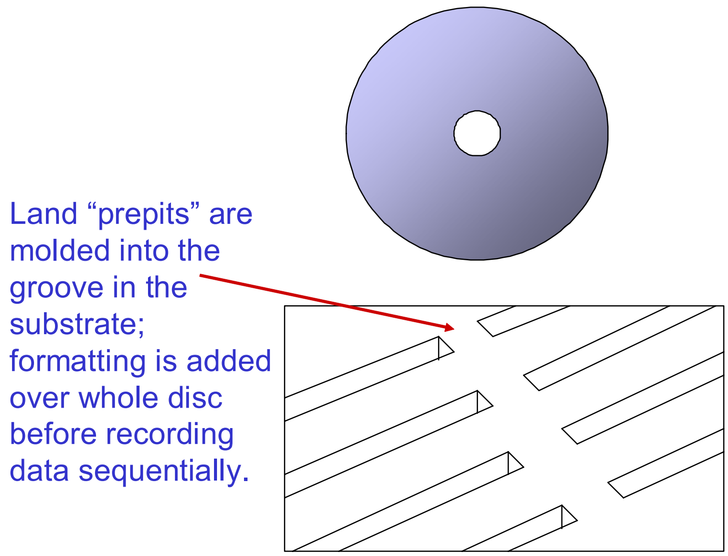


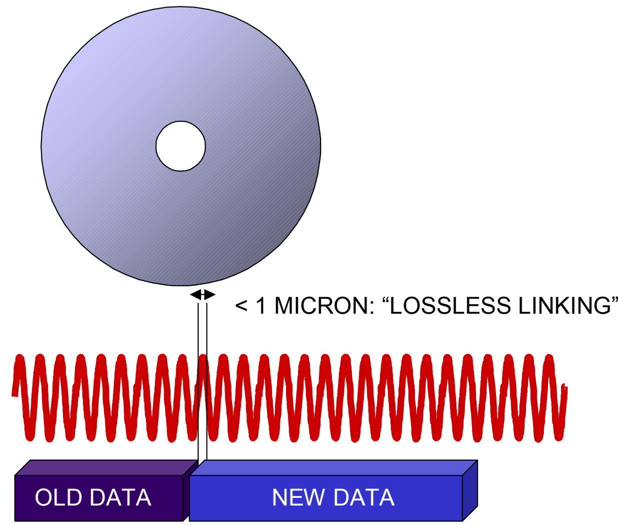
Figure 34

DVD+R and DVD+RW use the high frequency 817-kHz signal in their groove as a tool for data addressing. Instead of a CD-R ATIP, these discs contain an ADIP (ADdress In Pregroove) that begins the addressing information in an are of the disc no accessible to DVD players. Unlike the molded sector or pre-pit information that serve as a kind of "postal zip code" for addresses, the high frequency signal acts as a series of very closely spaced distance markers placed every "50 feet" or so. New data can be added to old data using the signal as a guide so that the difference in placement is less than 1 micron. This is the "lossless linking" that avoids the errors that would appear if the spacing of old and new data were any farther apart. This high-frequency signal method allows the DVD+RW format to offer some significant features:

- Erasing files is similar to the "drag-and-drop" method of floppy disks.
    - Data writing does not have to be sequential.
    - Erasing a file leaves the erased area open for insertion of new data
- Formatting a DVD+RW is faster than DVD-RW—just under a minute
    - Formatting actually takes longer; but it appears "in the background," freeing up the computer to do other things while formatting continues.
    - Older software can take as long as 87 minutes for a DVD-RW but newer software allows background formatting for DVD-RW, too.
- Fully erasing a DVD+RW is faster than DVD-RW.
- Finalizing a DVD+RW is faster than DVD-RW--less than a minute after recording.
    - Some "finalizing" takes place during recording, similar to background formatting.
    - DVD-RW finalizing time depends on the amount of data—more data on a disc actually reduce the time to finalize the disc.
- It is easy to edit video files straight to disc on a DVD+RW with Philips' VR format or Sonic Solutions' Open DVD architecture.

FORMAT ADDRESSES—DVD+RW

The disc has a 817-kHz signal molded into the disc groove on the substrate. Signal acts as a guide for adding data anywhere on the disc.



The high frequency signal acts as “mile posts every 50 ft.” for addresses instead of using “postal codes.”

Figure 35

Comparative Speed of DVD Recordable Drives

FORMAT	SINGLE-SIDE CAPACITY	DATA TRANSFER AT 1X SPEED (MBps)*	million bytes/s*
DVD-Recordable	4.7 GB	1.321	1.385
CD-R	0.7 GB	0.1459	0.1536

*MBps measures in units of 1,024 (2^{10}) while "millions of bytes per second measures in units of 1,000.

Figure 36

The time spent for the drive to actually record a disc is only 20% or less of the time invested in an editing/authoring/recording project. What may be more frustrating is discovering that all the time invested in editing, authoring, processing, and recording a DVD is wasted because it does not play in any DVD player except the drive in which is was recorded. This is still a stumbling block in this early stage of the technology. Panasonic introduced set-top players that also play DVD-RAM discs, but in all other cases DVD-RAM’s format for video prevents it from being used in the vast majority of players on the market—or already in people’s homes. DVD+R and DVD-R are physically compatible (that means they have the right dimensions and shape) and are logically compatible (a term that means the DVD-Video format that can be recorded on them is recognized and correct) with DVD players, and they are much more likely to be successful in the latest players. Some older drives, however, may not be able to recognize the discs. DVD+RW and DVD-RW have the same problem to a greater degree. Their lower reflectivity might confuse an older DVD player into thinking that they have a second layer recorded on them so that the player continues to hunt for information that is not there. Those older players or drives that check format codes may not recognize the code for the DVD-RW and refuse to play them altogether. Before investing in one format or another based on recording speed rates or data transfers, one should check to see if the player expected to play the recorded disc can actually recognize it. Compatibility with DVD players and drives is improving all the time as newer players are developed to handle new media types.

Can DVD Players Play DVD–recordable discs?

(recorded in the DVD-Video format)

	DVD	DVD-R Either general or authoring	DVD-RW	DVD-RAM	DVD+R	DVD+RW
1st players*	yes	many	some	no	many	some
2nd generation players**	yes	most	many	no	most	many
Present players***	yes	yes	most	no	yes	most
Multi-read players	yes	yes	yes	no	yes	yes

Figure 37

1 Of the first players introduced into the market, 95% will play the DVD-R 3.95 GB discs (the first DVD-Rs and the present authoring DVD-R, but only half are likely to play the 4.7 GB general purpose version DVD-R or the DVD+R. Few of these players may be able to play the DVD-RW.

2 Almost all of the second generation players will play the 3.95 GB DVD-R discs, and roughly 95% will play the 4.7GB DVD+R and DVD-R discs. DVD+RW and DVD-RW performance improves with the number of players that recognize them, but those players are still far fewer than those that successfully play DVD+R and DVD-R.

3 Almost all DVD players sold after November 1999 should play DVD+R and DVD-R discs, and most will also play DVD+RW and DVD-RW also.

WHICH FORMAT SHOULD I CHOOSE?

The first recordable DVDs tried to match the 4.7-GB capacity of the DVD, but initial limitations restricted them to 2.6 GB in the case of DVD-RAM and 3.9 GB in the case of the DVD-R. Present versions of both media have achieved the goal of 4.7 GB, and two-sided discs double that amount to 9.4 GB before formatting. DVD+RW seemed to address most problems very well, but early adopters soon learned that their DVD+RW recording systems could not record DVD+R discs that followed six months later. All of these running changes and differences in design and application make the recordable DVD very interesting to those who follow the changes but very confusing to anyone who needs to choose a format right now. Each format has its strengths and weaknesses, just as Betamax and VHS did a quarter century ago. The market determined the winner in the video cassette war, and the market will also decide which format is the most popular for recordable DVD as well.

There is a major difference in this contest of formats from the video cassette format battle. The choice between VHS or Betamax was a critical one because the recorders and players were the same devices. Choosing the “wrong” format prevented users from exchanging tapes with anyone else who had selected the alternate format. Recordable DVD, however, does not force a critical choice. The chief issue of compatibility is with DVD players and drives, and both DVD+R/+RW and DVD-R/-RW appear to be evenly matched in that regard. DVD-RAM's compatibility is severely limited because of its protective cartridge; but as far as the "plus camp" and the "dash camp" go, there is no "wrong" choice. The decision should be based on which format offers the user more of the features he or she needs—and plays on the DVD players and drives one expects to use.

In that regard, there is little practical difference between DVD-R and DVD+R. Both formats are nearly identical in performance. The design of the rewritable DVD-RW was for video applications, not data. The DVD Forum expected the DVD-RAM to handle data applications. The result is that DVD-RW's sequential recording makes formatting, erasing, and rewriting more difficult and time-consuming. DVD+RW's design is for both video and data, and it has a distinct advantage in storing and backing up data. Some drive manufacturers have tried to address the problem by building "dual" drives that will record both DVD-R/-RW and DVD+R/+RW discs, and the response from the press and consumers has been enthusiastic. What they may have failed to notice is that the ability to record both formats means a premium in the cost of the drive simply for an extra processor chip and the royalties for the additional format. Dual-format drives are an inelegant solution to the format conflict, but they do eliminate the problem of trying to guess which format to select.

BLUE LASERS—DÉJÀ VU ALL OVER AGAIN

The Digital Versatile Disc is a great medium for carrying a lot of data whether those data are used for video, super high-fidelity audio, games, information, or any combination of these programs. There are, however, limitations to the format. As great as 4.7 GB of capacity per side seems, it is not enough for more than twenty minutes or so of high-definition video in the MPEG-2 compression format. DVD movies look wonderful in comparison to VHS cassette recordings, but they are merely the best our present TV standards can show. They are not HDTV, and HDTV is the new quality standard of the future. In order to be capable of carrying high-definition video, DVDs need either more capacity or greater data compression.

The other limitation is, of course, that there are three competing, incompatible recording formats that are often not playable on regular DVD players. In order to resolve both limitations at the same time, some DVD developers have proposed a new, future DVD standard for both players and recorders based on a different laser diode—a blue-violet laser rather than the ruby-red lasers used for CDs, CD-Rs, DVDs, and all three recordable DVDs. The original intent was to have these new players and recorders able to play today's DVDs, DVD-Rs, and DVD-RWs in addition to future HD DVD discs and allow a single standard to end the confusion over DVD recording and playback. This was such a good idea that several other groups proposed competing, incompatible "standards" to end the confusion even further!

Just as DVDs used smaller pits and more tracks to pack more information on a disc the same size as a CD-R, HD DVD will again shrink the pit sizes and pack more tracks on the same sized disc. The pits will have to be so small, however, that they will be smaller than the wavelength of a red laser beam; and the beam will be unable to track the disc. The laser reader/writer will have to use a smaller wavelength of light to read the edges of the pits, and a smaller wavelength means a beam of a different color.

Light is merely energy that is visible to the human eye. We first begin to see light energy as it passes from below visibility, the infrared range, to the red range. Hot coals, for example, glow "red-hot" as their heat increases to visibility. Light energy remains visible through the color spectrum until it passes beyond violet to the ultra-violet range and beyond. White light is the combination of all the visible wavelengths together. If white light passes through a prism and bounces off an interior prism wall, it spreads out according to the wavelengths of the energy components in a "rainbow" effect. In a real rainbow, sunlight passes through billions of water droplets acting as prisms to divide the light.

Rainbow Colors Spread According to Their Wavelengths:

(nanometer=1 billionth of a meter)

- Red 780-622 nm
- Orange 622-597 nm
- Yellow 597-577 nm
- Green 577-492 nm
- Blue 492-455 nm
- Violet 455-390 nm

Ruby-red lasers for CD=780nm; DVD= 650 nm

Blue-violet laser for DVD HD = 405 nm

Figure 38

Figure 38 shows that the range of wavelengths for each color in the visible spectrum is different. Red has the widest range and the longest wavelengths. The laser diodes used in CD players and CD-R/-RW burners are ruby-red lasers with a wavelength of 780 nm. A different red laser diode produces the beam needed for the smaller pit sizes of DVDs. A beam of 650 nm reads DVD information and a high-power version utilizing 70 milliwatts or more records at the same wavelength onto DVD-R, DVD-RAM, and DVD-RW discs. DVD-R authoring discs require a 635-nm burning laser.

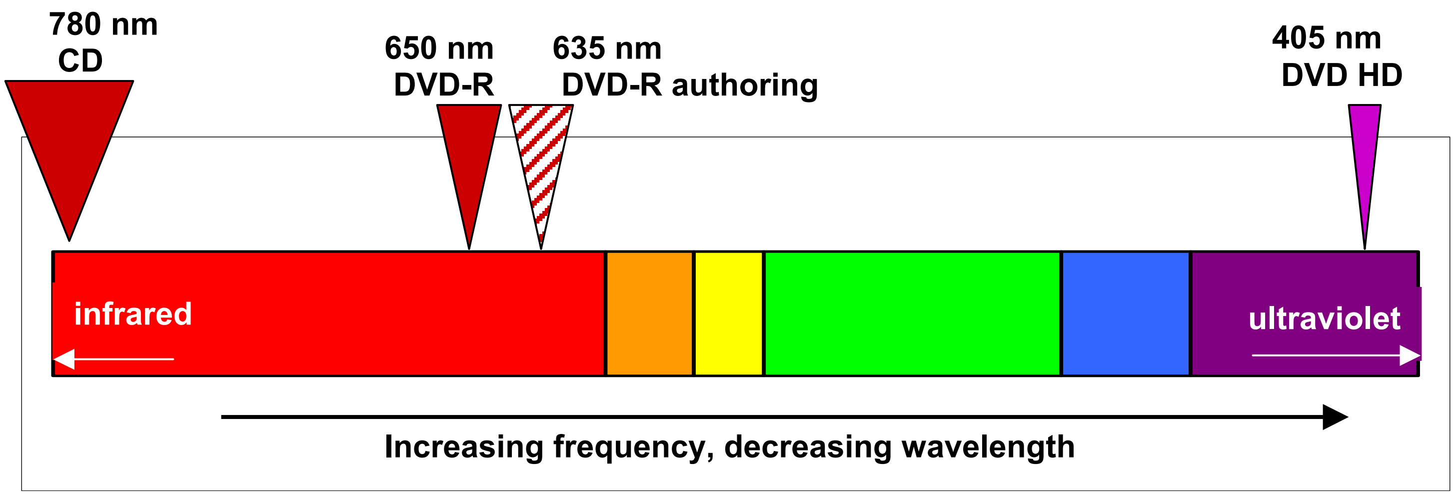


Figure 38

In order to decrease pit sizes further to pack more information on a disc, engineers have to move beyond red lasers. One proposal for the new HD DVD is based on blue-violet laser diodes with a wavelength of 405 nm, approaching the ultra-violet range. This wavelength is slightly more than half that of the red CD wavelength of 780 nm. See Figure 40 below.

Blue-violet lasers are more expensive and difficult to build than ruby-red lasers and may have a shorter lifetime. Manufacturers, however, now feel confident that they can produce enough of them with a significantly long enough life to make them practical as a replacement for the common red laser found in CD and DVD players and drives.

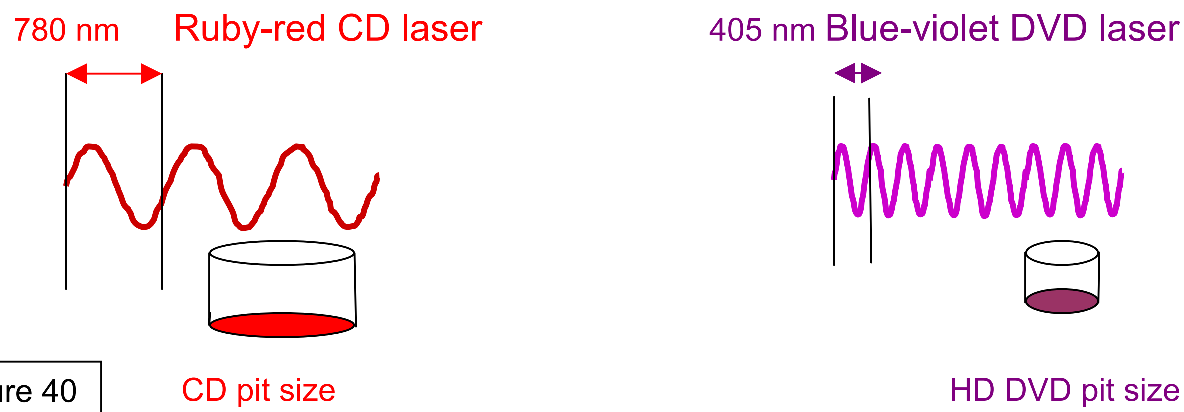


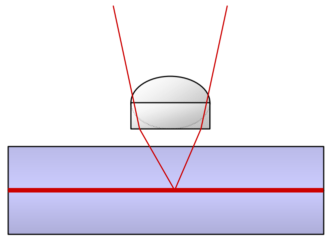
Figure 40

One HD video recording format using the same MPEG-2 encoding used in today's DVDs is known as Blu-Ray. This disc is very different from today's two-piece DVD sandwich because it uses a single substrate with a very think recording layer. The substrate itself does not even need to be translucent because the recording and reading lasers do not need to penetrate it. The initial versions of these discs are contained in a cartridge, but that may change in time. The specifications for the Blu-Ray format appear in Figure 41.

Proposed Specifications for the "Blu-Ray" DVD

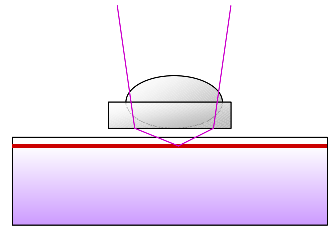
	Blu-Ray DVD	Present DVD	Present CD
Disc thickness:	1.2 mm	1.2 mm	1.2 mm
Disc diameter:	120 mm	120 mm	120 mm
Data capacity:	23 -25 GB/side	4.7 GB/side	.650 GB
Playing time:	>120 min HD video >13 hrs. standard video	133 min standard video	74 min audio
Laser wavelength:	405 nm	650 nm	780 nm
Laser type:	blue-violet	ruby-red	ruby-red
Track pitch	.4 μ	.74 μ	1.6 μ
Minimum pit length	.2 μ	.4 μ	.83 μ
Pit width	.25 μ	.35 μ	.650 μ
Plays:	HD DVD, DVD, DVD-R, DVD-RW	DVD, many DVD-R, some DVD-RW, some DVD+RW	CD, CD-R

Sony's Blu-ray Disc



DVD-RW/+RW

- •Requires a 650 nm. red laser
- •Blank disc made of two 0.6 mm disc halves
- •Total Thickness is 1.2 mm.
- •Phase change recording layer in middle of disc
- •Laser lens is millimeters above surface of disc.
- •Capacity = 4.7 GB



Sony Blu-Ray DVD

- •Requires a 405 nm. blue-violet laser
- • Cartridge holds disc with a 0.1 spacing layer covering a polycarbonate substrate
- •Total Thickness is 1.1 mm.
- •Phase change recording layer near surface of disc
- •Laser lens is microns above surface of disc.
- •Capacity = 23.3 GB

Figure 42

Blu-Ray is just the first of several different proposals for High Definition video. Toshiba and NEC are working on their own version of a blue-laser DVD that offers a capacity of up to 30GB, enough for three hours of HD video. Their format is known as HD-DVD and uses a disc very similar in construction to today's DVD discs, which allows present DVD manufacturing equipment to be modified for production rather than have manufacturers invest in all new equipment. A single layer HD-DVD version has a capacity of 15GB, and the dual-layer version holds twice that amount. A rewritable version further in the future can hold 20GB and the dual-layer version of the rewritable disc could hold as much as 32GB of information. The format proposes using more advanced compression than MPEG-2 to shrink HD files to sizes that can easily fit on these blue-laser discs. Other cost-conscious attributes are a single plastic lens that can operate with both blue and red lasers than the more complex glass lens for a blue laser and a separate lens for a red laser required by the Blu-Ray disc. Although the HD-DVD disc has received the approval of the DVD Forum, that approval is for the disc as a DVD video carrier, not necessarily as a recording medium.

A group from Taiwan, the AOSRA (Advanced Optical Storage Research Alliance), is working on another system physically similar to the Blu-Ray disc but differs from it in terms of the encoding, error correction, and file structure. AOSRA believes there are two advantages for their proposal: 1) the format is less expensive because it avoids the onerous royalty payments that are beginning to burden optical media and encoding systems, and 2) it offers more than five hours of HD video. Sony is the first manufacturer to introduce Blu-ray recorders and media intended for professional use. The discs themselves are quite a bit different from DVD recordable discs and DVDs in their structure. They are composed of a single polycarbonate substrate instead of two halves. The laser lens is positioned very closely the disc in a form of "near-field recording." The numerical aperture* of the lens is 0.85 rather than the 0.65 of lenses used in regular DVDs. See Figure 43.

*The numerical aperture is a measure of a lens's ability to gather or disperse light and its ability to resolve fine detail. The expression of numerical aperture (NA) is a mathematical number derived from the sine of an angle of light passing through a lens. For example, a lens with a numerical aperture of 0.7 would form a 45° angle from the point of focus at a fixed focal length to the center of the lens.

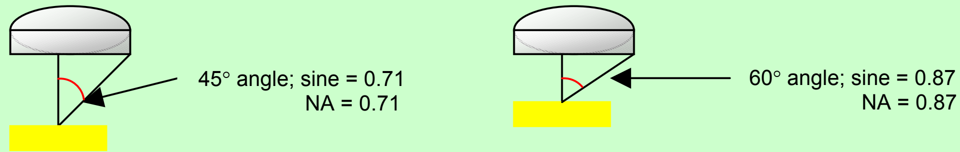


Figure 43

There is a fourth alternative solution proposed by those who either do not want to have to upgrade all of their mastering facilities to press ever-smaller pits for a more expensive and, perhaps, shorter-lived laser diode, or who feel that the blue laser has too many shortcomings. This group proposes using a different compression scheme from MPEG-2 that can compress more video data without sacrificing video quality. Advances in algorithms have made such compression possible. HD-capable DVD players would retain the red laser diodes but include different circuitry to identify and decode HD signals while still being able to read today's DVD discs. The players would require only a single laser reader instead of both blue and red diodes, and prices would remain low for consumers. Prices for discs would also remain reasonable because only software upgrades would be required for the pressing facilities rather than all new mastering and test equipment and, perhaps, new molding presses. This group also argues that it is too early to introduce a new format for consumers while standard DVD is still in its growth period and has reached only half of US household penetration.

High Definition Video Proposals

	Blu-Ray	HD-DVD	AOSRA	Alternate
Recording layer:	.1 mm thick	.6 mm thick	.1 mm thick	.6 mm thick
Laser:	blue	blue	blue	red
Wavelength	405 nm	405 nm	405 nm	650 nm
N/A:	.85	.65	.85	.65
Lens(es):	2	1	2	1
Capacity:	23 - 27GB	15GB and 30GB	17GB and 27GB	4.7GB
Encoding:	MPEG-2	Windows Media 9 or similar	AVC (proprietary)	MPEG-4 or Windows Media 9
Cartridge:	yes	no	no	no
Backers:	Hitachi, Matsushita, Pioneer, Philips, Sony, Sharp, Samsung	NEC, Toshiba	28 Taiwanese companies	

Figure 44

LIFETIME EXPECTATIONS OF OPTICAL DISCS

Information is stored on optical discs in order to be saved for later retrieval. How long can that storage period last with comfortable assurance that the data can be retrieved? The question is often asked, "How long will a CD-R or DVD+/-R last?" but what people really want to know is "How long is my information safe?" There are two parts to that answer: 1) as long as there is equipment that can recognize the disc and retrieve digital data correctly, and 2) as long as the errors accumulating over time do not exceed a threshold at which data cannot be retrieved correctly. The first factor is one that most people forget, but it is likely to be the shorter of the two.

Media do not last forever; but at long as they outlast their intended audience they are very useful. Cave paintings at Chauvet-Pont-D'Arc in France are over 30,000 years old. The Chinese invented paper about 400 A.D., and this medium is seeing wider use every year despite futuristic claims of paperless offices. The shellac or vinyl record is a format nearly 120 years old; magnetic tape is 70 years old. Specific formats are showing shorter life cycles as technological developments bring better, smaller, and less expensive ways to store information; but the generally accepted lifetime of a successful consumer format is calculated to be about thirty years—the same as a human generation. This is no coincidence; consumers do not like to jump from one format to the next and be concerned about transferring their data and memories from one to the next. They prefer to stick to one comfortable, familiar format for most of their life and make the leap just once. The younger generations are the ones who adopt the new formats. The older generations adapt.

Digital media are still relatively new, and the CD itself has only celebrated twenty years of popularity. The great advantage digital media have is that the information they store can be transferred in the digital code without apparent loss as long as all the code remains intact. That was not true of analogue media that transferred their own inherent flaws along with the stored data to another analogue medium with its own inherent flaws. The flaws accumulated, and the quality of the transfer was inferior to the original. Newer digital formats include methods of accepting transfers from older formats; and as long as the storage media can last the thirty years of the respective retrieval format's lifetime, engineers are happy.

Optical discs, both CDs and DVDs, should easily reach the thirty-year mark and beyond if they are manufactured well and are stored properly. Contrary to popular belief, these discs <u>do degrade</u> over time under the effects of heat, humidity, internal chemical reactions, mechanical stresses, UV light, oxidation, and accumulated scratches. The amount of degradation is measured in the accumulation of errors, and the end of life is defined as the point at which the error rate is so high that data cannot be reliably retrieved even with error correction. The fewer the initial errors, the longer the life expectancy can be.

The expected lifetimes can vary for the different types of media and the choices of materials used for each:

- CD-R--Claims have ranged from 50 years to 212 years.
  - Organic dyes—cyanine, azo-cyanine, phthalocyanine.
    Phthalocyanine shows the best resistance to UV light and to heat, but the other dyes have seen significant improvements under controlled tests. Dye type is less of a factor in determining life than it was ten years ago.
  - Mirror layer—gold, silver alloy
    Gold does not tarnish in the presence of sulfur or oxides of sulfur as silver or silver alloys would; but in a disc with a good lacquer seal, no air or sulfur should reach the metal reflective layer. There are almost no gold discs left simply because gold is too expensive and silver alloys have proved more than sufficient. A uniformly small grain size of the deposited layers should provide a longer life for the medium.
  - Structure
    CD-Rs are a single piece of polycarbonate coated with dye and covered with the metal layer and protective lacquer. It is the upper surface that is more susceptible to

physical damage than the bottom of the disc. The CD-Rs have relatively large pit marks and wide tracks that can still be resolved through moderate scratches on the bottom of the disc.

- CD-RW—should last at least as long as CD-Rs, perhaps longer. CD-RW discs have the reputation of being unstable, but factors such as packet-writing complexities and incompatibilities, varying laser spot geometries from different drives, and file corruptions are more to blame for the difficulties than the design or materials of the discs.
  - Recording layer—layers of indium-silver-antimony-tellurium
    The recording layers are inherently more stable than organic dyes are immune to the effects of UV light and moderate heat. The alloy crystallizes at 200° C. (420° F.), well above temperatures that would damage CD-Rs. Chemical changes due to humidity (polycarbonate plastic can absorb water.) can promote ion migration if the disc is not made well.
  - Mirror layer—aluminum alloy
    Aluminum is less expensive than silver alloy but has no other advantages or disadvantages. (Silver is used in CD-Rs because the dyes would corrode aluminum.) A uniformly small grain size of the deposited layers should provide a longer life for the medium.
  - Structure—same as that for CD-R

- DVD+R/-R—claims are up to 70 years
  - Organic dyes—azo-cyanine, cyanine, and metal chelate dyes are used for the write-once versions of DVD discs. These versions of dye have to react quickly to the application of the burning laser because the pit marks are very small and the disc speed is very quick.
  - Mirror layer—silver alloy as in the CD-R
  - Structure
    The fragile recording layer and mirror layer are sandwiched between two halves of a DVD disc. This offers better protection for these layers than that offered by CD-R and CD-RW disc. On the other hand, the pit sizes are much smaller and the track pitch is much narrower than that of the CD versions; so obstruction from scratches on the bottom of the disc is more likely. The bonding agent between the two halves introduces more questions about chemical stability. The hub area may or may not be bonded together, and the lack of bonding will mean more care has to be taken when inserting the discs in a protective case or a locking hub mechanism to prevent cracking. Tilt, the measure of flatness of a disc, is more critical for DVDs than for CDs.

- DVD-RW/+RW/-RAM
  - Recording layer—layers of indium-silver-antimony-tellurium
    These layers are the same as those for CD-RWs but use a different chemical formulation.
    Mirror layer—aluminum alloy that is thicker than that for CD-RWs in order to also act as a thermal conductor.
  - Structure—same as that for DVD write-once media.

The estimates of life for these media depend chiefly on heat and light stability tests done on the organic dyes and the sputtered metal alloys in rewritable discs. The estimates do not take into account regular daily use and the damage done by handling the discs on a regular basis. The common estimate of heat durability is based on a formula developed by Dr. Svante Arrhenius of Sweden in 1889 to determine activation energy in chemical reactions. Engineers subject discs to different levels of heat for periods of time and measure the rates of increased errors. Using the "Arrhenius Equation," the engineers can plot the expected rate of chemical degradation over time to estimate the expected life of data on the discs. Under normal conditions, today's discs can easily outlive the format they support as long as the discs are properly made in the first place and cared for properly. Proper care includes:

1. Keeping discs out of direct sunlight and with limited exposure to light in general.
2. Keeping discs in a cool, dry environment. What is most comfortable for humans is most comfortable for discs, too.
3. Keeping the discs away from large swings in temperature and humidity.
4. Keeping discs in protective cases when they are not being used.

Arrhenius reasoned that the temperature had a direct influence on chemical reactions, and he proposed an equation to determine the effect heat had on activation energy:

$$k=A*\exp^{(-E_a/R*T)}$$

In his equation, Arrhenius uses k as the rate coefficient, A is a constant, E_a is the activation energy, R is the universal gas constant (8.314×10^{-3} kJ $mol^{-1}K^{-1}$), and T is the temperature in degrees Kelvin. Tests conducted on different dyes at differing temperatures produced the graph above (Figure 45). At a temperature of 25° C. (77° F.), the dyes will remain stable for a period of 30, 50, or 100 years, depending on the dye being used. The 100-year result is for a typical phthalocyanine dye. The calculation is strictly on the heat stability of the dye itself. Mishandling or exposure to high levels of UV light will have additional deleterious effects on life expectancy.

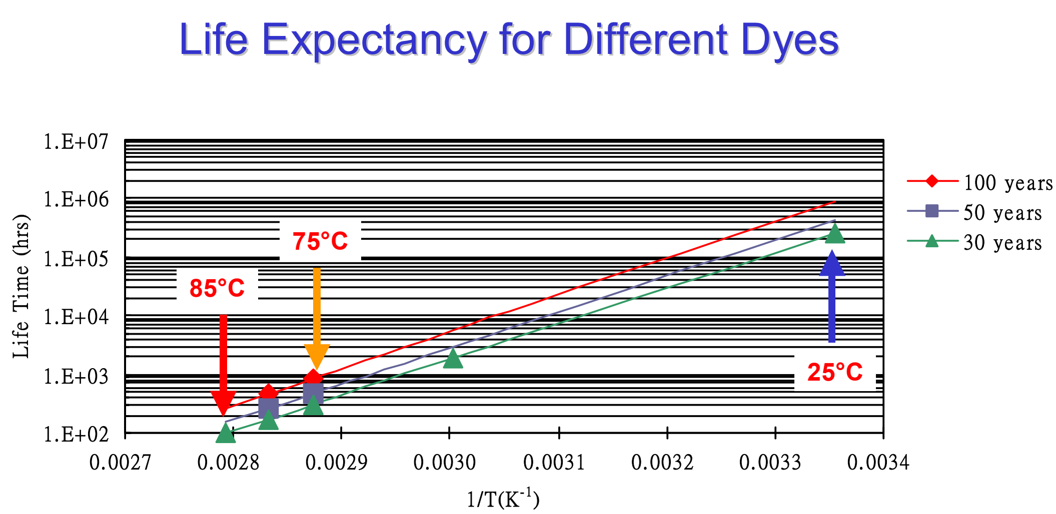


Figure 45

$$k=A*\exp^{(-E_a/R*T)}$$

Care and Handling of Optical Discs

The estimated lifetimes of optical discs can only be reached if reasonable care is taken of them during handling and storage. Most people are familiar with handling these discs, but even a cursory glance at the bottom of discs in public libraries or from DVD rental stores indicates that the discs are subjected to far greater abuse than their designers planned. That almost all of these discs still play properly is a testament to their built-in durability, but accumulated damage will hasten the day that even good players will refuse to read them.

The most important points in their care and handling are:

- Handling
    - Hold the discs on the outer edge or through the center hole only to avoid fingerprints on the bottom of the disc.
    - Avoid flexing the discs when removing them from a player or recorder or a storage case. Flexing will distort the disc's flat design and can even damage the inner recording and mirror layers.
    - Do not put excessive pressure on the center hub when inserting the disc in its case. The center hub area, particularly on DVDs, is fragile. A crack in the hub area can lead to shattering of the disc in a high-speed drive.
    - Pick discs straight up from a flat surface; do not slide them.
        - Some discs have a special protective coating of extremely fine silicone dioxide power mixed with the lacquer that offers very good resistance to scratches.
- Labeling
    - Use only water-based or alcohol-based pens designed for optical discs.
        - The use of other solvents may damage the lacquer surface on CDs and CD-R/RW discs.
        - The pressure from a ballpoint pen on the surface of a CD or CD-R/RW will damage the lacquer, mirror, and dye layers and create errors on the disc.
    - Paper labels are not recommended for DVD discs.
        - The expansion and contraction of moisture in the paper and the accumulation of heat in a DVD drive can alter the flatness of a disc enough that it falls out of the tilt specification and may not be able to be read.*
        - Paper labels do offer extra protection for the fragile upper surface of a CD-R or CD-RW.
            - Paper CD-R labels must be aligned as precisely as possible to avoid disc imbalances.
            - A disc with a misaligned label should be discarded. Trying to peel the label off will likely damage the disc.
            - Labeling music discs should not be a problem because they are most often read at 1X, but any imbalance may reduce digital audio extraction speeds.
            - Labeling data CD-Rs is not recommended because of the risk of imbalance-induced errors because CD-ROM discs are generally read at the highest speeds.
- Cleaning
    - Any cleaning should be done radially, that is, from the center hole out to the edge rather than around the disc. This prevents any accidental scratch from lining up with a recording track. The best solution for cleaning optical discs is a solution designed for such discs or the same solution used to clean eyeglasses made from plastic.
    - Compressed air used to blow dust off a disc should be used carefully if the temperature of the air is cold enough to cause a stress fracture.
- Storage
    - Optical discs should be kept in storage cases for protection against contaminants, light, or accidental scratches.
    - Storage cases should stand on their edges so that the disc hangs from its center hub.
    - The ideal storage environment should be cool, dry, and dark.

        4° C (39° F) < Ideal storage range < 20° C (68° F) at 20-50% relative humidity

        Archival: 18° C (65° F) at 35% relative humidity

*John Carrier, the inventor of modern air conditioning, developed his first system as a dehumidifier for a printing plant that had trouble keeping paper in registration when the paper expanded or contracted depending on the humidity in the plant. Keeping the air dry kept the paper stable as it ran through multiple presses.

Memorex has been a well-recognized and trusted supplier of high quality media for many years. We realize that the consumer will determine which medium or format to choose given enough accurate, honest information to see what fits his or her needs best. Memorex supplies, and will continue to supply, all the media types available to the market and takes pride in helping to inform the consumer so that he or she can choose what is best.

Bijlage 10: Redundant Arrays of Independent Disks (RAID)-configuraties

RAID-niveau	**Minimum aantal schijven**	**Pluspunten**	**Minpunten**
JBOD (Just a Bunch of Disks	2	Eenvoudige opzet, eenvoudig in te voeren	Geen foutcorrectie, disk defect = data op defecte schijf verloren
0	2	Snelste doorvoer van data voor alle data, eenvoudige opzet, eenvoudig in te voeren	Geen foutcorrectie, disk defect = data op alle schijven verloren
1	2	100% foutcorrectie, eenvoudige opzet, snel lezen voor alle data	Relatief duur
2	3	Foutcorrectie, ook voor disks zonder ingebouwd correctie systeem	Geen praktische toepassing
3	3	Snelle data doorvoer voor sequentiële data, efficiënte foutcorrectie	Kan niet gelijktijdig schrijven en lezen
4	3	Snel lezen voor alle data, efficiënte foutcorrectie	Langzaam schrijven
5	3	Snel lezen voor alle data, efficiënte foutcorrectie, beste voor netwerk toepassingen	Schrijfsnelheid vanwege pariteitsberekeningen afhankelijk van de gebruikte processor of controller
6	4	Robuuste foutcorrectie, tolereert twee falende schijven	Nog rekenintensiever dan RAID-5 dus relatief dure controller

Bron: http://nl.wikipedia.org/wiki/Redundant_Array_of_Independent_Disks (geraadpleegd op 25-08-2009).

Bijlage 11: Opvolger Blu-Ray

28 februari 2008. Wereldwijd werken onderzoekers hard aan de opvolger van de 'Blu-ray Disc'. Deze vierde generatie optische informatiedragers krijgt een nóg grotere opslagcapaciteit. Daarvoor moeten op hetzelfde schijfje wél steeds meer bits worden geperst. De leesfouten die dat oplevert, kunnen voor een groot deel worden voorkomen door betere algoritmes voor signaalverwerking. Dat laat de Chinese onderzoeker Li Huang zien in zijn promotieonderzoek. Maandag 3 maart verdedigt hij zijn proefschrift.
Na de cd (1980, 650 megabyte) en de dvd (1994, 4,7 Gigabyte) is nu ook de 'Blu-ray Disc' op de markt. Deze lijkt het inmiddels definitief te hebben gewonnen van de 'High Definition DVD', mede door het recente afhaken van grote elektronicaproducenten als Toshiba. De Blu-ray Disc (BD) mag dan met zijn 25 Gigabyte opslagcapaciteit voor de consument het nieuwste van het nieuwste zijn, op de achtergrond zijn onderzoekers al druk bezig met de vierde generatie van optische dataopslag. Deze schijfjes -120 millimeter in doorsnede, nog steeds even groot als een cd- gaan in de toekomst waarschijnlijk tot 100 Gigabyte aan data bevatten; vier keer zoveel als een 'Blu-ray Disc'.

Dichter op elkaar

Daarvoor wordt wel het uiterste gevergd van de technologie. Zo komen de bits op het plastic schijfje noodgedwongen steeds dichter op elkaar te liggen. "De compact disc was nog groot genoeg om ruimte te houden tussen elke rij putjes", vertelt de Chinese promovendus Li Huang. Hij deed zijn promotiewerk voor een deel aan de faculteit Elektrotechniek, in de groep Signal Processing Systems. "Bij de volgende generaties optische schijfjes kwamen ze echter steeds dichter bij elkaar te liggen." Bij de opvolger van BD liggen zelfs een aantal rijen tegen elkaar aan (zie figuur). De laser krijgt hierdoor moeite twee bits naast elkaar te onderscheiden. Een 'nul' wordt zo nu en dan aangezien voor een 'een', of andersom. Meer leesfouten in ieder geval.

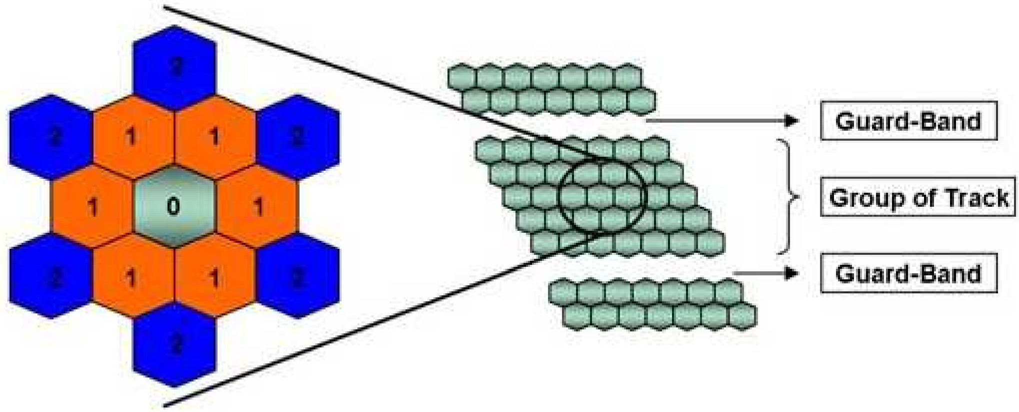
De oplossing lijkt simpel: bouw een kleinere laser in, die de hobbels en putjes op het oppervlak van de schijf preciezer kan detecteren. "Dat is inderdaad een optie, maar die kleinere lasers zijn meteen een stuk duurder en daar willen de fabrikanten van dit soort spelers niet aan", legt Huang uit. Hij stelde zich daarom als doel algoritmes te ontwikkelen waarmee het nieuwe type overvolle schijfjes toch goed te lezen is. Daartoe werkte hij aan een concept waarbij meerdere rijen bits tegelijk worden gelezen. Zo kan de elektronica de bits in groepjes verwerken, wat de verwerking sneller en betrouwbaarder maakt. "In feite heb ik de complexiteit van de dataverwerking verminderd. Daardoor wordt het snel lezen van een optische schijf met hoge datadichtheid mogelijk."

Draadloze netwerken

Opvallend genoeg zijn dezelfde technieken ook bruikbaar bij de communicatie via draadloze netwerken. Om de betrouwbaarheid en de snelheid daarvan te vergroten, maken deze vaak gebruik van meerdere zenders en meerdere ontvangers. Heb je er bijvoorbeeld van elk twee, dan zijn er al vier dataverbindingen. Huang: "Al die signalen beïnvloeden elkaar. Deze interferentie maakt het al gauw ingewikkeld om bij de ontvanger weer de juiste data uit het signaal te destilleren." De promovendus maakte de signalen uit de zenders daarom hoekafhankelijk. Zo kon het aantal benodigde signalen flink omlaag. Net als bij de optische schijven maakte hij daarmee de signaalverwerking minder complex. En dat leidt tot minder fouten en een hogere snelheid. Volgens de promovendus zullen van dit deel van het onderzoek ook mobieltjes en draadloos internet kunnen profiteren.

Optische illusie?

Huang deed een deel van zijn onderzoek aan het Data Storage Institute in Singapore. Via een videoverbinding verdedigde hij zijn promotiewerk onlangs al voor zijn thuisuniversiteit, de National University of Singapore (NUS). Met deze universiteit heeft de TU/e de afspraak dat promovendi die aan gezamenlijke projecten werken, gelijktijdig aan beide universiteiten kunnen promoveren.



Op de cd zat tussen elke rij bits een lege 'veiligheidsband' om interferentie tussen opeenvolgende spoortjes te voorkomen. Op de vierde generatie optische informatiedragers is zo weinig plaats meer over dat de rijen bits elkaar raken. De figuur laat slechts een schematische weergave van de bits op een schijfje zien. In werkelijkheid zijn de bit-gebiedjes niet hexagonaal, maar rond of uitgerekt.

De putjes zijn niet perfect

In de 28 jaar die tussen de eerste cd en de allernieuwste types schijven zit, is de basistechnologie niet veel veranderd. De schijf is van polycarbonaat en wordt middels spuitgieten in een mal aangebracht. In het polycarbonaat zitten honderden miljoenen putjes. Deze lopen, afgewisseld door vlakke stukken, in een spiraal van binnen naar buiten. Op het oppervlak zit een dun laagje aluminium, dat het laserlicht waarmee de schijf wordt gelezen, beter weerkaatst. Een dunne laklaag beschermt het aluminium.

Als alles optimaal werkt het lezen van de cd of dvd als volgt: een lensje bundelt laserlicht op het oppervlak van de draaiende schijf. Hoe het licht weerkaatst wordt van de dunne laag aluminium hangt af van de aanwezigheid van wel of geen putje onder het laserlicht. Doorgaans wordt aan een waargenomen putje een '1' toegekend. Kaatst het licht gewoon terug van een vlak stuk van de cd, dan leest het systeem een '0' uit.

Dit verhaal gaat op wanneer de putjes een nette, strakke ronde vorm hebben. Van de zijkant gezien een ondiepe kuil met rechte verticale wanden, honderd nanometer diep en vijfhonderd breed.

Maar in de praktijk is dat natuurlijk niet zo. Vanwege de beperkingen in het productieproces heeft die 'rechte' kuil afgevlakte hoeken. Daardoor is het lastig te bepalen waar de put precies begint. Ook zit de put vaak niet op de exacte locatie waar die moet zitten. En tenslotte is als gevolg van de benodigde hoge productiesnelheid de vorm van het putje meestal niet rond, maar uitgerekt.

Bron: http://web.tue.nl/cursor/internet/jaargang50/cursor22/onderzoek/onderzoek.php?page=o1 (geraadpleegd 25-08-2009).

Bijlage 12: Nabije-veld optische opslag op schijven met een beschermlaag

Promotie van dhr. ing. J.M.A. van den Eerenbeemd: "Nabije-veld optische opslag op schijven met een beschermlaag" HTS-ingenieur in de technische natuurkunde, Nederland.
promotor Prof.dr.ir. J.J.M. Braat (TNW)

De opslagcapaciteit van een optische schijf wordt beperkt door het oplossend vermogen van het lees/schrijf-systeem. Het Blu-ray Disc (BD) systeem, een opvolger van DVD, haalt een opslagcapaciteit van 25 GB op een enkele laag, welke de hoogste is van alle commercieel beschikbare systemen. Het BD systeem nadert de grenzen van wat fysisch haalbaar is met conventionele optische data systemen in termen van golflengte en numerieke apertuur. De opslagcapaciteit van optische schijven verder vergroten is dan ook niet triviaal.

Dit onderzoek, uitgevoerd bij Philips Research, gebruikt een Solid Immersion Lens (SIL) om de opslagcapaciteit van optische data systemen te vergroten tot voorbij de grenzen die bereikt kunnen worden met conventionele lenzen. De voordelen van een SIL kunnen alleen worden benut als de afstand van de SIL tot de schijf beduidend kleiner is dan de golflengte van het gebruikte licht. Aanvankelijk werd aangenomen dat de datalaag bij gebruik van een SIL boven op een schijf moet liggen waardoor deze laag extreem kwetsbaar is. Dit onderzoek laat zien dat zelfs in combinatie met een SIL een dunne beschermlaag boven op de datalaag gebruikt kan worden. Hierdoor neemt de betrouwbaarheid van nabije veld optische opslagsystemen toe. Een bijkomend voordeel is dat een dergelijke beschermlaag de mogelijkheid biedt om meerdere datalagen te gebruiken waardoor de opslagcapaciteit van het systeem verder toeneemt.

Op SIL gebaseerde lenzen, waarmee door een beschermlaag kan worden gelezen, zijn ontworpen, gemaakt en gekarakteriseerd. Deze lenzen zijn geïmplementeerd in een opstelling voor nabije veld optische data opslag. Hiermee zijn optische schijven met een beschermlaag succesvol beschreven. De resultaten beschreven in dit proefschrift maken aannemelijk dat een opslagcapaciteit van 100 GB per laag, op een schijf ter grootte van een CD, mogelijk is[101].

Bron: http://www.tudelft.nl/live/pagina.jsp?id=9f68ee43-c012-46a9-8717-1532abc51aa9&lang=nl (geraadpleegd 25-08-2009)

[101] Zie ook http://www.tudelft.nl/live/pagina.jsp?id=e3791bf0-8a21-4d58-81c3-d01a12c073ba&lang=nl, http://www.opticsinfobase.org/abstract.cfm?URI=ISOM/ODS-2005-WD2 en http://www.faqs.org/patents/app/20090190461 (geraadpleegd 26-08-2009).

Bijlage 13: Layer-Selection-Type Recordable Optical Disk (LS-R)
Bron: http://jjap.ipap.jp/link?JJAP/45/1235 (geraadpleegd op 25-08-2009).

Japanese Journal of Applied Physics
Vol. 45, No. 2B, 2006, pp. 1235–1238

Layer-Selection-Type Recordable Optical Disk with Inorganic Electrochromic Film

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(Received July 28, 2005; accepted September 28, 2005; published online February 24, 2006)

We have introduced a tungsten oxide film to a layer-selection-type recordable optical disk (LS-R) as an inorganic electrochromic (EC) film. The EC film showed a large transmittance change in a wide wavelength range. Layer selection was demonstrated with a dual-layer disk whose spacing was 0.3 μm, and the capacity of a 20-layer LS-R was estimated to be 1 TB.
[DOI: 10.1143/JJAP.45.1235]

KEYWORDS: large capacity, multilayer, layer selection, 1 TB/disk

1. Introduction

The ever-increasing demands on digital recording devices require them to have a storage capacity around 1 TB. The multilayer disks[1,2] and three-dimensional (3-D) optical memories[3,4] that have been investigated, however, need to have wide spacer layers in order to avoid interlayer crosstalk, and the optical absorption in each layer limits the number of layers in optical systems such as digital versatile discs (DVDs) and Blu-ray discs (BDs).

In a layer-selection-type recordable optical disk (LS-R),[5] on the other hand, the selected layer has a high reflectivity and the other layers have a low reflectivity and a high transmittance (Fig. 1). The layer is selected by changing the reflectivity of the corresponding electrochromic (EC) film by applying a voltage to it. With this configuration, the interlayer crosstalk is substantially reduced. One advantage of the LS-R is that the width of the interlayer can be less than the depth of focus, so the total thickness of the LS-R can be small and there is no serious aberration when a laser is focused on any of the layers. Another is that it can have a large number of layers without absorption in each layer decreasing the intensity of the laser light. This means that a capacity around 1 TB can be obtained using the conventional optical system.

The previously reported LS-R with an organic EC film,[5] however, had some problems. One was that its contrast at blue wavelengths was so low that the blue laser needed for high-density storage could not be used for reading and writing. Another was that the organic EC film was so delicate that it was easily damaged by sputtering.

This paper therefore reports an LS-R that instead uses an inorganic EC film that lets us improve the optical characteristics and fabricate all the films by sputtering.

2. Preparation of EC Devices

Figure 2 shows the schematic diagram of inorganic EC devices. We chose tungsten oxide (WO_3) as the inorganic material because it is a typical EC material[6,7] and changes color in response to irradiation with a wide range of wavelengths. It also has a large coloration efficiency, so we can obtain a large transmittance change. The device shown in Fig. 2(a) is a single-layer disk and the device shown in Fig. 2(b) is a dual-layer disk in which the layer on the side from which light is incident is designated Layer 0 (L0) and the other layer is designated Layer 1 (L1).

The indium–tin-oxide (ITO) film serving as a transparent electrode, the tungsten oxide (WO_3) film serving as an EC film, the tantalum oxide (Ta_2O_5) film serving as an electrolyte, and the underlying ITO film were deposited on the glass substrate by sputtering. The distance between the EC film in L0 and the EC film in L1 was 0.3 μm.

3. Results and Discussion

3.1 Optical characteristics of inorganic EC devices

We first confirmed that the state of a testpiece could be changed from decolored to colored by applying a voltage. As shown in Fig. 3, the reflectivity at 660 nm changed from 7% in the decolored state to 17% in the colored state when 10 V was applied.

Figure 4 shows, for the same sample, the transmittance changes measured at wavelengths ranging from 400 to 800 nm. It shows that an EC device with a tungsten oxide film has a large contrast over a wide wavelength range. The transmittance at 400 nm was improved from about 0% in the previous device[5] to 16% in the inorganic device. This means that this inorganic EC device can be expanded for a large capacity with a blue laser.

3.2 Layer selection in dual-layer devices

Figure 5 shows the results of layer selection in a dual-layered test piece. We used a sample with two different areas of EC layers. The smaller area (enclosed by blue dotted lines) corresponds to L0, and the larger one (enclosed by red dotted lines) corresponds to L1. When the EC film was colored, the area changed to blue.

When no voltage was applied, both layers were in the decolored state as shown in Fig. 5(a). When a voltage was applied to L0, only the smaller layer L0 was colored as shown in Fig. 5(b). When the voltage was applied to L1, on the other hand, the larger area changed to blue as shown in Fig. 5(c). Thus, layer selection was confirmed by the different colored areas.

3.3 Layer selection by conventional optical system

Figure 6 shows the results of layer selection by a conventional optical system. The top graphs show the state of the voltage applied to each layer. The upper oscillographs show the focus error signal and the lower ones show the reflectivity levels. The reflectivity of the disk depends on the combination of the L0 state and L1 state, which change from (colored in L0 and decolored in L1) to (colored in L0 and colored in L1) to (decolored in L0 and colored in L1) to (decolored in L0 and decolored in L1). A DVD tester was

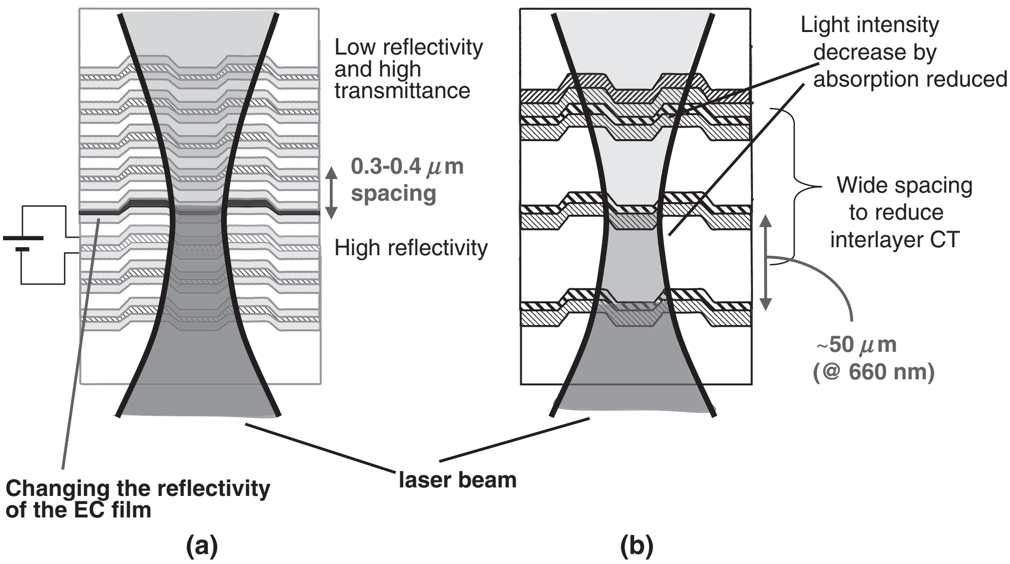


Fig. 1. Concepts of (a) LS-R and (b) conventional multilayer disc.

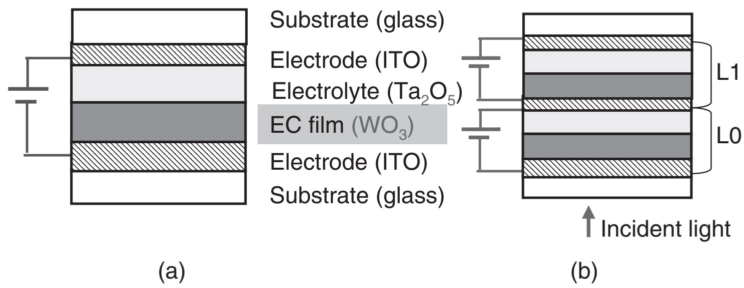


Fig. 2. Schematic diagrams of inorganic EC devices: (a) single-layer device ($R = 7\%$) and (b) dual-layer device ($R = 17\%$).

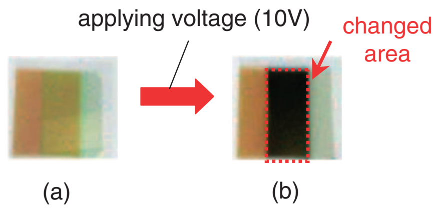


Fig. 3. Color change in inorganic EC device: (a) decolored device before applying voltage and (b) colored device after applying voltage.

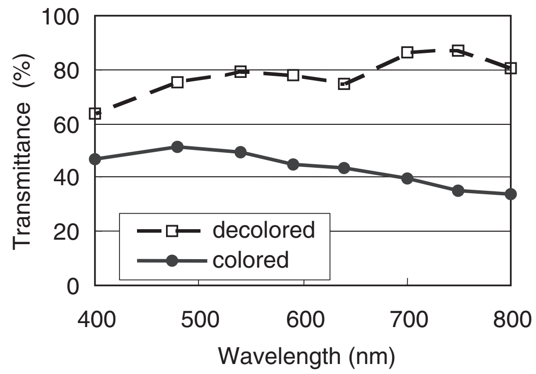


Fig. 4. Transmittance changes measured in inorganic EC device: (a) decolored device before applying voltage and (b) colored device after applying voltage.

used as a conventional optical system in which the wavelength was 660 nm, the NA of the objective lens was 0.6, and the reading power was 0.5 mW.

Voltage was first applied only to L0 as shown in Fig. 6(a), and then the disk was irradiated with laser light focused on L0 as shown in Fig. 6(b). When voltage was then applied to both L1 and L0, the reflectivity changed as shown in Fig. 6(c). When voltage was then applied only to L1, the reflectivity became high as shown in Fig. 6(d). Finally, when no voltage was applied to either layer, the reflectivity decreased as shown in Fig. 6(e).

Layer selection was thus performed by a conventional optical system even though the layer spacing was only 0.3 μm, which is less than the depth of focus. The constant focus error signal observed when changing the selected layer also confirms that the spacing is less than the focal depth.

3.4 *Writing marks on inorganic EC disk*

Figures 7 and 8 show the results obtained when writing marks on the disk. The reflectivity at a wavelength of 660 nm was designed to be 0% in the decolored state. The write/read conditions are listed in Table I. Marks 5 μm long were recorded in order to evaluate the reflectivity. The optimum recording power was 30 mW. The mark reflectivity R_m recorded at the optimum power was almost 0, which is the same as the reflectivity of the decolored state (R_d) at the

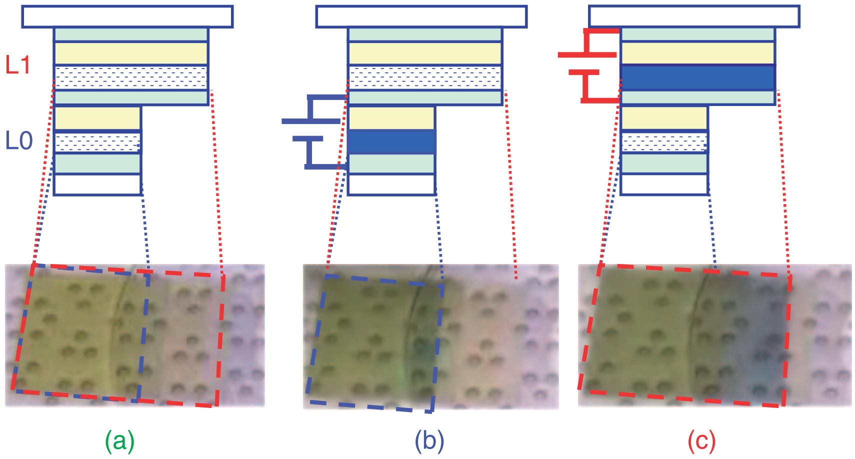


Fig. 5. Results of layer selection in device with EC films having different areas: (a) colored sample before applying voltage, (b) L0-colored sample after applying a voltage to L0, and (c) L1-colored sample after applying voltage to L1.

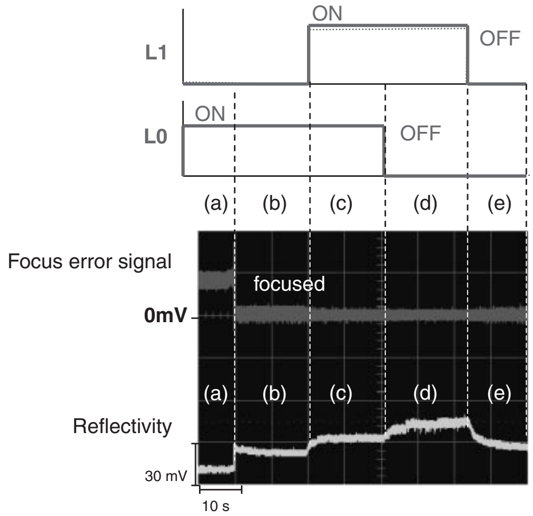


Fig. 6. Reflectivities and focus errors observed at four combinations of states of L0 and L1: (a) L0-colored state produced by applying voltage to L0, (b) disk irradiated with laser light focused on L0 after voltage is applied to L0, (c) L0-colored and L1-colored states produced by applying voltages to both layers, (d) L1-colored state produced by applying a voltage to L1, and (e) decolored states obtained without applied voltage.

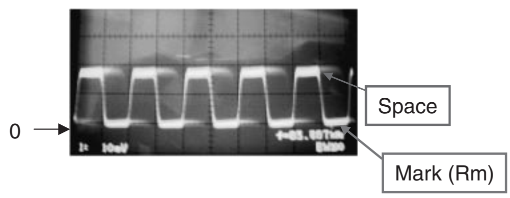


Fig. 7. Waveform of marks recorded on EC disk.

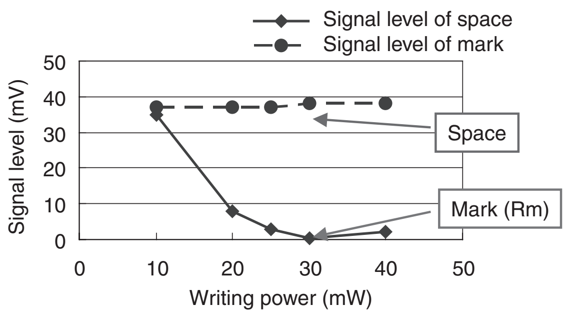


Fig. 8. Signal level as a function of writing power.

Table I. Experimental conditions.

Wavelength (nm)	660
NA	0.65
Linear velocity (m/s)	5
Reading power (mW)	2
Writing power (mW)	30
Mark length (μm)	5

Table II. Calculation conditions.

Wavelength (nm)	660
Number of layers	20 (L0 to L19)
Reflectivity of colored state, R_c (%)	≥10
Reflectivity of decolored state, R_d (%)	≤0.5
Reflectivity of mark, R_m (%)	≤0.5

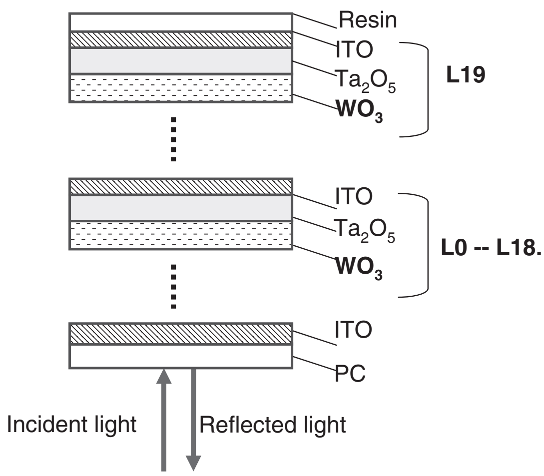


Fig. 9. Calculated structure of 20-layer disk.

recording power. This means that the interlayer crosstalk is sufficiently low.

The mechanism of recording is unclear and is under investigation. The power needed for the recording marks in the tungsten oxide film was high and the reflectivity in the mark became low after the recording. We think that the state of the tungsten film was somehow changed by the incidence of a large amount of energy.

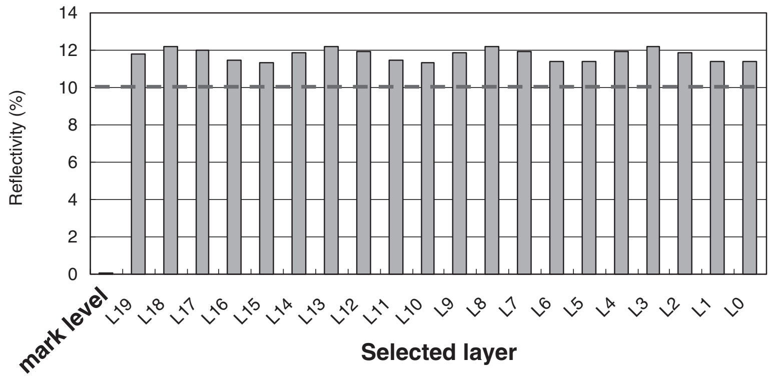


Fig. 10. Simulation results for 20-layer disk.

3.5 Design of 20-layer disk

To estimate the potential data capacity, we designed a 20-layer structure. The calculated structure is shown in Fig. 9 and calculation conditions are listed in Table II. We took optical interference into consideration in the calculation because the thicknesses of all the layers are less than the wavelength of the incident light.

Figure 10 shows the simulation results for the 20-layer structure. The average reflectivity is 11.8% for the colored states and 0.1% for the mark areas. The contrast ratio $(R_c - R_m)/R_c$ is 99%. A 20-layer LS-R was thus designed with a high contrast for the 660 nm wavelength. A device with the same EC characteristics can also be designed for 400 nm, and its contrast and reflectivity will be close to those of conventional disks.

3.6 Estimation of potential capacity

The results in §3.5 were used to estimate the potential storage capacity of a layer-selection-type recordable optical disk. The data capacity was assumed to be 50 GB/layer because the technology to write and read such a capacity has already been developed[8,9] and is applicable to an LS-R.

The 20-layer structure we designed was intended to be used at a wavelength of 660 nm, but the transmittance change of the tungsten oxide film it uses is large over a wavelength range including the wavelengths of blue lasers. An optical system with a NA of 0.85 and a wavelength of 400 nm could provide a storage capacity of 50 GB/layer, making the capacity of a 20-layer disk 1 TB.

4. Conclusions

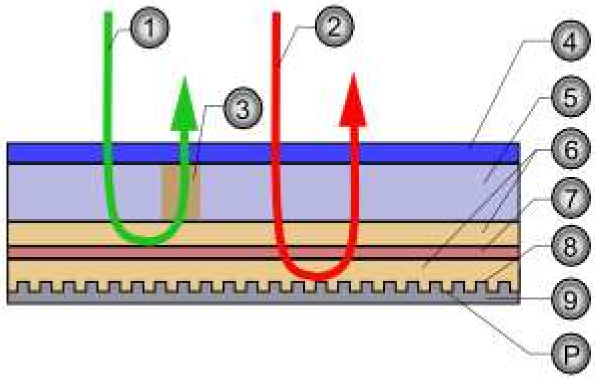
We have fabricated a layer-selection-type recordable optical disk (LS-R) using an inorganic electrochromic (EC) material. Over a wide wavelength range it has a large transmittance and optical characteristics better than those of a similar disk using an inorganic EC material. Layer selection was demonstrated with a dual-layer disk whose spacing was less than the depth of focus, and a high-contrast 20-layer LS-R was designed. Our results show that it should be possible to make a 1 TB LS-R that can be used with a conventional optical head.

Acknowledgments

We thank Dr. Harukazu Miyamoto, Mr. Hiroyuki Minemura, Mr. Toshimichi Shintani, Dr. Takeshi Maeda, and Ms. Yumiko Anzai for helpful discussions.

1) I. Ichimura, G. Hashimoto, K. Saito, T. Yamasaki, T. Yukumoto, T. Maruyama and K. Osato: Tech. Dig. Int. Symp. Optical Memory, 2004, p. 52.
2) H. Kitaura, K. Hisada, K. Narumi, K. Nishiuchi and N. Yamada: Proc. SPIE **4342** (2002) 340.
3) M. Miyamoto, M. Nakano,Y. Kawata, S. Miyata and M. Nakabayashi: Tech. Dig. ISOM/ODS, 2005, MC3.
4) F. Wu, H. Shieh, D. Huang and T. Milster: Appl. Opt. **43** (2004) 5498.
5) K. Kojima and M. Terao: Jpn. J. Appl. Phys. **43** (2004) 7058.
6) A. Hjelm, C. Granqvist and J. Wills: Phys. Rev. B **54** (1996) 2436.
7) P. Monk, R. Mortimer and D. Rosseinsky: *Electrochromism: Fundamentals and Applications* (VCH, Weinheim, 1995).
8) A. Hirotsune, J. Ushiyama, H. Minemura, H. Kudo, H. Miyamoto, R. Tamura and K. Adachi: Jpn. J. Appl. Phys. **44** (2005) 3467.
9) H. Kudo, H. Minemura, H. Miyamoto, R. Tamura and K. Adachi: Jpn. J. Appl. Phys. **44** (2005) 3445.

Bijlage 14: Holographic Versatile Disk



Holographic Versatile Disc structure
1. Green writing/reading laser (532 nm)
2. Red positioning/addressing laser (650 nm)
3. Hologram (data)
4. Polycarbon layer
5. Photopolymeric layer (data-containing layer)
6. Distance layers
7. Dichroic layer (reflecting green light)
8. Aluminium reflective layer (reflecting red light)
9. Transparent base

P. PIT

Current optical storage saves one bit per pulse, and the HVD alliance hopes to improve this efficiency with capabilities of around 60,000 bits per pulse in an inverted, truncated cone shape that has a 200 micrometer diameter at the bottom and a 500 micrometer diameter at the top. High densities are possible by moving these closer on the tracks: 100 GB at 18 micrometers separation, 200 GB at 13 micrometers, 500 GB at 8 micrometers and a demonstrated maximum of 5 TB for 3 micrometer separation on a 10 cm disc.
The system uses a green laser, with an output power of 1 watt (of 808nm, the green light output (at 532nm) is much less), high power for a consumer device laser. So a major challenge of the project for widespread consumer markets is to either improve the sensitivity of the polymer used, or develop and commoditize a laser capable of higher power output and suitable for a consumer unit.

Bron: http://en.wikipedia.org/wiki/File:HVDstruct.png (geraadpleegd op 25-08-2009).

Dramatically increased storage density – Holographic Information Storage breaks the density limits of conventional optical storage by recording through the full depth of the medium instead of recording on the surface only. One HVD can store upwards of 200 gigabytes of data, the equivalent of more than 40 of today's DVDs, and that is just for starters. Future implementations will be able to store more than 1.3 terabytes.
Additionally, unlike optical discs, which record one data bit at a time, HVDs allow over 10 kilobits of data to be written and read in parallel with a single flash of light – and the recording and reading processes do not require spinning media. Data transfer rates of up to 20 megabytes per second (far faster than DVDs) are easily achieved with rotating or translating media.

Bron: http://www.ecma-international.org/news/TC44_PR_Jan2005.pdf (geraadpleegd op 25-08-2009).