CD: Confusion Dispelled

CDs are a wonderful medium for storing music or other "stuff". They are compact (anything named "Compact Disc" had better be), they are relatively rugged, and they are capable of quite good fidelity. So it makes a lot of sense to put our music on them, either for everyday use or for "permanent" backup storage.

The trouble is, almost anyone who has tried to record music on a CD has run into obstacles. There are questions about what kind of blank CD to use, how to prepare music for recording, how to use the software, and of course the perennial favorite: "Why won't this CD play in my car CD player?"

In the course of researching this presentation, I discovered that CDs are really pretty amazing things. Did you know that the top surface of a CD is actually more fragile than the bottom? That the information on a disk is recorded in the form of little bumps imbedded inside the plastic, and that for a long time, those bumps were the smallest things manufactured by humans? That the plastic layer on the bottom of a CD is actually a lens – it focuses the laser on the tiny bumps inside. Well, that's just the beginning. The way these things work is really amazing. Just wait 'till we get into that part of the presentation.

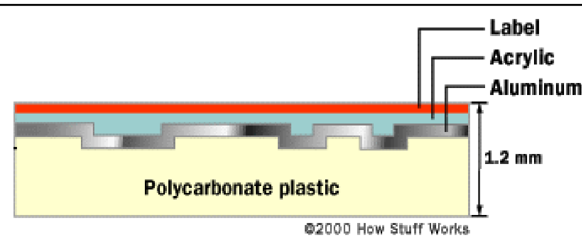
We'll talk about how CDs work; in part because it **is** so amazing, and in part because once you understand a little about the way they work (and their evolutionary history), the rest of this CD burning stuff makes a whole lot more sense.   We'll talk about the differences between audio and data CDs and how to create them. We'll also go over the differences between CDs, CD-ROMs, and CD-RWs, and what that has to do with why you can't play your new CD in the car.

I will take you through the process of creating a music CD in two different ways, just to be sure you really get it, then go on to show you how to make a data CD. You might be surprised at how easy it is. (I was.)

Then we'll touch on getting music *off* of a CD – just a touch, because that is all it needs - and we'll finish up with a peek at what comes after CDs. Well, obviously, that's DVDs, so we'll glance at them and then peek over the horizon.

How CDs Work

You may be familiar with the way vinyl records are made: a long wiggly spiral groove is cut into a master disk, then a metal "stamper" is made from the master, then the stamper is pressed into a blob of hot vinyl, so the vinyl winds up being a flat disk with a long wiggly groove, just like the master. Making a CD is similar in many ways. A master is made from a glass disk using a laser, then "stampers" are made from the master, and used to mold the final CD. The top surface of the CD, containing the tiny bumps, is coated with a very thin layer of reflective metal, usually gold or aluminum, and a layer of acrylic plastic is added on top of the metal. The label goes on top of the acrylic.



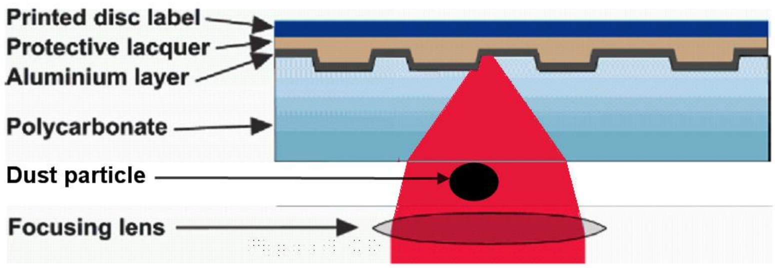
Cross-section of a CD

Because the acrylic is often very thin, it is easy to damage the bumps in the metal layer beneath it if you scratch it or even write on the label with a ball-point pen. Even some felt-tipped pens can be dangerous, because the solvent used in the ink can dissolve the acrylic and destroy the bumps, too. Sharpie brand markers are generally pretty safe because their solvent evaporates relatively quickly.

CDs are read by shining a laser on the underside of the disk as it spins, and reading the light reflected back from the aluminum layer inside the disk. The bumps I've mentioned are arranged in one long spiral track that starts at the inside of the disk and works its way to the outer edge. (The opposite of a vinyl record.)

Now here's where things start to get amazing.

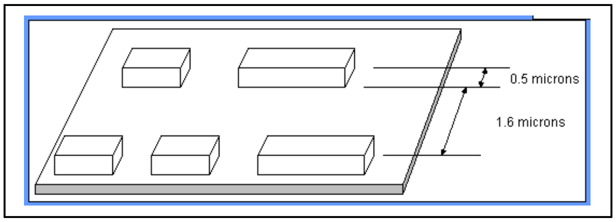
The bottom layer of polycarbonate plastic is precisely 1.2 mm thick. Because of the way that light bends when it enters the polycarbonate from the air, the beam from the laser can be relatively broad at the surface



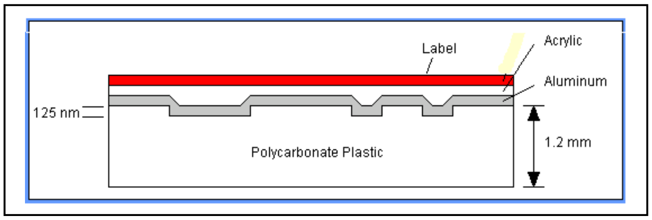
of the disk, and that bending focuses the beam to a tiny spot right where the metal layer with the bumps is. This means that little scratches or dust particles won't block the whole beam, and the laser can read right through them!

The most amazing things about CDs have to do with the scale on which they operate. For instance, take that long spiral track that the data is recorded on. If you stretched that track out straight it would be almost 5 miles long! Now, to get 5 miles of track on a 12 cm disk, the track has to be wound pretty tight. And the bumps have to be pretty small. Very small. Incredibly small. In fact, for many years those bumps were the smallest things ever manufactured by humans.

This drawing shows the pits (or bumps, depending on which side of the disk you are looking at) in two adjacent tracks. The track is half a micron wide, and separated from the next track by 1.6 microns. (Just in case you aren't used to thinking in terms of microns: a micron is 1/1000 of a millimeter. And in case millimeters don't do it for you: a typical human hair is about 100 microns in diameter. So it would take 200 bumps placed side-by-side to be as wide as a hair.) Imagine how challenging it must be for the laser to follow the track without wandering over to the next one. And just to add a little more challenge, that the outer parts of the track are a lot farther around than the inner ones, so if the data is going to be read at a constant rate (which it is), the motor has to turn the disk faster or slower, depending on where in the track the laser is at the moment. When playing an audio CD, the disk spins at about 500 RPM when reading near the center and at about 200 RPM near the outer edge.



Here is another drawing of the cross-section of a CD. Now, this drawing is **not** to scale. I mentioned before that the polycarbonate layer is 1.2 millimeters thick – well, the bumps are 125 nanometers high. A nanometer is very, very tiny. $1/1000^{th}$ of a micron. To get an idea just HOW tiny that is, let's blow up a CD.



If you were to enlarge a real CD so that the bumps were, say, an inch high, the polycarbonate would be very thick. Picture a CD a foot thick, and you're not thinking nearly big enough. Picture 8 feet thick and you're still not in the ballpark. Picture a CD 8 stories high – not even close. To get bumps one inch high, you'd have to make your CD 800 feet thick! Now take that 80-story CD with its one-inch bumps, and mentally shrink the whole thing until it is less than a sixteenth of an inch high. Those are tiny bumps.

125 nanometers isn't an arbitrary number. The bumps are that high because that is ¼ the wavelength of the light from the infrared laser that is used to read them. What that means is that when the light from the laser bounces off of the "lands" between the bumps, the reflected light is in phase with the incoming light and doesn't interfere with it. When it bounces off a bump, however, the reflected light is out of phase with the incoming light and cancels it out. So when the laser is focused on a land, it gets a reflection back, when it is focused on a bump, it gets no reflection. Ones and Zeros. Brilliant.

Error Handling

But, brilliant as it might be, when you're pushing the technology that far, there are bound to be some errors. To cope with those errors, and minimize their effect, several techniques are used. First, extra bits are recorded with each byte – these bits are chosen to help the reader detect and correct small errors in reading.

Second, the bytes in the data stream are interleaved – in other words, they might write byte number one, followed by byte 4, then byte 7, then bytes 2, 5, and 8, then 3, 6, and 9, etc. (In reality, consecutive bytes are spread farther apart than in this example.) This is done so that if several bytes in a row can't be read (maybe there is a smudge on the disk surface) that one large impact is spread out into several small impacts so it is less noticeable.

Then more error correcting bits are added. If that doesn't provide enough protection and errors still get through, the player will try to "fill in" the missing data by interpolation.

After CDs had established themselves as a music distribution medium, CD-Rs – recordable CDs - were developed. And people were able to make their own CDs at home. And that is when the confusion began.

Recordable CDs

CD-Rs are just like CDs, only different.

The bottom layer is 1.2mm of polycarbonate, with a reflective layer of metal above it, and a layer of acrylic above that, just as in a CD. But instead of having pits or bumps in the reflective layer, there is a layer of organic dye between the metal and the polycarbonate. The dye is normally transparent to the infrared laser, but if it is exposed to light of the right wavelength and intensity, it will turn opaque. So if you "burn" little dark spots in this dye layer, when the disk is read back, the light will pass through the unexposed places and be reflected, but will be absorbed by the burned places. The reader sees this as ones and zeros.

The dye isn't perfect, and it neither transmits nor absorbs 100% of the light, so what the reader actually gets is "brighter" or "dimmer", not on or off. So there are more errors in reading a CD-R than a CD. And the difference between light and dark tends to decrease over time, so over a period of years or tens of years, the errors start to pile up, and eventually the disk may become unreadable.

The dye is most sensitive to a slightly different wavelength of light than that used in the first CD readers. That, plus the greater ambiguity of the data, can keep CD-Rs from being read in older readers that were designed for CDs. If you have an old CD player that you REALLY want to make CDs for (like, maybe it's firmly attached to your car), you might try different brands of blank disks, to see if a different dye works better in your player.

Before we leave CD-Rs, I want to mention that the blank disks that you buy aren't really blank. Remember that data is written on a CD in a long spiral track, with only 1.6 microns between adjacent tracks. A CD burner that could position the laser that accurately on its own would cost more than we can afford.

So to guide the laser as it writes on a blank disk, the disk has a groove stamped into it – like a vinyl record – but the groove is in the top of the polycarbonate, so the reflective layer has the groove too. This groove helps to guide the laser as it writes the tiny spots in the dye. Also like a phonograph record, the groove has "squiggles" in it. These squiggles contain information such as the position (time) on the CD, which helps the reading laser find a particular spot to read from.

At the beginning of this grove, 'blank' disks also contain information about the disk type, recommended writing speeds, and who manufactured it.

X-Ratings

Ok, I know you thought that I was going to try to slip that reference to writing speeds right past you, but we can pause here for a moment to talk about disk speeds.

An audio CD is meant to be played at the speed at which the music is recorded. In other words, it should take 74 minutes to play through a full audio CD. If you play (or record) it twice as fast, you are operating at 2 times normal speed, or 2X. These days, you can get CD drives that will read a disk at up to 52X.

Now, if playing a disk at 1X means that it spins at 500 RPM when reading near the center, then to read at 52X it would have to turn at 26,000 RPM! That's Pretty Damn Fast. At that speed centrifugal force could literally pull the disk apart and send pieces of it flying out through the sides of the computer like shrapnel! In reality, the disk will approach 52X only near the outer edge, where it "only" has to go a little over 10,000 RPM.

Speed is particularly important when you are writing a disk. In order to make the dye turn black, you have to pump a certain amount of light energy into it, and if you are going fast, you have to use a more powerful laser. In addition, the dye has to be able to react faster. That is why blank CDs have speed ratings. If you try to burn a disk faster than it is rated for, it probably won't work, even if your laser is powerful enough. And if you have trouble reading disks burned at their rated speed, writing them at a lower speed might well help.

Re-Writable CDs

Once you have "burned" spots into the dye of a CD-R, they are there permanently – you can't erase them. CD-RW – ReWritable CDs – can be written to, then erased and written to again. This makes them very convenient to use as back-up for data on your computer.

CD-RWs are just like CD-Rs, only different.

If you replace the layers of dye and metal in a CD-R with a layer of amorphous polycrystalline material (an alloy of silver and other metals, including indium, antimony, and tellurium), you could have a CD-RW. This material is interesting stuff, because it can exist at room temperature in one of two stable states. In its crystalline state, it is shiny (reflective), and bounces the laser light back to the reader. In its amorphous state it scatters the light, so much less of it gets reflected back.

To write to the CD, the laser heats the tiny spots on the disk – remember that we are still talking about micron-sized spots of data – to over 1000 degrees Fahrenheit! This melts the material, which then quickly cools and "freezes" in its amorphous state, making a non-reflective spot.

Now, imagine doing that at the rate of millions of bits every second. With ½ micron accuracy. With a piece of machinery that retails for $50. I find it truly amazing.

To erase the disk, or a portion of it, the writing laser is used to heat the metal to about 400 degrees and hold it at that temperature long enough for the crystals to organize themselves into their normal lattice structure (which is shiny), and cool slowly in that condition. It can take as much as half an hour to do that to a whole disk, especially an older one.

CD-RWs need a much higher power laser than CD-Rs, and there is less difference in the light reflected between bumps and lands. That means that CD-RWs are difficult to read, and can't be written, in a drive that wasn't designed to handle them. Writing speed is especially important in CD-RWs. Early CD-RWs could be written <u>only</u> at 2X. Then media were developed using a different alloy that could be written at any speed between 1X and 4X. *Then* "High Speed" disks that can be written between 4X and 10X (or 8X and 12X) came along. These are labeled "HS" disks and should be used only in a "HS" writer. You might think that a 4X disk could be written in either kind of writer, since 4X should equal 4X, but unfortunately, you'd be wrong. An HS disk won't work in a non-HS drive. Even worse, a non-HS disk will often *appear* to work in an HS drive, but then "forget" everything written to it within a few days. Perhaps within a few minutes.

You can tell if you have an "HS" writer because it will say so – in tiny, vertical print, to the right side of the "DISC" logo on the drive door. Actually, your drive door can make some pretty interesting reading. Besides "High Speed", or "Ultra Speed" – (8X – 12X), the door will probably tell you whether that drive can handle CD-RW (it will say "RW" or "ReWritable") CDs, DVDs, writable DVDs, and even what specific *kinds* of writable DVD media. We'll talk more about the various flavors of DVDs a bit later on.

You don't need to worry about reading speed because your drive will take care of that for you. It will go as fast as it can reliably read whatever disk you give it – up to the drive's maximum speed.

Data written to any CD-RW is less stable than CD-R data in general, meaning that it will deteriorate faster – over a period of many months to several years. So CD-RW IS great for backing up data, because you will make fresh backups fairly frequently. (You WILL do that, won't you? Please say "Yes".) CD-RW is NOT great for archiving family photos or your Last Will and Testament. (Assuming you're not planning to use it real soon.)

Making Coasters

True to their vinyl heritage, music CDs have no real file structure. The one long physical spiral of data is divided into several logical "tracks"; one track per song. There is a simple table of contents at the beginning of the disk that contains the location (in minutes and seconds) of the start of each track. And after the last song there is a "runout" track that tells the reader "Here endeth the disk". That is called a "session".

When you record music on a CD-R, your CD burning software writes the whole session – the table of contents, all the songs, and the runout track - all in one continuous stream.

If, for some reason, your computer can't supply the data to the CD burner fast enough, you've made a coaster. Making coasters is a technical term for creating useless CDs – ones that are good only for use as coasters. Or maybe for skeet shooting.

A more specific term for that situation is "buffer underrun". It means that the CD burner ran out of data as it was writing, and it can happen if your computer gets distracted by something else – receiving email, loading web pages, searching the hard disk, etc. – while burning a CD. For that reason, it is best to stop anything else that is running in your computer before making a CD. You don't want to start a virus scan while your CD burner is hungry for data. Slow computers and high disk writing speeds make the problem worse, of course.

Many new CD burners come with buffer underrun protection, sometimes called "Burn-Proof Technology". This means that the burner stores a fair amount of data internally, before writing it to the CD, and keeps track of how full its local buffer is. If it starts running low, the burner can slow the writing speed, or sometimes, even suspend the burn altogether until the computer gets around to supplying more data.

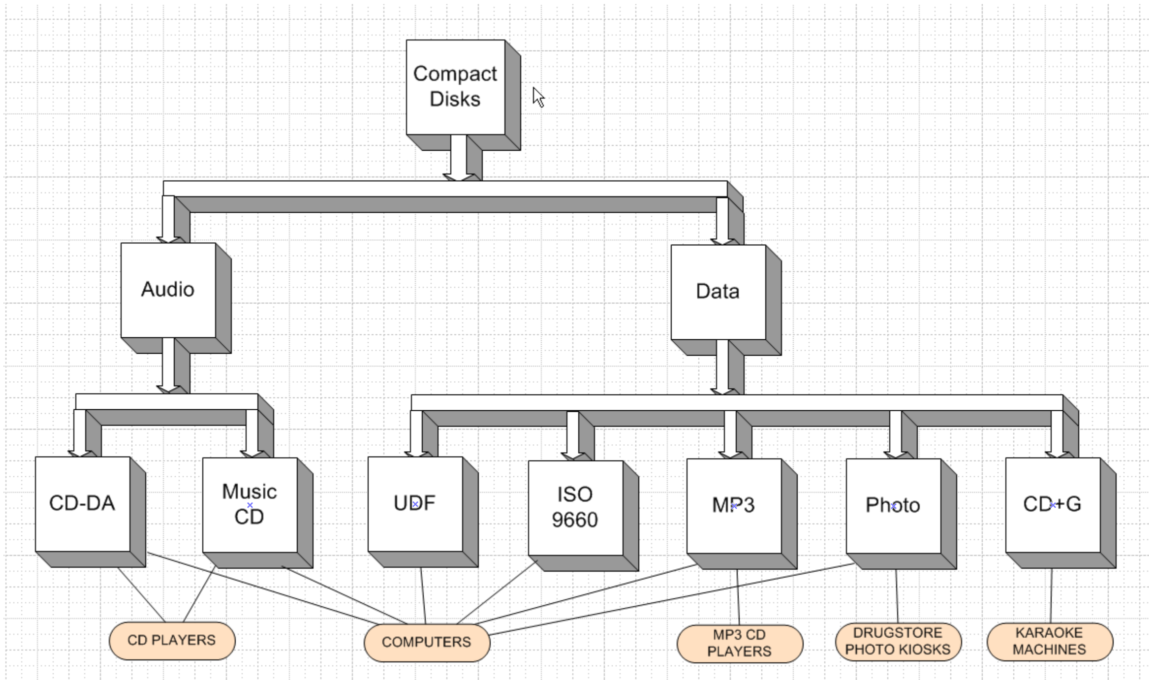
Multi- Session

CD burners can put more than one session on a CD-R, so you can, if you want, write a bunch of songs to a CD today, then add another session, complete with TOC (Table Of Contents), songs, and runout track, tomorrow. However, most audio CD players, unless they are labeled "Multi Session", will be able to read only the first batch of songs. They won't even be aware that there is more on the disk.

You could, if you wanted to, put some dances on a CD in an audio session, and put some cue sheets on the same disk in a data session. Your computer will read both of them perfectly happily, but your home or auto CD player will only see the audio session, and ONLY if it is the first session on the disc. Otherwise it won't read it at all.

Most CD burning software will let you leave a session "open" and add more tracks to it at another time. But since that means that the TOC and runout track are not written, you won't be able to read the disk in most players until you close it. If you are making a multi-session disk, your must close the final session, and close the disk as well, before it can be read in a reader. (A CD **writer** in another computer may be able to read a disk that hasn't been closed, but an ordinary **reader** won't be able to.)

CD Formats



When recordable CDs came along, it was obvious that they could be very useful for storing data, too. But the simple Table Of Contents in audio CDs was totally inadequate for storing and finding files on a CD-R, so several new formats were developed and the CD family tree split into a few different branches.

The audio side of the family is pretty simple. There is really only one format – CD-DA (Compact Disk - Digital Audio) – which is the single-session “TOC + music tracks + runout track” format we have been talking about. You can buy blank “Music CD-R”s in the store, but the only difference between these and ordinary CD-Rs is that you pay extra for them. That is because the music industry, on the assumption that you are pirating the music you are going to put on them, demands a “royalty” payment for each blank music CD sold.

On the data side, things get a little more complicated. Several formats have come and gone, but the most prominent among the ones that remain include:

- Photo CD – This is a format developed by Kodak. I suspect you can guess what it is for.
- CD+G (CD plus graphics) – This is an audio format that can include limited graphics. It is primarily used for karaoke machines.
- MP3 – This contains music, but as files in MP3 format. That makes it a data, not an audio, format. MP3-CDs hold about ten times as much music as an audio CD. They can’t be read in ordinary CD players, but they CAN be read in computers and in MP3-CD players, which are becoming more common. You can even get an MP3-CD player in many new cars.
- ISO 9660 (where ISO stands for the International Standards Organization – a group that has a lot to say in a lot of industries these days). This is a “Lowest Common Denominator” type of file system that can be read on most computers, regardless of what operating system they are running. If you want your data CD to be readable on whatever computer it finds itself in, this is the format to use.
- UDF (Universal Data Format) – ISO 9660 doesn’t provide enough flexibility to accommodate re-writable disks, so UDF was developed as the format to end the proliferation of formats. It is intended

to be the standard format for current and all future, yet-to-be-thought-of, removable storage. Whether it succeeds in that lofty goal remains to be seen.

How To Make An Audio CD (Part One)

The first thing you have to decide is what format you're going to use, and that depends on where your new CD is going to be played / read. Do you need an audio disk for playing on any CD player? Than you should use CD-DA. Do you want to save MP3 files for a computer or an MP3-CD player to read? Then you'll need an MP3-CD. Backing up data on your computer? Then you want UDF.

You also want to consider whether this is going to be permanent (CD-R) or temporary (CD-RW) storage.

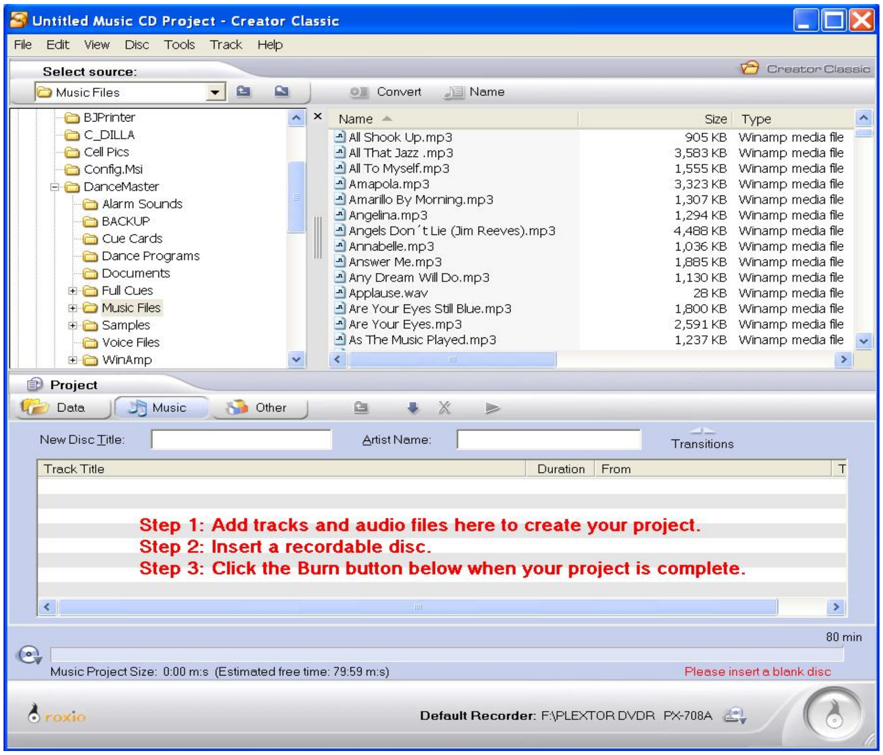
You'll find that most CD software is easy to use, <u>now that you understand the basic concepts of CD formats</u>. CD software tends to be "project oriented", in that it considers each collection of files to be burned to be a "project". You can save projects on your computer and re-load them later, to be burned again, perhaps with modifications. This can be especially handy when you discover that you've made a coaster.

If your computer has a CD burner, it almost certainly came with a program to create CDs and (maybe) DVDs. The chances are good that this program is a limited version of either Nero or Roxio, and the chances are also pretty good that it comes in the form of a "suite" of individual programs for copying CDs, creating audio and data CDs, and perhaps DVDs. There are additional CD / DVD writing programs that you can buy and/or download, including Windows Media Player, and Music Match Jukebox, which is available for free.

The general procedure with any CD software is to open the program, drag files from somewhere and drop them in the burning window, arrange them in the order you want (if it's an audio CD), choose the proper burn mode (here is where your new-found understanding of CD burning helps a lot), and click "Burn".

Let's run quickly through the process of making an audio CD for general-purpose use. I'll show you how to do it using two different pieces of software, so you can get a feel for the general process and adapt it to whatever software you are using.

When you open an Audio CD project with Roxio EZ CD Creator, this is what you get:



In the top left section, you select the folder that contains the files you want to burn, then in the right hand portion you select the songs you want. Then you drag them to the bottom section, where it says "Add tracks and audio files here" (AKA the playlist). Of course, you can drag some songs from one folder, then switch to another folder and drag more from there. You can also drag song files from Windows Explorer.

Note that if you are creating an audio CD, you can drag MP3 files to the playlist. When it is time to burn the disc, the MP3 files will be uncompressed into PCM (similar to WAV) form before burning, so they will take up MUCH more space. You can't squeeze more than 74 minutes of audio into an audio CD. (Well, ok, you can get 80 minutes on "long-play" CD-Rs.)

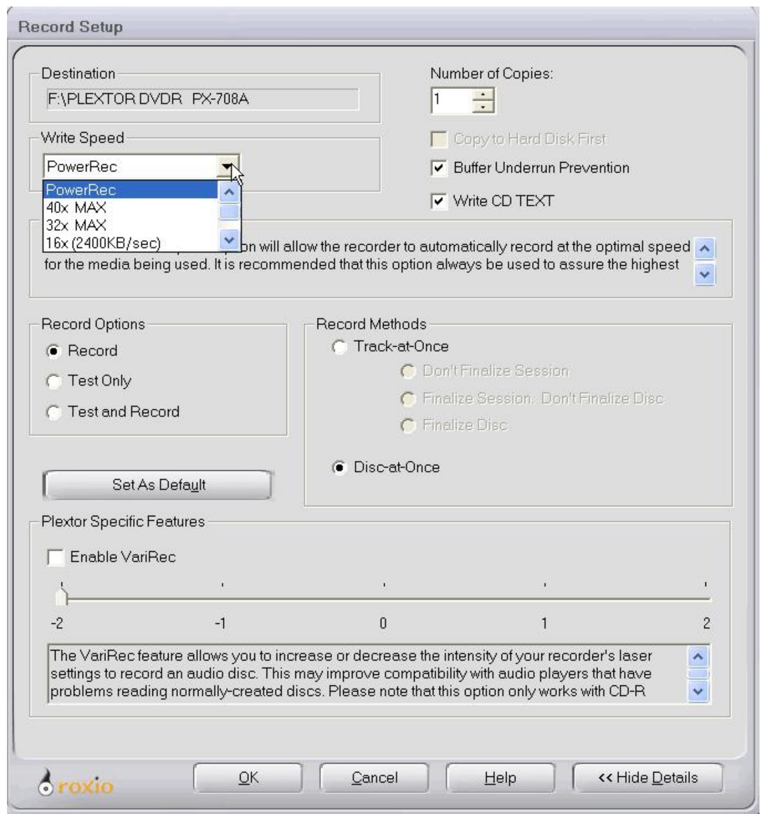
Once you have all your songs collected, you can re-arrange them into the order you want by clicking and dragging them.   Then click the “Burn” button.

The next screen is where some of our new CD knowledge will come in handy.

You can choose the speed that you want to write the CD with. The program knows, from having read the information in the “pre-groove” on the disc, what the recommended maximum and minimum writing speeds are. Using the default setting (“PowerRec”, in this case), the program will make a “test burn” and figure out for itself the best speed, but you can override that if you want to – maybe you know that you have had poor results with this brand of CD-R before and you want to slow it down in hopes of doing better.

(CD-Rs and -RWs have a special area on the disk set aside for the CD burner to play with. This is called the Power Calibration Area, and the burner can use it to determine how much power the laser needs, and how slowly it has to go, in order to burn this particular CD.)

The “Number of Copies” selector is fairly self-evident, so we’ll move on to “Buffer Underrun Prevention”. If your drive and software are new enough to support it, and because you want to avoid making a coaster, you should choose to use this. For the life of me, I can’t think of any reason not to.



If you want to be compatible with the most players possible, don’t choose to write CD text (the CD name & artist), but if your CD player can display that information, by all means include it.

The “Record Methods” box deserves a little discussion. Remember that a completed audio CD contains (at least) one session, consisting of the TOC, some music tracks, and the runout track. You can choose to write all that at the same time and have a completed CD, which is what we want to do in this case, so we choose “Disk-at-Once”.

If we wanted to capture some tracks now, but add more tracks at another time, we could choose “Track-at-Once” and “Don’t Finalize Session”. Then the CD burner would write a temporary TOC (in a hidden place on the disk) plus the music tracks, but no runout track. Later, when we add the rest of our songs, we will choose to “Finalize the Disc”. That will tell the burner to write the additional music tracks, the real TOC, and the runout track. We will waste a little space on the disc because there will be a gap between the first and second batches of tracks, but a player will still be able to read the disc, so there is no real harm done.

If we were making a multi-session disc (more on that later) we would choose “Track-at-Once” and “Finalize Session – Don’t Finalize Disc”.   Then when we had all our sessions recorded, we would choose “Finalize Disc”, so the disc could be read on a multi-session player.

Over in the “Record Options” section, we can choose to have the program: make a test burn at the speed we have chosen, make a test burn and then make the recording if it is okay, or just go ahead and record. Since we have chosen “automatic” mode, where the burner will figure out the optimal speed, we can choose “Record”.

Not much left to do now but to click "OK".

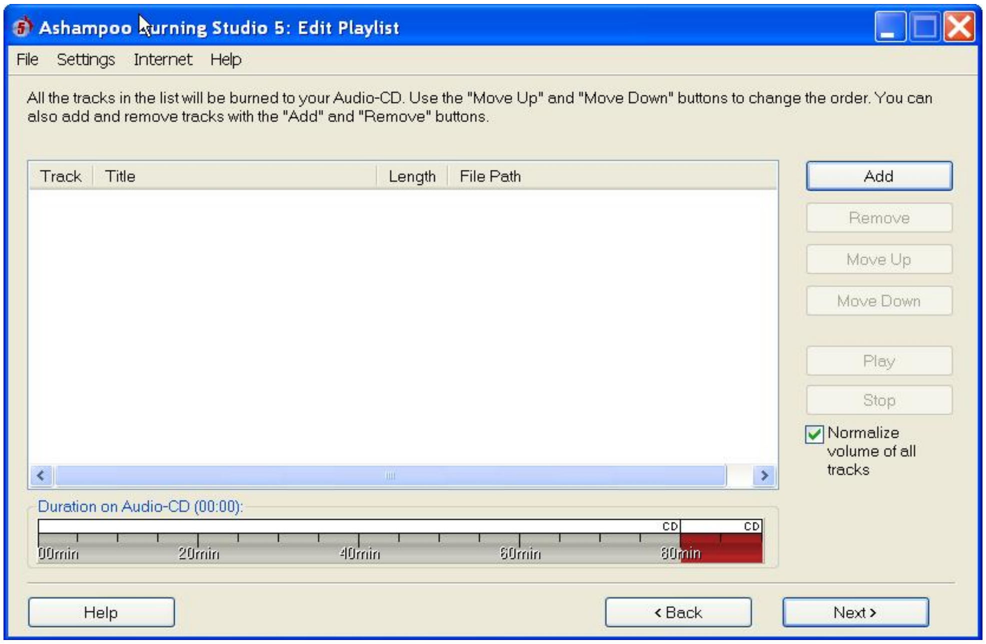
How To Make An Audio CD (Part Two)

There are lots of CD/DVD burning programs besides "the Big Two" available. An inexpensive ($29.95) but well-regarded example is one called Ashampoo. (I don't *know* where the name came from – it certainly wasn't my idea!) Ashampoo won't let you do everything that Roxio and Nero will, but as a result, Ashampoo is easier to use. And chances are, you don't want to do any of those things anyway.

When we start Ashampoo, once again we choose the type of disk to make, but this time the choices are a little better explained. Each menu item includes a list of where these disks can be played. If we choose "Burn Music", we get to choose between a regular audio CD, which is what we want this time, or several other ways to store music on a CD. If we have an MP3-CD player, or are going to play the music on a computer, we could select an MP3-CD, which could hold about 10 times as much music. But it wouldn't work in ordinary CD players. Or we could make a WMA-CD, which is the same idea, although WMA-CD players are still fairly rare.

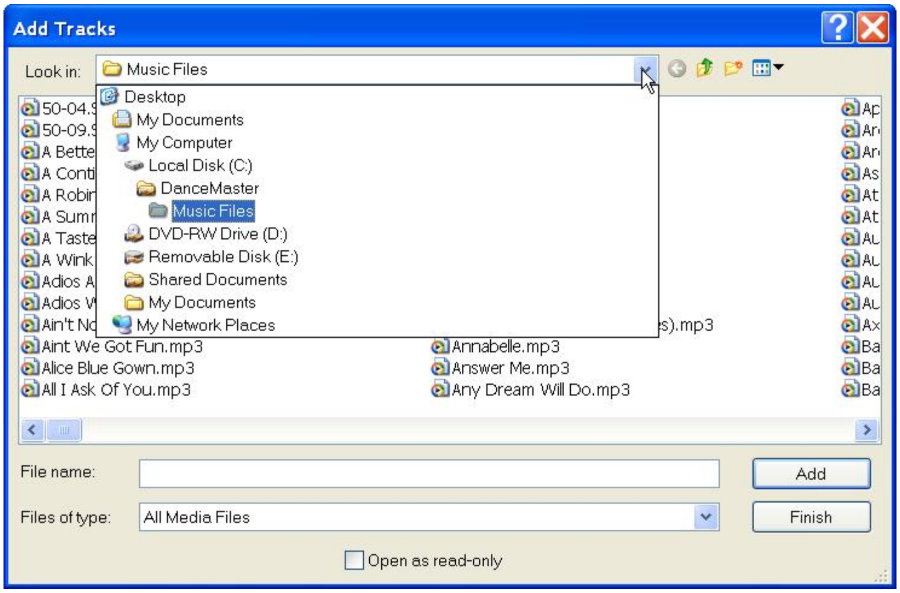
Because we now understand how CDs work, and why there are different kinds of CDs, most of these menu choices make sense. (At least, I hope they do!) Disk images might need a bit of explanation, though.

Remember that a CD consists of the data we want to record, plus a table of contents, plus lead-in and run-out tracks. (A session.) Remember too, that the order of the bytes is scrambled, and the bits within the bytes are scrambled, expanded, checksumed, and otherwise processed to a fare-thee-well. As you might guess, a "disc image" is a file containing all our data after it has been run through the Cuisinart. It is an image of the data just as it is recorded on the disc.



You probably won't have occasion to create a disk image, but it is possible that you might download software, such as an emergency boot disk for your computer, distributed as a CD image file, which you would then burn to a physical CD before using.

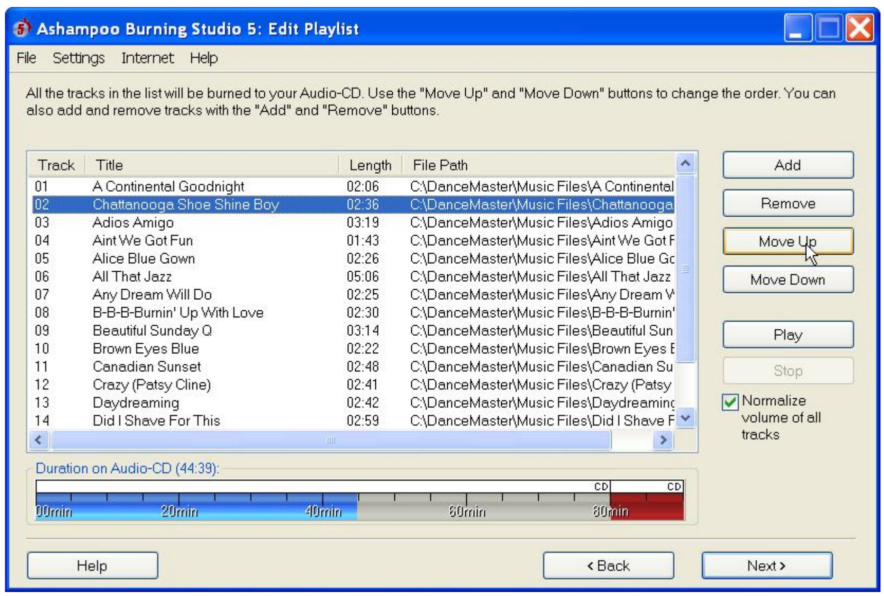
Having chosen to make a music CD, we now get to choose the songs to include. The next screen (the Edit Playlist window) makes it fairly apparent what we are supposed to do next.

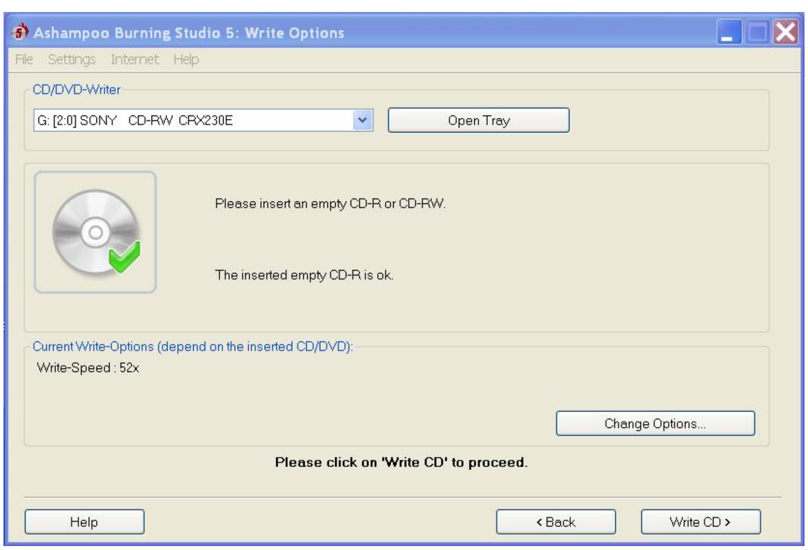


When we click "Add" the Add Tracks screen pops up, and once again, we specify what folder the music is in. Then we select the songs we want. When we are finished with the Add Tracks window (click "Finish"), our selections are transferred to the Playlist window.

In Ashampoo, instead of dragging the songs into the order you want, you select a song and use the "up" and "down" buttons to move it.

Ashampoo has a nifty feature that will "normalize" the volume of all the songs on your CD, so that regardless of whether they were recorded loud or soft, they will play at about the same level. This usually works pretty well, but I'm not sure I would use it if I were putting Brahms and Van Halen on the same disk. Not that I can picture myself wanting to do that, but you get the idea.





Once you have your music arranged, click "Next" to move on to the Write Options screen.

Select the drive you want to use (if you have more than one) and click "Write CD". Ashampoo will expand the MP3 files, and if they won't fit on your CD in their uncompressed form, it will give you an error message and ask you to remove some. If they WILL fit, it will display the Writing Progress screen and burn the disk. After a little while, you pop the disk out of the burner, add a label (or write on the disk itself – *carefully*), and Ta

Da! You're done. A CD full of music you can play anywhere.

Getting Music OFF of a CD

So far, we have talked about putting music, in the form of computer files onto a CD. I should probably take a minute to mention a couple of points about going the other way.

There are two basic methods of getting music from a music CD into your computer. The original way was to use the CD player's circuitry to play the digital music and convert it into an analog waveform, while using your computer's sound card to capture that waveform and convert it back into digital form. A fairly ugly process that introduces significant distortion. But it kept the recording industry happy.

Nowadays most audio programs, including Winamp, Music Match, and even Windows Media Player can capture digital audio data directly from your computer's CD player. This process is called "ripping", and because the music doesn't go through the conversion to analog and back again, the fidelity is very good. What's more, the process can go as fast as your CD drive can go. An analog capture takes place in real-time – as long as it takes the music to play. In theory, you could rip the same material at 52X in about 2 minutes. In practice, the free audio software limits your speed, usually to well below 10X. If you buy the paid versions, you can go faster.

Did you notice that I said the fidelity is very good, but I didn't say "perfect"?

Remember back near the beginning of this presentation (about 4 hours ago) I mentioned that we have to expect some errors when reading a music CD? The player, and CD technology, do their best to make the errors unnoticeable. However, when you "rip" music from a CD, you get the raw digital data, errors and all. When you burn your own CD from these ripped tracks, your playback errors get added to the original errors. If you go through enough generations of this, the result can get to sound pretty bad. In that case, or if you found the CD you are copying on the floor of the golf clubhouse, you might be better off using the original analog recording process, which will let the CD drive do its best to smooth over the errors.

Data CDs

With all this talk about unavoidable errors, you might be getting a little nervous about keeping data on a CD. It is all very well for the player to smooth over a couple of missing notes in a concerto, but a couple of missing zeros in your bank balance is another matter altogether!

For that reason – a data storage medium has to be perfect – a fair amount of space on a data CD is devoted to error detection and recovery. When errors happen, the error correcting codes used can usually figure out what the bytes should have been. If not, then the CD reader reports an error to the computer, and the computer reports it to you as a "File could not be read" error. That is a pain in the neck, but better than having it make guesses.

By now you may be wondering: "Why would I want to make a data CD, anyway?" Well, for backing up your computer data, of course, and perhaps for putting MP3 files (as much as 12 hours of music) on a CD. You do have your music already backed up on vinyl, but you have put a lot of work into recording and editing it. You wouldn't want to have to do it again. Plus your cue cards, graduation photos, last year's tax return – all sorts of stuff you really don't want to loose.

Computers have become tremendously more reliable than they were 10 years ago, when you could count on having to re-format your hard drive and start from scratch at least a couple of times a year. Despite that, the chances are pretty good that at some point you will really, <u>really</u> wish you had a recent backup of your stuff. And making a backup is 'way easier than trying to re-create all your lost data.

As you will recall from the CD family tree diagram above (a long way above), the term Data CD encompasses several formats. We'll talk here about just two of them – ISO 9660 and UDF.

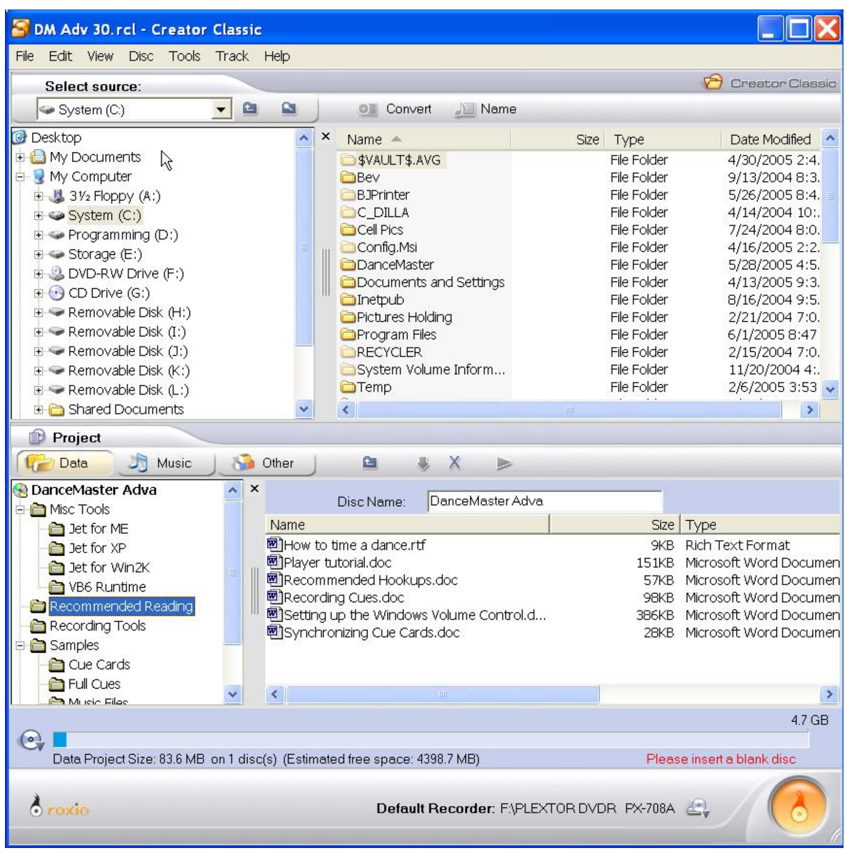
ISO is the "Lowest Common Denominator" data format. Just about any computer that has a CD drive can read an ISO 9660 CD. That makes it the format of choice if you want to mass-produce CDs for wide distribution. I will take the liberty of assuming that you aren't going to do that in the near future and concentrate on UDF.

UDF data is written in relatively small chunks called "packets" – which is why you will sometimes hear the term "Packet-Writing Software". It allows files to be written individually, expanded, and erased – in fact; it allows you to use a CD-RW as you would a big floppy disk. The main drawback is that most operating systems, including versions of Windows prior to XP, can't read or write UDF CDs directly. You need to use "packet writing software" such as Roxio's "Drag-To-Disk" (a.k.a. "DirectCD") or Nero's "InCD", which allow you to drag and drop files onto the program's window, from whence they are automatically transferred to the CD. Packet-writing software requires that you "format" a CD-R or CD-RW before using it, and a complete format can take as much as half an hour. However, most packet-writing programs allow you to start using the disk before it has finished formatting, even though that slows the overall process.

If you want to move data to another computer using a UDF disk, the destination computer must have packet-writing software (or at least packet *reading* software) installed on it too. Interestingly, Drag-To-Disk appears to write a small program on each disk it creates. If you put your UDF CD into a computer that has no packet-writing program installed, this program runs and offers to install a packet-reader for you, so the disk can be read.

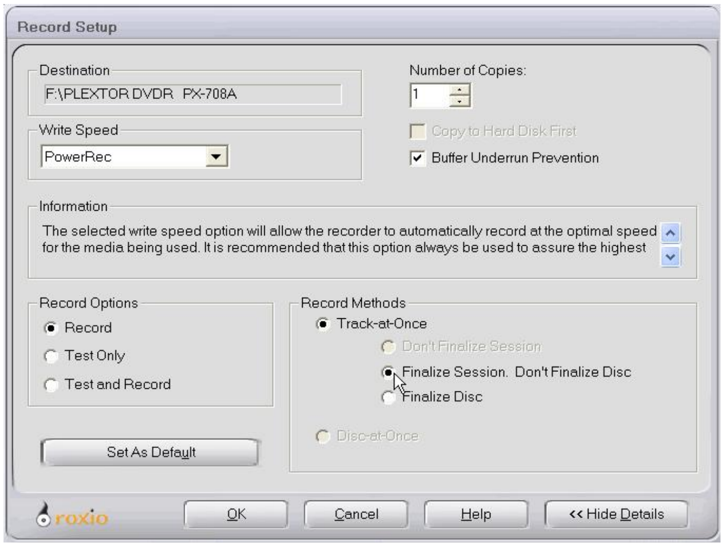
Making a Data CD

At this point you would probably guess that making a data CD involves selecting "DataCD" in your CD burning software, then dragging files and folders onto the playlist window, and clicking "Burn". Well, you'd be right.



As before, you use the top part of the screen to select the folders and files you want to burn. This time though, the bottom of the screen has a folder tree of its own. Using that, you can create a folder structure on the CD, and you can drag files from various places on your hard disk and drop them into the proper folder on the CD

This is where CD "projects" can come in handy. Once you have set up a CD, with the proper files from the hard disk being sent to the right folders on the CD, you can save the project to be re-burned at another time. Of course, this is great if you're in the software distribution business, but until you get around to that it can be very useful for backups. You specify the folders that contain your most critical stuff, and direct them to the place on the CD that you want. Then, when you are ready to burn next month's CD, the hard work is already done.



When you click the "Burn" button, you get the same choices as before, but you might want to leave the disc open this time, since you aren't looking for universal compatibility. Especially if you have enough room left on the disc to add your next backup in another session.

Windows XP

Windows XP has built-in support for CD-R and RW discs, so you don't need third-party software to use them. If you disable any packet-writing-software currently running in your XP computer (Go to My Computer, right-click the CD-RW drive, choose "Properties", click the "Recording" tab, and checkmark "Enable CD Recording on this drive") then put a blank CD-R or CD-RW into your drive and wait a few seconds, a window will appear, asking what you want to do with the disk. Choose "Open a writable CD folder", and you will get an empty Windows Explorer window.

You can drag files to, and delete files from, that window, and it will pretty much act like any other Windows folder. You can even open, edit, and save the files you see there. Behind the scenes, though, Windows has actually written those files into a temporary location on your hard drive. If you try to eject the CD from the drive, another pop-up will appear, asking you whether to actually burn the files to the CD or to discard them. If you choose to burn them, Windows will then write and close the CD in (I believe) ISO format. Then you can read that disk in another computer, whether it has packet-writing software installed or not.

The next time you put that CD back in your computer and look at it with Windows Explorer, it will show you the usual list of files and folders on the CD. If you drag more files over to that window, the list will split into two parts – files on the CD, and files ready to be written. And once again, before you eject the disc you will be asked whether you want to burn the waiting files. If you do, Windows will write another session to the disc. Once a session has been written, you can't erase a file from the CD, but if you copy another file with the same name to the disc, the old one will be marked "deleted" and will be logically replaced by the new one. The space it used on the disk won't be released, though.

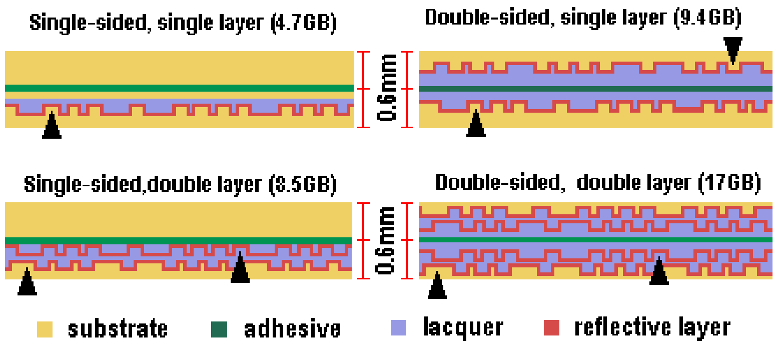
If, instead of a blank CD-RW, you insert one that has been formatted using a packet-writer, Windows will use UDF instead of ISO on that disc, and as you drag files to, and delete files from, that window, they will actually be written to, and (really) delete from, the disc. Your CD-RW will act like a big floppy disk.

Beyond CDs

As nifty as it is, CD technology is starting to show its age. It has been around for almost 20 years, which is a very long time for any computer technology. During that time, hard disk sizes have exploded, and the size of the files that we want to save or transfer has grown too. We don't just want to listen to music, we want to watch video. So now it is time for DVDs.

DVDs are much like CDs, except that they hold a heckuva lot more. While a CD typically can hold about 650 megabytes of data, a DVD will hold 4.7 gigabytes – more than 7 times as much. How does it do that? By making everything smaller, of course. The space between tracks has been reduced from 1.6 microns to 0.8. The bumps are about half as long as CD bumps. And the wavelength of the light used to read the data is shorter. Also, because the drives used to read and write the data have gotten better, there is less data space invested in error correction.

Partly because of the shorter wavelength of the red lasers used with DVD, the polycarbonate plastic base layer is thinner – 0.6 millimeters rather than 1.2. (Remember that the plastic is actually a lens that is used to focus the laser.) This would make the discs too weak, so they glued two disks back-to-back, making a double-sided disc capable of holding 9.4 gigabytes. (All DVDs are double-sided, but in many cases the second side is covered by a label instead of being written on.)



Not content with that achievement, manufacturers went on to develop double-layer DVDs. In these disks the bottom layer of bumps and lands is semi-transparent, so the laser can read or write to that layer, or, by changing the laser's focus, *through* that layer to a second disc glued on top of it. That boosts the capacity to 8.5 gigabytes. Do that on both sides, and you have a 17.6 gigabyte disc! About 27 times the capacity of a CD.

Let's see now… if you can fit about 12 hours of MP3 music on a CD, you could play a double-sided, dual-layer DVD continuously for… almost two weeks!

I don't know about you, but I thought that the technology used in CDs was pretty impressive. DVD technology makes that look simple.

DVD-RAM vs DVD-R vs DVD-RW vs DVD+RW vs…

The adoption of DVD technology in general, and especially for computer (non-video) applications, has been slowed significantly by the development and promotion of competing standards. Fortunately, drive manufacturers are now producing drives that are compatible with multiple standards, so it is becoming less of an issue. The formats of interest to us are DVD-R, DVD-RW and DVD+RW.

DVD-R is a write-once medium, like CD-R, and the other two are Re-Writable, like CD-RW. The only significant difference that I can find between the + and – versions is that the + format is more oriented toward random access and may be more compatible with older DVD video players. (There are several significant technical differences, but your eyes are starting to glaze over, so I'll spare you the details.) As a practical matter, you can use whatever flavors your drive supports.

DVD Audio

In addition to video and data DVDs, there are DVD-Audio discs on the horizon. Audio CDs sound pretty darn good, but DVD-Audio will sound downright spectacular.

"Full multi-channel surround sound can be recorded in high fidelity PCM creating a sound field with the ambience and fullness of a live performance. DVD-Audio PCM can be recorded with a range of frequencies that are more than four times that of a CD; giving instruments a liveliness and expression that is not possible on a CD. DVD-Audio PCM also has a much greater dynamic range than that possible on a CD - making louds louder and quiets quieter."

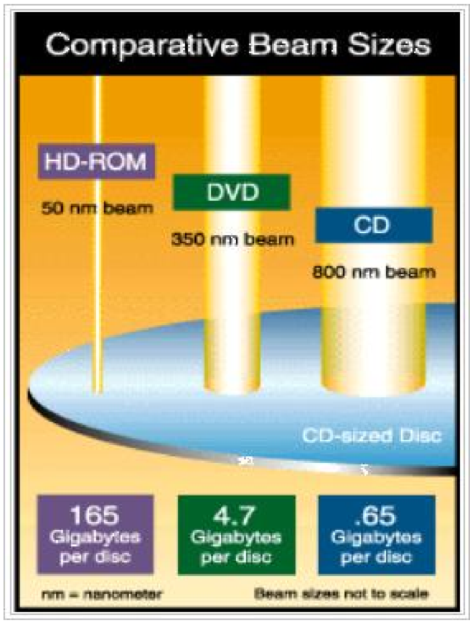
"Full multi-channel surround sound" means that rather than the 2-channel stereo on CDs, DVD-Audio supports 6 discrete channels: front left, right, and center, rear left and right, and subwoofer.

And you think sounding your hall is a pain in the neck now? Just wait.

Beyond DVD

If you are concerned about not being able to put more than two weeks' worth of continuous music on a DVD, you can relax. Help is on the way.

Actually, rather than music, it is high-definition video that is driving the next generation of disc. There are currently two different standards battling to be the Next Big Thing. HD-DVD, backed by Toshiba and others, can pack as much as 45 gigabytes on a disk by using 3 layers, and Sony's Blu-ray, which can hold 50 gigabytes per side on two layers. Both of these formats use shorter-wavelength violet lasers, which can be focused to make a smaller spot, so the bumps containing the data can be made even smaller. Blu-ray is available now in Japan, and both technologies, or perhaps a compromise hybrid, are slated for release here in time for this Christmas. Let's see, now… one MP3 dance takes about 2.5 megabytes, and that goes into 50 gigabytes… I don't have enough fingers.



Of course, even that isn't enough for some people, so engineers at IBM and Noram Technologies have gone farther. Deciding that light just can't be focused to a sharp enough spot, they have leapfrogged ahead and are using a particle beam to read and write their disks.

Using this technology, they are able to cram 165 gigabytes onto a 12 CM disc. What's more, their beam (consisting of charged gallium ions) can write on a variety of materials, including metal, to produce virtually indestructible discs.

However, even the optimists among them don't foresee the day when you will have a particle beam accelerator in your living room, so they are aiming their marketing at "government agencies, banks, insurance companies, scientific users, and libraries".

But I'm sure the time will come – and shockingly quickly – when even you and I won't be satisfied with a mere 50 Gigabytes on a disc. Even though we can't, today, imagine what we would need it for. And I'm equally sure that the technology that delivers it will be as mind-boggling then as this stuff is today.

Now you know more than you thought there WAS to know (let alone wanted to know) about CDs. I hope that, armed with this new understanding, you are prepared to go forth and burn.