# Physical Media for Music Release

Although downloadable digital files have largely replaced physical media, the compact disc (CD) is still a popular medium for music distribution. The compact disc was the first digital medium designed for the consumer market and has become the most popular medium for commercial releases. It was envisioned as a replacement for the phonograph record, but with several important enhancements: not the least of which are the increased dynamic range and resistance to wear-induced noise. The technical details of the system include special data encoding procedures necessary to correct errors and a physical tracking system to allow reading of the data on any CD player. While arguments persist about the sampling rate and quantization level chosen for the CD, few would deny the overall advantages presented by the digital storage of musical data. On a disc of slightly less than 5 inches in diameter, up to 650 megabytes of data may be written, allowing for up to 72 minutes of stereo music. The storage of additional data allows fairly precise cueing of the selections in a rapid, random access manner. The specifications for the audio CD were developed by Philips and Sony and are documented in the so-called Red Book.

## Tracking

Because the data are stored as binary optical information, some way of aligning the laser beam that reads the disc is necessary. On a phonograph record, the stylus (needle) simply rides in the groove that contains the data using gravity and a sophisticated mechanical balancing system. Obviously, this cannot be employed to track the data on the CD. The CD is tracked using the same optical information that contains the data. The data are encoded as pits that are created by a high-power laser beam, the intensity of which is modulated by the data to be written. Once the entire disc is written, the surface is plated with a thin metal coating. The coating is read from the bottom of the disc by scanning with a focused laser beam that reflects into a photosensitive element. The pit depth is 1/4 of the wavelength of the laser light used to read the data (780 nm), so the beam reflected from the pit bottom cancels the incident beam while that reflected from the land reinforces the beam, creating an interference pattern. By using two additional pickup beams, one to the left and behind the data pickup beam and one to the right and ahead of the data pickup beam, the relative beam intensities are used to tell the mechanism when the beams stray from the data track. The rotation rate is varied to maintain a constant linear velocity, which may be adjusted to allow more data to be recorded.

## Data encoding

Like the DAT, the raw audio samples are encoded along with synchronization and error detection/correction (CIRC) information and are interleaved before being written to the CD itself. Sub-code data (like the copy-protect bit) are also used on the CD, allowing many different types of data in addition to audio data to be read and identified, as in CD-ROM and the other variants of the CD. Unlike the DAT, which uses eight-to-ten modulation, the CD uses EFM (eight-to-fourteen modulation). This adds a lot of "extra" bits, but it has the advantage of lowering the bandwidth necessary to handle the output data. Data are coded as edges of pits, so several 0 bits in succession are coded by a single pit. EFM greatly reduces the number of short pits and the overall number of pits, as well, making manufacturing easier.

In the process of encoding, sub-code information is added to the CD data. One sub-code byte is added to every 32-bit symbol as output from the CIRC encoder. Each bit in the sub-code byte is assigned a designation P,Q,R,...,W. Only the P and Q bits are defined in the Red Book. (The remaining bits can carry user information, but are usually 0's on audio CDs.) The P bit is zero during music tracks and 1 between tracks. The P bit alternates between 0 and 1 at 2 Hz at the end of the disc (lead-out).

The Q bits from 98 frames form a sub-code word 98 bits long. This word conveys information about track number, time, address and error correction. The first two bits provide synchronization. The address bits determine the mode for the following data (the lead-in area gets a different mode from the actual audio data region.) The actual Q sub-code bits describe timings, copy permission, number of channels, and pre-emphasis. There is also CRCC error detection provided for the sub-code data.

# Mastering for Specific Media

Mastering is the process by which recordings are delivered to manufacturing plants for duplication and distribution. Not so long ago, we were given only two formats: vinyl LP or cassette. Today, the CD is the preferred medium for distribution, with cassette still holding a share of the market. Vinyl is limited mainly to special purpose releases, often for DJ use or for distribution of smaller projects (7" 45 or 33 RPM). The form in which the final recording is to be distributed determines the format in which the master recording must be delivered. Optimally, we would like the final medium to sound just like the master recording. Unfortunately, each medium has sonic characteristics that may require the mastering engineer to take into account these characteristics and alter the recording in a way so as to make the final recording more faithfully represent the original sound. An experienced mastering engineer will be able to find any problems with the program material that would create undesirable effects in the finished product. These problems vary from one format to another.

## Cassette duplication:

The least expensive and most often used distribution medium was once the analog cassette. These tapes may be duplicated on any cassette recorder in small quantities or may be commercially duplicated in larger quantities. Small quantity duplications are often done at real-time speeds: that is, the original tape is played regular speed and the recording is done at regular speed on a blank cassette. Some machines allow 2x real- time duplication, whereby both machines run at twice the normal speed. In commercial duplication facilities, banks of record-only machines are controlled from a master playback machine, which may be a cassette, reel-to-reel, or DAT machine. Depending on the system, duplication can be done to pre-loaded cassettes or to large reels or blank tape that are then cut and loaded into cassette shells. Duplication can be done from real-time up to 64:1.

High-speed duplication is generally not favored for music duplication. So-called audiophile duplicators will run real-time duplication and some even duplicate both sides of the cassette at the same time, with playback from a four-channel digital system. It is possible to keep the recording digital up to the actual duplication to analog cassette. Noise reduction encoding is done at the time of recording, so a decision about what, if any, type of noise reduction is to be used must be made.

When mastering for cassette distribution, the main limitation will be the dynamic range of the analog cassette. Often, multi-band limiting or compression will be required to help the final tape reproduce the wide dynamic range of the original recording. Also, the type of tape (Type I, Type II, Type IV) may be selected to best fit the original material. Dolby HX-Pro processing during duplication will preserve more of the high frequency response on the product, regardless of the deck on which it is played. In addition to the duplication of the music, graphics such as cassette labels and J-card inserts for the tape case are required. With full color printing, the graphics costs often surpass the cost of actual tape duplication. Not including mastering, graphics, and set-up charges, cassette duplications ran around $2.00/ tape.

Mastering media for cassettes include reel-to-reel tape, DAT and CD-R. The factory will need to make a copy of the master tape from which to duplicate the actual cassettes. For bin-loop high-speed duplication, a reel-to-reel copy (duplication master) is made and used as an endless-loop source to duplicate the many copies. Since several generations of copies are involved, the final quality may not be perfect. Test tapes are usually provided to customers in order to approve the sound before the entire run is made.

## Vinyl Records:

Prior to the invention of the CD, vinyl long-playing (LP) records were the final product delivered to the consumer. Some listeners still prefer the sound of vinyl, although their options are limited, since all major manufacturers have adopted the CD as the medium of product delivery. The process of manufacturing LPs involves many physical processes that may alter the frequency content of the program. The mastering engineer must account for these alterations in order to end up with an acceptable recording. Like cassettes, LPs have some limitations to the dynamic range possible, especially at lower frequencies. The low-frequency content will determine how closely spaced the grooves may be cut; thereby determining how much music may be recorded on the disc. Also, since the frequency response of the pickup is non-linear, the RIAA equalization curve is required on playback to make the final output sound correct (much like the equalization curve used with analog magnetic tape recorders). Finally, since the groove pitch (grooves/inch) limits the amplitude of the signal, the pitch is determined by the amplitude of the program material; quiet passages have more grooves/inch and loud passages have fewer grooves/inch. Out-of-phase signal content between the left and right channels causes the stylus to move up and down, potentially ejecting it from the grooves during playback. This will need to be considered when delivering tapes for record production.

The actual process of cutting a record involves playing the master tape or file through an equalizer into the cutting lathe. The lathe actually cuts grooves into the lacquer disc master. A digital delay or tape deck with a special preview head is used to delay the signal to the lathe, allowing some quick EQ or level changes as the tape is played back for cutting.

## Compact Discs

For many years, the compact disc (CD) has been the dominant medium of music delivery, although downloading has recently cut significantly into its share of the music market. It has advantages of nearly random access, self-contained cueing information, non-degrading reproduction and near-archival lifetime. Although originally difficult to master, replicated CDs are now possible from CD-R copies, greatly simplifying the process of preparing for CD replication.

The usual method of pre-mastering for CD release involves the use of a digital editor to assemble the program material into a continuous digital data stream. The songs are assembled with silent spaces of 2 to 4 seconds between cuts and with the final EQ and other settings to produce the exact sound desired at the output of the system. Programs such as Toast/Jam, Nero, and several others may be used to assemble the sound files for the CD and burn them to CD-R in the proper order with the desired spacing between cuts, even making adjustments in the track amplitude.

Unlike tape and vinyl media, the CD reproduces the original signal exactly, with no equalizing or coloration. While this is strictly true, there is some confusion about the sound of CDs, partially due to the many re-issues of older recordings that were prepared for vinyl release. When originally recorded, the master tapes were equalized to account for the shortcomings of the vinyl medium, boosting the high frequencies to compensate for the eventual losses. When played back on a CD, the high frequencies sound overly emphasized. Even in some digitally mastered CDs, there can be an apparent emphasis of high frequencies. Care must be taken to guarantee, even with CDs, that the sound delivered to the customer is exactly what the engineer wanted. By using a mastering house with an experienced engineer, the master can be digitally equalized to deliver the desired sound at the output of the CD player.

One consideration is the possibility of CD amplitude causing distortion on some CD players. If the CD is mastered to full 0 dBFS, some analog output stages may overload due to D/A converter overshoot feeding into analog amplifiers with limited amplitude capability. The current trend in making louder and louder CDs contributes to this problem. Although everyone wants their CD to play louder than (or at least as loud as) all the other CDs, we should remember that playback systems DO have volume controls.

## CD-Rs:

Single unit CD printing machines have been developed and are cheap and readily available. Since the blank CDs cost about $.30, this method of production is now cost-effective for more than a few copies, even though replication costs under $1 per unit. The CD-R (CD recordable) allows inexpensive creation of individual CDs playable in standard CD players from most computer-based recording systems and from stand-alone recorders. The CDs created by this system are not as robust as replicated CDs, since they rely on a dye layer rather than the metalized film used in standard CDs

## Some general practices

When preparing any project for release, it is recommended that you listen to the "final" mixes on different speaker/stereo systems and at different volume levels. The idea is to get the finished project to sound the best you can on the widest array of systems. While we are tempted to make the program sound great on the studio monitors, we must also make it sound good on the average home stereo and even on a "boom-box" at the beach. This might require some equalization or compression that would not be optimal for studio listening. Remember that the finished product is designed for the consumer environment. A good mix should sound good on any system.