

This article
discusses the technical and
practical considerations of
creating a
Red Book audio CD
suitable for duplication.

CD MASTERING
CD MASTERING

by Rick Ording 1999

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Contents [Click on a link to navigate its page.](#)

[INTRODUCTION](#)

[SOUND RECORDING MASTERING](#)

[MASTERING STUDIOS](#)

[CD FORMATS](#)

[CD AREAS](#)

[CD TRACKS](#)

[CD SECTORS](#)

[RED BOOK](#)

[PQ SUB-CHANNEL DATA](#)

[SESSIONS](#)

[YELLOW BOOK](#)

[BLUE BOOK](#)

[CD RECORDER TYPES](#)

[DISC AT ONCE vs TRACK AT ONCE](#)

[WRITING SPEED](#)

[SUSTAINED DATA TRANSFER RATES](#)

[DRIVERS](#)

[SOFTWARE](#)

[HOST COMPUTER](#)

[RAM CACHE](#)

[SUMMARY SO FAR](#)

[CREATING A RED BOOK AUDIO CD](#)

Introduction

As a teenager I wanted to make records. When it became clear to me that no-one else wanted me to (what do record companies know! eh?) I decided to do it for myself. Bit by bit I taught myself everything I needed to know and slowly built up a modest collection of equipment. One process, however, remained a mystery, CD mastering and duplication. It seemed to me an expensive and esoteric practise, and so it was until the arrival of fast affordable home computer systems and cheap CD recorders.

CD surface magnified 5,000 times.



This year I researched the subject extensively and finally bought myself a CD recorder and some software. And now I know what it's all about. And if you read this so will you. There's a lot to learn and no easy way to simplify things, but if you manage to get to the end of this article you will know exactly how to produce a professional quality audio CD suitable for replaying on any audio CD player or to be sent to a CD factory for duplication. So, here we go.

During this article I will discuss: Sound recording mastering processes, CD formats, CD recording hardware, CD recording software, computer based CD recording systems, and the steps necessary to create a Red Book audio CD.

Sound recording mastering

The production of an audio CD LP (long player) requires four distinct processes.

1 Multitracking During multitracking the individual components of the recording are originated and recorded to the separate tracks of MIDI and audio multitrack systems.



2 Mixdown mastering involves assembling these components into balanced, effected and finished 2-track stereo mix masters conventionally recorded onto a DAT recorder, 2-track analogue tape recorder, CD-Recorder or hard disk recorder.

3 Production mastering stage 1 Production mastering (my term) involves two stages. First all the individual 2-track masters are "tweaked". They may be EQ'd to ensure overall consistency throughout the LP and compressed and enhanced. Some of these processes may be carried out in the analogue domain but when complete all the finished mixes will reside on a computer hard disk drive as 16-bit 44.1kHz digital stereo audio files.

4 Production mastering stage 2 Next all the tracks are assembled together into a coherent LP using CD mastering software. Running order is decided upon, tracks are "normalised" to ensure that dynamic range is maximised, the relative level of each track determined, and fade-in, fade-outs and crossfades are set. Then all the necessary settings are made which relate to the way CDs store and replay tracks including the PQ Code data (more on this later).

The final product of the production mastering process, the Production Master, will usually take the form of a Sony PCM-1610/1630 2-track stereo master (stored on a U-matic video cassette) ready to be sent to the CD factory for duplication. You will be interested to know that more and more factories are accepting Red Book CDs as Production Masters. This has significant advantages for home music makers as you will see.

This article concerns itself with the second stage of

Production Mastering and how these processes can be completed at home using an affordable computer based software and CD-Recorder system.


Mastering Studios In the past Production Mastering has had two disadvantages. Firstly it was the point at which the home recordist (and indeed studio producer, engineer, and artist) relinquished total artistic control. Going to a mastering studio involved putting your precious work into the hands of a mastering engineer, listening to his advice and trusting that the unfamiliar sound coming from his monitors was all for the best.

Admittedly there was (and is) an advantage in that a good mastering engineer will know better than you how a well balanced recording should sound, offer an invaluable objective view, and have at their disposal an arsenal of esoteric and wonderful "audio sweetening" machinery. For these reasons most major record



label funded commercial LPs are mastered by industry renowned mastering engineers such as Bob Ludwig and Ted Jensen.

The second disadvantage is more compelling and has to do with an arm and a leg. Professional mastering can be prohibitively expensive for the home recordist, especially one only seeking to duplicate short runs to order using a CD-Recorder at home.



Before we go on to discuss how we can accomplish the production mastering processes at home we need to know something about CD formats and CD recording hardware.

CD formats There are several different formats of CD. Originally CD was developed by Phillips and Sony as a replacement for vinyl. They defined a standard audio format to be used by all domestic CD players and published it in a book with a red cover, thus we have the Red Book Audio CD standard format!

CD areas All CDs have three distinct areas. The Lead-In Area contains a TOC (Table Of Contents) and is the first area on a CD occupying the innermost 0.4mm of the disc. The TOC contains a list of everything on the CD including the Track ID positions (or start times) of all the audio and data tracks on the disc. The Program Area contains all the actual audio or data tracks. The Lead-Out Area simply marks the end of the Program Area.

CD tracks All CDs can have a maximum of 99 tracks. Tracks IDs mark the beginning of tracks. A track can be a minimum of 4 seconds long (600 sectors).

CD sectors The data on all CDs is stored in chunks called sectors. There are 330,000 sectors on a CD each of which can hold 2352 bytes. This adds up to a total data capacity of approximately 744MB (Mega Bytes). Different CD formats use this capacity in different ways..

There are now a number of 80 minute CDs available but beware, your software and hardware may not be able to write CDs longer than 74 minutes.

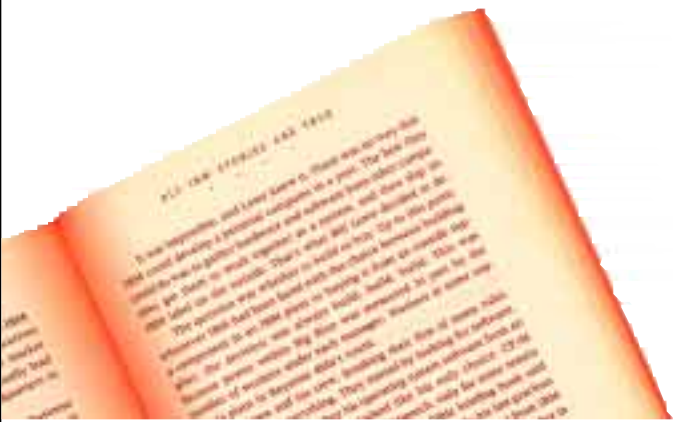
Red book Red Book audio CDs use nearly all of their storage capacity to store audio samples. A single minute of 16-bit 44.1kHz stereo audio uses 10MB of storage. The maximum running time of an audio CD is 74 minutes using 740MB of its total 744MB capacity. The remaining 4MB holds error correction and sub-channel data.

PQ sub-channel data Sub-channel (or sub-code) data is designated by the letters P through to W. In the Lead-In Area the Q sub-channel contains the TOC complete with Track ID positions. In the Program Area the P sub-channel data indicates where music tracks start and end while the Q sub-channel contains time information. During CD Production Mastering it is often necessary to edit the PQ sub-channel data in order to set the Track ID positions, particularly where music tracks crossfade into one another. Incidentally, sub-channels R to W are mostly unused at present.

The Q sub-channel contains four other data fields which we will need to set during Production Mastering.

1 Pre-emphasis Pre-Emphasis On/Off is a sub-code which turns a CD players De-Emphasis circuitry on to allow it to decode CDs encoded with Pre-Emphasis, a now largely unused early form of digital noise reduction.

2 ISRC (International Standard Recording Code) code This sub-code holds the "serial number" of each audio track in a format prescribed by the Red Book standard. It can be used by music industry organisations to keep track of copyrights and royalty payments for record companies, composers and artists etc.





3 Media catalogue number This sub-code defines a 13 digit bar code for CDs and should be set if the CD is to be duplicated for commercial distribution in retail shops. Codes are allocated by the EAN and UPC authorities.

4 Copy prohibit on/off This is a sub-code that domestic digital recorders (such as DAT, DCC, Mini-Disc and CD-R recorders) can read to determine whether or not digital copying (or cloning) is to be permitted by their SCMS (Serial Copy Management System) circuitry.

Sessions A session is a collection of tracks. Every time data is recorded to a CD a session is created. Red Book audio CDs must be written in one complete session without pauses, a process called "disk-at-once" by CD-Recorder manufacturers. Because domestic CD players only read the TOC in the Lead-In Area of a disc, a subsequent session which places a second TOC followed by audio tracks on the program area of a disc will never be "seen" by the player. CD-ROM drives are able to recognise all the sessions on a disc and treat them as separate drive volumes.

Yellow book After the Red Book standard had been established it was realised that CDs which store digital audio could just as well store any other type of digital data and the CD-ROM format was defined (Yellow Book). CD-ROMs use a significant number of their bytes for error correction and thus the room left for storage of actual data is approximately 650MB.

CD-ROM drives are included as standard with all desktop computers and with the appropriate software these drives can extract Red Book audio CD data as computer files and copy it to the computer's hard drive where it can be treated like any

other audio file.

Blue book Subsequently many other formats have been developed (Orange, White, Green and Photo CD) but Blue Book (CD Extra) is probably the other format of interest to music makers. Essentially it is a mixed format that allows both audio and CD-ROM data to be included on the same disc. Such a disc will have two so called "sessions". The first will include all the audio data complete with its TOC. The second will be a CD-ROM session, unplayable by a domestic CD audio player but recognisable when placed in the CD-ROM drive of a computer system.



The idea is that an artist can include some new (multi) media material such as animation, interviews, videos etc to complement the audio section. Because a CD-ROM session will eat into the total storage capacity of the disc this material may only be a "taster" for a more comprehensive and separately available CD-ROM production. Recently several LPs (including Coldcut's brilliant "Let US Play") have included a complete second CD-ROM disc. Many sound recording magazines include Blue Book cover CDs containing PC, Mac and audio sessions.

CD-Recorder types Now we know something about CD formats we can move on to discussing different types of CD recorder hardware and the CD formats they are capable of creating. There are currently two recorder/disc types.

1 CD-R (Recordable) These recorder/disc combinations can only write discs once. This means that disc data cannot be erased and new data rewritten at a later date.



2 CD-RW (ReWriteable) These recorders/disc combinations are capable of writing, erasing and writing once again. **WARNING!** CD-RW discs cannot be replayed in conventional CD players unless they are MultiRead capable.

Both of these formats are implemented in two hardware types.

1 Domestic hi-fi recorders These recorders can accept either a stereo analogue signal or an SPDIF (Sony Phillips Digital Interface) digital input from a device such as a CD player, or DAT recorder. They are capable of automatically converting DAT ID markers into CD track markers. Although offering a quick and easy way to duplicate CDs they suffer from three primary disadvantages.



Firstly blank discs cost are high. £5+ for CD-R, £9+ for CD-RW. This because the music industry, in fear of widespread infringement of its copyrights, insisted on a royalty levy for every blank disc sold. Secondly these recorders cannot produce Red Book CDs. Thirdly they cannot be employed to record any other type of digital data, such as computer files stored on a computer's hard drive.

2 Computer front ended recorders The second recorder type are computer front-ended. This means they are connected to a computer system like any other storage device, usually using the SCSI (Small Computer System Interface) protocol which supports the kind of sustained data transfer rates necessary for creating an audio CD. The data to be recorded is prepared and stored on a hard drive and an appropriate

application is employed to transfer it to the recorder and write, or burn, the disc. Such a system has several advantages over hi-fi recorders.



Firstly branded blank CD-R discs (I use Phillips) cost around £1.50 each. Secondly, these recorders are capable of producing any format of CD including Red Book and Blue Book. Thirdly they can backup ANY data residing on the hard drive so you could, for example, archive your multitrack MIDI and audio data as computer files. Fourthly, data to be written can be comprehensively arranged and formatted prior to recording. You can, for example, set tracks to crossfade and determine the precise locations of Track IDs. And fifthly these recorders cost less than their hi-fi counterparts and come packaged with CD writing software.

Disc-At-Once vs Track-At-Once Another issue that affects both recorder types is whether they are capable of writing a disc from beginning to end without pauses, a necessity if a single session is to be created as demanded by the Red Book Audio standard. Disc-At-Once recorders can do this, Track-At-Once recorders cannot. Make sure the recorder you buy is capable of Track-At-Once recording mode.

Writing speed determines how fast your disc will be written. Computer front ended recorders can write discs faster than real time. At 4 x real time a 60 minute disc will be written in

approximately 15 minutes (although the optional verification procedures will take a further 15 minutes if you choose to run them). 6 x drives are now available but BEWARE! It'll be no good having a faster recorder if your hard drive and connection technology can't supply it with a steady and uninterrupted stream of data fast enough.

Sustained data transfer rates To transfer data from your hard drive to your recorder without interruption requires a robust and fast interconnect technology and SCSI has been proved to be just that. IDE is the most popular connector, since it is cheaper and a machine with a fast PCI bus, fast IDE transfer rate, and low application load will do just fine with IDE. There are even some parallel-port CD-R/CD-RW machines which connect easily to the PC's standard printer ports, but they tend to be the least reliable option.

I use standard SCSI and it works fine with my recorder writing at 4 x real time. At this speed data needs to be received by the recorder at 689 kilobytes per second.

Drivers You need to ensure that the CD Recorder you are planning to buy is supported by the CD mastering applications you want to use. That means visiting relevant manufacturer web sites and checking that drivers and extensions have been developed. I wanted to be able to use Toast, Jam and MasterList CD (of which more later) and found that all of these applications supported the Yamaha 400TX drive. A word of warning here. It is the drive mechanism that is important. My drive is actually a One Technologies unit (essentially a box with power supply and SCSI connector) but the CD-Recorder mechanism fitted inside is the Yamaha.

Adaptec Toast screenshot



Software

If you choose a computer front-ended recorder (and you should!) you will need some software to drive it. I use a Mac and so only have three application options (go you PC users, have a laugh at my expense!).

The first is Adaptec Toast. This application can be used to write any CD format including audio CDs but not to Red Book standards. That means an audio CD it produces will not be acceptable by a CD factory for duplication. It also means that you cannot cross-fade tracks, edit track ID positions, alter track levels, or set any of the Q sub-channel codes. I therefore only use this software to archive computer files.

Adaptec Jam screenshot

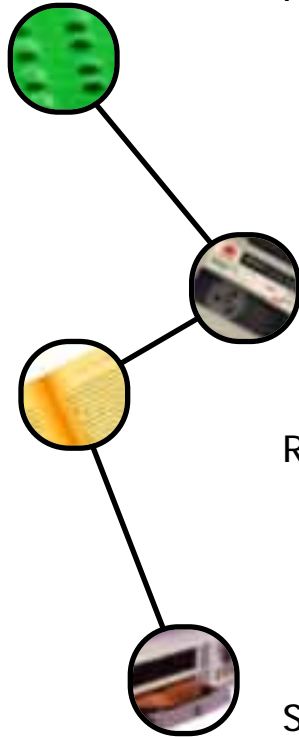


The second is Adaptec Jam. Jam is fully Red Book compliant. It allows you to select your audio files and then determine how they will play on the finished CD. Fades and crossfades may be set, relative levels between tracks tweaked and PQ sub-channel codes fully edited and set. During writing Jam processes the audio files on-the-fly according to your settings (providing you have a fast enough computer, otherwise you will have to create a disc image first).

Finally there is Digidesign's MasterList CD application. As far as I am aware this is a fine program. It's one disadvantage appears to be that you cannot listen to tracks as you edit them unless you have Digidesign audio interface hardware, which I don't. Both Toast and Jam allow you to preview tracks through the Mac or PC's internal speakers or stereo audio outputs.

PC users have a choice of Adaptec's Jam, and Easy CD Creator for Windows, or Sonic Foundry's excellent CD Architect. No doubt there are others, just ensure they can

produce Red Book CDs.



Host computer Older computer systems may struggle to write discs effectively whatever the spec of your software and recorder. You will need to satisfy yourself that your CPU, RAM, hard drive and interconnect technology are all up to the job in the first place. It may help you to know that I use a 2 year old Apple Mac 8200 / 601 PowerPC running at 120MHz with a SCSI AV hard drive and SCSI 4 x CD-R recorder and have never experienced any problems whatsoever.

PC users should read the minimum system spec's accompanying Windows compatible software at the relevant sites.

RAM cache It's worth having a reasonable amount of RAM allocated to your software during writing to allow a large RAM cache to be set. This will help prevent the damaging effects of data transfer bottlenecks should they arise whilst writing a CD. Essentially a reservoir of data is kept topped up in RAM during writing.

Summary so far Let us summarise what we have learned so far.

- The second stage of Production Mastering involves preparing and arranging digital audio data ready for CD duplication.
- The traditional process of creating a CD Production Master

on a Sony U-matic video tape is expensive.

- There are several formats of CD. Red Book is the standard for audio CDs, Blue Book for mixed format audio and CD-ROM CDs.

- During Red Book audio CD mastering various sub-channel codes must be edited and set.

- To be suitable for use as a Production Master a CD must be Red Book.

- Discs created on CD-RW recorders suffer from playback compatibility problems.

- Computer front-ended CD-Recorders are more flexible than their domestic counterparts and the discs they use are considerably cheaper.

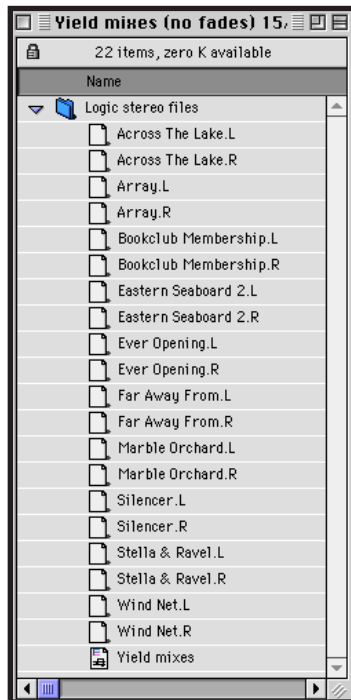
- To create a Red Book CD a recorder must support Disc-At-Once mode and write all the data in one complete session.

- It is important to match your recorder to the software you wish to use.

- Red Book CD writing applications allow considerably flexibility in determining how tracks will replay.

- Your host computer system must be up to the job.

So, armed with all this knowledge, how do we go about creating a Red Book CD suitable for selling to customers or sending to a CD factory for duplication? Read on.



Creating a Red Book audio CD

Finally we get to the crux of the biscuit. I'm going to assume that you have completed all your mixes and the first stage of production mastering. Now here's what you do.

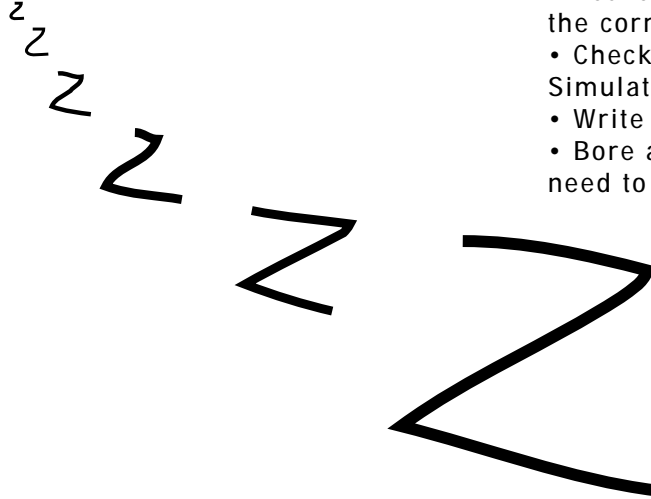
- Transfer all your stereo audio files onto a separate hard drive or hard drive partition. You may do this by recording DAT masters digitally via a digital interface on a soundcard into a stereo editing application such as Bias Peak or Sound Designer, or onto a pair of tracks in an audio sequencer such as Cubase VST or Logic Audio. You may also extract audio tracks from a preexisting audio CD or CD-ROM placed in your CD-ROM drive. Depending on the writing software you use these files may need to be in a particular format. Adaptec Jam can import files in a number of formats including; WAV, AIFF, Sound Designer II, Sound Designer regions, Sound Designer playlist, stereo interleaved, or split stereo. Many audio sequencers (such as Cubase VST and Logic Audio) combine two mono tracks (or files) when recording stereo (so called "split stereo"). Jam does not require you to convert these into stereo interleaved, which is nice. Check your manuals.

Adaptec Jam preferences



- Ensure that all the files have been "normalised" (the peak amplitude in each file is as loud as 16 bits allow).
- Disable any unnecessary drivers and extensions (Mac users turn off Apple Talk especially).
- Power down and disconnect everything unnecessary from your SCSI chain.
- Reboot and optimise your hard drive with a defragmentation program. This will ensure your files will be read smoothly from the hard drive during CD writing.

- Boot your Red Book CD writing application.
- Set up the RAM Cache.
- Import your files.
- Place them in your desired running order.
- Make any changes in levels between tracks.
- Set the desired pause lengths between tracks.
- Set any fade in/out and cross fades between tracks.
- Edit Track ID start positions.
- Set pre-emphasis to OFF.
- Set Copy Prohibit as desired.
- Leave the ISRC field empty (unless you have obtained the correct codes).
- Leave the EAN/UPC fields empty (unless you have obtained the correct codes).
- Check that the disc will write successfully by activating Simulation Mode and checking the speed.
- Write the disc.
- Bore all your friends with your music by pretending you need to "check your mixes" on their CD players.



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