Digital Recorders

There are many types of digital tape recorder using various (non compatible) formats. They all use the principles of digitizing sound covered in the digital audio easy, and they all face the same challenge: how to get a high enough frequency response to record the massive amounts of data audio needs. There are two fundamental approaches- many tracks, or a very high tape speed.

The machines that use the multi track systems are very expensive, (they need up to four tracks per audio channel) but are very reliable, and with some models the tape can be edited with a razor blade. High speed machines get the speed from a rotating head, just like video recorders. In fact the first of these were modified VTRs, and the new budget multitracks use standard consumer type video transports and tape.

Incidentally, it is this relationship of digital recorders to video that accounts for the funny sample rate of 44.1 khz. A single video frame has 490 lines, each recorded as a diagonal stripe across the tape. It turns out you can stuff 3 stereo samples in one of these lines. At 30 frames per second, you get 44,100 samples. Of course these numbers are based on black and white television. Color television runs a tad slower, so if you use a color VCR for recording, the sample rate winds up at 44,056.

The most important formats found today are Sony multitrack, Sony PCM, DAT, ADAT, and Tascam DA-88.

Studio Multitracks

Sony DASH Multitracks are the workhorses of pro studios. Similar machines are made by Studer and a few others. They cost about as much as a house but are unsurpassed in sound and reliability.

DASH stands for Digital Audio, Stationary Head. The quarter inch format uses 8 digital tracks to record a stereo signal. Some versions of these can be edited with a razor blade. The half inch machines record on up to 48 digital tracks, and depending on tape speed, can give up to 48 channels of audio.

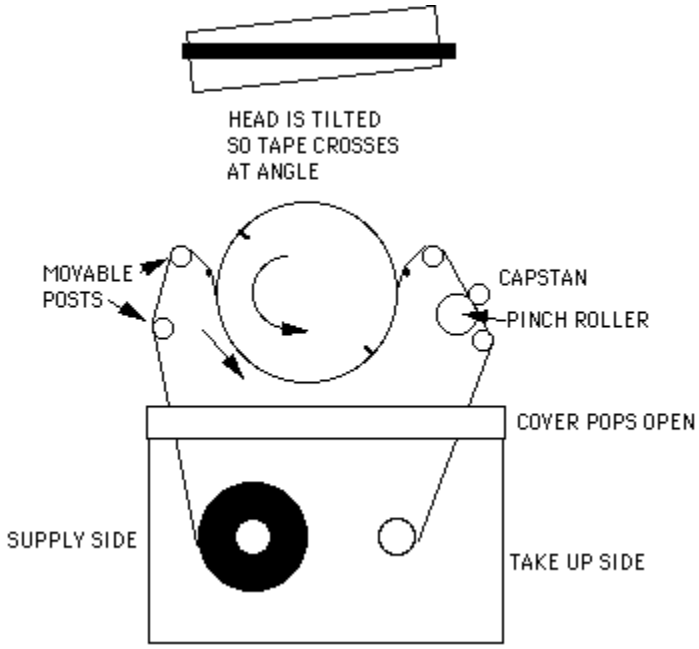
PCM

Sony PCM systems are accessories to standard video decks. The 1630 and similar models use 3/4 in videocassettes, and are found in pro situations, especially CD

mastering facilities. The F-1 was a consumer version, designed to be used with Betamax video decks (they work fine with VHS decks and many tapes were made this way). F-1 is no longer made, but systems survive, especially in electronic music studios. F-1 recordings have a 44,056 khz sample rate, a fact that causes problems (like a pitch change) when the data is transferred to a newer medium.

DAT

DAT recorders record on a very narrow, slowly moving tape. They achieve the bandwidth necessary for this trick with a rotating head (Actually two heads on a rotating cylinder). Individual bits of data take up a microscopic area of tape; therefore the tape must be treated very gently, and never touched by human hands. The tape is normally hidden inside the plastic cassette out of reach: when it is inserted into the DAT recorder, the case is opened by the mechanism and threaded around the head spool. This is known as loading.



The head will spin whenever tape is loaded, and the tape is always contacting the head, even in fast forward and rewind. If you don't run the tape for a period of ten minutes or so, most decks unload to prevent head wear. This means an extra delay when you press play.

The tape travels at 8.15 mm per second, but the head rotation of 2000 rpm gives an effective speed of 3.15 meters per second. (124 ips).

DATA ENCODING

Even at this speed the data has to be processed heavily to allow error free recovery at the other end. Some bit patterns, such as 00010000, would give a very narrow blip in the playback signal that is especially hard to detect. To avoid these, the usual 8 bit data words are recoded as selected 10 bit words, with the difficult ones left out. (This is called ETM for Eight to Ten Modulation. CDs use Eight to Fourteen Modulation.)

Each track (with a rotary head the tracks run across the tape at an angle) is just under an inch long. This is enough for 56448 bits after ETM demodulation. These are divided into 196 blocks of 288 bits. 256 bits of a block are used for data, the others for synchronization and error detection. Within a track, 128 blocks are for audio data and 16 for sub code data (IDs, Time and so forth); the rest are used to precisely control the way the tape moves across the heads.

A single 16 bit sample occupies 0.0003 inches. Naturally, any kind of a hole or dropout on the tape is going to have disastrous consequences. To prevent this, the data is scattered around the tape, a technique known as interleaving. Within each block, data bytes are mixed with parity bytes and error correcting bytes for other blocks. A total is kept of the data and parity, and if they don't match, that block is marked as containing an error. If the damaged region isn't too big (less than 22 blocks) the error correction bytes can be used to completely reconstruct the data. Within a somewhat larger region (74 blocks) interpolation can keep the music going. With more damage than this, the machine usually shuts off.

Error Indicators

Many decks have a light that flashes when errors are detected. Others have a hidden feature that gives some statistic, like errors per second. Errors are inevitable. Even a calibration tape will have two or three per second, and fresh recordings will read in the 20s or 30s. It is a good idea with a new machine to make a recording on a fresh tape and note the error rate. Then put the tape away. When doubt arises, play the reference tape and see what the error rate is. If it has gone up sharply, clean the heads. If you didn't happen to make a reference tape, you can tell the heads need cleaning when no tape will play properly. If a single tape stops playing, the tape is damaged or simply worn out. They can go surprisingly fast. In fact, enough tapes are unusable right out of the box that most engineers use two DATs when making critical recordings.

Head Cleaning on DATS

Proper cleaning of a DAT head requires disassembly of the machine and should be done by a qualified technician. Manufacturers used to include abrasive type head cleaners with the machines, but these should be used sparingly (if at all). Only clean when you know it's necessary.

About Time:

The time from the beginning of tape is recorded in every track of the tape as part of the subcode. If you start recording in the middle of a tape, the machine reads the time at that spot and keeps recording time subcode appropriately. If the tape is blank, this won't work. Therefore, every inch of a DAT tape should have something recorded on it. If you want silent spots on the tape, record zeros; either with the REC MUTE or by turning the input down. To find the end of recorded space, simply hit FAST FORWARD. You will be left cued up to the first blank. (Some decks have a special End Search function to do this.)

Start IDs:

Start IDs are also recorded in the subcode data of the tape. They run for about 9 seconds (so they are easy to find in fast motion) and contain a digital code indicating a start point.

On most decks, a start ID is recorded every time you hit the RECORD button and new one will be added if you Pause. Some decks feature an AUTO mode, where a Start is added if the signal stops for a second or so and restarts. Generally, you can record a start ID anywhere you want one, even while playing back. They are also easily removed.

Program Numbers

A program number is another chunk of data recorded in the subcode. These are the numbers searched for during Previous Play or AMS operations Most of the time the deck includes a program number with each start ID, but not always. (For instance, there will be no program numbers when you add IDs during play.) To sort out program numbers, most DATs have a RENUMBER function.

Skip IDs

Skip IDs instruct the deck to find the next start ID. You may write them in Record or Play mode.

End ID

An End ID marks that spot as the end of tape. The deck will not play or fast forward past the End ID. Adding them is just like adding START IDs. You should avoid having more than one of these on the same tape.

SCMS

The Serial Copy Management System is designed to enforce copyright protection of some kinds of material. Decks that follow the SCMS standard are locked out of digital recording under certain circumstances. This is accomplished by means of a two bit code known as ID6 and a byte called category code, which identifies the source of a digital input. The topic is confused by the fact that DAT machines made before SCMS was adopted may follow anther scheme called the "DAT Conference Specification" or ignore this issue entirely. The Topic is confused even further by the provisions that "professional" gear is exempt from SCMS.

The basic tenet of SCMS is that copyrighted material may be digitally copied only once. Copyright materials distributed on digital media (CDs, prerecorded DAT, Digital Broadcast) will have the ID6 set to 11 (binary). An SCMS deck is supposed to reset the ID6 to 10 if it was 11, and refuse to copy a digital signal coded 10. If ID6 is 00 unlimited copying is allowed.

The conference system was a little simpler. Such decks would not make digital copies of anything with a sample rate of 44.1 or anything with a an ID6 other than 00. If the source is analog, a conference type machine will mark the tape copyable (ID6=00) and an SCMS unit will mark it copy once (ID6=11). An SCMS machine recognizes an external A/D converter as analog and treats it the same way.

Loopholes

This state of affairs is not popular with the people who record for artistic reasons, as it is dreadfully inconvenient to be unable to copy your tapes. Various ways around SCMS have been found:

- You can buy quasi-legal boxes that will allow you to copy tapes regardless of the ID setting.
- Many decks can have the copy protection disabled by removing a jumper wire inside.

- You can always copy via analog connections, and the loss of quality is not noticeable.

SCMS and the Pros

Any DAT in professional use is exempt from SCMS, so machines designed for the pro market may dispense with it. In fact, it is hard to find a "consumer" DAT recorder right now, as the format was a flop in the audio market. However, all machines seem to follow SCMS sometimes.

The definition of a professional deck apparently lies in the type of digital input signal it will accept. Currently there are three standard types:

AES/EBU
: This is a pro format, and copying is unlimited. It uses XLR type connectors. When this is used, Start IDs and the like get lost.

IEC 958 type I
: Also pro format, but uses RCA connectors (is sometimes compatible with AES/EBU if levels are adjusted).

IEC 958 type II
: The consumer format, found on CD players mostly. Also known as S/P DIF or EIAJ CP-30. Uses RCA connectors.

Most pro decks now have two digital inputs, 958 type II and one of the other formats. On some machines SCMS is invoked if type II is used, others simply copy ID6 as it comes. Some examples of what happens on various decks:

- The Sony DTC 300 predates SCMS and copies everything at 48khz and nothing at 44.1.
- The Panasonic SV 3700 can be set to allow unlimited copies by a switch on the back.
- The Tascam DA 30 follows SCMS on the coaxial input, copies anything on the AES input. Analog input tapes are marked copy once (ID6=11). (All SCMS on a DA30 can be defeated by removing jumper W-402.)
- The Tascam DA 30 mk II records anything, and lets you set ID6 the way you want to.
- The Sony PCM 2300 uses the same input for IEC 958 I or II. It follows SCMS on type II input, copies anything on type I input, but allows you to mark tapes as copy prohibit if you want to.

Here is an example of a DAT machine:

BUDGET MULTITRACKS

ADAT and DA-88

The Alesis ADAT is an inexpensive eight channel multitrack digital recorder that uses SVHS videocassettes. It is extremely popular, as it offers digital quality at a cost substantially less than an equivalent analog machine. The Tascam DA-88 is a similar system based on 8mm videocassettes. ADATs seem to be outselling DA-88s by about 20 to 1, probably because the DA-88 costs more and came to market later. As with most audio gear , each machine has its fervent devotees. Professional studios seem to use the DA-88 for their own recordings (if there is no DASH machine available) but keep ADATs around for compatibility.

One interesting feature of both systems is that they are modular: two or more machines can be linked together to make a 16 track or bigger system. They also feature (with accessories in some cases) SMPTE synchronization and Midi Machine Control.

There are multi track digital outputs on these machines that allow you to copy tapes, but the individual inputs and outputs are analog. Some third party manufacturers make channel breakout boxes for disk based recording systems.

Unfortunately, the ADAT digital output (an optical connection sometimes called "lightpipe") is not compatible with the DA-88 (a multipin cable called "TDIF"). There are now converters available that also allow you to move the data into computers.

Here is a detailed discussion of ADAT.

CD Recorders

CD recording has been promised for a long time, but is only just now arriving on the shelves of your local stereo store. The recording industry has been opposed to the idea of digital recording for the masses and did everything possible, including lawsuits and and special taxes to slow it down. CD recorders made their debut in the early 90s, but the cost of recordable CDs was so high no one was very interested. But you can't stop technology- blanks have fallen from $30 each to under a dollar, so suddenly CD

recording is the cheapest method of preserving your music. There are currently 3 approaches to making CDs:

CDR drive attached to a computer

The CD recording logjam was finally broken by computer users, who embraced CDRs for storage of huge multimedia files. Recording of audio was always intended as a secondary function for these, and audio CDs made on a computer don't always play properly on a standard player. The trick is to get quality software (the giveaways don't quite cut it), a good CD burner, and optimize your computer for the process. To make an audio CD on computer, you have to put all of the files on your hard drive, then burn the CD in one pass.

The advantages of making audio CDs on a computer are the ease of making multiple copies and detailed control of the ID codes.

Stand Alone Pro CD Recorders

These machines look very much like a DAT recorder, with VU meters and a record button. You use them that way too. Unlike computer based systems, you can record in session mode, which allows you to add tracks one at a time. A disk recorded this way can only be played by a recorder or some rather expensive CD players. You can convert the CD to red book format by a process called "fixing up" or "finalizing". After that, you can no longer add tracks, but any you can play it on any CD player.

You can't erase a track one you've recorded it, but you can mark a bad one with a skip ID. Then some CD players won't play the bad track (but some will!).

Subcodes on stand alone CD recorders are pretty much limited to track IDs, and it can be tricky getting them where you want them. Some of the newest machines have features to address this problem. The latest machines also include built in sample rate converters so you make a digital dub from a DAT recorded at 48khz.

Stand Alone Consumer CD Recorders

These are brand new for Christmas '98. They are similar to the pro machines (a bit cheaper of course) but record only on special "Audio CDR" discs, which are expensive and hard to find. The Price of pro machines is falling fast, so it is unclear whether this format will still be around for Christmas 99.

CD media

CDRs record on a special disc which has a layer of dye in it. A laser heats a spot on the dye and a magnetic head applies a field that will change the color. This leaves spots where a traditional CD has pits, and a standard CD player can read the data.

There is some controversy concerning the kind of dye that is best for audio purposes. There are two kinds currently available: Cyanine is green before recording and phthalocyanine is gold. Cyanine is less expensive and widely available, but many feel the gold CDRs record with fewer errors and will possibly last longer. It is certainly true that some of the early model CD recorders worked better on one kind or the other.

Actually, what's on the back of the CDR is probably more important than what's inside it. Cheap CDRs have only a coat of varnish protecting the reflective gold layer. The ink from permanent marker pens will eat right through the varnish and gold, and a sticky label will peel it right off. For a dollar more, you can get a CDR with a rugged backing you can write on.

Whatever kind you use, keep them out of direct sunlight. They will be unplayable after about 12 hours of accumulated exposure. Don't let them get hot either.

CDs for Mastering and general distribution.

You may want to send a CD you have made to a duplication house to be made into an album. If so, take particular care in the recording of the CD- get the correct spacing between tracks, and make sure there are no overs (digital clipped audio samples). If these occur, or there are too many errors (something you can only control by using quality equipment and software), the duplication house will refuse to use your CD as the master, and charge you for making a new one.

You may want to make a small batch of CDR copies of your music for your friends. (With the advent of multi CD copiers, I expect copy stores to begin offering this service soon) If so, make sure your friends understand that CDRs are more fragile than regular CDs. And unfortunately, some of the cheaper CD players won't play CDRs at all.

CD-RW

Rewritable CDs have recently come to market, and a couple of new recorders that can use them have just been announced. The discs are pretty expensive, but since they are erasable, may be the wave of the future.

MiniDisk

Sony has been pushing recordable minidiscs for years as an alternative to the CD format. Minidisc is a rewritable magneto optical format. Because they use data compression, (and the first versions sounded pretty bad) minidiscs have never caught on with the general public. Recent generations aren't all that bad, and many musicians are finding them a reasonable low cost recording option.

Several companies have recently tried the waters with minidisc based four track recorders intended as replacements for portastudios. These have sound quality comparable to cassette, and have most of the features of random access recording. Unfortunately, the companies involved use different formats, so discs can't be exchanged.

Magneto Optical

Sony also has a pro version magneto optical recorder that records at high sample rates and 24 bit sample size. These sound fabulous but are very expensive and haven't really caught on either.

Hard Disk based Recorders

Recording on hard drives in computer systems is an important part of the modern audio scene described elsewhere. A few companies have tried to make stand alone hard disk recorders, on the grounds that such a machine would find a place in studios where a computer is a lot of hassle. If you can buy a separate device for what the computer editing software would cost (never mind the computer itself), why not? Currently there are two types of machine available, Darwin, and all in one studio types.

Darwin is a totally self contained 8 track hard disk recorder. Recording is standard CD quality, and it interfaces with ADATs. It can lock to ADATs (or other Darwins) for multi track recording and it can transfer data in lightpipe format to and from ADATs.

It has a variety of useful features, including some editing and an array of special effects. It does not have a visible mixer (digital mixing is available internally) and is

moderately expensive. It is used a bit in Nashville, but hasn't really found its market. The onslaught of inexpensive ADAT compatible digital mixers may improve sales.

All in one studios replace the cassette drive of the porta studio with a hard drive. To keep costs down, data compression is often used, with the usual sonic consequences. As the price of hard drives fall, most companies that make these are adding premium models with CD quality recording. For the musician on a budget and no plans for future expansion these are a fine option.

The advantages of hard drive recording are:

- Instant access to any point in a track
- "Versions" where one track can be matched with various combinations of others
- Editing of multitrack recordings

The disadvantage is that switching projects is much slower than changing a reel of tape.

Source: http://www.co-bw.com/Audio_Digital_Recorders.htm