Manufacturing Process for Pre-Recorded DCC

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Manufacturing process for pre-recorded DCC

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SUMMARY

An overview is given of the process steps and the equipment needed for mass-duplication of the pre-recorded Digital Compact Cassette (DCC). See fig. 4, last page.

The paper describes the background, why the various solutions have been chosen. A comparison with the process steps of the familiar MusiCassette is made.

Cassette Design

The exterior of the pre-recorded DCC-cassette is very different from its (analogue) MusiCassette counterpart.

Although the length and width dimensions are identical, the DCC misses the thicker front part of the compact cassette.

Furthermore it has holes for the hubs at one side of the cassette only — the bottom — leaving the top of the cassette free for a large "label".

Finally it has a "3.5 inch floppy-like" metal slider, which covers all holes and locks the hubs as long as the cassette is not inserted in a recorder/player.

The *interior* of the cassette is very similar to that of the well known compact cassettes. See fig. 1 on page 2.

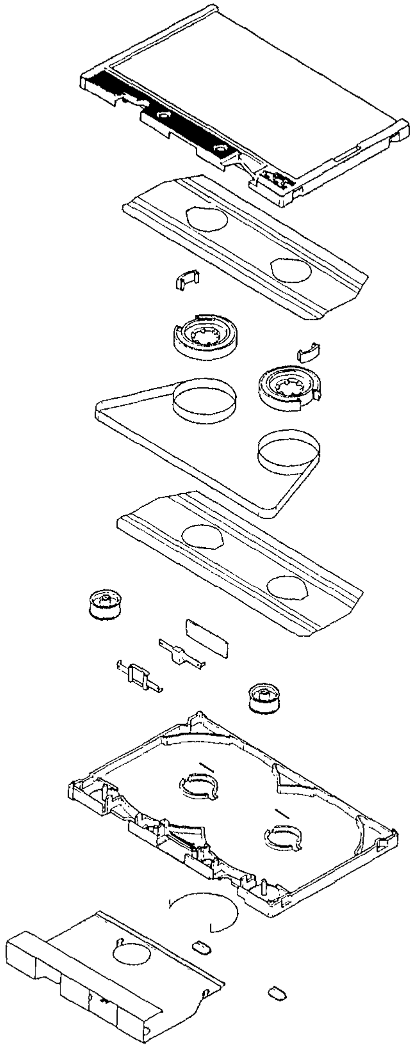

Fig. 1. Exploded view of D-0 cassette.

Tape and Tracks

The tape has the familiar 3.78 mm (0.15 inch) width, but otherwise different specifications.

The tracks on the DCC-tape are totally different from those on the MusiCassette.

In DCC for each "side" — tape direction — 8 main signal tracks plus 1 auxiliary signal track need to be recorded (see fig. 2).

The tracks are narrower and the position tolerances are tighter than on MusiCassettes.

Finally, the effective wavelength to be recorded on the DCC-tapes is 1 μm (1 micron). This, compared with the shortest wavelength on analogue MC-tapes (highest frequencies) of some 3 μm (3 microns).

To enable the use in DCC of tape which can be easily produced with industry-standard processes, a video (VHS) type coating is employed.
Also in video-recording 1 μm signals need to be recorded and played back reliably.

The coating thickness is 2 μm and the polyester substrate of the tape is 10 μm thick. Hence, mechanically the tape is very similar to the well known C-90 cassette tapes, which fact simplifies its handling on high-speed duplicating and cassette loading equipment.

As signal loss, caused by any distance between the recording/playback head and the tape becomes progressively more severe as the wavelength of the signal decreases, extra care needs to be taken to obtain a smooth and clean tape coating surface.

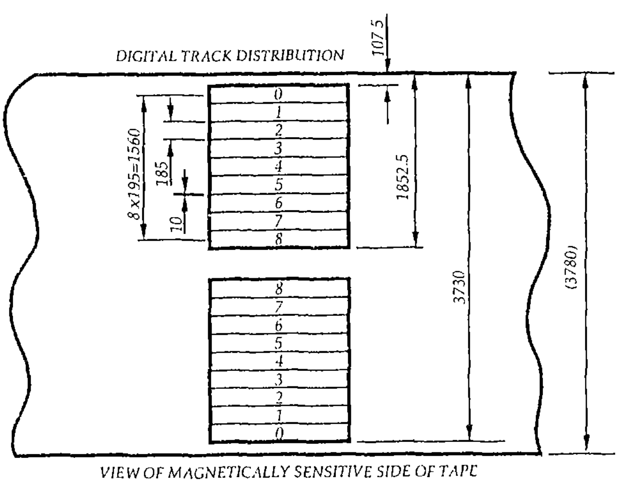

fig. 2.
Tape and track dimensions (in μm).

Volume duplicating

The heart of any industrial audio cassette tape replication facility is its high speed tape duplication process.

For analogue cassette tape duplication two processes have established themselves side by side.

- The first and oldest one is to run a ½ inch or 1 inch wide mothertape in an endless loop in a so called tape bin at high speed.

  The two pairs of stereo-signals on that tape (one pair forward and one pair reverse) are played back *simultaneously*.
  The audio-signals are fed to a number of slave-recorders, with 2 stereo recording heads each. The slaves are also running at high speed.

- The second and newer method is using a so called digital bin instead of an endless tape loop to supply the audio-signals to the slaves.

  This "digital bin" is not a real bin, but a computer-type digital data storage device, containing the four audio-signals in digital form.
  This storage device is usually a solid-state memory.

  The advantage of a "digital bin" over a real tape bin is its lack of tape wear which can cause signal degradation, drop-outs and even total loss of the mothertape in some cases.
  However a "digital bin" with the required quality is costly.
  Moreover the loading of the digital audio-signals into the memory — the "downloading" — is time consuming unless special intermediate signal storage media are employed.

Now let us take a look on how the equivalent set-up for high speed duplicating of Digital MusiCassettes looks like.
To do so we first consider the slave-recorders, then the master and subsequently the interconnection between master and slaves and the downloading procedure.

Slaves

The slaves, used for recording the digital signals onto the slave-tape, are basically similar to their analogue counterparts.

They both have supply and take-up positions for large pancakes of 3.78 mm (0.15 inch) wide tape.
They both run that tape at a high speed, typically 64 times the nominal cassette tape speed of 4.76 cm/s ($1^7/_8$ in/s) across the recording heads, laying down a large number of identical programs onto the tape, one after the other.

For digital, the recording heads are different.
Two separate recording heads are used, each for one of the two sectors ("sides") of the tape, which are duplicated simultaneously.
The heads are of the thin-film type, like their counterparts in the DCC-recorder, however, designed to be driven with higher frequency pulses and a higher recording current.
In digital recording no bias is applied.
Each head records 8 + 1 tracks, 8 main data tracks and 1 auxiliary track.
The narrow pulses are not recorded at all 8 tracks at exactly the same time, but slightly staggered (within a bitcell).
This is done to restrict heat dissipation in the head.

The position tolerances of the tracks on the tape are tighter than the ones on analogue tape. Therefore precise tape guiding is needed. On top of that, great care has to be taken to prevent foreign particles getting trapped between the tape and the recording head.
Such particles would force the tape away from the head, thus strongly reducing the amplitude of recorded pulses on the tape.

Besides cleaning the tape before it reaches the heads, this is achieved by creating a clean-air environment at the location of the head block.

The recording electronics consist basically of pulse-shapers, which convert the pulse-trains coming from the master in narrow, precisely timed, steep current pulses.

Master

From the two alternative master systems as used for analogue — endless loop tape bin and "digital-bin" — the latter is the most appropriate in digital high speed duplication applications.

Compared to the digital bins used in analogue high speed duplication today, the digital bin in DCC applications only needs to store a fraction of the number of bits, approximately one fourth. This is because the signals in the DCC-master bin can be "PASC-encoded", instead of 16 bit-linearly encoded as is usual in standard digital audio encoding.
And since only a fraction of the usual number of bits needs to be stored for the same program length, the use of a solid state memory (SSM) here really is both practical and economical.

To avoid time consuming and speed restricting processing of the bitstream(s) as they come out of the memory during high speed duplicating, the bits are stored in memory in the same pattern as laid down on the slave tracks. A separate memory is used for each individual track.

No error detection/correction is needed during "playback" of these signals, as by nature no drop-outs or similar signal degrading can occur in a solid state memory.

Assuming the SSM is large enough to store more than one total program, it becomes possible to run one program and simultaneously start loading the next program into a different part of the memory.

Master-slave interconnection

As we have just seen, the signals are stored in the master (SSM) as parallel bitstreams. Each bitstream is meant to feed one track of one of the two recording heads.

Using standard RS-485 interfaces and twisted pair flat cables, a straightforward and interference-free connection is made between master and slaves.

Naturally a different approach, whereby all signals coming from the SSM are multiplexed into one composite signal, sent over one glass-fibre wire to the slaves and subsequently de-multiplexed, is feasible as well.

The signals sent through the twisted pairs in the flat cable have, of course, the same bitrate as the signals passed to the slave recording heads.
Signals from the 2 x 9 channels are de-skewed in the slave recorder to compensate for possible individual delay differences in transmission.

Downloading

To fill the SSM — the digital bin — with digitized audio signals, a source is needed containing those signals. And not only the audio signals, but also all other information ranging from sync pulses to time codes, to ISRC codes, to text info, etc.

As it is most practical to have all that information together on one single carrier, after ample consideration a *recorded DCC-cassette* was chosen as the preferred intermediate carrier, the master cassette.
The DCC-cassette has a long list of advantages in this application:

- It contains all the required signals.
- It can be checked on any DCC-recorder on the programs functionality.
- The signal format is sturdy and reliable, as it was designed to remain intact under all kinds of adverse circumstances (consumer use).
- The cassette itself is small and inexpensive and therefore archiving of program tapes does not require much space and does not tie up much money.
- The cassette design itself lends itself to automatic handling, if so desired in future.
- No system conversion on shopfloor.
- From mastering to finished product, the same error monitoring system can be used (hard- and software).
- Finally, a finished cassette is identical to the original master cassette and can therefore be taken as "safety copy".

Having chosen the "intermaster"-format, we now turn to the actual downloading.

The master cassette is played back on a special tape deck. To avoid a lengthy loading procedure the download tape deck contains a double playback head, which can scan sector A and sector B (side 1 and 2) simultaneously.
The playback electronics deviate somewhat from those of a standard recorder:

- Sector B is played backwards and needs slightly modified processing.
- The signals coming from the tape deck are in the "parallel format" (RS-485).

But apart from these special requirements, normal error detection and correction processing is applied to the signals coming off the tape, thus guaranteeing that error-free signals are loaded into the SSM.

In future, it seems quite feasible to step-up the playback speed of the DCC-download player to 2 x normal or higher.

The downloading requires minimal operator attention:
Insert the cassette in the player and push the start button.
Downloading can take place while duplication of an earlier item is still in progress, either into the free space of the SSM in use, or into a second SSM (SSM's are inexpensive for DCC).

Master Recording

Recording unit

The DCC-master cassette contains all the signals as they later appear on the replicated Digital MusiCassettes. It is in fact a pre-recorded DCC-cassette according to standard.

The major difference between a DCC-cassette, recorded on a "consumer"-recorder and a pre-recorded one is that the latter can and will contain text information intertwined with the audio.
This text info is contained in the so called "sys-info"-channel, which cannot be recorded on a consumer recorder.

The consequence of this is that a "special" DCC-recorder is needed to prepare the master cassette.

The process of making the master cassette is very similar to the preparation of a CD-glass master for CD-replication.
Actually a CD-tape master is used as input.

The sys-info data (text) is prepared separately using a dedicated editor. This editor is nothing else than a standard PC with special editing program. The text output is put on a floppy.

The total mastering set-up consists of:

- A U-Matic (PCM 1630 system) recorder to playback the "CD-tape master".
- A PC to read the sys-info text floppy and to control the whole playback/recording process.
- A DCC-recorder with special electronics.

Sector A en B are recorded sequentially.

The whole process is largely automated. The mastering engineer only needs to load the correct tapes and floppy and set the correct parameters.

A separate unit is used to monitor and analyze the digital signals coming from the U-Matic tape.

It is during this mastering step that the 16-bit linearly encoded audio from the CD-tape master is converted to a bit-rate reduced PASC signal.

Playback unit

The ready made DCC-master cassette is checked afterwards in a so-called error monitoring unit, which is a deck, playing back sector A and B simultaneously and analyzing the quality of the recorded signals.

Cassette loading

D-0 assembly

In analogue MusiCassette production use is made of automatically assembled C-0 cassettes. These are cassettes which contain all components, except the magnetic tape.

For pre-recorded DCC-cassettes an identical approach is followed.
Only the parts are different and thus require adapted assembly equipment.

The "C-0" is here called a "D-0".

D-0 loading

Loading the slave tape in the cassettes is done in exactly the same way as in analogue MusiCassette production, that is, on a C-0 (here D-0) loader. The loader is slightly adapted to accommodate the different — asymmetrical — design and the slider of the DCC-cassette.

Quality Control

Full use is made of the fact that the recorded signals are fully digital.
This means that once the sound quality of the original encoded signal has been approved, further checking of sound quality *by listening* has become superfluous.

The (sound-)quality control of the whole replication process is reduced to monitoring electronically whether the digital "code-words" remained intact and can be read with good reliability.

This, of course applies also to all other digital info, that is recorded on the master cassette and is then replicated together with the digital audio.

Also here, the quality control procedures are more similar to the ones in a CD-factory than to the ones applied in a MusiCassette replication plant.

NOTE:

Due to the fact that the same format is used throughout the whole process from master cassette to finished product, only one type of error checking unit is needed. This includes pancake checking, which only needs a different playback deck, of course.
In fact the downloader is also an error monitoring unit with an extra buffer to connect it with the SSM.

Finishing

The finishing of the pre-recorded DCC requires adapted equipment as well.

The regular paper or direct printed labels on a MusiCassette are here replaced by an "L-card", which is permanently sealed onto the DCC behind a transparent L-cover.
This cover is ultrasonically welded onto the cassette itself and cannot be removed afterwards.

Additional information can be printed on the back of the cassette.

Finally, the packing of the cassette in the box is different too.
The design of the "case" has taken advantage of the fact that the cassette itself has already a full-colour label.
Moreover, the outer box does not have to provide hub-locks as with the analogue MusiCassette (see fig. 3, next page).

The simple two piece slider-box that resulted requires a drastically different packaging machine than the one for the 'Norelco-boxes'.

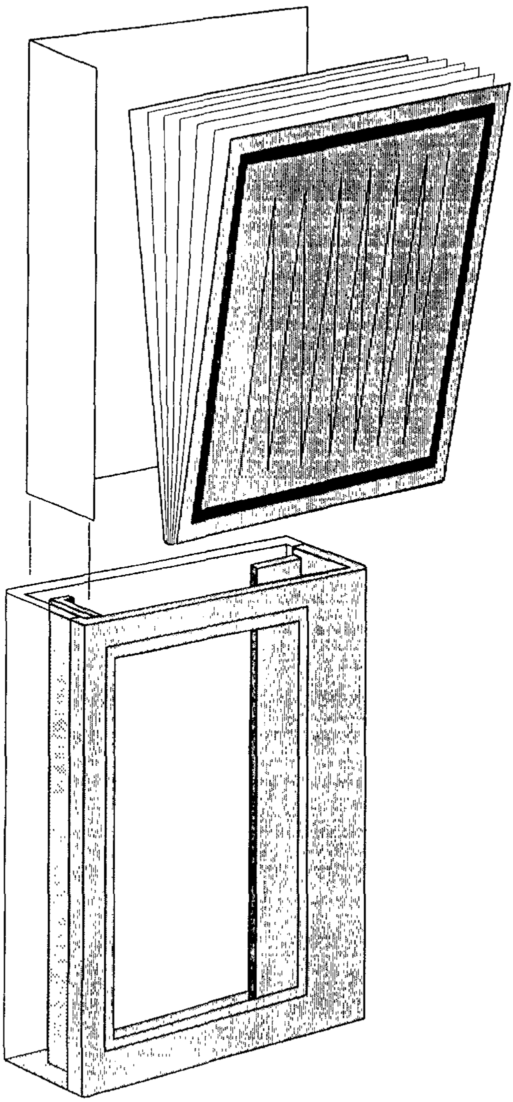

Fig 3. DCC-BOX and PRINTED MATTER

Concluding remarks

At first sight the replication process of pre-recorded DCC-cassettes is very similar to the well-known MusiCassette production (see fig. 4, last page).

However, in many details the process differs, and special equipment and tools are required.

In contrast to the analogue process, quality control can be highly automated.
Because of the chosen formats, standard monitoring systems can be used at different process points.

A finished cassette is identical to the original master cassette, hence can also be used as "back-up" master cassette, or master cassette in sister plants.

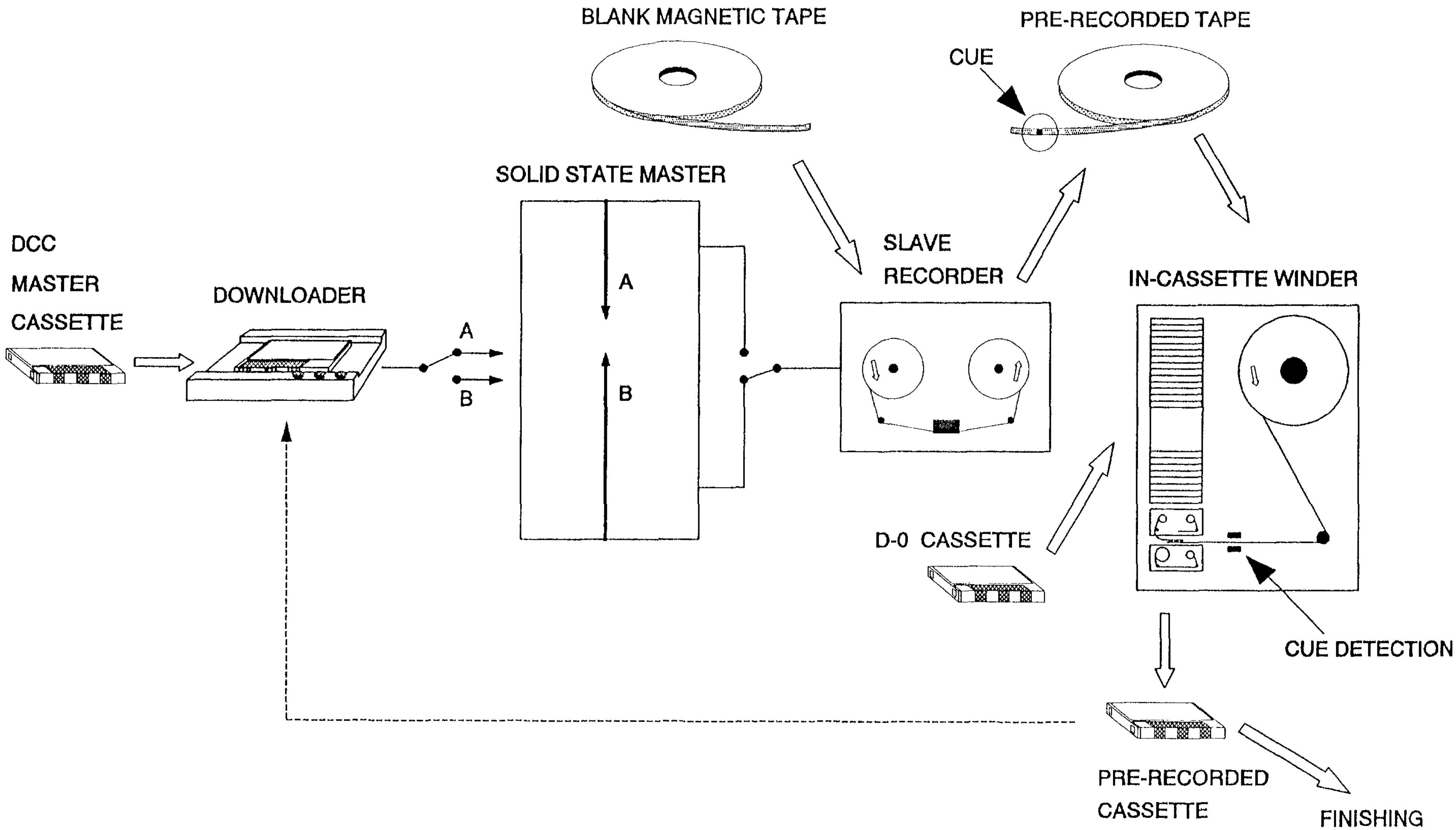

Fig.4 DCC DUPLICATION AND LOADING