DIGITAL dcc COMPACT CASSETTE

FUNDAMENTALS

THE NEW DIGITAL SOUND SYSTEM

INTRODUCTION

When Compact Cassette was invented by Philips in 1963, few foresaw that it would become the world's most popular sound carrier. But look at the situation today. Worldwide sales for last year were 2,600 million pre-recorded and blank cassettes, and 180 million cassette recorder or player units. That spells success in any language.

The secret of this success lies in the system's unequalled versatility. The rugged cassettes and decks will stand up to tough environments. They have earned and held their place in Hifi stereo systems, and are even more at home in personal sound machines, portables, headphone stereo and car stereo. And the huge Compact Cassette software repertoire ranges beyond the realms of music to other subjects like education and talking books.

In the eighties, another Philips invention captured the limelight. Compact Disc opened a new era of digital, perfect sound. Digital audio in the CD style offers high dynamic range and very low noise, as well as low distortion, wide channel separation and total absence of wow and flutter: in a word, better sound. Very close to the original sound. Digital audio also offers extra user convenience with fast track access and programming. It is robustly resistant to soiling or damage because of the error correction process. The recordings retain their original purity. Consumers recognize these facts; the overwhelming acceptance of Compact Disc proves the point.

Now, yet another Philips invention arrives at the centre of attention: Digital Compact Cassette, or DCC. DCC is the marriage of Compact Cassette to Digital Audio, and it forms a union that combines perfect sound and high convenience with even greater versatility.

Like Compact Cassette, DCC is a record and playback system that features both pre-recorded "Digital Musicassettes" and blank DCCs. With its advanced system of digital registration on tape, DCC is Compact Cassette made digital and totally modernised.

DCC is indeed an idea for the nineties. But also an idea of the nineties - for only with the latest advances in digital audio technology has it become possible to record digital quality sound on a new type of audio cassette, running at normal Compact Cassette speed. With its revolutionary and extremely efficient PASC coding, DCC achieves up to 18-bit resolution, producing superb digital sound of Compact Disc quality.

DCC operating convenience is well up to Compact Disc standards too, and this is particularly so with pre-recorded cassettes. Track and time codes on the tape, combined with autoreverse, make track access effortless and quick. Users don't have to worry whether

tracks are on the A-side or the B-side: DCC decks find their own way to any chosen track. A brand-new feature for pre-recorded cassettes is text mode. This allows the decks to display all sorts of supporting information about the recordings. Associated TV screens or remote controllers can display more extensive information.

The recognized ruggedness of Compact Cassette is enhanced in DCC by digital error correction, improved mechanical design and built-in tape protection.

As for styling, the new-design Digital Compact Cassette, smoother and slimmer, features an integral cover design. It has more eye appeal; is easier to handle, carry and store.

On top of this, DCC has its own unique and practical advantage: it is compatible with its analogue ancestor. Users can play their existing Compact Cassette collections on their new DCC machines. They can start in this way, and build up new DCC collections in their own time.

DCC is available to the consumer as a total system package, including machines from various major Consumer Electronics manufacturers, and blank cassettes as well as pre-recorded cassettes on leading music labels.

All these factors make DCC the logical, digital successor to Compact Cassette. It meets higher demands for sound quality, durability and style. It is destined for the new generation of music lovers in a new digital age.

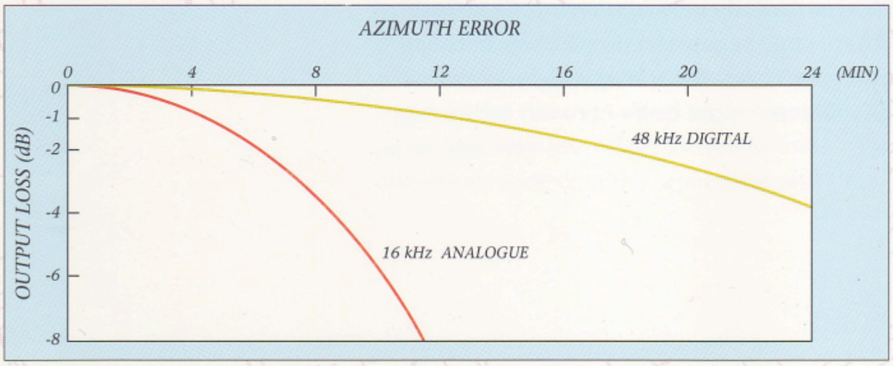
DCC is a totally new tape recording system addressing the musical possibilities of today and tomorrow. But it also makes the fullest possible use of the best of proven technology.

THE DCC CASSETTE.

The DCC cassette is a Compact Cassette with a difference. It has the same basic dimensions, records on forward and reverse tracks, and uses (video) chrome or equivalent tape. Modern technology, however, has produced a much improved design. Both the new cassette and its holder are more stylish and more convenient.

Autoreverse is an integral part of the DCC system; this means that the cassettes never need to be turned by hand. Drive hub openings are only required on the rear (inward-facing) side, leaving the entire front panel smooth and flat. This offers new scope for integrated artwork on Digital Musicassettes.

Azimuth error is less marked in digital recordings.



The cassette body is also made thinner overall, because the record/playback head is more compact.

The normally exposed tape, and the tape drive wheels, are covered by a slider. This provides the tape with built-in protection against soiling and scratches. It also locks the tape reels to solve an old problem of the cassette medium; in a DCC cassette there is little chance for the tape to unwind, get into a tangle, and then become jammed. When the cassette is loaded, the slider is automatically pushed aside. Thanks to this device, cassettes can safely be carried around without their holders. So not only is the cassette more attractive visually, it is also easier to pick up and use in all applications. and it takes up less storage space.

Even so, the holder is by no means superfluous. In contrast to the old Compact Cassette box, the DCC holder is a slide-out sleeve, much stiffer and with rounded edges, but still slim and compact. The front face can be open to display the art work on the cassette itself, and an information booklet can be included.

DCC inherits well-proven and reliable technology from thirty years of Compact Cassette development. DCC mechanisms are close derivatives of existing autoreverse mechanisms. Reliability, shock-resistance and robustness are all high because of the low number of moving parts. The excellent price/performance ratio of these well-proven mechanisms strengthens DCC's potential to become a fast-growing consumer product.

One brand-new feature of the DCC cassette is the two Azimuth Locking Pins (ALPs). In conjunction with the Fixed Azimuth Tape Guidance (FATG) mechanism fitted to the head assembly, the ALPs ensure not only improved tape-head contact, but also consistently repeatable alignment of the tracks on the tape with the heads.

The ALPs increase the wrap-around angle of the tape against the head. This extends the tape-head contact area and optimizes the physical conditions for signal recording and reading. The tape is also stiffened in this crucial tape guidance area, and this contributes to the high accuracy of the FATG mechanism.

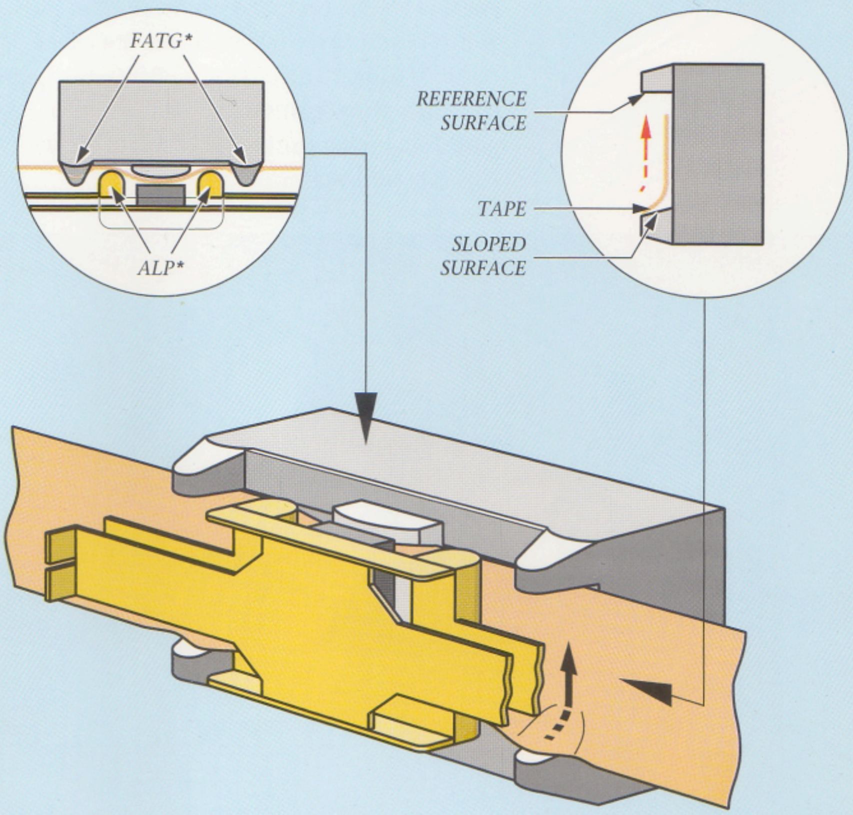
In the FATG mechanism, special slots are mounted on either side of the head assembly. The two top edges of the slots form reference surfaces to align the tape with the head. Meanwhile, the sloping profiles of the lower parts of the slots gently force the stiffened tape upwards against both reference surfaces. For all practical purposes, this simple device eliminates azimuth error.

The ALPs/FATG design requires no complicated mechanisms or close tolerances. Its very simplicity ensures permanently accurate tape-head alignment.

New materials are used in the DCC cassette itself. They are specified for use over a wider temperature range than the Compact Cassette.

The length of a blank DCC cassette can be indicated by holes in the rear of the housing. These enable DCC decks to calculate and display the remaining recording time. Accidental overwriting can be prevented by a record protection switch.

The tape itself is well proven; it has a standard videotape coating of chromium dioxide or cobalt doped ferroxide, 3-4µm thick in a total thickness of 12µm. As in Compact Cassettes, the tape is 3.76mm wide, and divided into two sectors. This format reduces access time, since less tape needs to be wound. It also allows continuous repeat playback.



Tape-head engagement: optimal wrap-around with the ALPs (inset), and azimuth alignment with the FATG (inset)

Tape Playing Times (minutes)

Hole	45	60	75	90	105	120	U
3		●		●		●	
4			●	●			●
5					●	●	●

● = hole present U = undefined

Tape playing times.

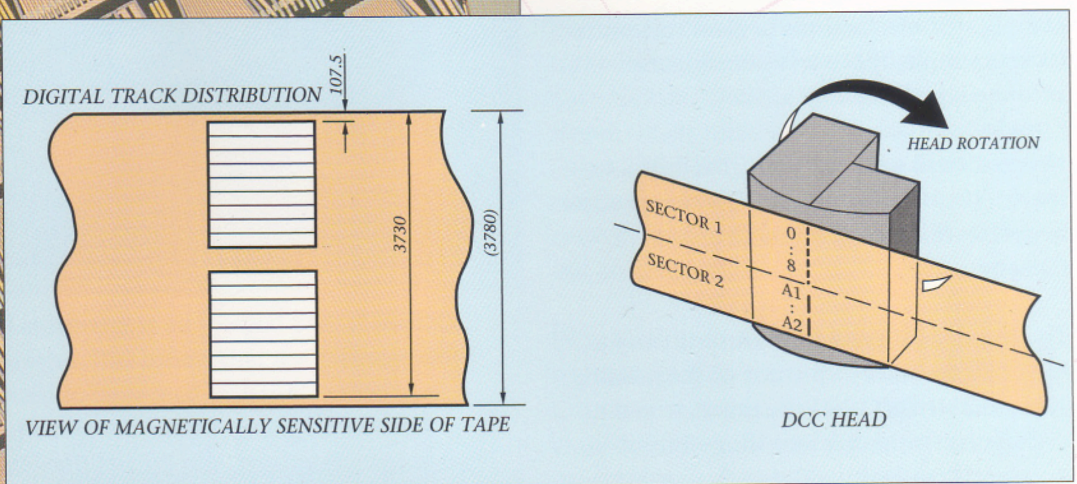
THE DCC HEAD ASSEMBLY

The DCC sound signal is recorded on eight parallel tracks, each 185 µm wide. The track width required for playback, on the other hand, is only 70 µm. This width factor helps to reduce the sensitivity to azimuth error. An additional track carries control and display subcode information.

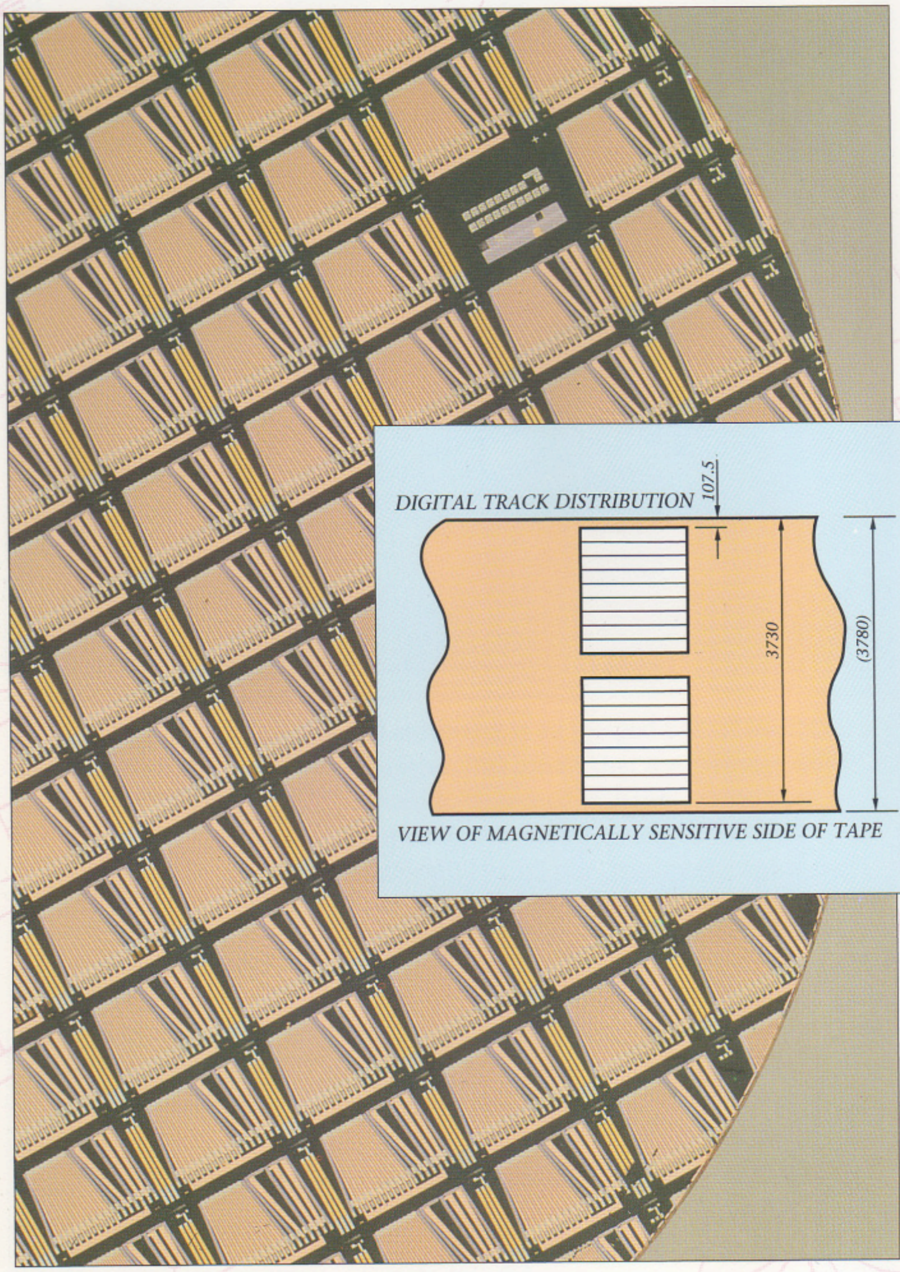
To achieve these miniature dimensions, the DCC record/playback head assembly calls on the high-tech thin-film head technology already well proven in multichannel professional recording. In one thin-film head assembly, three sets of head elements can appear:

- Nine Integrated Recording Heads (IRH) for digital recording
- Nine Magneto-Resistive Heads (MRH) for digital playback
- Two Magneto-Resistive Heads (MRH) for analogue playback

The digital heads occupy one half of the head surface, while the analogue heads occupy the other. Thus, both digital and analogue tapes can be handled by the autoreverse head assembly.



The DCC digital/analogue head : Showing the (reversible) disposition of digital heads 0-8 and analogue heads A1 and A2.

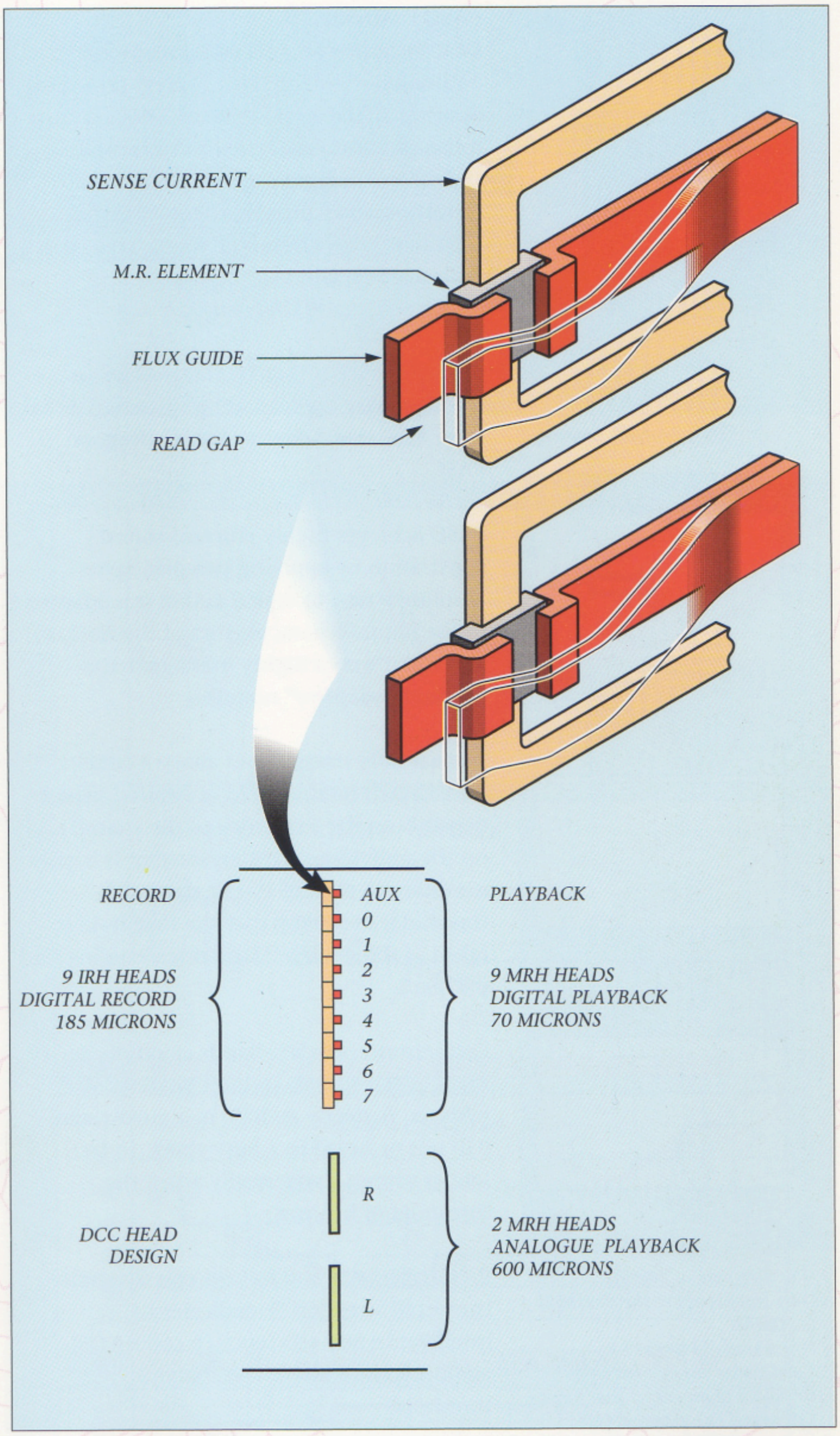


A section of the thin film wafer used in the construction of the DCC record/playback head.

In an integrated recording head, the signal current conductor is surrounded by a flux guide which concentrates the magnetic field into the recording gap in conventional fashion. The MRH playback head, on the other hand, features an advanced magneto-resistive element whose resistance varies with the magnetic field impressed on it from the tape, via the flux guide. A constant current is fed through the element, so that the voltage across it varies with the magnetic field on the tape. Magneto-resistive heads are excellent for reading DCC bit transition.

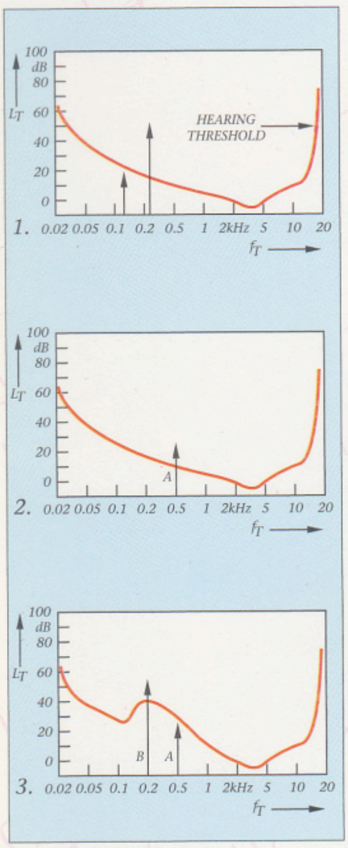
For analogue playback, the high stability and absence of noise and hysteresis of magneto-resistive heads also ensure top quality. At the same time, the inherently high bit rate capability allows for a wide frequency response.

The head face has a thin anti-wear coating; continuous tape travel across the head causes no damage.



Magneto-resistive playback head: the varying magnetic field from the tape varies the resistance of the element through which the current flows.

CODING



1.The threshold of hearing. Only sounds above the threshold are heard.
2.Soft sound (A) is audible.
3.Loud sound (B) increases the threshold to an extent that masks soft sound (A). Since (A) no longer needs to be coded, extra information capacity becomes available for more precise coding of (B).

PASC CODING.

DCC encoding and decoding techniques naturally follow the same general principles as other digital audio systems. Well-known techniques for Analogue-to-Digital and Digital-to-Analogue conversion, Error Detection and Correction, and Channel Modulation and Demodulation, have been optimized for the DCC tape medium. (Block Schematic Diagram).

The difference is that DCC introduces a revolutionary digital coding system of its very own; Precision Adaptive Sub-Coding, or PASC.

PASC achieves highly efficient sound registration by applying two principles absolutely new to digital audio: it is adapted to the natural characteristics of the human ear, and it uses a highly intelligent and efficient "adaptive" notation.

The ear only hears sound above a certain level called the threshold of hearing, which depends on the frequency of the sound, and on the individual. This means that it is only necessary to register sound above this threshold, providing that the threshold is taken as the reference for both recording and playback.

Furthermore, louder sounds can hide, or mask, softer sounds in their vicinity. A whisper, perfectly audible in a quiet room, will not be heard in a busy street. In fact, louder sounds dynamically adapt the threshold of hearing.

PASC calculates and follows this dynamic threshold adaption. It dedicates its intelligence and efficiency to coding the audible sounds above this dynamic threshold.

In this way, PASC achieves very efficient sound registration indeed, at only one quarter of the bit rate of Compact Disc's PCM. This level of efficiency creates adequate room for precise registration of what the ear actually hears, so that the sound quality of DCC is in every way comparable with Compact Disc.

HOW PASC CODING WORKS.

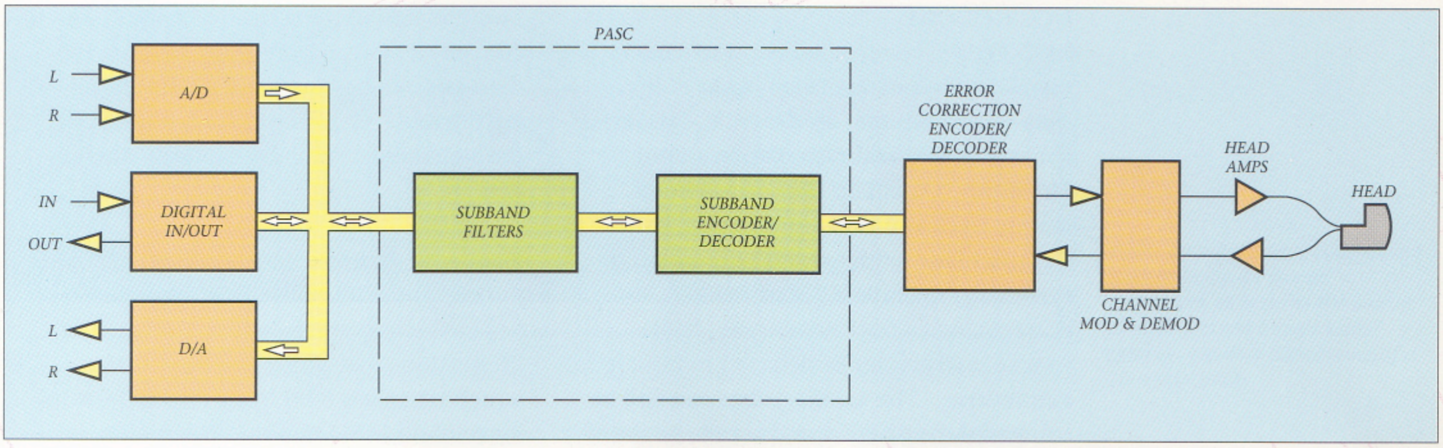
First the PASC processor establishes the dynamic threshold. To do this, it splits the (PCM) audio signal band into 32 sub-bands of equal width. Then, on the basis of the signal levels in each sub-band in relation to those in the adjacent sub-bands, it calculates the masking threshold for every sub-band. Sub-band signals above the dynamic threshold are now digitally coded with the refinement of resolution that they need, proportionate to their amplitude. Sub-band signals below the dynamic threshold are passed over; they need no encoding.

Intelligent and efficient PASC coding employs a "Floating point" representation. "Floating point" expresses each sample as two components, the exponent, or scale factor, and the mantissa, or resolution.

The process is analogous to expressing distances, for example, in millimetres, metres or kilometres. The scale factor is the multiplier indicating the dimension of the measurement; in this case the scale of the signal within the dynamic range. The scale factor, 6 bits long, covers the range from -118dB to +6dB in 2dB steps.

The mantissa gives the measured value of the sample (to be multiplied by the scale factor). A sample value of 50, for example, can be expressed by a scale factor of 100 and a mantissa of 0.5. The length of the mantissa is determined by the quantization level allocated to the sample. This depends on the amplitude of the sample above the threshold, the rate of change of the waveform pattern, and the available data capacity. Mantissa length can vary from 2 bits to 15 bits. Since the audio signal varies relatively slowly compared with the sampling rate, both the masking threshold and the scale factor are calculated, not once for every sample, but once for each group of 12 samples forming a PASC frame.

For the mantissa, the number of bits of information to be encoded varies from sample to sample, according to the quantization level. The resultant digital values are distributed over the full data



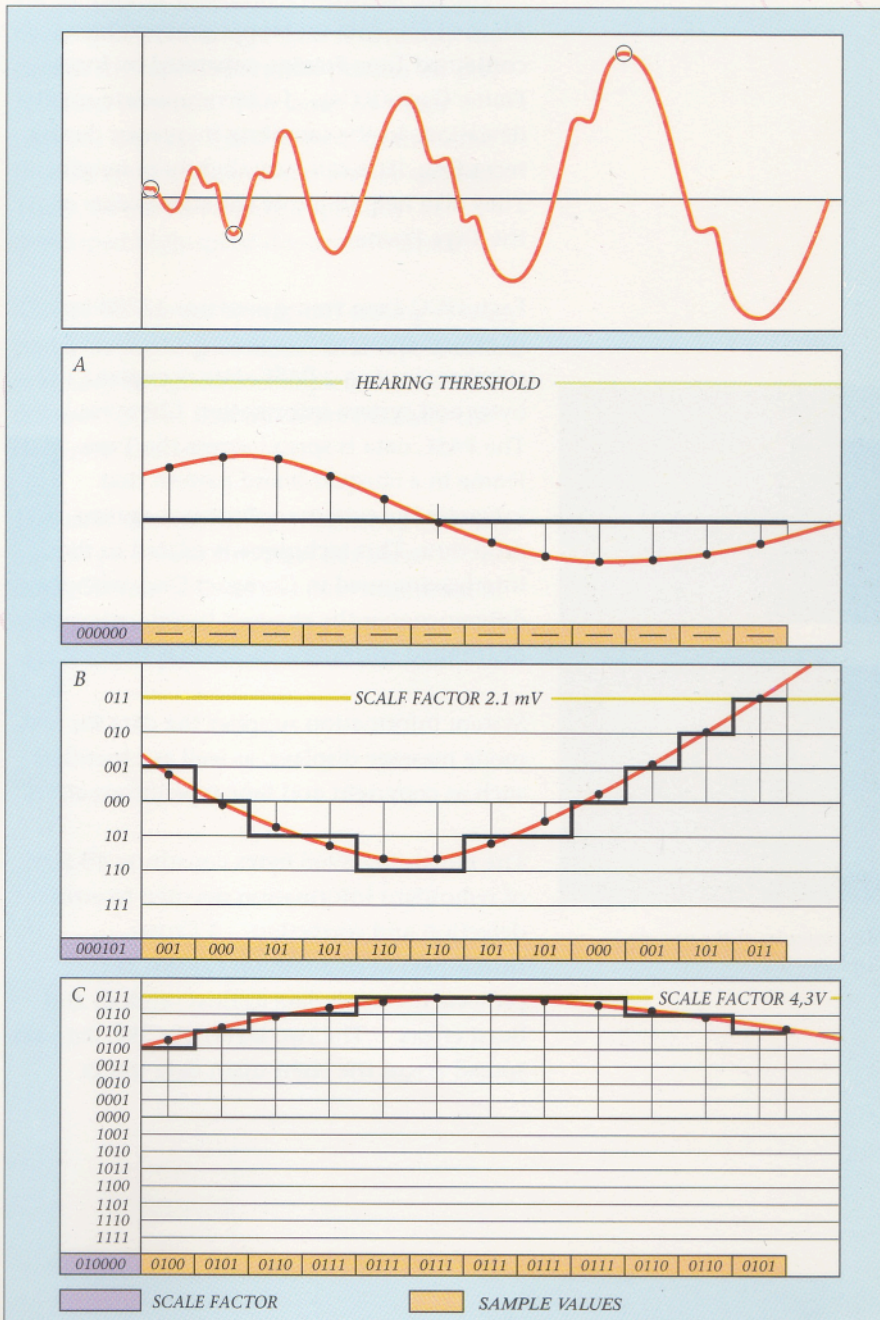
Schematic diagram: DCC

capacity of the PASC frame, in order of their significance. This process, called adaptive allocation, optimizes the sample resolution in relation to the available data capacity.

"Floating point" representation and adaptive allocation dramatically improve the coding efficiency achieved by PASC.

PASC is not only based on the natural characteristics of the ear. During its development, it has been constantly evaluated by trained ears. Critical parameters like the dimensions of a PASC frame, the resolution refinement, and the range and step size of the scale factor were ultimately determined, not by the calculations, but by the most extensive and intensive listening tests.

PASC is thus optimised primarily on audio performance, not on efficiency. The result is sound quality equal to Compact Disc. More than that; with its floating point representation, PASC can extend the quality of digital sound to even greater dynamic ranges.



PASC coding:
In floating point, the mantissa is the purely numerical value of a sample, e.g. 0.7. The scale factor gives the maximum value of the scale on which the mantissa is measured, e.g. 10 mV. Together, these indicate 10 x 0.7 = 7 mV.

A. Below the dynamic threshold, both the scale factor and the mantissa register zero.

B. Above the threshold, the scale factor is registered only once per 12 samples. For relatively fast-changing waveforms, quite low mantissa quantization (e.g. 3 digits for 8 values) is enough.

C. Higher mantissa quantization (e.g. 4 digits for 16 values) is required.

DCC CODING

DCC signals are recorded on nine parallel tracks on the cassette tape. Eight "Main Data" tracks contain all the PASC data, error correction data and system information. The ninth, "Auxiliary Data" track holds mainly track and time information, similar to Compact Disc, with extra tape markers for even easier operation. Start markers, for example, make track access easy, while reverse markers can be detected to initiate autoreverse. The auxiliary data can still be scanned during high-speed search, to speed up operation as well as making it easy.

All the DCC data on tape is grouped into self-contained Tape Frames, separated by Inter-Frame Gaps (IFGs). To accommodate small deviations in the sampling frequency during recording, IFGs can vary slightly in length. They also help to locate the start points of the Tape Frames.

Each DCC Tape Frame contains 12288 bytes of information, not including synchronization. PASC data occupies 8192 bytes and system information 128 bytes. The PASC data is spread across the Tape Frame in a chequer-board pattern that increases the system's robustness against drop-outs. This technique is related to the interleaving used in Compact Disc, with the difference that the chequer-board pattern is distributed within the individual tape frames.

System information supplies the data for text-mode message displays, as well as identifiers such as copyright and tape type information.

The remaining 3968 bytes constitute 40-50% of redundant information devoted to error detection and correction. A Cross-Interleaved Reed-Solomon Code (CIRC) protects the main data against random and burst errors. The two layers of CIRC data are spread across the eight main data tracks.

This powerful error correction code allows for correction of drop-outs up to 1.45mm in diameter, almost completely covering all eight tracks. It can even compensate for a drop-out bigger than a completely missing data track.

Finally, to optimise bit-transition detection during tape readout the DCC signal is fine-tuned to the characteristics of the medium. This is done by eight-to-ten modulation, which translates 8-bit bytes into DC-free 10-bit symbols for recording. The process is comparable with the eight-to-fourteen modulation (EFM) of Compact Disc.

In support of the revolutionary PASC, all the techniques which have made Compact Disc synonymous with audio excellence are applied to DCC. All are closely integrated, and optimized for the tape medium. They are fundamental to the extreme reliability and quality of this new digital audio system.

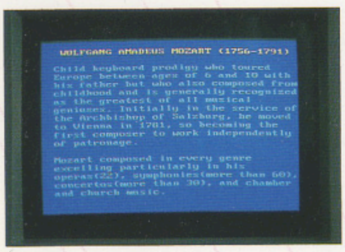
TEXT MODE (DISPLAY)

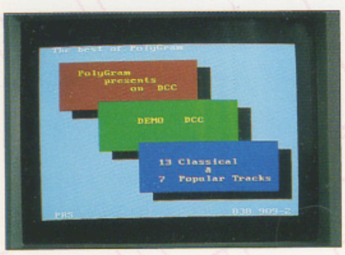
Through this brand-new feature, pre-recorded DCC cassettes carry various forms of textual information, which can be displayed on DCC decks, associated remote controllers or TV screens.

Text Mode information is organized in items; up to 255 different items can be included on the tape.
Certain items supply defined categories of information:

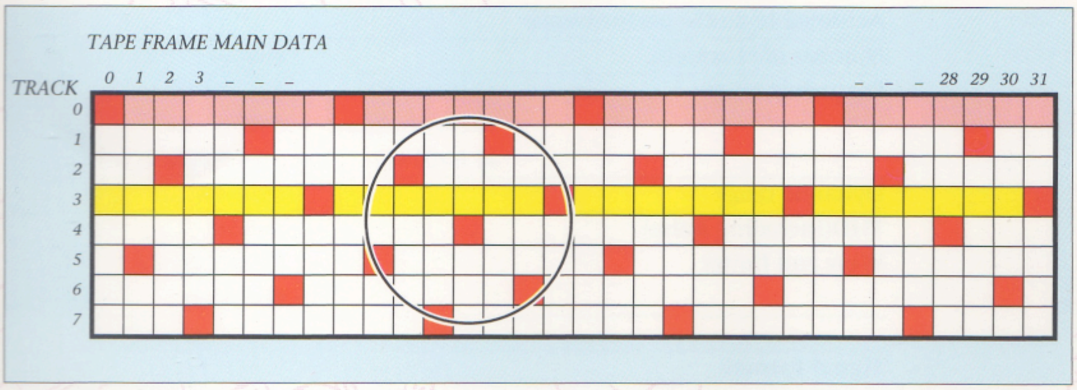
- The album title
- The complete list of track titles
- The names of the artists on each track
- Lyrics which can be displayed in synchronism with the music

Texts can be written on the tape in up to seven languages, allowing consumers to make their choice.





Two examples of the text mode (display).



PASC data bytes in chequer-board pattern in a tape frame.
A drop-out as large as the outline shown does not impair sound quality, nor does the absence of a complete track.

Simple graphics, 16 colours, several fonts and visual effects like scrolling are all part of the text mode feature.

The texts are formatted for three sorts of display:

- 1 line of 12 characters
- 2 lines of 40 characters
- 21 lines of 40 characters

Text mode offers interesting and useful information, uniquely characteristic of DCC. The extra user-convenience of being able to identify the cassette and read about the music constitutes very visible added value for DCC buyers. In addition, text mode opens the way to new applications and greatly improved versions of existing ones.

TAPE MASTERING AND DUPLICATION

As the union of Compact Cassette and digital audio, DCC is based on a wealth of already developed technology. This is certainly the case in the tape duplication process for pre-recorded cassettes. The same, 64-times normal, copying speed is used, in the same flexible system of slave and master stations. These, however, employ a specially-developed high-speed duplication head.

An easy-to-use authoring and editing system, based on existing Compact Disc tape masters, is already designed and implemented. New features such as text mode are basically the only new challenge.

This new system, firmly established on a wide base of proven technology, has been implemented with an absolute minimum of teething troubles. The way to the new repertoire of pre-recorded DCCs is open.

TECHNICAL DATA

Achievable audio performance		
Number of channels		Stereo
Frequency range	at fs=48kHz	5-22000Hz
	at fs=44.1kHz	5-20000Hz
	at fs=32kHz	5-14500Hz
Dynamic range		>105dB
THD(including noise)		>95dB
Wow and flutter		Quartz crystal precision

Signal format	
Sampling frequencies	48,44.1,32kHz
Coding	PASC
Audio bit rate	384kbits/s(at 48kHz)
Error correction system	C1,C2 Reed Solomon block code
Modulation system	Eight to ten (ETM)
Pre-emphasis	Optional

Cassette	
Recording time	Up to 2x45 min(D90). Provision for 2x60 min(D120)
Tape type	(Video) Chrome or equivalent
Tape width	3.78mm
Tape speed	4.76cm/s
Number of tracks	8 digital audio 1 subcode
Track width	>185µm
Track pitch	195µm

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