THE MD (MINI-DISK) SYSTEM - A CONTRIBUTION TO THE DIGITAL AUDIO DISK STANDARD

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BY

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It is surely not an accident, that the possibilities of using LSI (large scale integration) in the record industry, and possibly creating a significant change thereby, is being discussed during the LSI decade. But it certainly is a coincidence that this comes virtually on the 100th anniversary of the phonograph record. The development which our record technology has experienced during that time has led to enormous improvements as far as fidelity, playing time, price reduction and distribution are concerned, without really altering the original analog methods of recording and playback. But in spite of these admirable advances, we appear to have reached the upper limit of quality attainable in this technology. Due to the handling of records, the impulse type of ticks and pops cannot be entirely avoided. The signal-to-noise ratio, especially for the low frequencies (rumble), is unsatisfactory. The multiple tape copies necessary during production of the program produce modulation noise as well as cumulative time base and compression effects which adversely affect the transparency of the recording (Fig.1). That is why direct-to-disk recordings, which circumvent, in their production, the tape copies of the first and second generation, enjoy increasing popularity. Because these direct recordings cannot make use of the usual artistic editing and their manufacturing limitations on quantity, their production costs remain high and their use is not possible for complex works such as symphonies, complete operas, etc.

DIGITAL TECHNOLOGY PROVIDES ANSWERS

From the communications field we know of methods which virtually eliminate disturbing influences, by converting analog signals into digital language and later, after transmission or storage, re-convert these into the original analog signals. This is done by measuring the instant amplitudes of sound waives at very short intervals and by assigning to each of these values a pre-arranged code. This data in the form of

pulses is transmitted or stored. Any errors which may appear are corrected, and it is finally returned to its original analog form. This is done through so called Pulse Code Modulation, PCM for short.

Very high quality sound signals require a great amount of data per unit of time, i.e., the transmission band width must be made greater than for normal analog technology, and with it, the storage density on the disk record as well.

This results, of necessity, in a digital record which is totally incompatible with traditional phonograph records.

This incompatibility is more than compensated by the unusual advantages of such a disk:

- Much greater S/N ratio; great dynamic range.
- Elimination of pulse type disturbances through error correction.
- Practically no cross-talk.
- Negligible distortion.
- Time base errors are corrected.
- Virtually no quality reduction when generating several generations during production.

The technical prerequisites required to allow this technology, which has hitherto only been available to the communications field, to be made available to entertainment electronics, are known today:

- Codes which almost fully correct for errors are available.
- The enormous strides which large scale integration (LSI) has made in recent times, will soon provide us with D/A converters of very high precision.
- Records featuring high storage capacity and playback methods with extremely wide band width are available from video disk technology.

THE PROBLEM OF STANDARDIZATION

As is the case with the phonograph record throughout the world today, it would be desirable to evolve a world wide standard for the PCM disk before such a record is marketed; a standard which will assure decades of excellent quality. Such a standard must take into consideration both the total electronic processing to be used, as well as the high density storage system (disk/playback unit). There is a certain interdependence between these two.

When choosing a code, the following must be considered:

- high, but not exaggerated demands on quality and fidelity.
- compatibility with the code employed in the studio.
- possible compatibility with codes of other future transmission channels (e.g. PCM satellite transmission).
- simple but adequate error correction system, keeping equipment costs reasonable.

The high density storage system (disk/playback unit) should fulfill the following demands:

- simple and serviceable replication method for the disk.
- compact in size - small diameter.
- double faced disk.
- playing time per side at least 45 minutes.
- search capability for individual selections.
- no excessive demands on accuracy.
- simple handling of both record and playback unit.
- secure protection against damage to the record.
- long life expectancy for both disk and player.

In view of these problems of world standardization, numerous national and internationa standards committees have been organized, whose members include virtually every major record and high fidelity manufacturer. So far these efforts have bourne some fruit; the original demand for compatibility between videodisk and such an audio record is no longer in the foreground. However, agreement must yet be achieved for the code as far as quantisation, sampling rate and bit rate are concerne and for the player, the type of high density storage as well as the disk diameter.

It is important to remember that the entertainment electronics field has available two groups of high density storage systems: Table 1 . Those systems which play back without record contact and those in which the pickup touches the disk.

The second group may be divided into those with piezo-electric or electrostatic pickups riding in a groove, and electrostatic ones without a groove.

It is conceivable that those systems which have a groove structure can be made compatible. It is possible to use a pressure transducer (piezo-electric) both for PVC pressed disks and those made of a conductive material intended for electrostatic playback. The storage densities achieved are comparable.

TELEFUNKEN/TELDEC -- A SUGGESTED PCM AUDIO DISK

Telefunken and Teldec suggest the following standard for a digital audio disk based on prior work in the videodisk field and the above descriptive analysis:

For the high density storage system:

1. A conventionally pressed PVC record, with a trapezoidally shaped, vertically recorded information groove on both of its sides. Protected against damage by a cassette. The record to remain inside the cassette during playback.

2. Playback using a piezo-electric pressure transducer. This type of pickup has recently been greatly improved as far as its groove tracking behavior and service life are concerned. The latest of these transducers can play extremely short wave lengths down to 0.5 mm.

For the encoding parameters, the following is suggested:

1. QUANTIZATION

14 bit linear. The S/N achievable with 14 bit (86 dB) is fully sufficient for a program dynamic range optimized for normal living rooms. The much greater cost of a 16 bit system appears justified only for recording use, with its much greater overload reserve demand.

2. SAMPLING RATE

48 kHz. This frequency is compatible with the rate suggested by the Technical Commission of the Federal Association of the German Phonograph Industry and the RIEE, and expands on the suggestion of the CMTT for digital transmission via cable, micro-wave links and satellites, Simple transcoding is possible.

3. TRANSMISSION CODE

Biphase. The selected piezo-electric pressure transducing system with its high resolution down to the smallest wave lengths, permits a biphase code. Even though this requires twice the band width when compared with the Miller code, its demodulation is accurate and simple.

Additional technical data for the disk

Playing Time:	2 x 60 minutes
Number of transmission channels:	4
Addressing:	Automatic search
Diameter:	135 mm (5.3")
Groove spacing:	1.66 µm ≙ 0.065 mils ≙ 600 lines/mm ≙ 15,240 Lpi

Playback groove velocity:	Constant: 1.89 m/s ≙ 6.2 ft/s ≙ 4.23 mph
Revolutions per minute:	between 278 and 695 rpm
Smallest wave length:	0.61 µm ≙ 0.024 mils
Transmission rate:	3.072 Mbit/s
Storage Density:	approx: 1000 kbit/mm^2 = 645.16 Mbit/inch^2

The playback unit concept for these disks permits the following uses:

- User selectable stereo or binaural reproduction.
- Separately recorded "ambiance" to permit the user free choice of mixing, depending on whether loud speakers are used in connection with room accoustics, or binaural head phone listening.
- Separate recording of vocal or solo instrument to permit a choice of balance during playback or to allow the user to add his own solo part (so-called add-a-part records).
- Spoken recording of album liner notes.
- Using the automatic addressing feature, 2 hours of stereo per side for extra long works such as oratorios, operas and concertos.
- Quadraphonic sound with absolute channel separation.

RECORDING AND MANUFACTURING THE DISK

It was the purpose of our research to bring the tape-to-disk transfer, plating and pressing processes for this high density record on the one hand, and the playback unit technology on the other into agreement to permit use of today's phonograph record technology, while fulfilling the increased mechanical tolerance demands which a digital disk poses.

The recording of the digital information from tape is done mechanically in real time onto a metal blank. This original already possesses the centering and profile of the finished record, obviating the need for additional work on the stamper which might adversely affect tolerances. The direct cutting of the mother has the distinct advantage over optical systems by eliminating seven additional mechanical steps which may increase the chance of increasing the number of faults significantly. (Table 2 & Fig. 2)

This new PCM disk uses practically the same methods and materials used today in the manufacture of the traditional record. Additional investments are not required. The comparatively low number of faults which such a disk has, is one of the reasons why this system, with a data redundancy of only 30% for error correction, suffices in spite of the tremendous storage density.

THE "MD" (MINI-DISK) SYSTEM -- A CASSETTE RECORD

All high density systems using record contact playback use surface recorded information. The disk surface protection as well as the simplified structural concepts disk/player are combined in the MD (mini-disk) system.

The disk is protected against damage by a fully enclosed cassette, which is only partially opened for playback within the player itself. Playback is from below the disk. Within the centering area, recognizable from its pressed conical shape, the disk contains a ferro magnetic material. During playback, a magnet pulls the record into the centering ring and holds it there. The playback from below and the centering system, aside from precise centering, have the advantage that in the record press, it is no longer necessary to have top and bottom stampers in accurate alignment with one another. The disk is, of course, free to move within the cassette (Fig. 3).

The cassette replaces the traditional albums and permits a compact collection when compared with traditional long playing records of identical playing time (Fig. 4).

THE PCM DISK WILL EVENTUALLY GAIN THE UPPER HAND

The results of our research and development shows that todays record and all of its parameters can be significantly improved upon using available and near future sound storage technologies involving high density PCM systems. Besides the handling ease of this disk, the MD System playback unit concept permits problem free operation, automatic selection search and a very compact size as well.

In view of the incompatibility with the world wide conventional records and playback units, it is a foregone conclusion, provided we get a world wide standard for the PCM disk, that we will see a gradual change-over to the new disk.

	Playback systems with mechanical pick-up contact			Playback systems without mechanical pick-up contact	
Information track	Groove	Groove	Groove-less	Groove-less	Groove-less
Record compound	PVC	PVC + carbon	PVC + carbon	PVC	PVC - metallized metallized surface
Pick-up system	Piezo-electric	Electro-static	Electro-static	Photo-electric	Photo-electric

TABLE 1: High Density Disk Systems

		PIEZO-ELECTRIC SYSTEM	OPTICAL SYSTEM
1.	MATRIX PROCESS	- - - -	Photo-resist coating
2.		- - - -	Exposure under clean room conditions
3.		- - - -	Developing
4.		- - - -	Silvering
5.		- - - -	Metal master
6.		Direct cutting into metal surface	Electro-plated mother
7.		Stamper	Stamper
8.	RECORD MANUFACTURING	Pressing	Pressing
9.		- - - -	Metallizing
10.		- - - -	Sealing

TABLE 2: High Density Disk System Manufacturing Process

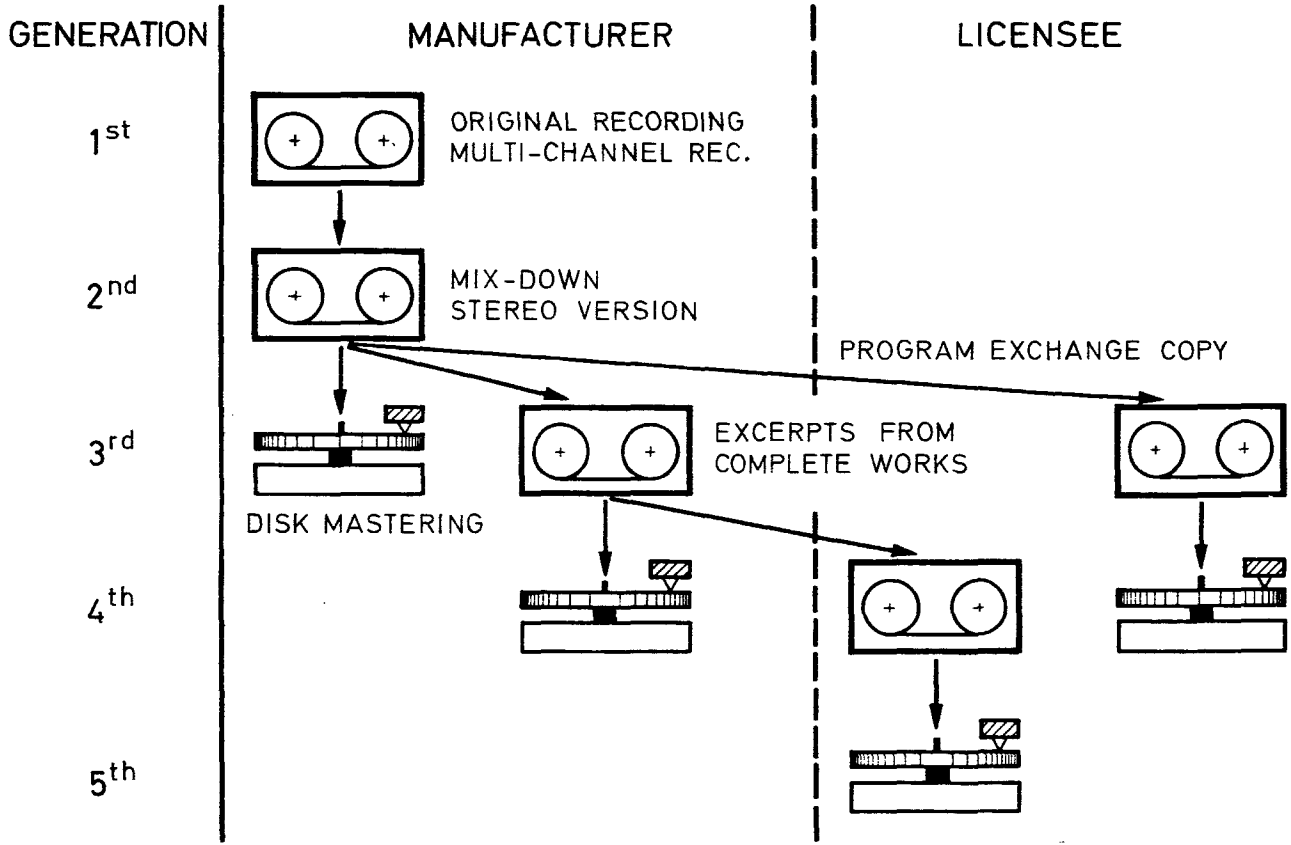
GENERATION
MANUFACTURER
LICENSEE
1st
ORIGINAL RECORDING
MULTI-CHANNEL REC.
2nd
MIX-DOWN
STEREO VERSION
PROGRAM EXCHANGE COPY
3rd
EXCERPTS FROM
COMPLETE WORKS
DISK MASTERING
4th
5th

Fig. 1

Fig. 2

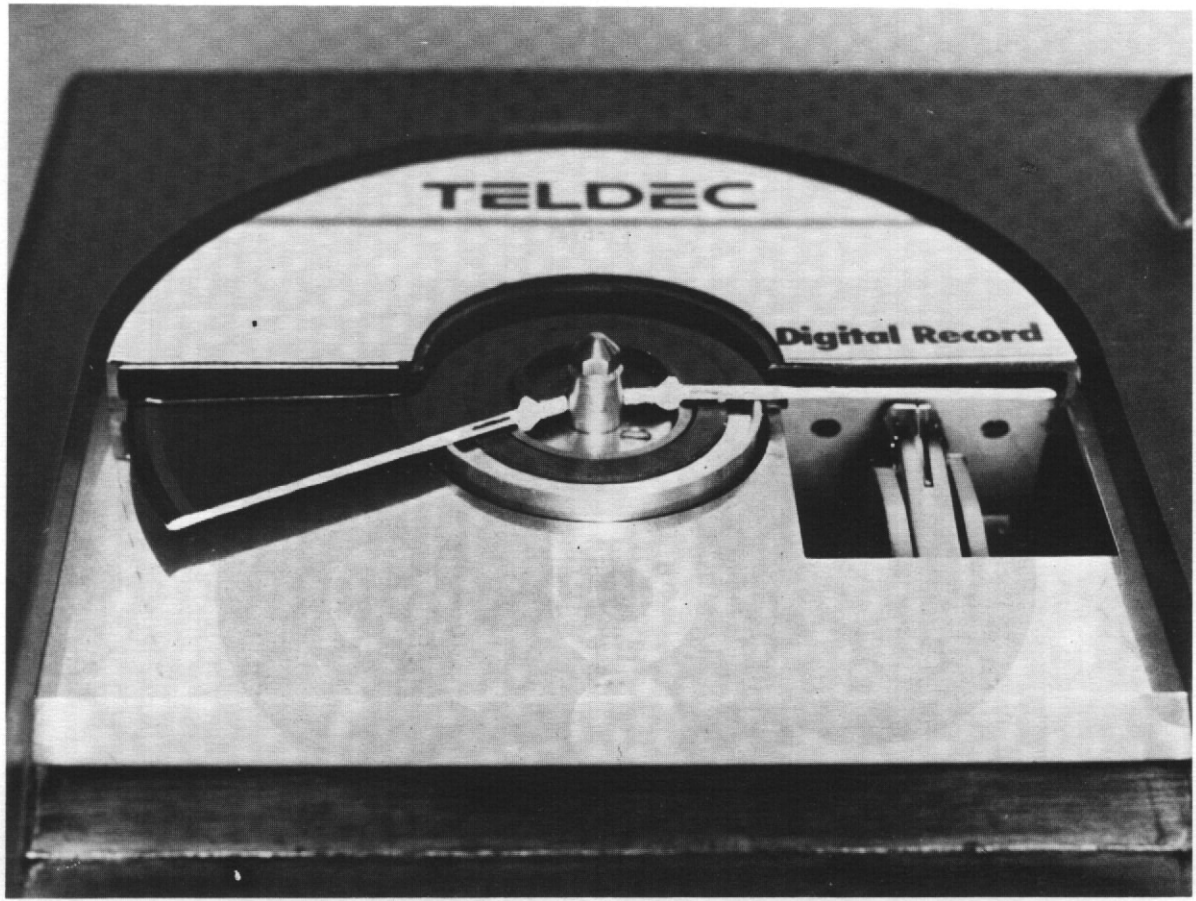

Fig. 3

Fig. 4