Preprint 2908 (F2)

20-Bit 8-Channel Digital Audio Recorder

T. Okuda, K Koyanagi, Y Yokomachi,
C. Yamawaki, T.Iwaki, T. Sasada, T.Ishikawa

MS Project Team, Precision Technology Laboratories,
SHARP Corporation, Japan

Presented at the 88th Convention 1990 March 13–16 Montreux

AES

AN AUDIO ENGINEERING SOCIETY PREPRINT

20-BIT 8-CHANNEL DIGITAL AUDIO RECORDER

T. Okuda, K. Koyanagi, Y. Yokomachi,
C. Yamawaki, T. Iwaki, T. Sasada and T. Ishikawa

MS Project Team
Precision Technology Laboratories
Corporate Research and Development Group
SHARP Corporation

ABSTRACT

This paper describes the functions and the composition of a Digital Multi-channel Recorder (DMR).

The DMR is the recording unit to realize the 8-channel digital audio recording and the digital editing for professional and semi-professional use.

By using the DMR with sub-systems, the following functions are available :

1. 8-channel digital recording with 8mm wide tape.
2. The 20-bit linear quantization and 48, 44.1, 32kHz sampling frequencies.
3. Punch in/out, synchronized recording with other channel and mixdown.
4. Analog signal and auxiliary information recording.

Furthermore, this unit realizes lower cost and compact size.

1. Introduction

The recent progress of digitization technology in the signal processing and recording is remarkable. This new technology is desired by consumers with CD and DAT. On another side, the home music-productions are now going to be done at some fields , like commercial song, pops and so on , by the progress of musical instrument supported with electronic technology. However, the digital home music-production system, especially the digital multi-channel recorder, has not been developed sufficiently yet. Therefore, the needs of high performance digital multi-channel recorder for personal use have been increasing.

From above point of view, we have developed this DMR to realize the high quality recording and editing for professional, semi-professional and superior amateur use.

This report describes the functions and the composition of the DMR.

2. Overview of the DMR System

Basic parameters, block diagram and external appearance of the DMR are shown in Table 1, Fig. 1 and Photo. 1 respectively.

8 PCM channel, 2 analog tracks and 2 auxiliary tracks are available in the fundamental mode. Then 5 data-tracks are provided for one channel. As the encoding/decoding signal processing is united every 5 tracks, each channel can be recorded and/or played back independently. 20-bit data slot per sample is provided for PCM channel, then a dynamic range greater than 120dB is available.

48, 44.1 and 32kHz sampling frequencies are available. Besides the above, an optional sampling frequency is enabled to be established from 28 to 54kHz arbitrarily.

To keep the linear recording density constant, the tape speed is varied with the sampling frequency. In the fundamental mode, the tape speed is 127mm/sec (5 IPS) at the sampling frequency of 48kHz. Then a 20-minutes' recording is available with a compact size cassette (D 77 x W 118 x H 15.9) loaded with 8mm wide tape. In the half-speed mode, 10 data-tracks are provided for one channel. Although the number of PCM channel is reduced to 4-channel, a 40-minutes' recording is available.

As a PCM recorder unit, the DMR provides only digital I/O port for PCM channel. By using the DMR and sub-systems such as

A/D・D/A converters, mixer, crossfader, synchronizer and controller, the high quality digital multi-channel recording and some electronic editing functions, as follows, are realized.

1. Punch in/out
   The arbitrary part of a recorded channel is replaced with newly recorded signal.
2. Over dubbing
   On playing back some channel, sources are recorded to the other channel, synchronizing with the played back channel.
3. Ping-pong recording
   The playback signal of one channel is recorded to another channel.
4. Mixdown recording
   The playback signals are mixed, and then re-recorded.
5. Vari-pitch
   On playing back, the tape speed is variable in the range of ±12.5 %.
6. Auto locate
   The arbitrary part on the tape is located with tape count or absolute time recorded on the tape.

To achieve above recording and editing functions, we have developed the precision components and the high technologies as follows :

1. Thin film heads to realize high track density like 40 data tracks and 4 sub-tracks in 8mm wide tape and high linear recording density (54.4kBPI).
2. Head-guide unit to be composed of one recording head, two playback heads and tape guides precisely.
3. Tape transport mechanism to enable the precise tape traceability and the stable tape-to-head contact.
4. Signal processing technologies and original LSIs to perform a high error correcting capability.
5. Electronic control of all functions except for the cassette insertion.

For all above features, the DMR is integrated into 5.25" form factor, and then considered to realize an electronic recording/ editing equipment compactly.

3. Head-Guide Unit

The head-guide unit is composed of a recording head, playback heads and tape guides. By combining these elements into one block, the geometrical arrangement of heads, the relative position between heads and tape et al. are maintained accurate. Fig. 2 shows the schematic diagram of the tape-guide unit.

3.1 Magnetic Heads

We have developed the thin film magnetic heads newly. They generate 40 data-tracks and 4 sub-tracks in 8 mm wide tape. Playback heads utilize the magneto-resistive (MR) effect [1] and thus the high output level is obtained under the high recording density. An inductive head, with incorporated driver IC, is employed as a recording head.

The playback head 1, the recording head, and the playback head 2 are arranged along the tape running direction. The playback head 2 is used to monitor the recording condition, and the playback head 1 is used for usual playback.

When the punch in/out is carried out on certain channel, the data played back from the playback head 1 is decoded by the decoding circuit. Then the decoded data and the input data are combined to make new encoded data. The new encoded data is recorded by the recording head at the same tape position of the old data.

The time necessary for data-decoding and data-encoding must coincide with the tape running time from playback head 1 to the recording head. So that, both the distance, between these heads and the tape running velocity are settled with high accuracy.

3.2 Track Pattern

Fig. 3 shows a track pattern of the DMR. The track pitch of data track is 170μm, and the recorded track width and the playback track width are respectively 150μm and 40μm.

3.3 Tape to Head Contact

Both tape tension and the head crown shape are optimized, so that the high density recording (54.4 kBPI, $\lambda min = 0.75μm$) and the long life of magnetic tape and heads are realized.

3.4 Tape Guides

Overwriting is necessary in order to re-record the new data at arbitrary channel for punch in/out. Then relative tape height to magnetic head must be kept unvaried. So that, tape guides are combined with magnetic heads.

The magnetic tape is wrapped around the guide poles at some angles and then the tape waving is depressed at the guide poles and the guide flanges. Ceramics is adopted as tape guides in order to realize the long life of magnetic tape and head guide unit.

4. Tape Transport Mechanism

4.1 Outline of Mechanism

This DMR has 4 magnetic heads (1 recording head, 2 playback heads and 1 erase head). The tape cassette inserted through the front bezel is loaded automatically. Then the magnetic tape is drawn out automatically and runs along the head-guide unit.

This DMR has 5 motors (1 capstan motor, 2 reel motors, 1 cassette loading motor, and 1 tape drawing-out motor).

4.2 Tape Driving Method

In order to keep the high density recording, it is necessary to stabilize the tape tension around the magnetic heads. Furthermore, the tape speed must be constant so that the tape running time from the playback head 1 to the recording head is kept unvaried. For above purposes, the dual capstan driving mechanism is adopted. The capstan is driven directly by the hole-motor controlled with PLL servo. Different tape speeds are realized quickly by changing the reference frequency of PLL servo.

Fig. 4 shows a relation between the tape speed variation and the frame error rate. In this figure, the horizontal axis shows the frequency at which the speed is varied sinusoidally ±12.5%. Thus, this DMR has the sufficient ability of the variable pitch control for practical use.

4.3 Tension-Control Method

The tape tension within the dual capstans is varied by the low frequency fluctuation of the supply-side tape tension. Therefore, the supply-side tape tension is controlled by the feed back control from the tension sensor to the supply-reel motor.

The takeup-side tape tension is controlled by controlling the torque of the takeup-reel motor in proportion to the takeup-reel radius. (Fig. 5)

4.4 Depression of Tape Waving

For overwriting, it is necessary to transport the tape at the proper position within ±27μm with respect to the magnetic heads. (Fig. 6) The factors of the position error between the tape and the magnetic heads are the assembly error of the head-guide unit, the tape waving and so on. Therefore, the tape waving must be depressed within the precision of the order of μm.

For above purpose, the tape guides are set up in tape transport mechanism as well as the head-guide unit.

4.5 Cassette and Cassette Loading Mechanism

As we have designed the cassette loading mechanism compactly and are using the tape cassette which width is less than about

120mm, a 5.25" form factor size unit is realized.

As the tape is used to be drawn out, the DMR can be adapted to various cassette by designing the tape transport mechanism and the cassette loading mechanism newly.

5. Signal Processing Technologies

5.1 Outline of Signal Processing

The track-to-channel assignment is shown in Fig. 7. To save the tape consumption, the PCM signal of one channel is distributed to 5 tracks in the fundamental mode. On the other hand, the circuits of the whole 40 tracks become huge. To integrate these complex circuits, we employ the time-dividing technology and multiplex the processing circuits of 10 tracks to 1 circuit.

The block diagram of the DMR unit is shown in Fig. 8. Commands are fed to the mechanism controller (microprocesser), then interpreted. The mechanism controller also performs software servo control of the tape tension.

When playback is performed, reproduced signal on each track, picked up by the yoke type thin film MR head, is amplified by PB-AMP. MPX combines PB-AMP's outputs every 10 tracks and then selects either playback head 1 or 2. The multiplexed signals are digitized by 8-bit A/D converter, then fed to the digital signal processing block. EQ, PLL and MODEM circuits perform equalization, detection and demodulation respectively. The demodulated symbols (8-bit data) are stored in the memory. To perform interleaving, the memory is controlled by USC. ECC performs error correction. As for the errors beyond the correcting capability, USC performs interpolation. Then playback signals are output.

On recording, USC divides input signals (20 bit samples) into 8 bit symbols and then stores the symbols in the memory. ECC reads symbols from the memory, and then calculates C1 and C2 parities. After that, symbols are fed to MODEM then modulated. REC-AMP records modulated data to tracks with the pulse-train recording.

Analog track is recorded with frequency modulation, of which carrier is 30 kHz. Auxiliary track(1), as a control track, is provided for the system information and the address on the tape. Auxiliary track(2), as a time code track, is provided for external time code such as SMPTE and EBU.

5.2 Modulation and Equalization

Because of limited bandwidth, some modulation and equalization are required in the magnetic data recording . The 8/10 modulation is employed in the DMR. Although this modulation has a defect of small Tmin, it has many advantages such as no DC components, wide window margin and small Tmax/Tmin. [2]

To reduce intersymbol interference, the 7-tap digital FIR filter is employed as an equalizer. The eye pattern after equalization is shown in Photo. 2.

5.3 Error Correcting Code and Interleaving

Random or burst errors tend to occur due to the high density magnetic recording and due to the discontinuous area on the tape, which is generated by punch in/out [3]. To correct these errors, powerful error correcting code is required.

We employ the product code of C1(32, 30, 3) and C2(40, 32, 9) Reed Solomon code over $GF(2^8)$. The symbols of C1 is along the track. The symbols of C2 is dispersed widely by interleaving. Then we get miscorrection probability less than 10^{-12} even if the playback symbol error rate is 10^{-3}. The random error correcting capability is shown in Fig. 9.

5.4 Control

The command and the status of the DMR are transfered with two asynchronous serial lines. Thus the DMR can be controlled by a personal computer, with RS-232C port and level converter . Commands consist of mechanism control commands (STOP, PLAY, EJECT et al.) and signal processing commands (REC, MUTE et al.), and then all function of recorder unit can be controlled.

5.5 LSIs

We have developed 8 species of integrated circuit . They consist of 3 CMOS gate array, 2 CMOS standard cell, 1 BiCMOS standard cell and 2 bipolar ICs. As for the digital signal processing block, circuits for 2 PCM channel are realized with 4 LSI and 1 RAM, and circuits of 8 PCM channel are integrated into the 2 PCBs. (size = 198 X 140mm)

6. Conclusion

We have developed 20-bit 8-channel Digital Audio Recorder to realize the high quality recording and editing of the home music-production for professional, semi-professional and superior amateur use.

The compact size and the economical price have been achieved by development of the multi-track thin film heads, the high performance mechanism and exclusive LSIs.

This DMR can be controlled easily by the use of controller (personal computer et al.). This DMR is available for various applications like digital storages and data recorders , and the worldwide activity is expected.

7. Acknowledgement

The authors are grateful to the following personnel of SHARP Corporation; Messrs. H.Okada, S.Kakiwaki, H.Ohtsuka, H.Mizumaki, H.Takeuchi, T.Koyama and M.Tsuji for their support to the project, Mr. T.Kira and other members for the development of the thin film magnetic heads.

References

[1] T.Miyauch et al. "Inverse Effect of Magnetostriction in Yoke Type MR Heads", IEEE Transactions on Magnetics, MAG-23, No.5, Sept. 1987.

[2] S.Fukuda et al. "8/10 Modulation Codes for Digital Magnetic Recording", IEEE Transactions on Magnetics, MAG-22, No.5, Sept. 1986.

[3] K.Sugiyama et al. "The Signal Processing of a Professional Use Digital Audio Recorder", AES Tokyo Convention, [B-2], June 1987.

TABLE 1 BASIC PARAMETERS OF THE DMR

ITEM		CONTENT					
Mode		Fundamental			Half-Speed		
Number of PCM Channel		8			4		
Number of Tracks	PCM	40					
	Analog	2					
	AUX.	2					
Number of Tracks per Channel		5			10		
Quantization (bits/sample)		20					
Linear Recording Density (kBPI)		54.4					
Tape		MP (Hc = 1500 Öe)					
Modulation		8/10 (Tmin=0.8 : Tmax=3.2)					
Error Correction Code		Product Code of RS(32,30),RS(40,32)					
Sampling Frequency (kHz)		48	44.1	32	48	44.1	32
Tape Speed (IPS)		5	4.6	3.3	2.5	2.3	1.7
Recording Time (minutes)		20	22	30	40	44	60
Transmission Rate (MBPS)		10.9	10.0	7.3	5.4	5.0	3.6
Recording Capacity (GB)		1.6					

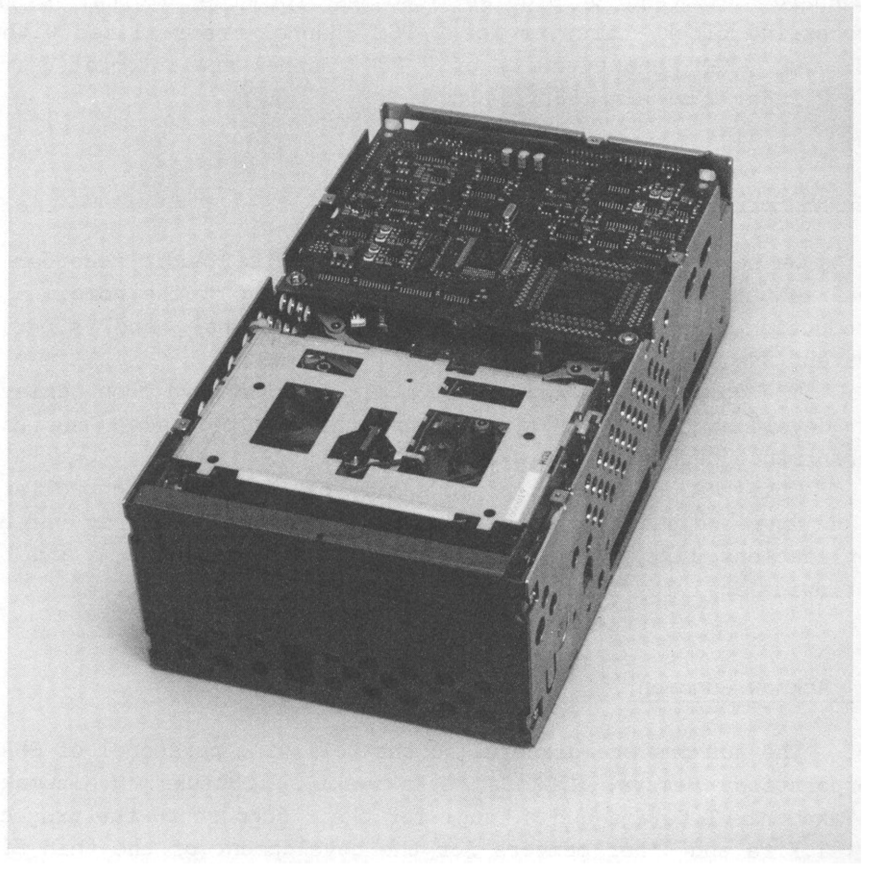

PHOTO.1 APPEARANCE OF THE DMR

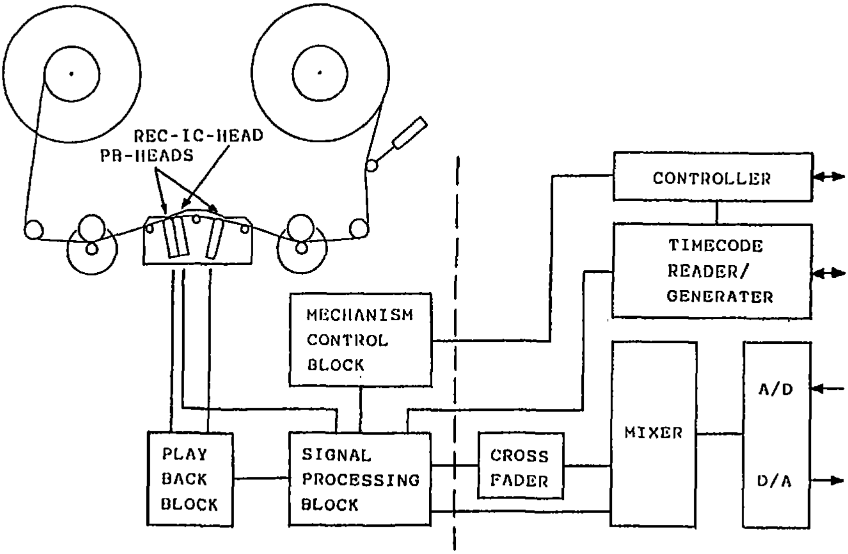

FIG.1 BLOCK DIAGRAM OF THE DMR SYSTEM

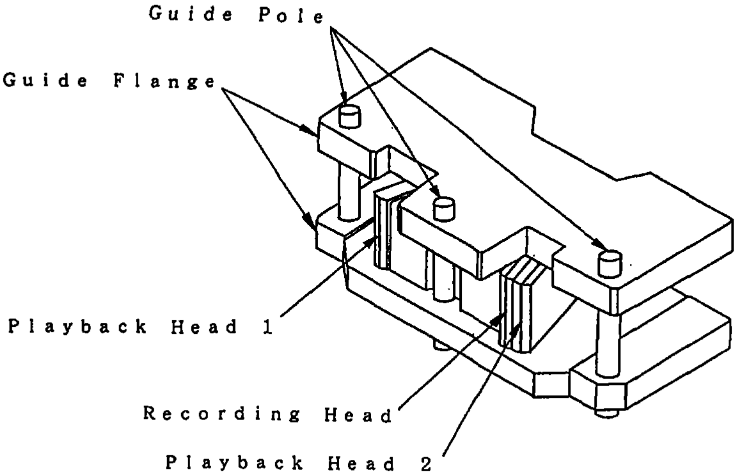

FIG.2 SCHEMATIC DIAGRAM OF HEAD-GUIDE UNIT

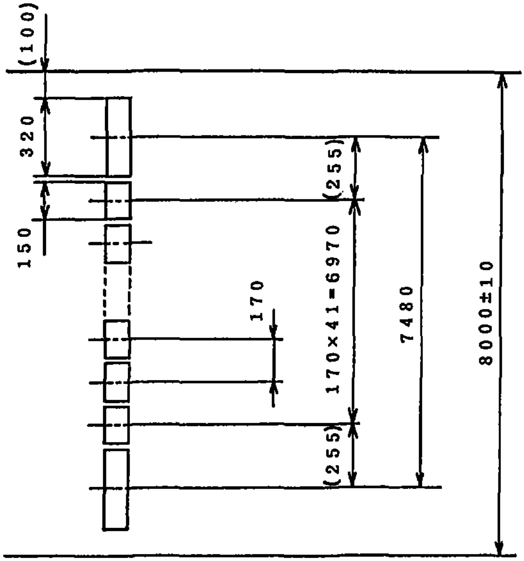

FIG.3 TRACK PATTERN

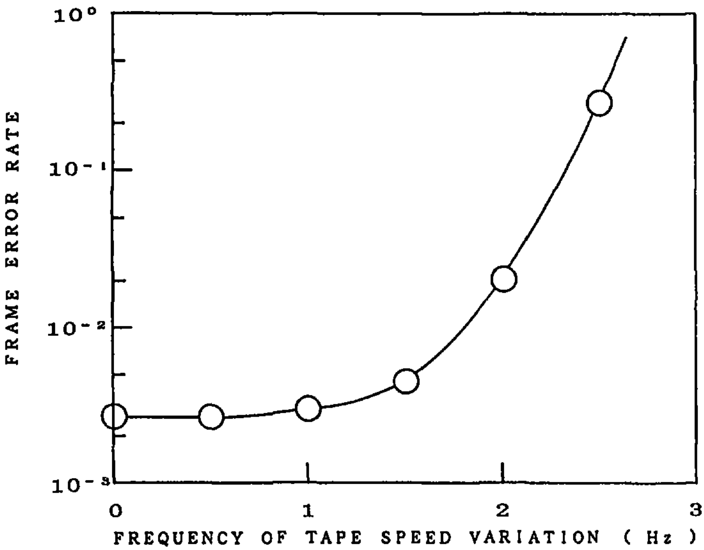

FIG.4 RESPONSIBILITY OF VARI-PITCH CONTROL
(Tape speed is varied sinusoidally ±12.5%)

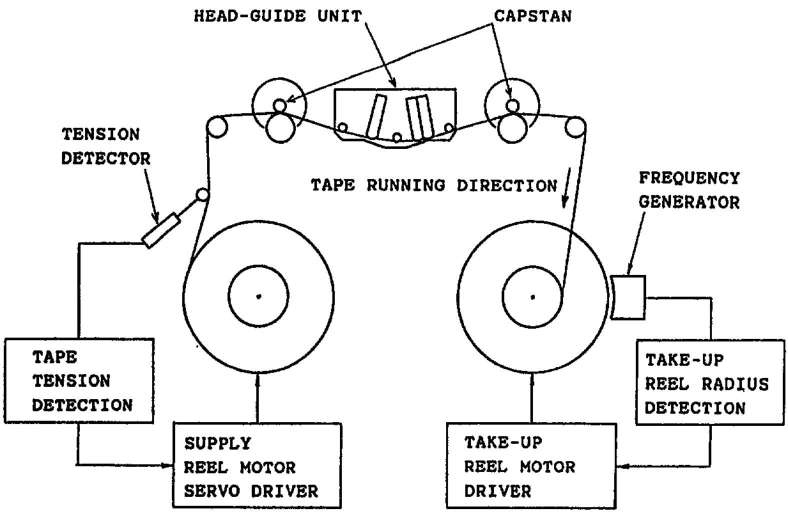

FIG.5 SCHEMATIC DIAGRAM OF TENSION CONTROL

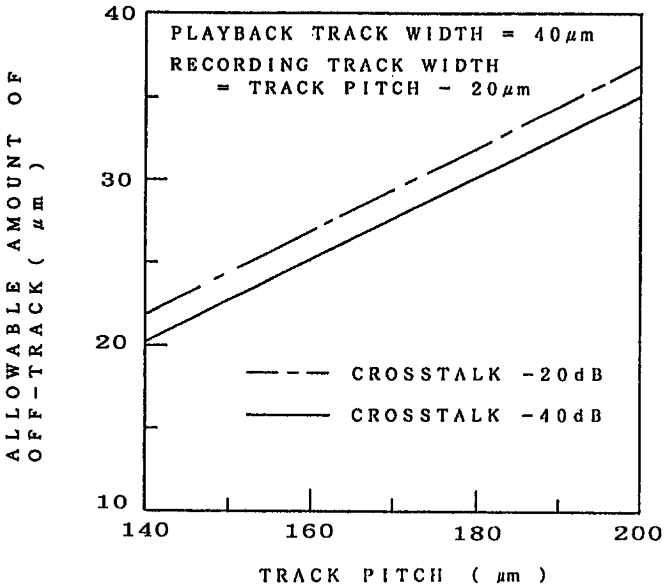

FIG.6 EFFECT OF TRACK PITCH TO ALLOWABLE AMOUNT OF OFF-TRACK

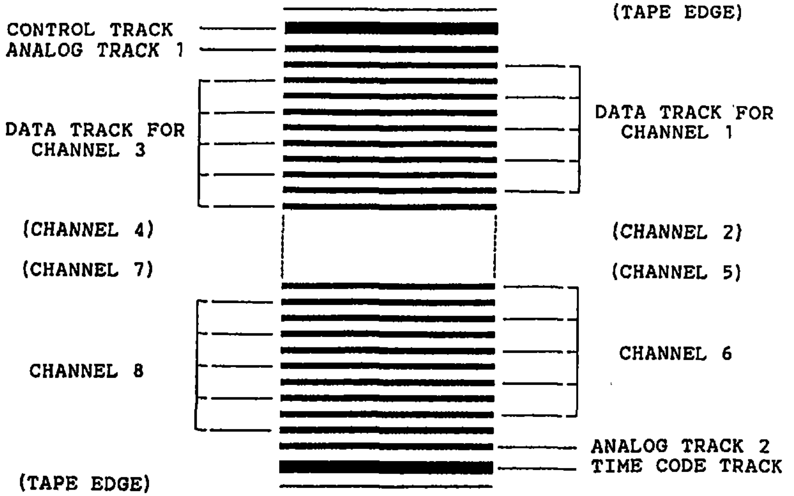

FIG.7 CHANNEL ASSIGNMENT

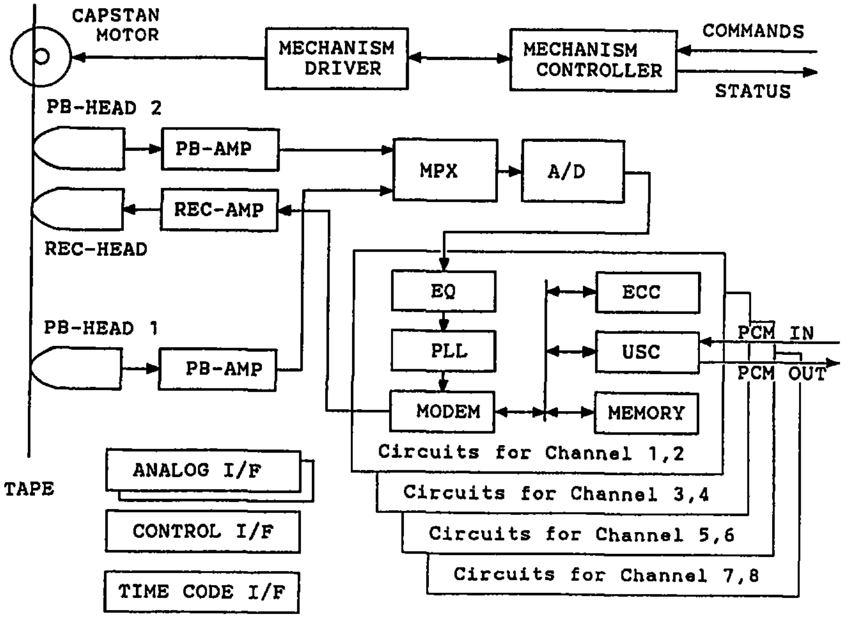

FIG.8 BLOCK DIAGRAM OF THE DMR CIRCUIT

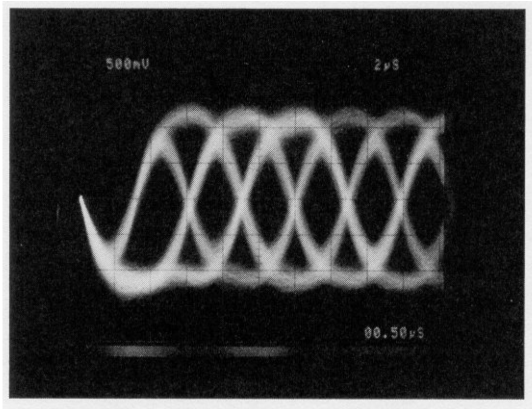

PHOTO.2 EYE PATTERN

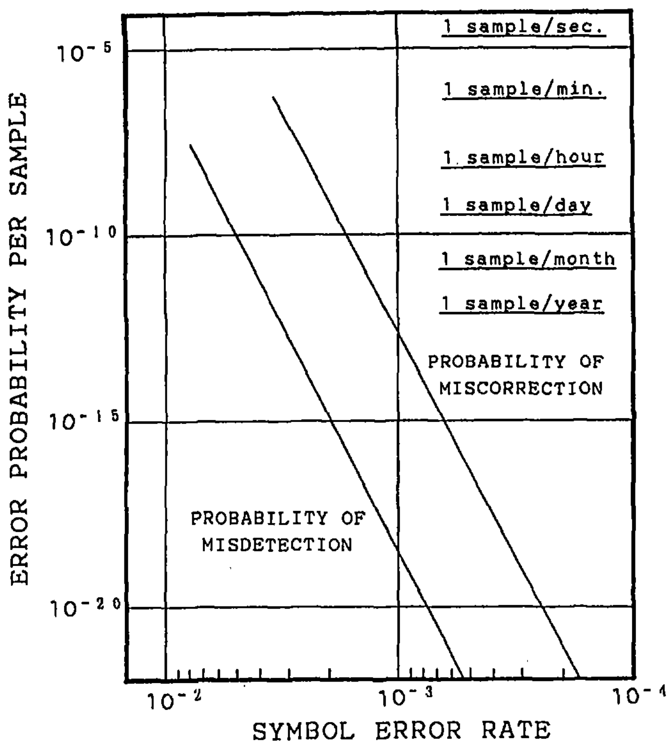

FIG.9 RANDOM ERROR CORRECTION CAPABILITY