Preprint 2589 (E-1)

Time code in sub data area of R-DAT,

H. Yamazaki, T. Ketori, T. Morita,
S. Okazawa, H. Nogima and Y. Abe
Fostex Corporation
Tokyo, Japan

**Presented at
the 84th Convention
1988 March 1-4
Paris**

TIME CODE IN SUB DATA AREA ON R-DAT

H. Yamazaki, T. Ketori, T. Morita,
S. Okazawa, H. Nojima and Y. Abe
FOSTEX Corporation, Tokyo, Japan

ABSTRACT

Control functions of tape locating and synchronizing with other equipment are indispensable when using the R-DAT format in professional applications. The time code characteristic of R-DAT, is unsuitable for this purpose and it is preferable to use the SMPTE/EBU time code which is more popular today. SMPTE/EBU time code, however, cannot be recorded directly due to the difference in frame cycle. In view of this situation, we have devised a format for recording in the sub data area, which allows use of the SMPTE/EBU time code in the conventional manner and also reading out under high tape speeds. We have developed a product incorporating a control system which fulfills the above objective. In the following, we wish to propose application of this new format.

1. INTRODUCTION

R-DAT equipment (1) designed for consumer use is full fledged for professional applications as its high quality recorded sound is based on a sampling frequency of 48KHz and quantization of 16 bits. As Dr. Roger Lagadec had already proposed (Tokyo 1987) (2), if this R-DAT format can be directly applied to professional use, it will have great merit since low cost consumer LSI's and tapes can be used, the equipment will be highly portable since it can be reduced in size, and furthermore, the numerous variety of consumer software expected to appear on the market, can be used.

Electrical input and output specifications, selection of appropriate connectors, editing function, cueing function, record/reproduce functions corresponding to various sampling frequencies, etc. must be considered for professional applications. In addition, interchangeability between consumer equipments must not be lost to allow using consumer software.

These conditions, naturally, are prerequisites but the most important requirement in professional equipment is the ability to synchronize.

In the professional audio-visual production studio, picture, music, background sound, effects sound, lip sync and narration are separately made and edited. In these system, the various equipment must be matched in timing and run in synchronization. Also, the function of finding the recorded content at a given location, locating it at a specified point, and chasing another equipment already running, are also prerequisites. Given these abilities, it becomes possible for the R-DAT to be used as the slave of other recorders and visual equipment such as a VTR, and can be operated as part of an audio visual record/ editing system.

To be able to realize such a synchronizing function, a method of recording a synchronizing signal must be devised. However, a synchronizing signal recording format has not yet been standardized in the newly born R-DAT. The most popular signal used for synchronizing, at present, is the SMPTE/EBU time code. In the following discussion, the recording format we have devised for applying the SMPTE/EBU time code to R-DAT, and a brief outline of the prototype machine incoporating this synchronizing function, will be explained.

2. STUDY OF THE TIME CODE

2-1. Time code in the consumer R-DAT format

The consumer R-DAT format itself has a characteristic time code. We shall study here whether or not this time code can be used for the above mentioned objective.

The content of this time code are -

1) A-TIME indicating the absolute time from beginning of the tape.
2) R-TIME indicating the running time from beginning point of the recording.
3) P-TIME indicating the time from beginning of each program.

The hour, minute, second and frame informations are represented by BCD code and contained in one pack ("Pack" will be explained in item 3-2 Sub code of R-DAT).

This code has a concise style which effectively utilizes the R-DAT format. Actually, the function of searching a location upon the tape has already been established in products of several companies. However, this format has been conceived for singular use of R-DAT, and for the purpose of synchronizing with other equipment, it must be converted to match the SMPTE/EBU time code. As the frame cycle peculiar to R-DAT is 33.3 frame/sec., a frame converter, shown in Figure 1, is required but the converting is very complicated. Furthermore, measures must be taken to allow for the fact that this code has only time information and no clock information, such as that contained in the SMPTE/EBU time code.

Also, other information, in addition to time information, cannot be recorded as it has no provision such as the user bits in the SMPTE code.

In view of these facts, we have determined that there are few merits in using this time code.

2-2. SMPTE/EBU time code

The SMPTE/EBU time code is the most widely used today in synchronizing equipment at sound recording, video recording and editing. Figure 2 shows the composition of the SMPTE/EBU time code. As shown here in Figure 2, one frame of the SMPTE/EBU time code is composed of from bit "0" through bit 79, and the content is time information in hour, minute, second and frame; user bit; and frame synchronizing pattern. Frame cycle is 30 frame/sec. for NTSC, 29.97 frame/sec. for the drop frame, 25 frame/sec. for PAL/SECAM, and 24 frame/sec. for motion picture film. And this data is modulated by biphase and recorded as time data on the AUX track of a VTR or ATR. Owing to employment of the biphase modulation recording system, the SMPTE/EBU time code can reproduce the clock by itself to allow synchronizing the picture and sound.

Although this is a synchronizing signal originally designed for visual equipment, the fact that it has both clock information and tape position information for synchronizing and that it can be easily recorded in the same way as for sound signals, it is widely utilized for synchronizing between audio recorders.

There are examples of different time codes other than this SMPTE/EBU time code but the original objective of this code is in interconnection with other equipment and by the fact that generality is most important, we feel that it is most appropriate if study is conducted on applying the SMPTE/EBU time code which is employed in almost all equipment today.

3. DETERMINING THE RECORDING LOCATION

When applying SMPTE/EBU time code to the R-DAT format, it must first be determined where to record it.

The R-DAT track format is shown in Figure 3. Two auxiliary tracks of 0.5mm are provided along the upper and lower edge of the tape on which recordings can be made by a stationary head longitudinally to direction of travel and the angled tracks made by the rotary head consists of the main data area in which the sound signals are digitally recorded, and the sub data area in which data other than sound is recorded. When an attempt is made to record SMPTE/EBU time code on this R-DAT tape, the locations in which free recording can be made are the following two:

1) On the auxiliary track using a stationary head.
2) Record it as the sub-code in digital signals with a rotary head.

In the following, these two methods shall be compared in study to determine their merits and demerits.

3-1. AUX track

As these two tracks are reserved for spares, these can be used to record the biphase modulated time codes by a stationary head, in the same method as in conventional analog VTR recorders. However, what greatly differs here is that in a VTR, the video signal and time code are perfectly matched as they are analog signals recorded and reproduced in real time but in the R-DAT, about 60 msec. time lag occurs as the sound signal is digitally processed at recording and reproducing. To prevent this time lag, the time code must be delay processed at recording and reproducing.

The next point is, as the R-DAT tape speed is an extremely slow 8.15 mm/sec., the recorded wavelength of each bit of the SMPTE/EBU time code on the auxiliary tracks will be, for example, 1.7 µm for the NTSC which is the shortest frame cycle, and to maintain interchangeability between equipment, the relative position of the stationary head and rotary head must, at least, be kept at an accuracy under the above mentioned. Also, due to this extremely short record wavelength, drop out arising from tape edge deformation and clinging of dirt, and existence of bit jitter occuring from tape wow, there will be great difficulty in attaining stable recording and reproducing of time codes. In addition, although high speed search of more than 100 times is possible in R-DAT, stable reproduce output during this operation requires a wide band amplifier and therefore, will be difficult due to the aforementioned extremely short wavelength.

In view of the above, this method although simple to use, cannot be said as a recording method superior over the following which employ the sub code.

3-2. Sub code of R-DAT

High density recording is realized in the R-DAT by a rotary head guard bandless azimuth recording. Tape speed at normal record/reproduce is 8.15 mm and is 1/6 that of compact cassettes. Due to this, the tape can be fast wound at more than 100 times of normal recording speed. In addition to recording sound, the R-DAT format design allows recording various data for full utilization of this high speed operation.

The sub code format will be explained first in the following.

Figure 3 shows the track format. The length of one track is equivalent to 90 degrees around the circumference of a 30mm drum and the main data is recorded on the center 60 degrees. PCM sound data and some other information are all recorded in this area. The ATF (Automatic Track Finding) signal is recorded on 2.3 degrees each at both sides of this area and stable tracking can be applied with only the rotary head. In addition, there are two sub data areas on the outer adjacent sides.

Both data to be recorded in this sub data area and that which is added to the PCM sound signal and recorded on the main data area, are called sub code. However, sub codes recorded in the main data area cannot be recorded separately from the sound data. Therefore, we shall discuss the sub data area since it can be handled more freely.

Next, a detailed explanation will be made on the R-DAT sub code format in the sub data.

The two sub data areas adjacent to the main data area consist of eight blocks each. One block, as shown in Figure 4, consist of 36 symbols of 8 bits to each symbol.

Symbol 1 is the synchronize pattern, symbols 2 and 3 are data sw1 and sw2 for sub data identification, symbol 4 is the parity for sw1 and sw2, and symbols 5 through 36 are the data in the strict sense.

As shown in Figure 5, one sub code in the sub data area consists of a pair of even number and odd number blocks. This pair consists of 8 pack areas. Among these, 7 are used for the packs and the remaining one used for parity of these 7 packs. Therefore, the sub code format in the sub data area will be two blocks of even number and odd number as one pair.

On one track, 8 block pairs of this form exist in the sub data area consisting of 16 blocks. Consequently, there will be 8 packs each with identical numbers in these 8 pairs. Normally, the same data are repeatedly written over identically numbered packs in all 8 block pairs. By this method, the content of the pack can be read if at least, two continuous blocks of output can be obtained even during high speed search.

Figure 6 shows the relation between head and track during high speed travel. As shown here, at high speed winding, the head path will not correctly ride the original track but cut across several tracks. When the recorded pattern on the tape comes to run in the same direction to the head azimuth, data can be read out although partially. Theoretically, high speed search in excess of 100 times is possible to read more than two blocks of continuous data.

Figure 7 shows the data construction in one pack. A pack consists of 8 symbols from PC1 through PC8 and the leading 4 bit in the first symbol represent the pack item which is used for data identification. Also, an 8 symbol even number parity is recorded in the last symbol.

Outstanding features of the aforementioned sub code are as follows:

1) As the sound data and sub code are upon the same track, they are in perfect sync.
2) Reliability of the reproduced data is high as sub data in the format contains double error correction and double parity.
3) Data can be read at more than 100 times high speed search.

In view of these points, we have reached the conclusion that the sub data area is the most suitable location for recording the SMPTE/EBU time code.

4. PROBLEMS AT RECORDING SMPTE/EBU TIME CODES ON R-DAT

When it is attempted to record SMPTE/EBU time code in the sub code, the difference in frame cycle between the two and handling of the bit clock becomes a problem.

1) Frame cycle
One frame of R-DAT is 30 msec. (33.3 frame/sec.). On the other hand, as one frame cycle of SMPTE/EBU code is matched with one frame of a VTR or the motion picture film, as mentioned before, it will differ depending on the equipment used. For example, it will be about 33.3 msec. (30 frame/sec.) for NTSC, about 33.4 msec. (29.97 frame/sec.) for the drop frame, 40 msec. (25 frame/sec.) for PAL/SECAM and about 41.7 msec. (24 frame/sec.) for motion picture film which are all longer than R-DAT. For this reason, one frame of SMPTE/EBU time code cannot directly fit inside one frame of R-DAT. This problem can be solved if a frame converter is used at the R-DAT input/output to convert the SMPTE code to 33.3 frame/sec. for R-DAT recording but there are problems such as the necessity of a large exclusive circuit and a separate consideration must be made in processing the user bit which is recorded together with time information in the SMPTE/EBU time code.

2) Bit clock
Besides the data content, the SMPTE/EBU time code can be used as a synchronizing clock as it employs biphase modulation. When this clock is reproduced, the frequency and phase must be accurately reproduced. In order to do so, not only the data content of the time code but information for bit clock reproducing must be recorded in parallel.

3) High speed search
The tape location information at high speed search is generally obtained by pulses (tachopulse) from a roller rotating together with the tape. If high speed search of more than 100 times is done by R-DAT, the tachopulse method will be inaccurate due to tape slipping at the roller. Therefore, it is necessary to obtain location information from the SMPTE/EBU time code also at high speed search.

5. SMPTE/EBU TIME CODE FORMAT IN THE SUB CODE

As mentioned above, since the SMPTE/EBU time code frame cycle is longer than that of R-DAT, one frame of time code cannot fit into one frame of R-DAT. Therefore, there is no choice but to give up attempting to fit SMPTE/EBU time code into one frame of R-DAT. However, what is required here is, not to record the SMPTE/EBU time code as time information but to allow output of the original time code in accordance to the format at reproducing. This means recording the time code as time order data regardless to the content, then while maintaining sync with the sound signal, reconstructing it into the time code frame structure at reproducing. Following is the method we had devised.

1) An 80 bit lot of time code data is punctuated by the R-DAT frame cycle (30 msec.) and recorded in sub data area of the same track where sound data is recorded.
2) The number of bits and phase information necessary at reproducing are added to 1), above, and recorded.

This method is explained by Figure 8. The sound signal is cut out by the R-DAT frame cycle of 30 msec. and recorded. Simultaneously, time code is also recorded but it is not the data of this time code occuring over a length of 30 msec. which is identical in length to the sound signal, that is to be recorded but the past 80 bits length is recorded. The length of time corresponding to 80 bits of time code is 33.3 msec. for NTSC, 33.4 msec. for the drop frame, 40 msec. for PAL/SECAM, and thus, they are all longer than 30 msec. of the R-DAT frame. Therefore, there will be partial duplication in each frame that is recorded. Normally, this partial duplication can be stripped off at reproducing and output as a continuous data. At high speed search, data can be reproduced only intermittently but as 80 bits equivalent to one frame of time code exists, the content can be read out.

The method of accurately recording and reproducing the bit clock is explained next.

The bit clock information must also be considered, in addition to time information, at record and reproduce of the time code. As mentioned before, the time code bit clock has a slight phase difference against the cut out point. If this phase difference "t" expressed by 8 bits and the number of bit clocks "n" is previously added to the aforementioned 80 bit time code and recorded, the recorded time code including the bit clock can be correctly reproduced.

The pack format is shown in Figure 9.

Two packs are used for the time code without any alteration in the R-DAT format. The presently reserved 1110 is used to indicate that this tape is for professional application. The next four bits shall be 0000 and 0001 to both identify SMPTE/EBU time code and distinguish between the two packs. "t", "n", and the 80 bit time code data are put in the pack data area.

6. INTERCHANGEABILITY WITH CONSUMER EQUIPMENT

For the audio signal section, interchangeability with consumer equipment is no problem as the R-DAT format is directly applied.

The same sub data format is used in the consumer equipment and our system, except for the pack item.

In other words, sub codes in a tape written by consumer equipment can all be read in our system. When a tape recorded in our system is reproduced in consumer equipment, data only specified by pack item 1110 cannot be read but there is absolutely no fear of misoperation.

For these reasons, we believe there is no problem in interchange-ability.

7. COMPOSITION OF THE PROTOTYPE

Figure 10 is the block schematic of the prototype (named the Digital Master Recorder). The sound signal processing system is no different from the consumer R-DAT.

The SMPTE/EBU time code is, first, biphase demodulated and the time code data and clock are returned to their original form. This data is applied to the microcomputer where the sub data is generated based on the frame signal from CTRL and the 8 times sampling frequency. This sub data is recorded on the tape together with the PCM audio data.

The reproduced sub data is returned to the original time code in the microcomputer, biphase modulated and output as SMPTE/EBU time code.

The synchronizer outputs a transport control signal by this time code, and this signal will issue an FF or REW command to the slave if its tape is away from the correct position, and issue a PLAY command if the position is near to the correct position and at the same time, output an FM 9.6KHz signal for controlling the tape speed.

The digital master recorder enters the FF, REW or PLAY mode by these signals. When in the PLAY mode, the digital master recorder adjusts the master clock based on the FM 9.6KHz signal and the variable speed function further makes small adjustment for synchronizing.

Our digital master recorder was able to operate as a slave by these arrangements.

This prototype digital master recorder was exhibited at the 83rd AES Convention (1987, New York) and was highly evaluated. Its physical appearance is shown in Figure 11.

8. CONCLUSION

The SMPTE/EBU time code can be recorded in the R-DAT sub code area and furthermore, by adding a variable speed function, it was confirmed that R-DAT can be used as the slave for video and audio equipments.

Possessing sufficient basic performances for a professional digital audio tape recorder, the low running cost digital master recorder should be widely applied in the future. Consequently, standardization of the time code format is an absolutely necessary requirement. On this occasion of presenting our proposal, we hope there be active debate on various time code formats for R-DAT, and the day a common specification is standardized shall come soon in the near future.

9. ACKNOWLEDGEMENTS

We wish to express our appreciation to Mr. H. Shinohara, president, Fostex Corporation; Mr. M. Matsumoto, chief, R & D; and Mr. S. Tamura, staff, R & D.

REFERENCES

1) The DAT Conference Standard; DIGITAL AUDIO TAPERECORDER SYSTEM (June 1987)

2) R. Lagadec, K. Okada; R-DAT AND PROFESSIONAL AUDIO Preprint, AES 2nd Regional Convention, Tokyo 1987

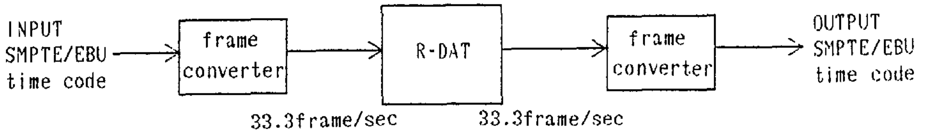


Figure 1. Frame conversion between SMPTE/EBU code and R-DAT.

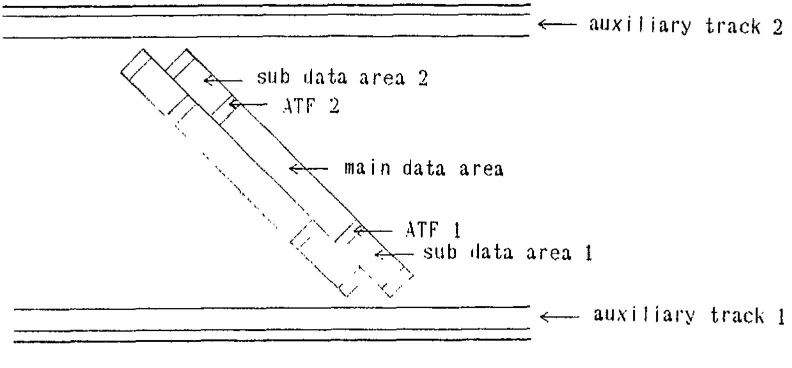


Figure 3. Track format of R-DAT

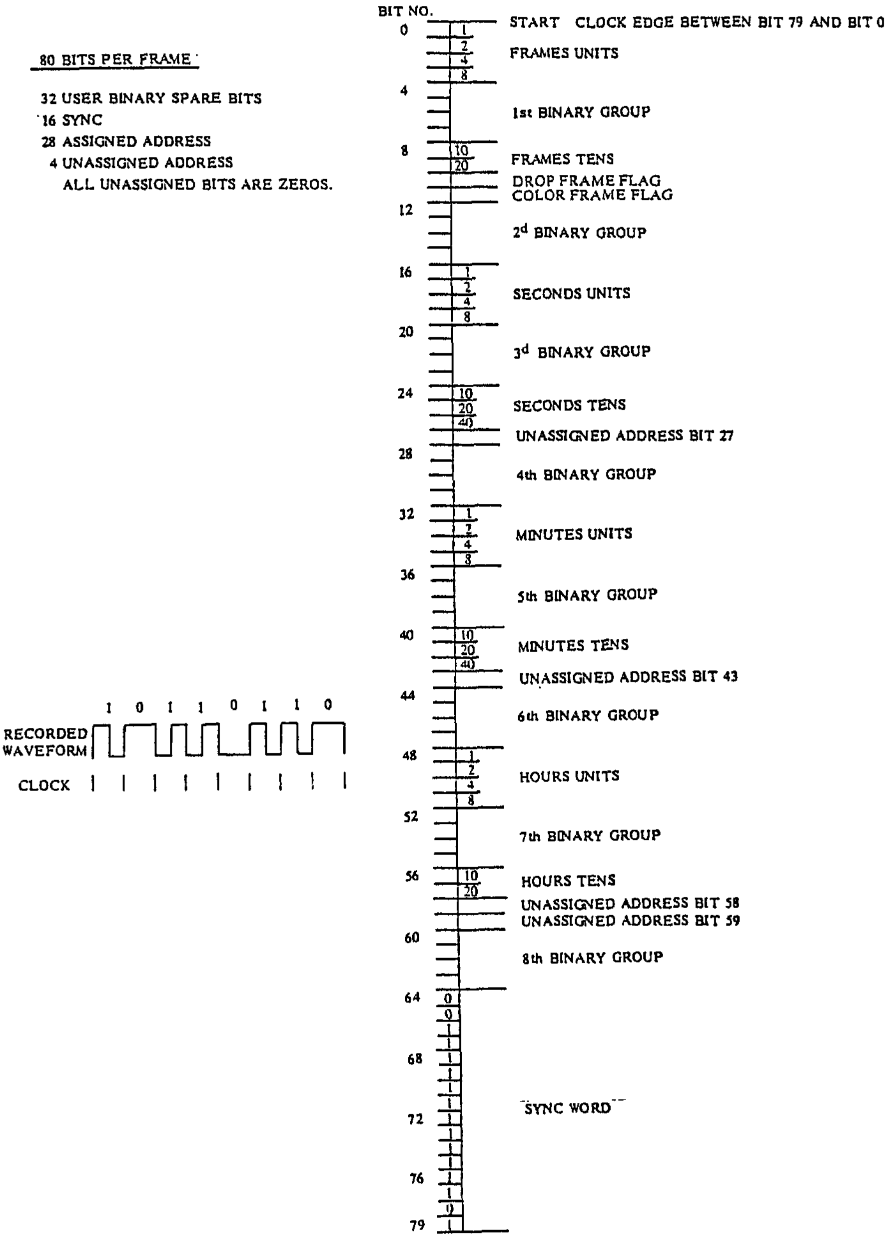


Figure 2 SMPTE/EBU time code format (after ANSI V98.12M-1981)

12 - 2589 E1

Sync.	sub ID		sub parity	sub data
	SW1	SW2		
8 bits	8 bits	8 bits	8 bits	32 symbols (8 bits x 32)

Figure 4. Structure of a block in sub data area.

		SW1		SW2		sub parity	sub data			
even block	Sync.	control ID	data ID (0000)	pack ID	block address (xxx0)	parity	pack area 1	pack area 3	pack area 5	pack area 7
odd block	Sync.	program No.ID 2	program No.ID 3	program No.ID 1	block address (xxx1)	parity	pack area 2	pack area 4	pack area 6	SP parity

Figure 5, Block pair and packs.

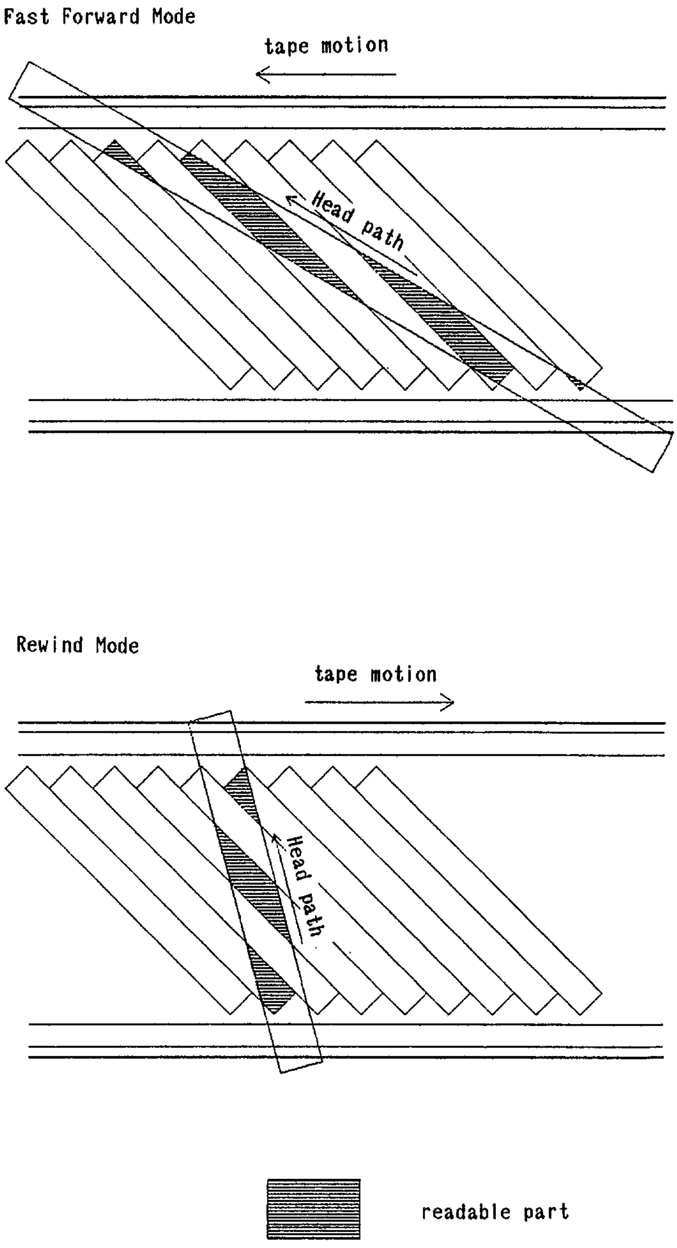


Figure 6, Head path in fast winding mode.

	MSB	LSB
PC1	pack item	
PC2		
PC3		
PC4	pack data area	
PC5		
PC6		
PC7		
PC8	pack parity	

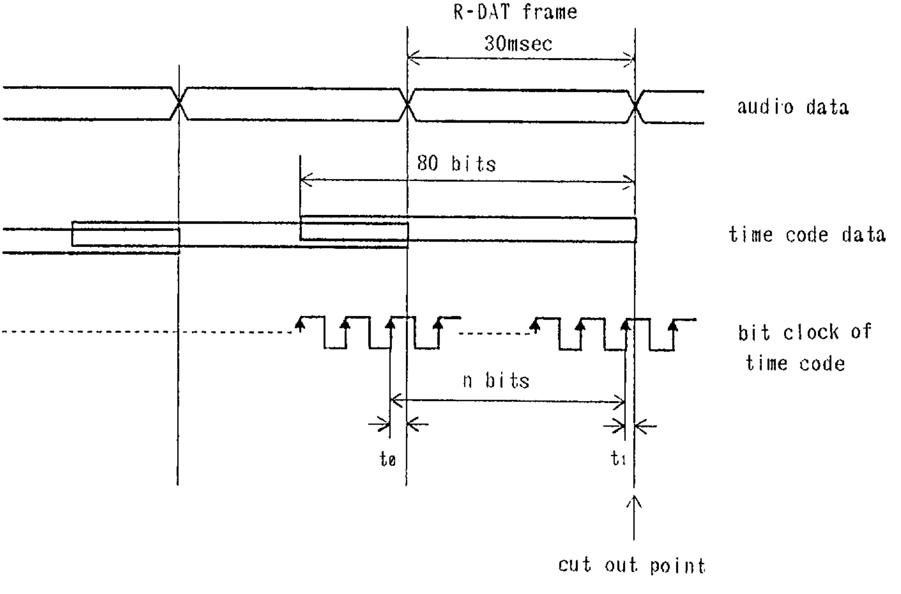
PC8 = PC1 ⊕ PC2 ⊕ PC3 ⊕ PC4 ⊕ PC5 ⊕ PC6 ⊕ PC7
(⊕ : MOD 2)

Figure 7, Pack format.

	MSB							LSB
PC1	1	1	1	0	0	0	0	0
PC2	phase difference :t							
PC3	number of bit clocks:n							
PC4								
PC5	time code data							
PC6								
PC7								
PC8	pack parity							

	MSB							LSB
PC1	1	1	1	0	0	0	0	1
PC2								
PC3								
PC4	time code data							
PC5								
PC6								
PC7								
PC8	pack parity							

Figure 9, Data format in packs.



bit clock frequency = $n / (30\text{msec} + t_0 - t_1)$

Figure 8, Timing relation between audio data and time code.

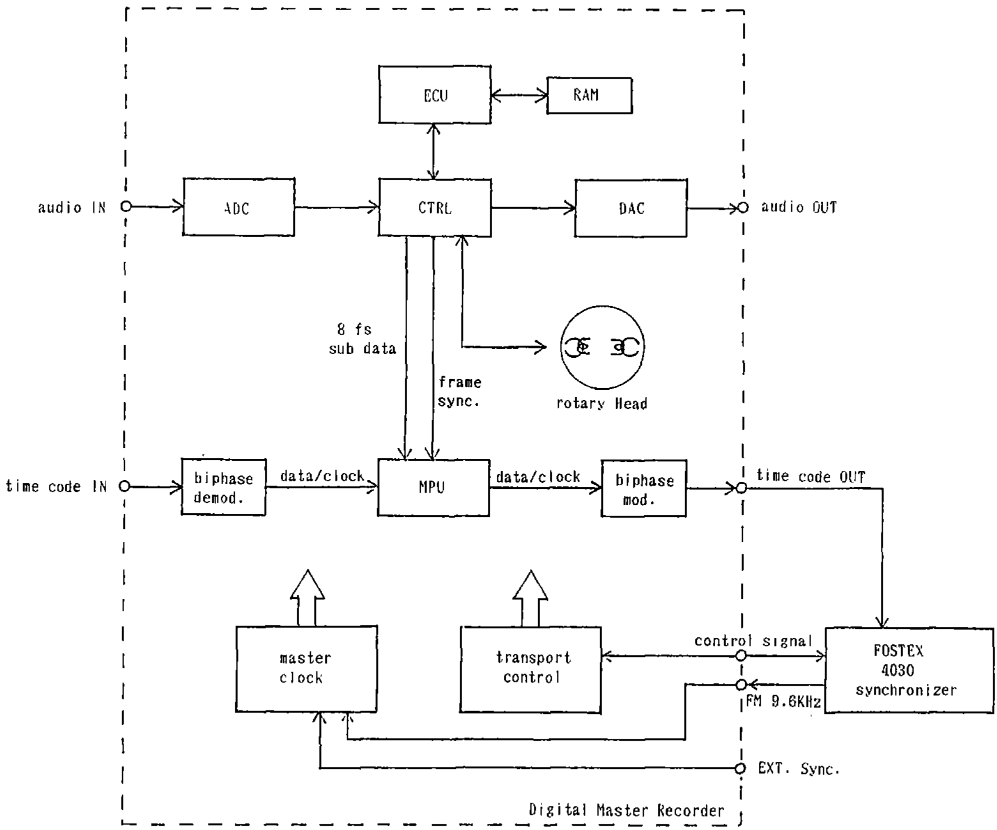


Figure 10. Block diagram of Digital Master Recorder

Figure 11, Our prototype DIGITAL MASTER RECORDER.