OUTLINE OF MINI DISC SYSTEM

Features of Mini Disc System

A mini disc (MD) is 64 mm in diameter and stores a maximum of 72 minutes worth of music signals like a compact disc (CD). Music signals are recorded on a disc in the form of EFM-modulated digital signals. The wavelength of the laser beam for reading such digital signals is 780 nm (typical), the disc revolution is between 1.2 m/s and 1.4 m/s, and the track pitch is 1.6 μm, which are the same as those of the compact disc.

In order to record 72 minutes worth of music signals on a 64 mm dia. mini disc, stereophonic music signals are sampled at 44.1 kHz and quantized into digital signals (1.41 Mbps) by a 16-bit (full scale) analog-to-digital converter. Such digital signals are processed by means of up-to-date digital signal contraction technology to reduce bits to be transmitted to approx. 1/4.789 (approx. 294 kbps). The digital signal contraction technology adopted for the mini disc is called ATRAC (Adaptive TRansform Acoustic Coding), which extracts audible sound components adroitly and converts them into short digital codes, making use of the human auditory characteristics.

As shown in Figure 1 below, such a transformation means that signals recorded on a mini disc are read out and expanded to approx. 4.789 times as long sound as the original signals. Provided one second worth of signals are read out of a mini disc, the signals are reproduce in 4.789 seconds worth of music sound.

* Read-out time from disc

* Music reproducing time

* Time elapsed

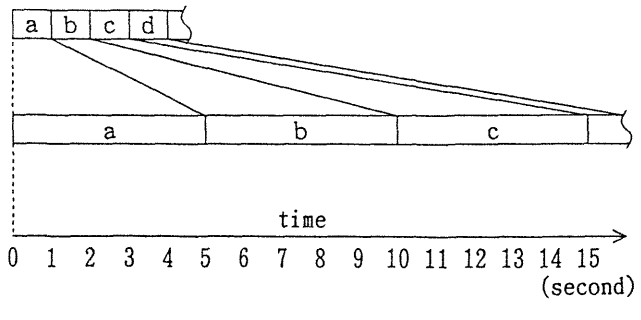


Fig.1 : Amounts of data read out of disc and music data

As digital signals read out of a disc are transmitted, they are converted into music signals which are approx. 4.789 times as long as the original in time. Thus, memory for storing data read out of the disc is necessary. Since the memory capacity is limited, data reading from a disc should be stopped when the memory becomes full. When a space is secured in the memory, data reading from the disc restarts. When the disc becomes full, reading is stopped. Such an intermittent operation is required.

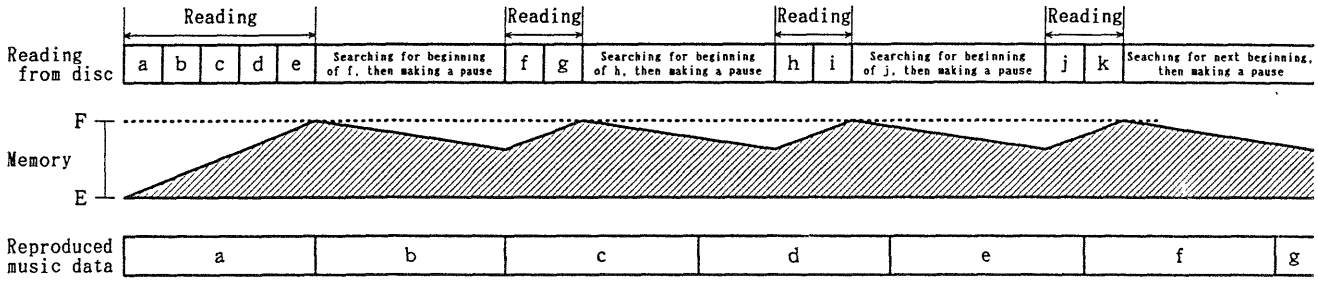


Fig.2 : Principle of MD signal reproduction

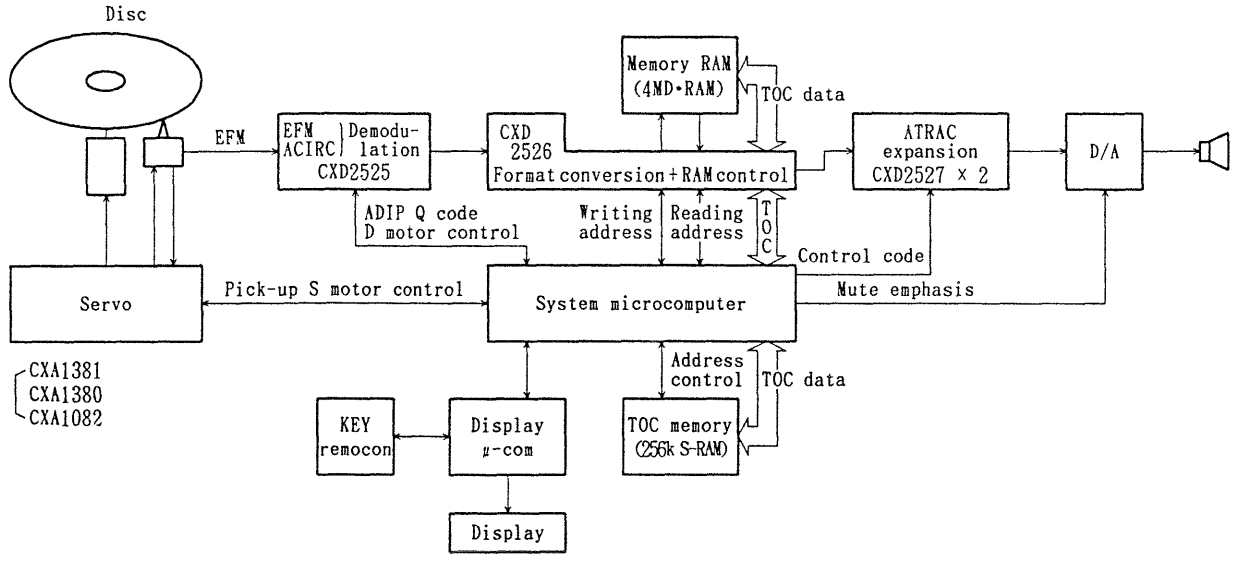


Fig.3 : MD reproduction and IC operation

Figure 2 shows the principle of operation. As soon as digital data read out of a disc is written into the memory, it is converted into sound. It is read by the ATRAC decoder CXD2527, converted into 16-bit music data sampled at 44.1 kHz, and made into music sound through digital-to-analog conversion. Since data written into the

memory is 4.789 times as much as data read out of the memory, the memory becomes full soon. When the memory becomes full, no other data may be written in it. Data reading from the disc is discontinued to make a pause until data in the memory is converted into music signals and a space for writing data is secured in the memory. During the pause, data is being sent from the memory to the ATRAC decoder and music signals are reproduced without a break.
The microcomputer controls the music number, and the beginning and end of the music in terms of addresses on the disc, whose data is transmitted to the ATRAC decoder. It also controls the reading address extracted by pickup, writing address in the memory, and, the search address during pause.
Figure 3 shows the system diagram of the first-generation SONY MD LSI kit. The MD system reproduces contracted digital data in an optical system as used for a CD system. Accordingly, it employs shock-proof by using semiconductor memory.

Types of Mini Discs and Recording Method

The mini discs are roughly divided into two types: Premastered mini discs, and recordable mini discs.
A premastered mini disc has pits like a compact disc. Laser beam is irradiated onto the mini disc, and data (0 or 1) is judged from the intensity of light reflected by the pits. A recordable mini disc, one of magneto-optical discs, has a magnetic layer. Magnetic substances in the layer are magnetized into the N and S poles, which correspond to 0 and 1 digital signals. When laser beam is irradiated onto the magnetized substances, the plane of polarization of the laser beam slightly rotates on the N and S poles in the reverse directions, which is called the Kerr effect. The reflectance of the magneto-optical disc is between 0.15 and 0.25. Since it is less than 0.7, which is the reflectance of the normal CD, the magneto-optical disc is called a low reflectance disc. (The aluminum-evaporated disc is defined as a high reflectance disc.) The MD format includes a hybrid disc having the features of these two types of discs. The hybrid disc has pits in the internal

circumference, as ROM. The outer circumference of the hybrid disc serves as RAM. As a matter of course, the hybrid disc is a low reflectance disc. Figures 3-1 and 3-2 show the structures of the premastered disc and recordable disc.

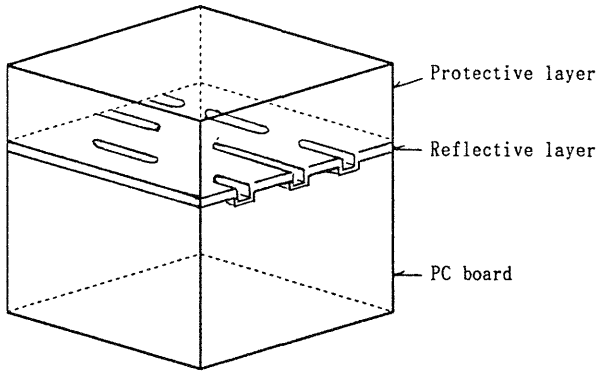


Fig.3-1 : Premastered MD

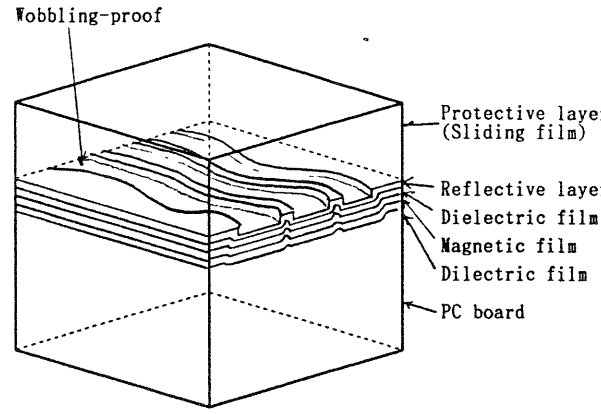
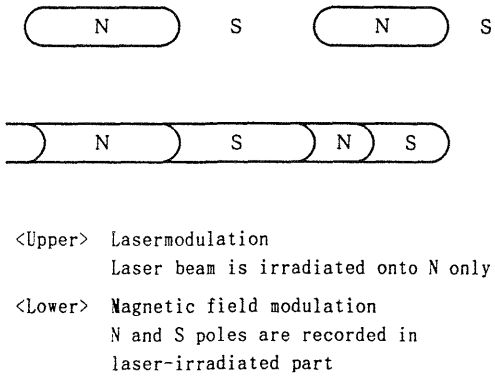


Fig.3-2 : Recordable MD

If magnetized substances are heated, the residual magnetic flux of them disappears over a certain temperature. When the magnetic substances are cooled then in a magnetic field, the magnetic substances are magnetized in the direction of the magnetic flux. Making use of such phenomena, data recorded in a magneto-optical manner may be rewritten. In recording, laser beam is concentrated to a part of the magnetic layer on a disc and heats the part to as high as 220 to 240°C to erase data. Therefore, higher power beam is emitted through the objective lens. The MD Standard specifies that the recording laser beam power is 2.5 to 5.0 mW.

There are two recording methods of the magneto-optical discs. The whole magnetic layer of a disc is magnetized in the same direction in advance. The disc is placed in the magnetic field in the reverse direction, and laser beam is irradiated onto only the parts that should be reversed magnetically. Such a method is called the laser modulation method. In the other method, the N and S poles of the magnetic field applied to a disc externally are changed while irradiating laser beam onto the disc to record data. It is called the magnetic field modulation method.

The laser modulation method requires preliminary erasure of all data before rewriting. Thus, the magnetic field modulation method is adopted to the mini disc systems, since it is capable of direct overwriting. The magnetomotive force of the magnetic field externally applied to a magneto-optical disc should be as high as 8 to 24 kA/m. On the other hand, the inductance cannot be high enough, since EFM signals should be recorded as the signal reversing rate less than 200 nsec. at ±90% variation. To compensate for the shortage of coils, the current should be increased. Thus, the magnetic head drive circuit is quite special and complicated. And also it is very difficult to take remedy against radiation. Figure 4 shows the difference in the recording patterns of the laser modulation method and magnetic field modulation method. Figure 5 shows the image of magnetic field modulation.



<Upper> Lasermodulation
Laser beam is irradiated onto N only
<Lower> Magnetic field modulation
N and S poles are recorded in
laser-irradiated part

Fig.4 : Recording patterns

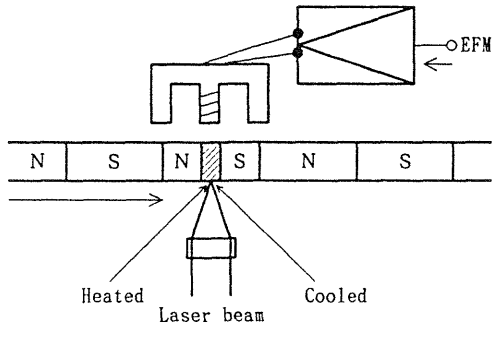


Fig.5 : Principle of magnetic field modulation

In the MD system in question, the magnetic head on a resin part slides at a distance of 120 μm from the magnetic film on a disc.

Servo for Mini Disc (Figure 6-1)

As described above, mini discs are divided into the premastered mini discs (with pits) and recordable mini discs. The principle of the premastered mini discs is the same as the compact discs. Thus, the following describes the principle of the recordable mini discs.
A recordable mini disc has, in its inner area, pits, which stores the information of the recording power of the disc, the beginning of the recordable area, U-TOC data recording area, lead-out area, and other data. Outside the pit area, there is a recordable area. The recordable area has no pits but has a groove, which serves as the guide of tracks. Digital signals are recorded along this groove. This groove is not straight but winds to the right and left in order to store the revolution data of the disc. The disc revolution is so controlled that the average frequency of the wind is 22.05 kHz. Such wind is called wobble. The wobble also contains address data indicating positions on the disc. An address is expressed in 42 bits in a sub-code frame (1/75 second). Biphase-modulated address data is frequency-modulated and recorded in wobbles. Such address data is called ADIP (ADdress In Pregroove) data. Frequency-modulated data is recorded in wobble at 22.05 kHz with 1 kHz deviation. Address data recorded in wobble is used for searching, etc.

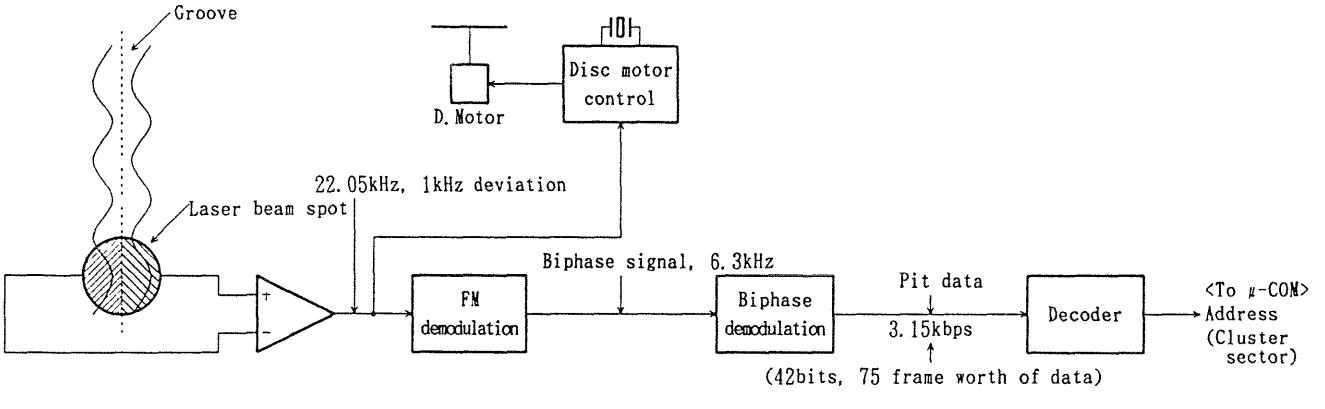


Fig.6-1 : Groove data (ADIP) control

Figs.6-2 and 6-3 show the dimensions of the pit and groove of a mini disc. As shown in these figures, the tracking error polarity differs with the pit and groove, since the groove is wider than 1/2 of the track pitch.

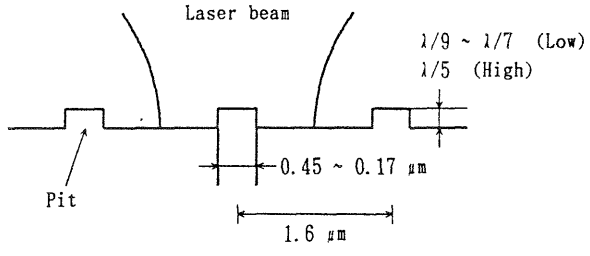


Fig.6-2 : Pit

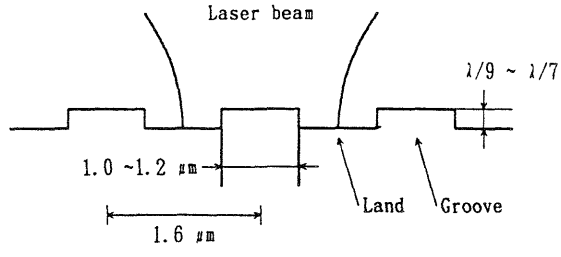


Fig.6-3 : Groove

As described above, attention should be paid to the following matters in regard to the recordable mini disc.

Pickup

Pit: Data is read out according to the luminous energy of reflected light.

Groove: Data is read out according to the difference in the luminous energy received by two detectors caused by difference in the polarization directions.

TE

The polarities of the pit and groove are reversed.

CLV

Pit: Revolution is controlled by EFM signals.

Groove: Revolution is controlled by wobbles.

Data Units and Recording of Mini Disc

Figure 7 shows the units of data of the mini disc. Audio data is divided into 16 bits through sampling at 44.1 kHz. 512 samples are contracted into digital audio signals. Data of 512 samples (11.61 ms) is contracted into 1 sound frame. Time of 512 samples is contracted into data transmission time of 1 sound group (2.424 ms). Five and half sound groups form 1 frame. Like 1 sub-code frame of the compact disc, the time of 1 frame is 1/75 second (13.3 ms).

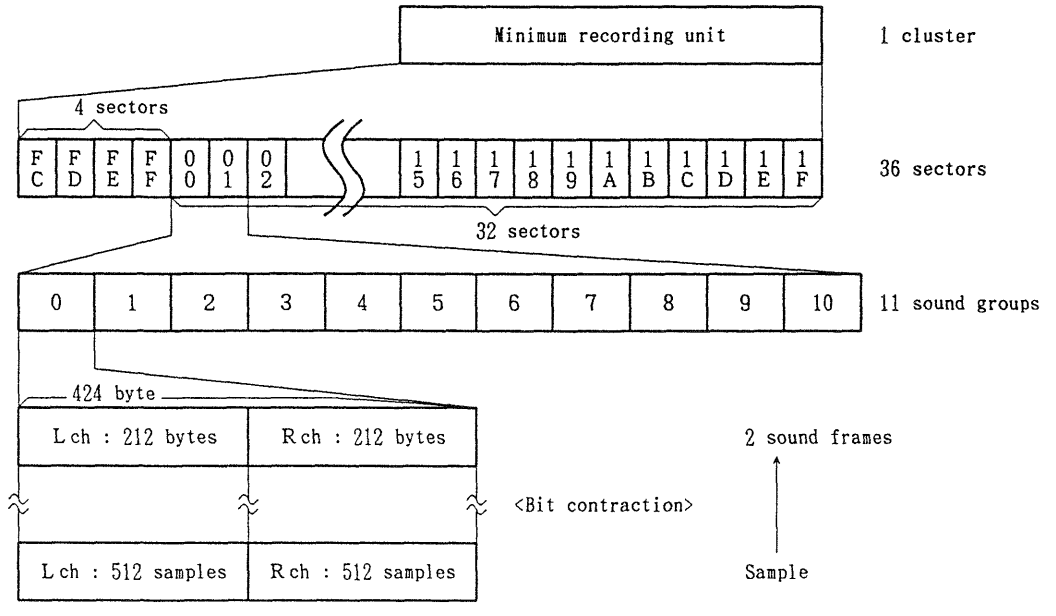


Fig.7 : Data units of MD

Thirty-six frames form a cluster. Each cluster has binary frame numbers, which begin with FC and ends with 1F. Music data is called main data and is recorded in 32 frames (with frame numbers 00 to 1F). 32 frames worth of main data is converted into stereophonic music data for 2.043 seconds (512 x 5.5 .... = 2.043) If it is converted into monophonic music data, the time is twice as long. On a premastered disc, sub-data is recorded in the remaining 4 frames (FC to FF). On a recordable disc, sub-data is recorded in only the sector FF. The other three sectors are called the link sectors, which serve as a link between clusters. Linkage in other sectors is prohibited. Accordingly, a mini disc system stores data in the memory and records data on a disc when more than 1 cluster worth of data is stored, since it can only record data cluster by cluster.

Not in recording, the microcomputer is waiting in the pause state. Figures 8-1 and 8-2 shows the rules of linkage.

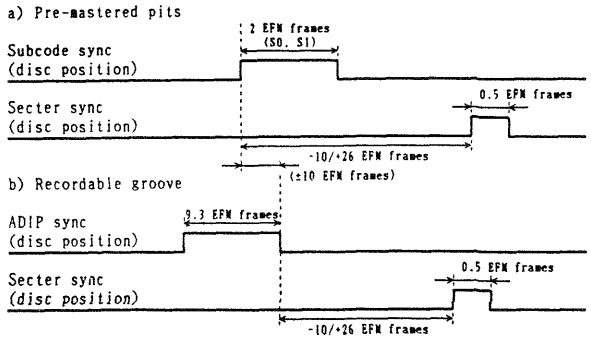


Fig.8-1

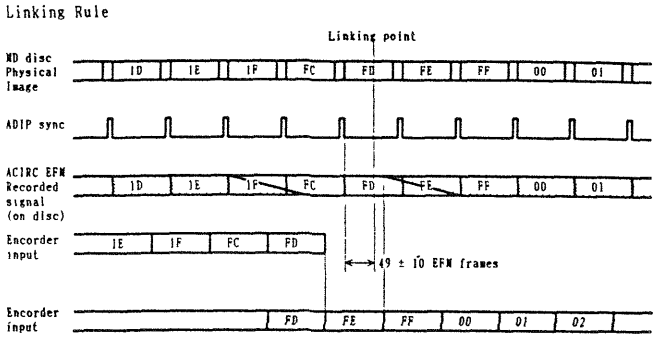


Fig.8-2

Note : The actual time of recording 1 cluster (36 frames) worth of data on a disc is found as shown below.

$$1/75 \times 36 = 0.48 \text{ (sec.)}$$

MD's Music Control Data and Music Pieces

One of the outstanding features of the mini disc is that music pieces and music control data (TOC) are recorded on a disc separately. As for the compact disc or digital audio tape, the areas for recording TOC and U-TOC data are determined on the medium, and the music track numbers, time data, recording type (stereophonic or monophonic), presence or absence of emphasis, SCMS data, etc. are recorded together with music signals. On the other hand, on a mini disc, only music signals are recorded in the music recording areas. The music track numbers and other data are recorded in the TOC or U-TOC areas. Therefore, for renumbering, only the U-TOC data has only to be rewritten on the mini disc, while, on the digital audio tape, sub-codes recorded in the music data areas need to be changed. However, this means that, if U-TOC data is not recorded or erased though music data is recorded, the MD system considers that the music data itself does not exist.

Details of the TOC and U-TOC are as shown below.
TOC is written in the lead-in area. The disc type (premastered, recordable or hybrid), maximum number of music pieces, lead-out area start address, and start and end addresses of the recorded music pieces (maximum TND: 225) are recorded in sector 0. The U-TOC start address, recording power, etc. are also recorded in sector 0 if the disc is a recordable MD. Sector 0 of the U-TOC or TOC area mainly contains the music track numbers, start and end addresses of the music pieces, SCMS, presence or absence of emphasis, recording type (stereophonic or monophonic), etc. These data must always be written in sector 0. Sector 1 of the U-TOC or TOC area contains the disc name and music names in ASCII codes. Its capacity is 2048 characters for TOC or 1792 characters for U-TOC. Sector 2 of the U-TOC or TOC area contains the data and time of recording in twelve BCD characters, each two of which are for the year, month, day, hour, minute, and second. Sector 3 of the U-TOC or TOC area contains the catalog number and ISRC code. Sector 4 of the TOC area contains the disc name and music names like in sector 1. The difference between sector 4 and sector 1 is that these names are written not in the ASCII code but in the font specified in the font code. ISO-8850-1 and shift JIS are used as the font codes. Sectors other than sector 0 of the TOC and U-TOC areas are optional.
Sectors 0 to 4 of the lead-in area and sectors 0 to 3 of the U-TOC area cited from the MD Standard are shown in the appendix.

Relationship between Recording Positions and Music Numbers on Mini Disc

The MD Standard specifies that TNO of a mini disc must always begin with 1 and end with 255 (maximum) and must be continuous. However, the user may erase unnecessary music pieces. This means that any of recorded music pieces having continuous numbers may be erased. Even in such a case, the TNO rule shown above requires that the MD deck must renumber the remaining music pieces automatically.

(a), (b) and (c) in Figure 9 show the automatic renumbering. (d) and (e) show the following sequences. In (d), the fifth music piece is recorded up to the lead-out area of the disc and is recorded following the erased area. The Link-P pointer is used for such recording. It is expressed in U-TOC (in sector 1).

(f), (g) and (h) show the sequences of erasing TNO 3 and recording another music piece. Like this, music pieces may be recorded on a disc in random positions, though the user does not know. Thus, the memory capacity according to the searching speed of the mechanism is needed. (Approx. 1.5 clusters worth of capacity for 1 megabit DRAM) The microcomputer must control the TOC data even in recording or playing back. Since only the clusters and sectors have addresses, the microcomputer must find and display time from these addresses.

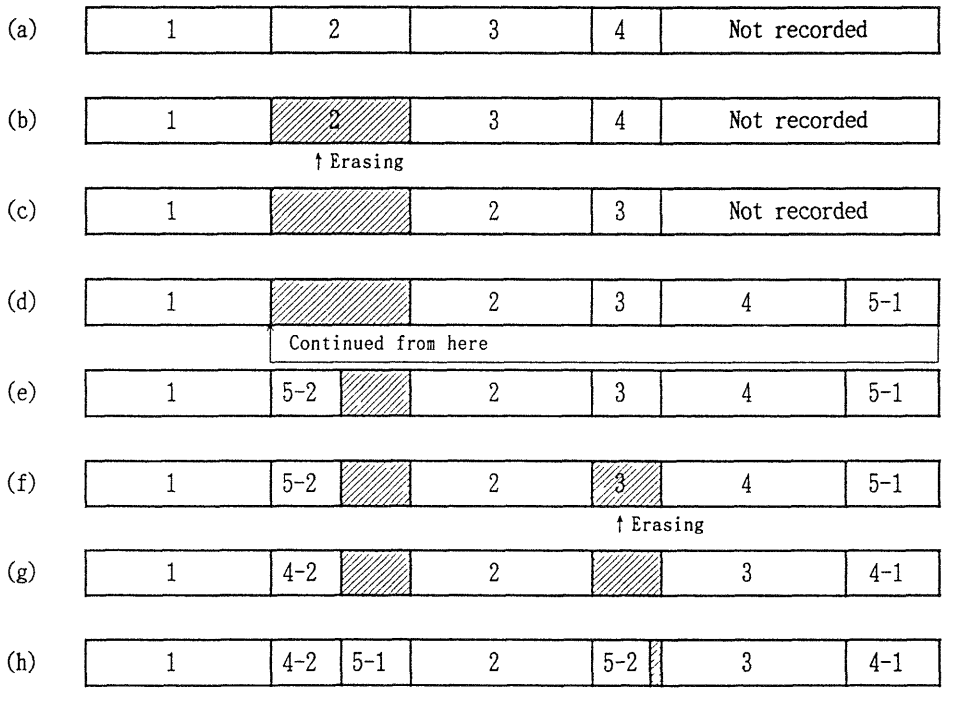


Fig. 9 Music recording positions on disc