

**SONY®**

***Training Manual***

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# **MiniDisc**

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## **Magneto Optical Basics**

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Course MO-1

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# MiniDisc

## Magneto Optical Basics

Prepared by:  
Sony Service Centre Europe &  
Sony Service Company  
A Division of Sony Corporation of America

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Course presented by \_\_\_\_\_

on \_\_\_\_\_

Attended by \_\_\_\_\_

# MiniDisc - Magneto Optical Basics

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## 1. Introduction

The Minidisc system is Sony's latest development . The development target was to design a digital disc format, that was easy to use, lightweight,not expensive, durable,recordable, enabling quick random access, shock resistant and of course with a sound quality comparable with its distinguished disc predecessors.

If it is true to say that the compact disc has replaced the analog long play recording, it is then also true to say that minidisc is a real possibility not only to replace the analog cassette, but also to allow much more possibilities .

As Sony has always been on the forefront of digital disc devolpments, the design and production of minidisc is a logical fact. Many developments that have proven their reliability in the past can be used, and exciting new developments are introduced in the Minidisc system.

This publication aims at getting you acquainted with the basic operational principles of the Minidisc system. It will not be based upon a particular model, other publications will be issued for that purpose  
In this way you will be able to use this publication for a longer period as basic introduction to Minidisc.

## 2. Basic technology overview

In this chapter a short overview of the Minidisc technology will be given, it will also get you familiarized with some technical terms which will be used in other chapters. Most of what is included in this basic overview will be explained in detail in the next chapters.

### 2.1. Specifications

|                          | Mini-Disc   | Compact Disc         |
|--------------------------|---|----------------------|
| Frequency Response       | 5-20kHz   | 2-20kHz              |
| Sample Freq              | 44.1kHz   | 44.1kHz              |
| Disc Size                | 2.5inches   | 4.7inches            |
| PB/REC Time              | 60/74 Mins.   | 74 Mins.             |
| Dynamic Range            | 105dB   | 96dB                 |
| Density/Coding           | 16 bit max/ATRAC<br>Adaptive TRanform<br>Acoustic Code        | 16 bit               |
| Laser light Output Power | PB = 0.4mW/0.8mW<br>for reading<br>Rec = 6.8mW<br>for heating | 0.2mW<br>for reading |

There is a resemblance of course between the Minidisc and the other disc formats, but there are many basic differences :

On a much smaller disc, the same time of music can be recorded and played.

The disc is delivered in a plastic cartridge (or caddy) used to protect the disc and ensure ease of handling. This cartridge has a resemblance with a 3.5 Inch floppy disc.

When going through these specifications some abbreviations may look familiar, as they are indeed taken from the CD/CD-ROM specification.

The Minidisc uses the same scanning (CLV) velocity of 1.2-1.4 M/sec and the same track pitch (1.6 Micron)

The signal format has the same sampling frequency as CD, EFM (eight to fourteen) modulation is used in the Minidisc, totally similar to CD/CD-ROM.

The CIRC (Cross-Interleave-Error-Correction) is also used, but named ACIRC as it is an Advanced CIRC format; more interleave was

included to ensure higher burst error recovery capability.

The coding is very different, the starting point is the CD-like music sample data, but this data is ATRAC converted (Adaptive Transform Acoustic Coding). This very complex system will compress the data in such a way that the audio quality still remains optimal, this is performed through transform models which take several psychoacoustic phenomena into account and which will also adapt to the input music type.

The optical parameters are similar to the ones in compact disc, but one major difference can be noted here : as the minidisc set must be able to record on discs, a higher laser power is needed. There will be a need for more than one power setting for playback/record modes, but the overall maximum laser power (mainbeam and sidebeams added) is about 6.8 mWatt.

## 2.2. Disc types

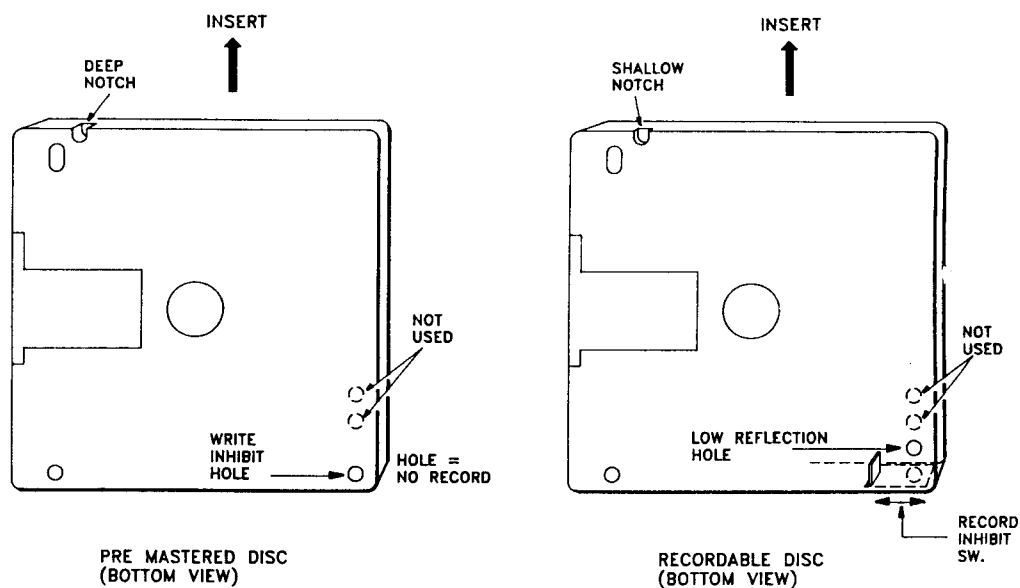


Fig 2 foto of 2 discs, one premastered, one recordable

At this moment 2 different types of Minidisc are proposed, one premastered, non-recordable, which is very similar to a compact disc.

The second type is the user recordable disc, of course the serial copy management system is included in this system.

### 2.3. Shock Proof capacity

A major feature is the shock proof capacity, the combination of data compression and buffer RAM enables us to have correct music readout for many seconds when the system is under high vibration or physical shock circumstances. Basically this system comes down to the fact that we read the data from the disc in a much quicker way than needed for the decoder. We then store this data in a buffer RAM and use it as a buffer tank for shock protection.

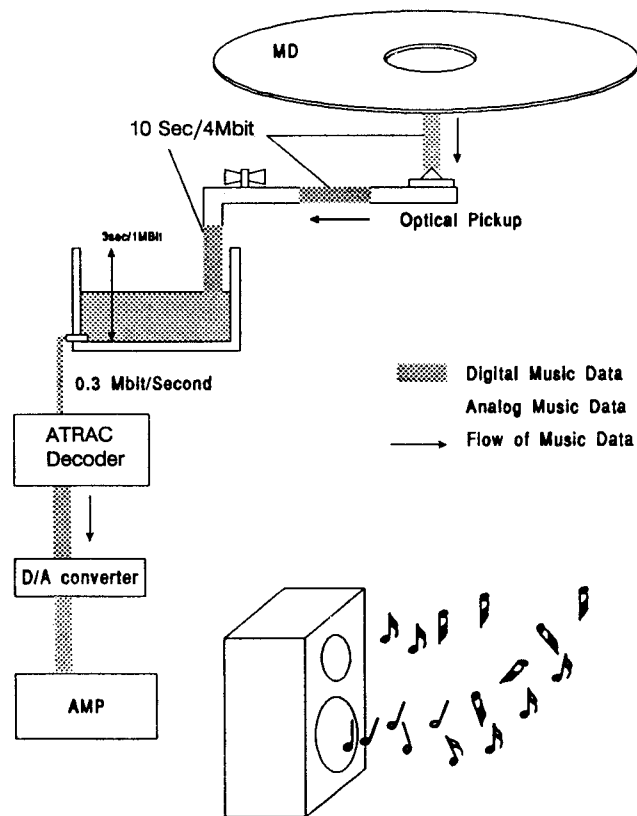


Figure 3. Shock proof memory

### 2.4. Random Access, Pregroove

Another major feature is the quick random access capability, this is a typical disc format feature compared with tape formats.

The recordable disc format uses pregrooves to enable quick spindle/tracking action. This pregroove is a fairly new concept for consumer disc electronics. It is a U-shaped groove in the recordable area coinciding with the spiral data track, this U-shaped groove has a sinewave pattern, which is modulated and can be used to derive quick and correct address information.

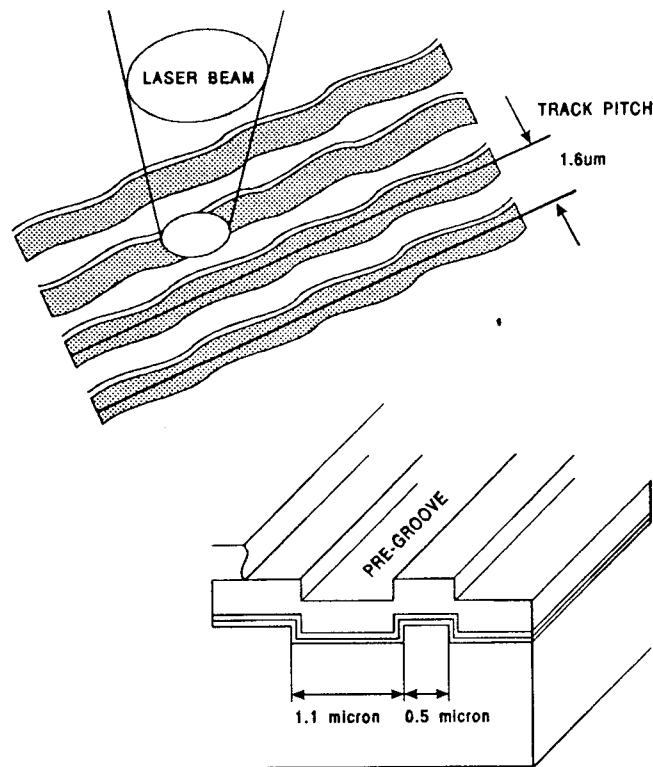


Figure 4.

## 2.5. Recordability

The premastered disc is not user recordable, the manufacturing is similar to compact disc manufacturing.

The recordable disc however is sold as a blank disc, recordable by the user. To enable this recordability, several technological breakthroughs were needed. Recordable discs already existed some time, but the technology used for these types were too power consuming, too heavy, too big to be used in a Minidisc.

Disc recording can be performed through more than one method, the Magnetic Field Modulation method however, is the most durable, and enables near endless re-recording possibilities.

A special alloy layer (Ferrite-Terbium-Cobalt) in the recordable disc is used for rec/play purposes, contrary to the stamped pit signal of the premastered disc.

The recordable layer will be heated up to a certain temperature (the Curie point), once this temperature is attained, the nature of the alloy is such that its magnetical direction can be changed by an external magnetic influence.

For recording we therefore use on one side of the disc a laser for heating, and just opposite this laser, on the other side of the disc a magnetic head. The older recordable disc systems were not able to work with a magnetic head just opposite the laser unit, which made servo control very difficult. Special about the now used alloy is that it does not need an extremely high temperature and also no very powerful magnetic force to be magnetised. Remember that this magnetisation is only possible when the Curie point is reached, once cooled, it will retain this magnetic information virtually forever.

Re-recording is performed by simple overwrite, in other words, old information is not erased first but is immediately changed to its new information contents.

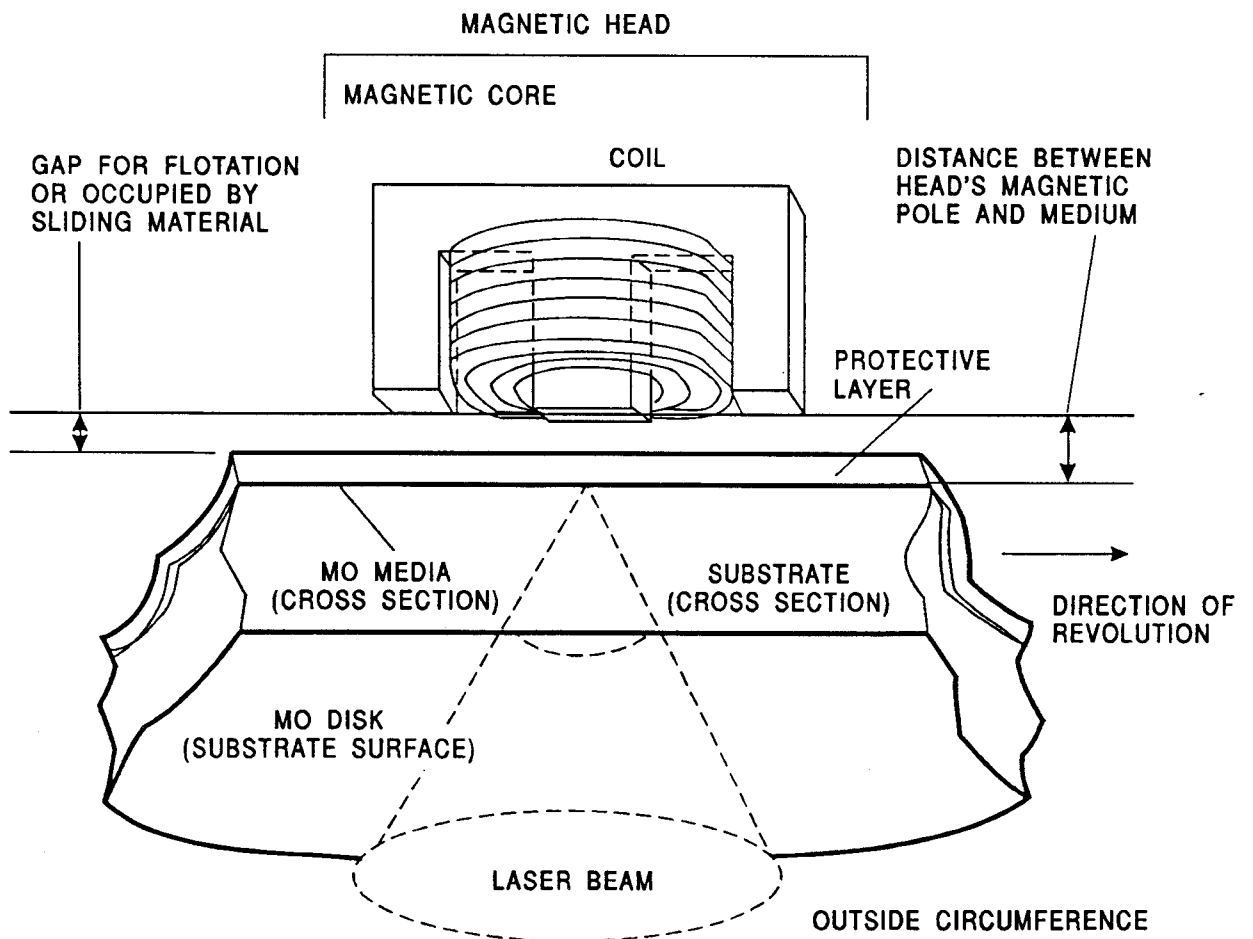
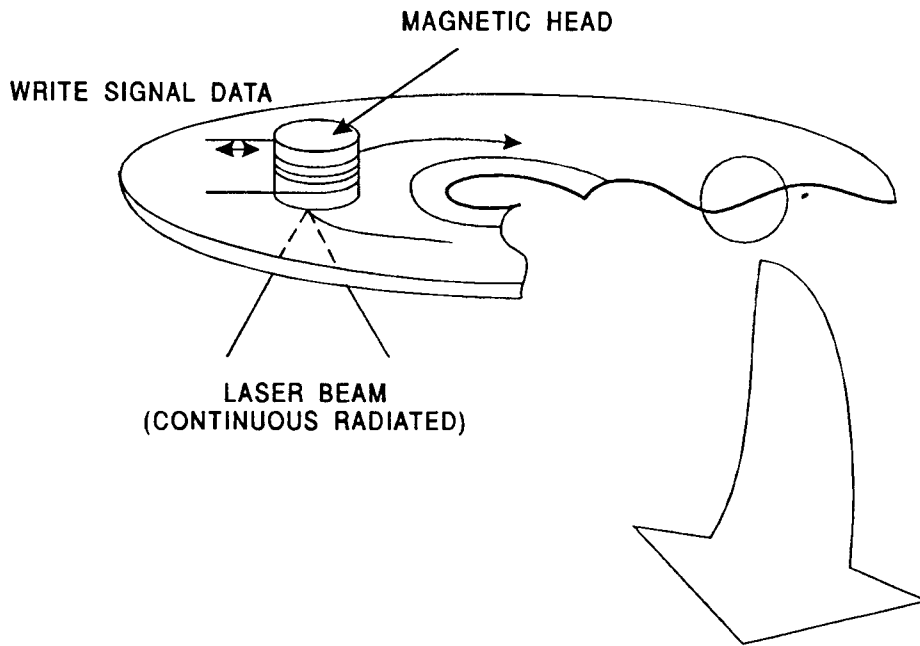


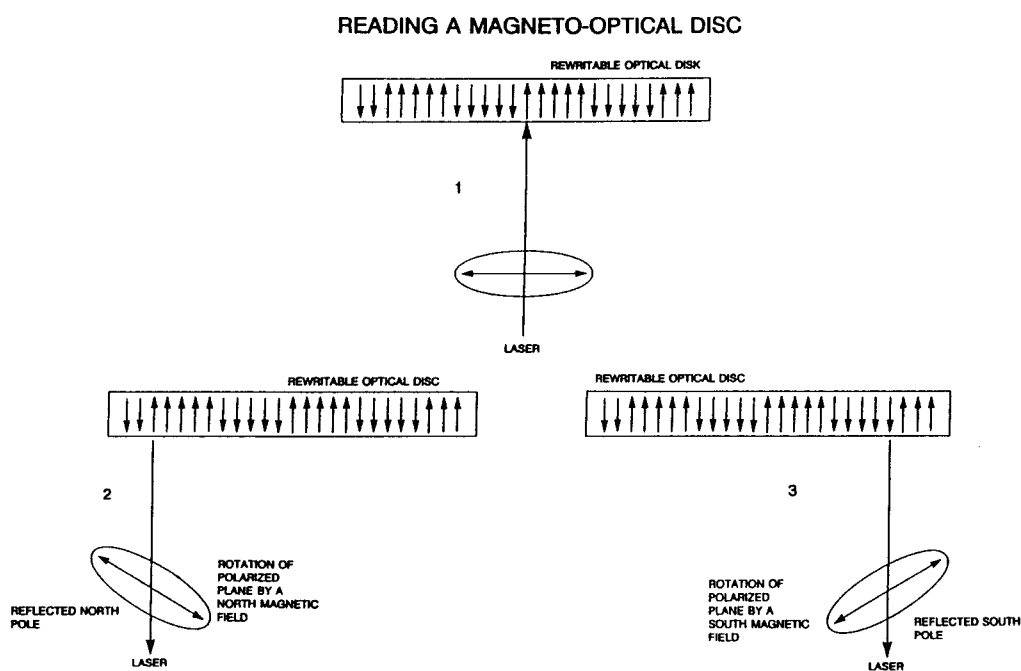
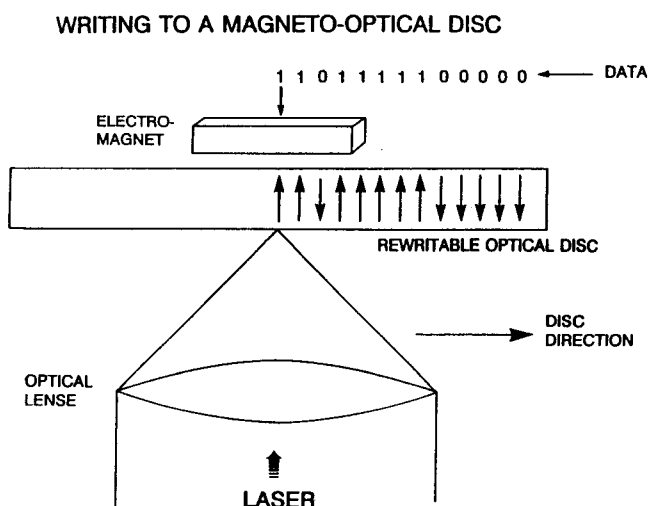
Figure 5.



The recording format is called Magnetic Field Modulation as it is the magnetic field applied by the magnetic head that will effectively modulate the magnetic layer on the disc, not the laser. The laser is only used for heating in the recording cycle.

Readout of such a magnetic signal is based upon another physics law. Remember that readout of a premastered disc is the same as a compact disc, the laser light emitted to the disc will be returned with an intensity (or level) depending on the pits stamped on the disc, correct detection of these level differences enables us to detect the data contents.

In case of the recordable minidisc, there will still be a laser light emitted to the disc when reading out, but as there are no pits, the returned signal level reveals no information. In this case it is the magnetised layer that will influence the polarisation of the laser beam, this phenomenon is called the Kerr effect. Detection of the data will in this case be based upon the differences in polarisation of the returned laser light.



Another advantage is the high resistance to disc tilt, due to the correct Magnetic Field Modulation. Most of the new technologies have been named now, they will be explained further in next chapters.

### 3. Block Diagram

The block diagram of a Minidisc can be compared with the block diagram of a Compact Disc, it is therefore obvious that knowledge of Compact Disc systems makes the introduction to Minidisc much easier.

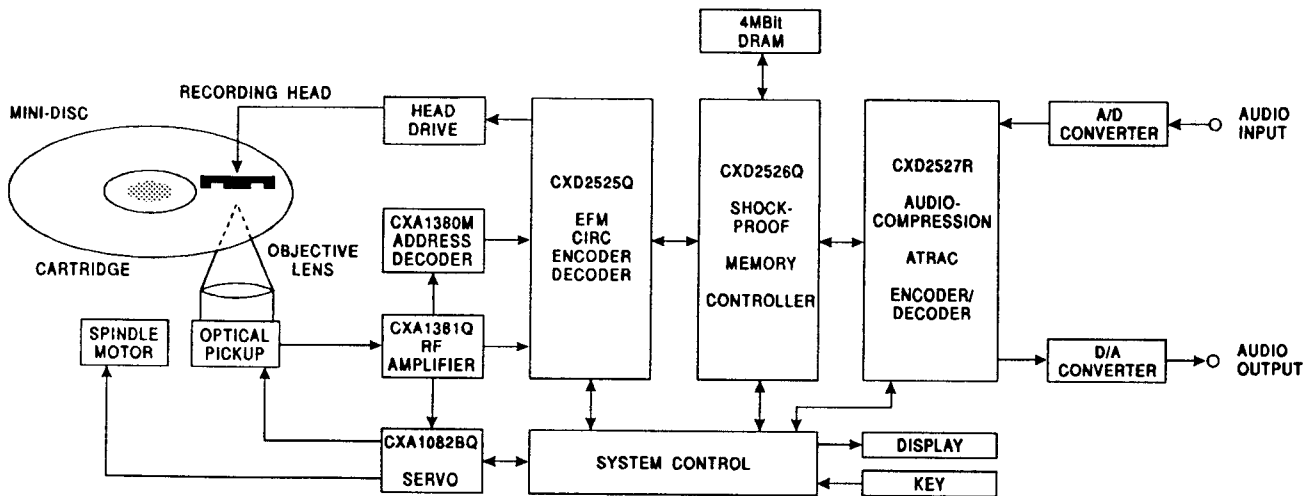


Figure 8.

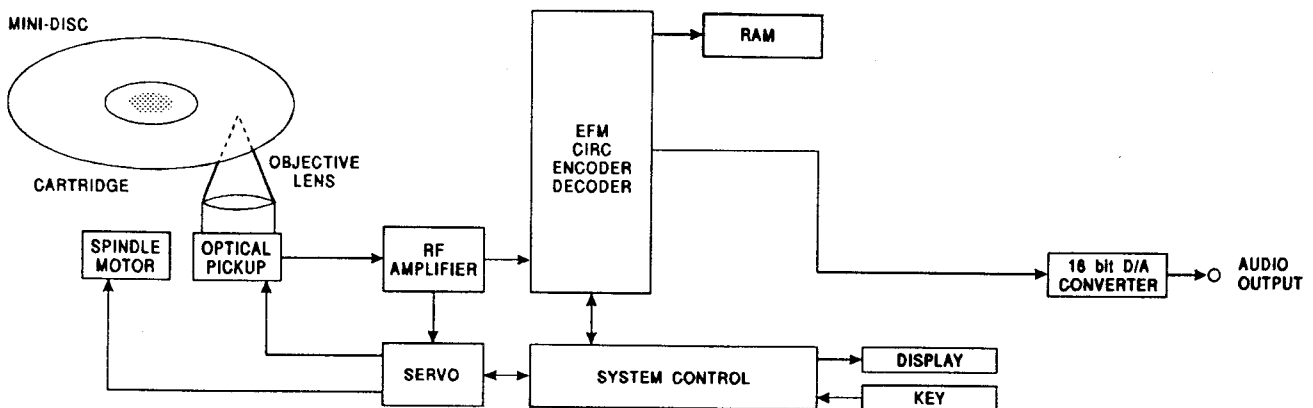


Figure 9.

The differences are mainly due to the recording capability of Minidisc ; A/D convertor, ATRAC encoder, EFM/ACIRC encoder head drive and magnetic recording head are not to be found in a compact disc.

The shock resistant memory controller is not only typical for playback, as it is highly used when recording, a similar system is nowadays also included in some CD discman types, but in such case only in playback..

The address decoder is typical for the readout of the recordable Minidisc type.

The ATRAC decoder is typical for Minidisc, this kind of decoding has not been performed on other disc systems.

Most of the other blocks can be related back to the Compact Disc format.

In order to have a quick understanding of the operation of Minidisc we will now trace the most important operation paths, and give a brief explanation, in next chapters all these items will be repeated with much more details.

### 3.1. REC/PB path

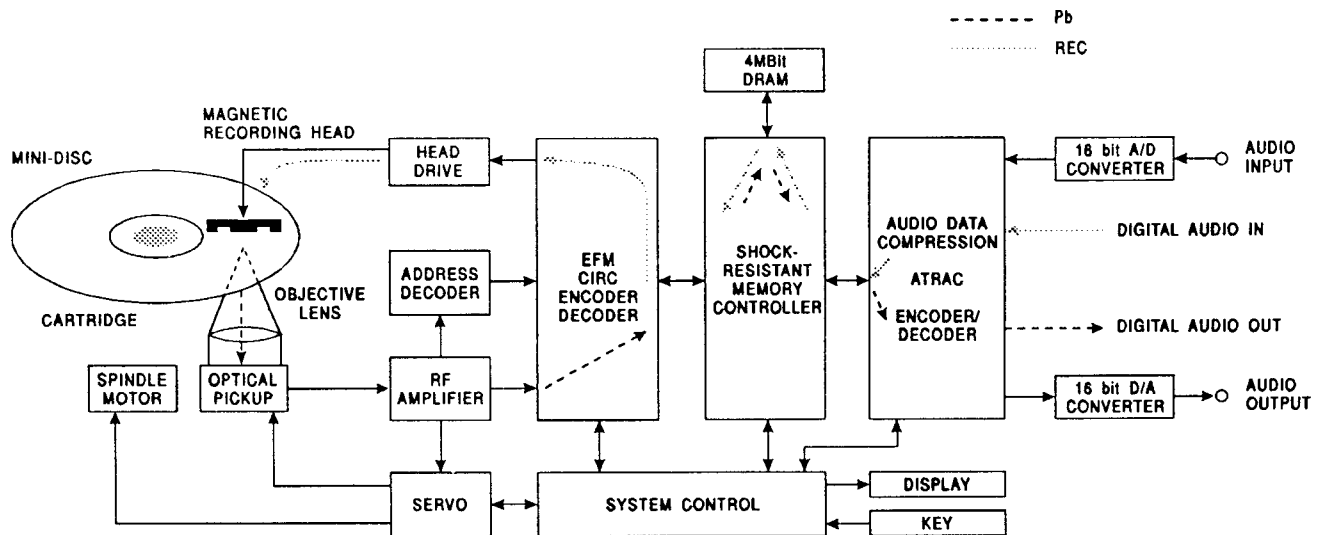


Figure 10.

Recording of any disc starts of course with audio input, this can be analog input or digital input (typically S/PDIF format). In case of analog input this will be A/D converted and fed to the ATRAC encoder, digital input is directly fed to ATRAC encoder. Here the digital data will be compressed according to several psycho-acoustic rules. The compression ratio is about 1/5.

The compressed data is sent to the EFM/ACIRC encoder through the shock proof memory, shocks during recording which might disable proper recording will be absorbed here. The EFM/ACIRC encoder will handle the digital audio data similar to the compact disc encoding; error encoding and interleave is performed, subdata is added and all this is EFM modulated.

Recording is then performed through the magnetic recording head while the laser unit is used for spot heating of the disc.

Recording is not possible on the premastered disc. Only readout is possible, and readout of premastered compared with recordable discs is in the beginning not totally the same.

Readout will in both cases be performed by the optical pickup unit, the magnetic recording head is not used during readout. The optical detecting unit (in the pickup) is able to detect the pit signal as well as

the magnetic signal, both will be sent to the RF amplifier, in case of a premastered disc, focus and tracking signals, similar to the compact disc system will also be retrieved at this point. In case of recordable disc not only the already known focus/tracking signals are seen, but also the pregroove information is readout.

As from the RF amplifier, there is no more difference in handling between premaster and recordable readout RF. This RF signal is EFM demodulated, and error decoded in the EFM/ACIRC decoder.

It is then sent to the shock resistant memory controller, where it will be buffered before being input in the ATRAC decoder, when the set endures shocks while reading out and track jumps occur due to these shocks, this buffer memory will enable continuous music output while the system recovers from the shocks.

The demodulated data is then ATRAC decoded, in fact the original music is reconstructed in a transform system which is the exact reverse from the ATRAC encoding format. As from this point digital audio data output is possible, and through the D/A convertor analog audio is output.

### 3.2. Servo path

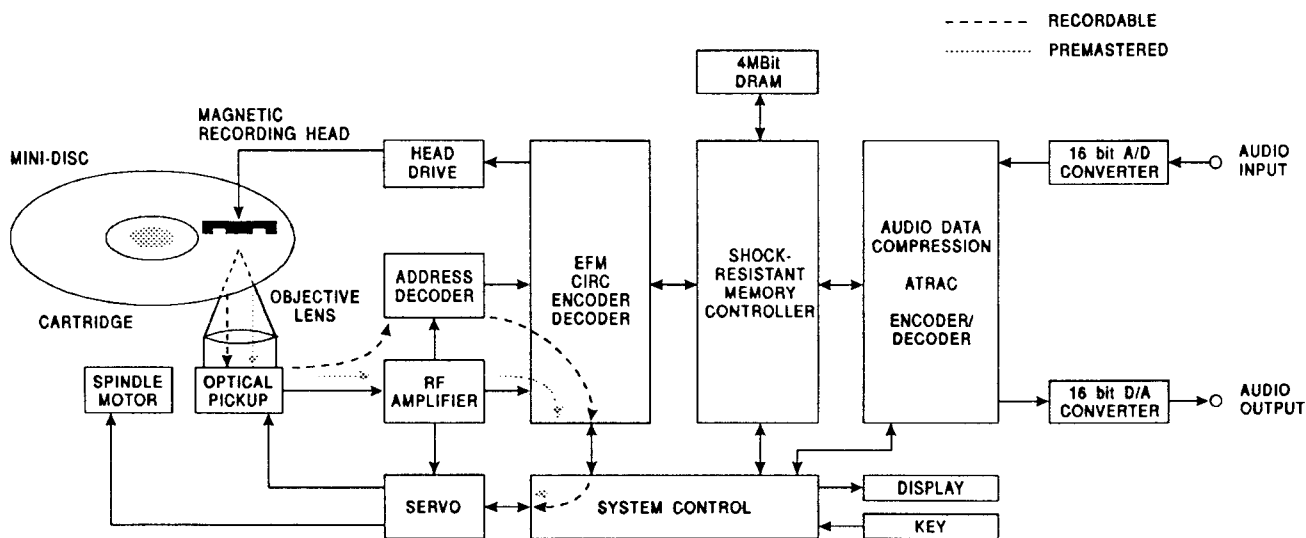


Figure 11.

The servo operation is also very similar to the Compact Disc servo. But as we now have more than one type of disc to handle, and as the recordable disc carries a pregroove the servo is more complex.

For both premastered and recordable disc, the focusing, tracking and sled circuit are similar; note however that the reflectivity of a premastered disc is much higher than that of the recordable disc. Due to this fact correct A.G.C. handling, especially in case of the recordable disc is very important, this is performed in the RF amplifier.

The spindle servo is not the same in premastered and recordable disc. In case of the premastered disc, the spindle motor is driven through the RF signal input in the EFM/ACIRC IC, and through the servo control. This is again the same as in a compact disc.

The recordable disc however is the most complex one. Here the pregroove is also used for this purpose. The pregroove signal is detected by the optical pickup main spot detector, and retrieved in the rf amplifier. A specific ADIP(address in pregroove) decoder will decode this pregroove signal, decoded address data will then be output from this ic as well as clock signals also retrieved from the pregroove. This output will be used by the EFM/ACIRC and servo side to control the spindle operation.

### 3.3. System control

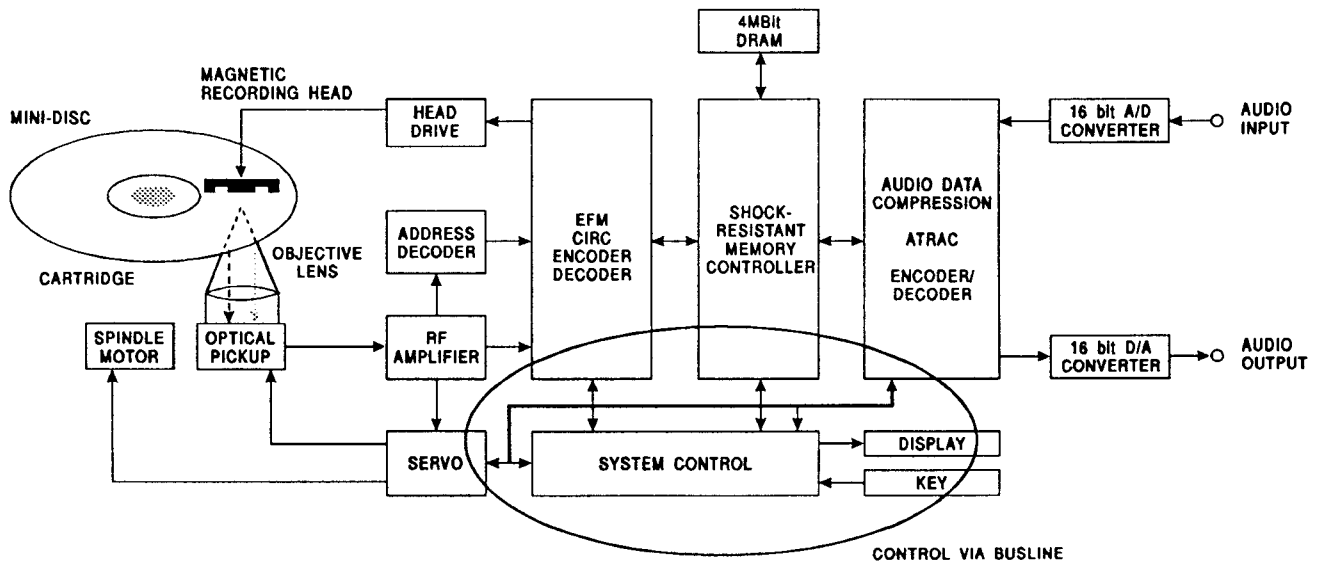


Figure 12.

It is obvious that such complex actions need a correct system control. The syscon reads and writes from and to the main ic's through a dataline system, but also through many dedicated lines.

Display output and user key input as well as internal detection switches are fed to the syscon.

Based upon all inputs, the syscon can drive each ic, within the proper timing and in a correct, coordinated sequence.

## 4.The Minidisc format

When discussing the Minidisc format many different items need to be considered ; physical format, data format, recording format etc...

All these items may seem to be put in a random way, but they have to be known before the rest of the system is explained to enable full understanding.

### 4.1.Physical format

When explaining the physical format of the Minidisc, we should remember that although the dimensions are always the same, we do have two different disc types, one for premastered discs (similar to CD but smaller) and one for recordable discs.

The outlook of a minidisc is similar to a floppy disc, the premastered/recordable medium is a 2 inch disc housed in a cartridge, closed by a shutter.

The main dimensions are following :

|                            |                      |
|----------------------------|----------------------|
| Cartridge size :           | 72 X 68 x 5 mm       |
| Weight :                   | 30g (including disc) |
| Center Hole in cartridge : | 18 mm diameter       |
| Disc diameter :            | 64 mm                |
| Clamping area :            | 16.4 mm              |
| Disc thickness :           | 1.2 mm               |

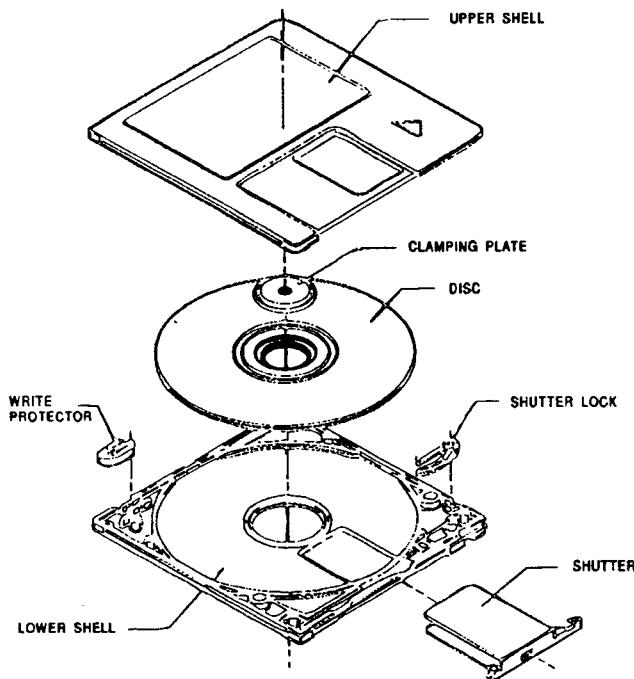


Figure 13.

There is a distinct difference in physical appearance between the premastered and recordable disc type. In the first case, only readout is needed, therefore only one side of the disc needs to be

opened. In that case the shutter is only on one side, leaving place on the other side for a label (showing graphics, information etc...). In case of a recordable type, there is a need for opening on top as well as bottom side, therefore the shutter is opening on both sides.

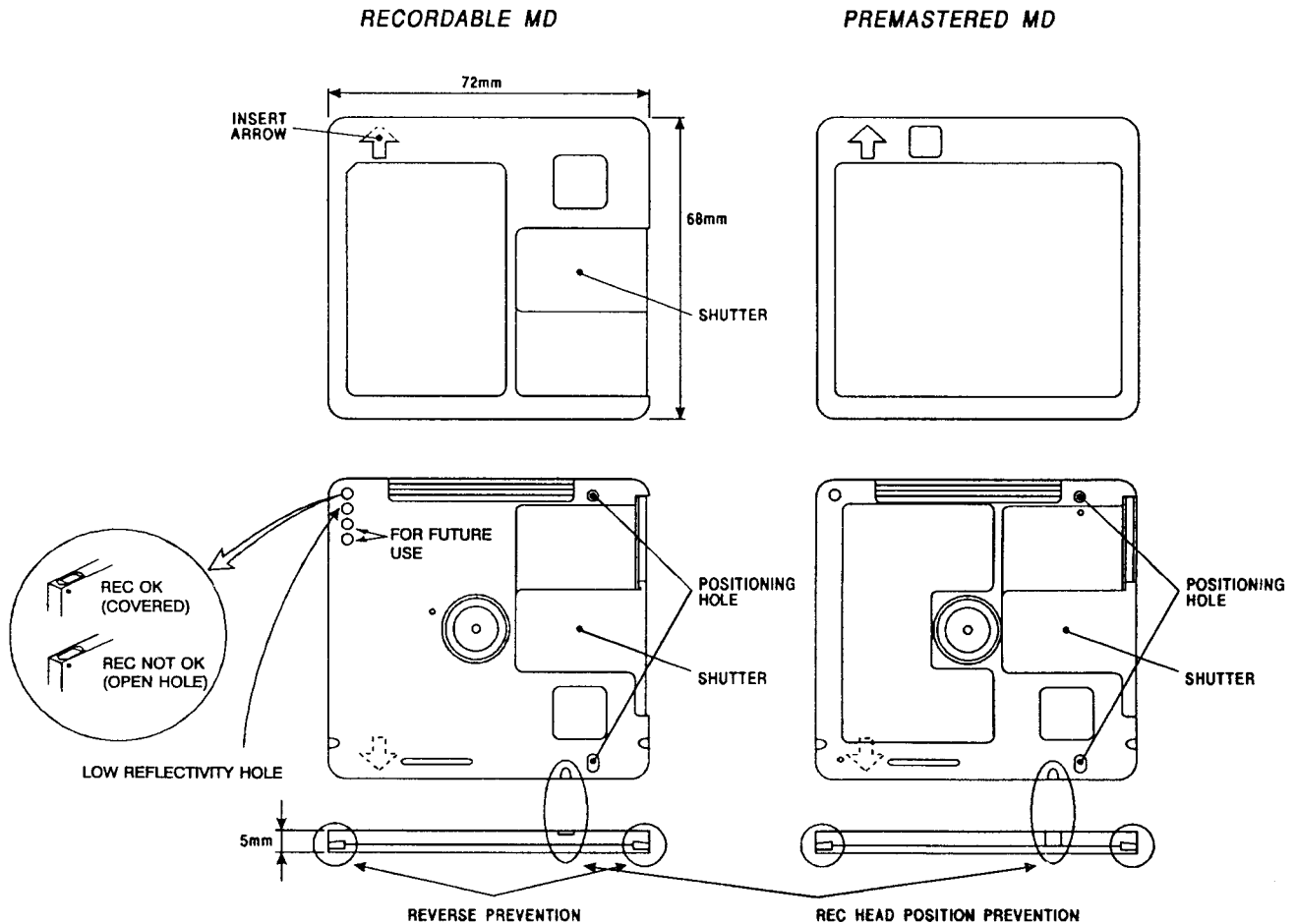


Figure 14.

As it is the case with most of the disc and cassette media, some holes and/or switches are used for information on the disc itself.

On the minidisc, there are 2 important information detection holes, one to distinguish between high/low reflectivity and another for write protect/record enable.

The premastered disc is of the high reflectivity type, similar to a compact disc, and it can not be recorded. It therefore has no low reflectivity hole and a fixed (open) write protect hole.

The recordable disc is of the low reflectivity type and can be recorded. It therefore has a low reflection hole and next to this one there is a record inhibit switch. The position of some more holes have been defined, but they are not used now, they are included for eventual future use.

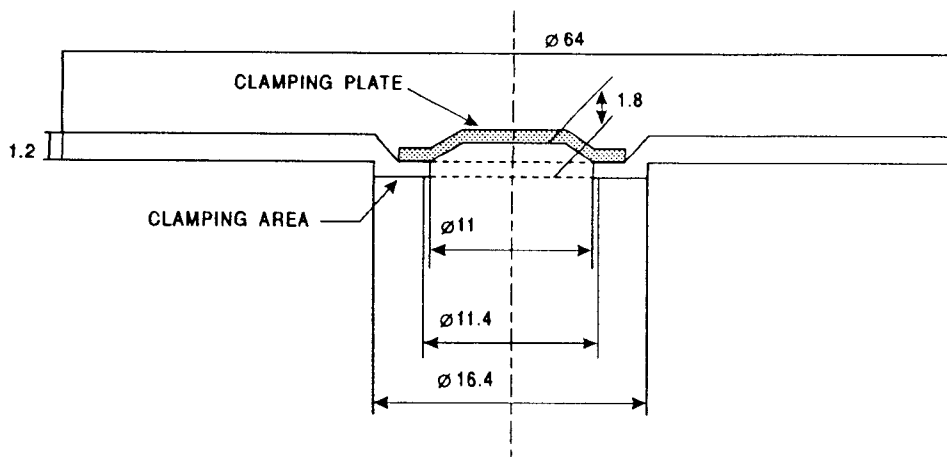


Figure 15.

When remembering the cross section of a Compact Disc, we see that the clamping area in the case of a Minidisc is somewhat different, clamping is performed through a magnetic clamping plate mounted in the disc itself, in this way correct centering which is very important is ensured.

The clamping as it is in Minidisc enables us to catch and stabilize the disc from bottom side only, which is more cost efficient and avoids the need for another hole in the cartridge.

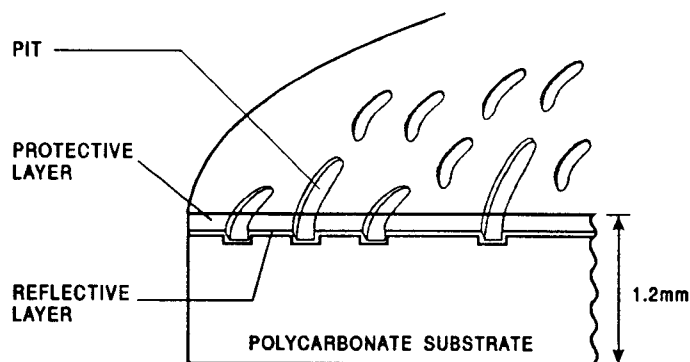


Figure 16.

The premastered disc is totally comparable with the Compact Disc, when looking at the cross section, reflection of the laser beam is also ensured by the pits.



The laser return level from such a disc is considered to be the high reflectivity level.

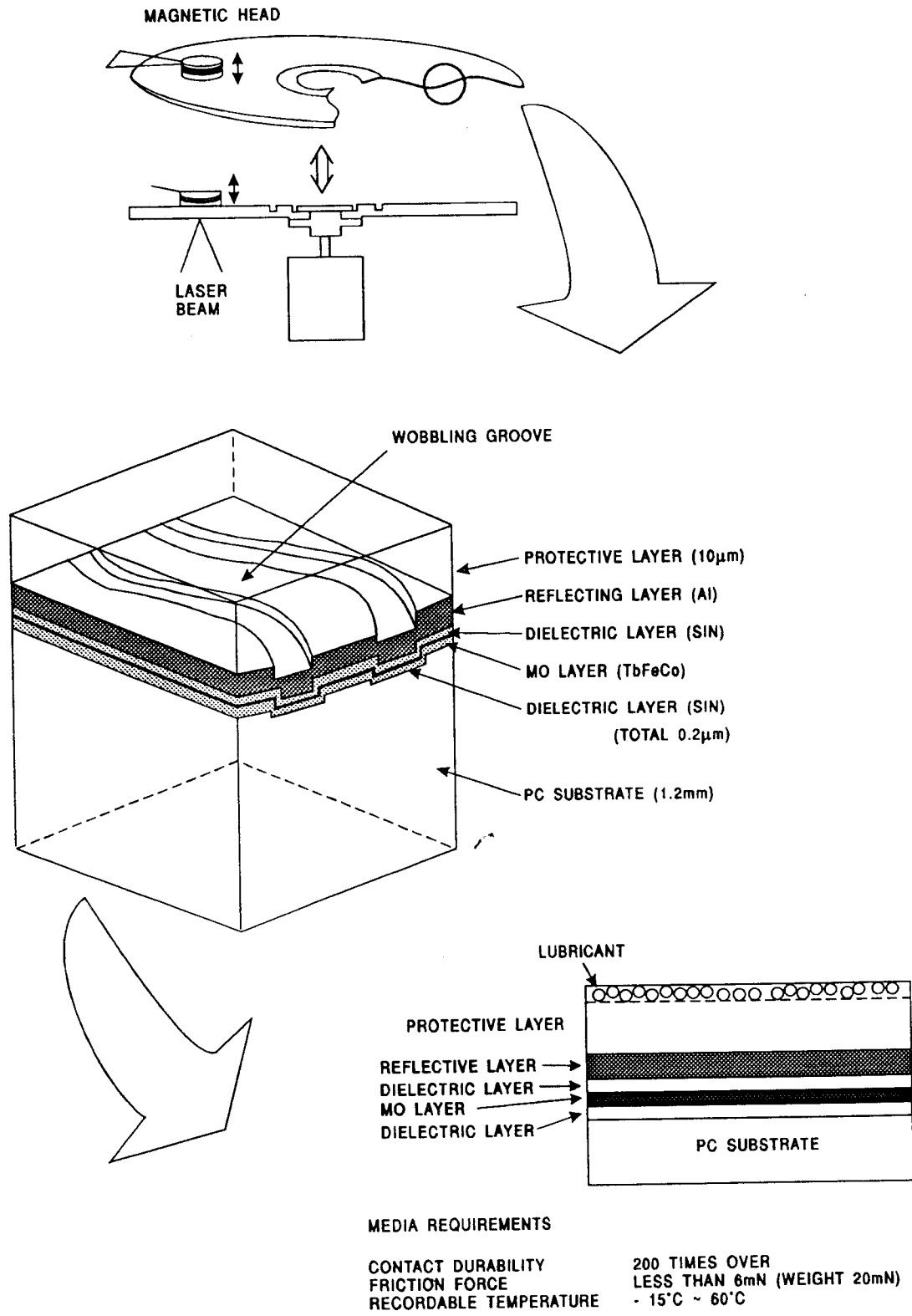
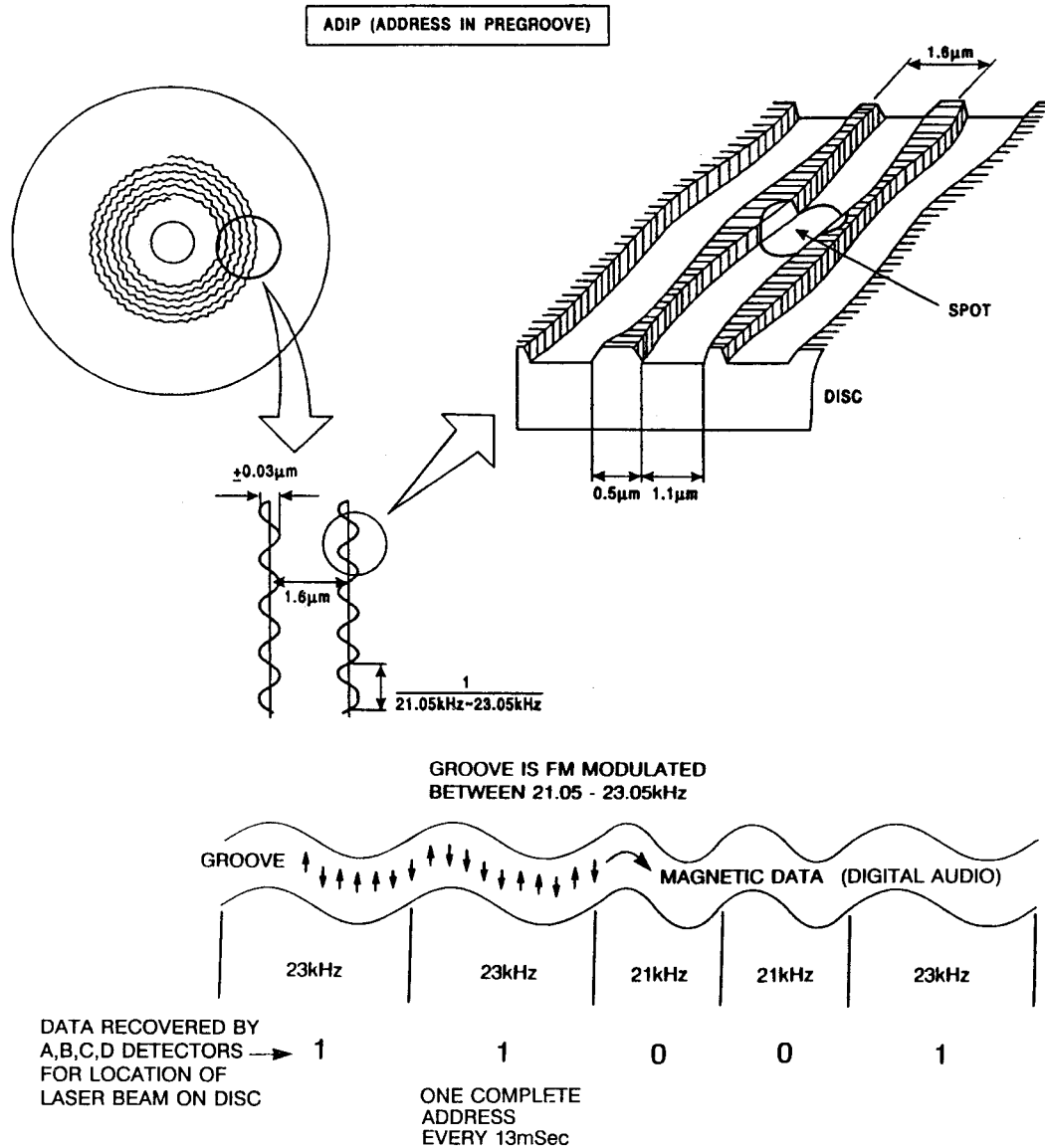


Figure 17. Low friction layer (contact with magnetic head)

The recordable disc has a different cross section, on a substrate, an MO layer (FeTbCo) is caught between dielectric layers, on top of this there is still a reflective layer, but the reflectivity in this case is much lower compared with the reflectivity from a compact disc, for that reason the recordable disc is also referred to as low reflectivity type and the signals retrieved from such a disc are handled likewise. On top of the reflective layer there is a protective layer over this last protective layer there is a lubricant, this lubricant is silicone grease.

Note that this lubricant can be deleted, it has now been included to enhance the smoothness of contact between magnetic head and disc.



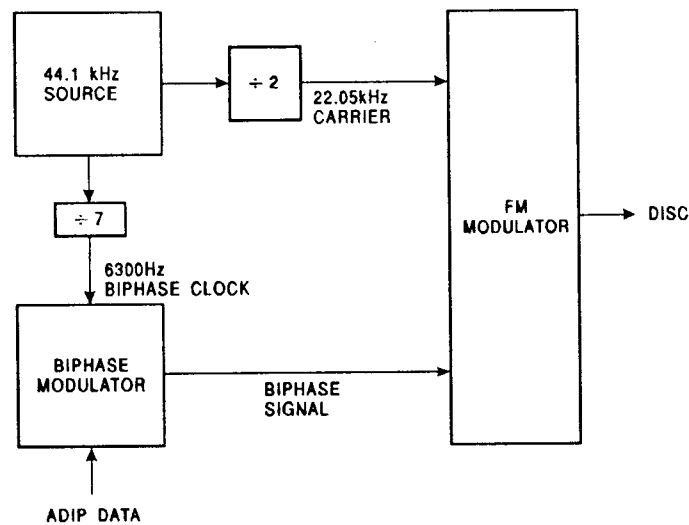
**Figure 18.**

Another important physical feature on the recordable disc is the wobble or pregroove. This is totally different from the Compact Disc.

A sine wave wobble is physically included into the disc, this wobble coincides with the data track on its spiral way.

This wobble signal is a  $22.05\text{Khz}$  frequency signal which is FM modulated with address information. This address information is exactly the same on each disc, it enables the system to control the CLV motor and to know the exact location of its laser unit.

It would be incorrect to say that on a recordable disc there is prerecorded data, a better way of saying is that the pregroove modulation enables detection of address information. This address information is referred to as ADIP : address in pregroove.



**Figure 19.**

ADIP encoding is of course performed prior to making the disc.

The ADIP data is biphase modulated with a 6300 hz clock, this clock is derived directly from a 44.1Khz source, also from this source a 22.05 Khz carrier is derived.

The biphase signal is then FM modulated onto the 22.05 Khz carrier, the resultant signal is then used for the pregroove. The modulated bitrate is 3150 bits/sec.

The Minidisc will use the carrier frequency as well as the address data for CLV operation and track addressing.

The contents of ADIP data will be explained later.

## 4.2. Recording on the disc

The premastered disc is manufactured similar to the Compact Disc format.

The recordable disc is manufactured as a disc containing a premastered lead-in area, with TOC information, but no pregroove in this area. After the lead-in area the pregroove and recordable area start and take the rest of the disc, the data contents is zero.

Recording of such a disc is based upon well known physical laws.

A substance, once it reaches a certain temperature, called the Curie point, it can be magnetically influenced by external magnetic fields. In other words, by heating up and applying external magnetical fields we can change the magnetic orientation. The substance that we will use for this purpose is a terbium-ferrite-cobalt alloy . Many other alloys can of course be used, but this one is particularly fit as it has some features that were needed for Minidisc :

A fairly low Curie point (about 185 centigrade) enabling quick heating with little power.

A low coercivity of about 80 Oersted (6.4 kA/m), enabling stable polarity reversal with a relatively weak field for which also no high power is needed.

### WRITING TO A MAGNETO-OPTICAL DISC

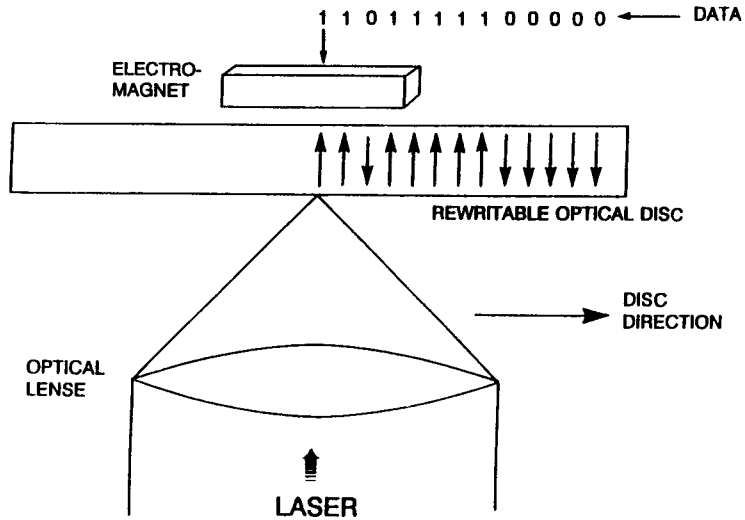


Figure 20.

The recording uses Magnetic Field Modulation, recording is performed in one time, the laser will on one side heat the magnetic layer up to the correct temperature, and on the other side, the magnetic head will impose the correct polarity. Recording and re-recording are performed by overwrite, the previous data is not erased first. A special magnetic head was developed which enables extremely quick flux reversals of approx. 100 Nanosec. This is important to ensure precise recording.

The layers surrounding the magnetic layer are adapted for the high temperature handling.

### 4.3. Readout of the disc

The premastered disc is read out similar to a compact disc. The laser light level reflected from the compact disc or premastered disc is depending on the pits stamped in the disc.

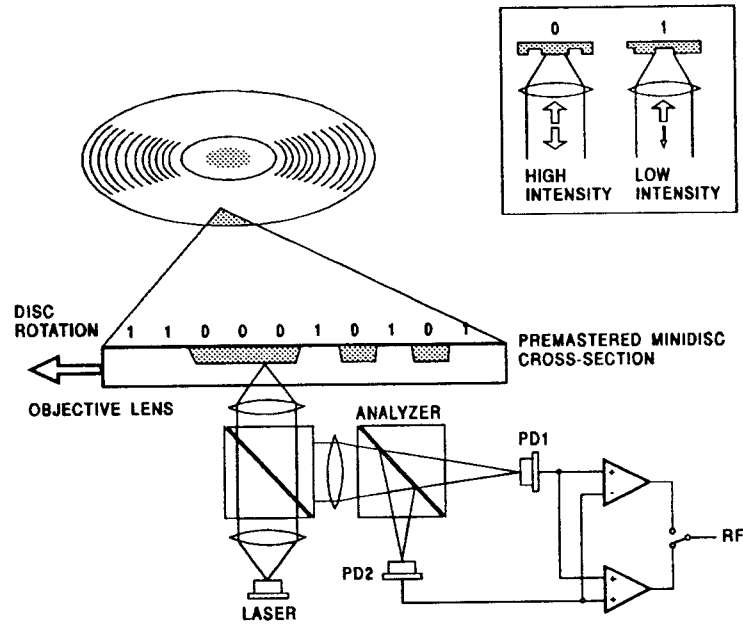


Figure 21.

On the recordable part of the recordable disc another physical law is involved : the laser light sent to the disc will hit the disc surface, pass through the magnetic layer and hit the reflective layer, in this way the laser light will also be reflected similar to the Compact Disc or premastered Minidisc. But as there are no pits, the reflected laser light level is constant. When passing through the magnetic layer, the so-called Kerr effect takes place: the polarisation of a light beam is changed when it passes through a magnetic medium. As the magnetic layer was modulated magnetically during recording it is obvious that the modulated contents will now pass on to the laser light.

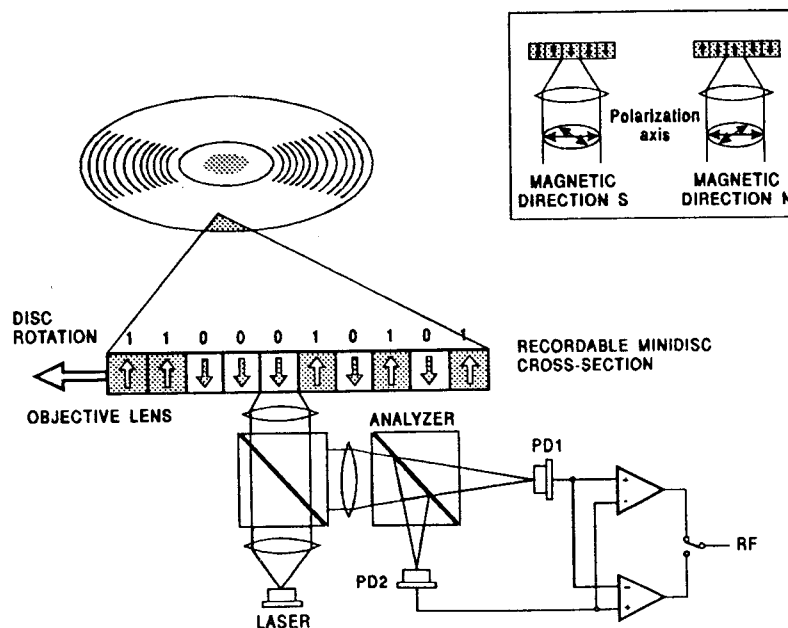


Figure 22.

#### 4.4. Track Layout

The premastered disc can again be compared with a Compact Disc, the information area consists of a lead-in area (table of contents), a program area and a lead-out area.

All these areas are prerecorded, none of them can be changed.

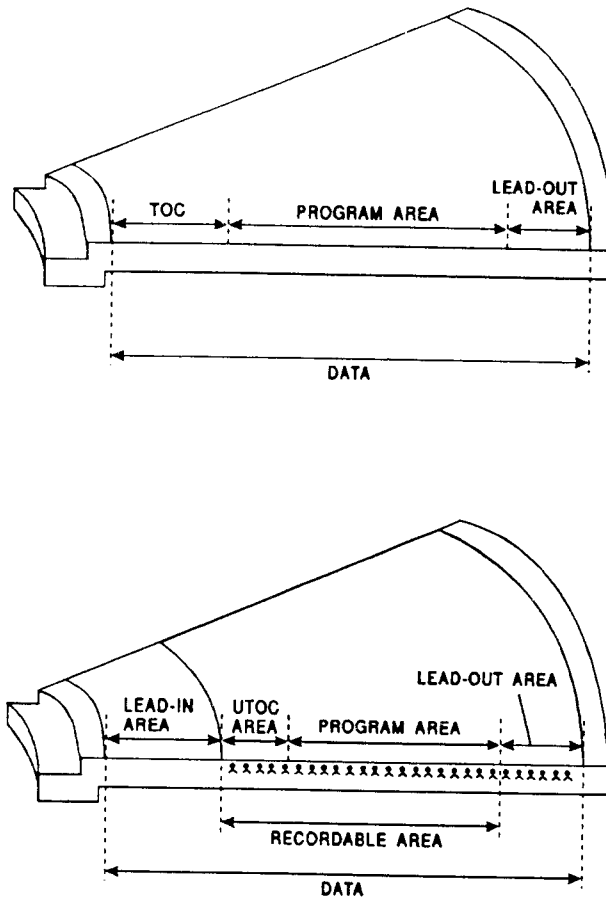


Figure 23.

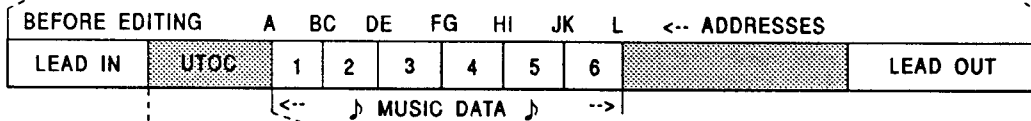
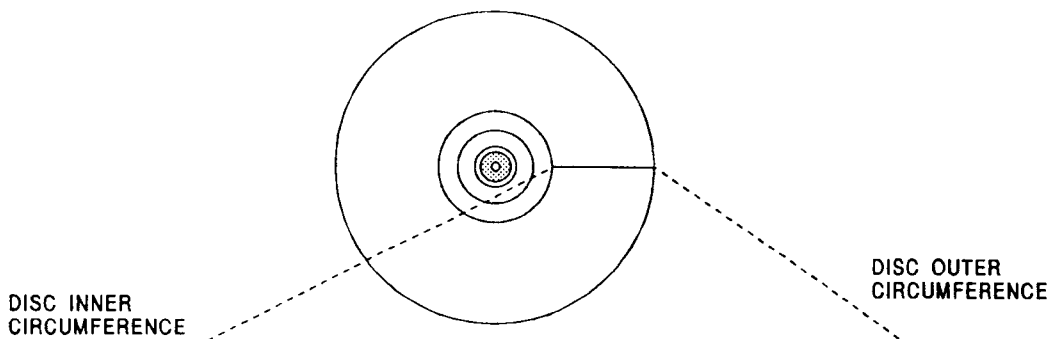
The recordable disc can be divided into non-recordable area and recordable area. The non-recordable area is similar to the lead-in area on the premastered disc.

It contains information concerning locations on the disc (for example, the start and end address of UTOC), but also information such as laser power level, disc type...

The lead-in area of a recordable disc is a pit signal, similar to a premastered disc, but in this case the reflectivity is much lower compared to a CD type. The Minidisc set will adapt to this lower reflectivity.

The recordable area starts with the UTOC or user table of contents.

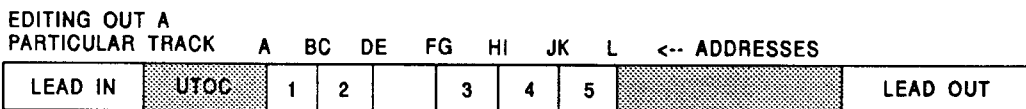
UTOC is an area similar to TOC, but in the case of a recordable disc, the allocation of addresses is not constant, it depends on the user. The way UTOC is handled is very similar to the way a computer allocates addresses on a floppy disc.



CONTENTS

| TRACK NUMBER | ADDRESSES |
|--------------|-----------|
| 1            | A B       |
| 2            | C D       |
| 3            | E F       |
| 4            | G H       |
| 5            | I J       |
| 6            | K L       |

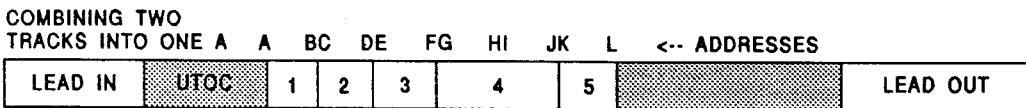
THE UTOC CONTAINS BOTH THE TRACK NUMBERS AND THEIR ASSOCIATED ADDRESS LOCATIONS.



CONTENTS

| TRACK NUMBER | ADDRESSES         |
|--------------|-------------------|
| 1            | A B               |
| 2            | C D               |
| 3 --> BLANK  | E F --> AVAILABLE |
| 4 --> 3      | G H               |
| 5 --> 4      | I J               |
| 6 --> 5      | K L               |

WHEN TRACK 3 IS EDITED OUT, TRACK NUMBERS 4, 5, 6 SIMPLY MOVE UP TO 3, 4, 5, ADDRESS EF BECOMES AVAILABLE FOR RE-RECORDING.



CONTENTS

| TRACK NUMBER | ADDRESSES |
|--------------|-----------|
| 1            | A B       |
| 2            | C D       |
| 3            | E F       |
| 4            | G H       |
| 5            | I J       |
| 6 --> 5      | K L       |

WHEN TRACKS 4 AND 5 ARE COMBINED, THEIR TRACK NUMBER IS 4 AND TRACK 6 MOVES UP TO 5. THEIR ADDRESSES AS WELL ARE COMBINED TO FORM GJ.

Figure 24.

One important note must be made here : similar to the use of a computer floppy disc, writing, erasing, dividing, editing, separating and all other possible data manipulations can only be considered complete when the UTOC area is updated.

If for example we try to record data, this will of course be recorded in the data area, but when the recording is ended, the start and end addresses need to be written in UTOC. If for one or another reason this is not performed (the writing in UTOC), the system will not be able to consider the recorded data as valid.

Another example : when we erase a music track (data track) we do not erase the data at all, only the start/end address in UTOC area will be erased. The area taken by the music data then becomes available and will be overwritten during next record session.

The same goes for all other possible recording operations.

The UTOC area also includes other informations such as disc type, copy protect codes, recording time and date etc...

After the UTOC area the recordable user area takes the biggest space on the disc and at the end of course a lead-out area, which in this case is recordable and also contains the pregroove

| AREA       | PREMASTERED | RECORDABLE |
|------------|-------------|------------|
| Lead In    | Yes         | Yes        |
| UTOC       | No          | Yes        |
| Music Area | Yes         | Yes        |
| Lead Out   | Yes         | Yes        |

Figure 25.



## 4.5. Data Format

The data format of a Minidisc is similar to the mode 2 of a CD-ROM, it is derived from the so-called Yellow Book specification. Note that also the data format of Compact Disc (the Red Book specification) uses these principles.

In this CD-ROM/MODE 2 data is divided in sectors, the same sector format is used in Minidisc, but another concept was included ; the CD-ROM sector format is now extended to cluster format.

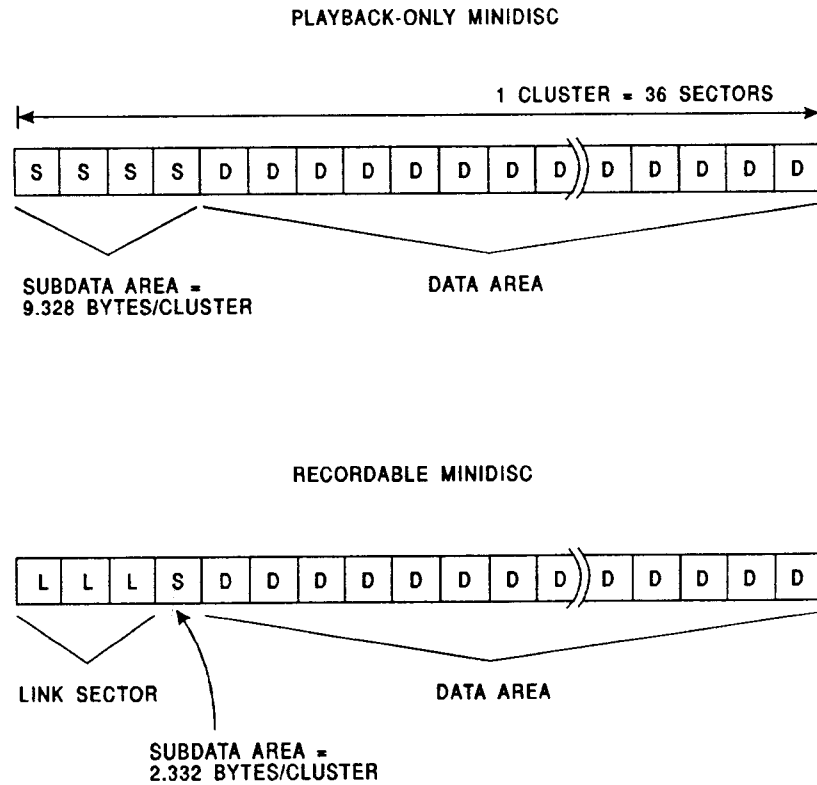


Figure 26.

One cluster comprises 36 sectors, in which 32 sectors are used for compressed data, and 4 sectors are used for link and subdata.

These 4 sectors (link/data) are different in premastered and recordable disc. In premastered discs these 4 sectors are filled with subdata, this can be graphic data (for display), information on the disc, lyrics etc... In other words it is a feature area.

In recordable discs 3 sectors need to be used as link sector and one for sub data.

### 4.5.1 The link concept

The reason for linking sectors comes from the ACIRC encoding, in CD and CD-ROM circ encoding and EFM modulation are used, in Minidisc the same CIRC encoding is used as well as EFM modulation, but CIRC is extended (ACIRC = Advanced CIRC).

CIRC was taken as starting point, but more interleave was included, to protect even better against burst errors.

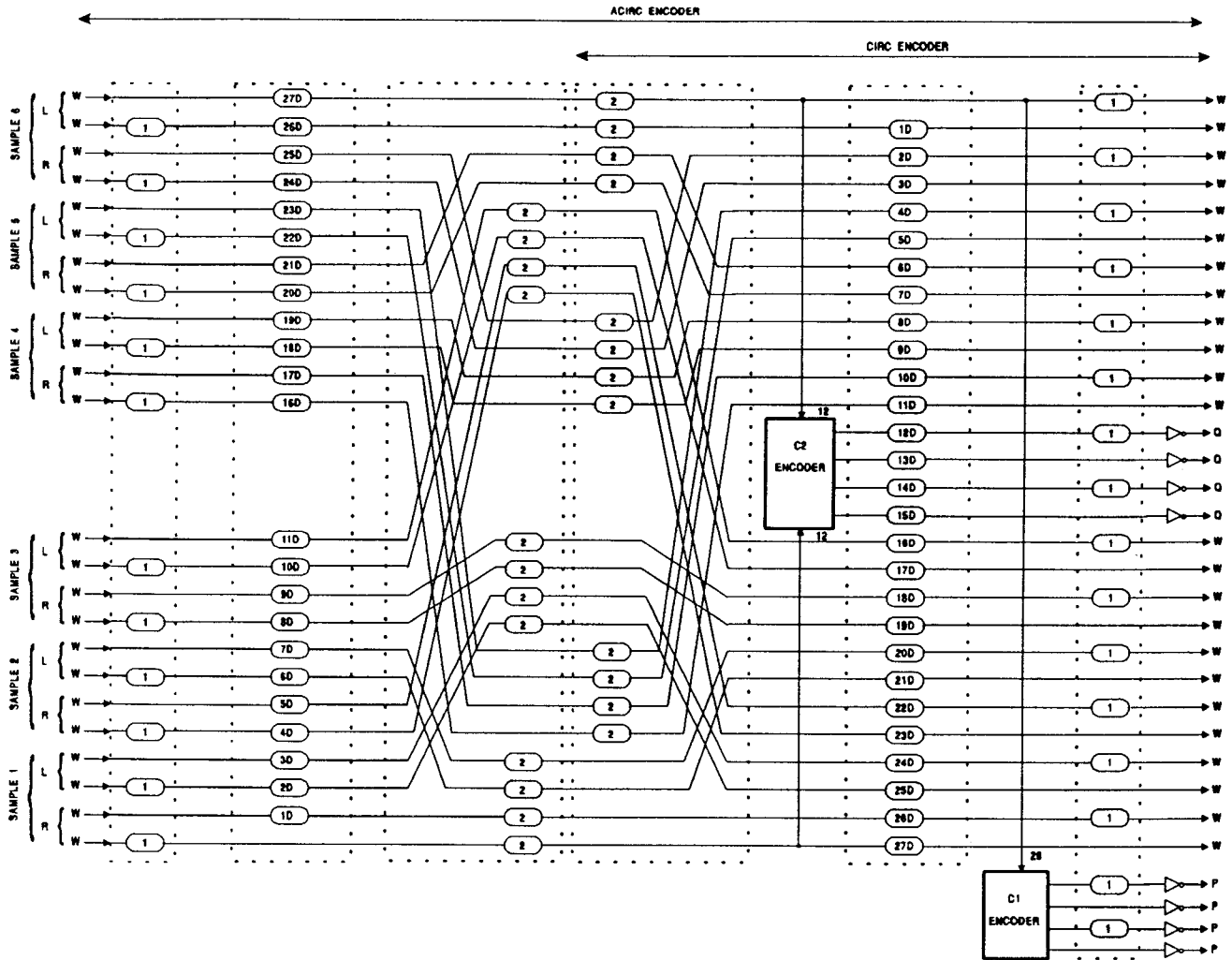


Figure 27.

One consequence is that the interleave goes beyond one sector, in CIRC the interleave takes 98 frames, in ACIRC the interleave takes 108 frames. And as the same frame/sector format is used in Minidisc, it is obvious that the interleave is not complete within one sector.

One cluster is the minimum area used when recording on a Minidisc, as the interleave of the last sector is not complete, the linking sectors are needed to separate one cluster from the next one. Imagine a cluster layout without linking area : we record one cluster, but as the interleave is not complete at the last sector of the cluster, these last interleave frames will be recorded into the first sector of the next cluster and of course destroy the information in that sector.

Obviously we must avoid this situation.

3 Link sectors are sufficient for this purpose, the first link sector and a part of the second link sector are used for the remaining interleave of the last cluster, another part of the second link sector and the third link sector is used for interleave of the next sector.

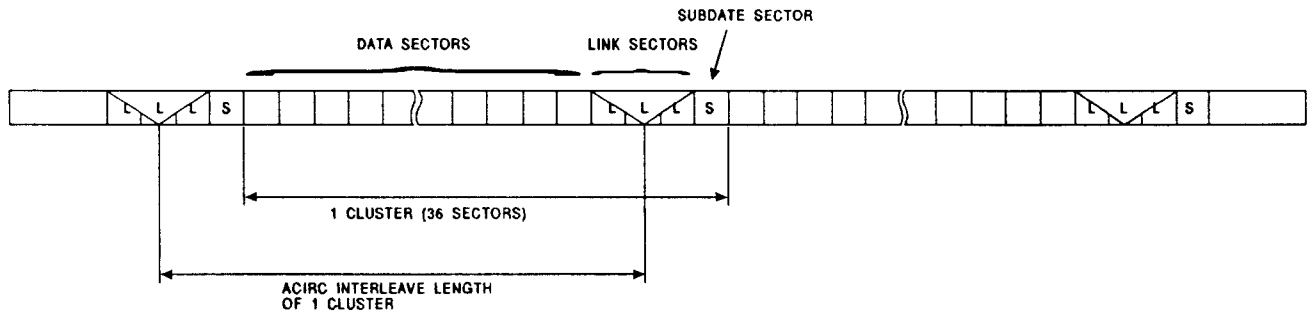
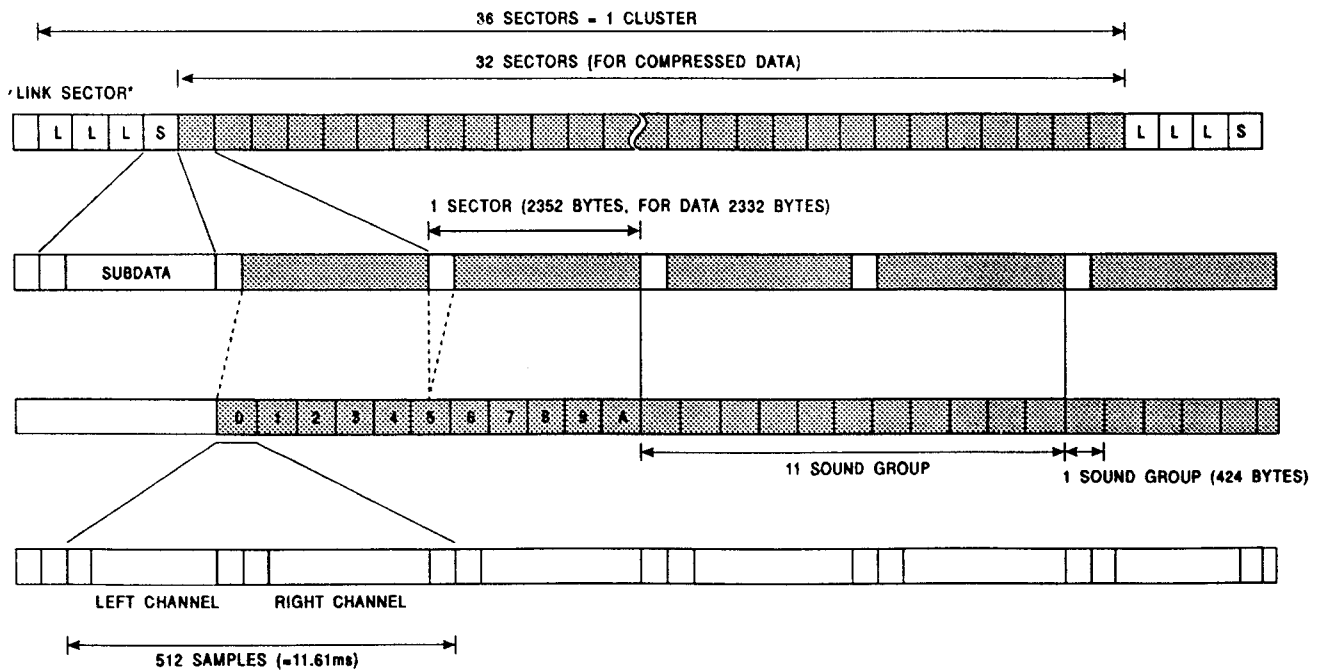


Figure 28.

This linking format is only necessary in recordable Minidisc, in the premastered format, data is written in one continuous stroke, it is not re-recordable, and therefore there is no need for linking sectors. As already mentioned, in that case the free space is used for subdata.

#### 4.5.2. Data format cont'd

We can now further analyse the data format, each sector contains in total 2352 bytes, of which 2332 bytes are data bytes. (comparable to the sector format of CD-ROM)



\* THIS BECOMES A SUBDATA SECTOR IN PLAYBACK-ONLY MINIDISCS.

Figure 29.

A further division is the sound group, a sound group is the smallest division, containing 424 bytes (212 left channel, 212 right channel) a sound group gives ATRAC compressed audio data equal to 512 uncompressed samples at 44.1Khz sampling rate.

In 2 sectors we find 11 sound groups, the first sector contains 5 full sound groups and the left channel half of the 6th sound group, the next sector starts with the right channel of the 6th sound group and continues with 5 more sound groups.

In this way we can calculate the amount of bytes per sector to be  $424 \times 5 + 424/2 = 2332$  Bytes.

At this point we can already calculate the compression rate used in the minidisc :

Each ATRAC compressed sound group contains 424 bytes, but as said above this represents 512 samples of 16 bit, 2 channel equalling

$512 \times 16 \times 2/8 = 2048$  bytes. Conclusion :2048 bytes were compressed to only 424 bytes.

#### 4.6.Address Structure

As mentioned before, the cluster format is used in Minidisc, the basic addressing structure is therefore based upon the cluster format. But another very important point is that the pregroove on the recordable disc uses this same address format.

In an earlier chapter it was explained that the pregroove is a 22.05Khz carrier frequency modulated with ADIP data, this ADIP data is the cluster and sector address.

We now have to differentiate again between the premastered and the recordable disc.

The premastered disc will carry the cluster/sector address in its subdata, the recordable disc will carry the cluster/sector address in the subdata (including the premastered lead-in area) as well as in the pregroove. In case of the recordable disc it is obvious that the location of the address data in the pregroove which is physically included in the disc and therefore not changeable has to coincide with the address in the subdata which is indeed recordable.

The cluster address is a 2 byte format, the sector address is a 1 byte format.

During lead-in (in premastered as well as recordable) the cluster address is increasing and has to end with the following address :

FFFF(H);1F(H) (cluster;sector). After lead-in , the cluster/sector addressing starts at 0000;FC and will increase sequentially and uninterrupted to the end of the disc.

As we already know that each cluster contains 36 sectors, the 32 first sectors are the data sectors, the sector address will start at 00(H) and go up to 1F(H), the first link sector is addressed FC(H),

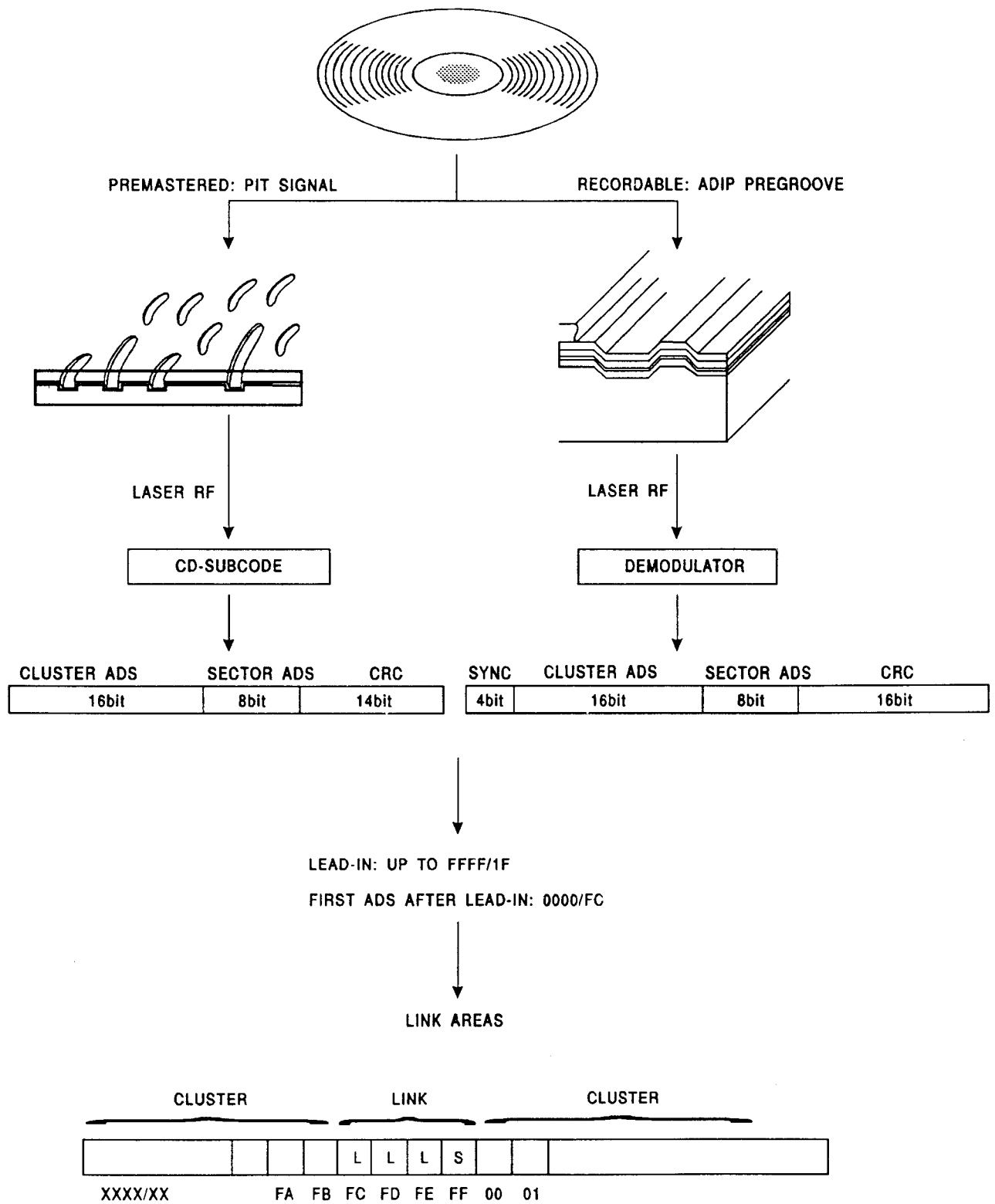


Figure 30.

In case of ADIP, the full sequence is following : each ADIP address is a 42 bit block, containing 4 sync bits, 16 cluster address bits, 8 sector address bits and a 14 bit cyclic redundancy check. These 42 bits are biphase modulated with a 6300 hz biphase clock, and then FM modulated onto the 22.05Khz carrier. The bit rate is 3150 bit/sec, the sector rate is in that case  $3150/42 = 75$  hz, which is the same as CD-ROM and CD.

### 4.6.1. Address in premastered disc

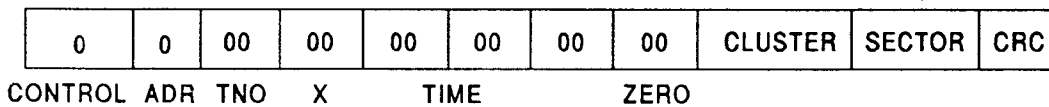
The block diagram already revealed that the data in Minidisc is also EFM modulated, it has also been noted that the general datastructure is derived from CD and CD-ROM.

It is therefore obvious that in all premastered areas the address data, cluster and sector data, will be inserted in the CD-like format.

#### SUBCODE IN PREMASTERED DISC

ON MD DISC, THE DATA IN THE SUBCODE CHANNEL IS DEFINED ONLY IN THE PRE-MASTERED PITS. SUBCODE P, R, S, T, U, V, W, ALL ZERO.

SUBCODE Q FORMAT (LEAD-IN, PRE-MASTERED AND LEAD-OUT AREAS):



- \* CLUSTER: 2 BYTES BINARY, MS Bit IS FIRST OUT.
- \* SECTOR: 1 BYTE BINARY, MSBit IS FIRST OUT.  
THESE ADDRESS INFORMATION ARE ACCORDING TO CHAPTER 5.
- \* CRC: A 16 bit CRC ON 80 bits Q-DATA FROM CONTROL TO SECTOR.

Figure 31.

### 4.6.2. Address in recordable area

The addresses in the recordable area are included in the datastream which will be handled in the next chapter.

## 4.7. Data structure

|   |  |          |          |          |
|---|--|----------|----------|----------|
| <div style="display: flex; align-items: center; justify-content: center;"> <div style="text-align: center; margin-right: 10px;">             ↑<br/>             Audio<br/>             Block<br/>             2332 Bytes<br/>             ↓           </div> </div> | <div style="display: flex; align-items: center; justify-content: center;"> <span style="font-size: 1.2em;">←</span> <span style="margin: 0 5px;">1 Byte</span> <span style="font-size: 1.2em;">→</span> </div> |          |          |          |
|   | Sync   | Sync     | Sync     | Sync     |
|   | Sync   | Sync     | Sync     | Sync     |
|   | Sync   | Sync     | Sync     | Sync     |
|   | cluster  | cluster  | sector   | mode     |
|   | 00000000   | 00000000 | 00000000 | 00000000 |
|   |  |          |          |          |

**Table 2. Audio sector data format**

|      |               |
|------|---------------|
| MODE | 0 : ZERO MODE |
|      | 1 : RESERVED  |
|      | 2 : MINI DISC |
|      | 3             |
|      | ⋮             |
|      | 255           |
|      | }             |
|      | : PROHIBITED  |

Each addressable block (each sector) has 2352 bytes, the first 12 bytes are a unique sync pattern, the next 4 bytes are header bytes, containing 3 address bytes (2 cluster, 1 sector) and a mode byte.

The mode byte describes the nature of the data fields

#### 4.7.1. Sound groups in the data structure.

In each sector there are 5 full and one half sound group, each sound group can be split in left channel and right channel sound group. The data structure of a sound group depends on the ATRAC encoding, please also refer to the ATRAC chapter for more information on this part. Each sound group is divided in sound parameter bytes, audio spectrum bytes and again sound parameter bytes, the second sound parameter bytes group is exactly the same as the first one, but reversed in order.

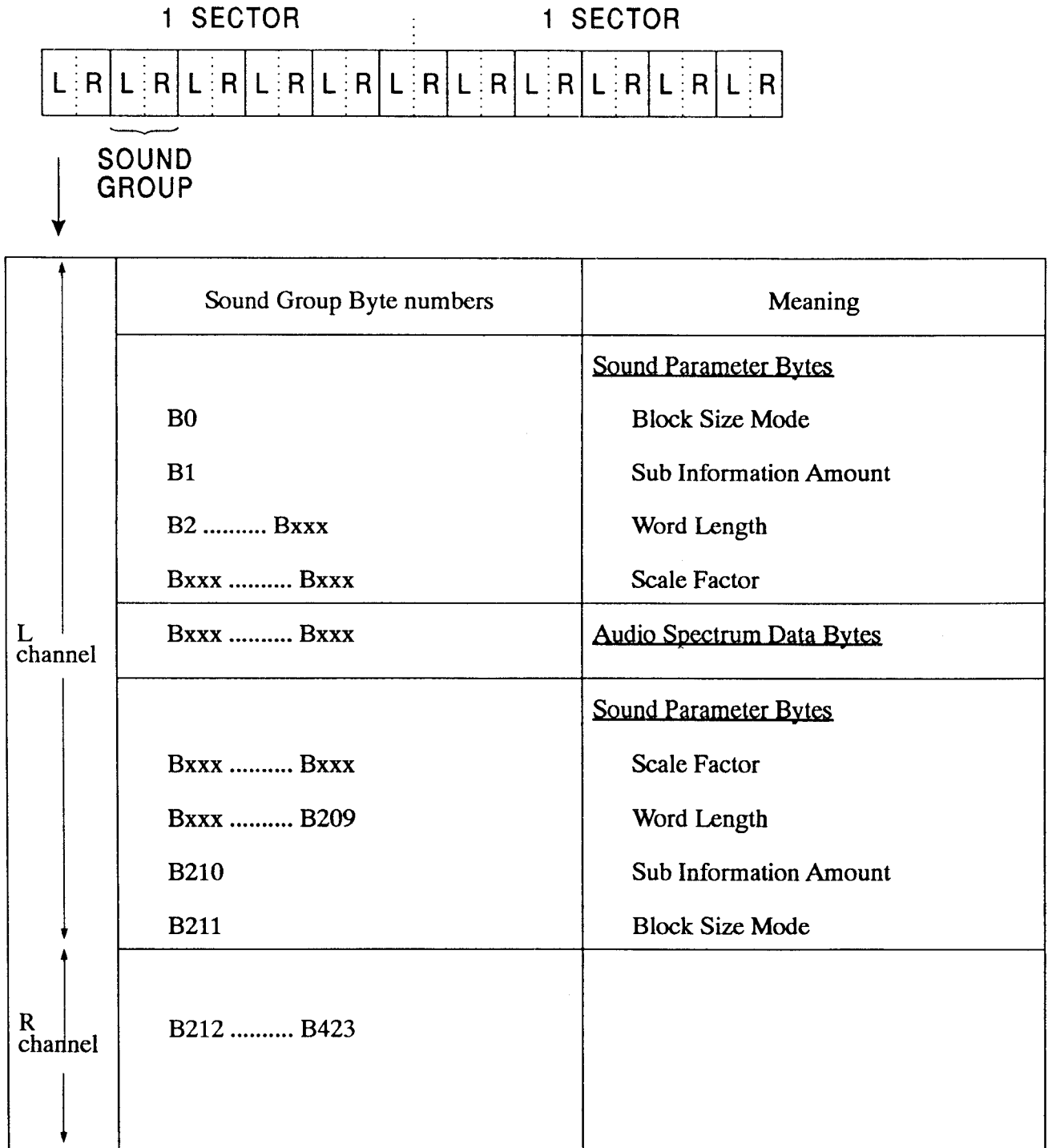


Table 3.



#### 4.7.2.Data structure in TOC and UTOC

The data structure in TOC and UTOC is basically the same as on the rest of the disc, as just explained. The general structure remains the same, the sync is the same, the cluster ,sector address and mode bytes are the same but in the data field of course there is a different type of data.

In the TOC there is initially an indication of disc type, this information is needed from the start as there is a difference in TOC information between premastered and recordable disc.

In case of premastered disc the TOC will contain following data :

|            |  |         |        |      |
|------------|--|---------|--------|------|
|            | ← 1 Byte →   |         |        |      |
|            | Sync   | Sync    | Sync   | Sync |
|            | Sync   | Sync    | Sync   | Sync |
|            | Sync   | Sync    | Sync   | Sync |
|            | cluster  | cluster | sector | mode |
| 2336 Bytes | Disk type<br>First/last TNO<br>Lead out start ADS<br>Used sector indication<br>Pointers for track numbers<br>Start/end of tracks<br>Track mode           - copy protect (SCMS)<br>- audio/other<br>- stereo/mono<br>- emphasis off/on (50/15 μS)<br>Pointers for track name table<br>Disc name (ASCII coded)<br>Tracknames (ASCII code)<br>Pointers for date/time table<br>Disc REC date/time<br>Track REC date/time<br>Pointers for track IRSC table<br>Bar code (UPC/EAN code)<br>ISRC code (DIN code) |         |        |      |

Table 4. Premastered TOC

In case of recordable disc the TOC will contain following data :

|                      |  |         |        |      |
|----------------------|--|---------|--------|------|
|                      | ← 1 Byte →   |         |        |      |
|                      | Sync   | Sync    | Sync   | Sync |
|                      | Sync   | Sync    | Sync   | Sync |
|                      | Sync   | Sync    | Sync   | Sync |
|                      | cluster  | cluster | sector | mode |
| ↑<br>2336 Bytes<br>↓ | Disk type<br>Laser REC power<br>Lead out start ADS<br>Used sectors indication<br>Power calibration area start ADS<br>UTOC start ADS<br>REC user area start ADS |         |        |      |

**Table 5. Recordable disc TOC**

The UTOC area also contains a power calibration area and a reserved area, both after the real UTOC data.

|                      |  |         |        |      |
|----------------------|--|---------|--------|------|
|                      | ← 1 Byte →   |         |        |      |
|                      | Sync   | Sync    | Sync   | Sync |
| ↑<br>2336 Bytes<br>↓ | Sync   | Sync    | Sync   | Sync |
|                      | Sync   | Sync    | Sync   | Sync |
|                      | cluster  | cluster | sector | mode |
|                      | First/last TNO   |         |        |      |
|                      | Used sectors indication  |         |        |      |
|                      | Disc-ID (optional)   |         |        |      |
|                      | Pointer for defective AREA start ADS (optional)  |         |        |      |
|                      | Pointer for empty position on parts table  |         |        |      |
|                      | Pointer for the rest of REC area start ADS   |         |        |      |
|                      | Pointers for start ADS   |         |        |      |
|                      | Start/end ADS  |         |        |      |
|                      | Link positions of start/end ADS  |         |        |      |
|                      | Track mode <ul style="list-style-type: none"> <li>- copy protect (SCMS)</li> <li>- audio/other</li> <li>- stereo/mono</li> <li>- emphasis off/on (50/15 μS)</li> </ul> |         |        |      |
|                      | Pointers for empty position on name table  |         |        |      |
|                      | Pointers for track name table  |         |        |      |
|                      | Disc or track name (ASCII coded)   |         |        |      |
|                      | Link positions on previous item  |         |        |      |
|                      | Pointers for track date/time table   |         |        |      |
|                      | Disc REC date/time   |         |        |      |
|                      | Power calibration area   |         |        |      |
|                      | Reserved area  |         |        |      |

Table 6. Recordable disc UTOC

### 4.7.3 Lead-out

Lead-out contains premastered pits on the premastered MD, this is again the same as on a Compact Disc.

On the recordable disc, the lead-out area contains no data, there is just the pregroove. Detection of the start of lead-out can therefore be performed on the pregroove ADIP data.

### 5.ADIP

The use of ADIP (address in pregroove) is typical for the recordable Minidisc, it is not used in the premastered disc.

The pregroove system as well as the data format were already explained in previous chapter. Only a small recapitulation is needed now.

The pregroove is a U shaped depression in the disc surface, coinciding with the spiral data track, it starts at the end of lead-in and goes up to the outer circumference of the disc. This pregroove does not only follow the spiral data track, but with the data track as center point it will show a sine wave pattern.

The pregroove is a 22.05 KHz sine wave, frequency modulated by the ADIP (Address in Pregroove) information. The ADIP information is an address block information containing sync, cluster and sector address and cyclic redundancy check. This binary information is biphase modulated with a 6300 hz clock.

The address information will be repeated in the magnetically recorded data (in the header section of each sector), location of address in pregroove and address in data will be the same (within specified limits).

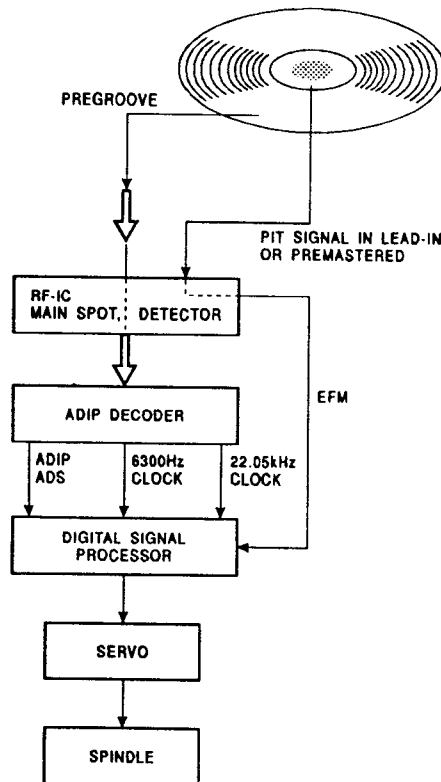


Figure 32.

During readout, the main (ABCD) spot detector will be used to detect the ADIP signal. A specific ADIP decoder is needed in view of the FM modulation.

Outputs from this decoder will be used to run the disc CLV section, these outputs are :

The 22.05 KHz groove frequency for CLV run-up (CLV-S mode)

The 6300 hz biphas clock for CLV operation (MDS in CLV-A mode)

The ADIP data for CLV fine operation (MDP in CLV-A mode)

The CLV is driven by these signals, which are input to the digital processor, of course, as there is a link between the digital processor and system control this operation is at all moments fully under control.

The digital processor has to perform CLV operations, similar to a Compact Disc. With Minidisc however, the situation is more complex, when a premastered disc is to be played, CLV is handled in the same way as in a Compact Disc ; based upon an initial internal run-up and the EFM signal the CLV is handled.

When a recordable disc is inserted, the situation is complex, remember that the lead-in area of a recordable disc has no pregroove, so initially the system will start again similar to the Compact Disc. In the pregroove, ADIP signals are used as indicated above.

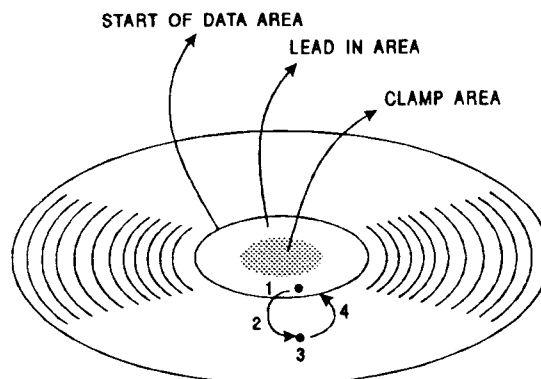
Notice also the fact that switches need to be included, to switch between MO/CD , high and low reflectivity.

## 5.1.Start up sequence

As the start up sequence of a recordable Minidisc is somewhat different from the CD or premastered start up, it is worth mentioning.

The lead-in area of a recordable Minidisc is pit information, but with low reflectivity. Here the start will be performed, similar to a premastered or CD situation, the addressing in this area runs up to a specified address FFFF;1F (cluster;sector). When the address FFFX;XX is seen the system will perform a +/- 0.35 Sec track jump to the recordable area. This track jump will give the system enough transition time to switch from pit to magnetic signal, from EFM address information (CLV steering) to ADIP information.

Of course this 0.35 Sec jump will land the laser at an unspecified position, but the ADIP information will be read out and this will enable correct return to the beginning of the recordable area.



1. DETECTING OF ADS FFFX/XX
2. 0.35ms JUMP
3. ADS READOUT
4. JUMP TO START OF DATA AREA

Figure 33.

## 6. The Minidisc Optical Block Unit

The optical block unit used in Minidisc resembles the one used in Compact Disc ; therefore knowledge of that type OPU is the ideal starter for the one in Minidisc.

There are however some major differences :

The Minidisc optical block is also used for recording purposes, the used power is in that case much higher (up to about nearly 7mw total power). In playback the used laser power is the same as for compact disc (about 0.5 mW).

Readout of the recordable disc through this optical block is not based upon a pit signal, but upon the polarization of the reflected laser beam. Readout of the premastered disc is the same as on a compact disc. One optical block assembly is used to readout both signals. It is obvious that in order to obtain this dual readout possibility, as well as the higher power handling, new technologies needed to be used. These will now be explained.

A first note must be made concerning the laser power : when talking about laser power we must distinguish between total laser power and power of the main beam.

When using total laser power we refer to the original 3 beam system, as used in Compact Disc, and we add the power of main beam and sidebeams. In case of the Minidisc the total power is just under 7 milliWatt.

When using the main beam power only, we have of course a lower power (in Minidisc, about 5 milliWatt) as we only take a part of the total power into account.

This distinction should be remembered as there may exist some confusion when comparing publications.

When following the laser beam from laser unit to detector unit, we see initially the same path as in the compact disc OPU.

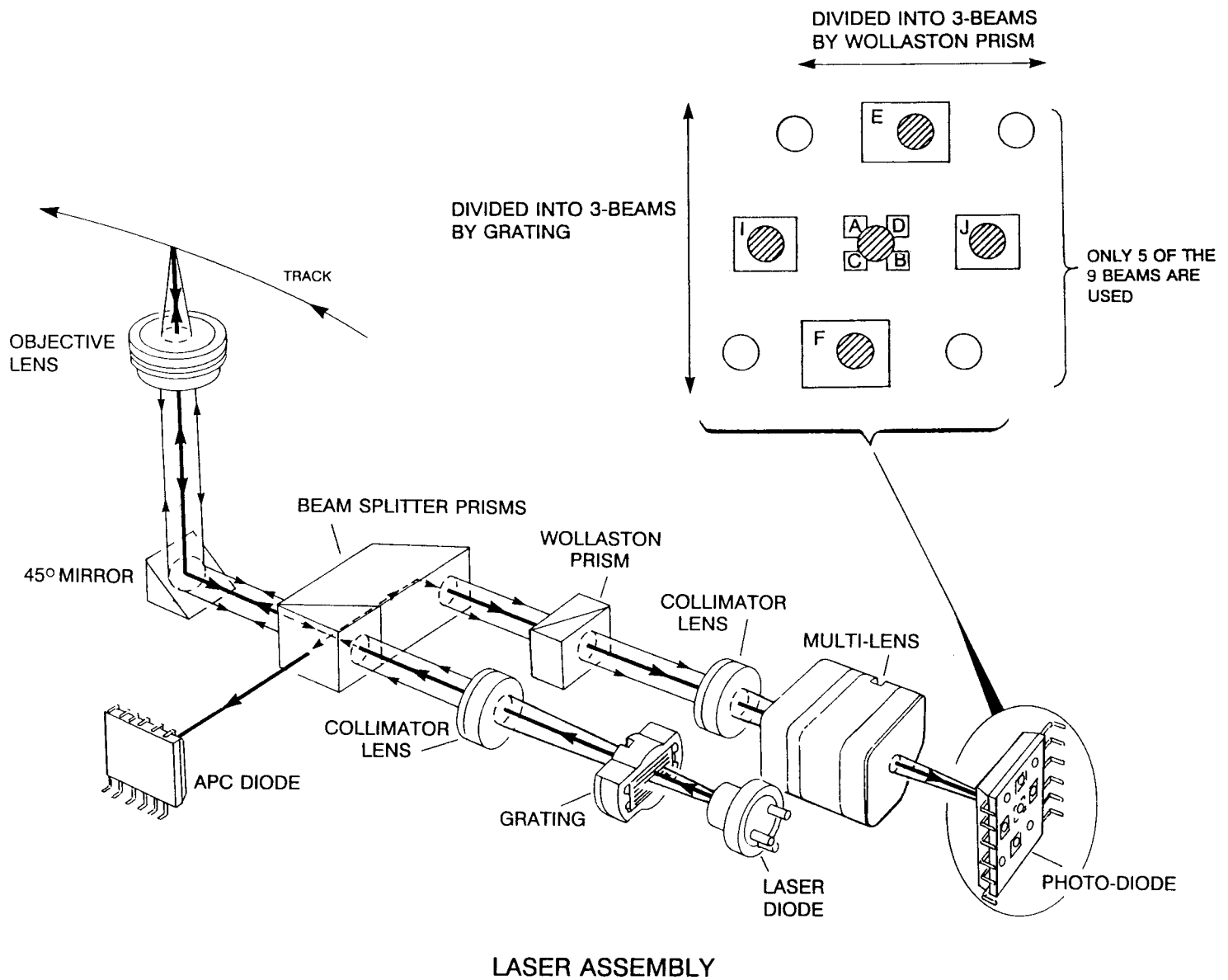
The beam is emitted from the laser, passes through a diffraction grating where the side beams (E and F beams) are created. As from this point we have the 3 beam laser light. The collimator lens is used to create a parallel beam. The beams pass through a beam splitter, but at this moment the beam splitter is of no real use.

A 45 degrees mirror will point the laser correctly to the disc.

An objective lens is used for focusing purposes.

As explained in the disc section, on the disc there are two possibilities, either the pit signal or the magnetic signal (Kerr effect). But in both cases we will have a reflection of the laser light which will carry the information we need. Also for the recordable disc the return will carry a component from the pregroove (also referred to as "wobble").

The return laser light goes through the objective lens and the 45 degrees mirror. In the beam splitter it is sent to the photodetector side. Note also that the APC (automatic power control) photo diode is located at this point. In the CD optical block the APC diode was located at the back of the laser emitter. In the laser unit which is used now in Minidisc a back APC photo diode would not give a correct feedback signal, the front APC diode gives the correct feedback signal (i.e. the return is directly related to the laser power).



**Figure 34.**

After the beam splitter, the return laser light follows a different path from the emitted (from laser diode) laser light.

The beams are sent through a Wollaston prism, this special type of prism is used to extract from the main laser beam the polarization (north/south or X/Y) components as set by the magnetic layer on the disc. After the Wollaston prism the beams are sent through a multi lens, which is a combination of a concave and a cylindrical lens, resulting in a correct spot configuration on the detector.

The detector unit is similar to the compact disc detector unit, but 2 more detectors are included, the I and J detectors. These two detectors will catch the side beams, extracted through the Wollaston prism and containing the data.

The use the different detectors in the detecting unit is not exactly the same as in the compact disc, this will be explained later.

## 6.1. The Wollaston principle.

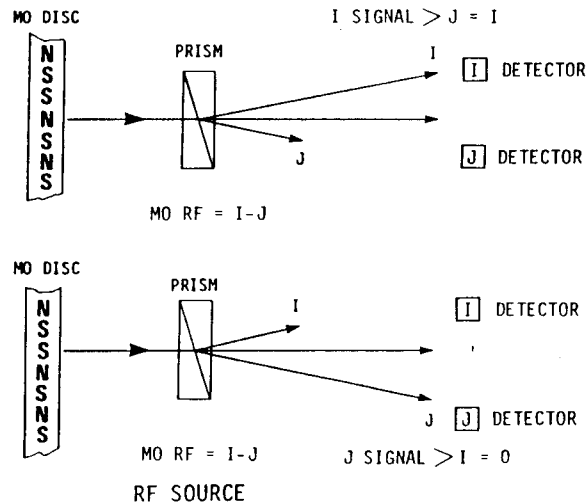
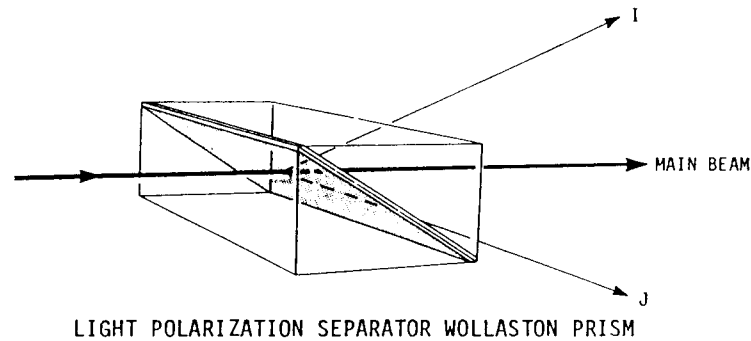
Before getting to the operation of the Wollaston principle, remember which kind of signals we can expect here :

We have 2 types of disc, the premastered and the recordable.

The premastered disc gives a main beam related to the pit structure and the E and F sidebeams related to the tracking.

The recordable disc gives in the lead-in area a pit signal as well as E and F signal, but with a decreased level. After the lead-in area the main beam polarization has been influenced by the magnetic layer on the disc (Kerr effect). The main beam has also been modulated by the (wobble) pregroove. Besides the main beam, the E and F sidebeams are still present.

I & J OUTPUT DEPENDS ON MAGNETIC FIELD ENCOUNTERED



**Figure 35.**

The Wollaston prism is a combination of 2 rock crystals bonded together at a precise angle of 45 degrees.

Any incident beam will result in 4 outputs :

2 main outputs, each containing a main polarization part (north/south or X/Y), these 2 beams are so close to each other that they can be considered and treated as an unchanged main beam as they will practically recombine.

The 2 other beams are highly important, the Wollaston prism separates the north and south oriented components of the incident beam and emit these components as side beams. (Note that we use the terms north/south for ease of understanding, we may as well consider this in an X/Y grid)



These side beams we call the I and J beams. Prerequisite for this operation is that the laser beam was originally polarised with an E-vector perpendicular to the pregroove. The laser diode indeed creates such a beam.

Note that this beam originally has north as well south orientation, the Kerr effect will make one of the two more dominant.

The E and F beams will also each create side beams due to the Wollaston effect, but these side beams are not used as they are not significant.

The I and J beams now become the most important beams, for the recordable disc the use is obvious, as the beam reflected from the disc contains a north/south polarization related to the data, the extraction of north/south components by the Wollaston prism will enable us to read out the data correctly.

If for example the laser beam has been momentarily north polarised by the Kerr effect on the disc, the north polarised component as extracted by the Wollaston prism will be significantly bigger than the south component, in that case, the I beam will be detected with a higher level than the J beam. If on the other hand the south polarization is dominant, the J beam will become bigger.

The subtraction of I-J will therefore enable the Minidisc system to interpret the magneto-optical signal and convert it to a correct datastream.

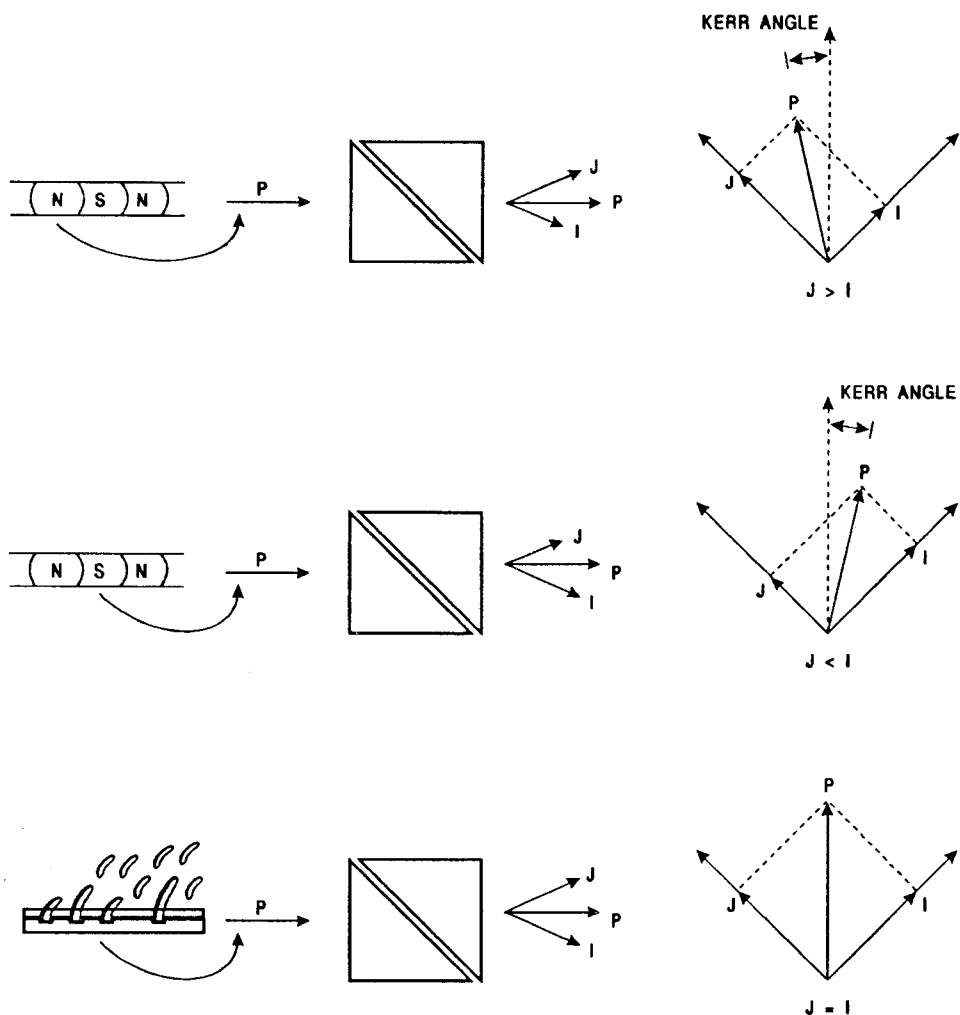


Figure 36.

But also the premastered disc system uses the I and J sidebeams, contrary to the Compact Disc system. It is now very important to remember that the Wollaston prism is such that the I and J components come at a 45 degree angle : no matter what the polarization of the incoming beam is, the sum of I and J sidebeams will always give an indication of the level, which is effectively wanted for the pit signal. With a laser signal which has not been influenced by the Kerr effect, we can expect the north/south component to be equal and thus the summing of I and J will give us a perfect reconstruction of the original signal.

## 6.2.The Detector Block

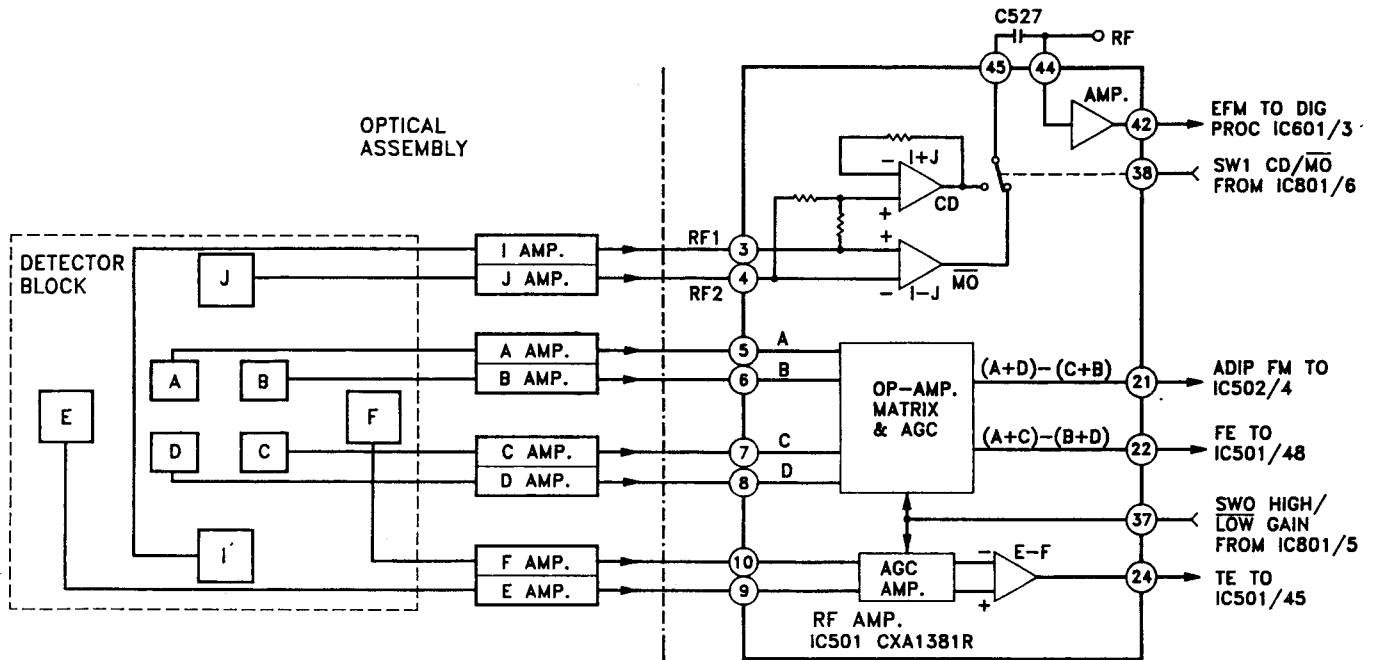


Figure 37.

The detector unit is again similar to the one used in a Compact Disc, but the I and J detectors have been added.

As mentioned before, the E and F beams also create sidebeams in the Wollaston prism, but these will not be detected as there are no detectors at the place where they will arrive.

We now have ABCD, E,F,I and J detectors.

I and J will be used to detect the magneto-optical (I-J) as well as the pit (I+J) signal.

E and F will still be used for tracking.

ABCD will be used for AGC ( $A+B+C+D$ ), focus ( $(A+C)-(B+D)$ ) and pregroove (wobble) ( $(A+D)-(C+B)$ ) detection.

### 6.3.Laser power and Noise handling

As mentioned before, this laser assembly has to handle different power levels. During readout the level is fixed at 0.5 mWatt, both for premastered as well as recordable disc. During recording, the level is set by data in the table of contents of each disc. There are 16 possible power levels between 2.5 And 5 mWatt (main bema power), according to the specifications.

Handling of this power of course needs some power control, as well as temperature control. For that reason the APC circuit is included, working with the front APC photodiode to monitor the power level and control it accordingly. The system is also temperature controlled.

One of the problems with laser diodes is the noise handling, noise is excited during the start of emission, as the characteristic at that point is not linear; and there is also a noise component caused by reflection of laser light from the disc, back into the laser emitting unit, this reflection interferes with the original laser emission.

In order to avoid such problems, a UHF oscillator is included.

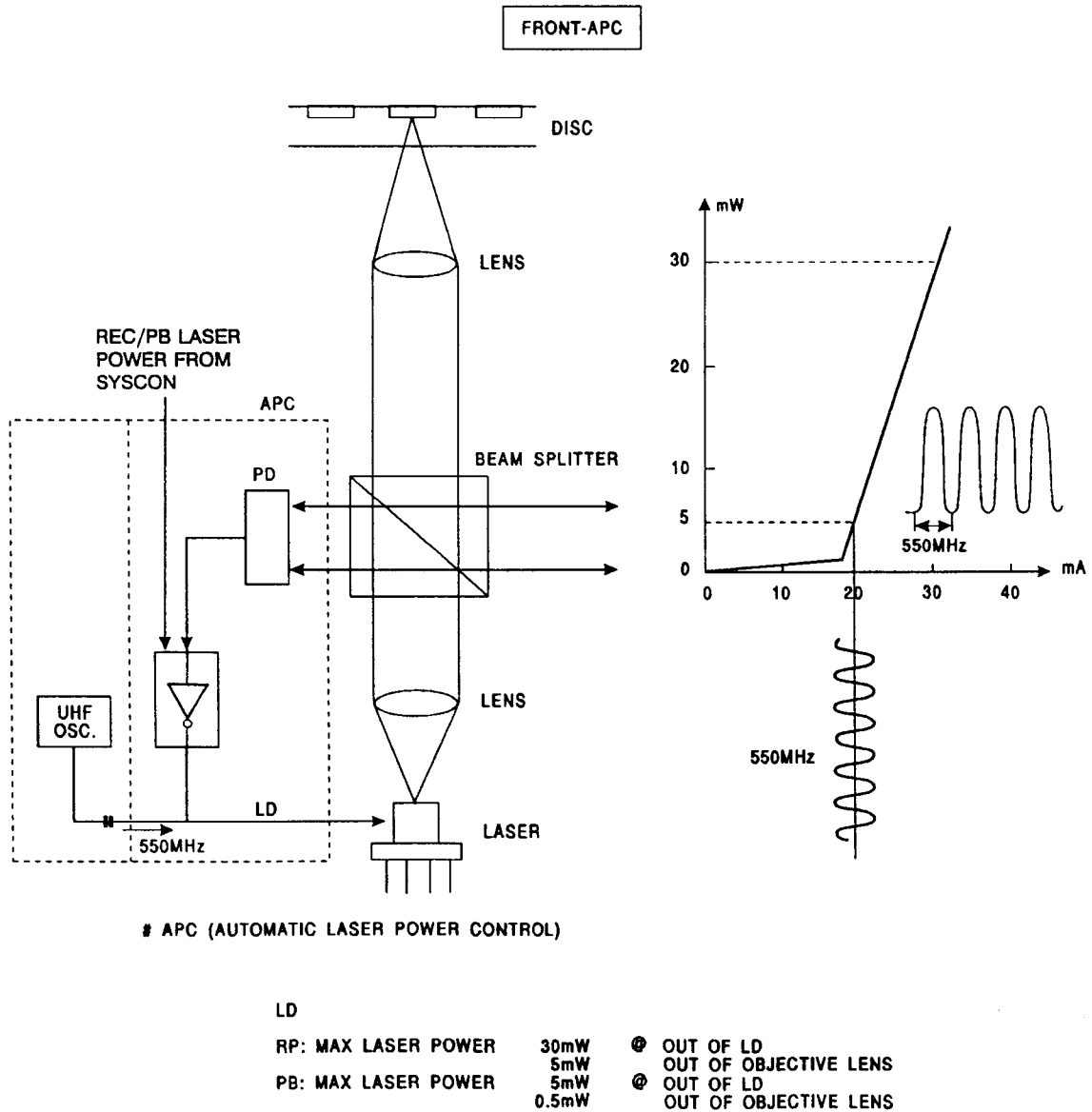


Figure 38.

Consider the DC bias as the normal supply voltage for the laser diode, added onto this is a 550 mhz oscillation, the result will be a high frequency modulated laser beam, it will switch on and off on the 550 mhz rhythm imposed by the UHF oscillator.

For readout of the data from the disc this UHF laser oscillation does not interfere, due to the big difference between the UHF laser modulation frequency (550 MHz) and the relative low data modulation frequency (few MHz) on the disc. The noise cancellation is mostly due to the fact that the UHF frequency is chosen in such a way that reflections from the disc to the laser unit will arrive into the laser unit when this one is off. Of course, when a reflection arrives, and the laser is off, there can be no interference and therefore no noise.

## **7. Anti Shock Operation**

One of the main features of the Minidisc is its anti-shock capability, this anti-shock capability is depending on the amount of memory that is included in the set.

The data rate needed by the audio decoder is about 0.3 Mbit/sec, this to produce correct, continuous audio output.

The amount of input data to the audio decoder depends on the linear speed of the disc (the CLV speed). As this speed is the same as in a Compact Disc system, the readout rate is about 1.4 Mbit/sec.

We then have an input data rate that is nearly 5 times higher than the output rate. We can benefit largely from this fact by using a buffer RAM.

A buffer RAM size of 1 mbit enables us to store about 3 seconds of music, therefore large shocks, causing track jumps and data input loss can be recovered through the use of this buffer RAM.

The first generation MD players use a 4 mbit RAM, enabling a shock proof time of about 10 seconds (some parts of the RAM are also used for other operations).

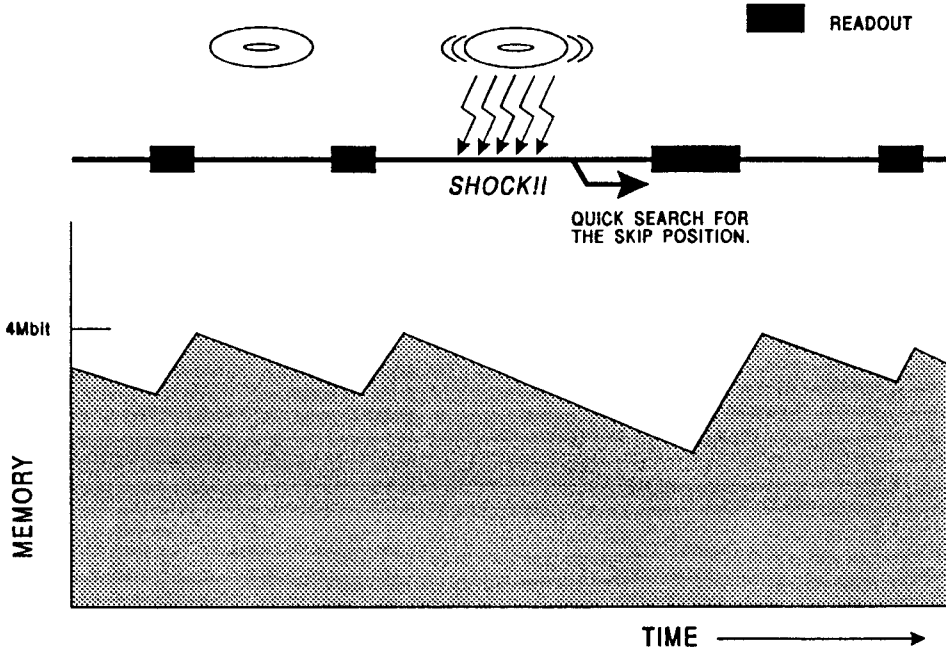
The operation is as follows :

At first, the RAM is empty. Data readout starts, and the EFM/ACIRC decoded data starts to enter the RAM. Of course initially the data has to go straight into the ATRAC decoder, but as the input to the RAM is much higher than needed, the RAM will be used as buffer.

The microcontroller of the MD player controls tracking servo and buffer RAM in such a way that the amount of data in the buffer RAM is always as high as possible.

Practically speaking, the MD will go into PAUSE mode whenever the buffer RAM is nearly in overflow status, when this happens, no data is input and the RAM level lowers, then again the PAUSE will be released until a high level has been reached and so on.

# MERIT OF SHOCK PROOF MEMORY



# PRINCIPLE OF INTERMITTENTLY READOUT

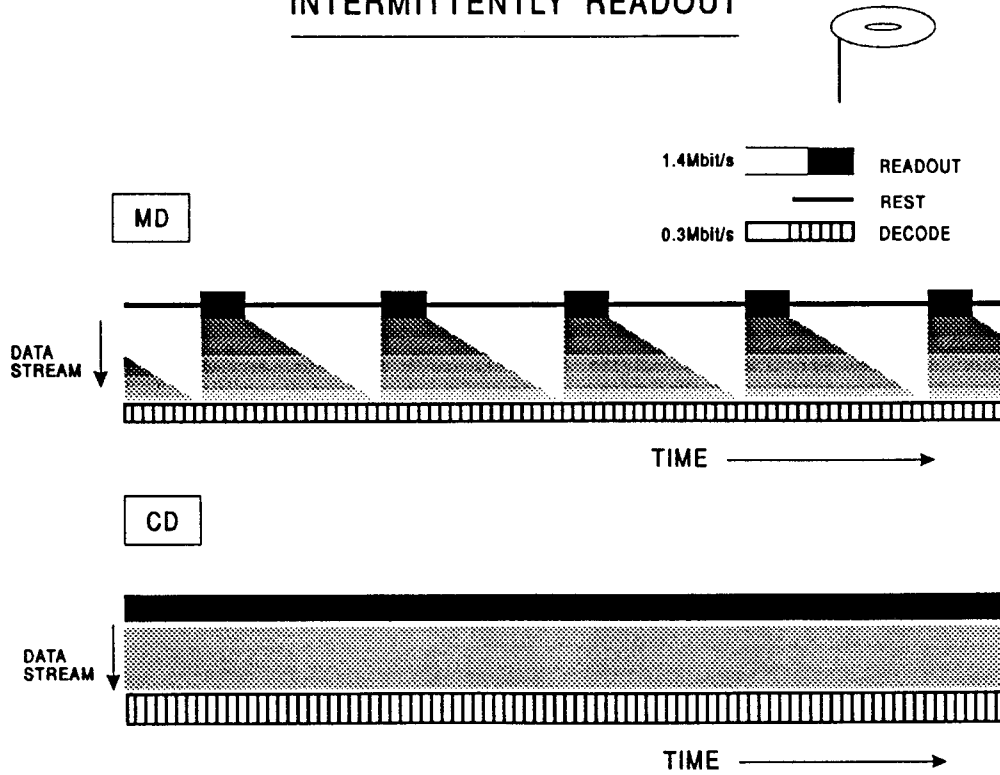
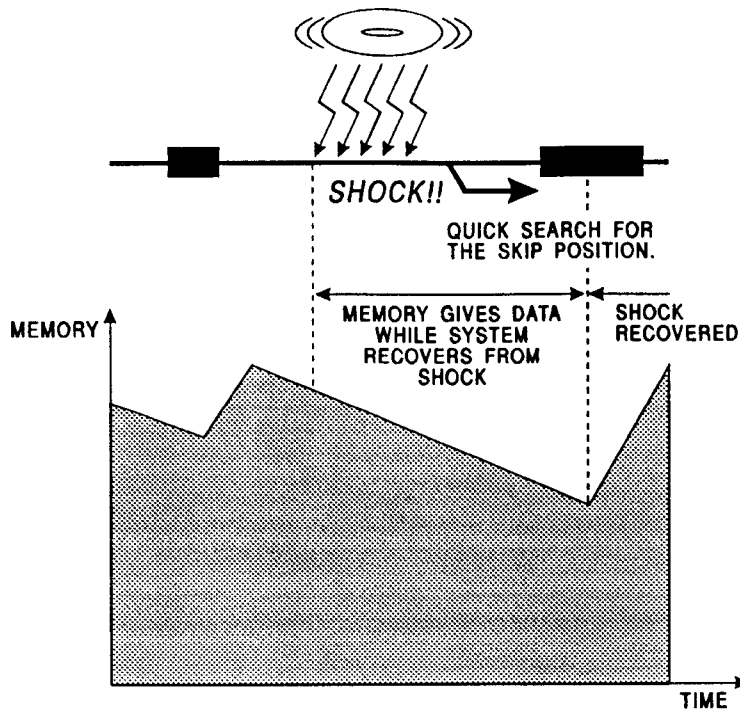


Figure 39.



**Figure 40.**

If a shock causes a track jump, the buffer RAM continues to send data to the ATRAC decoder as there is still enough data available. In the meantime the microcontroller knows that it is under a shock condition (can be found through many ways, refer also to Compact Disc), and will start to recover.

This recovery action goes as follows : the system has in its RAM the remaining data along with the addresses; based upon the addresses of the last correct data the system will try to put the laser unit back on the correct position and restart readout.

When this last address is found on the disc (in other words, the system has recovered from the shock) data will be read out as from the next address location and sent to the buffer RAM.

If this operation is performed within the timing limit of the RAM contents, the audio signal is reproduced continuously , glitchless and noiseless.

The same buffer RAM is used while recording, to store multiple clusters, and also when a shock occurs during recording the system will try to recover through RAM operation.

It should be noted however that when recording the anti shock operation is more critical.

## 8. ATRAC Know-How

ATRAC is the abbreviation for Adaptive Transform Accoustic Coding. When reading this carefully, the most important actions of the ATRAC system become apparent : audio input is coded, according to a transform method which is adaptive. This means that the transform method can adapt to the input signal; this in accordance with accoustical phenomena.

The main target for the ATRAC encoding system is to decrease the information density and in that way increase the recordable time on a small disc , all this however without degrading the sound quality. The decoder on the other hand will restore the original audio data based upon the compressed data input. The word compression is often used for this kind of action, although the meaning in this application is not totally the same as in a computer environment.

In a normal C.D. system, the basic bit stream is 16 bits, 2 channels, 44.1 kHz sampling rate.  $16 \times 2 \times 44.100 = 1.4$  Megabit/sec. After further processing (EFM,CIRC...) this becomes about 4 Megabit/sec. With this bitrate we can put 74 minutes of music on the 12 cm. disc format.

If we want to put the same amount of music time on a disc of nearly half that size it is obvious that the bitstream has to be reduced drastically. There are several ways to do this, but not many ways give an acceptable result, in most cases (example : reducing the amount of sampled bits or the samp[ling rate]) the result will be a degraded sound.

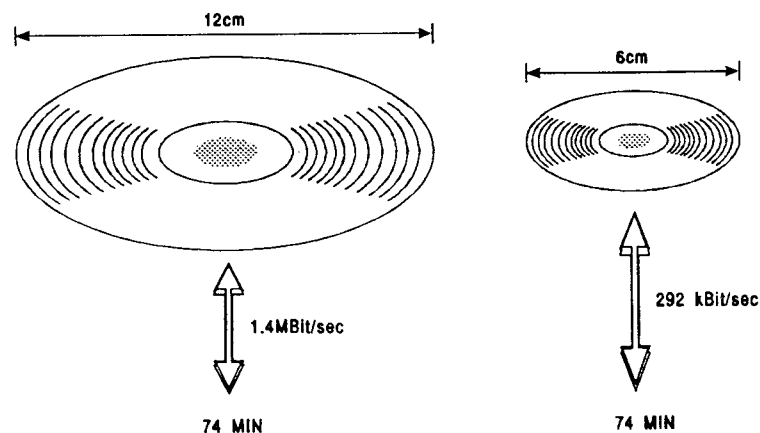


Figure 41.

### 8.1. ATRAC input

The ATRAC system is highly sophisticated , as it is based upon complex mathematical and psycho-acoustical methods. Several complex manipulations are performed similarly and in connection with one another. It is therefore very difficult to give a simple, and clear overview of this system.

The input to the ATRAC encoder is still the 16 bit, 2 channel, 44.1 kHz sample rate bitstream, exactly the same as in a CD system.

The output however will not be the 1.4 Megabit/sec datastream, but it will be a 292 kilobit/sec datastream, this is about 5 times less than the CD system, for that reason the Minidisc compression rate is about 1:5.

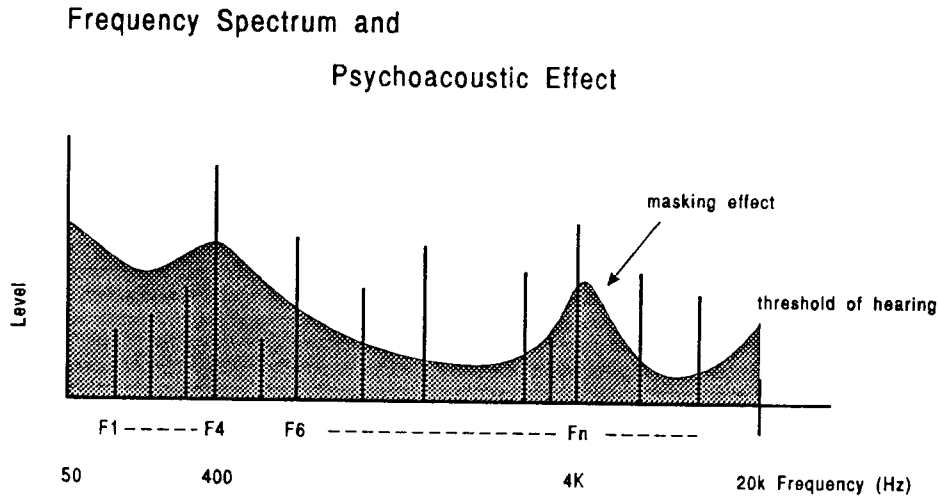
When reconstructing such a compressed signal, a dynamic range of about 105 dB and a THD+N of about 92 dB are the theoretical limits.

## 8.2. Psychoacoustics

As said before, the system is very complex, first we need to know what the psycho-acoustical phenomena are that we use :

- The sensitivity of a human ear is not equal over the total frequency range. A sound, at a given frequency and at a given level can be perceived by our hearing system (combination of ear, nerve system and brains); another sound, with another frequency, but with the same level may not be perceived by our hearing system, this depends on its frequency, and the sensitivity of our hearing system for that frequency.

This phenomenon can be shown with a diagram : for each frequency our hearing system has a certain threshold. Any sound below this threshold can be deleted.



Frequency components and levels

extracted by [ATRAC]

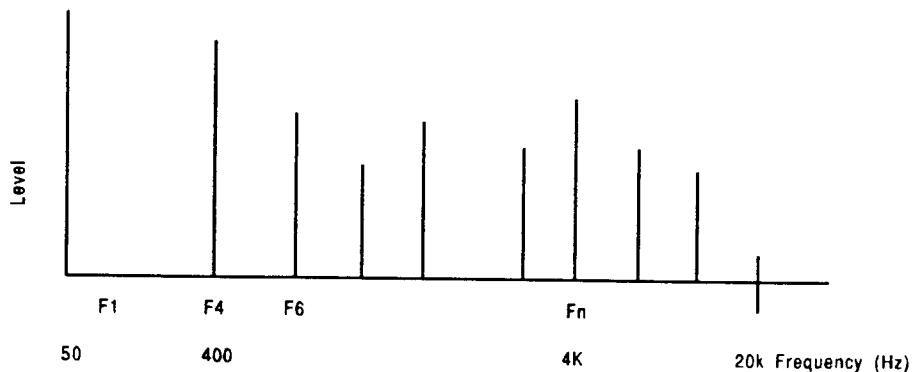


Figure 42.

It is true that these thresholds can vary slightly from person to person, but this phenomenon is already known for a long time, it has been tested for many years, we can consider the thresholds used now to be ideal averages.

The ATRAC system will effectively delete all data related to sound below these thresholds over the full frequency range.



- Our human hearing can be divided into so-called critical bands, they are mainly based upon the human hearing sensitivity in the frequency domain, the sensitivity will be equal in a certain critical band. The width of these bands is not always the same, in the lower frequency area they will be smaller than in the higher frequency areas. At 100 Hz the bandwidth is 100 Hz, at 1000 Hz it is 160 Hz and at 10.000 Hz it is 2.500 Hz.

About 25 of these critical bands are defined.

The ATRAC system will be based upon this critical band system, to adapt to the sensitivity, and in that way to enhance the bit reduction rate. It should be noted however that the ATRAC system uses more bands (about 52), but they conform to the basic 25 critical bands.

- Another important item is the masking effect. We know that usually a sound is composed of several basic frequencies, each with a certain level. If we evaluate these levels, we can notice that a high level frequency existing together with a low level frequency will mask the low level frequency.

For example : if two persons are talking to each other and at the same time a train passes by the high level train "sound" will mask the lower level talk.

This phenomenon is also used in ATRAC, the sound will be analysed, converted to its composing basic frequencies and by comparing the levels, the masked frequencies can be deleted.

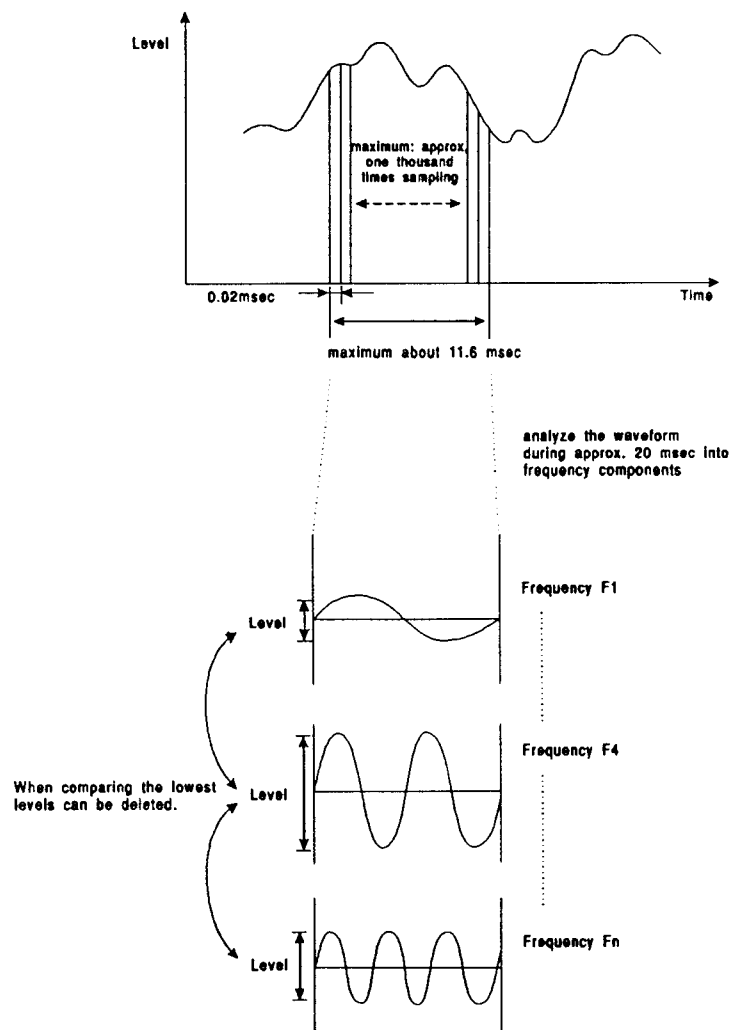


Figure 43. Sound waveform and sampling

### 8.3 ATRAC operation

We now know about the basic psycho-acoustical phenomena that are taken into account. The next step is to analyse the basic block diagram of ATRAC.

At first, the incoming (digital) sound is analysed for frequency bandpassing. The high frequency band is separated (above 11 kHz) first. Next the middle and low frequency bands (0-5.5kHz / 5.5-11 kHz) are separated. While the middle/low band analysis takes place, the high frequency band is delayed to keep correct timing .

The 3 bands will now go through the MDCT blocks (MoDified Cosine Transform) separately. This is a highly complex mathematical transform method. It can be compared with a Fourier analysis, the input sound which is still in the time domain will be analysed, the composing frequencies and their levels over a certain time slot will be extracted. At this moment a transition is made from time domain to frequency domain.

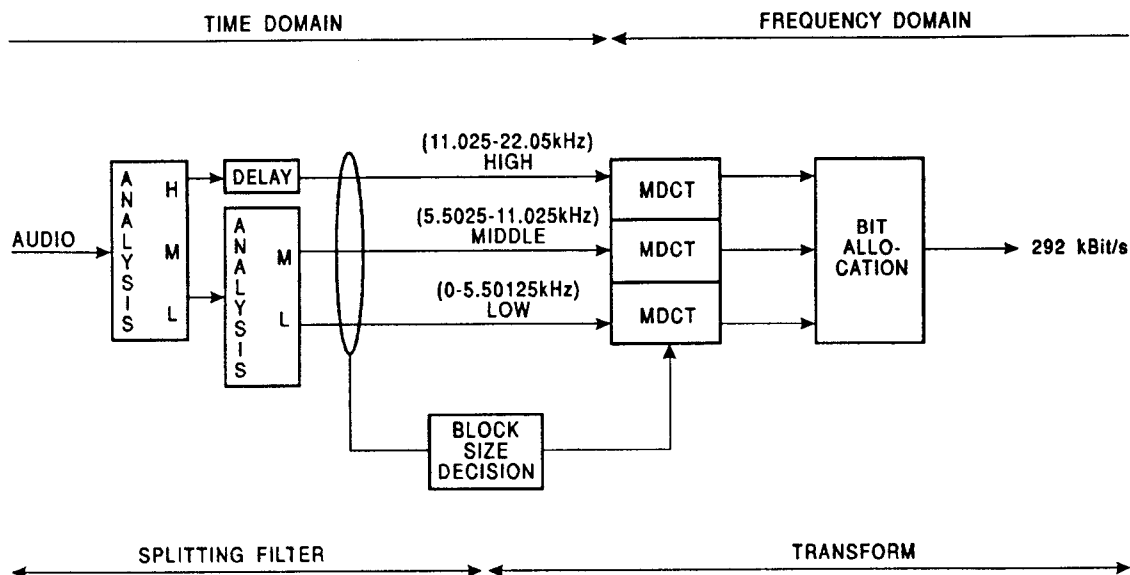


Figure 44.

At the same time however, based upon the input to the MDCT blocks, a decision is taken on the block size.

This block size relates to the time /frequency blocks, depending on the type of input sound, a decision can be taken to allocate more or less time to it, and analyse it then on a high or lower level.

The maximum time slot for analysis as one block is 11.6 millisecc., there are 8 possible other timings, with as smallest  $11.6/8 = 1.45$  millisecc.

The idea behind this block decision is following : there are several types of sound, and our hearing system also recognises this, and adapts to it.

Take for instance a short impulse type sound, on the time axis this is a very short burst, therefore we do not need to allocate a big time block to analyse this. Such a short burst needs also no detailed analysis, as the sound level changes are very sharp, and only these changes need to be known.

The second example is the opposite : take a slow varying sinus type sound as input, on the time axis this takes a long time, and we will need to allocate a long time slot to analyse it. At the same time it is then possible to analyse this sound in a very detailed way, this is also necessary as our hearing system will do the same with such sounds.

The ATRAC block decision will allocate time /frequency blocks in accordance with these ideas. This also results in a bit reduction.

Also in the case of short time blocks, noise cancelling pre-echo techniques can be used. The basic block decision flow chart takes a certain time block of sound, compares it with the adjacent time blocks and looks if there are high level differences, based upon this comparison the decision about the amount of time/frequency blocks can be taken.

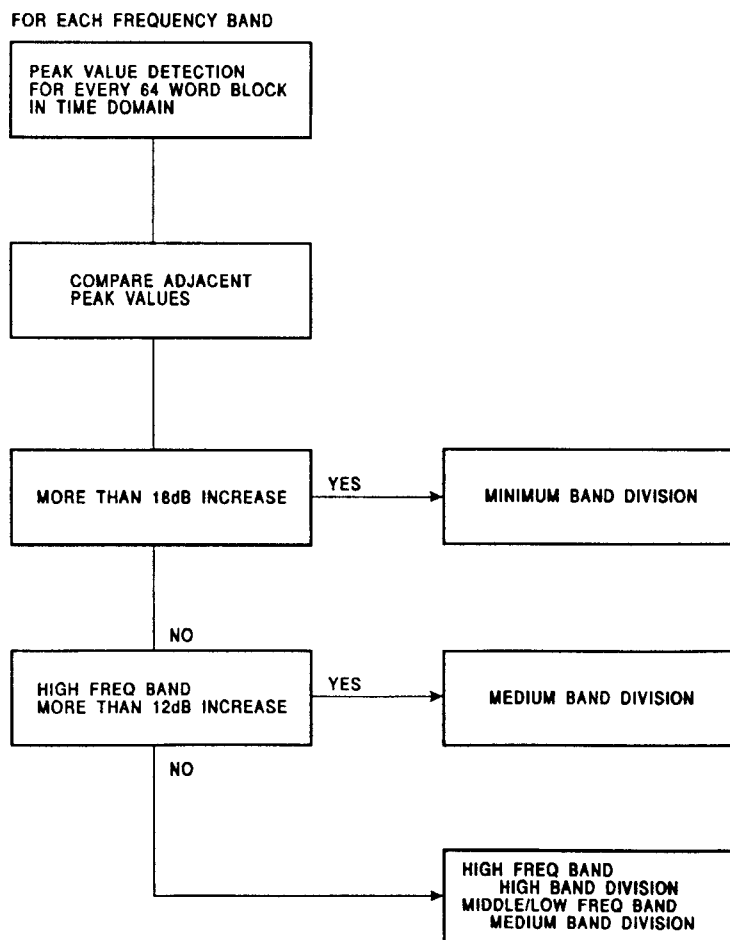
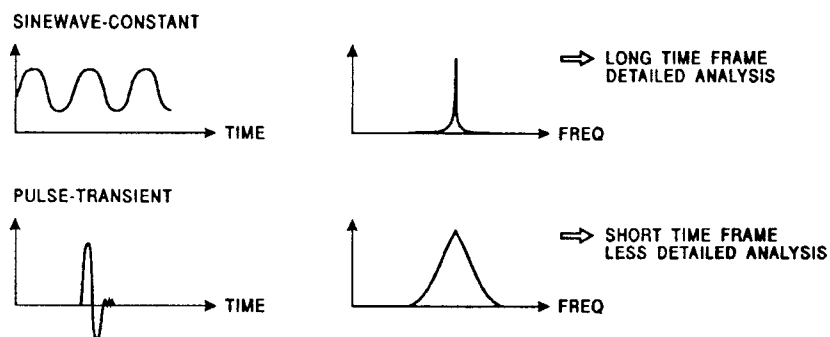


Figure 45.

The output of the MDCT blocks is frequency domain information, and as mentioned before, it can be seen as a frequency/level analysis of the input over a certain time block.

On this output the mentioned psycho-acoustical phenomena can be used to reduce the bit rate.

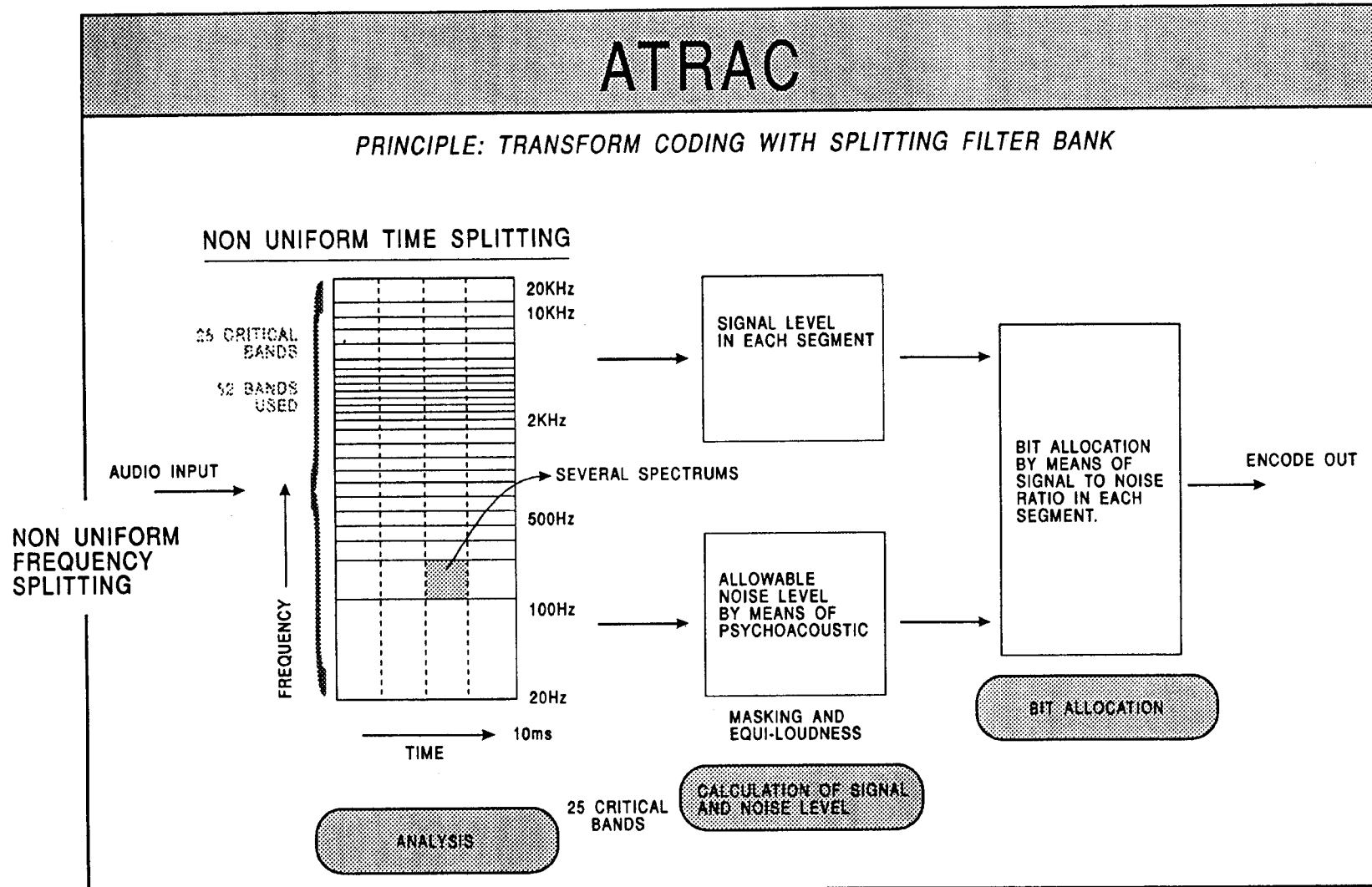


Figure 46.

The last stage then is the bit allocation ; the significant information is not transmitted as audio data, comparable with a CD format. In this case the sound data, after analysis in the MDCT blocks is further analysed to retrieve the significant information only.

Each frequency/time data block is known now, along with its level, this is not represented by a fixed amount of bits, but by a variable amount of bits, from 0 to 15, representing the dynamic range of that part. The scale factor gives the relative level of the signal, the rest of the bits can be deleted as quantisation noise.

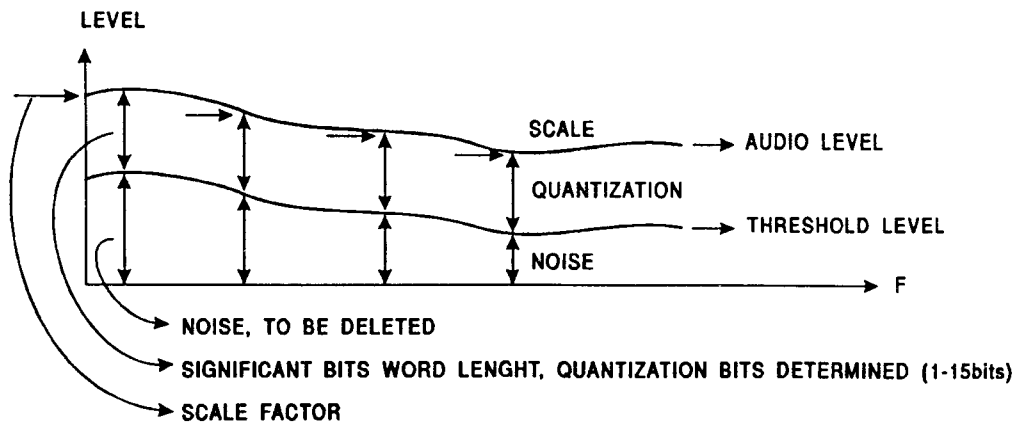
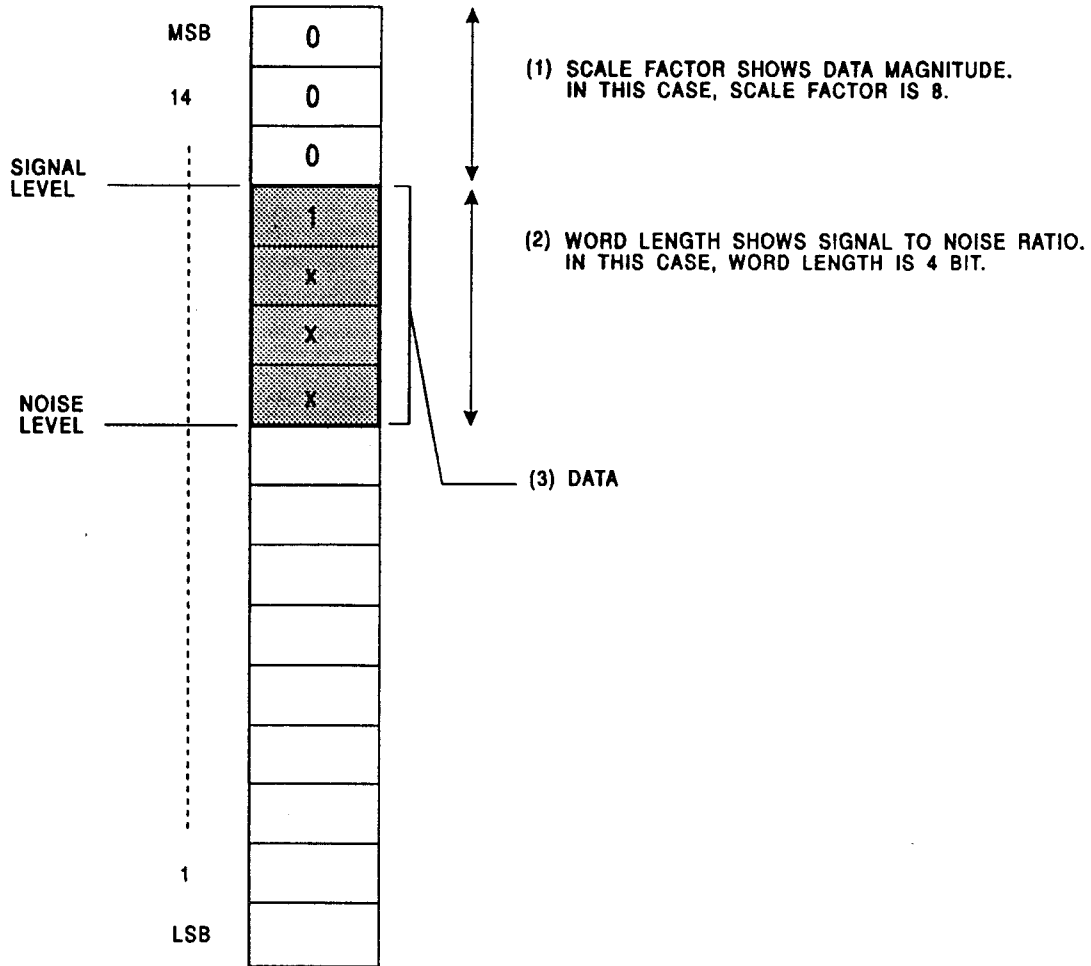


Figure 47. Scale factor and word length

Output of the ATRAC encoding system can in no way be compared any more with the data as used in a CD system. In the Minidisc system the data recorded on the disc is describing word lengths, scale factors and spectrum data (data in each block), comparable with floating block data in computers.

The ATRAC decoder will receive this information from the Minidisc, and will do exactly the opposite routine as the encoder unit, in this way the original signal will be reconstructed, minus the deleted parts, but these parts were not necessary in the first place, so the difference between original sound and ATRAC reproduced sound is minimal.

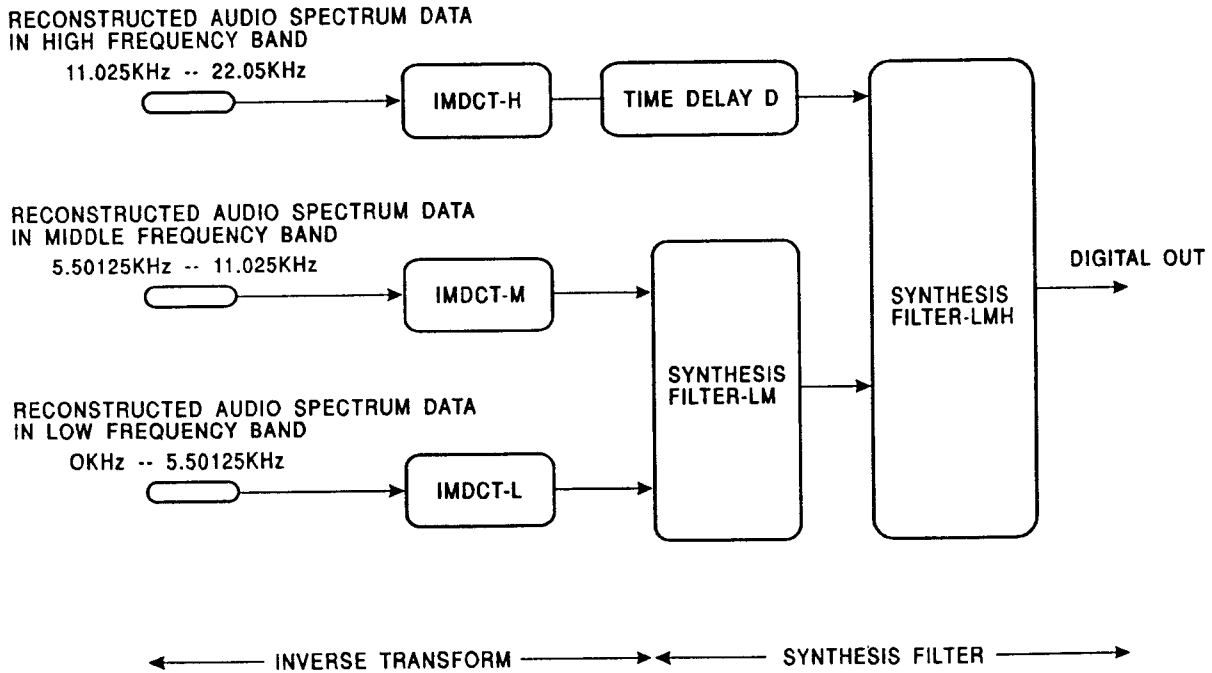


Figure 48.

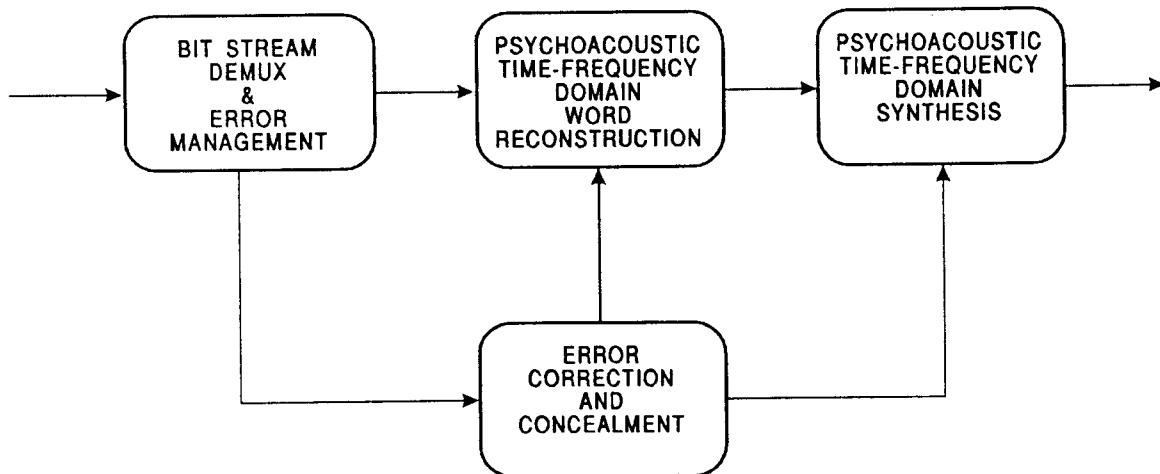


Figure 49. Single-channel decoder block diagram

Another benefit of transferring the audio in this way is the possibility to change some of the parameters (in order to improve it even more) in the future without creating compatibility problems.

The system design is indeed such that algorithms can be changed, as long as basic formats are used.

## 9. Conclusion

The basic principles of Minidisc have now been highlighted, following items should now be understood :

- Basic difference between Compact Disc and Minidisk
- Difference between premastered and recordable discs.
- Minidisc data formats
- Recording and readout of recordable discs
- Meaning of regroove/address in pregroove
- Minidisc optical block operation
- Shock proof capacity
- ATRAC basics
- Basic signal flow / block diagram

Starting from this knowledge it will now become possible to understand circuit descriptions and other more technical publications which may appear in the future.

It should also be clear at this point that the MD system can have a great future, and has a big potential for further development, also in other application fields. It is then obvious that proper knowledge of the basics will always be needed.