UNIT III

OPTICAL RECORDING AND REPRODUCTION

3.1 DISC

In the Laser Vision System, Figure 3.1 (a), which records video information, the signal is recorded on the disc in the form of a spiral track that consists of a succession of pits. The intervals between the pits are known as lands. The information is present in the track in analog form. Each transition from land to pit and vice versa marks a zero crossing of the modulated video signal. On the compact disc, Figure 3.1 (b), the signal is recorded in a similar manner, but the information is present in the track in digital form. Each pit and each land represents a series of bits called channel hits. After each land/pit or pit/land transition there is a 1, and all the channel bits in between are 0, (see Figure 3.2).

The density of the information on the compact disc is very high; the smallest unit of audio information (the audio hit) covers an area of 1 pm² on the disc, and the diameter of the scanning light spot is only 1 pm. The pitch of the track is 1.6 pm, the width 0.6 pm and the depth 0.12 pm. The minimum length of a pit or the land between two pits is 0.9 pm; the maximum length is 3.3 pm. The side of the transparent carrier material

![Figure 3.1 (a) Details of laser vision system showing the optical pickup and the disc microstructure and (b) Compact discs](image)

T in which the pits are impressed, the upper side during playback if the spindle is vertical, is covered with a reflecting layer R and a protective layer P. The track is optically scanned from below the disc at a constant velocity of 1.25 m/s. The speed of rotation of
the disc therefore varies from about 8 rev/s to about 3.5 revs (or 480 rpm to about 210 rpm).

![Diagram of a compact disc](image)

**Fig. 3.2** (a) Cross section through a compact disc in the direction of the spiral track. T transparent substrate material, R reflecting layer, P protective layer, P the pits that form the track, (b) I the intensity of the signal read by the optical pickup plotted as a function of time. The signal, shown in the form of rectangular pulses is in reality rounded and has sloping sides. The digital signal derived from this waveform is indicated as a series of channel bits Ch.

### 3.2 PROCESSING OF THE AUDIO SIGNAL

For converting the analog signal from the microphone into a digital signal, pulse-code modulation (PCM) is used. In this system the signal is periodically sampled and each sample is translated into a binary number. From Nyquist’s sampling theorem the frequency of the sampling should be at least twice as high as the highest frequency to be accounted for in the analog signal. The number of bits per sample determines the signal-to-noise ratio in the subsequent reproduction.

In the compact disc system the analog system is sampled at a rate of 44.1 kHz, which is sufficient for the reproduction of the maximum frequency of 20 kHz. The signal is quantized by the method of uniform or linear quantization, the sampled amplitude is divided into equal parts. The number of bits per sample (these are called audio bits) is 32
i.e. 16 for the left and 16 for the right audio channel. This corresponds to a signal-to-noise ratio of more than 90 dB. The net bitrate is thus $44.1 \times 10^3 \times 32$ or $1.41 \times 10^6$ audio bits per second. The audio bits are grouped into frames, each containing six of the original samples.

![Image of compact disc track](image)

**Figure.3.3** The information on the compact disc is recorded in digital form as a spiral track consisting of a succession of pits. The pitch of the track is $1.6\mu m$ and the depth of the pit $0.12\mu m$. The length of a pit or the land between two pits has a minimum value of $0.9\mu m$ and a maximum value of $3.3\mu m$.

Successive blocks of audio bits have blocks of parity bits added to them in accordance with a coding system called Cross-Interleaved Reed-Solomon Code (C IRC). This makes it possible to correct errors during the reproduction of the signal. The ratio of the number of bits before and after this operation is 3 : 4. Each frame then has Control and Display (C & D) bits added to it; one of the functions of C & D bits is providing the information for the listener, after this operation the bits are called data bits.

Next, the bit stream is modulated, that is to say the data bits are translated into channel bits which are suitable for storage on the disc (see Figure.3.2 (b). The Eight-to-Fourteen Modulation (EFM) is used for this purpose. In EFM code blocks of eight bits are translated into blocks of fourteen bits. The blocks of fourteen bits are linked by these margin bits. The ratio of the number of bits before and after modulation is thus $8:17$. For the synchronization of the bit stream an identical synchronization pattern consisting of 27
channel bits is added to each frame. The total bit rate after all these manipulations is \(4.32 \times 10^6\) channel bits/s.

From the magnitude of the channel bit rate and scanning speed of 1.2 m/s it follows that the length of a channel bit on the disc is approximately 0.3 \(\mu m\).

The signal produced in this way is used by the manufacturer to switch On and Off the laser beam that illuminates the light sensitive layer on a rotating glass disc, called the master. A pattern of pits is produced on the disc by means of a photographic developing process. After the surface has been coated with a thin silver layer, an electroplating process is applied to produce a nickel impression called the metal father. From this father disc, impressions called mother discs are produced in a similar manner. The impressions of mother discs, called sons or stampers, are used as tools with which the pits \(P\) are impressed into the thermoplastic transparent carrier material \(T\) of the disc.

### 3.3 Readout from the Disc

The disc is optically scanned in the player. This is done by AlGaAs semiconductor laser. Figure 3.4 shows the optical part of the pickup. The light from the laser \(L_a\) (wavelength 800 nm) is focused through the lenses \(L_2\) and \(L_1\) onto the reflecting layer of the disc. The diameter of the light spot \(S\), Figure 3.5, is about 1 \(\mu m\). When the light falls on an interval between two pits, the light is almost totally reflected and reaches the four photodiodes \(D_1\) to \(D_4\) via the half-silvered mirror \(M\). When the spot lands on a pit—the depth of a pit is about \(\frac{1}{4}\) of the wavelength in the transparent substrate material—interference causes less light to be reflected and an appreciably smaller amount reaches the photodiodes. When the output signals from the four photodiodes are added together the result is a fairly rough approximation to the rectangular pulse pattern present on the disc in the form of pits and intervals.

The optical pick-up shown in Fig. 14.4 is very small (about 45 * 12 mm) and is mounted in a pivoting arm that enables the pick-up to describe a radial arc across the disc, so that it can scan the complete spiral track. Around the pivotal point of arm is mounted a linear motor that consists of a combination of a coil and permanent magnet. When the coil is energised the pick-up can be directed to any required part of the track,
finite locational information being provided by the C & D bits added to each frame on the disc. The pick-up is this able to find independently any particular passage of music indicated by the listener. When it has been found the pick-up must then follow the track accurately to within ±0.1 µm without being affected by the next previous track. Since the track on the disc may have some slight eccentricity, and since also the suspension of the turntable is not perfect, the track may have a maximum side-to-side swing of 300 µm. A tracking servo system is therefore necessary to ensure that the deviation between pick-up and track is smaller than the permitted value of + 0.1 pm and in addition, to absorb the consequences of small vibrations of the player.

The tracking-error signal is delivered by the four photodiodes D. to D. When the spot S, seen in the radial direction, is situated in the centre of the track, a symmetrical beam is reflected. If the spot lies slightly to one side of the track, however, interference effects cause asymmetry in the reflected beam. This asymmetry is detected by the prism P, which splits the beam into two components. Beyond the prism, one component has a higher mean intensity than the other. The signal obtained by coupling the photodiodes
as \((D_1 + D_2) - (D_3 + D_4)\) can therefore be used as a tracking error signal.

As a result of the *aging or soiling of the optical system*, the reflected beam may acquire a slowly increasing, more or less constant asymmetry. Owing to a dc component in the tracking error signal, the spot will be *slightly off-centre* of the track. To compensate for this effect a *second tracking error signal* is generated. The coil that controls the pick-up arm is therefore supplied with an alternating voltage at 600 Hz, with amplitude that corresponds to a *radial displacement* of the spot by +0.05 µm. The output sum signal from the four photodiodes which is at a *maximum* when the spot is at the centre of the track is thus modulated by an alternating voltage of 600 Hz. The *amplitude* of this 600 Hz signal *increases* as the spot moves off-centre. In addition the *sign* of the 600 Hz error signal *changes* if the spot moves to the other side of the track. This second tracking-error signal is therefore used to correct the error signal mentioned earlier with a direct voltage. The output sum signal from the photodiodes, which is T processed in the player to become the audio signal, is thus returned to its maximum value.

![Figure.3.5 A magnified view of the light spot Sand its immediate surroundings, with a plan view.](image)

The *depth of focus* of the optical pick-up at the position S (see Fig. 14.4) is about 4 pm. The *axial deviation* of the disc, owing to various mechanical effects, can be maximum of 1 mm. It is evident that *are servo system* is also necessary to give correct focusing of the pick-up on the reflecting layer. The objective lens L1, can therefore be displaced in the direction of its optical axis by a combination of a coil and a permanent magnet, in the same way as in a loudspeaker. The *focusing-error signal* is also provided
by the row of photodiodes D1 to D4. If the spot is *sharply focused* on the disc, two sharp images are precisely located between D1 and D2 and between D3 and D4. If the spot is *not sharply focused* on the disc, the two images on the photodiodes are not sharp either and have also moved closer together or further apart. The signal obtained by connecting the photodiodes as \((D1 + D4) - (D2 + D3)\) can therefore be used for controlling the focusing servo system. The deviation in focusing then remains limited to \(+ 1 \mu m\).

### 3.4 RECONSTITUTION OF THE AUDIO SIGNAL

The signal read from the disc by the optical pick-up has to be reconstituted to form the analog audio signal. Figure 3.6 shows the block diagram of the *signal processing* in the player.

![Figure 3.6 Block diagram of the signal processing in the player](image)

In Demod the *demodulation* follows the same rules that were applied to the EFM modulation, but now in the *opposite sense*. The information is then temporarily stored in a *buffer memory* and then reaches the *Error-Detection and Correction Circuit* (ERCO). The parity bits can be used here to correct errors, or just to detect errors if correction is found to be impossible. These errors may originate from a defect in manufacturing process, damage during use, or finger marks or dust on the disc. Since the information is interleaved in time, errors that occur at the input of ERCO in one frame are spread over a large number of frames during decoding in ERCO. This increases...
the probability that the maximum number of correctable errors per frame will not be exceeded. A flaw, such as a scratch, can often produce a train of errors called an *error burst*. The error-correction code used in ERCO can correct a burst of about 4000 data bits, largely because the errors are spread out in this way.

If more errors than the permitted maximum occur, they can only be detected. In the *Concealment, Interpolation and Muting* (CIM) block, the errors detected are then masked. If the value of a sample indicates an error, a new value is found by *linear interpolation* between the preceding value and the next one. If two or more successive sample values indicate an error, they are *muted* (made equal to zero). At the same time a gradual transition is created to the values preceding and succeeding it by causing a number of values before the error and after it to decrease to zero in a particular pattern.

In the *digital-to-analog converter* (DAC) the 16 bit samples first pass through *interpolation filters* $F$ and are then translated and recombined to re-create the original analog signal $A$ from the two audio channels $L$ and $R$. Since samples must be recombined at exactly the same rate as they are taken from the analog audio signal, the DACs and also CIM and ERCO are synchronized by a *clock generator*, $C$, controlled by a quartz crystal.

Figure 3.6 also illustrates the *control of the disc speed* $n_D$. The bit stream leaves the buffer memory at a rate synchronised by the clock generator. The bit stream enters the buffer memory, however, at a rate that depends on the speed of revolution of the disc. The extent to which $n_D$ and the sampling rate are matched determines the *filling degree* of the buffer memory. The control is so arranged as to ensure that the buffer memory is at all times filled to 50% of its capacity. The analog signal from the player is thus completely free from *wow and flutter*, yet with only moderate requirements for the speed control of the disc.

### 3.5 VIDEO DISC MASTERING AND REPLICATION

The production process of a video disc is more or less comparable with that used for conventional gramophone record. First a master recording is made. It consists of a glass plate with a photosensitive layer deposited on one side. The coded signal of the information to be stored modulates the beam of a 1mm laser which writes the information in the surface of the disc. Cutting is done on real time basis; that it requires
only as much as the program lasts and recording takes place at the disc’s rotational speed of 30 r.p.s for NTSC and 25 r.p.s respectively for PAL and SECAM. In principle, every normal type of TV signal source can be connected to the cutting devices. In practice however, 50 mm magnetic recording tape is used as a program carrier.

Figure 3.7 Video disc mastering and replication

Exposure to the laser beam is followed by a development process which leaves a pattern of pits on the master from which, via a galvanic process; stampers are made which are used for disc production in a way similar to processing of gramophone records.

After processing, an extremely thin metal coating, not more than 0.04 pm thick is deposited on the information side which is then sealed with a protective layer, as shown in Figure 3.8.

3.6 VIDEO DISC FORMATS

The three non-interchangeable video disc formats fall into two basic categories optical and capacitance The laser optical system (also called VLP) which is employed by Philips, uses a laser beam to electronically encoded information stored on the disc. The capacitance system (also called capacitance electronic disc or CED), employed by both JVC and RCA, uses a stylus and tracking arm similar to that of conventional record player to recover the information recorded on the grooves of the disc. There are two variations of
the laser optical system *reflective* and *transmissive*. There are also two variations of capacitance system, the *video/ audio high density system* (VHD) and the capacitance electronic disc system (CED).

![Diagram](image)

Figure.3.8 the upper half of this diagram shows the tracks of pits, while the lower half shows a cross-section of the disc indicating how the information pits are protected by a transparent protective coating

3.7 LASER VISION

The cores of the Philips laser vision are the *shiny silver video discs* which hold the pre-recorded program - material. These are *optically read* by a high precision laser, built into the laservision player. *The laservision system features a level of picture and sound without a parallel in video.* Flaw less picture reproduction, full of rich colours, is accompanied by high stereo sound when the player is connected to a stereo TV or hi-fi audio system.

There are two types of Laser vision discs.

*Long play discs* for straight forward uninterrupted playback of entertainment programs and *active play discs* which involve the viewer in learning a new skill or subject and making full use of the player’s many *versatile picture search facilities* that help you to quickly locate any point on the disc and study parts in detail.
Figure 3.9 When the scanning beam hits a pit in the silvery disc underside the beam is reflected. The beam then passes back to the photodiode which creates the signal output.

The information etched on the reflective material of the disc in a series of pits is read off with a fine beam created by a helium-neon laser. By means of a series of lenses, gratings, prisms and mirrors, the laser beam is directed to the disc underside where it is moved by a scanning lens. When it hits a pit in the silvery surface, Figure 3.9, the beam is reflected. The reflected beam then passes back to the photodiode which creates the signal output.

In a similar system, which is worked in France by Thomson CSF, the laser beam is not reflected from the surface of the disc, but is actually transmitted through it. Variations in the quality of the beam, created by the information etched on the disc, are then used to construct the electrical signals need to create a TV picture.

3.8 SELECTAVISION (RCA)

The cheapest and the most basic of the three video disc formats, with the current models offering only mono sound and picture search, selectavision discs, based on the capacitance system, have a maximum running time of one hour per side. The RCA stylus recovers information from the disc surface by direct electrical means. The selectavision disc is either formed from or coated with electrically conductive material and the stylus serves as a conductive, electrode. Although the groove appears to be smooth, it does have tiny pits along the bottom which produce changes in electrical capacitance between the disc surface and the stylus electrode.
Figure 3.10 The RCA selectavision system employs a capacitance sensing stylus electrode, which is guided along shallow grooves and detects capacitance changes as it passes over shallow pits (a) Front view (b) Side view.

These changes in capacitance are sensed by a tuned circuit to produce an output of video signals.

Figure 3.11 The TeD employs a stylus shaped like the prow of a boat which senses mechanically the hill-and-dale modulations that contains the information.
The TeD and RCA systems rely on a stylus following a minute surface groove and *fail to function if the disc surface is damaged*. For this reason, the floppy TeD disc is always stored in a sleeve which is itself loaded into the player for automatic extraction of the vital foil, the sleeve remaining inside the player until the disc has played. RCA discs, which must also be warp free and are rendered useless by finger marks which confuse the capacitance effect, are stored in a *caddy* from which the player automatically extracts the disc for playing.

### 3.9 VIDEO HGH DENSITY (JVC/THORN-EMJ)

Technically and price wise, VHD falls between laservision and selectavision. The JVC system resembles the RCA approach in it’s of capacitance pick up from electrically conductive disc with a spiral of pits on its surface. But the 25cm (10inch) JVC disc has a smooth surface with no groove. The stylus electrode is constrained to follow the spiral pits by a servo system. The spiral of program pits (which the electrode stylus tracks to produce picture on TV screen) is interlaced with a spiral of tracking pits which are sensed to control the servo system to guide the electrode.

![Figure 3.12 video signal pick up in VHD system uses a cantilever arm](image)

**Figure 3.12 video signal pick up in VHD system uses a cantilever arm**

Figure 3.12 illustrate the method of controlling the stylus. The stylus is mounted at the end of a cantilever pick up arm opposite that end on which a magnet is attached. Fixed coils are positioned near the magnet a single coil is wound around but not in contact with the magnet and a pair of vertical coils are positioned one each on either side
of the coil and in phase opposition to each other. Thus the stylus can move transversely and longitudinally in response to the particular current flowing in these coils. The current is varied by a tracking error signal, or by a command to move the stylus to a desired track permitting various functions during playback.

**Figure.3.13 the JVC system**

The JVC disc rotates at twice the speed of the RCA disc, and gives a playing time of one hour each side. It can also provide *instant replay* of selected short passages. *Freeze frame* is possible but not easy, for examples, it requires a memory to store one of the two frames recorded for each resolution of the disc.

Because there are no *grooves* and *no tracking stylus to follow them* the JVC electrode is required only to slide over a smooth disc surface and will doubtless have a *longer life* than any other system employing a stylus in groove. However, no one yet knows how long a disc wilt last, especially when used to display still frames with any contact system there is inevitably some abrasion.

Although the JVC system is relatively simple to construct, it requires *complex servo control system* which may put the price higher than the mechanically very simple RCA system.
3.10 VIDEO DISC SYSTEMS — A COMPARISON

Common to all video disc systems is the process in which a program (originally recorded on magnetic tape) is recorded on to a master metal disc. The metal master is then used to mass produce plastic discs which are played on the video disc player (VDP).

Plastic discs for the laser video (L V) optical pick-up system are coated with metal on one side (the recorded surface) and then bonded with the metal inside for protection. Carbon is added to discs for the two capacitive pick-up systems, CED and VHD, to make the disc conductive. A lubricant for smoothing the pick-up and reducing wear is added to the CED discs. This lubricant is necessary because the CED system has grooves on the disc for stylus tracking. This makes the CED system simpler (no servo tracking is required) but does produce some wear. However, the wear on a CED disc in no way compares with the wear of a conventional audio record. RCA demonstrated this by playing a single groove of a CED disc 9000 times without noticeable deterioration in the video display.

The three video disc systems also have similarities. All three systems use a plastic disc rotating on a turntable. In all the systems, the player picks up in formation represented by changes in the disc surface and converts the information into signals for playback on a television set. All systems use frequency modulation (FM) for both video and audio signals. Each disc has a spiral track to carry the information rather than a series of circular tracks.

In spite of all the basic similarities, the systems differ not only in the pick-up technique (optical versus capacitive) but also in the format in which the information is encoded and in the method by which information is tracked. Other differences include size, material, rotation speed and signal-protection schemes.

3.11 RECORDING SYSTEM

In the optical video disc there is a single information track in which all the information is stored for the reproduction of a colour television program with two sound channels and data signals.

The nonlinearity of the master recording process limits the choice of possible encoding
Technique and a two-level signal recording was found to be the most attractive solution. On this track the information is enclosed in the length and the spacing of the pits or, in other words, for a routing disc in the repetition frequency, determined by the average length of the pits, and a pulse width modulation of the frequency determined by the modulation of the length of the pits. Figure.3.14.

The composite video signal employed in the video disc system is frequency modulated on a carrier at 8MHz which is pulse width modulated by two hi-fi audio channels at 2.3 MHz and 2.8 MHz.

Figure.3.15 shows the block diagram of the signal processing for coding the video and audio system. Before FM modulation of the video signal pre-emphasis time constant of 50µs and 12.5 µs are employed. The audio signal are FM modulated on carrier of 2.3MHz and 2.8 MHz with a frequency deviation of +100KHz and a pre-emphasis of 75 µs. The two audio carriers are summed with the FM carrier and after limiting, the output

signal is used to modulate the intensity of a laser beam passing through an electrode optical modulator in the master recording machine.

The spectrum of video and audio signals. The master is used as a starting point for the production of disc.
3.12 PLAY BACK SYSTEM

Reading back the information, the reflected light returning from the disc falls on a photodiode and its output is amplified and corrected according to the frequency characteristic of the player. A high-pass filter separates the video information and the filters have a crossover frequency at 3.5 MHz. The separated FM signals are then demodulated and a de-emphasis is applied to compensate for the pre-emphasis employed more recording, in order to achieve a better S/N ratio and a more uniform frequency response. The playback system shown in Figure.3.16.