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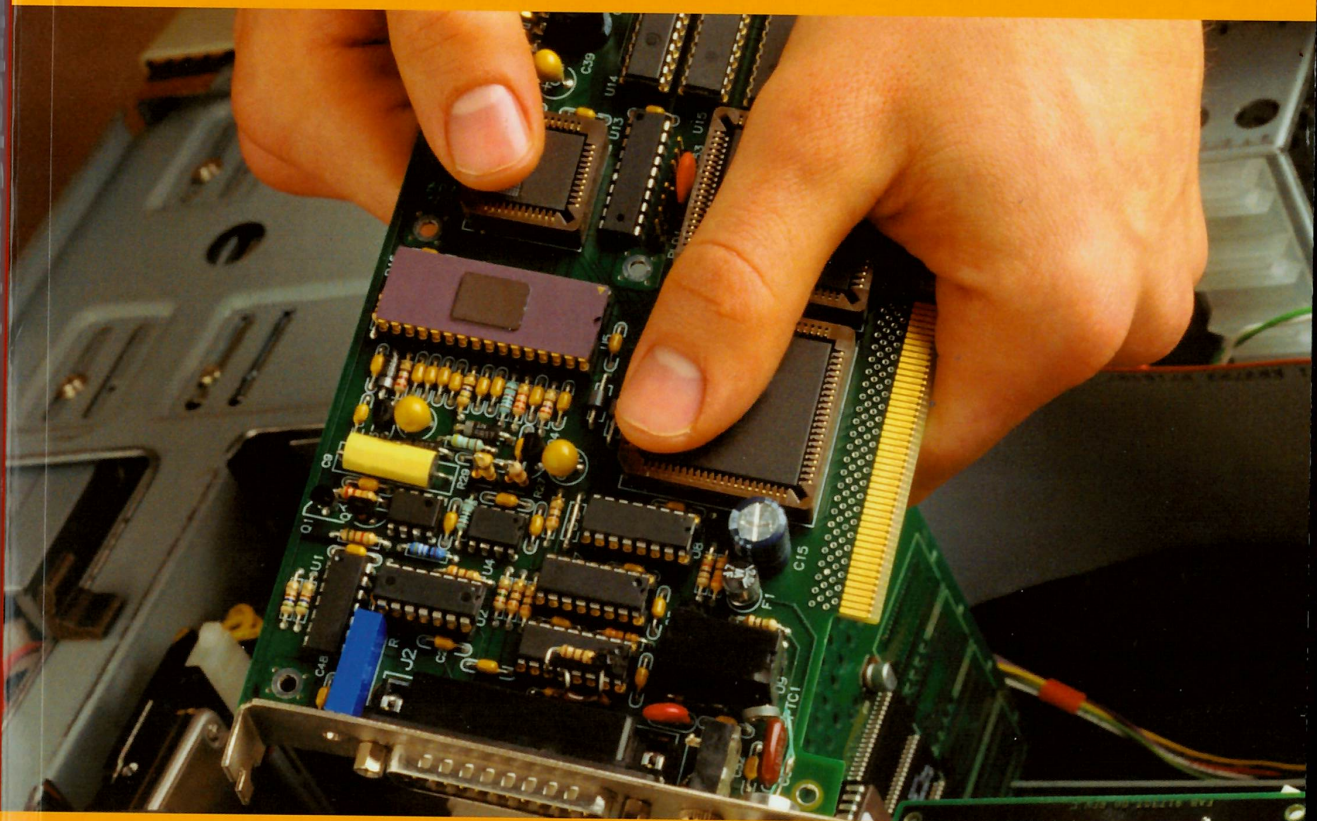
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Electronic and Electrical Servicing

Consumer and Commercial Electronics



Ian Sinclair & John Dunton



Electronic and Electrical Servicing

Consumer and commercial electronics

Second Edition

Ian Sinclair

and

John Dunton



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Contents

<i>Preface to the second edition</i>	vii
<i>Acknowledgements</i>	ix
Unit 1 D.c. technology, components and circuits	1
1 Direct current technology	3
2 Conductors, insulators, semiconductors and wiring	21
3 Resistors and resistive circuits	30
Unit 2 A.c. technology and electronic components	45
4 Magnetism	47
5 Capacitance and capacitors	60
6 Waveforms	70
Unit 3 Electronic devices and testing	79
7 Semiconductor diodes	81
8 Transistors	93
Unit 4 Electronic systems	105
9 Other waveforms	107
10 Transducers and sensors	116
11 Transducers (2)	125
12 Electronic modules	133
Unit 5 Digital electronics	149
13 Logic systems	151
14 Digital oscillators, timers and dividers	163
15 Digital inputs and outputs	171
Unit 6 Radio and television systems technology	179
16 Home entertainment systems	181
17 Frequency modulation	198
18 Television systems	206
19 Television receivers	219
Unit 7 PC technology	231
20 The personal computer	233
21 Installing a PC	248
22 Keyboard, mouse and monitors	257
23 Drives	269
24 Printers	281
25 Health and safety	293
Answers to multiple-choice questions	312
Index	313

telegraphs. The power that is required is in the low milliwatt level, and even a few milliwatts can produce considerable pressure amplitude at the eardrum, often more than is safe for your hearing when the earphone is a snug fit into the ear.

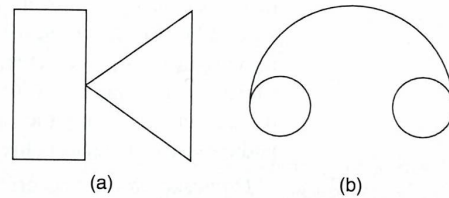


Figure 10.7 Symbols for (a) loudspeaker, and (b) headphones

The methods that are used for loudspeakers and for headphones are essentially the same as are used for microphones, because the action is (unusually) reversible.

Loudspeakers for domestic equipment are often **full-range** units, meaning that one loudspeaker transducer deals with the whole range of audio signals. This is not really satisfactory because it is very difficult to make a loudspeaker unit that will cope with such a range, and the few full-range units that can be classed as hi-fi loudspeakers are usually of exotic (and expensive) design, such as the Quad electrostatic units. Small full-range speakers of acceptable quality are widely used in radios, cassette recorders and compact disc players at the low end of the price range.

For anything that can be (loosely) classed as hi-fi, separate loudspeakers are used for the audio range, with one (woofer) dealing with the lower frequencies and another (tweeter) dealing with the high frequencies. The two units are normally enclosed in one cabinet, but on speaker sets such as those intended for home cinema equipment, the tweeters are arranged around the room and a single subwoofer (for the frequencies in the range 30–150 Hz) is located centrally. The stereo effect depends almost completely on the higher frequencies, so the positioning of a woofer/subwoofer is not critical. A filter, called a **cross-over unit**, separates the signal into lower and upper frequencies so that the higher frequencies are fed to the tweeters and the lower frequencies to the woofers.

Most loudspeakers use the moving-coil principle (Figure 10.8). The coil is wound on a former at the apex of a stiff diaphragm which is held in flexible supports so that the coil is in the intense field of a permanent magnet. A signal current through the coil will then vibrate the diaphragm, producing sound waves at the same frequency and with the same waveshape as the signal. To be really effective, a loudspeaker has to be housed in a cabinet (**enclosure**) whose design assists the loudspeaker to move a large volume of air, acting like a transformer for air waves. Even in a fairly good enclosure, the efficiency of a typical hi-fi loudspeaker is very low, around 1%.

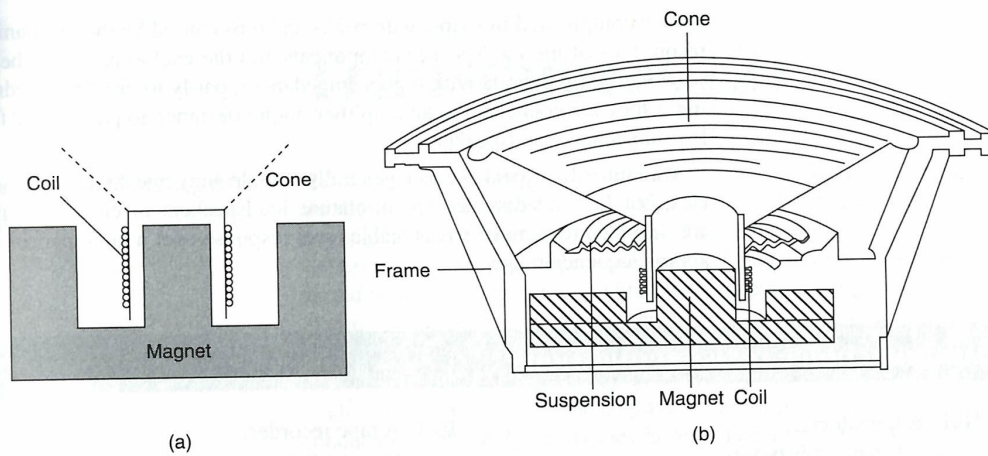


Figure 10.8 Moving-coil loudspeaker: (a) cross-section of coil and magnet, and (b) cutaway view of complete unit

Miniature loudspeakers, typically of diameter 70 mm or less, are used as warning transducers in cars, signal devices on electronic equipment, and in toys. These small units can be used also as microphones, although their efficiency as a microphone is low and the frequency response is uneven. Confusingly, the same term is also used for hi-fi loudspeakers that are noticeably smaller than average.

Headphones

Headphones can be constructed using any of the principles used for loudspeakers, but the most widespread and successful type is the **electrodynamic** (or **orthodynamic**) principle. This uses a diaphragm which has a coil built in, using printed circuit board techniques. The coil can be a simple spiral design, or a more complicated shape (for better linearity), and the advantage of the method is that the driving force is more evenly distributed over the surface of the diaphragm.

The **piezoelectric** principle has also been used for headphones in the form of piezoelectric sheets that can be formed into very flexible diaphragms. A piezoelectric material is one whose dimensions can be changed by applying an electric field, and which will generate an electric field if the material is compressed. Quartz crystals are piezoelectric, and another crystalline material that is extensively used is barium titanate.

Moving-coil headphones have also been manufactured and the quality that can be attained justifies the high prices that are attached to these units.

Subminiature earphones, often referred to as *earbuds*, are designed for use with portable CD or MP3 players, and run at a typical rated power of 3 mW. These use the same dynamic mechanism as larger earphones. The impedance is typically 32Ω .

Moving-coil loudspeakers and earphones have a nominal value of impedance, typically 4 ohms, but a graph of impedance plotted against frequency

capacitor had charged via the resistor up to the threshold before the trigger could change state. If the switch contacts bounce, the change in voltage at the input is not rapid, because of the time constant, so the output voltage is unaffected. Buffers and logic gates are obtainable with Schmitt switching characteristics, and microcontrollers often have Schmitt inputs on some pins. Although this can be effective, it is not perfect, and more elaborate methods are often used.

Another method of debouncing switch contacts is to connect the switch to an RS flip-flop. Figure 15.3(a) shows a typical switch debounce circuit. To understand what happens, we need to recall how the RS flip-flop works: the output changes only when one input is at logic 0 and the other is at logic 1. When the inputs are both at logic 1, the output remains unchanged in whatever state it was last set.

When the switch is at position A, the input to the flip-flop is $\bar{R} = 1$, $\bar{S} = 0$, and this gives $Q = 1$ as the output. Now while the switch is being changed over, both inputs will momentarily be at logic 1, but this does not change the output. When the switch contacts are in position B, the inputs to the flip-flop are $\bar{R} = 0$, $\bar{S} = 1$, giving $Q = 0$. If the switch contacts bounce, making $\bar{R} = 1$, $\bar{S} = 1$, the output remains at 0, so that the switch bounce has no effect. This method of debouncing is usually preferred, and is completely effective when properly implemented.

Debouncing for key pads like those used in telephones, calculators and computer keyboards is usually carried out by application-specific integrated circuit (ASIC) keyboard encoders or software run on a microcontroller. The switches will typically be arranged as a matrix, with the controller driving the rows and reading the columns. When a switch is closed, the controller detects that it has been closed and a time delay starts. Changes in the switch setting have no effect until the end of the time interval. This interval can be several tens of milliseconds, since you cannot type quickly enough to operate a key more than once in that time.

Practical 15.1

Connect a switch and resistor so that when the switch is closed the resistor is connected between a 5V supply and ground. Use a counter or oscilloscope to measure the pulses caused by bouncing. Assemble a debouncing circuit (either Schmitt or RS flip-flop) and verify that the output of the debouncing circuit changes only once for each switching at its input.

Digital outputs

The outputs from digital circuits may be used to control devices such as motors, to switch on loads via a relay or to drive display devices (see Figure 15.4). Displays are the most common output devices that allow us to interact with electronic systems.

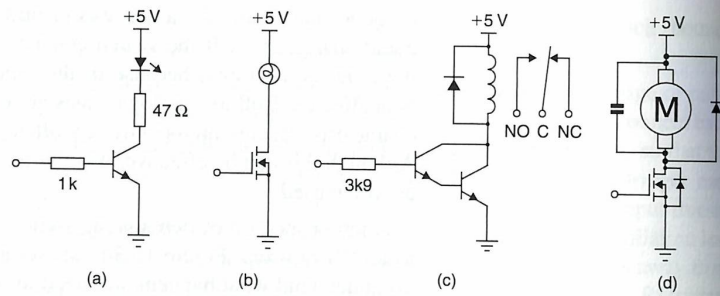


Figure 15.4 Driving loads from digital outputs: (a) transistor driver for high-current LED, (b) FET drive for an indicator bulb, (c) driving a relay with a Darlington pair (note protection diode), and (d) switching a small motor with a MOSFET (note protection diode and electromagnetic compatibility (EMC) suppression capacitor)

Light-emitting diodes (LEDs) indicators are diodes that emit light when current passes in the forward direction. Using different semiconductor materials, LEDs can be made to emit light of different colours. Single LEDs can be used to indicate binary numbers by using one LED for each power of two, on for one and off for zero.

Number displays based on segmented displays made with LEDs are commonly used for indicating denary numbers, using integrated circuits (ICs) that convert binary-coded decimal (BCD) to segment drive for a seven-segment type of display (Figure 15.5). As for all LEDs, the amount of current being passed needs to be limited, and this is usually done with a resistor in series with the LED. The brightness of the output is roughly proportional to the current.

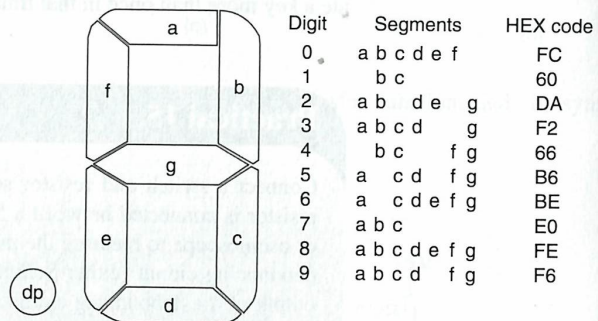


Figure 15.5 Seven-segment display

The format of LED indicators can be **common anode** or **common cathode**. For a seven-segment display, for example, each bar can be the cathode of a diode, all of whose anodes are connected, or each bar can be an anode of a diode, with all the cathodes connected. On a common-cathode

display, the cathode will be earthed and each anode connection driven to a positive voltage so as to illuminate a bar. On a common-anode display, the anode connection will be made to a positive voltage, and the cathode connections earthed by the driver circuits as required.

Liquid crystal displays (LCDs) make use of a quite different principle. They depend on a liquid crystal material that polarizes light when an electrical potential is applied. The display is made by sandwiching this liquid crystal material between transparent metal electrodes deposited on glass substrates (Figure 15.6a), one or both of which are transparent and polarizing. Light passing through it will be polarized by the glass polarizing filter and so the light can be switched on or off by altering the voltage across the liquid crystal, which changes its polarization. The amount of power that is needed is very small, and the brightness of the display is just the brightness of the light that is used. The contrast of the display depends on how well the liquid crystal polarizes; at high and low temperature extremes this may not be as good as at room temperature. This is the principle now widely used for all types of displays, including computer monitors and television displays.

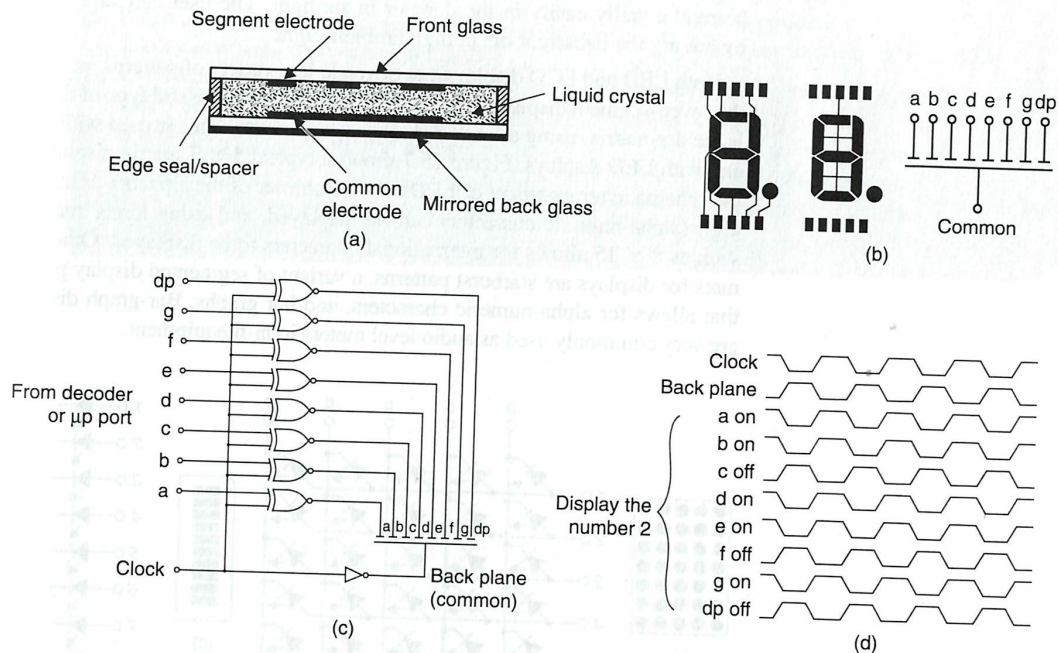


Figure 15.6 Liquid crystal displays: (a) LCD construction, (b) seven-segment display pattern and connections, (c) drive circuit, and (d) drive waveforms

The drive voltage must be a.c. at a high audio frequency, with no trace of d.c., otherwise the liquid crystal may become permanently polarized and the display will lose contrast. LCD displays like those in watches and calculators are reflective, so that they are most visible in bright light, but

backlighting can be used if the displays have to be read in the dark. One noticeable disadvantage is that the display is clearly visible only when you look straight at it. Visibility is much reduced when viewing at an angle.

Transmissive displays (TMCs) are used with a white backlight, and the liquid crystal dots will transmit whatever colour is selected from the whole spectrum of white light. These displays are ideal for use in low-lighting conditions.

Reflective displays (RFCs) are used illuminated by white light, and will reflect whatever colour is selected from each liquid crystal dot. No backlight is needed, so that power requirements are very low, but they can be used only in bright lighting conditions, and the perceived colours will alter if the illumination is not white light.

Transflective displays (TFCs) combine both TMC and RFC principles, and use both a backlight and the ambient light to provide a display that can be read equally easily in the dark or in sunlight. The user can save power by having the backlight off in high ambient light.

Both LED and LCD displays can be made in a variety of patterns, of which the seven-segment display is the most common. Another useful type of display is the dot-matrix, using a set of dots for each character. This is used with LCD and with LED displays. Figure 15.7 shows a typical 5×7 matrix display and the schematic arrangement of LEDs. Any character of the alphabet or number digit (alpha-numeric character) can be displayed, and using larger matrices such as 8×15 allows for international characters to be displayed. Other formats for displays are starburst patterns, a variant of segmented display pattern that allows for alpha-numeric characters, and bar graphs. Bar-graph displays are very commonly used as audio level meters in hi-fi equipment.

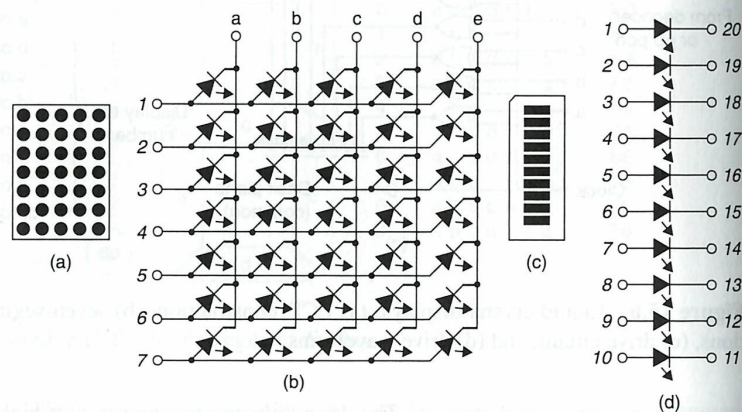


Figure 15.7 Typical displays: (a) matrix display, (b) typical LED connections, (c) bar graph, and (d) LED connections

All forms of display require driver circuits that will accept normal digital logic level inputs and provide outputs that are suitable for operating the display segments. For number or alphabetical displays, combined decoder-drivers are used to implement the decoding logic required; illustrated in (Figure 15.5). The decoder-driver and display is often combined so that no wiring is needed other than power supplies and inputs.

Multiple-choice revision questions

- | | |
|--|---|
| <p>15.1 Which switch debouncing method is most appropriate for the type of switch called SPCO (single-pole change-over)?</p> <p>(a) RC input Schmitt</p> <p>(b) microprocessor software delay</p> <p>(c) RS flip-flop</p> <p>(d) NAND gate.</p> | <p>(c) 20 mA</p> <p>(d) 50 mA.</p> |
| <p>15.2 When a standard seven-segment LED display is driven, each segment draws about 5 mA from the supply. What is the difference between the maximum and minimum current drawn for the numbers from 0 to 9?</p> <p>(a) 5 mA</p> <p>(b) 25 mA</p> | <p>15.3 What is the effect of a low-value d.c. drive on an LCD?</p> <p>(a) will damage the display</p> <p>(b) all the segments are displayed simultaneously</p> <p>(c) light is emitted</p> <p>(d) will cause the display to explode.</p> |
| | <p>15.4 What is the main advantage of a dot-matrix display?</p> <p>(a) low current requirement</p> <p>(b) can display any pattern</p> <p>(c) requires fewer resistors</p> <p>(d) costs less than a seven-segment type.</p> |



Figure 19.5 Components marked with this symbol in the service schematic are safety critical and should be replaced with identical types, as directed by the service manual

pattern generators, through digital oscilloscopes with the facilities for the display of both time- and frequency-based signals, to signal strength meters suitable for selecting the required transmissions and accurately aligning aerial systems.

Most consumer devices are mains powered, and when work is carried out on such equipment components the demanding safety requirements of mains connection must be met.

Particular care must be taken over **critical components**, usually marked out on a service sheet (Figure 19.5). These must be replaced with factory-approved components because a replacement may otherwise present a safety hazard. The repairer would be held liable for damage caused as the result (of a fire, for example) caused because a critical component had been replaced by an unapproved substitute.

Video recording

The recording of analogue video signals on magnetic tape follows the same basic principles as analogue audio recording. However, the very wide bandwidth of the video signal requires that the tape pass the record head at a much greater speed than is possible with a conventional analogue tape machine. To achieve the required speed of tape past the head, two or more heads are mounted on a spinning drum which is mounted to scan the head across the tape at a shallow angle. This allows the tape to move relatively slowly past the spinning drum. The helical scan system has been under development since the late 1950s, with the VHS system introduced in the early 1980s and largely unchanged today. Additional features include multiple heads to provide better still-frame playback and long play/record performance, and there have been massive reductions in unit cost owing to improved manufacturing and electronic integration. The general arrangement of helical scan **VCR** tape path is shown in Figure 19.6.

When the cassette is inserted in the machine, the first operation is threading; this is feeding the tape through the tape path around the drum so that it can be played or recorded. To achieve this, the front cover of the cassette is lifted as the cassette drops into position. The unthreaded position of the loading arms means that the slant poles, guide rollers, tension pole and capstan spindle are behind the tape; these are all mounted on movable loading arms. The threading operation uses the loading arms to move the slant poles, guide rollers, etc., to their operating position (Figure 19.5), carrying the tape around the circumference of the head drum and past the audio, control and erase heads. The slant poles now perform their main function, which is to guide the tape on to the drum at the correct angle for it to be scanned by the passing of the heads.

The analogue audio signal is recorded on a narrow strip along one edge of the tape, while field sync. pulses are recorded on the opposite edge. The heads and tape travel in the same direction to minimize frictional losses and to extend the mechanical lifetime.

The luminance signal is frequency modulated on to a carrier of about 4.3MHz, which swings through the range of about 3.8–4.8MHz between

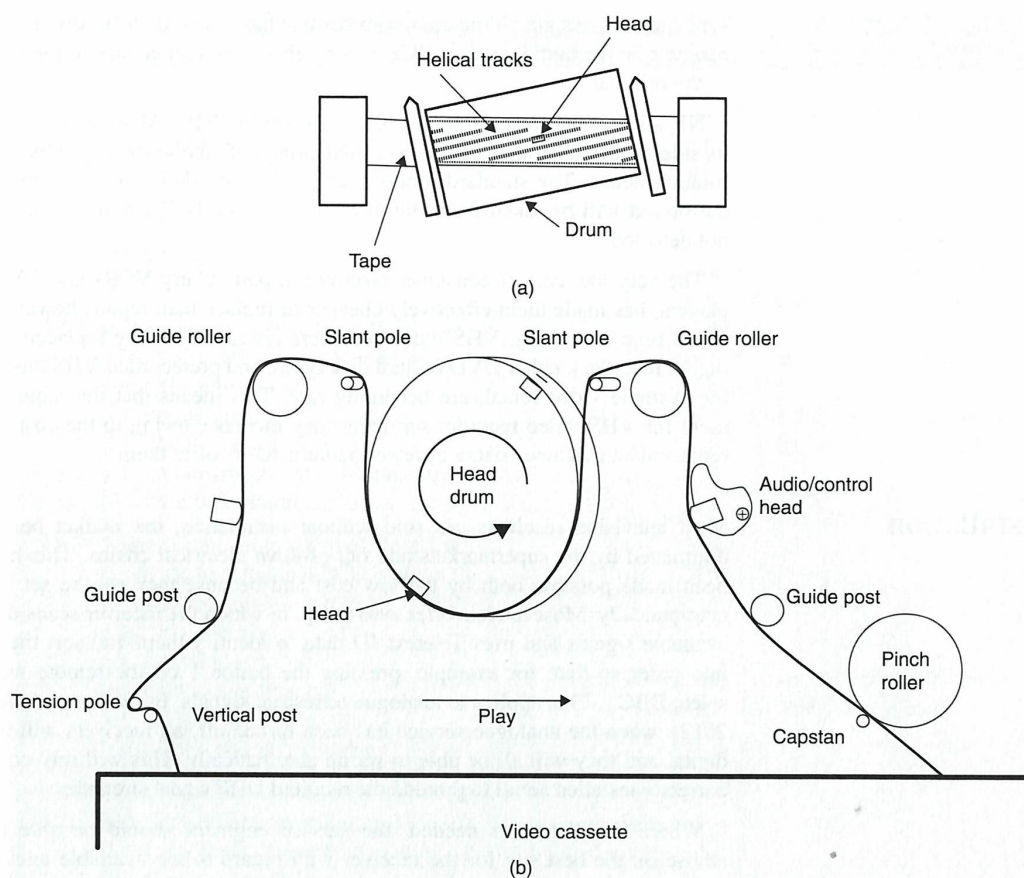


Figure 19.6 Tape transport of typical helical scan video recorder: (a) tracks on tape, and (b) tape path

sync. pulse tip and peak white. Because this FM signal is of constant amplitude, it can be recorded on tape without needing a higher frequency bias signal as used in audio recording, since it is not affected by the amplitude distortion introduced by the magnetic hysteresis of the tape. The FM luminance signal is used as the recording bias signal for the chrominance component, which is down-converted to a **colour under frequency** of about 625 kHz and added to the luminance signal for recording. The replay follows the inverse process; the tape speed is locked to the required vertical sync. rate, the luminance and chroma signals are recovered along with the sound signal. These are typically available via the SCART connector and on some new machines and most older ones remodulated onto a UHF carrier for input to the television receiver aerial socket.

To ensure synchronism, the tape capstan drive motor is locked to the vertical sync. pulses, while the head drum rotation is locked to the horizontal

Optical (CD/DVD) drives

the easiest method is to mount the old drive in an external drive casing, plug into the USB or Firewire port of the computer, and use Windows to copy data files.

The optical drive allows the use of CD or DVDs that carry computer codes, and these are extensively used to contain programs and other information (such as multimedia text, pictures, audio or video). Older CD-ROM drives are read-only, but a later generation of drives permits both reading and writing. The conventional CD-ROM will hold about 700Mbytes of data. The later development, the DVD read/write drive, is almost universally fitted to modern computers, and can read or write CD or DVDs, either the R (write once only) or the RW (write, read, delete, rewrite) type.

The optical system makes use of optical recording, using a beam of light from a miniature semiconductor laser. Such a beam is of low power, a matter of milliwatts, but the focus of the beam can be to a very small point, about $0.6\mu\text{m}$ in diameter; for comparison, a human hair is around $50\mu\text{m}$ in diameter. The beam can be used to form pits in a flat surface, using a depth which is also very small, in the order of $0.1\mu\text{m}$. If no beam strikes the disk, then no pit is formed, so that this system can digitally code pulses into the form of pit or no-pit. These pits on the master disk are converted to pits of the same scale on the copies. The pits/dimples are of such a small size that the tracks of the CD can be very close; about 60 CD tracks take up the same width as one vinyl LP track, and the tracks on a DVD are closer still. The pits are arranged into a spiral track starting near the hub of the disk and ending near the edge. Digital signals of 8 bits are converted into 14-bit signals to allow for error-reduction methods to be used, and also to avoid long runs of the same digit (0 or 1) occurring.

Reading a set of pits on a disk also makes use of a semiconductor laser, but of much lower power since it need not vaporize the material. The reading beam will be reflected from the disk where no pit exists, but scattered where there is a pit. The rotational speed of the disk is controlled so that the rate of reading pits is constant. This means that the disk spins more quickly at the start of the track than it does at the end. By using a lens system that allows the light to travel in both directions to and from the disk surface it is possible to focus a reflected beam on to a photodiode, and pick up a signal when the beam is reflected from the disk, with no signal when the beam falls on to a pit. The output from this diode is the digital signal that will be amplified and then processed eventually into an audio signal. Only light from a laser source can fulfil the requirements of being perfectly monochromatic (one single frequency) and coherent (no breaks in the wave-train) so as to permit focusing to such a fine spot.

Focusing and track location are automatic. The returned reading beam is split and the side beams detected so that servo circuits can locate the track and focus on it. This mechanism must not be disturbed unless you have had training in servicing optical drives.

The optical reader drive uses the laser beam reading system that was originally developed for music CDs, but the speed of rotation of the disk is usually much higher. When you buy a CD-ROM drive, you will see this speed quoted as a multiple of the normal speed of the music CD, such as 20×, 32×, and so on. This allows the disks to be read at higher speeds, so that information can be read from a CD almost as quickly as it could from old hard drives. The normal rotational speed of DVDs is much higher, so that higher speeds are more usually in the range of 2× to 10×. At the time of writing, optical drives that are being fitted to computers will take either the older single-layer writable DVD (4.7 GB) or the later double-layer type (8.5 GB). Further developments of the DVD system such as Blu-ray and HDVD can store much larger amounts of data per disk.

Note that the double-layer disks cannot (at the time of writing) be written with a continuous file of 8.5 GB; you need to record one layer to its limit and then write a separate file on the other layer.

The form of optical drives is fairly well standardized now, as a slim 5¼ inch casing. The front panel holds a drive-on light, a volume control and a headphone jack. This allows the use of the drive for playing ordinary audio CDs. The output audio signal is typically 0.6 V r.m.s. at 1 kHz.

When a button on the front panel is pressed, a tray slides out so that a disk can be placed in the tray, and pressing the button again will cause the tray to slide back in. The drive motor then spins the disk (taking a second or so to build up to full speed), and from then on the disk can be accessed, usually as drive D:. Windows allows you to specify Autostart, so that when a CD or DVD is inserted it will run its program(s) automatically.

There are three connectors at the rear of the CD-ROM drive, the power connector feeding +5 V and +12 V DC, an audio output connector for amplifiers, and the data interface. The audio interface typically uses a four-pin connector. The data interface uses a 40-pin insulation displacement connector (IDC) type.

The CD-ROM drive contains a low-power laser, but because the beam can focus to such a small point, it can cause damage to your eyes. No attempt should be made to use a CD reader with the casing removed, and if focusing problems are encountered, the unit should be returned to the manufacturer.

Figure 23.7 shows a simplified block diagram for a typical optical drive unit. The control signals set the speed of the drive motor, which is not constant; it runs faster when the inner tracks are being read and slower for the outer tracks, keeping the data speed constant. The beam position drives select the track and maintain focus, and the optical head reads the signals reflected from the track. These signals are then converted into conventional digital data in the interface.

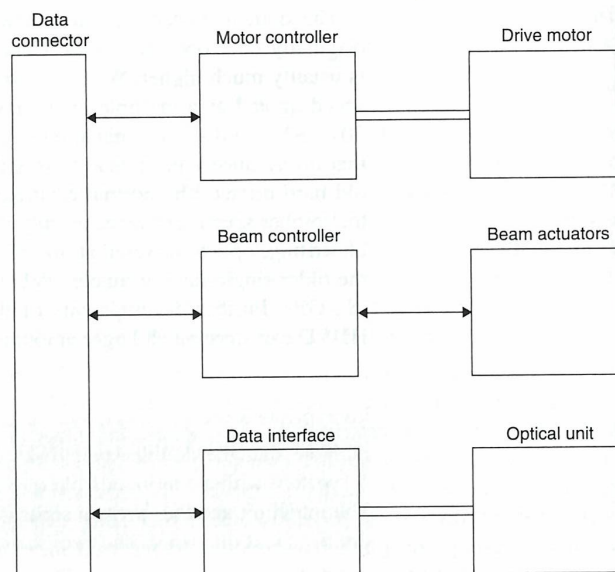


Figure 23.7 Block diagram, simplified, for a CD-ROM drive

Multiple-choice revision questions

- 23.1 A floppy is being written to and an error message appears. Which of the following **cannot** be the cause of the problem?
- the disk has had its write-protection set
 - there is no floppy-disk driver software
 - the disk is not formatted
 - the disk is full.
- 23.2 Any make of hard drive intended for a PC can be used as a replacement for a faulty unit. This is because:
- no driver software is needed
 - the controller on the motherboard can be used with any drive
 - the controller is built into the drive
 - all hard drives are of identical design.
- 23.3 A hard drive can have a large data capacity because it:
- is physically larger than a floppy
 - runs at a faster speed than a floppy
 - does not have to be inserted and removed
 - uses many platters of magnetic material.
- 23.4 Which of these is NOT an advantage of a hard drive as compared to a floppy?
- it has a much greater data capacity
 - it is faster in use
 - it does not need to be formatted
 - it can hold the Windows software.
- 23.5 A hard drive sometimes does not start until it is tapped. This is because:
- there is excessive friction on the drive motor spindle
 - there is too much software on the drive
 - the drive is not formatted
 - air has entered the drive casing.
- 23.6 A CD-ROM is inserted but does not start sending data to the computer. This is because:
- the drive is not formatted
 - the drive is faulty
 - Autostart has not been activated in Windows
 - the CD-ROM is faulty.