A triggered scope does not use a continuous or recurrent sweep, but uses a monostable multivibrator which is in its off state until a trigger pulse arrives, hence there is no deflection on the screen.

When an input signal is applied, a trigger pulse is generated and applied to the multivibrator, which switches on and produces a sweep signal, and a trace appears on the screen. After a specific voltage, depending on the CRT beam arriving on the RHS, the multivibrator switches back to its off state, causing the beam to return rapidly to the LHS. (The basic difference between recurrent and triggered scopes is that the recurrent sweep locks at the frequency of the input signal, while the triggered scope displays a trace for a specific period of time. Hence, the triggered scope is ON during a specific time interval and will display a waveform or a segment of waveform (e.g. a one shot waveform) regardless of the signal frequency. Hence transients or single clamped oscillations can be observed on the screen.)

Most triggered scopes use a convenient feature of calibrating the sweep speed, in time per cm or division. Sweep frequency is the reciprocal of the time period.

5. Intensity Modulation In some applications an ac signal is applied to the control electrode of the CRT. This causes the intensity of the beam to vary in step with signal alternations. As a result, the trace is brightened during the +ve half cycles and diminished or darkened during –ve half cycles. This process, is called intensity modulation or *Z*-axis modulation (in contrast to *X*-axis for horizontal and *Y*-axis for vertical). It produces bright segments or dots on the trace in response to positive peak or dim segments or holes in response to negative peaks.

BLOCK DIAGRAM OF OSCILLOSCOPE 7.4

The major block circuit shown in Fig. 7.4, of a general purpose CRO, is as follows:

1. CRT
2. Vertical amplifier
3. Delay line
4. Time base
5. Horizontal amplifier
6. Trigger circuit
7. Power supply

The function of the various blocks are as follows.

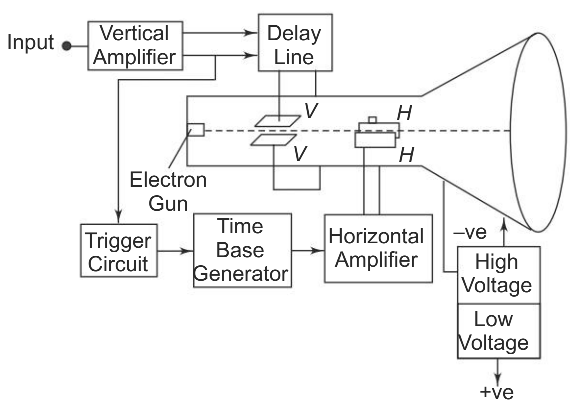

Fig. 7.4 Basic CRO block diagram

1. CRT This is the cathode ray tube which emits electrons that strikes the phosphor screen internally to provide a visual display of signal.

2. Vertical Amplifier This is a wide band amplifier used to amplify signals in the vertical section.

3. Delay Line It is used to delay the signal for some time in the vertical sections.

4. Time Base It is used to generate the sawtooth voltage required to deflect the beam in the horizontal section.

5. Horizontal Amplifier This is used to amplify the sawtooth voltage before it is applied to horizontal deflection plates.

6. Trigger Circuit This is used to convert the incoming signal into trigger pulses so that the input signal and the sweep frequency can be synchronised

7. Power Supply There are two power supplies, a –ve High Voltage (HV) supply and a +ve Low Voltage (LV) supply. Two voltages are generated in the CRO. The +ve volt supply is from + 300 to 400 V. The –ve high voltage supply is from – 1000 to – 1500 V. This voltage is passed through a bleeder resistor at a few mA. The intermediate voltages are obtained from the bleeder resistor for intensity, focus and positioning controls.

Advantages of using –ve HV Supply

(i) The accelerating anodes and the deflection plates are close to ground potential. The ground potential protects the operator from HV shocks when making connections to the plates.

(ii) The deflection voltages are measured wrt ground, therefore HV blocking or coupling capacitor are not needed, but low voltage rating capacitors can be used for connecting the HV supply to the vertical and horizontal amplifiers.

(iii) Less insulation is needed between positioning controls and chasis.

SIMPLE CRO 7.5

The basic block diagram of a simple CRO is shown in Fig. 7.5. The ac filament supplies power to the CRT heaters. This also provides an accurate ac calibrating voltage. CRT dc voltage is obtained from the HV dc supply through voltage dividers $R_1 - R_5$. Included along with this voltage divider is a potentiometer (R_3) which varies the potential at the focusing electrode, known as focus control, and one which varies the control grid voltage, called the intensity control (R_5).

Capacitor C_1 is used to ground the deflection plates and the second anode for the signal voltage, but dc isolates these electrodes from the ground.

Normally S_2 is set to its linear position. This connects the sweep generator output to the horizontal input. The sweep voltage is amplified before being applied to the horizontal deflecting plates.

When an externally generated sweep is desired, S_2 is connected to its external position and the external generator is connected to the input. The sweep synchronising voltage is applied to the internal sweep generator through switch S_1, which selects the type of synchronisation.

0.2 Comparison of Analog and Digital Instruments

Sr. No.	Parameter	Analog	Digital
1.	Accuracy	Less upto ± 0.1 % of full scale.	Very high accuracy upto ± 0.005 % of reading.
2.	Resolution	Limited upto 1 part in several hundreds.	High upto 1 part in several thousands.
3.	Power	Power required is high hence can cause loading.	Negligible power is required hence no loading effects.
4.	Cost	Low in cost.	High in cost compared to analog but now-a-days cost of digital instruments is also going down.
5.	Frictional errors	Errors due to moving parts are present.	No moving parts hence no errors.
6.	Range and polarity	No facility of autoranging and autopolarity.	Has the facility of autoranging and autopolarity.
7.	Input impedance	Low input impedance.	Very high input impedance.
8.	Observational errors	Errors such as parallax errors and approximation errors are present.	Due to digital displays, the observational errors are absent.
9.	Compatibality	Not compatible with modern digital instruments.	The digital output can be directly fed into memory of modern digital instruments.
10.	Speed	Reading speed is low.	Reading speed is very high.
11.	Programming facility	Not available.	Can be programmed and well suited for the computerised control.

10.4 Basic Block Diagram of DVM

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- Any digital instrument requires analog to digital converter at its input. Hence first block in a general DVM is ADC as shown in the Fig. 10.4.1.

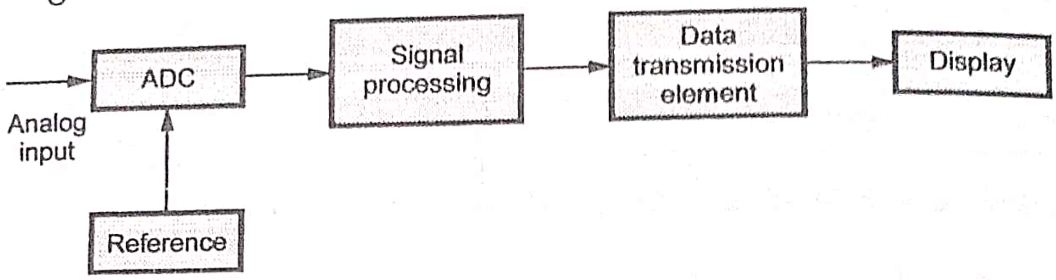


Fig. 10.4.1 Basic block diagram of DVM

- Every ADC requires a reference. The reference is generated internally and reference generator circuitry depends on the type of ADC technique used.
- The output of ADC is decoded and signal is processed in the decoding stage. Such a decoding is necessary to drive the seven segment display. The data from decoder is then transmitted to the display.

- The data transmission element may be a latches, counters etc. as per the requirement.
- A digital display shows the necessary digital result of the measurement.

10.5.3 Ramp Type DVM

- It uses a linear ramp technique or staircase ramp technique. The staircase ramp technique is simpler than the linear ramp technique.

10.5.3.1 Linear Ramp Technique

- The basic principle of such measurement is based on the measurement of the time taken by a linear ramp to rise from 0 V to the level of the input voltage or to decrease from the level of the input voltage to zero.
- This time is measured with the help of electronic time interval counter and the count is displayed in the numeric form with the help of a digital display.
- Basically it consists of a linear ramp which is positive going or negative going. The range of the ramp is ± 12 V while the base range is ± 10 V. The conversion from a voltage to a time interval is shown in the Fig. 10.5.4.

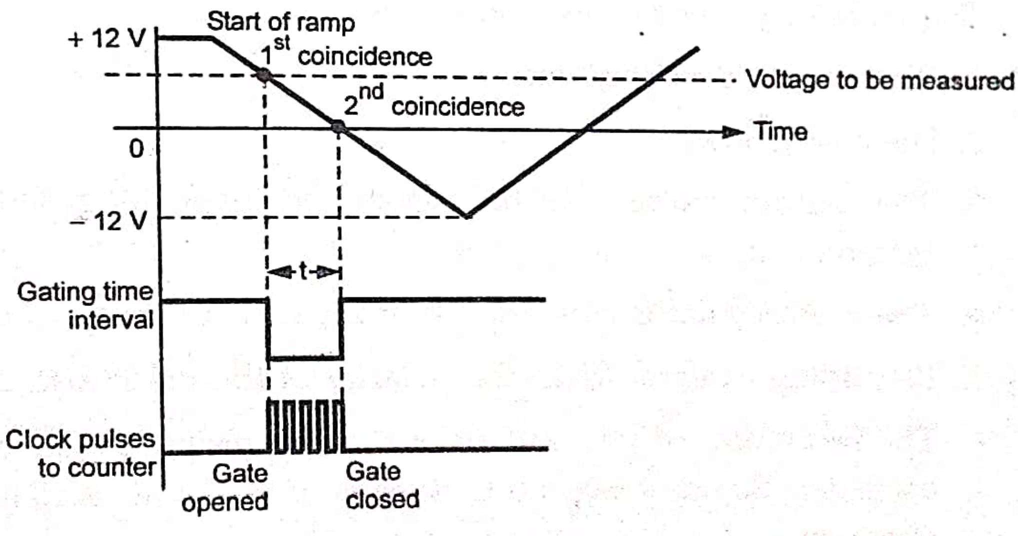


Fig. 10.5.4 Voltage to time conversion

- At the start of measurement, a ramp voltage is initiated which is continuously compared with the input voltage.
- When these two voltages are same, the comparator generates a pulse which opens a gate i.e. the input comparator generates a start pulse.
- The ramp continues to decrease and finally reaches to 0 V or ground potential. This is sensed by the second comparator or ground comparator.
- At exactly 0 V, this comparator produces a stop pulse which closes the gate. The number of clock pulses are measured by the counter.
- Thus the time duration for which the gate is opened, is proportional to the input voltage.
- The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the display.
- The block diagram of linear ramp DVM is shown in the Fig. 10.5.5.

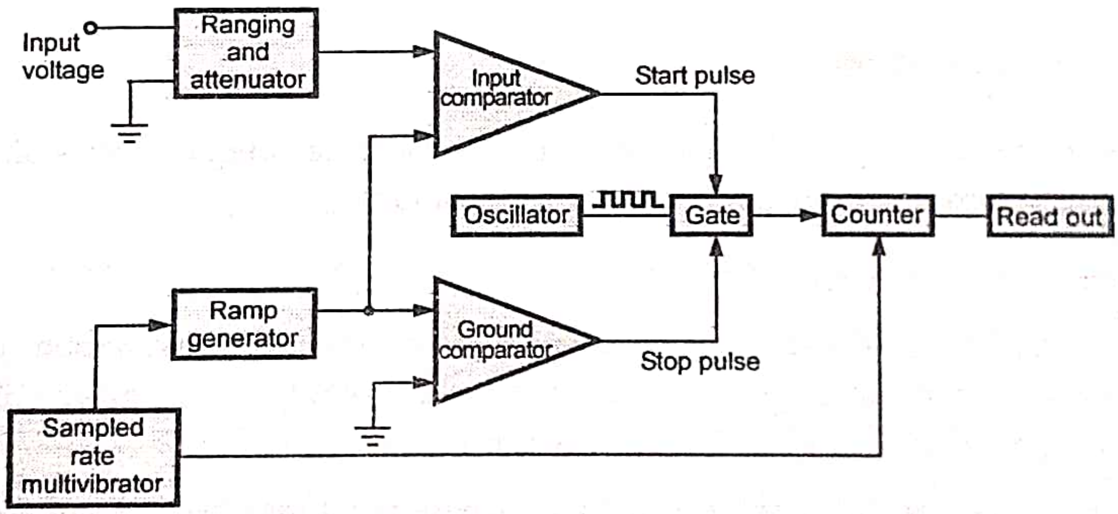


Fig. 10.5.5 Linear ramp type DVM

The **advantages** of this technique are :

1. The circuit is easy to design.
2. The cost is low.
3. The output pulse can be transferred over long feeder lines without loss of information.
4. The input signal is converted to time, which is easy to digitize.
5. By adding external logic, the polarity of the input also can be displayed.
6. The resolution of the readout is directly proportional to the frequency of the local oscillator. So adjusting the frequency of the local oscillator, better resolution can be obtained.

The **disadvantages** of this technique are :

1. The ramp requires excellent characteristics regarding its linearity.
2. The accuracy depends on slope of the ramp and stability of the local oscillator.
3. Large errors are possible if noise is superimposed on the input signal.
4. The offsets and drifts in the two comparators may cause errors.
5. The speed of measurement is low.
6. The swing of the ramp is ± 12 V, this limits the base range of measurement to ± 10 V.

DIGITAL MULTIMETERS 6.2

Analog meters require no power supply, they give a better visual indication of changes and suffer less from electric noise and isolation problems. These meters are simple and inexpensive.

Digital meters, on the other hand, offer high accuracy, have a high input impedance and are smaller in size. They gives an unambigious reading at greater viewing distances. The output available is electrical (for interfacing with external equipment), in addition to a visual readout.

The three major classes of digital meters are panel meters, bench type meters and system meters.

All digital meters employ some kind of analog to digital (A/D) converters (often dual slope integrating type) and have a visible readout display at the converter output.

Panel meters are usually placed at one location (and perhaps even a fixed range), while bench meters and system meters are often multimeters, i.e. they can read ac and dc voltage currents and resistances over several ranges.

The basic circuit shown in Fig. 6.2 (a) is always a dc voltmeter. Current is converted to voltage by passing it through a precision low shunt resistance while alternating current is converted into dc by employing rectifiers and filters. For resistance measurement, the meter includes a precision low current source that is applied across the unknown resistance; again this gives a dc voltage which is digitised and readout as ohms.

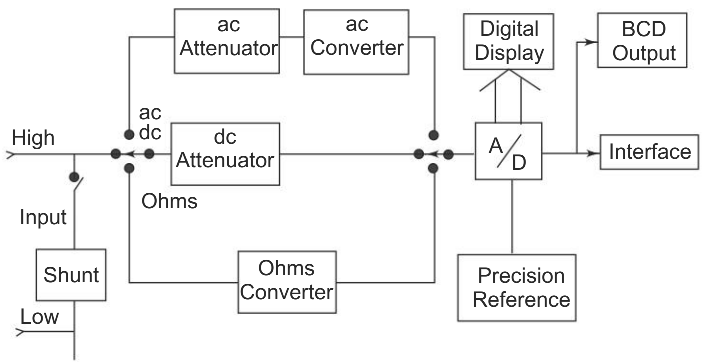


Fig. 6.2 (a) Digital multimeter

Bench meters are intended mainly for stand alone operation and visual operation reading, while system meters provide at least an electrical binary coded decimal output (in parallel with the usual display), and perhaps sophisticated interconnection and control capabilities, or even microprocessor based computing power.

A basic digital multimeter (DMM) is made up of several A/D converters, circuitry for counting and an attenuation circuit. A basic block diagram of a DMM is shown in Fig. 6.2 (b). The current to voltage converter shown in the block diagram of Fig. 6.2 (b) can be implemented with the circuit shown in Fig. 6.2 (c).

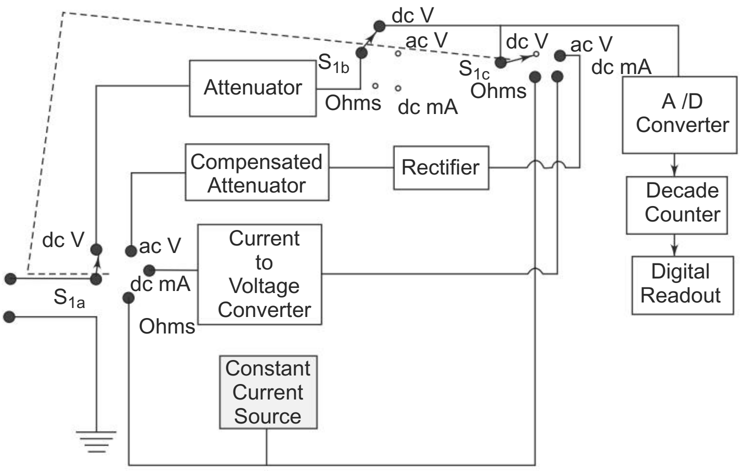


Fig. 6.2 (b) Block diagram of a basic digital multimeter

The current to be measured is applied to the summing junction ($\Sigma\ i$) at the input of the opamp. Since the current at the input of the amplifier is close to zero because of the very high input impedance of the amplifier, the current I_R is very nearly equal to I_i, the current I_R causes a voltage drop which is proportional to the current, to be developed across the resistors. This voltage drop is the input to the A/D converter, thereby providing a reading that is proportional to the unknown current.

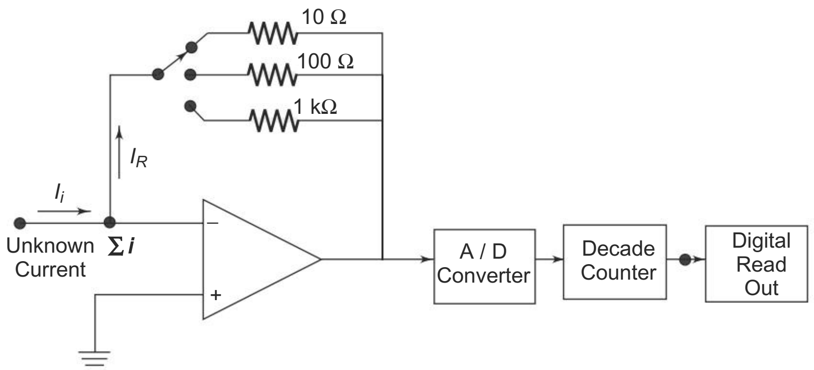


Fig. 6.2 (c) Current to voltage converter

Resistance is measured by passing a known current, from a constant current source, through an unknown resistance. The voltage drop across the resistor is applied to the A/D converter, thereby producing an indication of the value of the unknown resistance.

2.10 LIGHT EMITTING DIODES (LED)

The LED, Fig. 2.10 (a) is basically a semiconductor PN junction diode capable of emitting electromagnetic radiation under forward conductions. The radiation emitted by LEDs can be either in the visible spectrum or in the infrared region, depending on the type of the semiconductor material used. Generally, infra-red emitting LED's are coated with Phosphor so that, by the excitation of phosphor visible light can be produced. LEDs are useful for electronics display and instrumentation. Figure 2.10 (b) shows the symbol of an LED.

The advantage of using LEDs in electronic displays are as follows.

1. LEDs are very small devices, and can be considered as point sources of light. They can therefore be stacked in a high-density matrix to serve as a numeric and alphanumeric display. (They can have a character density of several thousand per square metre).
2. The light output from an LED is function of the current flowing through it. An LED can therefore, be smoothly controlled by varying the current. This is particularly useful for operating LED displays under different ambient lighting conditions.
3. LEDs are highly efficient emitters of EM radiation. LEDs with light output of different colours, i.e. red, amber, green and yellow are commonly available.
4. LEDs are very fast devices, having a turn ON-OFF time of less than 1 ns.
5. The low supply voltage and current requirements of LEDs make them compatible with DTL and TTL, ICs.

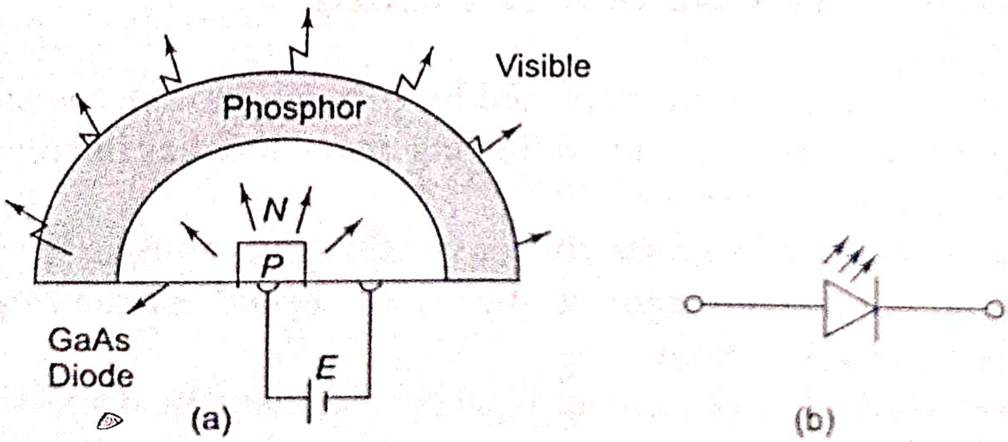


Fig. 2.10 (a) Structure of a Visible Emitter using GaAs PN Junction
(b) Symbol of LED

In germanium and silicon semiconductors, most of the energy is released in the form of heat. In Gallium Phosphide (GaP) and Gallium Arsenide Phosphide (GaAsP) most of the emitted photons have their wavelengths in the visible regions, and therefore these semiconductors are used for the construction of LEDs. The colour of light emitted depends upon the semiconductor material and doping level.

Different materials used for doping give out different colours.

1. Gallium Arsenide (GaAs) — red

2. Gallium Arsenide Phosphide (GaAsP) — red or yellow
3. Gallium Phosphide (GaP) — red or green

Alphanumeric displays using LEDs employ a number of square and oblong emitting areas, arranged either as dotmatrix or segmented bar matrix.

Alphanumeric LEDs are normally laid out on a single slice of semiconductor material, all the chips being enclosed in a package, similar to an IC, except that the packaging compound is transparent rather than opaque. Figure 2.10 (c) and (d) gives typical LED packages for single element LEDs.

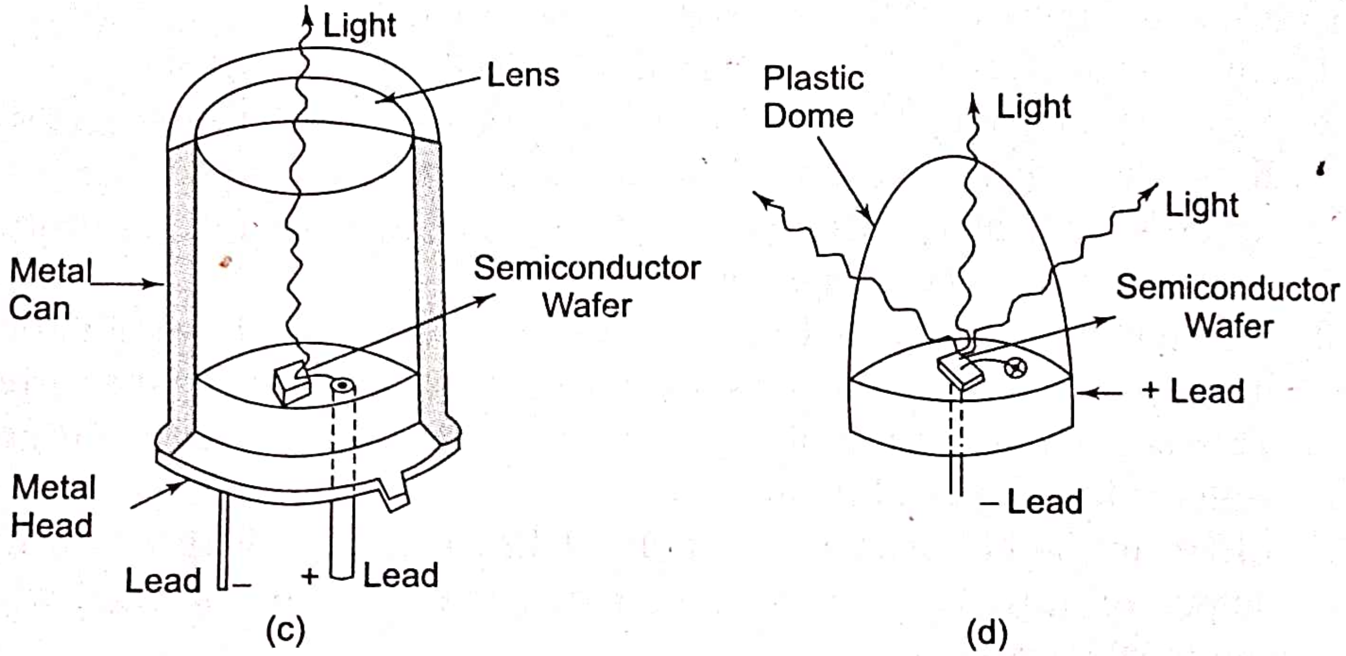


Fig. 2.10 (c) Metal Can To-5 Type (d) Epoxy Type

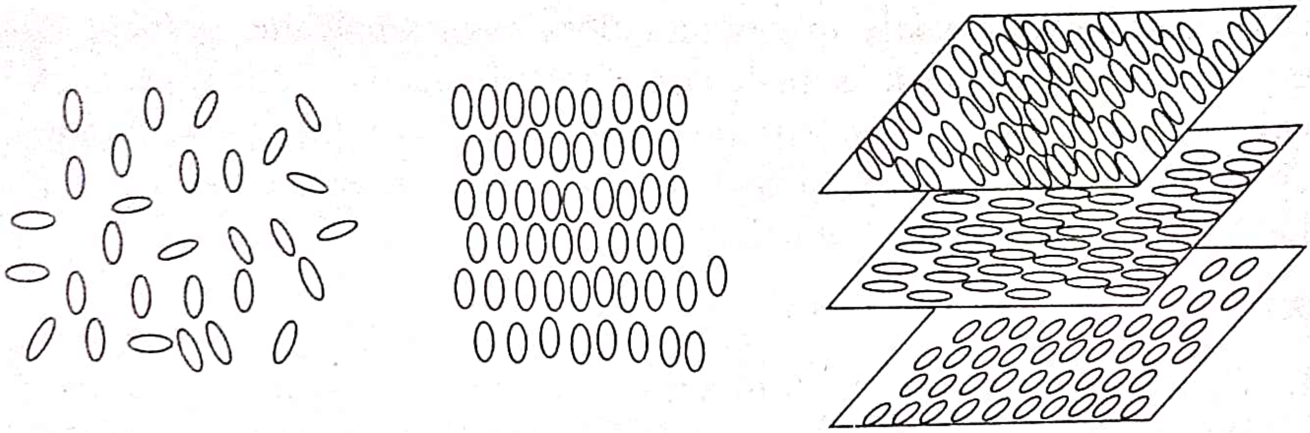
2.11 LIQUID CRYSTAL DISPLAY (LCD)

LCDs are passive displays characterised by very low power consumption and good contrast ratio. They have the following characteristics in common.

1. They are light scattering.
2. They can operate in a reflective or transmissive configuration.
3. They do not actively generate light and depend for their operation on ambient or back lighting.

A transmissive LCD has a better visual characteristic than a reflective LCD. The power required by an LCD to scatter or absorb light is extremely small, of the order of a few μW/cm. LCDs operate at low voltages, ranging from 1 – 15 V.

The operation of liquid crystals is based on the utilisation of a class of organic materials which remain a regular crystal-like structure even when they have melted. Two liquid crystal materials which are important in display technology are nematic and cholesteric, as shown in Fig. 2.11.



(a) (b) (c)

Fig. 2.11 Liquid Crystal Materials (a) Ordinary Liquids (b) Nematic Liquid Crystal (c) Cholesteric Liquid Crystal

The most popular liquid crystal structure is the nematic liquid crystal (NLC). The liquid is normally transparent, ~~but if it is subjected to a strong electric field,~~ ions move through it and disrupt the well ordered crystal structure, causing the liquid to polarise and hence turn opaque. The removal of the applied field allows the crystals structure to reform and the material regains its transparency.

Basically, the LCD comprises of a thin layer of NLC fluid, about 10 μ thick, sandwiched between two glass plates having electrodes, at least one of which is transparent.

(If both are transparent, the LCD is of the transmissive type, whereas a reflective LCD has only one electrode transparent.)

The structure of a typical reflective LCD is shown in Fig. 2.12.

The NLC material in Fig. 2.12 has a homogeneous alignment of molecules. While the glass substrate supports the LCD and provides the required transparency, the electrode facilitates electrical connections for the display. The insulating spacers are the hermetic seal.

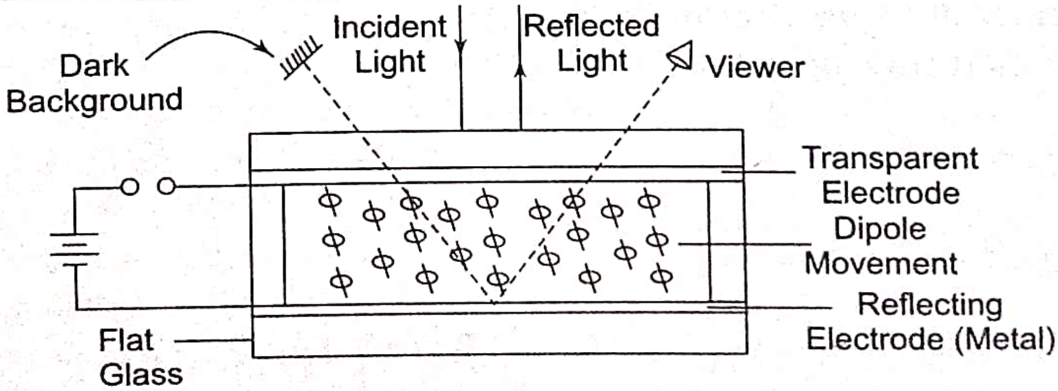


Fig. 2.12 Reflective Display Using NLC

The LCD material is held in the centre cell of a glass sandwich, the inner surface of which is coated with a very thin conducting layer of tin-oxide, which can be either transparent or reflective. The oxide coating on the front sheet of the indicator is etched to produce a single or multisegment pattern of characters and each segment of character is properly insulated from each other.

LCDs can be read easily in any situation, even when the ambient light is strong. If the read electrode is made transparent instead of reflective, back illumination is possible by a standard indicator lamp. Extending back illumination a step further by adding a lens arrangement. LCDs can be used as the slide in a projection system, to obtain an enlarged image.

Important Features of LCDs

1. The electric field required to activate LCDs is typically of the order of 10^4 V/cm. This is equivalent to an LCD terminal voltage of 10 V when the NLC layer is 10 μ thick.
2. NLC materials possess high resistivity > 10^{10} Ω. Therefore the current required for scattering light in an NLC is very marginal (typically 0.1 μA/cm^2).
3. Since the light source for a reflective LCD is the ambient light itself, the only power required is that needed to cause turbulence in the cell, which is very small, typically 1 μW/cm.
4. LCDs are very slow devices. They have a turn-on time of a few milliseconds, and a turn-off time of tens of milliseconds.

To sum up, LCDs are characterised by low power dissipation, low cost, large area and low operating speed.

LCDs are usually of the seven segment type for numeric use and have one common back electrode and seven transparent front electrodes characters, as shown in Fig. 2.13.

The back electrode may be reflective or transmissive, depending on the mode of operation of the display device.

Generally arrays of such characters are simultaneously fabricated using thin-film or hybrid IC technology for segments and conductors on glass plates, and then filled in with NLC material, followed by hermetic sealing.

LCD arrays utilising a dot-matrix are also possible, but they are not popular because of their slow operation.

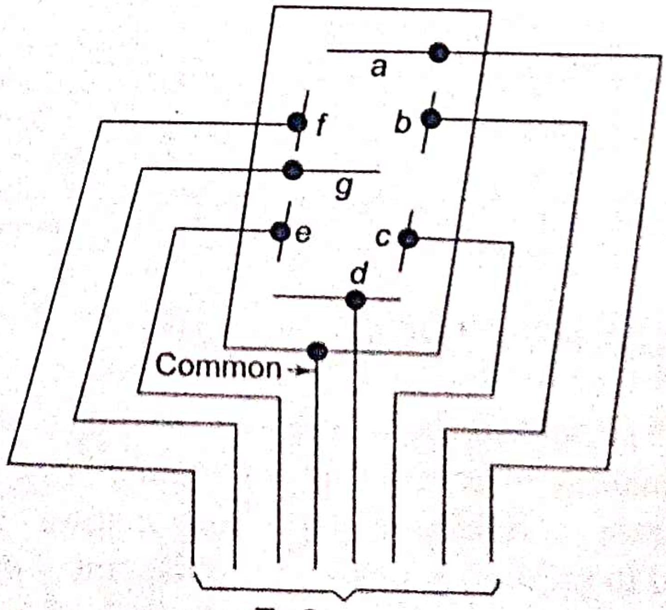


Fig. 2.13 Seven Segment LCD Character

2.12.3 Segmental Displays using LEDs

In segmental displays, it is usual to employ a single LED for each segment.

For conventional 7 segment LED displays (including the decimal point, i.e. the 8th segment), the wiring pattern is simplified by making one terminal common to all LEDs and other terminals corresponding to different segments. The terminals can be either of the common anode (CA) form or common cathode (CC) form, shown in Figs 2.18 (b) and (c).

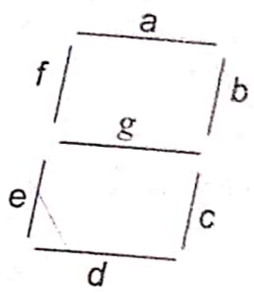


Fig. 2.18 (a) LED 7 Segment Format

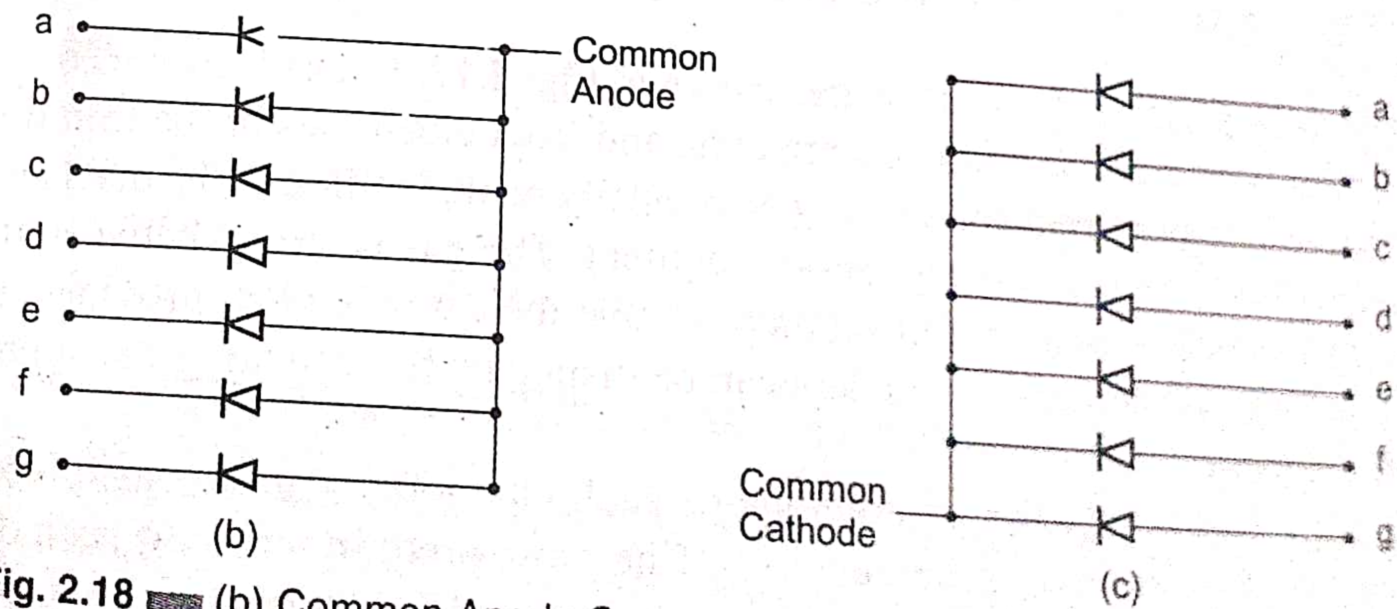


Fig. 2.18 (b) Common Anode Connections (c) Common Cathode Connections

A typical static single digit 7 segment LED display system and multi-digit are shown in Figs. 2.18 (a) and (d).

Multi-digit display system may be static or dynamic.

Common anode type displays require an active low (or current sinking) configuration for code converter circuitry, whereas an active high (or current sourcing) output circuit is necessary for common-cathode LED type display.

Both multi-digit and segmental displays require a code converter; one code converter per character for static display systems and a single code converter for time shared and multiplexed dynamic display systems, which are illuminated one at a time.

The typical circuit schemes described in the figures are only of the decimal numeric character. An 8 digit display system, operating on this principle and suitable for digital instrumentation is given in Fig. 2.18 (d).

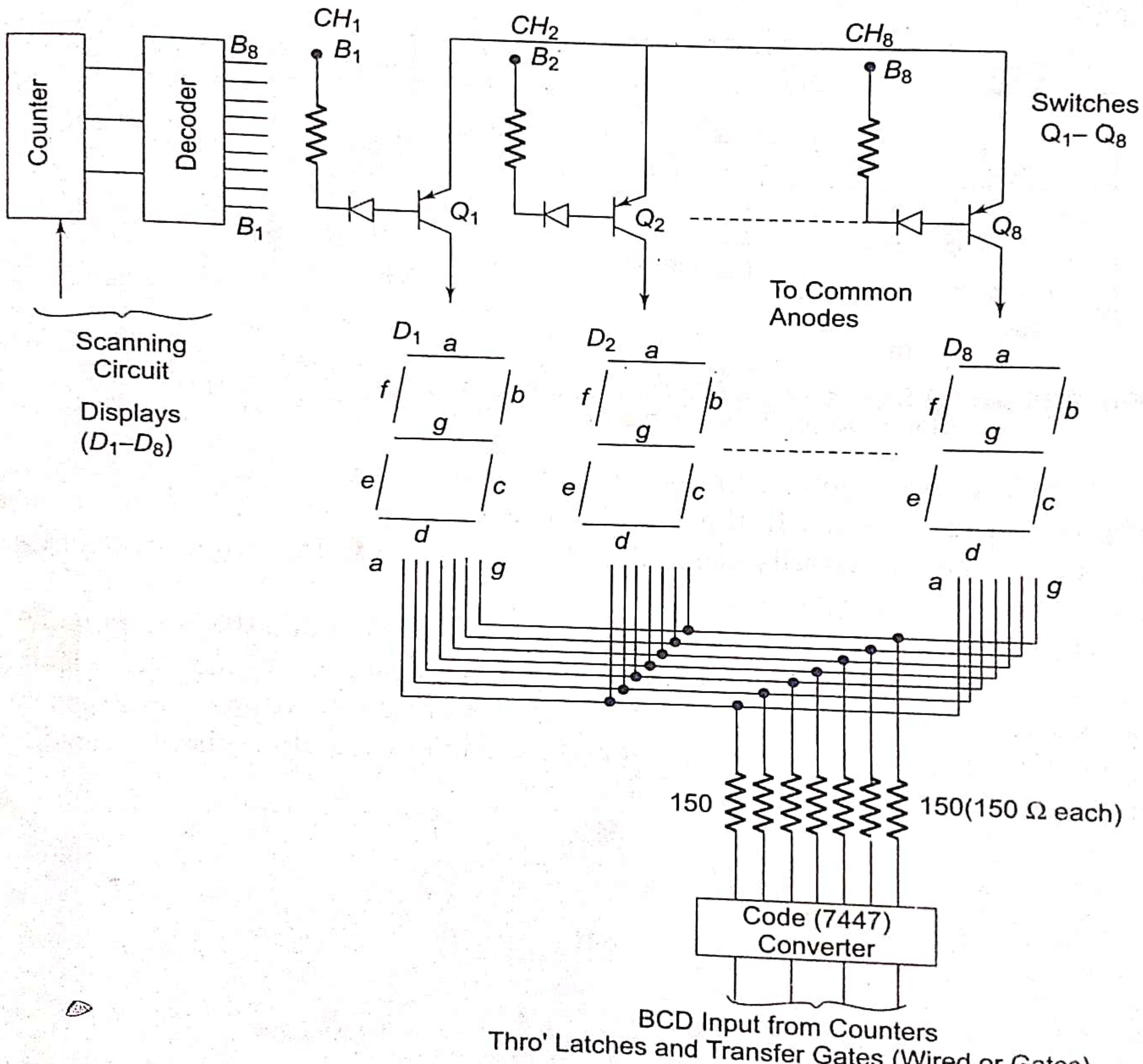


Fig. 2.18 (d) Multi-Digit Display System (8 Digit) Using LED 7 Segment Characters

It is also possible to generate hexadecimal numeric characters and conventional alphanumeric characters using 7 segment and 14 or 16 segment LED display units respectively, with a proper code converter. Both static and dynamic displays can be realised using LCDs, either in a common format (7 segment) or in single or multi character.

A chopped dc supply may be used, for simplicity, but conventionally an ac voltage is applied either to the common electrode or to the segment. Various segmental LCD driver circuits are displayed in Fig. 2.19.

Referring to Figs 2.19 (a) and (b), it is seen that an ac voltage (V_{ac}) is applied to either the common electrode or to the segment. High value resistances ($R > 1M$) are included in the circuit, as shown. The code converter controls the switches (S). V_{ac} is present across the selected segment and the common electrode when S is ON, and the voltage between any other segment (S-OFF) and the common electrode is zero. Hence the desired segments are energised, provided V_{ac} has a magnitude greater than or equal to the operating voltage of the LCD.

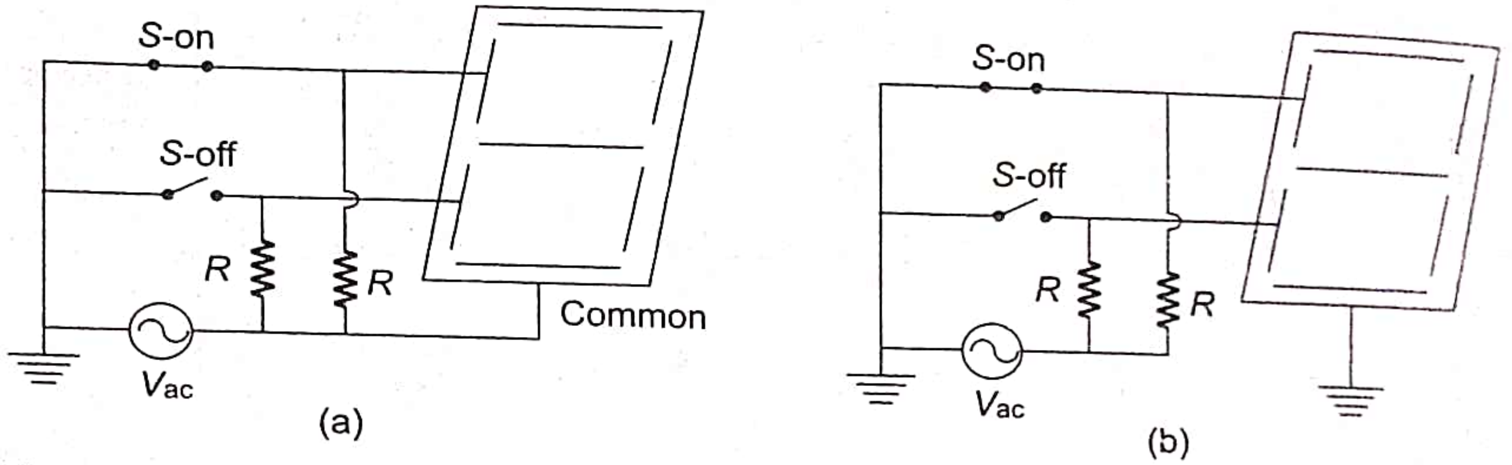


Fig. 2.19 (a) Segments Driving Circuits for LCD, Switching Method Common Electrode (b) Segments Driving Circuits for LCD, Switching Method

The basic operation of the phase shift method for driving the segment is shown in Fig. 2.19 (c). In this circuit, ac voltages of the same amplitude and frequency (not necessarily same phase) are supplied to the common electrode as well as the segments.

There will be a finite voltage drop between a segment and the common electrode only when the ac voltages applied are out of phase, and thus the selected segment is energised. On the other hand, when in-phase voltages are present, the voltage drop between a segment and the common electrode is zero, leading to the off state.

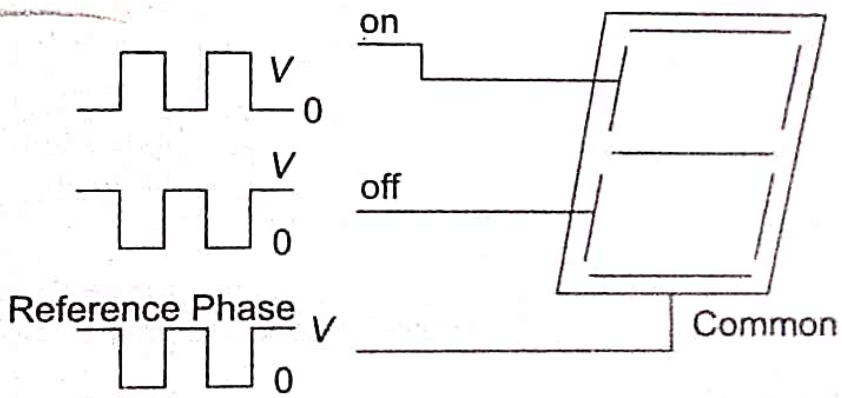


Fig. 2.19 (c) Segments Driving Circuits for LCD, Using Phase Shift Method