36B

MEASURING INSTRUMENTS IN ELECTRONICS

36.1 INTRODUCTION

You have already read about semiconductors, transistors, voltage-current sources, resistance, capacitance etc. Now you will study about their test and measurement. You must have seen a number of electrical gadgets like fridge, electric iron, bulb systems heat convector and electronic gadgets like TV, VCR, Two in one and Computer. You would know also about various specifications like input voltage required (AC or DC), frequency, current rating etc. which vary for gadget to gadget. You should also have observed that a TV / Radio / VCR mechanic brings with him a small measuring instrument with two leads to check (test) voltage, current, resistance, capacitor etc. at various electrical points of the gadget under repair. This instrument is known as multitester or multimeter. These are multirange and multifunction instruments and mainly available in two categories about which you will study in this lesson.

You will also study about another category called visual or display instrument namely CRO which shows on screen the shape of amplitude of electrical or electronic signal or pulses / waves as a function of time. This instrument finds application in medical electronics also as you should have noticed it attached with heart patient to monitor the heart beats etc. Like multimeter, this instrument (CRO) is also available in multirange. Other measuring instruments include watt hour meter, digital thermometers, frequency meters etc., but this lesson covers details of multimeter and CRO only.

36.2 OBJECTIVES

After studying this lesson, you should be able to :

- *identify various measuring instruments in electronics;*
- *describe the basic principle and functioning of a multimeter;*
- *appreciate the CRO over multimeter and use it as a display unit of waves (signals);*
- *explain principle of a transducer and list their uses in daily life;*
- *describe the phenomena behind the display devices; and*
- *distinguish between the LED and LCD devices and appreciate their utility in daily life..*

36.3 MULTIMETER AND ITS USES

As you know multimeter is the most versatile and useful test and measuring device for a common technician and electronics student. Here we are concentrating on its principle and applications. You will recognise a multimeter as shown in fig. 36.1

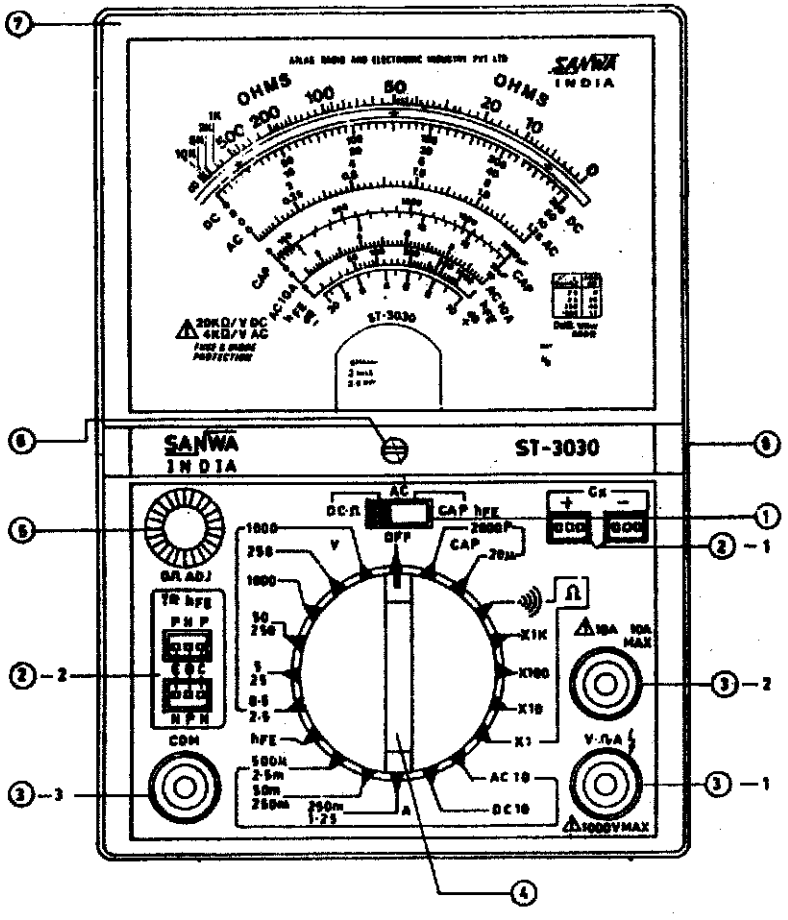

Fig. 36.1 : *Multimeter*

36.3.1 Working principle of a Volt-Ohm Milliameter (VOM)

The instrument is based on permanent magnet moving coil mechanism (PMMC) or d' Arsonval movement. The arrangement has been shown in fig.36.2.

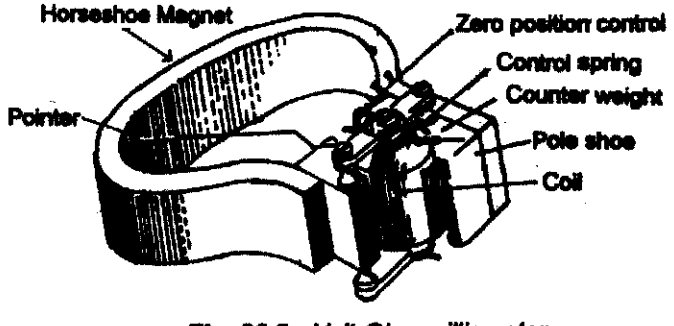

Fig. 36.2 : *Volt-Ohm milliameter*

There is a permanent horse shoe magnet M, a freely suspended coil to rotate freely in the magnetic field B, control springs and a pointer against a fixed reference called scale. When a current flows in the coil, an electromagnetic torque develops and it rotates the coil which causes the pointer to move on a fixed calibrated scale. The torque τ is given as

$$\tau = B \times A \times I \times N$$

where, B = magnetic flux density in air gap
A = effective area of the coil
I = current through the coil
N = number of turns of wire on the coil

Hence, the movement of the pointer is directly proportional to the current through the coil as B, A, N, are constants.

In the multimeters range switch is provided and thus various ranges are available on multimeter (VOM). For example the typical voltage range, current range of the multimeter and resistance range are given below,

- *Voltage range :* normally following two voltage ranges are found,

  0 - 1.5 volt

  0 - 1000 volt

For very high voltage an external jack marked 'DC 5000 V' for measurement upto 5000 volt is provided.

- *Current range:* commonly used current range of a multimeter is 0 - 500 mA

For higher current an external jack is provided to measure between + 10 A to - 10A.

- Similarly for *resistance measurement* the variable ranges are available in multiples of hundreds and thousands as shown in figure. 36.1

There is a switch in VOM which selects required mode for ac / dc measurement. The instrument is calibrated for different ranges and parameters (V, I, R).

36.3.2 Application of Multimeter

Besides measuring voltage, current, and resistance, the circuit of the multimeter can be upgraded to measure temperature, power, watthour and continuity of the circuit. For temperature measurement a multimeter is used in combination with a thermocouple.

Now a days digital multimeters (DMM) or solid state VOM have become very popular because of digital display, compact in size, better accuracy and additional feature of other test facilities like Transistor tester, capacitor measurement etc. The concept of the digital electronics, you will find in lesson 38 of this book.

The analog VOM is cheaper than DMM. Both VOM and DMM should have a good sensitivity dc scale good enough to read 0.2 volt or less. For example range of 0.2 volt - 0.6 volt or 200 mV to 600 mV is required for transistor biasing.

Similarly low current scale should also be there as you know that current in mA and μA are required for transistor and diode characteristics. Electronic multimeter is also available now a days. It has a balanced bridge dc amplifier and indicating meter. Field effect transistor is used in balanced bridge d.c amplifier. Rest of the parts like range switch, function switches are same. Rectification of diode power is used to convert a/c in d.c. for a.c. measurements.

36.3.3 Limitations of Multimeter

In analog multimeter loading effect may cause error in measurement. For example if voltage has to be measured then input impedance in voltmeter mode should be at least an order of magnitude higher than impedance of circuit under measurement. It means a meter with 10 MW resistance is suitable to measure voltage across a 100 k Ω resistor but not across a 10 M Ω resistor (because of serious loading effect). Further loading effects are noticeable at higher frequencies thus limiting the use of multimeter for low frequencies only.

Error may also be caused due to parallax in absence of mirror backed scale. Parallax (in seeing exact position of pointer) can be removed with the use of mirror. Sensitivity decreases with increase in bandwidth e.g. if an instrument with band width 10 Hz - 10M Hz has sensitivity of 1 mV become more sensitive (100 mV) if band width decreases to 5 MHz only.

DMM is convenient as it gives numerals instead of pointer deflection. Further its impedance is high. Its accuracy and resolution is also very high (Accuracy >> +.005 % of reading & resolution >> 1 point in 10^6) beside good stability.

INTEXT QUESTIONS 36.1

1. *A circuit has an impedance of 10 kW for measurement of voltage across it what consideration should be kept in mind for choosing a multimeter ?*

   ....

2. *After switching on the TV, one finds that it is a not receiving power from mains. How will you pin point a fault using a multimeter?*

   ....

3. *How will you measure the voltage of a live wire on the streat (from transmission pole) using a multimeter ?*

   ....

36.4 CATHODE RAY OSCILLOSCOPE (CRO)

Like multimeter Cathode Ray Oscilloscope CRO can also be used for measurement of voltage and current. Besides this gives you a visual of the signal under test which helps in real time analysis. The cathode ray oscilloscope is probably the most versatile tool for the development of the electronic circuits and systems. It has led to the development of modern electronics. The CRO allows the amplitude of the electrical signal in the form of voltage, current, power etc to be displayed on the screen as a function of time. In an oscilloscope, electron beam produced by a cathode impinges on a phosphor surface screen to produce a visible spot.

36.4.1 Working Principle of CRO

Before going on to the working of a CRO it is necessary to understand the construction of CRO (Fig.36.3). Basically a CRO consists of a cathode ray tube high voltage power supply, low voltage power supply, vertical amplifier, horizontal amplifier trigger circuit, time based generator etc. The cathode ray tube consists of an electron gun which produces electron beam, vertical plates for accelerating the beam to high velocity, horizontal plates for deflecting the beam and a phosphor screen where the deflection of electron beam

becomes visible. The high voltage power supply provides the voltage required for accelerating the electron beam while the low voltage power supply provides operating voltage for other circuits of the oscilloscope.

Similar to the conventional X and Y axe, the electron beam can be deflected in either of the two axes. Typically, X axis of the oscilloscope is deflected at a constant rate relative to time while the Y axis is deflected in response to input signal. The signal that is to be seen is fed into the vertical amplifier which in turn increases the potential of this signal to produce deflection. To synchronize the horizontal deflection system with the vertical input a synchronizing circuit called the *trigger circuit* is employed. It is a link between the vertical input and horizontal time base.

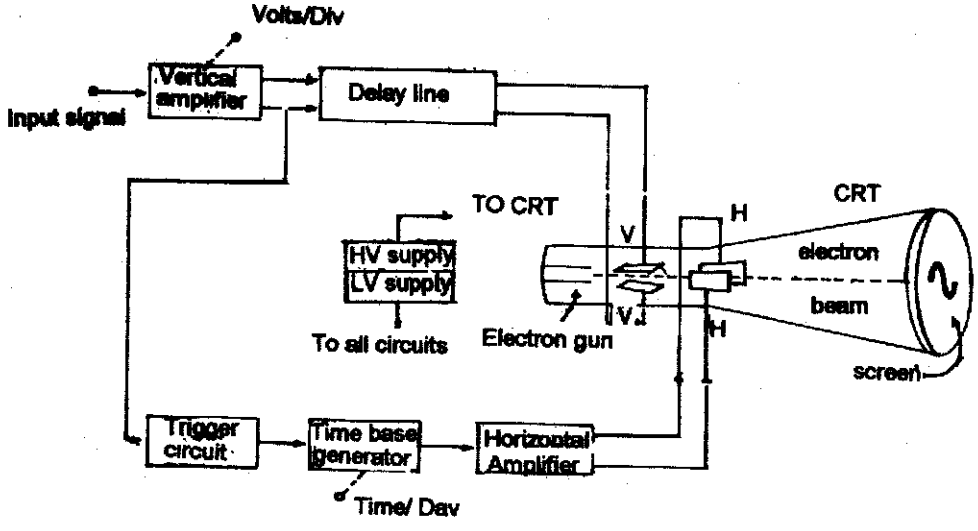

Fig. 36.3 : *Block diagram of CRO*

Here it is important to lay some emphasis on the screen for CRT' s. The screen material on the inner surface of the CRT is phosphor or zinc oxide. These materials have property of fluorescence which means that they emit light when stimulated by radiation. They have another property called phosphorescence i.e. they continue to emit light even the source of excitation is cut off. The intensity of light emitted from CRT is called Luminescence. It depends on number of bombarding electrons striking per seconds, energy of bombarding electrons, time for which beam strikes the given area and characteristics of phosphor.

36.4.2 Applications of CRO

Besides all function done by a Multimeter, a CRO gives a visual display of the signal which helps in real time signal analysis like frequency measurement, distortion measurement, phase & amplitude measurement comparison of two waves modulation depth etc.

Compare to a voltmeter CRO is an excellent device for measuring alternating voltages because it can be used for a wide range of frequency where voltmeters are used accurately over a narrow frequency range. One of the important feature of oscilloscope is that it can store a signal and sample a high frequency signal.

36.4.3 Limitations of CRO

Compare to the conventional measuring devices like multimeter, the CRO is bulky in weight and size as well as high input voltage is required to operate cathode ray tube. Moreover for high frequency measurement the cost of CRO increases substantially due to stringent requirement of amplifier and other related electronic circuitry. Due to transit time

limitation of electrons, it is not possible to display higher frequency range (such as microwave and optical waves).It is necessary to have some *precautions* while handling the front panels

(i) The phosphor should not be excited by excessive beam density. This factor is controlled with INTENSITY, FOCUS and ASTIGMATISM controls on front panel.

(ii) Long duration of excitation should be avoided.This is done using TIME / DIV control. In comparison to other time recording devices, such as pen and strips chart recorder, oscilloscope is far better device in the following sense-

(a) It results into faster operation.

(b) It displays the events that takes place over period of microseconds and nanoseconds.

INTEXT QUESTIONS 36.2

1. *How the flow of electrons can be controlled while traveling from cathode to screen?*

....

2. *How will you measure d.c voltage using an oscilloscope?*

....

3. *If 1volt peak to peak causes a 1 cm vertical deflection on an oscilloscope when the vertical step attenuator on X 1, then what will be the input voltage peak to peak if the trace is 0.4 cm long with the attenuator set on X 100 ?*

....

36.5 TRANSDUCERS

You should have seen many gauges and measuring systems for a number of physical quantities like pressure, volume, temperature, speed, light intensity etc. In general ***transducer is a device which converts the physical quantities in term of some measurable value.*** These may be mechanical, electrical, electronic ones. If the device is such that it converts non electrical signal (quantity) into electrical one or electronic one, it is called *transducer.* This is discussed in the following section.

36.5.1 Basic Principle of Transducers

As mentioned earlier transducer will convert the non-electrical signal into electrical one. For example a thermocouple generates thermo e.m.f. and is used in measurement of temperature. A condenser mike converts sound energy into electrical one. In a transducer, the output is calibrated and used to measure unknown values. Some of the transducers are discussed below.

36.5.2 Classification of Transducers

We can classify the transducers in various ways as given below,

(i) Based on ***physical quantity*** to be measured e.g. pressure transducer, velocity transducer, temperature transducer etc.

(ii) Based on ***electrical parameter or electronic parameter*** e.g. resistive, capacitive, inductive, piezoelectric, photovoltaic, hall effect pick up etc.

(iii) ***Active transducers:*** These are self generating transducers, for example thermocouple, photovoltaic cell. Such transducers do not require any external power.

(iv) ***Passive transducers*** for example resistance, capacitor, inductive, photoconductive. Such transducers require external power.

For a good transducer certain requirements are desirable such as it.

(i) should be compact;

(ii) the change (conversion) should be large for better accuracy;

(iii) should be reliable and free from damage due to temperature, pressure, jerk etc.

36.5.3 Working Principle & Examples of a few Transducers

Working principle and examples of a few transducers are given in the following table.

Name of Transducer	Principle of Operation	Typical Application
(a) Passive Transducers		
Pirani Gauge *(Resistive)*	Here resistance of heating element changes by change in pressure.	gas pressure, vacuum (atmosphere to10^{-3} Torr)
Thermistor *(Resistive)*	Resistance of some metal oxides (with -ve temp. coefficient of resistence -NTR) vary with temperature.	Temperature
Micro-phone *(Capacitor)*	Variation of capacitance between a fixed plate & a movable diap-haragm	Speeds, music, noise
Differential Transformer *(Inductor)*	Differential voltage of two secon-dary windings of a transformer is varied due to change in position of magnetic core through externally applied force (pressure, force etc.)	Force, Pressure, Displacement, position
(b) Self generating (no external power required)		
Thermocouple & Thermopile	e.m.f. is generated across the junction of two dissimilar metals or semiconductors when junction is heated.	temperature, heat flow, radiation
Photovoltaic cell	Voltage is generated in a semiconductor junction device (p-n) when radiation falls on the cell	Light meter (intensity) mode

It is difficult to consider all the types of transducers but a broad spectrum given above is sufficient to describe a transducer.

36.5.3 Application of Transducer

The applications of the transducers are numerous and can't be counted. Even sensors fall in the category because transducer is nothing but a good sensor. Some illustrative applications of the transducers are given below:

- in industry for test and measurement of dimensions and other physical quantities
- in medical field-like CRO in heart treatment, blood flow measurement, breathing rate; etc.
- in transport / vehicles as speed meter, fuel level measurement, temperature etc.;
- in household uses-like temperature measurement;
- in electronics for measurement of various voltages and currents. These are also used in electronic control and measurement systems.

INTEXT QUESTIONS 36. 3

1. *What type of transducer can be used to measure (briefly mention principle) the following:*

   (a) light intensity *(b) pressure* *(c) speed*

   .....

2. *Under which category following transducers fall (active or passive) and why?*

   (a) Thermocouple *(b) Capacitor microphone*

   .....

3. *What is the difference between a transducer and a meter ? Give example ?*

   .....

36.6 DISPLAY DEVICES

In section 36.3 digital multimeters have been mentioned in which the values of voltage, current or resistance are displayed in the numeric form. This is done with the help of display device. Further in music system you might have seen dancing lights or in many electronic and electrical gadgets pilot lights are used. This is another form of display units. The display devices basically can be classified as LED (Light Emitting Diode) fig. 36.4 and LCD (Liquid Crystal Display) Fig.36.5. These are solid state devices which consume very small power. The older version of displays included discharge tube models which used high operating voltage..

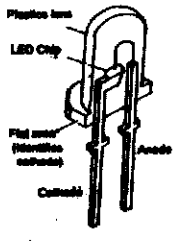

Fig. 36.4 : *Light Emitting Diode*

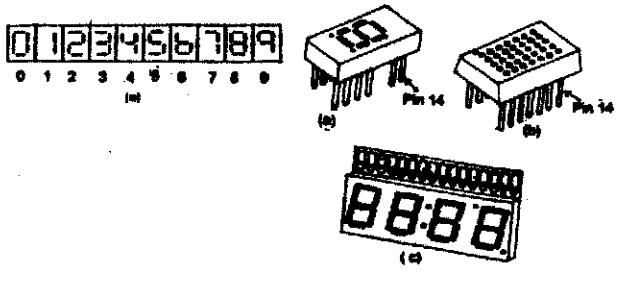

Fig. 36.5 : *Liquid Crystal Display*

36.6.1 LED - Working Principle

A voltage of about 1.6 V produce a forward current of about 20 mA. LED's are available in several colours - red, green, yellow and white. The colour depends upon the material used in LED chip : for example Gallium Arsenide Phosphonide (Ga As P) is used in producing red LEDs.

(a) Scope and Application of LEDs

LEDs hav a vast variety of applications. You might have seen big digital clocks at Railway stations, computer controlled displays at Airport carrying some message or information. LEDs are used for this purpose for alphanumeric displays which may be in the form of alphabets and /or numerical numbers. There are graphic display, which can give pictorial display also, but these are more complex.

The following figure 36.6 (a) represent construction of a common anode 7 - segment display and figure 36.6 (b) represent the actual display. The resistors each of 150 W has been used to limit the current to the safe level of 20 mA. On closing switches a,b & c in fig (b) the display is 7 (i.e. segments a, b,and c lit on. Both common anode & common

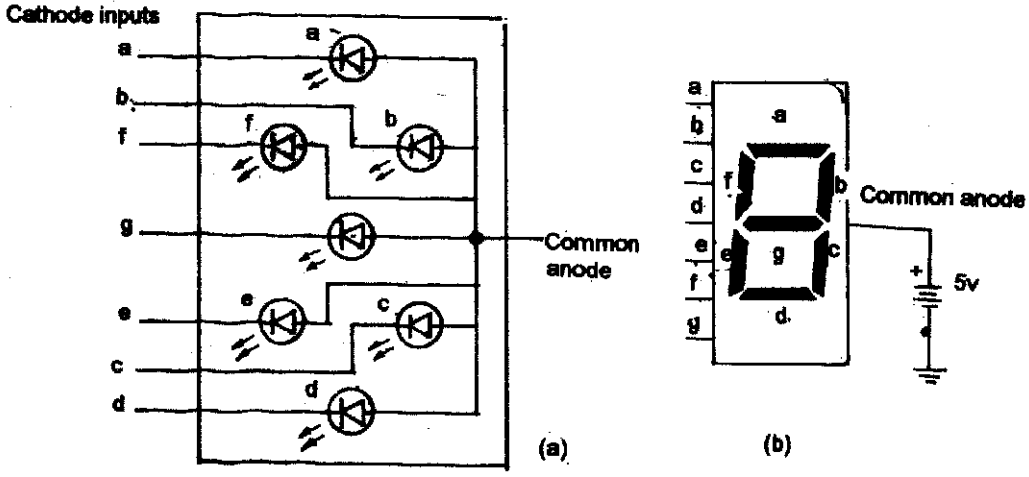

Fig. 36.6 : (a) *construction of a common anode 7-segment display,* **(b)** *Actual display*

cathode of segments LEDs are available and one can get both dot matrix. 7 - segment types of display. LEDs are also available in variety of packages e.g.. single digit & multidigits units.

36.6.2 LCD

The basic difference between LED and LCD is that former gives off light, but the later controls the light. LCD reflects part of surrounding light, while other parts of the display absorbs light and this is how contrast is created to read or see the display. Generally LCD show silvery background reflecting light while activated symbols and numbers are absorbing light (fig.36.7). Since LCD radiate no light, they are to be used in lighted areas only.

(a) Construction and Working

Fig.36.7 shows the magnified details of a LCD. The display consists of two glass plates with a special liquid crystal or nematic fluid filling the space between them.

The under surface of top plate has nearly invisible metallised shapes where the segments and symbols appear. The glass back plate is also metallised. Thus a polariser forms the

top and bottom of the sandwich. Contacts are made to the back plate and to each segment of the display. The segment on LCD are driven by low frequency a.c signals (30 Hz square wave input).

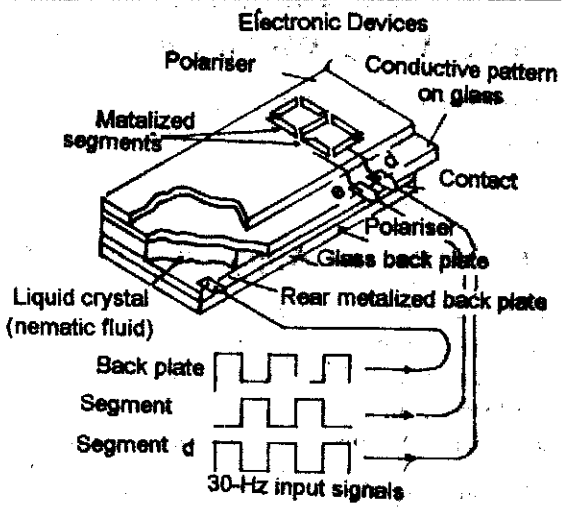

Fig. 36.7

(b) How does the system work

In the present example segment 'e' receives a 30 Hz signal that is 180^0 out of phase with back plate signal. Due to this segment 'e' is activated and appear dark on silvery back ground. Segment 'd' which receives 30 Hz signal in phase with that of back plate does not get activated & remain invisible. Direct current are not used to try LCD test, it will damage them.

(c) Scope and Application of LCD

LCD consume very small power (extremely low) and find application widely in calculators, digital watches, multimeters. They can be read in sunlight and area of high light intensity. These are used on petrol pumps service stations. The only difficulty is that they can't be read in dark. For this purpose a steady back up light can be used.

INTEXT QUESTIONS 36. 3

1. *Do LED and LCD both emit light ? Explain ?*

   .....

2. *Which of the two consume less power LED or LCD ? Why ?*

   .....

3. *Write one drawback each for LED and LCD ?*

   .....

36.7 WHAT HAVE YOU LEARNT

- Multimeters (VOM and DMM) and Cathode Ray Oscilloscopes (C.R.O.) are used to measure various electrical parameters.
- CRO has an additional advantage of having visual display of signal (electrical).
- Working of a multimeter (VOM) is based on the principle that the electromagnetic torque rotates the coil (as such pointer) and deflection is proportional to current.
- CRO's superiority over multimeter.
- Transducers are devices to convert non- electrical signal into measurable electrical signal.
- Transducers are classified as active and passive.
- Active transducers are self generating where as passive transducers require external power.

- LED gives off light but LCD control light.
- LCD consume very small power.

36.8 TERMINAL QUESTIONS

1. Name four instruments/gadgets of electronics (not measuring type) an mention application of each one.
2. State and explain the principle and working of a multimeter.
3. List down a few uses of multimeter.
4. Describle the limitations of a multimeter and how CRO is superior to it?
5. Distingish between the multimeter and a CRO.
6. State and explain the principle and working of a CRO.
7. What precautions should be taken while handling the front panels of a CRT.
8. What do you mean by a transducer give its basic principle.
9. Distingish between active and passive transducers.
10. Is transformer a tronsducer? Why?
11. What are display devices? Give one example of each.
12. How does a LCD work? Mention its application.
13. A 0 -150 V voltmeter has a guaranteed accuracy of 1 % full scale reading. The voltage measured by this instrument is 83 V. Calculate the limiting error in percentage ?
14. A signal of 10 Volt 1 KHz is applied to the input terminated 'y' plate of CRO and height of wave on vertical scale is 4 cm. Its frequency remain same and signal is reduced to 5 V. What will be the height of the wave on screen ?
15. Which of the following transducers do not require external power source - a). Thermistor, b). Thermocouple, c). Photovoltaic Cell, d). Pirani Gage.
16. Write true or false
    (a) LCD gives off light.
    (b) LED appears black on silvery background.
    (c) LED consumes more power than LCD.
    (d) LCD can be read in dark background.
17. For alphanumeric display do you need a seven segment display or eight segment display ? In adjoing figure for LED. What should be displayed ? See fig. 36.8.
    (1) When a, b and c are closed.
    (2) When a, b, d, g are closed.
    (3) When f, g, b, c are closed.

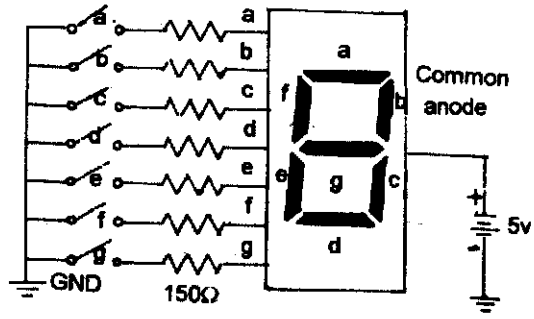

Fig. 36.8

ANSWERS TO THE INTEXT QUESTIONS

Intext Questions 36.1

1. Impedance in voltmeter mode should be at least an order of magnitude higher than the impedance of the circuit. Therefore the impedance of multimeter in the present case should be greater than 10 kW It can be 10 kW or higher.
2. If TV is not receiving power from mains than there is certainly problem either (i) with the chord connecting mains to TV power supply or (ii) with the power supply circuit of TV which may not be functioning). For part (i) one can check continuity of the chord wire. Any break will be detected. (ii) Power supply to be checked- like transformer is functioning or not or if there is discontinuity any where in the circuit, may be checked by Multimeter.
3. Voltage of live wire can be measured by commenting two terminals of Multimeter such that one is connected to live wire & the other to the ground/earth terminal after setting the Multimeter on proper range.

Intext Question 36. 2

1. Flow of electrons travelling form cathode to screen can be controlled as follows
   (a) velocity can be controlled at electron gun.
   (b) direction/deflection can be controlled by varying potential at X and Y deflecting plates.
2. It is very easy to measure d.c. voltage using oscilloscope. First of all the oscilloscope is switched on and set at proper range. The two leads + and - for d.c. voltage measured by connecting to ground and vertical amplifier section. This will be displayed on screen of C.R.O.
3. 40 volt.

Intext Questions 36.3

(a) **for light intensity:** the one which converts light energy into measurable electric current. The transducer used may be photovoltaic cell photoconducting cell.

(a) **for pressure :** The resistance change with pressure the transducer is used in pirani gage.

(b) **For speed:** Variation of capacitance between fixed plate and a moving diaphragm the transducer used may be a capacitor microphone type, LVDT type or differential voltage measurement type

Intext Questions 36.4

1. No, only LED (Light Emitting Diode emits light), LCD controls the light to create desired contrast to read the display
2. LCD consumes less power as it does not need emission of light for display
3. LED consumes more power
4. LCD can be used only in lighted areas.