Class : III B.Sc., Physics

Course : Electronic Instrumentation

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Unit – I: Analog Instruments

DC Voltmeter – Multirange Voltmeter – Transistor Voltmeter (TVM) – Solid State Voltmeter – Differential Voltmeter – AC Voltmeter using rectifiers – AC Voltmeter using half wave rectifier **#**AC Voltmeter using full wave rectifier**#** – Ohmmeter (Series Type) – Multimeter Operating Instructions.

Unit – II: Digital Instruments

Digital Multimeter – Digital Frequency Meter – Digital Measurement of Time: Time Base Selector – Period Measurement – **#**Digital Tachometer**#** – Digital pH meter – Digital Phase Meter – Digital Capacitance Meter.

Unit –III-a: Digital Display System and Intellectual Property Rights (IPR)

Classification of Displays – Light Emitting Diode – Liquid Crystal Display – Gas Discharge Plasma Display – Segmented Gas Discharge Display – Segmental Displays using LEDs – **#**Electro Luminescent Display**#**.

Text book:

H.S.Kalsi, Electronic Instrumentation , Learning Materials centre, New Delhi, 2nd edition, 2002.

UNIT – I: Analog Instruments

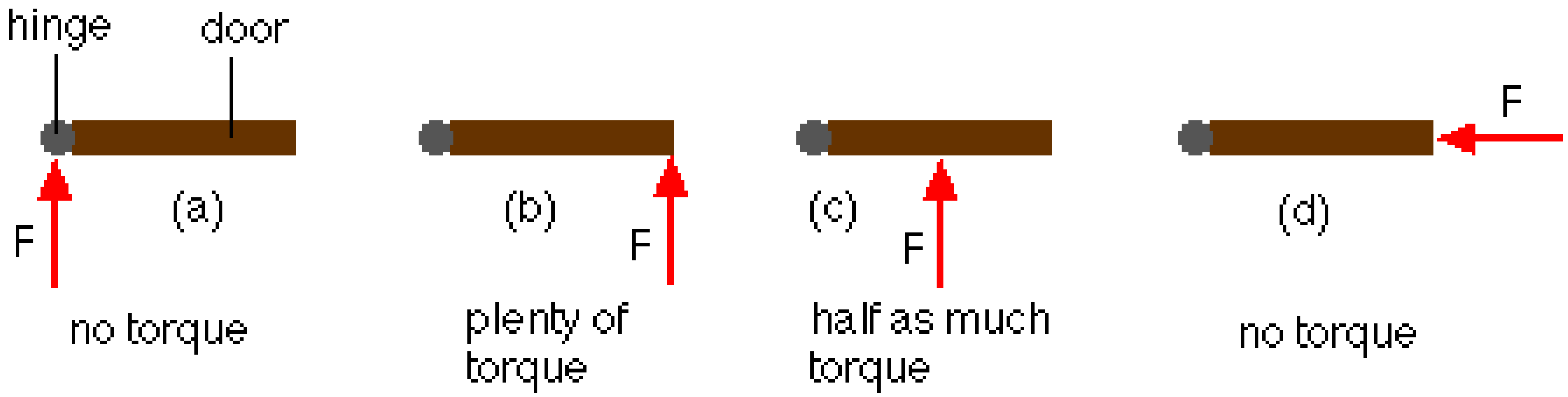
DC Instruments

Permanent Magnet Moving Coil or PMMC Instrument

Definition:

The instruments which use the permanent magnet for creating the stationary magnetic field between which the coil moves is known as the permanent magnet moving coil or PMMC instrument. It operates on the principle that the torque is exerted on the moving coil placed in the field of the permanent magnet. The PMMC instrument gives the accurate result for DC measurement.

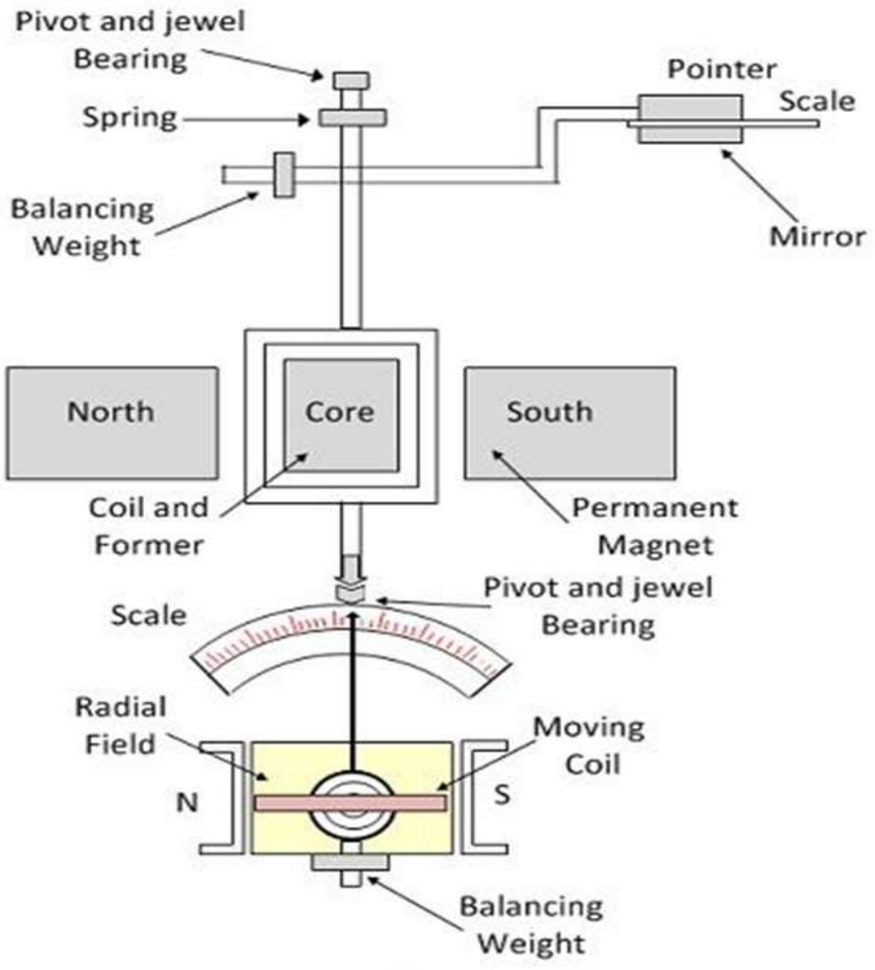
A torque is a force exerted at a distance from the axis of rotation; the easiest way to think of torque is to consider a door. When you open a door, where do you push? If you exert a force at the hinge, the door will not move; the easiest way to open a door is to exert a force on the side of the door opposite the hinge, and to push or pull with a force perpendicular to the door. This maximizes the torque you exert.



Construction of PMMC Instrument :

The moving coil and permanent magnet are the main part of the PMMC instrument. The parts of the PMMC instruments are explained below in details.

Moving Coil : The coil is the current carrying part of the instruments which is freely moved between the stationary field of the permanent magnet. The current passes through the coil deflects it due to which the magnitude of the current or voltage is determined.



Permanent Magnet Moving Coil Instrument

Magnet System: The PMMC instrument using the permanent magnet for creating the stationary magnets. The Alcomax and Alnico material are used for creating the permanent magnet

Control: In PMMC instrument the controlling torque is because of the springs. The springs are made up of phosphorous bronze and placed between the two jewel bearings. The spring also provides the path to the lead current to flow in and out of the moving coil. The controlling torque is mainly because of the suspension of the ribbon.

Damping: The damping torque is used for keeping the movement of the coil in rest.

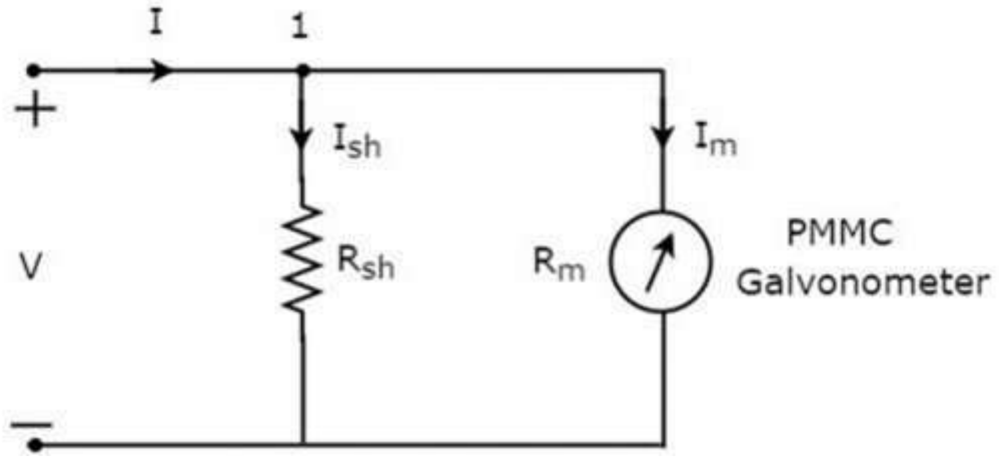
Pointer & Scale: The pointer is linked with the moving coil. The pointer notices the deflection of the coil, and the magnitude of their deviation is shown on the scale.

DC Ammeters

DC Ammeters

Current is the rate of flow of electric charge. If this electric charge flows only in one direction, then the resultant current is called Direct Current (DC). The instrument, which is used to measure the Direct Current called DC ammeter.

Circuit diagram :



If we place a resistor in parallel with the Permanent Magnet Moving Coil (PMMC) galvanometer, then the entire combination acts as DC ammeter. The parallel resistance, which is used in DC ammeter is also called shunt resistance or simply, shunt. The value of this resistance should be considered small in order to measure the DC current of large value.

We have to place this **DC ammeter** in series with the branch of an electric circuit, where the DC current is to be measured. The voltage across the elements, which are connected in parallel is same. So, the voltage across shunt resistor, $I_{sh}R_{sh}$ and the voltage across galvanometer resistance, I_mR_m is same, since those two elements are connected in parallel in above circuit.

Mathematically,

$$I_{sh}R_{sh} = I_mR_m$$

$$\Rightarrow R_{sh} = \frac{I_mR_m}{I_{sh}} \qquad \text{(Equation 1)}$$

The **KCL equation** at node 1 is

$$-I + I_{sh} + I_m = 0$$

$$\Rightarrow I_{sh} = I - I_m$$

Substitute the value of I_{sh} in Equation 1.

$$R_{sh} = \frac{I_mR_m}{I - I_m} \qquad \text{(Equation 2)}$$

Take, I_m as common in the denominator term, which is present in the right hand side of Equation 2

$$R_{sh} = \frac{I_mR_m}{I_m(\frac{1}{I_m} - 1)}$$

$$\Rightarrow R_{sh} = \frac{R_m}{\frac{I}{I_m} - 1} \qquad \text{(Equation 3)}$$

Where,

R_{sh} is the shunt resistance

R_m is the internal resistance of galvanometer

I is the total Direct Current that is to be measured

I_m is the full scale deflection current

The ratio of total Direct Current that is to be measured, I and the full scale deflection current of the galvanometer, I_m is known as **multiplying factor, m**. Mathematically, it can be represented as

$$m = \frac{I}{I_m} \qquad \text{(Equation 4)}$$

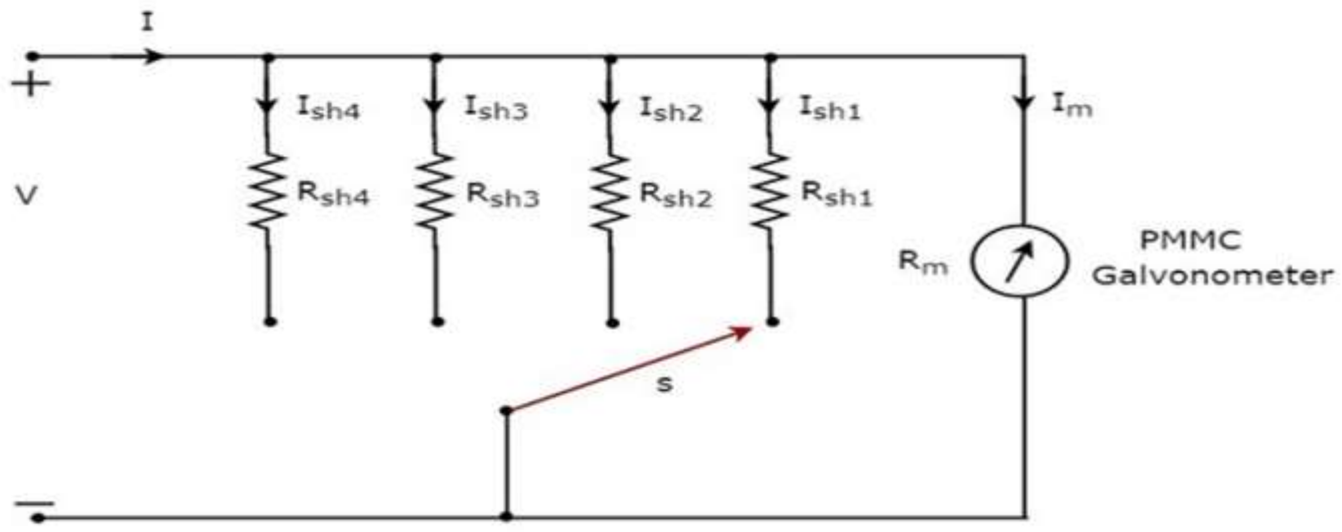
$$R_{sh} = \frac{R_m}{m - 1} \qquad \text{(Equation 5)}$$

We can find the value of shunt resistance by using either Equation 2 or Equation 5 based on the available data.

Multi Range DC Ammeter

Multi Range DC Ammeter

The DC ammeter for measuring the Direct Currents of **multiple ranges**, then we have to use multiple parallel resistors instead of single resistor and this entire combination of resistors is in parallel to the PMMC galvanometer. The circuit diagram of multi range DC ammeter is shown in below figure.



Place this multi range DC ammeter in series with the branch of an electric circuit, where the Direct Current of required range is to be measured. The desired range of currents is chosen by connecting the switch, S to the respective shunt resistor.

Let, m_1, m_2, m_3 and m_4 are the **multiplying factors** of DC ammeter when we consider the total Direct Currents to be measured as, I_1, I_2, I_3 and I_4 respectively. Following are the formulae corresponding to each multiplying factor.

$$m_1 = \frac{I_1}{I_m}$$

$$m_2 = \frac{I_2}{I_m}$$

$$m_3 = \frac{I_3}{I_m}$$

$$m_4 = \frac{I_4}{I_m}$$

In above circuit, there are four **shunt resistors**, $R_{sh1}, R_{sh2}, R_{sh2}$ and R_{sh4} .

Following are the formulae corresponding to these four resistors.

$$R_{sh1} = \frac{R_m}{m_1 - 1}$$

$$R_{sh2} = \frac{R_m}{m_2 - 1}$$

$$R_{sh3} = \frac{R_m}{m_3 - 1}$$

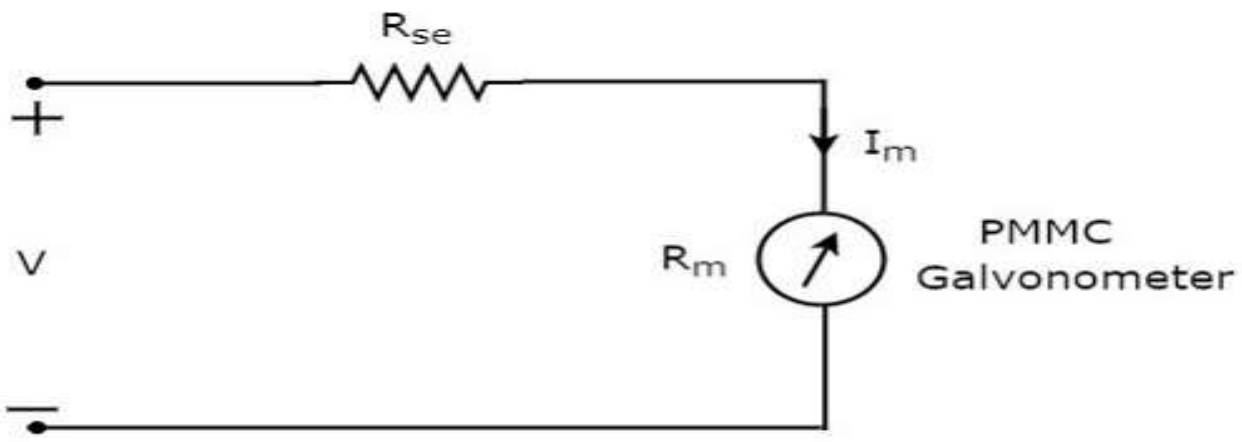
$$R_{sh4} = \frac{R_m}{m_4 - 1}$$

The above formulae will help us find the resistance values of each shunt resistor.

DC Voltmeters

DC Voltmeters

DC voltmeter is a measuring instrument, which is used to measure the DC voltage across any two points of electric circuit. If we place a resistor in series with the Permanent Magnet Moving Coil (PMMC) galvanometer, then the entire combination together acts as **DC voltmeter**.



We have to place this DC voltmeter across the two points of an electric circuit, where the DC voltage is to be measured.

Apply **KVL** around the loop of above circuit.

$$V - I_m R_{se} - I_m R_m = 0 \qquad \text{(Equation 1)}$$

$$\Rightarrow V - I_m R_m = I_m R_{se}$$

$$\Rightarrow R_{se} = \frac{V - I_m R_m}{I_m}$$

$$\Rightarrow R_{se} = \frac{V}{I_m} - R_m \qquad \text{(Equation 2)}$$

Where,

R_{se} is the series multiplier resistance

V is the full range DC voltage that is to be measured

I_m is the full scale deflection current

R_m is the internal resistance of galvanometer

The ratio of full range DC voltage that is to be measured, V and the DC voltage drop across the galvanometer, V_m is known as **multiplying factor**, m. Mathematically, it can be represented as

$$m = \frac{V}{V_m} \quad \text{(Equation 3)}$$

From Equation 1, we will get the following equation for **full range DC voltage** that is to be measured, V .

$$V = I_m R_{se} + I_m R_m \quad \text{(Equation 4)}$$

The **DC voltage drop** across the galvanometer, V_m is the product of full scale deflection current, I_m and internal resistance of galvanometer, R_m . Mathematically, it can be written as

$$V_m = I_m R_m \quad \text{(Equation 5)}$$

Substitute, Equation 4 and Equation 5 in Equation 3.

$$m = \frac{I_m R_{se} + I_m R_m}{I_m R_m}$$

$$\Rightarrow m = \frac{R_{se}}{R_m} + 1$$

$$\Rightarrow m - 1 = \frac{R_{se}}{R_m}$$

$$R_{se} = R_m\,(m - 1) \qquad \text{(Equation 6)}$$

We can find the **value of series multiplier resistance** by using either Equation 2 or Equation 6 based on the available data.

Multi Range DC Voltmeter

Multi Range DC Voltmeter

The DC voltmeter for measuring the DC voltages of **multiple ranges**, then we have to use multiple parallel multiplier resistors instead of single multiplier resistor and this entire combination of resistors is in series with the PMMC galvanometer. The circuit diagram of multi range DC voltmeter is shown in below figure

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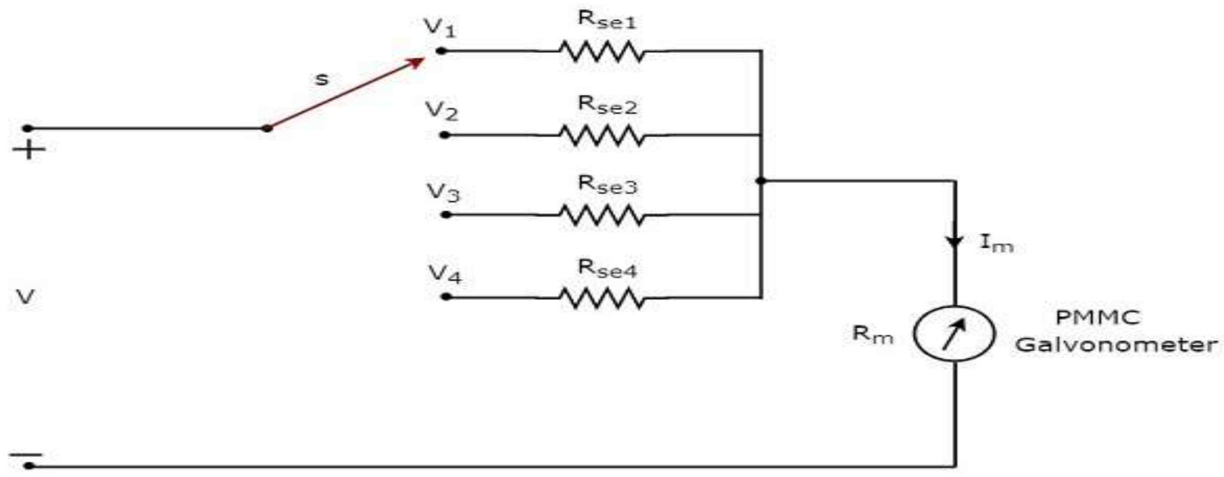


We have to place this multi range DC voltmeter across the two points of an electric circuit, where the DC voltage of required range is to be measured. We can choose the desired range of voltages by connecting the switch s to the respective multiplier resistor.

Let, m1,m2,m2 and m4 are the multiplying factors of DC voltmeter when we consider the full range DC voltages to be measured as, V1,V2,V3 and V4 respectively.

Following are the formulae corresponding to each multiplying factor.

$$m_1 = \frac{V_1}{V_m}$$

$$m_2 = \frac{V_2}{V_m}$$

$$m_3 = \frac{V_3}{V_m}$$

$$m_4 = \frac{V_4}{V_m}$$

In above circuit, there are four **series multiplier resistors**, $R_{se1}, R_{se2}, R_{se3}$ and R_{se4} . Following are the formulae corresponding to these four resistors.

$$R_{se1} = R_m \left(m_1 - 1 \right)$$

$$R_{se2} = R_m \left(m_2 - 1 \right)$$

$$R_{se3} = R_m\left(m_3 - 1\right)$$

$$R_{se4} = R_m\left(m_4 - 1\right)$$

So, we can find the resistance values of each series multiplier resistor by using above formulae.

Solid State Voltmeter

- Solid State Voltmeter – Figure 4.13 shows the circuit of an electronic voltmeter using an IC OpAmp 741C
- This is a directly coupled very high gain amplifier. The gain of the OpAmp can be adjusted to any suitable lower value by providing appropriate resistance between its output terminal, Pin No. 6, and inverting input, Pin No. 2, to provide a negative feedback
- The ratio R2/R1 determines the gain, i.e. 100 in this case, provided by the OpAmp
- The 0.1 µF capacitor across the 100 k resistance R_2 is for stability under stray pick-ups. Terminals 1 and 5 are called offset null terminals
- A 10 kΩ potentiometer is connected between these two offset null terminals with its centre tap connected to a – 5V supply. This potentiometer is called zero set and is used for adjusting zero output for zero input conditions

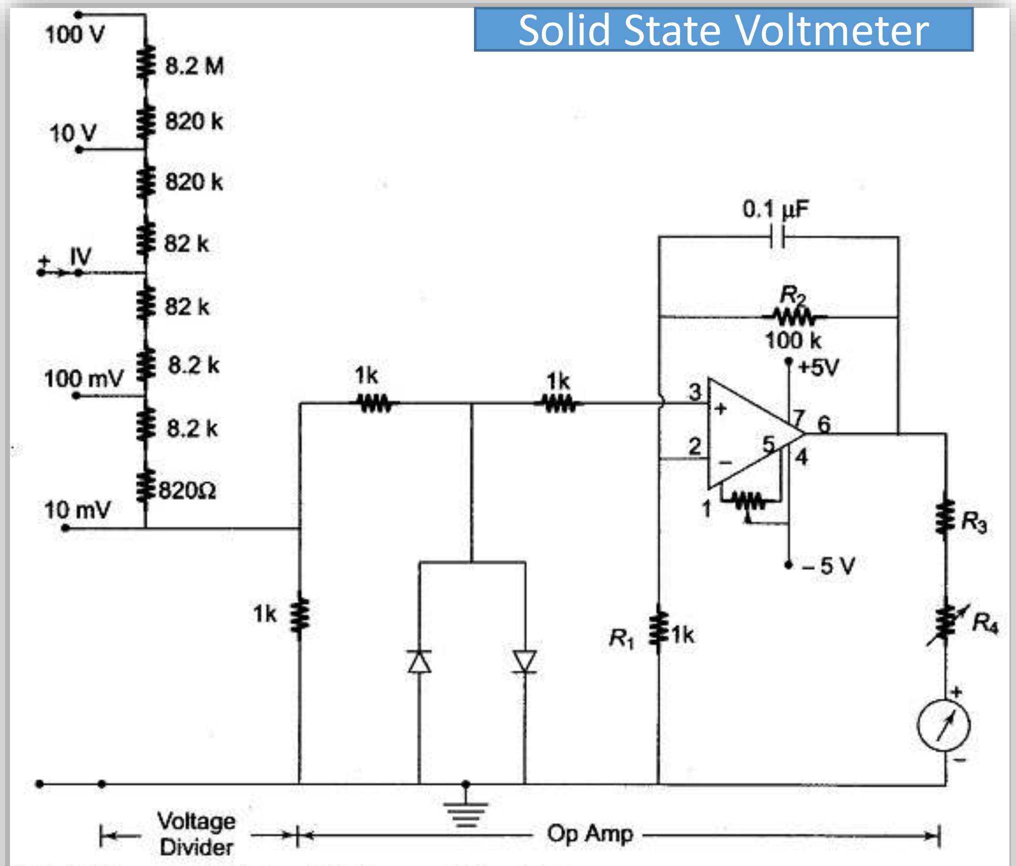


Fig. 4.13 Solid State mV Voltmeter Using OpAmp

- The two diodes used are for IC protection. Under normal conditions, they are non-conducting, as the maximum voltage across them is 10 mV
- If an excessive voltage, say more than 100 mV appears across them, then depending upon the polarity of the voltage, one of the diode' conducts and protects the IC
- A µA scale of 50 – 1000 µA full scale deflection can be used as an indicator. R4 is adjusted to get maximum full scale deflection

Differential Voltmeter

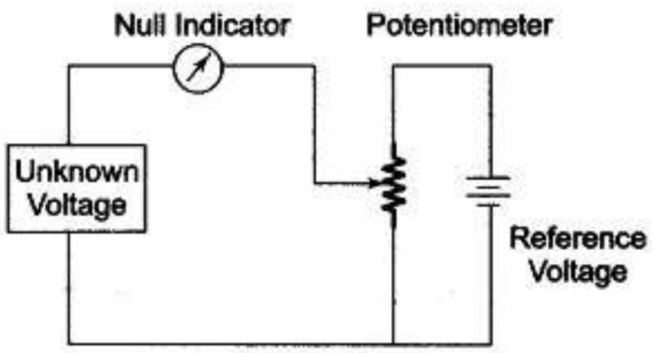


Fig. 4.14 (a) Basic Differential Voltmeter

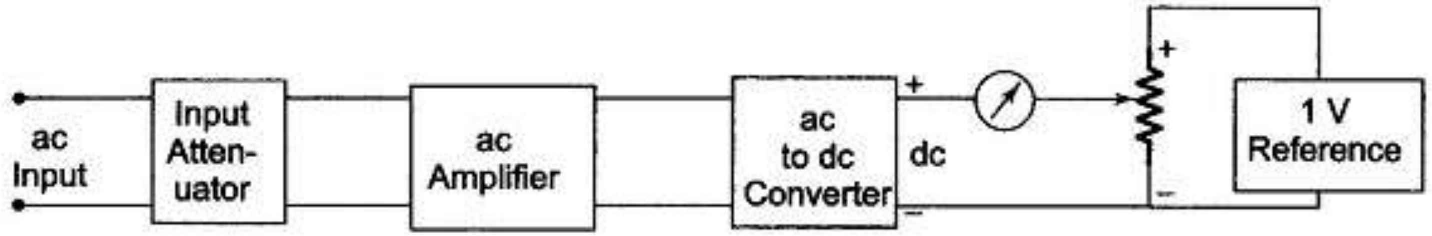


Fig. 4.14 (b) Block Diagram of an ac Differential Voltmeter

- The Differential Voltmeter technique, is one of the most common and accurate methods of measuring unknown voltages

- In this technique, the voltmeter is used to indicate the difference between known and unknown voltages, i.e., an unknown voltage is compared to a known voltage

- Figure (a) shows a basic circuit of a differential voltmeter based on the potentiometric method; hence it is sometimes also called a potentiometric voltmeter

- In this method, the potentiometer is varied until the voltage across it equals the unknown voltage, which is indicated by the null indicator reading zero

- Under null conditions, Voltage the meter draws current from neither the reference source nor the un-known voltage source, and hence the differential voltmeter presents an infinite impedance to the unknown source. (The null meter serves as an indicator only.)

- To detect small differences the meter movement must be sensitive, but it need not be calibrated, since only zero has to be indicated

- The reference source used is usually a 1 V dc standard source or a zener controlled precision supply. A high voltage reference supply is used for measuring high voltages

- The usual practice, is to employ voltage dividers or attenuators across an unknown source to reduce the voltage.

- In order to measure ac voltages, the ac voltage must be converted into dc by incorporating a precision rectifier circuit. A block diagram of an ac differential voltmeter is shown in Fig. (b)

AC Instruments

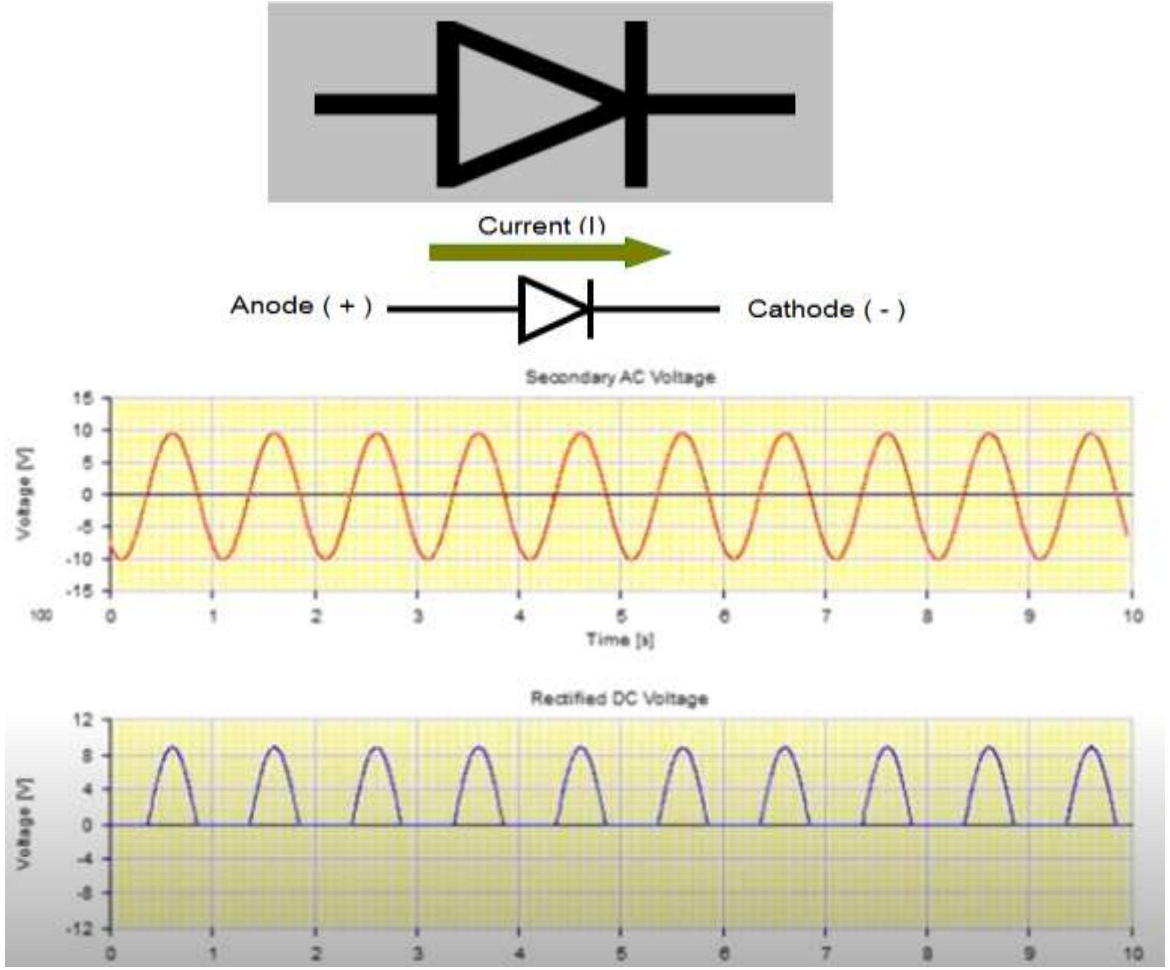
AC Voltmeters

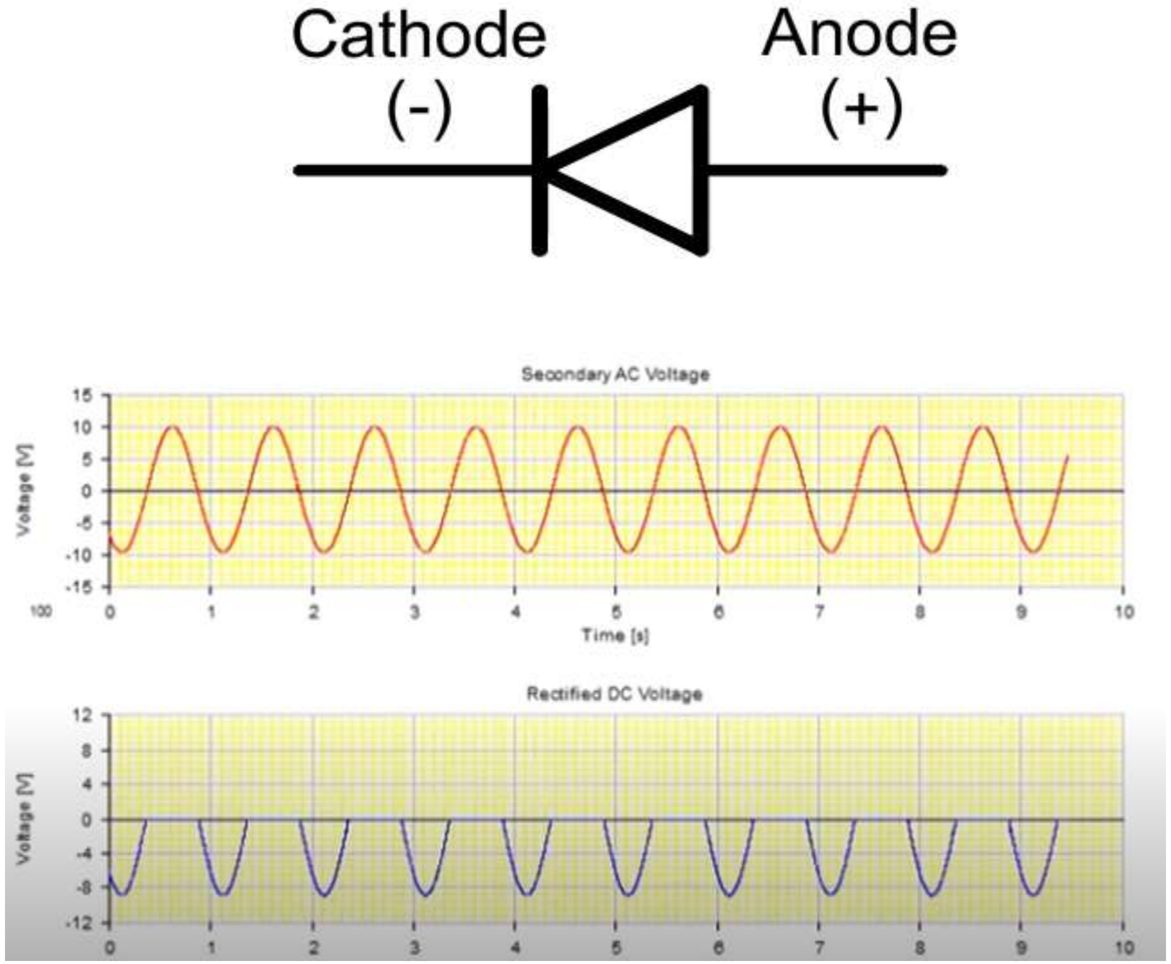
The instrument, which is used to measure the AC voltage across any two points of electric circuit is called **AC voltmeter**. If the AC voltmeter consists of rectifier, then it is said to be rectifier based AC voltmeter.

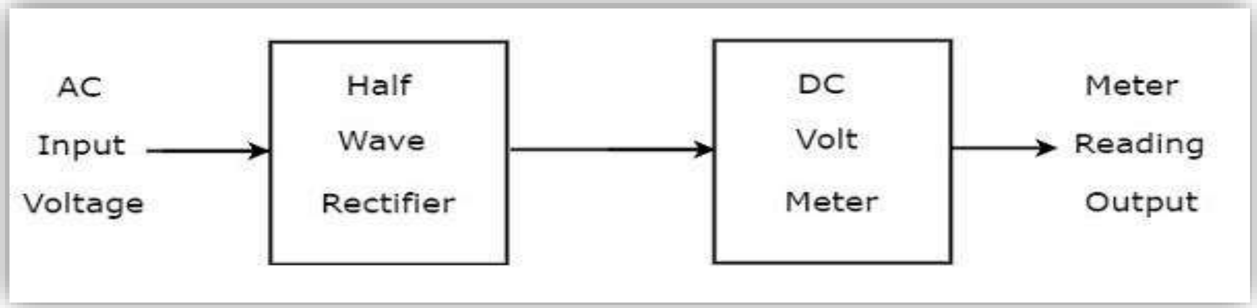
AC Voltmeter using Half Wave Rectifier:

If a Half wave rectifier is connected ahead of DC voltmeter, then that entire combination together is called AC voltmeter using Half wave rectifier. The **block diagram** of AC voltmeter using Half wave rectifier is shown in below figure.

- The **half wave rectifier** is the circuit designed using the diode which is used for converting the AC voltage signal into the DC voltage. The **half wave rectifier** only passes the one **half** of the input sine **wave** (either positive or negative) and rejects the other **half**







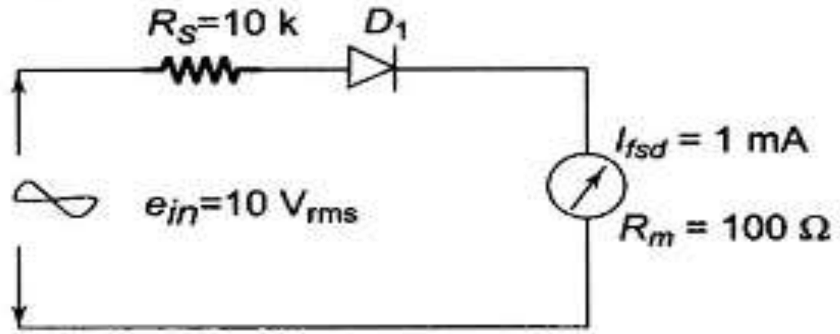


Fig. 4.18 ▬ ac Voltmeter Using Half Wave Rectifier

- If a diode D_1 is added to the dc voltmeter, as shown in Fig. 4.18, we have an ac voltmeter using half wave rectifier circuit capable of measuring ac voltages. The sensitivity of the dc voltmeter is given by

$$S_{dc} = 1/I_{fsd} = 1/1 \text{ mA} = 1 \text{ k}\Omega$$

- A multiple of 10 times this value means a 10 V dc input would cause exactly full scale deflection when connected with proper polarity. Assume D_1 to be an ideal diode with negligible forward bias resistance. If this dc input is replaced by a 10 V rms sine wave input. The voltages appearing at the output is due to the +ve half cycle due to rectifying action

- The peak value of 10 V rms sine wave is,

$$E_p = 10 \text{ V rms} \times 1.414 = 14.14 \text{ V peak}$$

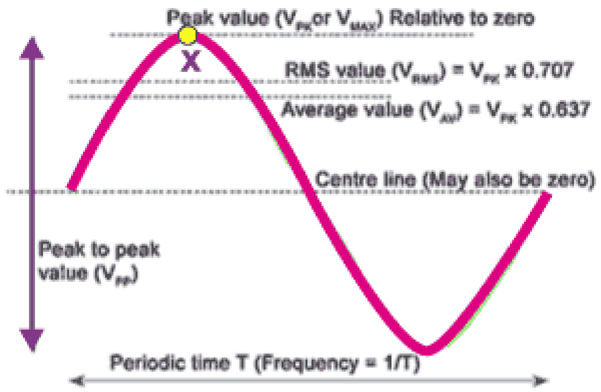
- The dc will respond to the average value of the ac input, therefore

$$E_{av} = E_p \times 0.636 = 14.14 \times 0.636 = 8.99 \text{ V}$$

- Since the diode conducts only during the positive half cycle, the average value over the entire cycle is one half the average value of 8.99 V, i.e. about 4.5 V

- Therefore, the pointer will deflect for a full scale if 10 V dc is applied and 4.5 V when a 10 V_{rms} sinusoidal signal is applied. This means that an ac voltmeter is not as sensitive as a dc voltmeter. As

$$E_{dc} = 0.45 \times E_{rms}$$



AC Voltmeter using Full wave Rectifier

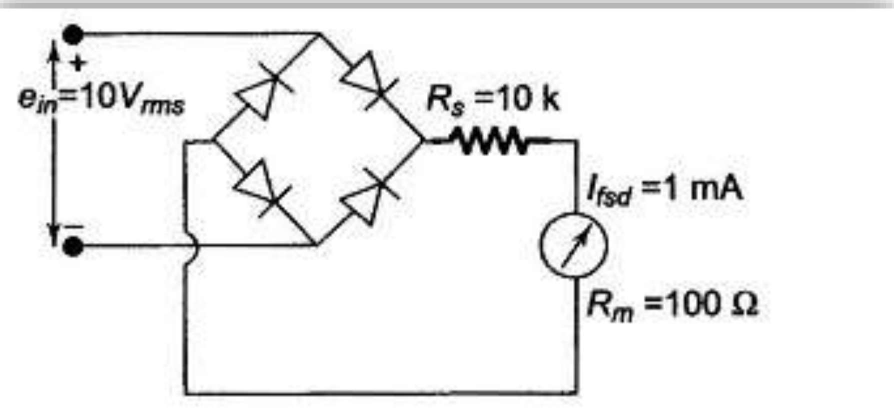


Fig. 4.20 ac Voltmeter Using Full Wave Rectifier

- Consider the circuit shown in Fig. 4.20. The peak value of a 10 V rms signal is

$$E_p = 1.414 \times E_{rms}$$
$$= 1.414 \times 10 = 14.14 \text{ V peak}$$

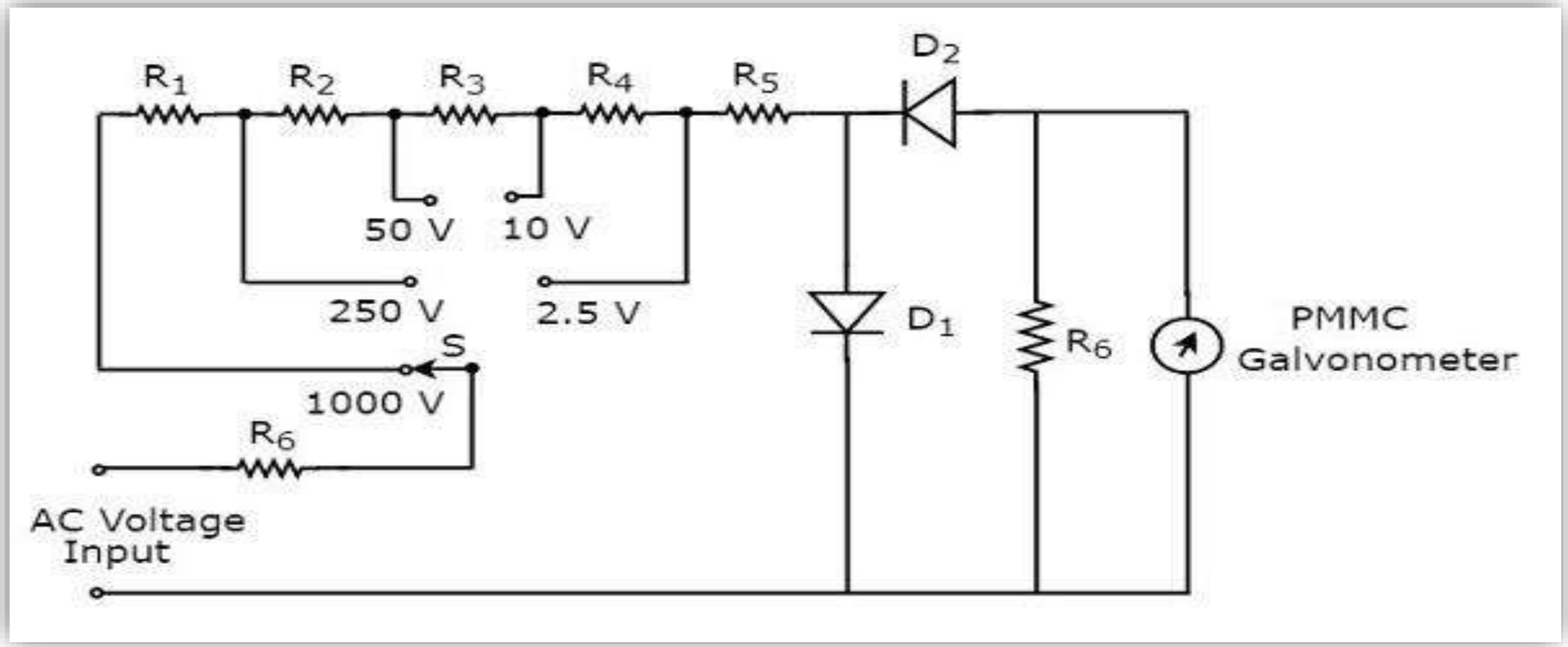
- Average value is $E_{av} = 0.636 \times E_{peak}$

$$= 14.14 \times 0.636 = 8.99 \text{ V}$$
$$\cong 9 \text{ V}$$

- Therefore, we can see that a 10 V rms voltage is equal to a 9 V dc for full scale deflection, i.e. the pointer will deflect to 90% of full scale, or

$$\text{Sensitivity (ac)} = 0.9 \times \text{Sensitivity (dc)}$$

Multi range AC voltmeter



- The above circuit is a multi range AC voltmeter. We know that, we will get AC voltmeter just by placing rectifier in series (cascade) with DC voltmeter.
- The above circuit was created just by placing the diodes combination and resistor, R6 in between resistor, R5 and PMMC galvanometer.
- We can measure the AC voltage across any two points of an electric circuit, by connecting the switch, S to the desired voltage range.

Transistor Voltmeter(TVM)

Transistor Voltmeter – Direct coupled amplifiers are economical and hence used widely in general purpose low priced VTVM' s. Figure gives a simplified schematic diagram of a dc coupled amplifier with an indicating meter.

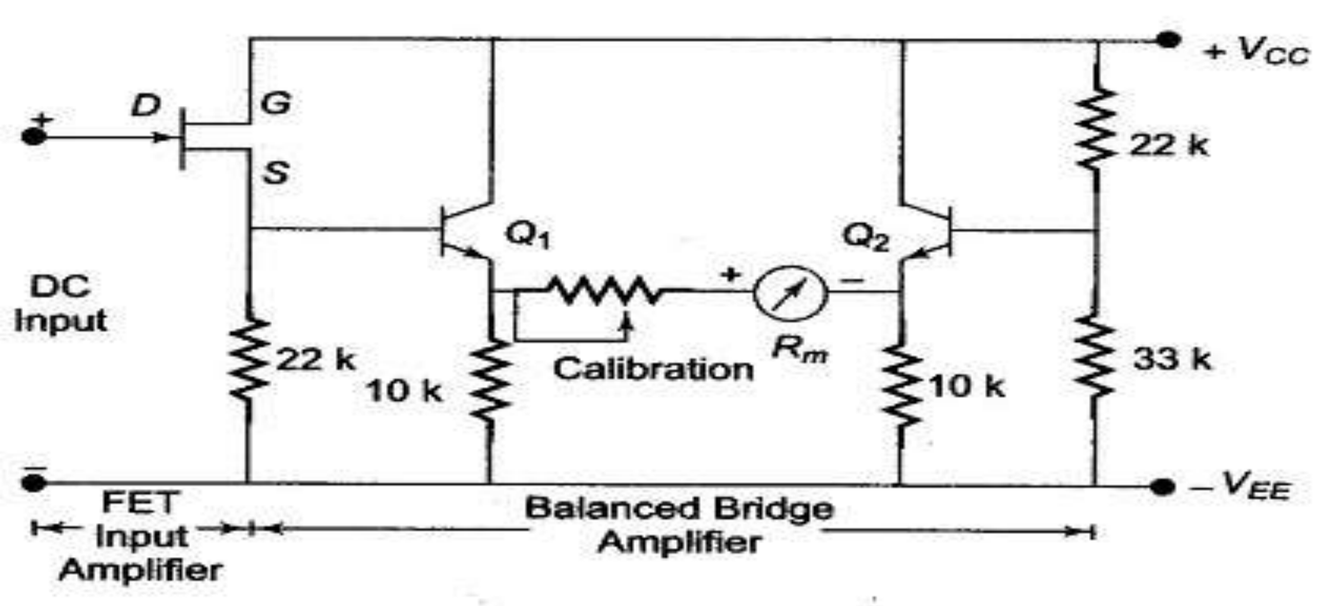


Fig. 4.9 Transistor Voltmeter

- The dc input is applied to a range attenuator to provide input voltage levels which can be accommodated by the dc amplifier
- The input stage of the amplifier consists of a FET which provides high input impedance to effectively isolate the meter circuit from the circuit under measurement
- The input impedance of a FET is greater than 10 MΩ. The bridge is balanced, so that for zero input the dial indicates zero
- The two transistors, Q1 and Q2 forms a dc coupled amplifier driving the meter movement. Within the dynamic range of the amplifier, the meter deflection is proportional to the magnitude of the applied input voltage

- The input overload does not burn the meter because the amplifier saturates, limiting the maximum current through the meter

- The gain of the dc amplifier allows the instrument to be used for measurement of voltages in the mV range

- Instruments in the µV range of measurement require a high gain dc amplifier to supply sufficient current for driving the meter movement

- In order to avoid the drift problems of dc amplifiers, chopper type dc amplifiers are commonly used in high sensitivity voltmeters

Series Type Ohmmeter

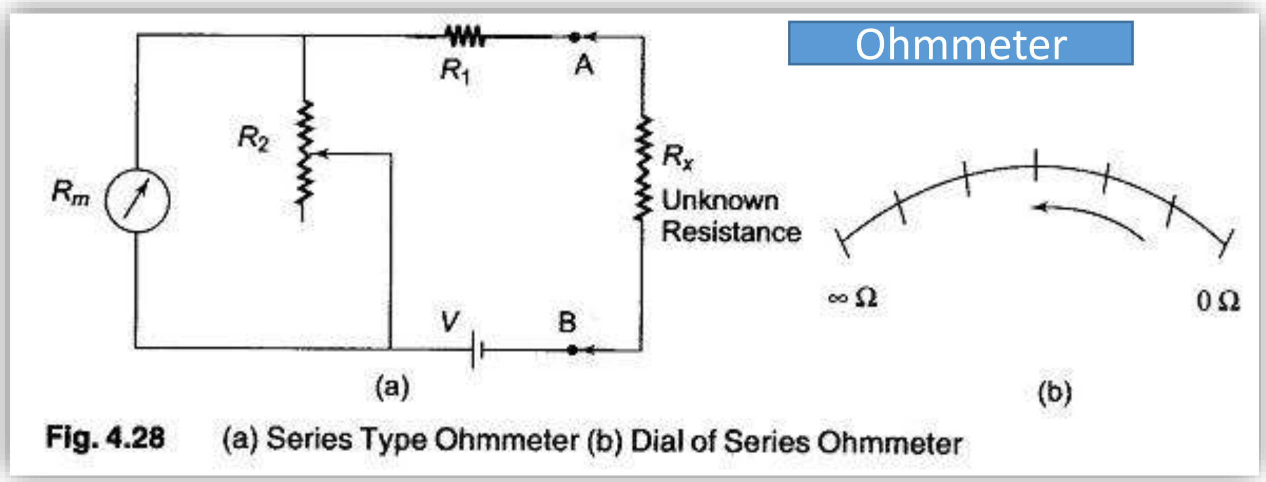


Fig. 4.28 (a) Series Type Ohmmeter (b) Dial of Series Ohmmeter

R_1 = current limiting resistance
R_2 = zero adjust resistance
V = battery
R_m = meter resistance
R_X = unknown resistance

- A D' Arsonval movement is connected in series with a resistance R_1 and a battery which is connected to a pair of terminals A and B, across which the unknown resistance is connected. This forms the basic type of series ohmmeter, as shown in Fig.(a)

- The current flowing through the movement then depends on the magnitude of the unknown resistance. Therefore, the meter deflection is directly proportional to the value of the unknown resistance

Calibration of the Series Type Ohmmeter:

- To mark the "0" reading on the scale, the terminals A and B are shorted, i.e. the unknown resistance Rx = 0, maximum current flows in the circuit and the shunt resistance R_2 is adjusted until the movement indicates full scale current (I_{fsd}). The position of the pointer on the scale is then marked "0" ohms

- Similarly, to mark the "∞" reading on the scale, terminals A and B are open, i.e. the unknown resistance Rx = ∞, no current flow in the circuit and there is no deflection of the pointer. The position of the pointer on the scale, is then marked as "∞" ohms

- By connecting different known values of the unknown resistance to terminals A and B, intermediate markings can be done on the scale. The accuracy of the instrument can be checked by measuring different values of standard resistance, i.e. the tolerance of the calibrated resistance, and noting the readings

- A major drawback in the series ohmmeter is the decrease in voltage of the internal battery with time and age. Due to this, the full scale deflection current drops and the meter does not read "0" when A and B are shorted. The variable shunt resistor R2 across the movement is adjusted to counteract the drop in battery voltage, thereby bringing the pointer back to "0" ohms on the scale.

- It is also possible to adjust the full scale deflection current without the shunt R_2 in the circuit, by varying the value of R1 to compensate for the voltage drop. Since this affects the calibration of the scale, varying by R_2 is much better solution. The internal resistance of the coil R_m is very low compared to R_1. When R_2 is varied, the current through the movement is increased and the current through R_2 is reduced, thereby bringing the pointer to the full scale deflection position.

- The series ohmmeter is a simple and popular design, and is used extensively for general service work.

- Therefore, in a series ohmmeter the scale marking on the dial, has "0" on the right side, corresponding to full scale deflection current, and "∞" on the left side corresponding to no current flow, as given in Fig. (b)

- Values of R_1 and R_2 can be determined from the value of Rx which gives half the full scale deflection.

$$R_h = R_1 + R_2 \parallel R_m = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

Where R_h = half of full scale deflection resistance

- The total resistance presented to the battery then equals **2_{Rh}** and the battery current needed to supply half scale deflection is **$I_h = V/2\ R_h$**

- To produce full scale current, the battery current must be **doubled**

- Therefore, the total current of the ckt, **$I_t = V/R_h$**

- The shunt current through R_2 is given by **$I_2 = I_t - I_{fsd}$**

- The voltage across shunt, **V_{sh}, is equal to the voltage across the meter**

Therefore

$$V_{sh} = V_m$$

$$I_2 R_2 = I_{fsd} R_m$$

Therefore

$$R_2 = \frac{I_{fsd} R_m}{I_2}$$

But

$$I_2 = I_t - I_{fsd}$$

$$R_2 = \frac{I_{fsd} R_m}{I_t - I_{fsd}}$$

But

$$I_t = \frac{V}{R_h}$$

Therefore

$$R_2 = \frac{I_{fsd}\ R_m}{V/R_h - I_{fsd}}$$

Therefore

$$R_2 = \frac{I_{fsd}\ R_m\ R_h}{V - I_{fsd}\ R_h}$$

As

$$R_h = R_1 + \frac{R_2\ R_m}{R_2 + R_m}$$

Therefore

$$R_1 = R_h - \frac{R_2\ R_m}{R_2 + R_m}$$

Hence

$$R_1 = R_h - \frac{\frac{I_{fsd}\ R_m\ R_h}{V - I_{fsd}\ R_h} \times R_m}{\frac{I_{fsd}\ R_m\ R_h}{V - I_{fsd}\ R_h} + R_m}$$

Therefore

$$R_1 = R_h - \frac{I_{fsd}\ R_m\ R_h}{V}$$

Hence, R1 and R2 can be determined

Multimeter Operating Instructions

The combination volt-ohm-milli ammeter is a basic tool in any electronic laboratory. The proper use of this instrument increases its accuracy and life. The following precautions should be observed

- ✓ To prevent meter overloading and possible damage when checking voltage or current, start with the highest range of the instrument and move down the range successively
- ✓ For higher accuracy, the range selected should be such that the deflection falls in the upper half on the meter scale
- ✓ For maximum accuracy and minimum loading, choose a voltmeter range such that the total voltmeter resistance (ohms per volt x full scale voltage) is at least 100 times the resistance of the circuit under test
- ✓ Make all resistance readings in the uncrowded portion on the meter scale, whenever possible
- ✓ Take extra precautions when checking high voltages and checking current in high voltage circuits
- ✓ Verify the circuit polarity before making a test, particularly when measuring dc current or voltages
- ✓ When checking resistance in circuits, be sure power to the circuit is switched off, otherwise the voltage across the resistance may damage the meter
- ✓ Renew ohmmeter batteries frequently to insure accuracy of the resistance scale
- ✓ Re-calibrate the instrument at frequent intervals
- ✓ Protect the instrument from dust, moisture, fumes and heat

UNIT – II: Digital Instruments

Digital Voltmeters:

- Digital Voltmeters (DVMs) are measuring instruments that convert analog voltage signals into a digital or numeric readout. This digital readout can be displayed on the front panel and also used as an electrical digital output signal.

- DVM is capable of measuring analog dc voltages. However, with appropriate signal conditioners preceding the input of the DVM, quantities such as ac voltages, ohms, dc and ac current, temperature, and pressure can be measured.

- DVMs have various features such as speed, automation operation and programmability.

Ramp type digital voltmeter

The operating principle is to measure the time that a linear ramp takes to change the input level to the ground level, or vice-versa. This time period is measured with an electronic time-interval counter and the count is displayed as a number of digits on an indicating tube or display. The operating principle and block diagram of a ramp type DVM are shown in Figs.

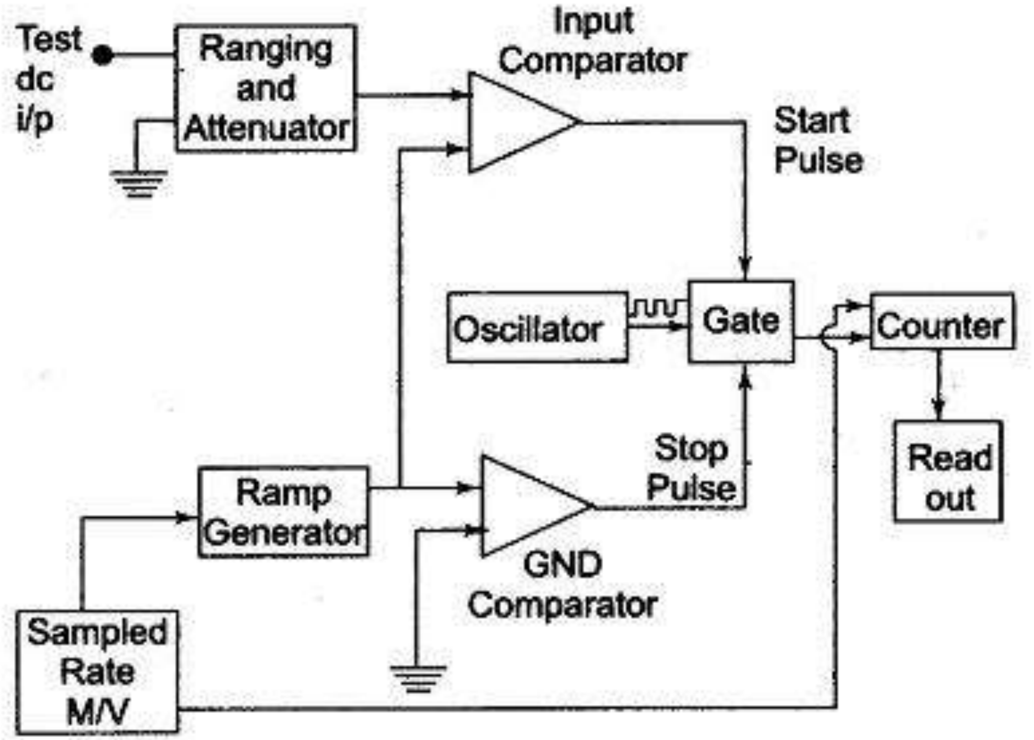


Fig. 5.2 Block Diagram of Ramp Type DVM

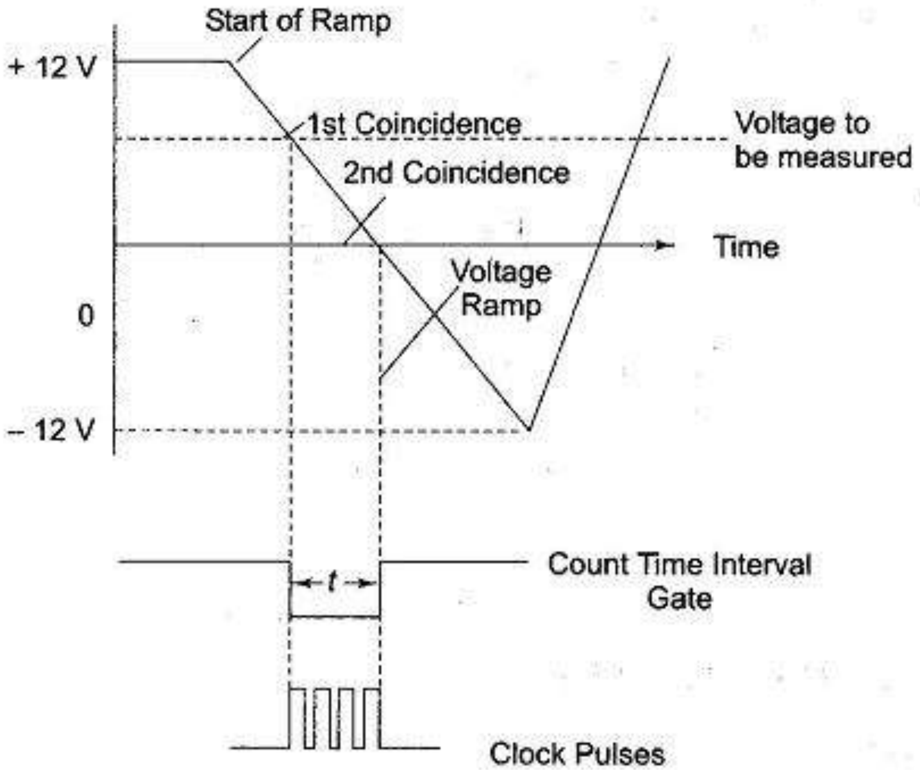


Fig. 5.1 Voltage to Time Conversion

- The ramp may be positive or negative; in this case a negative ramp has been selected.

- At the start of the measurement a ramp voltage is initiated (counter is reset to 0 and sampled rate multivibrator gives a pulse which initiates the ramp generator).

- The ramp voltage is continuously compared with the voltage that is being measured. At the instant these two voltage become equal, a coincidence circuit generates a pulse which opens a gate, i.e. the input comparator generates a start pulse.

- The ramp continues until the second comparator circuit senses that the ramp has reached zero value. The ground comparator compares the ramp with ground. When the ramp voltage equals zero or reaches ground potential, the ground comparator generates a stop pulse.

- The output pulse from this comparator closes the gate. The time duration of the gate opening is proportional to the input voltage value.

- In the time interval between the start and stop pulses, the gate opens and the oscillator circuit drives the counter. The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the readout.
- Therefore, the voltage is converted into time and the time count represents the magnitude of the voltage.
- The sample rate multivibrator determines the rate of cycle of measurement. A typical value is 5 measuring cycles per second, with an accuracy of ± 0.005% of the reading.
- The sample rate circuit provides an initiating pulse for the ramp generator to start its next ramp voltage. At the same time a reset pulse is generated, which resets the counter to the zero state.

Advantages and Disadvantages:

- The ramp technique circuit is easy to design and its cost is low. Also, the output pulse can be transmitted over long feeder lines.
- However, the single ramp requires excellent characteristics regarding linearity of the ramp and time measurement. Large errors are possible when noise is superimposed on the input signal. Input filters are usually required with this type of converter.

Dual slop type digital voltmeter

In ramp techniques, superimposed noise can cause large errors. In the dual ramp technique, noise is averaged out by the positive and negative ramps using the process of integration.

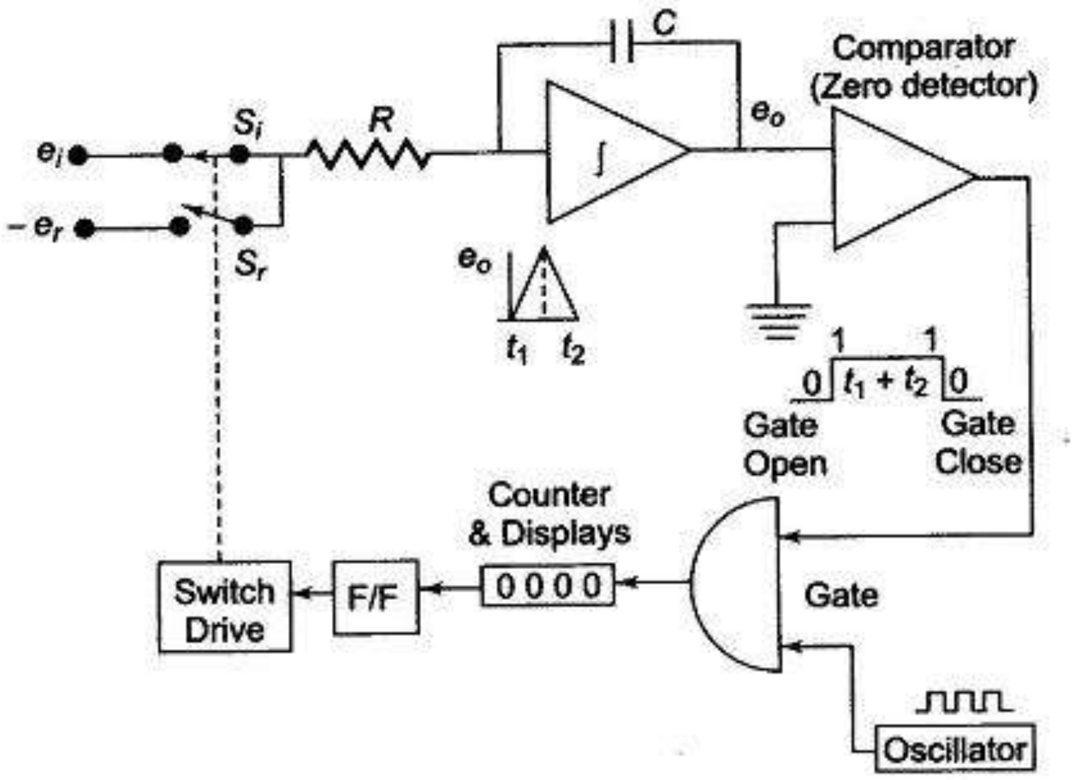


Fig. 5.4 Block Diagram of a Dual Slope Type DVM

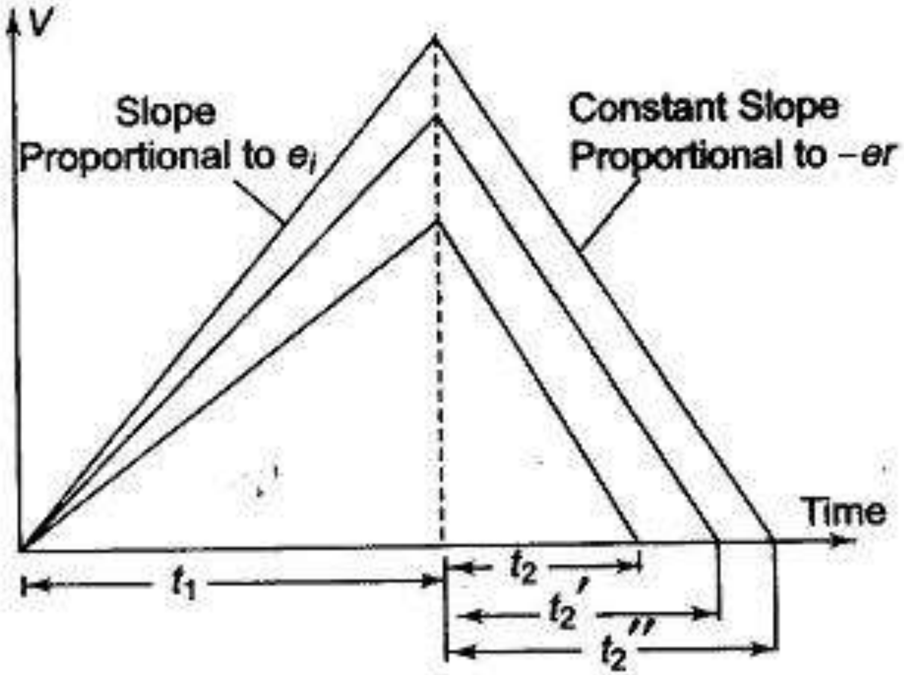


Fig. 5.3 Basic Principle of Dual Slope Type DVM

Principle of Dual Slope Type DVM

- As illustrated in Fig. 5.3, the input voltage ’e_i’ is integrated, with the slope of the integrator output proportional to the test input voltage.

- After a fixed time, equal to t1, the input voltage is disconnected and the integrator input is con-nected to a negative voltage ‘e_r ‘ .

- The integrator output will have a negative slope which is constant and proportional to the magnitude of the input voltage. The block diagram is given in Fig. 5.4.

- At the start a pulse resets the counter and the F/F output to logic level ‘0’. Si is closed and Sr is open. The capacitor begins to charge. As soon as the integrator output exceeds zero, the comparator output voltage changes state, which opens the gate so that the oscillator clock pulses are fed to the counter. (When the ramp voltage starts, the comparator goes to state 1, the gate opens and clock pulse drives the counter.)

- When the counter reaches maximum count, i.e. the counter is made to run for a time ‘t1‘ in this case 9999, on the next clock pulse all digits go to 0000 and the counter activates the F/F to logic level ‘1’. This activates the switch drive, ei is disconnected and –er is connected to the integrator.

- The integrator output will have a negative slope which is constant, i.e. integrator output now decreases linearly to 0 volts. Comparator output state changes again and locks the gate. The discharge time t2 is now proportional to the input voltage.

- The counter indicates the count during time t2. When the negative slope of the integrator reaches zero, the comparator switches to state 0 and the gate closes, i.e. the capacitor C is now discharged with a constant slope. As soon as the comparator input (zero detector) finds that e0, is zero, the counter is stopped.

- The pulses counted by the counter thus have a direct relation with the input voltage.

During charging

$$e_o = -\frac{1}{RC}\int_0^{t_1} e_i\, dt = -\frac{e_i t_1}{RC} \qquad (5.1)$$

During discharging

$$e_o = \frac{1}{RC}\int_0^{t_2} -e_r\, dt = -\frac{e_r t_2}{RC} \qquad (5.2)$$

Subtracting Eqs 5.2 from 5.1 we have

$$e_o - e_o = \frac{-e_r t_2}{RC} - \left(\frac{-e_i t_1}{RC}\right)$$

$$0 = \frac{-e_r t_2}{RC} - \left(\frac{-e_i t_1}{RC}\right)$$

$$\frac{e_r t_2}{RC} = \frac{e_i t_1}{RC}$$

$$e_i = e_r \frac{t_2}{t_1} \qquad (5.3)$$

If the oscillator period equals T and the digital counter indicates n_1 and n_2 counts respectively,

$$e_i = \frac{n_2 T}{n_1 T} e_r \quad \text{i.e.} \quad e_i = \frac{n_2}{n_1} e_r$$

Now, n_1 and e_r are constants.

$$\text{Let } K_1 = \frac{e_r}{n_1}. \text{ Then } e_i = K_1 n_2 \qquad (5.4)$$

From Eq. 5.3 it is evident that the accuracy of the measured voltage is independent of the integrator time constant. The times t_1 and t_2 are measured by the count of the clock given by the numbers n_1 and n_2 respectively. The clock oscillator period equals T and if n_1 and e_r are constants, then Eq. 5.4 indicates that the accuracy of the method is also independent of the oscillator frequency.

The dual slope technique has excellent noise rejection because noise and superimposed ac are averaged out in the process of integration. The speed and accuracy are readily varied according to specific requirements; also an accuracy of ± 0.05% in 100 ms is available.

Digital Multimeter

- 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, offer high accuracy, have a high input impedance and are smaller in size. They gives an unambiguous reading at greater viewing distances

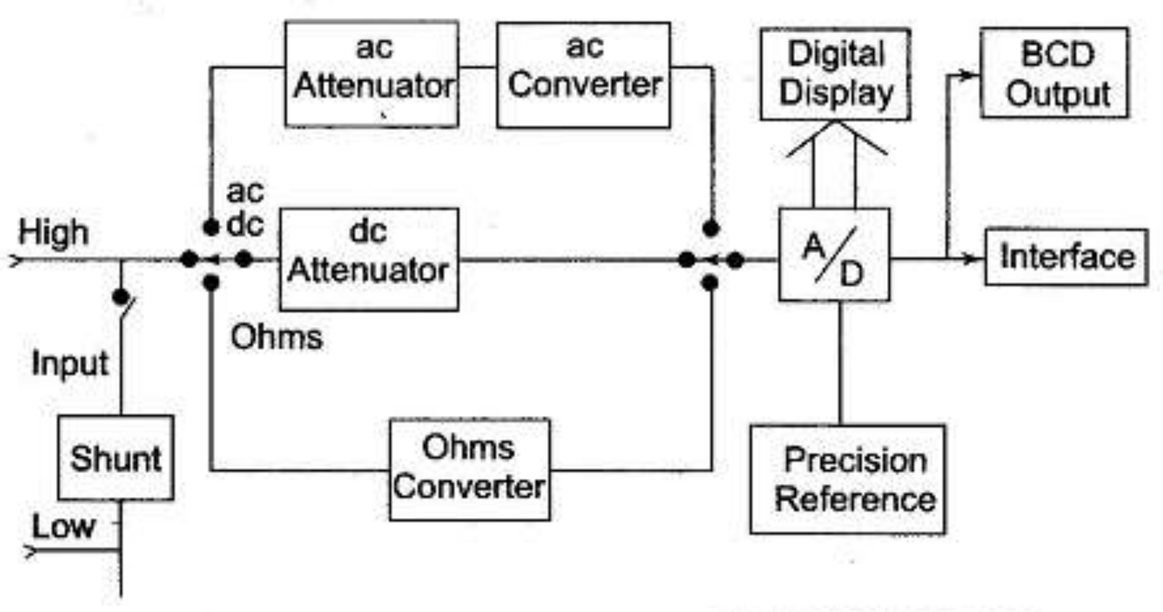


Fig. 6.2 (a) Digital Multimeter

- The output available is electrical (for interfacing with external equipment), in addition to a visual readout.
- The three major classes of Working Principle of Digital Multimeter are **panel meters**, **bench type meters** and **system meters**
- All Working Principle of Digital Multimeter employ some kind of **Analog to Digital (A/D) converters** 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
- 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

Digital frequency meter

The Principle of Operation of Digital Frequency Meter is, the signal waveform is converted to trigger pulses and applied continuously to an AND gate, as shown in Fig. 6.4. A pulse of 1 s is applied to the other terminal, and the number of pulses counted during this period indicates the frequency.

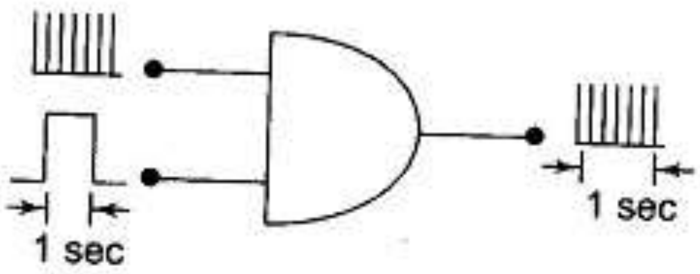


Fig. 6.4 Principle of Digital Frequency Measurement

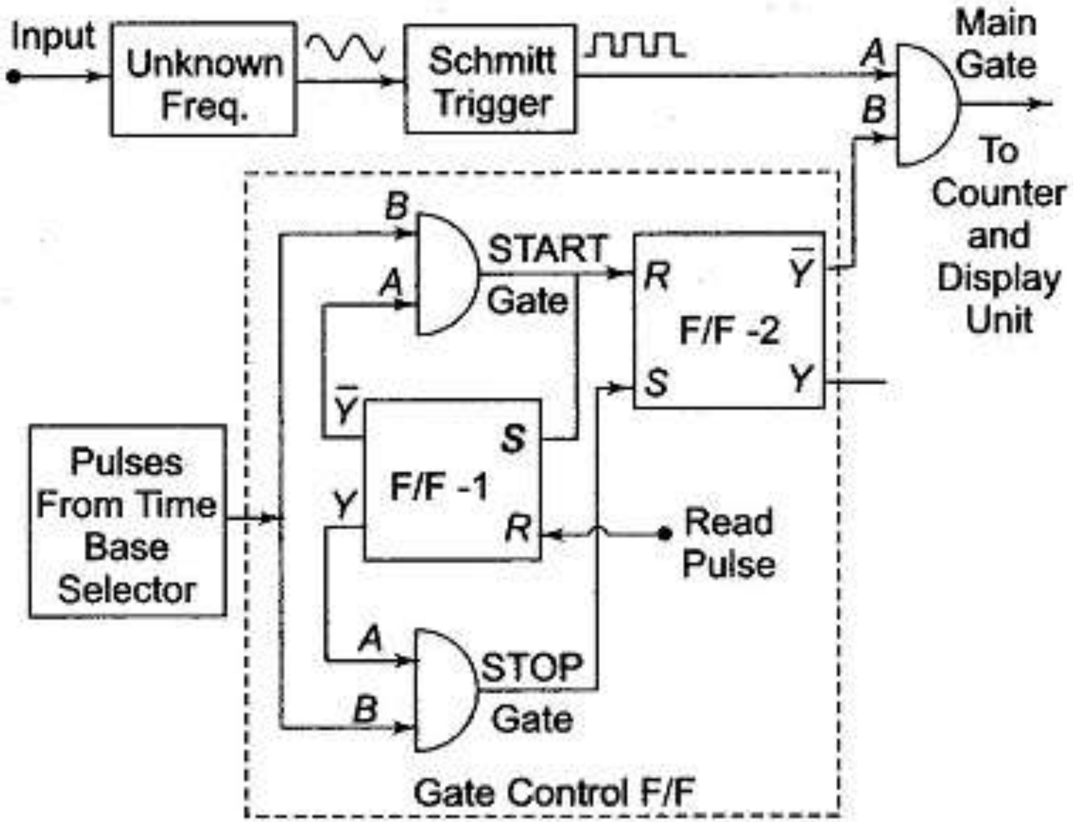


Fig. 6.6 Basic Circuit for Measurement of Frequency Showing Gate Control F/F

S	R	Y	$\bar{Y}$
1	0	1	0
0	1	0	1

- The basic circuit for frequency measurement is as shown in Fig. 6.6. The output of the unknown frequency is applied to a Schmitt trigger, producing positive pulses at the output. These pulses are called the counter signals and are present at point A of the main gate. Positive pulses from the time base selector are present at point B of the START gate and at point B of the STOP gate.

- Initially the Flip-Flop (F/F-1) is at its logic 1 state. The resulting voltage from output Y=1 is applied to point A of the STOP gate and enables this gate. The output $\bar{Y}$=0 of the F/F-1 is applied to the input A of the START gate and disables the gate.

- As the STOP gate is enabled, the positive pulses from the time base pass through the STOP gate to the Set (S) input of the F/F-2 thereby setting F/F-2 to the 1 state and keeping it there. The resulting 0 output level from $\bar{Y}$ of F/F-2 is applied to terminal B of the main gate. Hence no pulses from the unknown frequency source can pass through the main gate.

- In order to start the operation, a positive pulse is applied to (read input=1) reset input of F/F-1, thereby causing its state to change. Hence $\bar{Y}$ = 1, Y= 0, and as a result the STOP gate is disabled and the START gate enabled. The resulting $\bar{Y}$=0 of F/F-2 is applied to terminal B of the main gate. This same read pulse is simultaneously applied to the reset input of all decade counters, so that they are reset to 0 and the counting can start.

- When the next pulse from the time base arrives, it is able to pass through the START gate to reset F/F-2, therefore, the F/F-2 output changes state from 0 to 1, hence Y changes from 0 to 1. This resulting positive voltage from Y called the gating signal, is applied to input B of the main gate thereby enabling the gate.

- Now the pulses from the unknown frequency source pass through the main gate to the counter and the counter starts counting. This same pulse from the START gate is applied to the set input of F/F-1, changing its state from 0 to 1. This disables the START gate and enables the STOP gate. However, till the main gate is enabled, pulses from the unknown frequency continue to pass through the main gate to the counter.

- The next pulse from the time base selector passes through the enabled STOP gate to the set input terminal of F/F-2, changing its output back to 1 and fi = 0. Therefore the main gate is disabled, disconnecting the unknown frequency signal from the counter. The counter counts the number of pulses occurring between two successive pulses from the time base selector. If the time interval between this two successive pulses from the time base selector is 1 second, then the number of pulses counted within this interval is the frequency of the unknown frequency source, in Hertz.

Digital measurement of time

The Principle of Operation of Digital Measurement of Time is, **the beginning of the time period is the start pulse originating from input 1, and the end of the time period is the stop pulse coming from input 2**. The oscillator runs continuously, but the oscillator pulses reach the output only during the period when the control F/F is in the 1 state. The number of output pulses counted is a measure of the time period.

Time Base Selector:

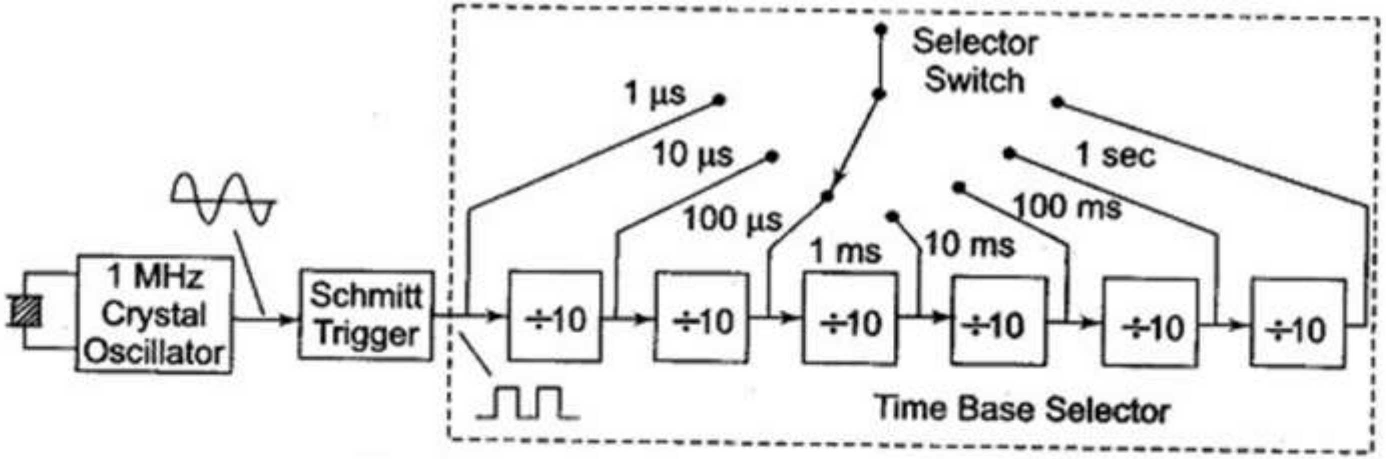


Fig. 6.8 Time Base Selector

- It is clear that in order to know the value of frequency of the input signal, the time interval between the start and stop of the gate must be accurately known. This is called **time base**.

- The time base consist of a fixed frequency **crystal oscillator**, called a **clock oscillator**, which has to be very accurate.

- The output of this constant frequency oscillator is fed to a **Schmitt trigger**, which converts the input sine wave to an output consisting of a train of pulses at a rate equal to the frequency of the clock oscillator.

- The train of pulses then passes through a **series of frequency divider decade** assemblies connected in cascade. Each decade divider consists of a decade counter and divides the frequency by **ten**. Outputs are taken from each decade frequency divider by means of a selector switch; any output may be selected.

- The circuit of Fig. 6.8 consists of a clock oscillator having a 1 MHz frequency. The output of the Schmitt trigger is 106 pulses per second and this point corresponds to a time of 1 microsecond. Hence by using a 6 decade frequency divider, a time base with a range of 1 µs — 10 µs — 100 µs — 1 ms —10 ms — 100 ms — 1 s can be selected using a selector switch.

Measurement of Time (Period Measurement) :

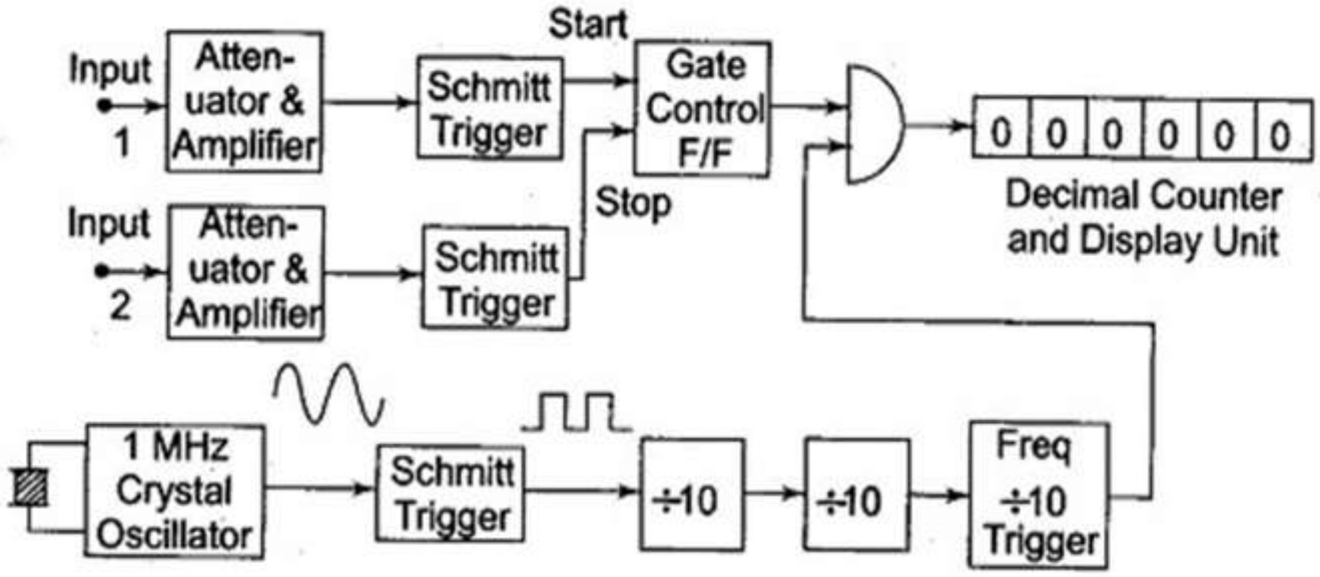


Fig. 6.9 Basic Block Diagram of Time Measurement

- Figure 6.9 shows the circuit for measurement of time period. The gating signal is derived from the unknown input signal, which now controls the enabling and disabling of the main gate.

- The number of pulses which occur during one period of the unknown signal are counted and displayed by the decade counting assemblies.

- The only disadvantage is that for measuring the frequency in the low frequency range, the operator has to calculate the frequency from the time by using the equation $f = 1/T$.

- For example, when measuring the period of a 60 Hz frequency, the electronic counter might display 16.6673 ms, where the frequency is

$$f = 1/T = \frac{1}{16.6673 \times 10^{-3}} = 59.9977 \text{ Hz}$$

- The accuracy of the period measurement and hence of frequency can be greatly increased by using the multiple period average mode of operation.

Digital pH Meter

- The Digital Measurement of hydrogen ion activity (pH) in a solution can be accomplished with the help of a pH meter
- pH is a quantitative measure of acidity. If the pH is less than 7, the solution is acidic (the lower the pH, the greater the acidity). A neutral solution has a pH of 7 and alkaline (basic) solutions have a pH greater than 7
- The pH unit is defined as **pH = – log (concentration of H+)**

  where, H+ is the hydrogen or hydronium ion

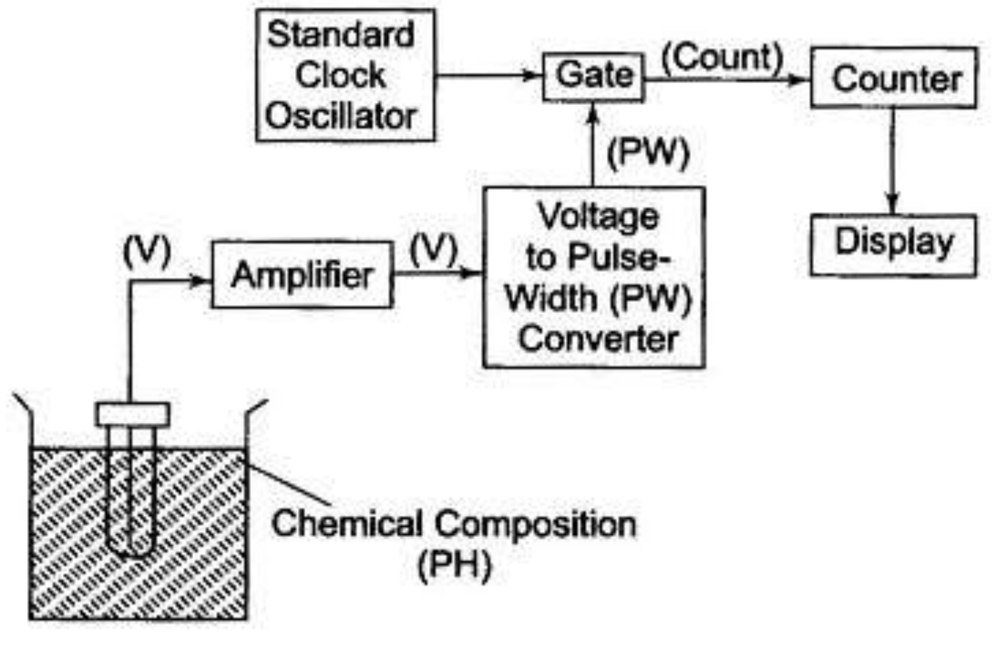


Fig. 6.20 Digital pH Meter

- In this the meter is replaced by an analog to digital converter (ADC) and a digital display. A frequently used ADC for this application is the dual slope converter. A basic block diagram of a digital pH meter is shown in Fig
- The dual slope circuit produces a pulse which has a duration proportional to the input signal voltage, that is, a T pulse width signal
- The pulse width is converted to a digital signal using the pulse to turn an oscillator On or Off, generating a count digital signal. The count signal is in turn counted or converted to a parallel digital signal for display by the counter

Digital Tachometer

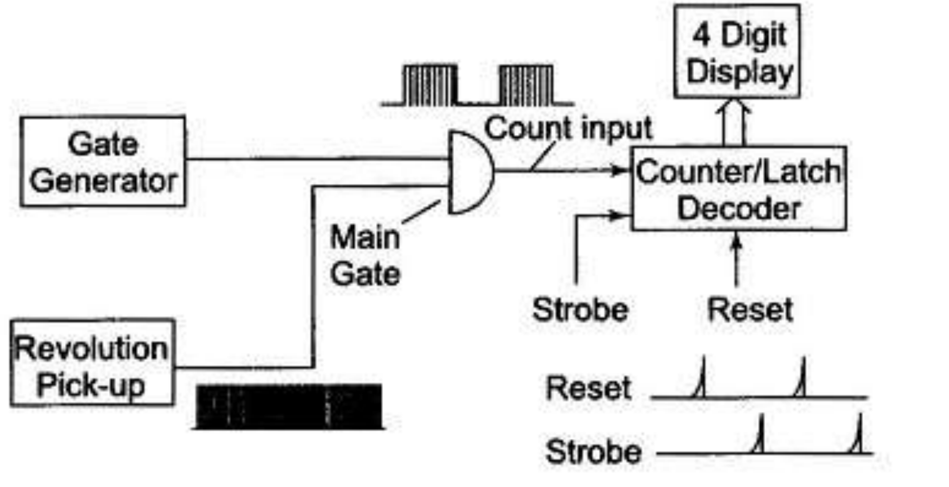


Fig. 6.19 Basic Block Diagram of a Digital Tachometer

- Digital Tachometer Working Principle technique employed in measuring the **speed of a rotating shaft** is similar to the technique used in a conventional frequency counter, except that the selection of the gate period is in accordance with the rpm calibration
- Let us assume, that the **rpm of a rotating shaft is R**. Let **P be the number of pulses** produced by the pick up for one revolution of the shaft
- Therefore, in one minute the number of pulses from the pick up is **R x P**. Then, the frequency of the signal from the pick up is **(R x P)/60**. Now, if the gate period is G s the pulses counted are **(R x P x G)/60**

$$\frac{(R \times P \times 60)}{60 \times P} = R \text{ pulses}$$

- In order to get the direct reading in rpm, the number of pulses to be counted by the counter is R. So we select the gate period as 60/P, and the counter counts
- we can read the rpm of the rotating shaft directly. So, the relation between the gate period and the number of pulses produced by the pickup is **G = 60/P**
- If we fix the gate period as one second (G = 1 s), then the revolution pickup must be capable of producing 60 pulses per revolution

A stroboscope or stroboscopic tachometer is also called a flashlight stroboscope used for the measurement of angular velocity or rotational speed by the stroboscopic method. It consists of a flashing light of variable frequency in which the flashing frequency of the stroboscope light can be adjusted

Digital Capacitance Meter

- The capacitance is linearly proportional to the time constant, when a capacitor is charged by a constant current source and discharged through a fixed resistance, we can use a 555 timer along with some digital test equipment to measure capacitances
- A better way is to measure only the capacitor discharge time, as shown in Digital Capacitance Meter Block Diagram Fig. 6.27.

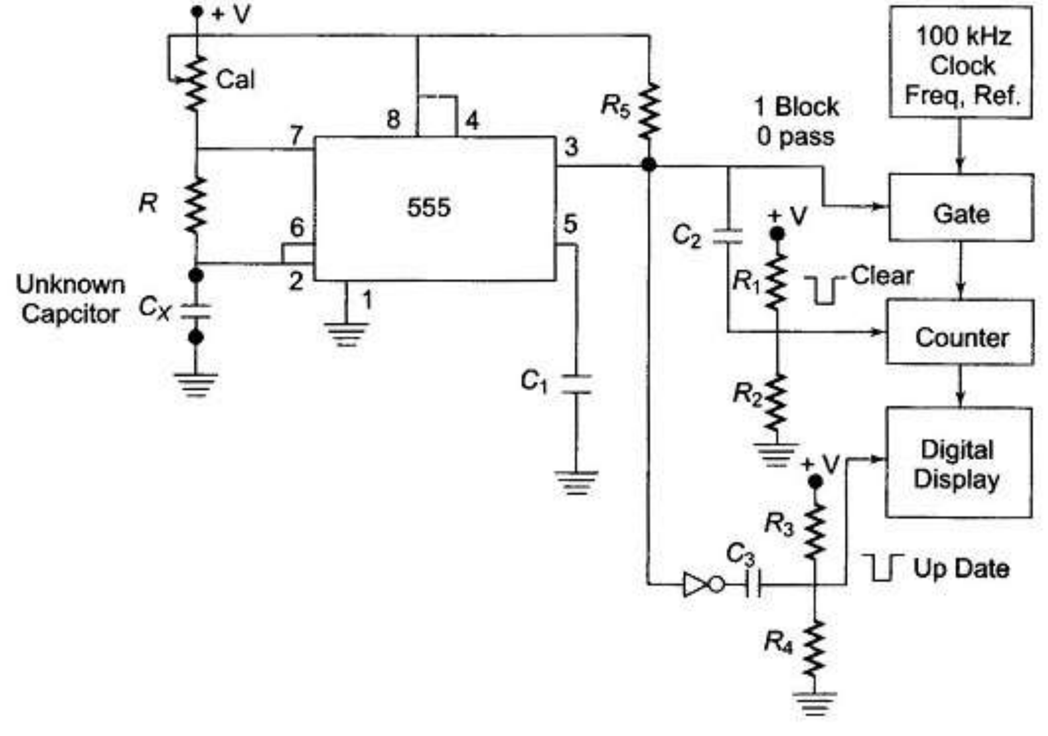


Fig. 6.27 Block Diagram of a Basic Digital Capacitance Meter

- With this method, any leakage in the capacitor under test will make the capacitor appear smaller in value than it actually is, and is an effective indicator of how the test capacitor will behave in most timing and bypass circuits
- In this Digital Capacitance Meter Block Diagram circuit, the 555 timer is used as an **astable multivibrator**. At the peak of the charging curve, a digital counter is reset and a clock of 100 kHz pulses is turned on and routed to the counter
- When the discharge portion of the cycle is completed, the display is updated and the value of the capacitor is readout. By selecting the proper reference frequency and charging currents, one can obtain a direct digital display of the value of the capacitance

Digital Phase Meter

- The simplest technique to measure the **phase difference between two signals** employs two flip-flops. The signals to be fed must be of the same frequency
- First, the signals must be shaped to a square waveform without any change in their phase positions, by the use of a zero crossing detector. The process of measuring the phase difference of Digital Phase Meter can be illustrated by the schematic diagram shown in Fig

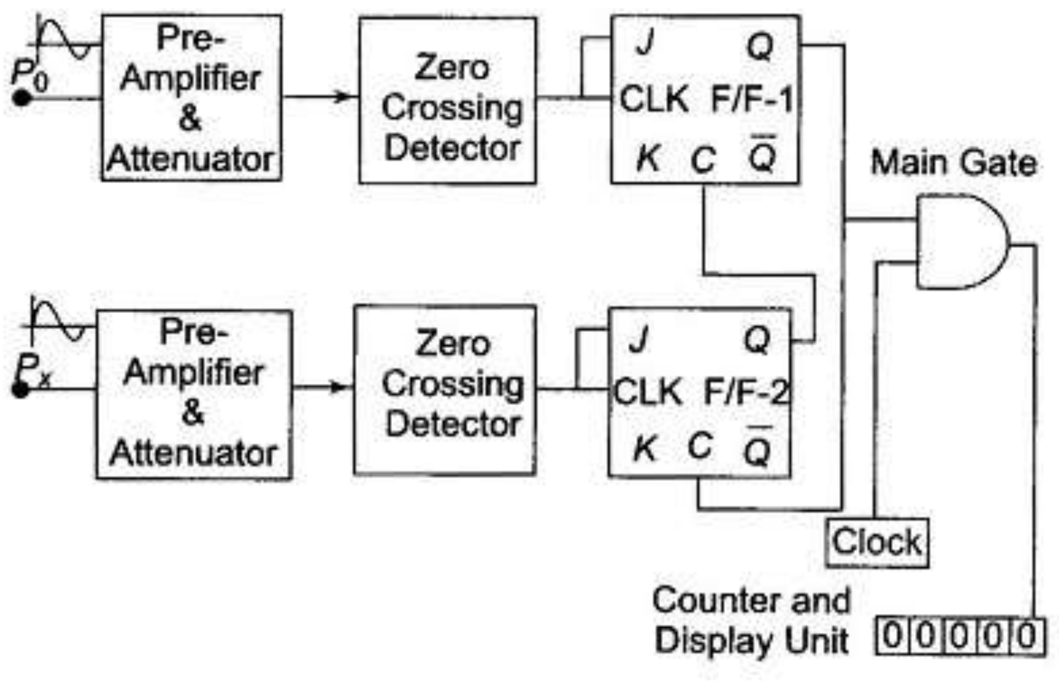


Fig. 6.26 Digital Phase Meter

- The block diagram of Digital Phase Meter consists of two pairs of preamplifier's, zero crossing detectors, J-K F/Fs, and a single control gate. Two signals having phases Po and Px respectively are applied as inputs to the preamplifier and attenuation circuit. The frequency of the two inputs is the same but their phases are different.

- As the Po input signal increases in the positive half cycle, the zero crossing detector changes its state when the input crosses zero (0) giving a high (1) level at the output. This causes the J-K F/F-1 to be set (1), that is, the output (Q) of F/F-1 goes high. This high output from the F/F-1 enables the AND gate, and pulses from the clock are fed directly to the counter
- The counter starts counting these pulses. Also this high output level of F/F-1 is applied to the clear input of F/F-2 which makes the output of the F/F-2 go to zero (0)

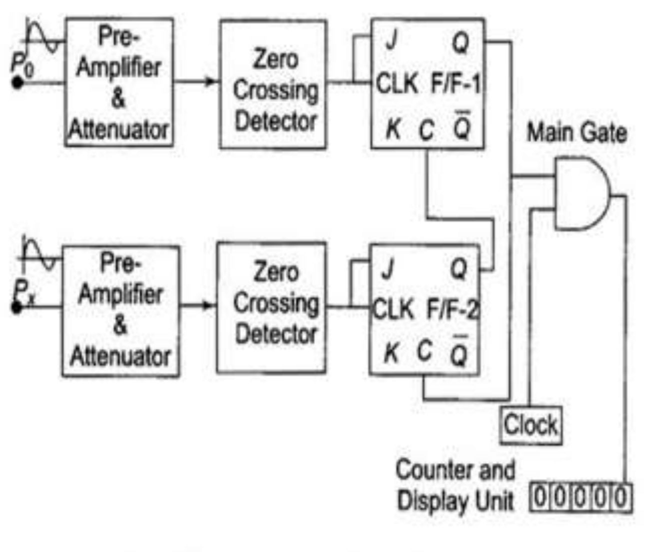


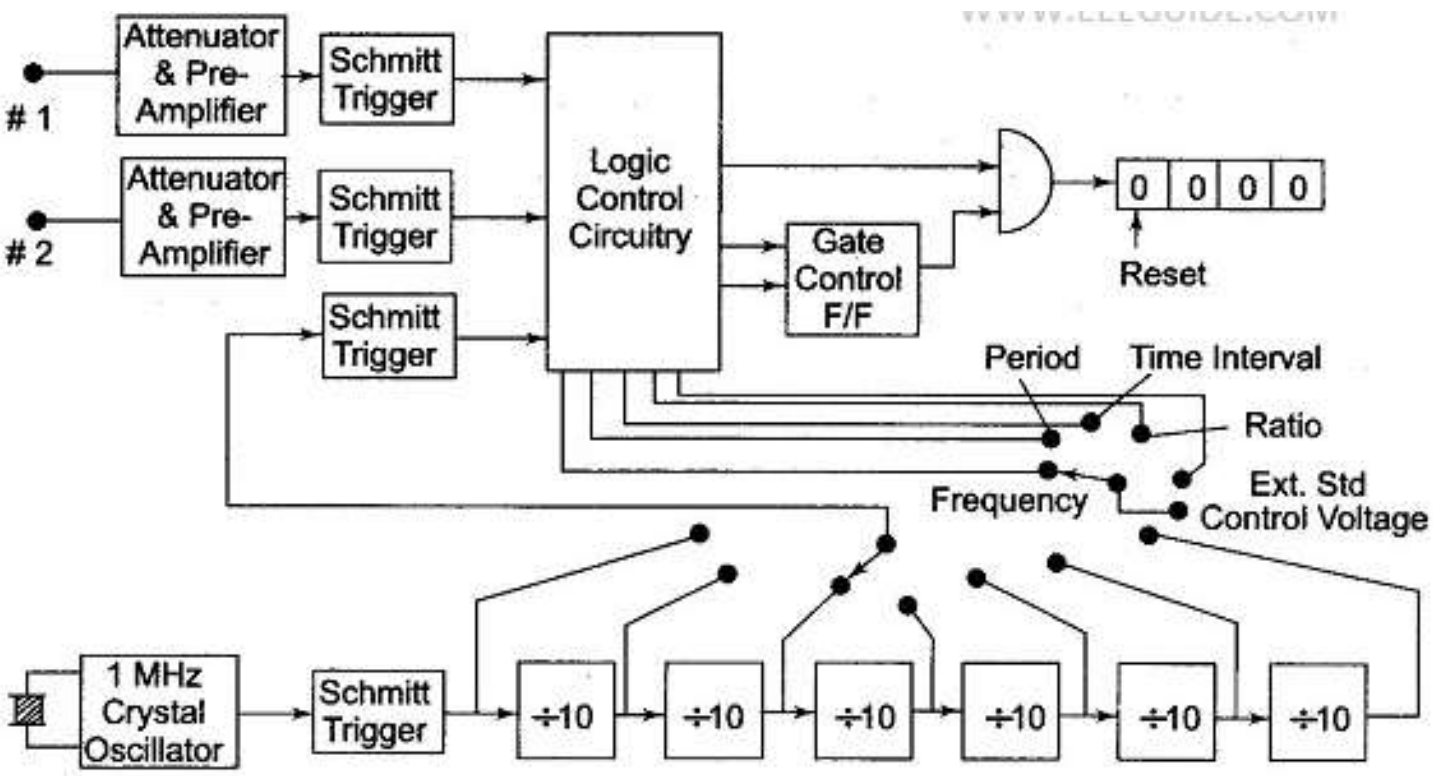
Fig. 6.26 Digital Phase Meter

- Now as the input Px which has a phase difference with respect to Po, crosses zero (0) in the positive half cycle, the zero detector is activated, causing its output to go high (1). This high input in turn toggles the J-K F/F-2, making its output go high
- This output (Q) of F/F-2 is connected to the clear input of F/F-1 forcing the F/F-1 to reset. Hence the output of F/F-1 goes to zero (0). The AND gate is thus disabled, and the counter stops counting
- The number of pulses counted while enabling and disabling the AND gate is in direct proportion to the phase difference, hence the display unit gives a direct readout of the phase difference between the two inputs having the same frequency f

Universal Counter (Timer)

❖ All measurements of time period and frequency by various circuits can be assembled together to form one complete block, called a Universal Counter Timer.

❖ The universal counter uses logic gates which are selected and controlled by a single front panel switch, known as the function switch. A simplified block diagram is shown in Fig.



- With the function switch in the frequency mode, a control voltage is applied to the specific logic gate circuitry. Hence, the input signal is connected to the counted signal channel of the main gate.
- The selected output from the time base dividers is simultaneously gated to the control F/F, which enables or disables the main gate. Both control paths are latched internally to allow them to operate only in proper sequence.
- When the function switch is on the period mode, the control voltage is connected to proper gates of the logic circuitry, which connects the time base signals to the counted signal channel of the main gate. At the same time the logic circuitry connects the input to the gate control for enabling or disabling the main gate.
- The other function switches, such as time interval ratio and external standards perform similar functions. The exact details of switching and control procedures vary from instrument to instrument.

Unit –III: Digital Display System

Different Types of Display Devices

Commonly used displays in the digital electronic field are as follows

1.Cathode ray tube (CRT)

2.Light emitting diode (LED)

3.Liquid crystal display (LCD)

4.Gas discharge plasma displays (Cold cathode displays or Nixies)

5.Electro-luminescent (EL) displays

6.Incandescent display

7.Bectrophoretic image displays (END)

8.Liquid vapour display (LVD)

Light Emitting Diode (LED)

- The Light Emitting Diodes, 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.

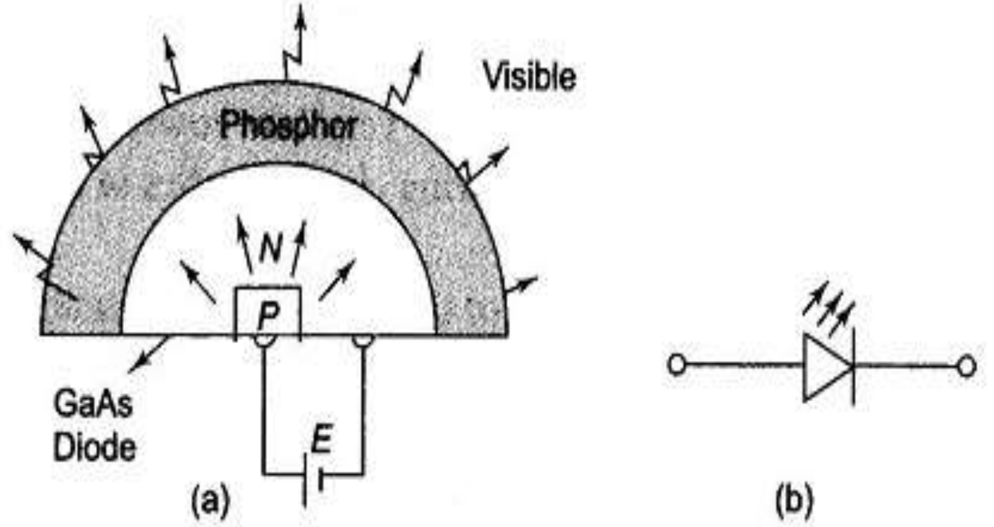


Fig. 2.10 (a) Structure of a Visible Emitter using GaAs PN Junction
(b) Symbol of LED

- 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.

The advantage of using LEDs in electronic displays are as follows

- Light Emitting Diodes are very small devices, and can be considered as point sources of They can therefore be stacked in a high-density matrix to serve as a **numeric** and **alphanumeric display**

- The light output from an LED is function of the current flowing through An LED can therefore, be smoothly controlled by varying the current. This is particularly useful for operating LED displays under different ambient lighting conditions

- 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

- LEDs are very fast devices, having a turn ON-OFF time of less than 1 ns

- The low supply voltage and current requirements of LEDs make them compatible with DTL and TTL, ICs.

- 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

- ✓ Gallium Arsenide (GaAs) — **Red**
- ✓ Gallium Arsenide Phosphide (GaAsP) — **Red** or **yellow**
- ✓ Gallium Phosphide (GaP) — **Red** or **Green**

Liquid Crystal Display (LCD)

- Liquid Crystal Display (LCD) are passive displays characterized by very low power consumption and good contrast ratio. They have the following characteristics in common
  - ✓ They are light scattering
  - ✓ They can operate in a **reflective** or **transmissive** configuration
  - ✓ They do not actively generate light and depend for their operation on ambient or back lighting
- A transmissive Liquid Crystal Display 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. Liquid Crystal Display operate at low voltages, ranging from 1-15 V
- The operation of liquid crystals is based on the utilization 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.

- 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

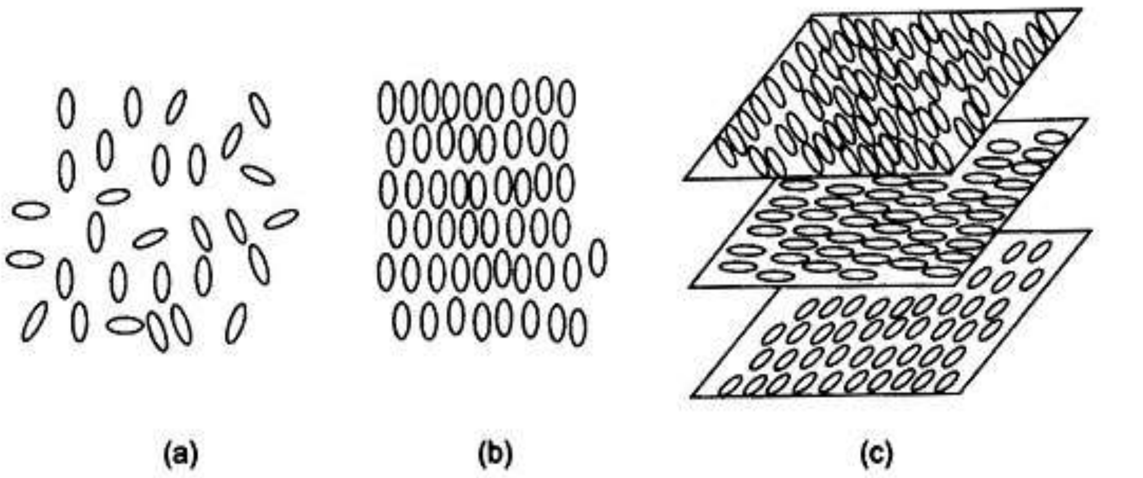


Fig. 2.11 Liquid Crystal Materials (a) Ordinary Liquids (b) Nematic Liquid Crystal (c) Cholesteric Liquid Crystal

- The removal of the applied field allows the crystals structure to reform and the material regains its transparency
- Basically, the Liquid Crystal Display comprises of a thin layer of **NLC fluid**, about 10μ 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

- 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

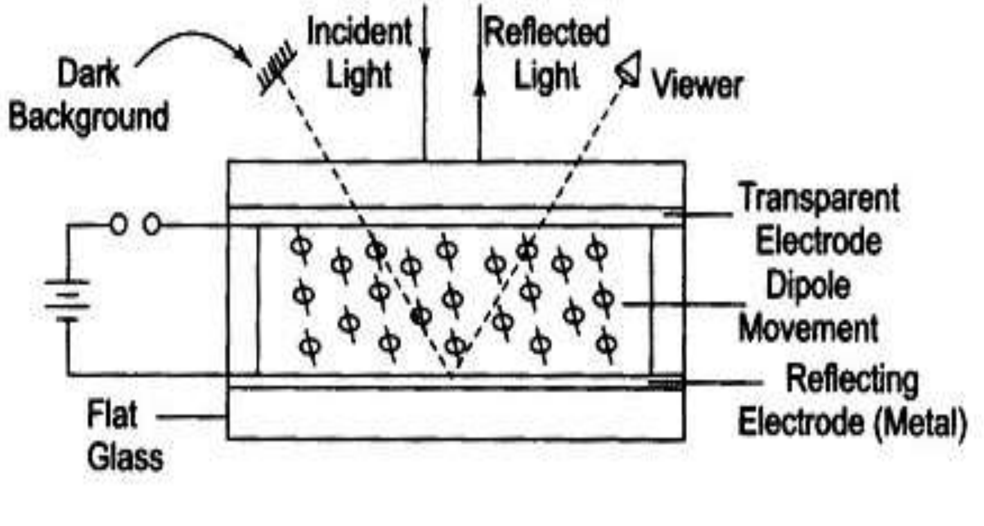


Fig. 2.12 Reflective Display Using NLC

- 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 multi segment pattern of characters and each segment of character is properly insulated from each other

Important Features of LCDs:

- ✓ The electric field required **to activate LCDs is typically of the order of 104 V/cm**. This is equivalent to an LCD terminal voltage of 10 V when the NLC layer is 10μ thick.
- ✓ NLC materials possess **high resistivity > 1010 Ω**. Therefore the current required for scattering light in an NLC is very marginal (typically 0.1 μA/cm2).
- ✓ 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.
- ✓ LCDs are **very slow devices**. They have a turn-on time of a **few milliseconds**, and a turn-off time of tens of milliseconds.
- ✓ 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.

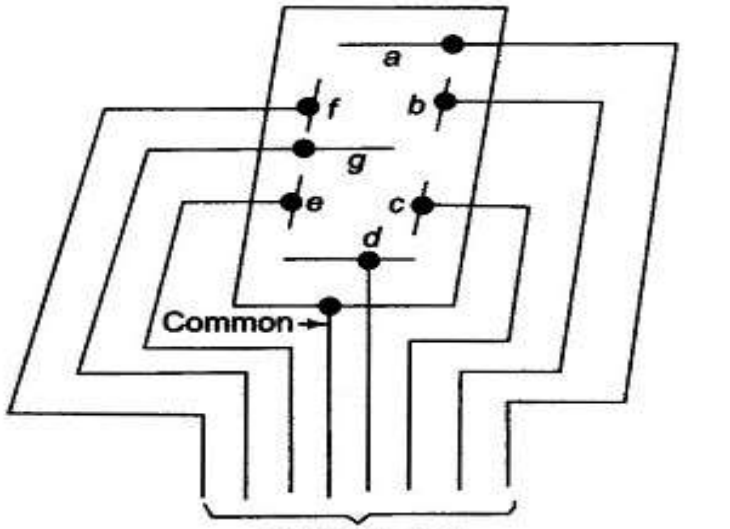


Fig. 2.13 Seven Segment LCD Character

Gas Discharge Plasma Display

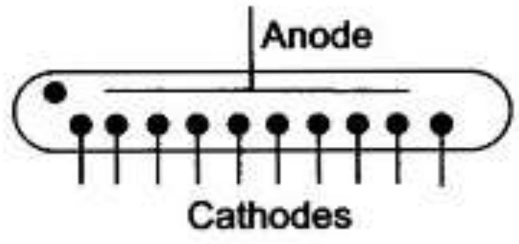


Fig. 2.14 Nixie Tube — Symbolic Representation

- These are the most well-known type of **alphanumeric Plasma Display**
- Their operation is based on the emission of light in a cold cathode gas filled tube under breakdown condition
- These cold cathode numerical indicators are called **Nixies** (Numicators and Numbertrons)
- This Nixie tube is a numeric indicator based on **glow discharge in cold cathode gas filled** tubes. It is essentially a multicathode tube filled with a gas such as **neon** and having a single anode, as shown in Fig.
- Each of the cathodes is made of a thin wire and is shaped in the form of characters to be displayed, for example, **numerals 0 to 9**. The anode is also in the form of a thin frame
- In its normal operation, the anode is returned to positive supply through a suitable current limiting resistor, the value of the supply being greater than the worst-case breakdown voltage of the gas within the tube
- The gas in the vicinity of the appropriate cathode glows when the cathode is switched to ground potential
- Since 10 cathodes have to be associated with a single anode inside the glass bulb, they have necessarily to be stacked in different planes. This requires different voltages for different cathodes to enable the glow discharge

- The standard Nixie is not the only format used with cold cathode technology—both **bar and dot matrix** versions are available

- The bar types have a cathode which forms the segment and operates in a fashion similar to the **standard neon tube**. Identical supply voltage and drivers are required

- In the dot type Plasma Display, each dot is in matrix fashion and operates as an individual glow discharge light source

- The required dots are selected by an **X-Y addressing array** of thin film metal lines, as shown in Fig

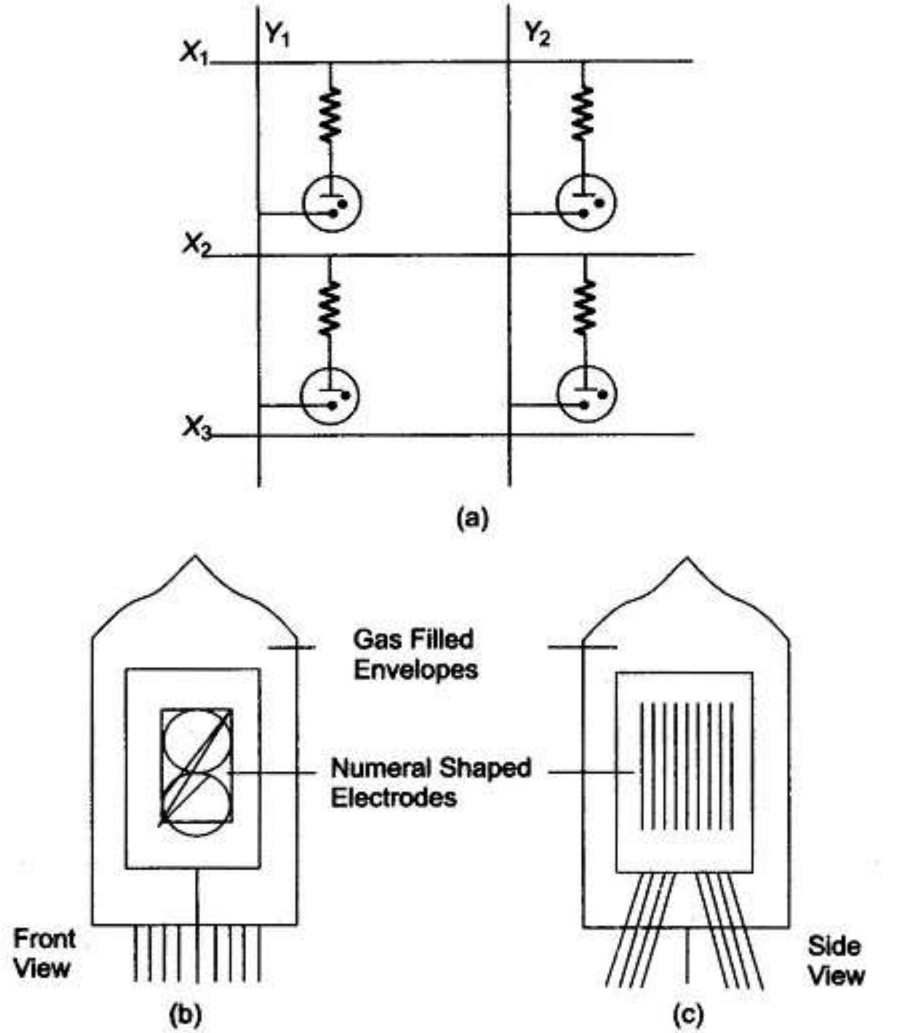


Fig. 2.15 (a) Matrix Operation of Display Panel Using Gas Filled Devices (b) and (c) Nixie Tube

Nixie tubes have the following important characteristics.

- The numerals are usually **large, typically 15-30 mm high**, and appear in the same base line for in-line read-out
- Nixie tube are single digit devices with or without a decimal point
- Most Nixie tube require **dc supply of 150-220 V**, and the selected cathode carries **current in the range of 1-5 mA**
- The Nixie tube can be **pulse operated** and hence can be used in multiplexed Plasma Display
- Alphabetical symbols can also be introduced in the Nixie tube

UNIT – III- a: Signal Generators

Basic Standard Signal Generator(sine Wave)

- The sine wave generator represents the largest single category of signal generator. This instrument covers a frequency range from a few Hertz to many Giga-Hertz. The sine wave generator in its simplest form is given in Fig. 8.1.

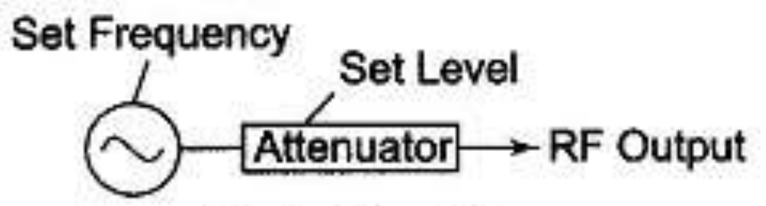


Fig. 8.1 Basic Sine Wave Generator

- The simple sine wave generator consists of two basic blocks, an oscillator and an attenuator. The performance of the generator depends on the success of these two main parts. The accuracy of the frequency, stability, and freedom from distortion depend on the design of the oscillator, while the amplitude depends on the design of the attenuator.

Standard Signal Generator

A standard signal generator produces **known** and **controllable voltages**. It is used as power source for the measurement of gain, signal to noise ratio (S/N), bandwidth, standing wave ratio and other properties. It is extensively used in the testing of radio receivers and transmitters.

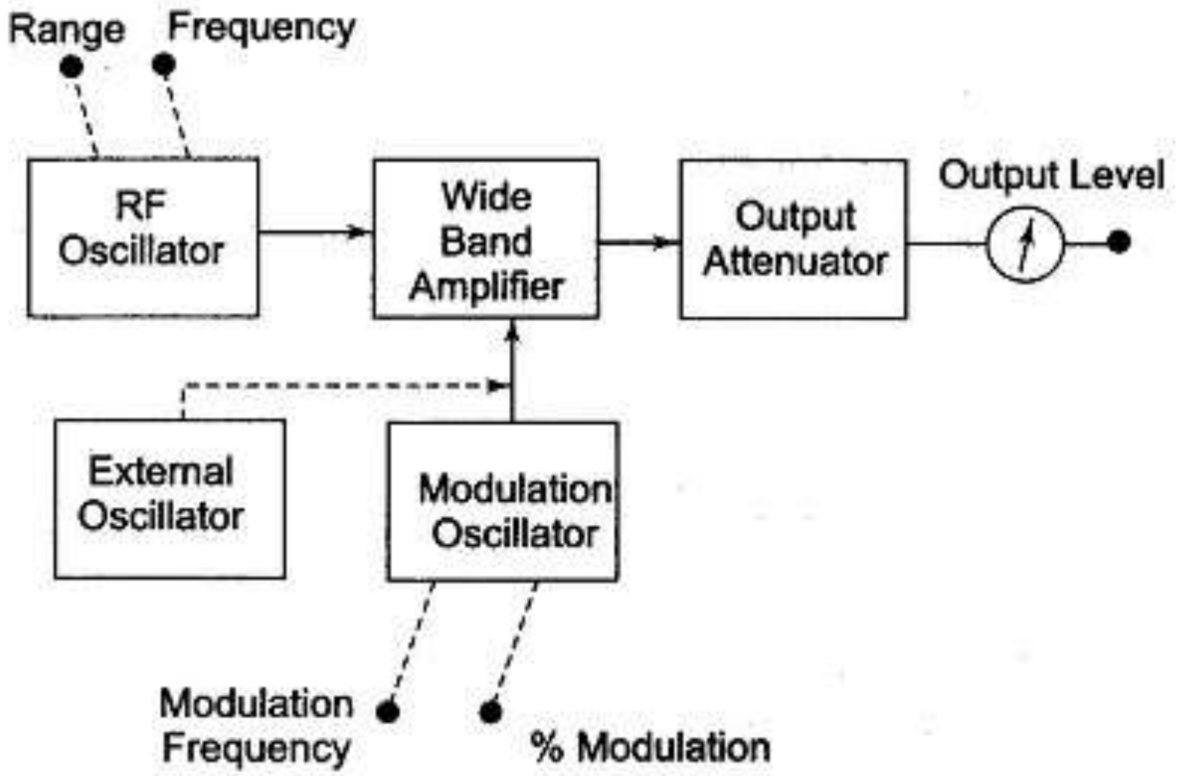


Fig. 8.2 (a) Conventional Standard Signal Generator

- The instrument is provided with modulating the carrier frequency and the modulation is indicated by a meter. The output signal can be Amplitude Modulated (AM) or Frequency Modulated (FM). Modulation may be done by a sine wave, square wave, triangular wave or a pulse. The elements of a conventional signal generator are shown in Fig.

- The carrier frequency is generated by a very stable RF oscillator using an LC tank circuit, having a constant output over any frequency range. The frequency of oscillations is indicated by the frequency range control and the vernier dial setting.

- Frequency stability is limited by the LC tank circuit design of the master oscillator. Since range switching is usually accomplished by selecting appropriate capacitors, any change in frequency range upsets the circuit design to some extent and the instrument must be given time to stabilise at the new resonant frequency.

- In high frequency oscillators, it is essential to isolate the oscillator circuit from the output circuit. This isolation is necessary, so that changes occurring in the output circuit do not affect the oscillator frequency, amplitude and distortion characteristics. Buffer amplifiers are used for this purpose.

Modern Laboratory Signal Generator

Modern Laboratory Signal Generator – To improve the frequency stability, a single master oscillator is optimally designed for the highest frequency range and frequency dividers are switched in to produce lower ranges. In this manner the stability of the top range is imparted to all the lower ranges.

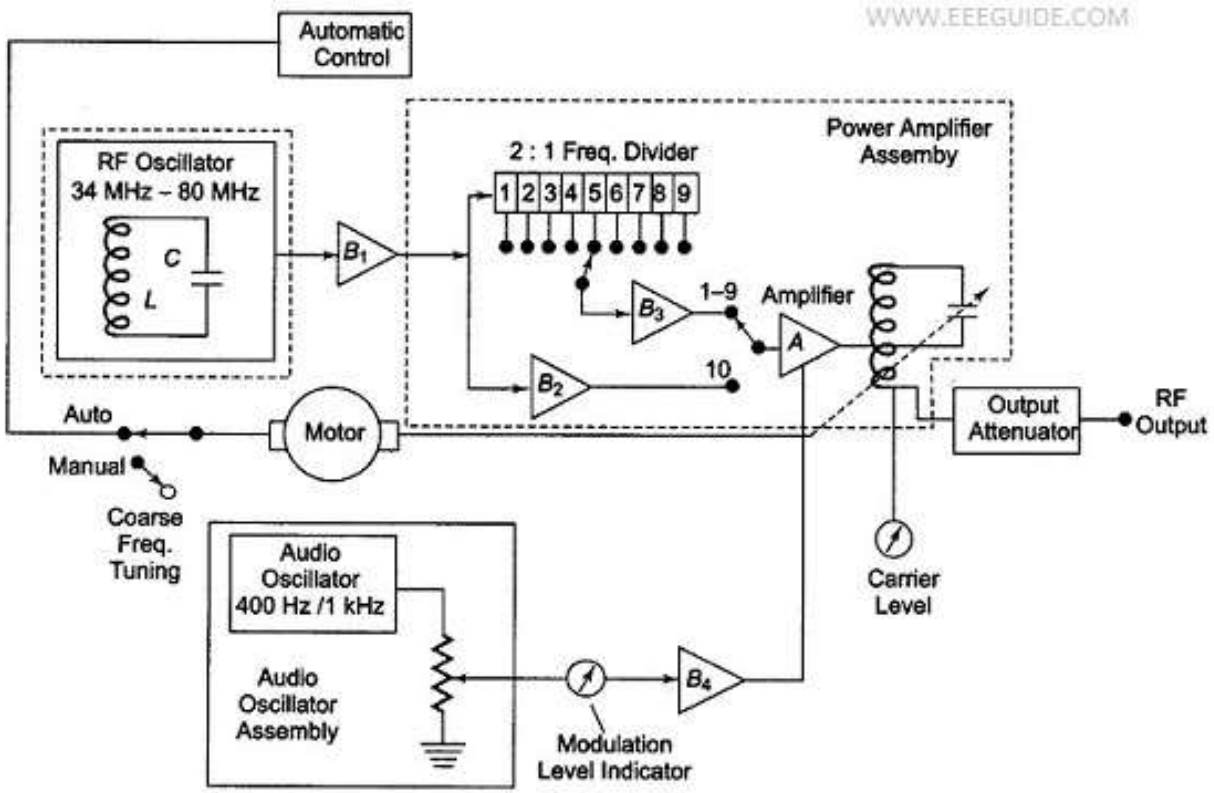


Fig. 8.3 Modern Signal Generator

- The master oscillator is made insensitive to temperature variations and also to the influence of the succeeding stages by careful circuit design. Temperature compensation devices are used for any temperature changes.

- The highest frequency range of 34 — 80 MHz, is passed through B1, an untuned buffer amplifier. B2 and B3 are additional buffer amplifiers and A is the main amplifier.

- The lowest frequency range produced by the cascaded frequency divider (9 frequency dividers of 2:1 ratio are used), is the highest frequency range divided by 512, or 29, or 67 — 156 kHz. Thus, the frequency stability of the highest range is imparted to the lower frequency ranges.

- The use of buffer amplifiers provides a very high degree of isolation between the master oscillator and the power amplifier, and almost eliminates all the frequency effects (distortion) between the input and output circuits, caused by loading.

- Range switching effects are also eliminated, since the same oscillator is used on all bands. The master oscillator is tuned by a motor driven variable capacitor. The oscillator can be fine tuned by means of a large rotary switch (control), with each division corresponding to 0.01% of the main dial setting.

- The master oscillator has both automatic and manual controllers. The availability of the motor driven frequency control is employed for programmable automatic frequency control devices.

- Internal calibration is provided by the 1 MHz crystal oscillator. The supply voltage of the master oscillator is regulated by a temperature compensated reference circuit.

- The modulation is done at the power amplifier stage. For modulation, two internally generated signals are used, that is, 400 Hz and 1 kHz.

- The modulation level may be adjusted up to 95% by a control device. Flip-flops can be used as frequency dividers to get a ratio of 2:1.

AF Sine and Square Wave Generator

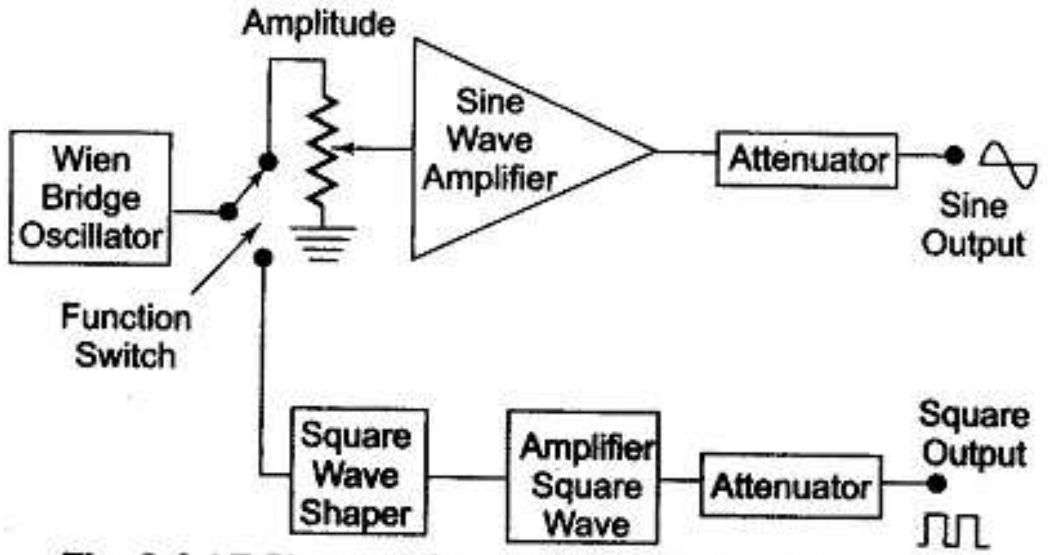


Fig. 8.4 AF Sine and Square Wave Generator

- The signal generator is called an oscillator. A Wien bridge oscillator is used in this generator. The Wien bridge oscillator is the best for the audio frequency range. The frequency of oscillations can be changed by varying the capacitance in the oscillator. The frequency can also be changed in steps by switching in resistors of different values.

- The output of the Wien bridge oscillator goes to the function switch. The function switch directs the oscillator output either to the sine wave amplifier or to the square wave shaper. At the output, we get either a square or sine wave. The output is varied by means of an attenuator.

- The instrument generates a frequency ranging from 10 Hz to 1 MHz, continuously variable in 5 decades with overlapping ranges.

- The output sine wave amplitude can be varied from 5 mV to 5 V (rms). The output is taken through a push-pull amplifier. For low output, the impedance is 600Ω.

- The square wave amplitudes can be varied from 0 — 20 V (peak). It is possible to adjust the symmetry of the square wave from 30 — 70%. The instrument requires only 7 W of power at 220 V — 50 Hz.