UNIT 13 ELECTRONIC INSTRUMENTS

Structure

13.1 INTRODUCTION

As you are aware, in practical applications of a system, we typically encounter a situation as shown in Fig. 13.1. In study of Signal Processing Circuits we assume that we have the

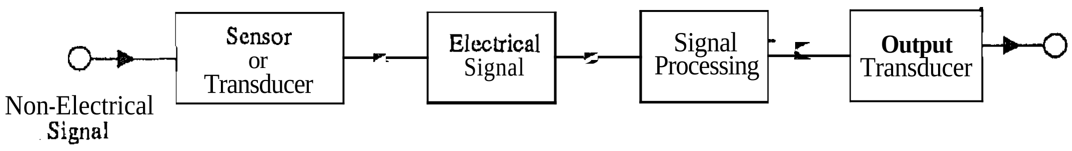


Fig. 13.1: Situation encountered in practical applications of a system.

desired electrical signal and do not worry about input sensor. The performance of a circuit is displayed on an instrument which can be seen by us. The signals of different shapes and time duration are provided by signal generators and a general purpose oscilloscope is used to display them.

We know that all circuits are made up of some active components like transistors, FET, MOSFET etc. and passive components like resistors, inductors & capacitors. To measure values of passive components, we use multimeter, bridges (for L&C) etc. In this unit, we will be studying Electronic Voltmeter (EVM), which is a more sensitive and hence accurate instrument as compared to Multimeter. EVM can also be used for very low current measurements by using a standard resistance. The power consumed by these circuits is of vital importance and hence we will also study the power meter. While studying the construction of power meter, we will see that the necessary torque required for meter movement is generated with the help of interaction of magnetic field and current and hence we will also discuss the art of measurement of magnetic field.

Objectives

After going through this unit, you will be able to understand

- basic construction, working and some of the applications of Oscilloscope,
- generation of various shapes of signals,

- accurate measurement of voltage using Electronic voltmeter,
- measurement of power, and
- measurement of magnetic field.

13.2 CATHODE RAY OSCILLOSCOPE

The cathode ray oscilloscope, generally referred to as the oscilloscope or simple "scope", is probably the most versatile electrical measuring instrument available. Some of the electrical parameters that can be observed with the oscilloscope are ac or dc voltage, indirect measurement of ac or dc current, time, phase relationships, frequency, and a wide range of waveform evaluations such as rise time, fall time, ringing, and overshoot. The oscilloscope consists of the following major subsystems:

- Cathode ray tube or CRT
- Vertical amplifier
- Horizontal amplifier
- Sweep generator
- Trigger circuit
- Associated power supplies

The heart of the instrument is the cathode ray tube. The remaining sub-systems are necessary for signal conditioning so that a visual representation of the input signal will be displayed on the face of the CRT.

13.2.1 Cathode Ray Tube (CRT)

The cathode ray tube used in an oscilloscope is very similar to the picture tube in a television set. A cross sectional representation of a CRT is shown in Fig.13.2. Major components of a general purpose CRT are:

- Evacuated glass envelope
- Electron gun assembly
- Deflection plate assembly
- Phosphor coated screen

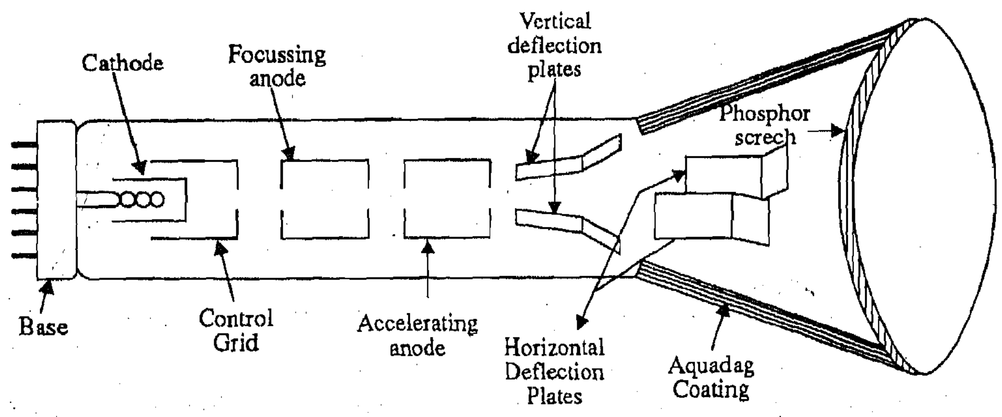


Fig.13.2 : Cathode ray tube with major components identified.

The glass envelope is evacuated to a fairly high vacuum to permit the electron beam to traverse the tube easily. Most laboratory quality oscilloscopes use a CRT which has circular screen approximately 5 inch in diameter. All electrical connections except the high-voltage connection are made through the base of the CRT.

The electron gun assembly consists of an indirectly heated cathode and the necessary heater, a control grid, focussing anode and accelerating anode. The purpose of the electron gun assembly is to provide a source of electrons, converged and focussed into a well-defined beam, which is accelerated towards the fluorescent screen. The electrons that make up the beam are given off by thermionic emission from the heated cathode. The cathode is surrounded by a cylindrical cap that is at a negative potential. This acts as a control grid. Because the control grid is at negative potential, electrons are repelled away from the cylinder walls and, therefore, stream through the hole where they move into the electric field of the focussing and accelerating anodes. The magnitude of the accelerating field is given by

$$E = \frac{V_a}{d}$$

where, V_a = accelerating anode voltage and d = distance between the cathode and second anode measured in meters. When electrons enter the electric field, which is assumed to be of uniform intensity, a force will be exerted on the electrons that will accelerate them along the axis of the tube. The magnitude of the force is given by

$$F = EQ = ma \Rightarrow a = \frac{EQ}{m}$$

where E = electric field intensity and Q = electronic charge = 1.6×10^{-19} C, m = mass of electrons, a = acceleration produced due to electric field. Using tlie expression for electric field in above equation, we obtain

$$a = \frac{V_a Q}{dm}$$

During the period of acceleration, the electrons are gaining kinetic energy as they gain velocities. If v is the velocity acquired then, .

$$\frac{1}{2} mv^2 = V_a Q \Rightarrow v = \sqrt{\frac{2V_a Q}{m}}$$

After the electrons leave the electron gun assembly at a speed given by above mentioned equation, they enter and pass through a region controlled by the deflection plates. One pair of plates control the vertical motion of the beam while the other pair controls the longitudinal component of the electron velocity. The deflection plates are described by two geometric parameters of length (L) of the plates and the plate separation (d). The deflecting action of the plates is dependent on the intensity of the electric field (E_d) between the plates given by

$$E_d = \frac{V_d}{d}$$

where V_d = magnitude of the deflecting voltage. This field will exert a force = $E_d Q$ on the electrons, deviating the beam from a straight line trajectory,

$$F_d = E_d Q = \frac{V_d}{d} Q = ma_y$$

$$\Rightarrow \quad a_y = \frac{V_d Q}{md} = \text{Acceleration along } y-\text{axis}$$

It can be shown that the lateral distance travelled by electron is given by

$$h = \frac{V_d Q t^2}{2dm}$$

where t = time required for electrons to pass through the plates is given by

$$t = \frac{L}{v}$$

Here v is the velocity of electrons when it comes out of electron gun assembly.

Combining these equations, we get

$$h = \frac{L^2 V_d}{4 V_a d}$$

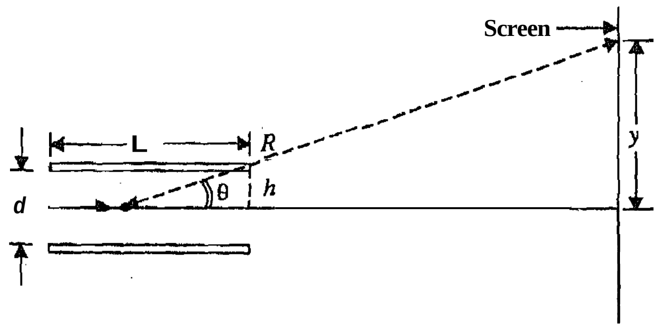


Fig.13.3 : Deflection of electron beam in CRT.

From Fig. **13.3**

$$\theta = \frac{h}{L/2} = \frac{2h}{L} = \frac{y}{R}$$

$$\Rightarrow y = \frac{2hR}{L}$$

$$= \frac{RLV_d}{2V_a d}$$

$$\Rightarrow \frac{V_d}{y} = \frac{2V_a d}{RL}$$

The term $\frac{V_d}{y}$ is referred to as "deflection sensitivity" and is defined as voltage required per unit deflection. When the electron beam strikes the phosphor-coated face of the CRT, a spot of light is produced due to "fluorescence" as phosphor is a florescent material. The high velocity electrons that strike the phosphor coated face of the CRT are either repelled by the collision or cause secondary emission of electrons to maintain electrical equilibrium of the screen. To provide return path to ground for these electrons, the inside surface of the CRT is coated with graphite called "aquadag".

13.2.2 The Basic Oscilloscope

The CRT and the associated controls for accelerating, deflecting and focussing the electron beam, permit us to obtain a lighted spot on the screen. To be of practical use as a measuring instrument, we must connect additional electronic circuitary to the CRT to provide a means of very fast deflection and control of the electron beam. The purpose of the electronic circuits is to cause the beam to trace on the CRT screen a reproduction of the signal we apply to the input terminals of the oscilloscope. A block diagram of a basic oscilloscope is shown in Fig. 13.4(a).

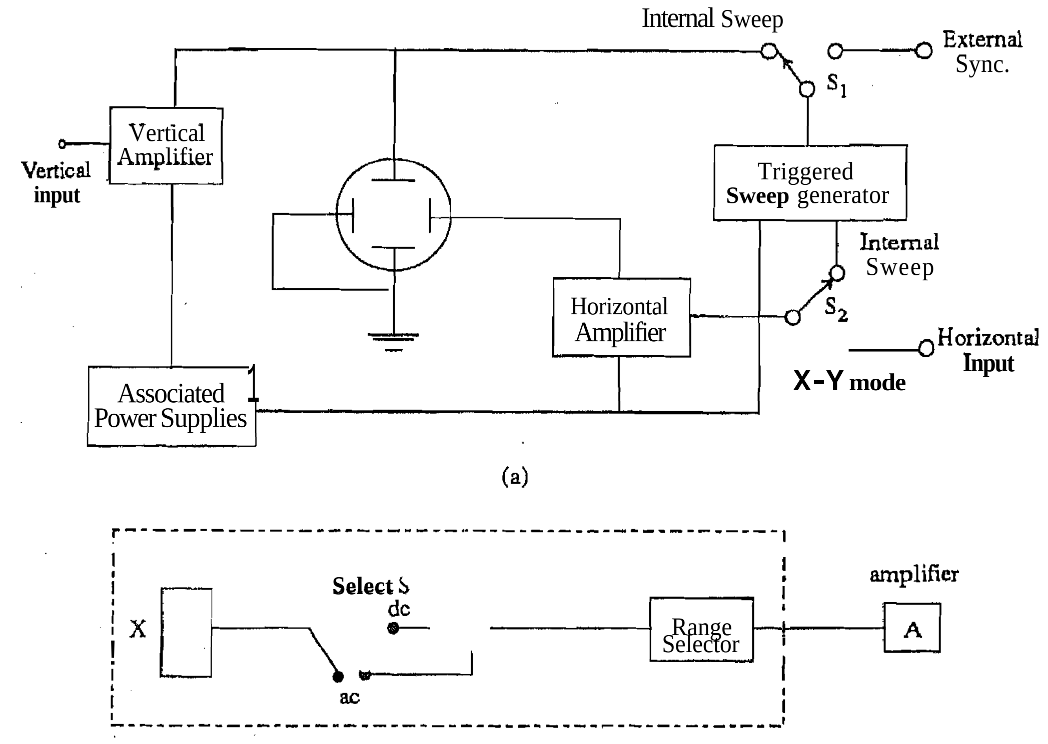


Fig.13.4 : (a) Block diagram **of a basic cathode ray oscilloscope (b) Input to amplifier of vertical plate.**

A signal to be displayed on the CRT screen is applied to the vertical input terminal where it is fed into the vertical amplifier. The signal is amplified and applied to the vertical deflection plates, which causes the beam to be deflected in the vertical plane.

Input to **the Amplifier** of **Vertical Plate**

The external signal is applied to the terminal marked x-input as shown in Fig. 13.4 **(b).** The select switch is put on the position ac or dc depending on the signal we are measuring. The input amplifier to the y-plate is normally calibrated for a standard input range of amplifier **A.** For higher voltage measurement we have a range selector which basically attenuates the signal to the desired input at **A** (we have already studied filters and ottenuators).

Input to the Amplifier of Horizontal **Plate**

As can be seen in Fig. 13.4 (a), the output of the vertical amplifier is connected to the internal sync position of switch S_1. With the switch set to internal sync, as it is for normal operation of the oscilloscope, the output of the vertical amplifier is applied to the sweep generator. The input voltage waveform irrespective af shape at a particular value triggers the switch, which' creates pulses and these pulses are then fed to the Sawtooth generator circuit and that provides the ramp signal. This signal triggers the sweep generator as shown in Fig. 13.5.

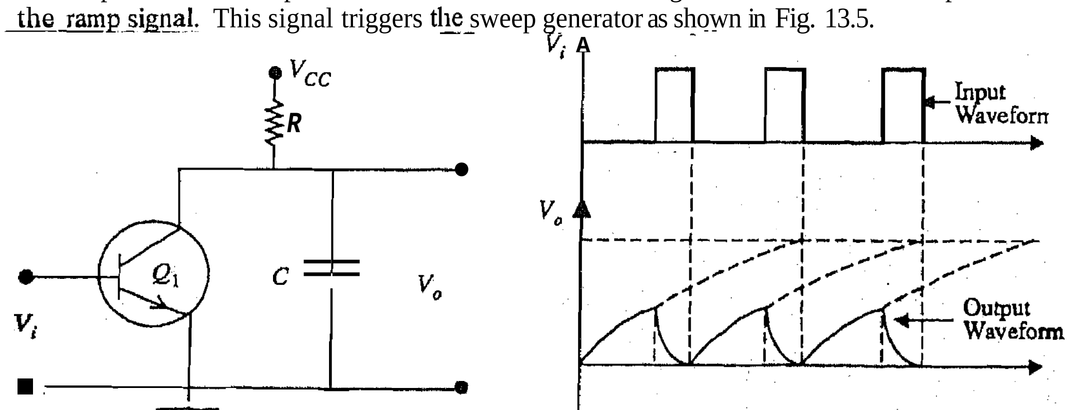


Fig.13.5 : Simple sawtooth generator and associated waveforms.

The purpose of sweep generator is to develop a voltage at the horizontal deflection plate that increases linearly with time. This linearly increasing voltage, called a 'ramp-stage' or a 'Sawtooth waveform', causes the beam to be deflected equal distances horizontally per unit time. The pulse for sawtooth generation can also be given by external source to which the input is synchronized (the sawtooth signal at the x-plate is generated at the same time the wave form at y-plate starts). Normally we use oscilloscope in internal synchronization mode. The horizontal amplifier serves to amplify the signal at its input prior to the signal being applied to the horizontal deflection plate.

The function of switch S_2, is to either generate sawtooth wave in x-plate, or put a direct signal to the x-plate of the oscilloscope. The sine wave from two oscillators can be introduced in x and y-plates of oscilloscope to get Lissajous figures, which allows measurement of frequency. The input signal to the horizontal amplifier depends on the position to which switch S_2 is set.

13.2.3 Laboratory Oscilloscopes

(i) Dual-trace Oscilloscope

A dual trace is obtained by electronically switching the single electron beam. Fig. 13.6 shows a block diagram of the two vertical input channels and the electronic switch that alternately connects the two input channels to the vertical amplifier. There are generally at least four modes of operation with dual-trace oscilloscopes; they are labeled **A,** B,

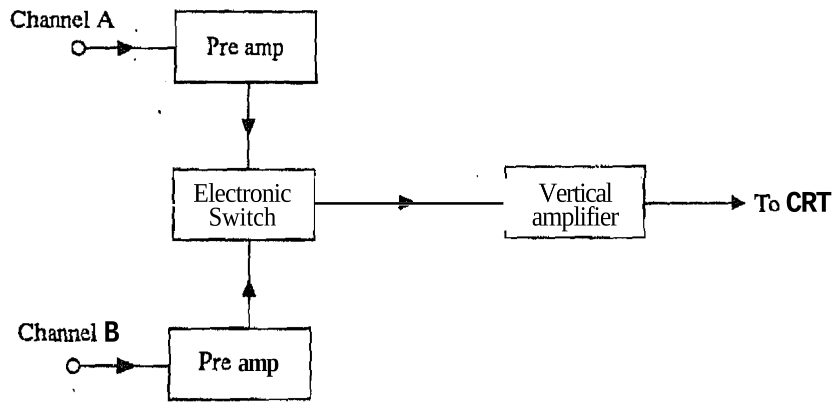


Fig.13.6 : Block diagram of the input channels of a dual trace oscilloscope.

alternate, and chopped. When set to **A** or B, only the input at that channel is displayed. In the alternate mode the inputs are displayed on alternate traces. Since the switching rate is synchronised with the sweep generator, switching occurs at the same rate as the output of the sweep generator. The "alternate mode" of operation is generally preferred when displaying relatively high-frequency signals. In the "chopped mode", electronic switching occurs at a rate completely independent of the sweep rate, and therefore each display has portions missing during which time the other signals is being displayed. The chopped mode is normally used at low sweep rates when the alternate mode would provide a display with appreciable flicker.

(ii) Storage Oscilloscope

There are many oscilloscope applications where the limited persistence of the CRT phosphor makes real time observation of one-time events nearly impossible. Although such events can be recorded photographically, this may prove to be fairly expensive and time consuming. The storage oscilloscope makes it possible to retain a CRT display for an extended period of time. The storage CRT uses two electron guns, the usual electron gun called a writing gun and a flood gun which uniformly bombards the entire CRT screen with low-energy electrons. The phosphor particles struck by these low energy electrons takes on a fairly low-level charge; however, unenergised particles remains in a no-change condition. When a trace is to be iecorded, the writing gun is turned on and high energy electrons strike the screen forming an image. The screen is erased by grounding the phosphor screen, which removes excess charge.

13.2.4 Measurement of Voltage, Current and Time

The range of applications of oscilloscopes varies from basic voltage, time, frequency measurements and wave form observations to highly specialised applications in all areas of science, engineering and technology.

Voltage measurements

The most direct voltage measurement made with an oscilloscope is the peak-to-peak value. The rms value of the voltage can easily be calculated from the peak-to-peak measurements if desired. To arrive at a voltage value from the CRT display, one must observe the setting of the vertical attenuator, expressed in volts/div, and the peak-to-peak deflection of the beam. The peak-to-peak value of the voltage is then computed as (see Fig. 13.7)

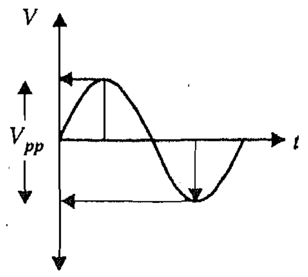


Fig. 13.7 : Voltage measurement.

$$V_{P\text{-}P} = \left(\frac{\text{volts}}{\text{div}}\right) \times \text{no. of div}$$

This can be easily explained with the example 13.1,

Example **13.1**

Let the waveform shown in Fig. 13.8 is observed on the screen of an oscilloscope. If the vertical attenuator is set to 0.5 volts/div, find the peak to peak amaplitude of the signal.

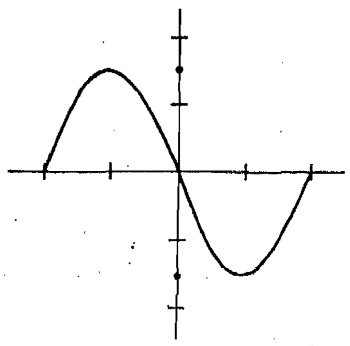


Fig.13.8

Solution :

$$V_{p-p} = \frac{\text{volts}}{\text{div}} \times \text{no. of div}$$
$$= \frac{0.5\text{v}}{\text{div}} \times 3\text{div}$$
$$= 1.5 \text{ V}$$

Period **and** Frequency Measurements

The period and frequency of periodic signals are easily measured with the oscilloscope. The waveform must be displayed in such a manner that one complete cycle is displayed on the CRT screen. Accuracy is generally improved if the single cycle displayed fills as much of the horizontal distance across the screen as possible. The period is calculated as follows:

$$T = \left(\frac{\text{time}}{\text{div}}\right)\left(\frac{\text{no,of div}}{\text{cycle}}\right)$$

The frequency is then computed as the reciprocal of the period.

$$f = \frac{1}{T}$$

13.2.5 Digital and Storage Oscilloscope

The storage oscilloscope described in earlier section are quite expensive and are now being replaced by digital oscilloscope. In these oscilloscope the signal on screen is sampled and digitized. The amplitude and time base per cm are displayed in numbers at a corner of the screen. The digitized signal can be put into a memory (like computer memory) and recalled (D/A converter) to display when desired. Thus they also serve as storage oscilloscope.

SAQ 1

Draw a pictorial representation of a general purpose CRT and label the components by name.

SAQ 2

Describe the basic principle of operation of dual-trace/storage oscilloscope.

SAQ 3

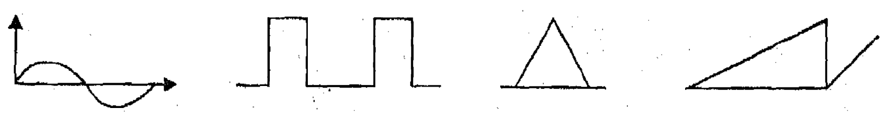
If the time/div control is set to 2μs/div and the displayed signal covers 4 div on the horizontal scale of the CRT screen, determine the frequency of the signal.

SAQ 4

Explain the principle of Digital Oscilloscope.

13.3 SIGNAL GENERATORS

A signal source is a vital component at a test set up. Signal sources provide a variety of waveforms for testing electronic circuits, usually at low power,' A function generator is an instrument that provides variety of output waveforms over a wide range of frequency. The most common output waveforms are Sine, pulse, triangular, ramp. The frequency range generally extends from a fraction of a Hertz to atleast several hundred kilohertz. The different wave shapes are given in Fig. 13.9.



Pig. 13.9 : Different shapes of wave form. (a) Sinusoidal **(b) Rectangular (c)** Triangular (d) Ramp.

Definition of **rise** time (T_r): Time taken by the signal to rise from 10% to 90% of the maximum value of the signal is called rise time.

Fall time (T_f): Time taken by the signal to fall from 90% to 10% of the maximum value of the signal is called fall time.

There are several circuits to provide such waveforms individually. For example, you are aware that an LC oscillator can provide sine wave while multivibralor can provide pulses. I-Iowever, by starting from any particular waveform we can with proper circuitary, generate other waveforms. In a function generator, a simple instrument is capable of providing different types of waveform. The most commonly used circuit is described below.

Function generator:

The primary waveform in the circuit shown is a square wave. This is because some square wave generator circuits offer significantly better amplitude and frequency stability characteristics with simpler circuits than sine wave generating circuits.

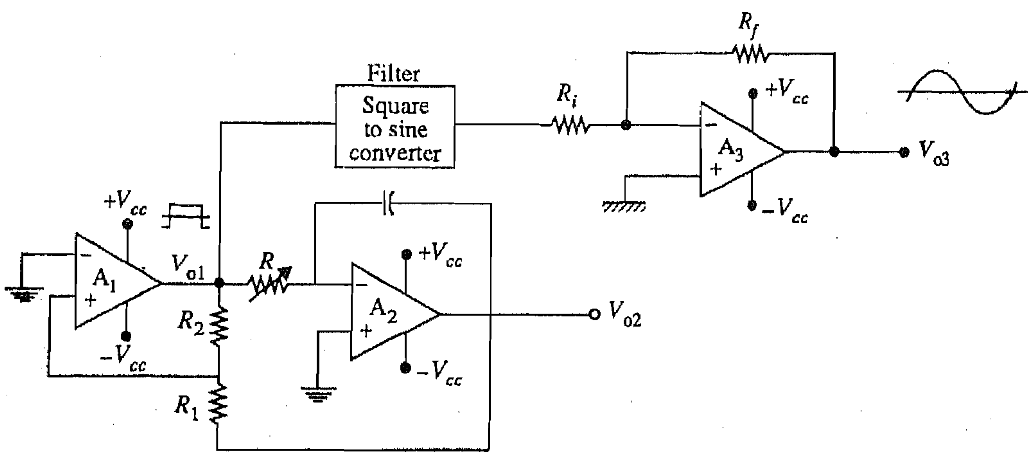


Fig.13.10 : Circuit of a basic function generator.

Working of the Circuit

The first stage A_1, which is a voltage comparator, generates a square wave output V_{01}. The output of A_1 is driven to saturation; therefore the square wave is either at $+V_{CC}$ or $-V_{CC}$ as shown in Fig. 13.11. The second stage, A_2, is an integrator that generates a **triangular** output at V_{02} as discussed later.

The square wave is also applied to a square-to-sine wave converter that filters out the odd harmonics making up the square-wave while passing only the fundamental sine wave. You will learn later that the square waves are produced by the combination of several sine waves, and by differentiation and integration we can convert pulses to triangular waves and vice-versa.

The operation of the circuit can be analysed by starting at the output of the comparator, which is either $+V_{CC}$ or $-V_{CC}$. Consider V_{01} to be at $-V_{CC}$. The voltage V_{01} will remain at $-V_{CC}$ until the voltage at the inverting input of A_1 exceeds the voltage at the non-inverting input, which in this case is at zero volts, The non-inverting input voltage, V_x, is due, in part, to the voltage V_{01} and, in part, to the voltage V_{02} and is given by

$$V_x = -V_{CC}\left(\frac{R_1}{R_1 + R_2}\right) + V_{02}\left(\frac{R_2}{R_1 + R_2}\right)$$

The output V_{01} changes state when $V_x = 0$, therefore

$$0 = -V_{CC}\left(\frac{R_1}{R_1 + R_2}\right) + V_{02}\left(\frac{R_2}{R_1 + R_2}\right)$$

$$\Rightarrow V_{CC}R_1 = V_{02}R_2$$

$$\Rightarrow V_{02} = V_{CC}\left(\frac{R_1}{R_2}\right)$$

The above expression determines the maximum amplitude of the triangular output, V_{02}. When output V_{02} reaches peak value, the output of the comparator changes states and the triangular wave begins to decrease linearly. The waveforms at V_{01}, V_{02} and V_x are shown in Fig. 13.11 for the case where $R_1 = R_2$.

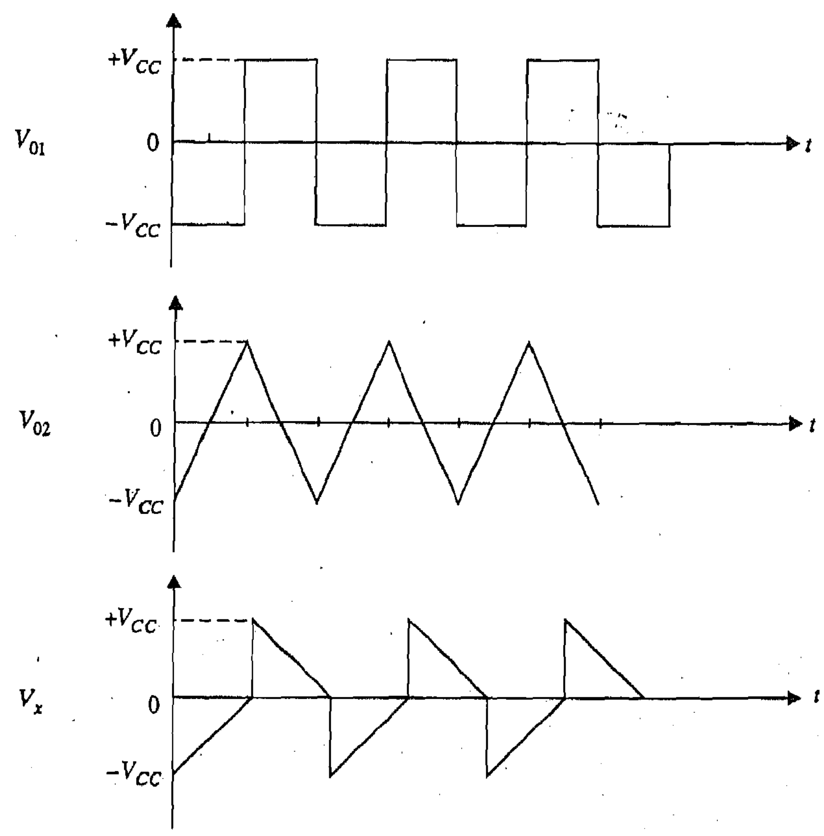


Fig.13.11 : Output waveforms for function generator.

The frequency of the circuit is controlled by the RC time constant of the integrator. To obtain an expression for the frequency, we begin with the expression relating capacitor current:

$$q = i_c t$$

$$\Rightarrow dq = i_c dt \Rightarrow i_c = \frac{dq}{dt}$$

Also, $q = CV_{02}$

$$\therefore i_c = \frac{d}{dt}(CV_{02}) = C\frac{dV_{02}}{dt}$$

Since the input resistance of the operational amplifier is very high, the current through resistor R is approximately equal to the charging current of the capacitor, therefore, we can write

$$i_R \approx i_c = C\frac{dV_{02}}{dt}$$

Also, since the voltage gain of the operational amplifier is very high, the voltage at the input of the amplifier is very nearly zero, therefore,

$$i_R = \frac{V_{01} - 0}{R} = C\frac{dV_{02}}{dt}$$

$$\Rightarrow dV_{02} = \frac{1}{RC}V_{01}dt$$

Integrating both sides,

$$\int dV_{02} = \frac{1}{RC}\int V_{01}\,dt = \frac{V_{01}}{RC}\times t$$

$$\Rightarrow V_{02} = \frac{V_{01}\times t}{RC}$$

We know,

$$V_{02} = V_{CC}\left(\frac{R_1}{R_2}\right)$$

$$\therefore V_{CC}\left(\frac{R_1}{R_2}\right) = \frac{V_{01}t}{RC}$$

$$\Rightarrow t = RC\left(\frac{R_1}{R_2}\right) \text{ as } V_{01} = V_{CC}$$

The above equation has been deduced assuming no initial charge and therefore no initial voltage on the capacitor. Therefore, the time t given above is the time for the capacitor to change from 0V until switching occurs, which is 1/4 cycle. Since $t = T/4$,

$$\therefore \frac{T}{4} = RC\left(\frac{R_1}{R_2}\right) \Rightarrow T = 4RC\left(\frac{R_1}{R_2}\right)$$

$$\therefore f = \frac{1}{T} = \frac{1}{4RC}\left(\frac{R_2}{R_1}\right)$$

Pulse Generators

Pulse generators are instruments that produce a rectangular waveform similar to a square wave but of different duty cycle. Duty cycle is defined as the ratio of the pulse width to the pulse period, expressed in percent.

$$\text{Duty cycle} = \frac{\text{Pulse width}}{\text{Pulse period}}\times 100$$

The duty cycle of a square wave is 50% whereas the duty cycle of a pulse is generally **from** approximately 5 to 95%.

The output of a stable multivibrator is a square wave. The duty cycle of the square wave **can** be varied by changing values of R and C.

SAQ 5

Describe the function generator.

SAQ 6

What is difference between a square wave and a pulse.

SAQ 7

Compute the frequency and the peak amplitude of the triangular output of the circuit shown in Fig 13.12.

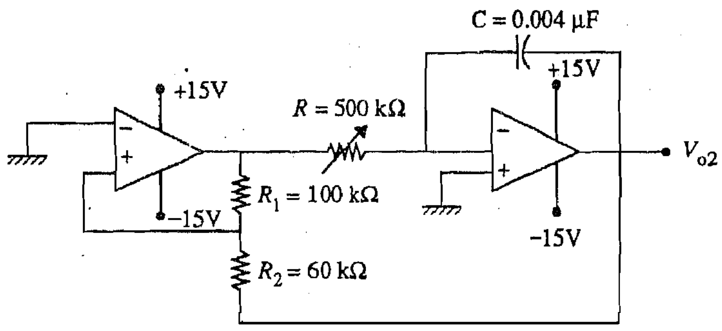


Fig. 13.13

13.4 ELECTRONIC VOLTMETER

Recall from class XII Physics course that the volt-ohm-milliarnmeter (VOM), is a rugged and accurate instrument, but suffers from certain disadvantages. The main problem is that it lacks both sensitivity and high input resistance. (A sensitivity of 20,000 Ω /V with a 0 to 0.5 V range has an input impedance of only 0.5×20,000 = 10 KR. The electronic voltmeter (EVM), on the other hand, can have an input resistance ranging from 10 to 100 MΩ, and input resistance will remain constant over all ranges instead of being different on each range as in the VOM. The EVM presents less loading to circuit under test than the VOM. The original EVMs used vacuum tubes, so they were called vacuum tube voltmeters (VTVM). With the introduction of the transistor and,other semiconductor devices, vacuum tubes are no longer used in these instruments. We will discuss below in detail the differential amplifier type of EVM.

The Differential-Amplifier type **of** EVM

The field effect transistors (FET) can be used to increase the input resistance of a dc voltmeter. Fig. 13.13 shows the schematic of a difference amplifier using field-effect transistor.

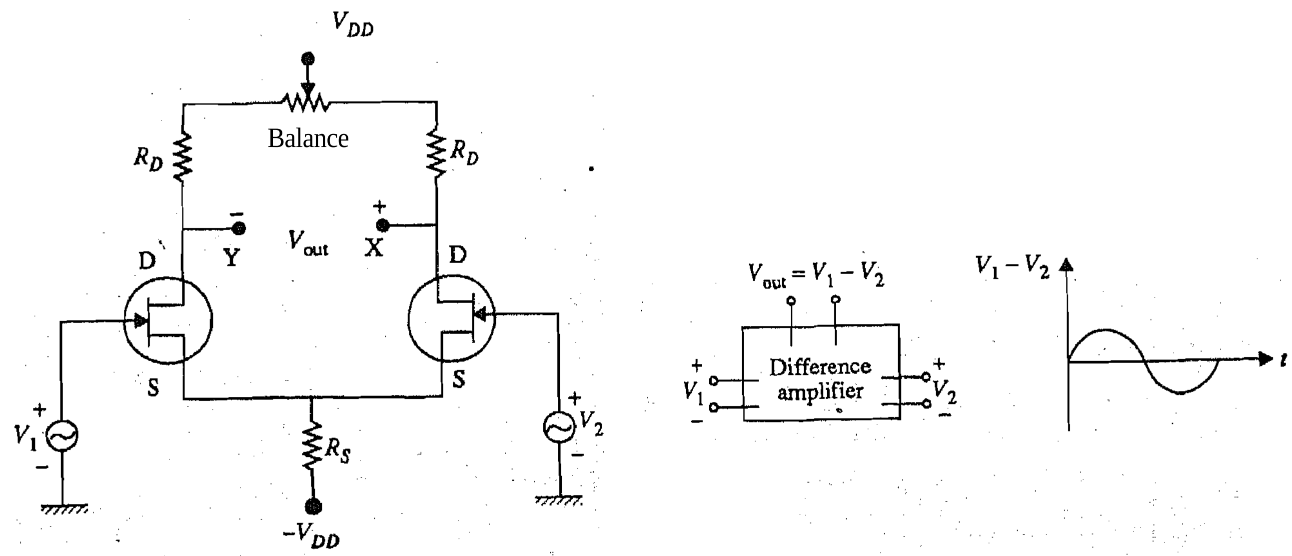


Fig.13.13 : Difference amplifier with balance adjustment.

This circuit also applies to a difference amplifier with bipolar junction transistors (BJTs). The circuit shown here consists of two FETs that should be reasonably matched for current gain to ensure thermal stability of the circuit. Therefore, an increase in source current in one FET is offset by a corresponding decrease in the source current of the other FET. The two FETs form the lower arms of the bridge circuit. Drain resistors R_D together form the upper arms. The meter movement is connected across the drain terminals of the FETs, representing two opposite corners of the bridge.

The circuit is balanced when identical FET's are used so that for a zero input there is no current through ammeter. If a positive dc voltage is applied to the gate of the left FET, a current will flow through the ammeter in the direction shown in Fig. 13.14.

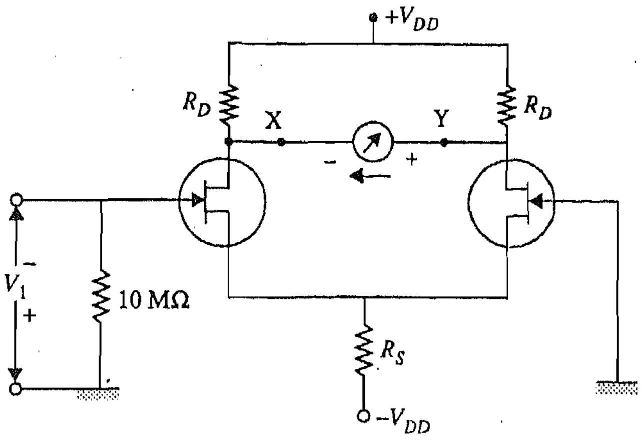


Fig.13.14 : The difference amplifier type EVM.

The size of the current depends on the magnitude of the input voltage. By properly designing the circuit, the ammeter current will be directly proportional to the dc voltage across the input. Thus, the ammeter can be calibrated in volts to indicate the input voltage.

By using Thevenin's theorem, we can find the relation between the ammeter current and the input dc voltage, where ammeter is considered as the load. To determine V_{Th}, we remove the ammeter and the output voltage is the voltage gain of a single FET times the difference of V_1 & V_2. Since V_2 is zero, the output voltage under open circuit condition is

$$V_{out} = g_m \left(\frac{r_d R_D}{r_d + R_D} \right) V_1 = g_m \left(r_d \parallel R_D \right) V_1$$

where r_d is the ac drain resistance, g_m= transconductance. To find the Thevenin resistance at terminals XY, we first set V_1 and V_{DD} equal to zero. Under this condition, both the FETs have a resistance of r_d as shown in Fig. 13.15. Assuming R_S to be relatively Large,

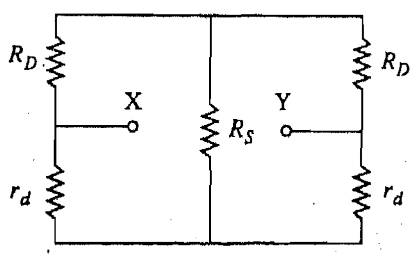


Fig.13.15 : Setting all voltages equal to zero to find R_{Th} of EVM.

$$R_{Th} = 2\,r_d \parallel 2\,R_D = 2\,(r_d \parallel R_D)$$

$$= 2\left(\frac{r_d\,R_D}{r_d + R_D}\right)$$

The Thevenin equivalent circuit with ammeter connected as a load is shown in Fig.13.16.

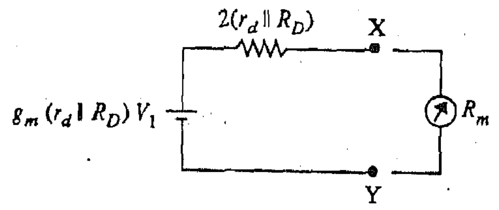


Fig.13.16 : Equivalent circuit of EVM.

From Fig. 13.16 the current through ammeter is found as:

$$i = \frac{V_{out}}{R_{Th} + R_m} = \frac{g_m\,(r_d \parallel R_D)}{2(r_d \parallel R_D) + R_m}\,V_1$$

where R_m = meter resistance.

If $R_D << r_d$, the above equation simplifies to

$$i = \frac{g_m R_D}{2R_D + R_m}\,V_1$$

This equation relates ammeter current to the input dc voltage.

SAQ 8

How does FET EVM differs from the VOM?

SAQ 9

Give circuit for the difference-amplifier type of EVM.

SAQ 10

Given a difference amplifier type of FET voltmeter,-find the ammeter current under the following conditions:

$V_1 = 1\text{V}$ $\qquad R_D = 10\ \text{K}\Omega$

$r_d = 100\ \text{K}\Omega$ $\qquad R_m = 50\ \text{M}\Omega$

$g_m = 0.005$ Siemens

13.5 POWER METER

Wattmeter is an instrument to measure the power or rate of consumption of electricity in **a** circuit in watts. The most commonly used powermeter is Siemen's wattmeter shown in Fig. 13.17.

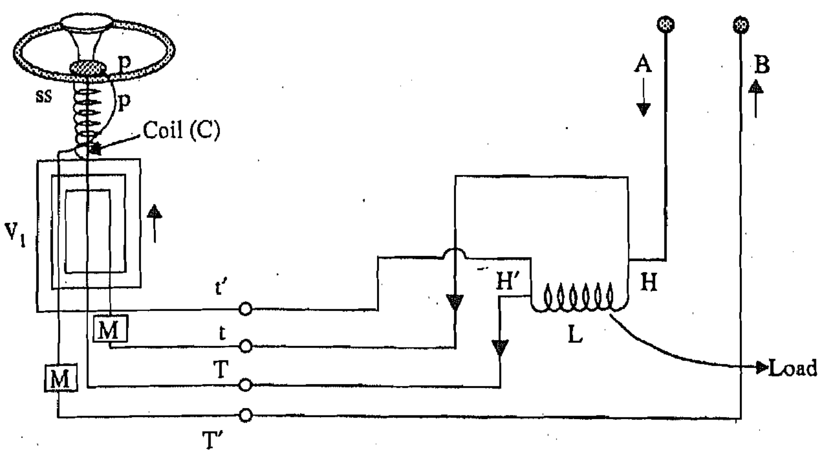


Fig.13.17 : Siemcn's Wattmeter.

The Siemen's Wattmeter is identical in principle with Siemen's electrodynamometer. It consists of two coils at right angles to one another. One coil C is movable and the other, V is fixed. The moving coil C is of low resistance and is inserted in the main circuit. The high resistance fixed coil V, is joined as a shunt (i.e. in parallel) to that part of the circuit for which the power consumption is required. In Fig. 13.17, this part is an electric lamp (L). On closing the circuit, the main current i passes through the moving coil and a small current, proportional to the voltage E across the lamp terminals, passes through V. The turning moment is proportional to the product of these two i.e. proportional to Ei or the Watts used in L. When the moving coil is brought back to its normal position by turning the torsion head and its pointer through an angle say 8, the turning moment is balanced by, the torsional moment. Since torsional moment is proportional to θ

$$Ei \propto \theta$$

or Watt expended in L $= K\theta$

Where the constant of proportionality K is a constant of the instrument and must be determined experimentally.

13.6 MAGNETIC FIELD METER

There are several techniques for the measurement of magnetic field. These are based on the change in the resistance of a material (magneto-resistance) under the application of magnetic field, or the voltage developed across a semiconductor under magnetic field (Hall effect). The instruments based on these principles will form a subject of study at higher level. In this section we shall discuss a method which is based on electromagnetic induction or the voltage developed across a coil when flux changes through a coil. The change of flux can be produced by moving the coil across a magnetic field. This method is often called determination of magnetic field by search coil,

A fluxmeter, an important instrument for measuring magnetic field strengths, has the same principle as that of a ballistic galvanometer. Fluxmeter consists of a moving coil suspended by a single silk fibre without torsion, the upper end of the fibre being connected to a fixed flat spring as shown in Fig. 13.18 (a) below.

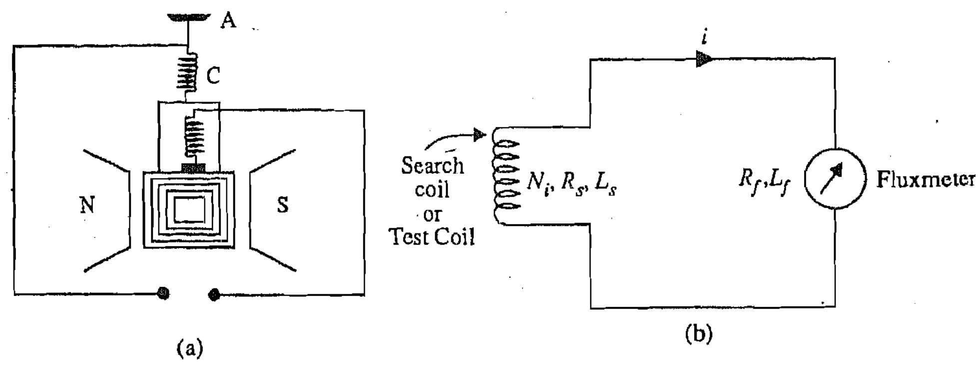


Fig.13.18 : (a) Construction of Fluxmeter (b) Fluxmeter in a circuit.

The coil is connected to the terminal X-X through two spirals C,C of thin silvered coil and is suspended in magnetic field of a permanent magnet NS. For direct measurement of the flux, a search coil is provided which can be connected to the terminals X,X as shown in Fig. 13.18 (b).

The expression for the change in magnetic flux of a fluxmeter can be derived as follows:

Let,

R_f = Resistance of fluxmeter

L_f = Self Inductance of fluxmeter

R_s = Resistance of search coil

N_1 = No, of turns in search coil

L_s = Self Inductance of search coil

The emf induced in the search coil is $-N_1 \frac{\ }{dt}$, where $\frac{\ }{dt}$ is the rate of change of flux in the search coil and the emf in fluxmeter coil is $G \frac{d\theta}{dt}$, where $\frac{d\theta}{dt}$ is angular velocity of the fluxmeter coil and G = NAB is a constant depending on the construction of the fluxmeter. In addition, the emf produced in the circuit due to self inductances is $(L_f + L_s)\frac{di}{dt}$ or $L\frac{di}{dt}$, where L is the total inductance of the circuit. The potential drop in the resistance is $(R_f + R_s)$ i or Ri where R being total resistance of the circuit. Using Kirchoff s law, we get

$$-N_1\frac{d\phi}{dt} + G\frac{d\theta}{dt} + L\frac{di}{dt} + Ri = 0$$

$$\Rightarrow N_1\frac{d\phi}{dt} = G\frac{d\theta}{dt} + L\frac{di}{dt} + Ri$$

In practical applications, the potential drop in resistances $(=Ri)$ is small and can be neglected in comparisons to other terms, giving

$$N_1\frac{d\phi}{dt} = G\frac{d\theta}{dt} + L\frac{di}{dt}$$

Integrating over time t, during which the flux change occurs,

$$N_1 \int_0^t \frac{d\phi}{dt} dt = G \int_0^t \frac{d\theta}{dt} dt + L \int_0^t \frac{di}{dt} dt$$

$$\Rightarrow N_1 \int_{\phi_1}^{\phi_2} d\phi = G \int_{\theta_1}^{\theta_2} d\theta + L \int_{i_1}^{i_2} di$$

$$\Rightarrow N_1 (\phi_2 - \phi_1) = G(\theta_2 - \theta_1) + L(i_2 - i_1)$$

Now, if we assume that the period in which the flux is changing is completely contained within the period (0-t) over which integration is carried, both the initial and final currents are zero, giving

$$N_1 (\phi_2 - \phi_1) = G (\theta_2 - \theta_1)$$

$$N_1 \Delta\phi = G\Delta\theta \Rightarrow \Delta\theta = \left(\frac{N_1}{G}\right)\Delta\phi$$

$$\Rightarrow \Delta\theta \propto \Delta\phi$$

which suggests that the deflection in the fluxmeter accurately follows any change in flux in the search coil.

13.7 SUMMARY

- Cathode ray oscilloscope is used for the measurement of electrical parameters like, ac and dc voltage, ac and dc current, lime-phase relationship, frequency and for observing various wave forms.
- Laboratory oscilloscope can be classified into two categories: (i) Dual-trace oscilloscope (ii) Storage oscilloscope.

  Signal generator provides variety of output waveforms over a wide range of frequency. The most common output waveforms are: sine, pulse, square, triangular and ramp.
- Electronic voltmeter is characterised by high input resistance.

  Power meter is used to measure the power or rate of consumption of electricity in a circuit.
- Magnetic field meter is an instrument for measuring magnetic field strengths.

13.8 TERMINAL QUESTIONS

1) Explain the functioning of a general purpose **CRO giving** black diagram.
2) Explain the basic principle involved in dual trace CRO.
3) How a storage **CRO** works? Explain.
4) Describe in detail the functions of a function generator.
5) Describe in detail the functioning of Differential-amplifier type electronic voltmeter.

6) How a Siemens power meter works? Explain.

7) Give in detail how magnetic field can be measured with the help of a fluxmeter.

13.9 SOLUTIONS AND ANSWERS

SAQs

1. See text
2. See text
3.

$$T = \frac{2\mu sec}{div} \times \frac{4div}{cyc} = \frac{8\mu sec}{cyc}$$

$$\therefore \quad f = \frac{1}{T} = \frac{1}{8\mu sec/cyc} = 125 KHz$$

4. See text
5. See text
6. See text
7. We know,

$$f = \frac{1}{4RC} \frac{R_2}{R_1}$$

$$= \frac{1}{4 \times 500 \times 10^3 \times .004 \times 10^{-16}} \frac{100 \times 10^3}{60 \times 10^3}$$

$$= 208 Hz$$

Also, $V_{02} = V_{CC}\left(\frac{R_1}{R_2}\right)$

$$= 15\left(\frac{60 \times 10^3}{100 \times 10^3}\right) = 9V$$

8. See text
9. See text

10.

$$i = \frac{g_m (r_d || R_D)}{2(r_d || R_D) + R_m}$$

Substituting all the values, we get

$$i = 2.5 \text{ mA}$$

TQs

1. See text
2. See text
3. See text
4. See text
5. See text
6. See text
7. See text

REGIONWISE LIST OF STUDY CENTRES FOR B.Sc. PROGRAMME

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1. HYDERABAD REGION (Andhra Pradesh)		
1	0102	V.R. College, Nellore-524001, **Andhra Pradesh**
2	0103	KBN College, Kothapet, Vijayawada-520001, **Andhra Pradesh**
3	0111	Aurora's Degree College, Hyderabad-500020, **Andhra Pradesh**
2. GUWAHATI REGION (Assam, Arunachal Pradesh & Sikkim)		
4	0401	*Guwahati University, Guwahati-781014,* **Assam**
5	0403	Bujhota Mahavidyala, Bongaigaon-783280, **Guwahati**
6	0408	Handique Girls College, Guwahati-781100, **Assam**
7	0409(P)	Govt. Science College, Jorhat-785010, **Assam**
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9	0414(P)	Debraj Roy College, Golaghat P.O. Golaghat-785621, **Assam**
10	0419	Lakhimpur Girls College, Khelmati P.O. North Lakhimpur-787031, **Assam**
11	2401	Sikkim Govt. College, *Tadong*, Gangtok-737102, **Sikkim**
3. PATNA REGION (Bihar)		
12	0501	Vanijya Mahavidyalay, Patna University, *Patna-800005*, **Bihar** (Patna Science College, Patna, Bihar)
13	0503	B.R.S. Bihar University Library, Muzaffarpur-842001, **Bihar** (L.S College, *Muzaffarpur*, Bihar)
14	0505	*Marwari College (T.M. Bhagalpur University)*, Bhagalpur-812007, **Bihar**
15	0508	Purnea College, Purnea 854301, **Bihar**
16	0509	Rajendra College, Chhapra-841301, **Bihar**
17	0515R	Balika Vidyapeeth, Lakhisarai-811311, **Bihar**
18	0521	Sindri College, P.O. Sindri-828122, Dhanbad, **Bihar**
19	0522	C.M. College, *Kilaghat*, Darbhanga, **Bihar**
20	0524	Bihar National College, Patna-800004, **Bihar**
21	0525	Mahila College, Chaibasa, P.O. Chaibasa-833201, Dist. West Singhbhum, **Bihar**
22	0528(P)	*St. Columbas College, P.O. College More, Hazaribagh-825301*
23	0529	Anugrah Narayan College, Boring Road, **Patna-800013**
4. DELHI REGION (1) (South and West Region, Gurgaon, Faridabad and Mathura)		
24	0702	MCRC, Jamia Millia Islamia, Jamia Nagar, New Delhi-110025
25	0711	Gargi College, Siri Fort Road, New Delhi-110049
26	0715	Acharya Narendra Dev College, *Kalkaji*, New Delhi-110019
5. DELHI REGION (2) (North and East Region including Meerut, Modinagar and Ghaziabad Districts of Uttar Pradesh)		
27	0728	Bhaskaracharya College of Applied Sciences, *Veer Savarkar Complex*, Pusa **New Delhi-110012**
28	0729	Kalindi College, East Patel Nagar **New Delhi-110008**
29	2743	Lajpat Rai (P.G.) College, Sahibabad-201005, **Uttar Pradesh**
6. AHMEDABAD REGION (Gujarat, Daman & Diu, Dadra & Nagar haveli)		
30	0801	L.D Arts College, Navrangpura, Ahmedabad-380009, **Gujarat**
31	0802	*General Education Building*, M.S University, *Vadodara*-390002, **Gujarat**
32	0806	JB Thacker Commerce College, Bhuj-370001, Gujarat (*Lalan College*, **Bhuj, Gujarat**)
33	0909	New Progressive Education Trust, Mehsana-384002, **Gujarat**
34	0922(R)	Shree Gattu *Vidyalaya*, Plo [illegible] 910, GIDC Estate, Ankleshwar, **Gujarat**
35	0928(R)	National Institute of *Management and Information Technology (NIMIT)* C/o Parag Ad., Jansatta press, **Rajkot-5**
36	2901	Govt. Arts College, Daman and Diu (U.T)-396210
7. KARNAL REGION (Haryana and Punjab)		
37	1001	*Mukandlal* National College, Yamuna Nagar-135001, **Haryana**
38	1005	Chhotu Ram College of Education, Rohtak-124001, **Haryana** (All India *Jat Heroes Memorial* College, Rohtak, **Haryana**)
39	1008	Govt. College, (Girls Wing), Sector-14, Railway Road, Karnal-132001, **Haryana**
40	1009	Govt. P.G. College, Hissar-125001, **Haryana**
41	1012	Markanda National College, Shahabad, *Kurukshetra*, **Haryana**
42	1013	Government P.G College, Jind-126102, **Haryana**
43	2201	D.A.V. College, Jalandhar-144008, **Punjab**
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44	1101	Government *Boys College, Sanjauli, Shimla*-171006, **Himachal Pradesh**
45	1105	Government College, *Dharamshala*-176215, **Himachal Pradesh**
46	1113	Govt. P.G. College, Bilaspur-174001, **Himachal Pradesh**
47	1115	Govt. Degree College, Recong Peio, Kinour Dist., **Himachal Pradesh**
9. JAMMU REGION (J&K)		
48	1201	University of Jammu, Department of Management Studies, Jammu Tawi-180001, **J&K** (Gandhi Memorial Science College, Jammu Tawi, **J&K**)
49	1206	Govt. Degree College, *Kathua*, **J&K**
50	1207	Govt. Degree College, *Rajouri*, **J&K**
51	1208	Govt. Degree College, Poonch, **J&K**
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53	0802	Dhempe College of Arts & Science, P.O. Box No. 222, Panjim, Goa-403001
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56	1401	Institute of Management in Govt. Vikas Bhavan, *Thiruvantapuram*-695011 **Kerala**, (University College, Thiruvantapura, Kerala)
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58	1404	Catholicate College, Pathananthitta-689645, **Kerala**
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60	1412	St. Alberts College, Ernakulam-682018, Kerala