Chapter 4

Cathode Ray Oscilloscope and Electronic Voltmeters

LEARNING OBJECTIVES

After reading this chapter, you will be able to understand:

- Horizontal deflection system
- Deflection of moving electrons in CRO tube
- Measurement of voltage and currents
- Measurement of frequency
- Lissajous method
- Analog and digital voltmeters
- Digital voltmeters
- Continuous balance type DVM
- Ramp type DVM
- Successive approximation type DVM

Cathode Ray Oscilloscope

Cathode ray oscilloscope (CRO) is a very useful and versatile laboratory instrument used for display, measurement analysis of waveforms and other phenomena in electrical and electronic circuits.

- It displays an input signal V_s another signal or time.

Construction, Operation and Working

- Cathode ray tube (CRT)
- Vertical amplifier
- Horizontal amplifier
- Time base
- Trigger base
- Trigger circuits
- Power supplies

In a CRO, CRT generates the electron beam, accelerates it to a high velocity, deflects the beam to create the image and the electron beam becomes finally visible on the phosphor screen.

- The time base of the oscilloscope generates correct voltage to supply the CRT to deflect the spot at a constant time dependent rate.
- Vertical amplifier increases the potential of input signal which is to be viewed, to a level that will provide a usable deflection of electron beam.
- To synchronize the horizontal deflection with the vertical input such that horizontal deflection starts at the same point of input vertical signal each time it sweeps, a synchronizing or triggering circuit is used.

Horizontal Deflection System

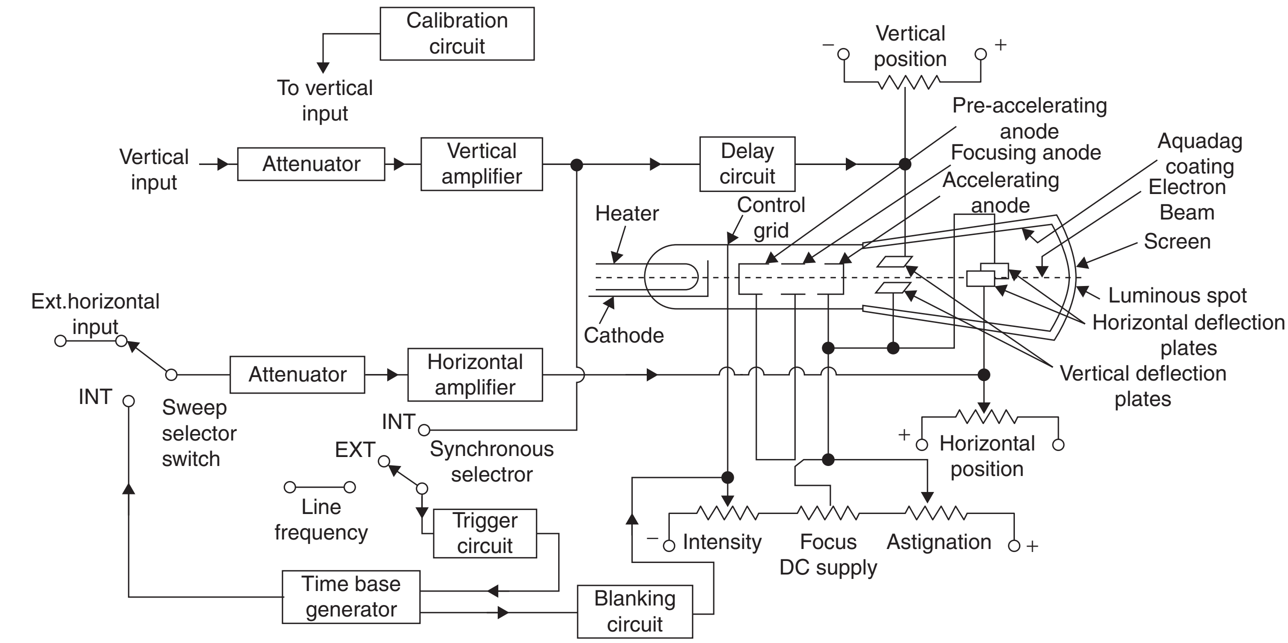
- It consists of a time base generator a trigger circuit and a horizontal amplifier.
- Time base generator controls the rate at which the beam is scanned across the face of the CRT and is adjusted from the front panel.
- The trigger circuit ensures that the horizontal sweep starts at the same point of vertical input signal.
- Horizontal amplifier to increase the amplitude to the signal generated in the sweep generator to the level required by the horizontal deflection plates of the CRT.

Vertical Deflection System

- It provides an amplified signal of proper level to drive the vertical deflection plates without introducing any appreciable deflection to the system.
- Attenuator sets the sensitivity of the oscilloscope.

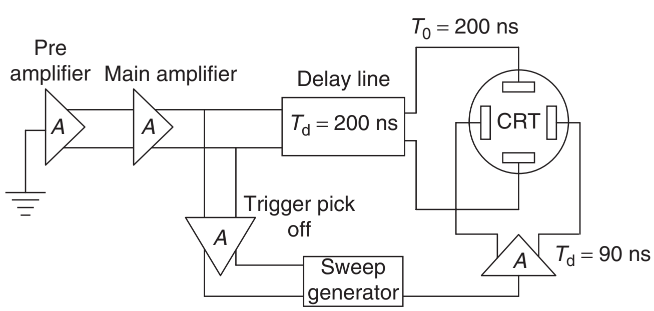
Vertical Delay Line

- All electronic circuitry in the oscilloscope causes a certain amount of time delay in transmission of signal voltages to the deflection plates.
- The horizontal signal is initiated by the portion of output signal applied to vertical CRT plates.
- Signal processing in horizontal channel consists of generating and shaping a trigger pulse that starts the sweep generator whose



output is fed to horizontal amplifier and then to horizontal deflection plates.

- The whole process takes time of the order of 80 ns or so. To allow the operator to observe the leading edge of the signal waveform, the signal drive for the vertical CRT plates must be delayed by at least the same amount of time.
- The signal voltage to the CRT plates is delayed by sometime and horizontal sweep is started prior to the vertical deflection.



CRO Control Panel

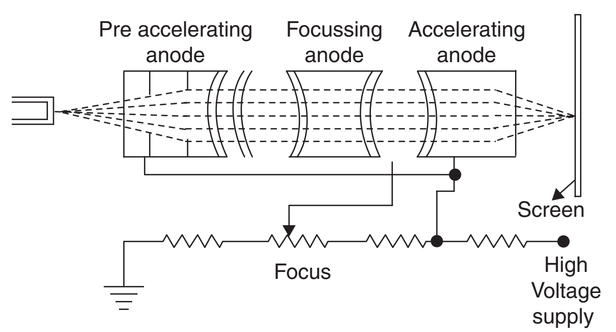
Intensity Control

It regulates the bias on the control grid and affects the electron beam intensity.

- If the negative bias on the grid is increased, the intensity of electrons beam is decreased by reducing the brightness of the spot.

Focus Control

- It regulates the positive potential on the focusing anode, which makes electron beam quite narrow and the spot on the screen is a pin point.



Horizontal Position Control

- It regulates the amplitude of DC potential which is applied to the horizontal plates, in addition to the usual saw-tooth wave.

By adjusting this control the spot can be moved to right or left as required.

Vertical Position Control

It regulates the amplitude of DC potential which is applied to vertical deflection plates in addition to the signal.

- By adjusting this control the image can be moved up or down as required.

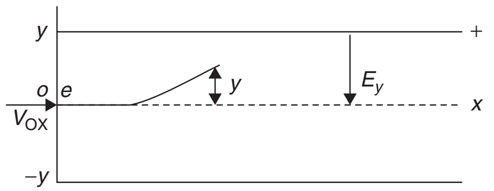
Deflection of Moving Electrons in CRO Tube

Force on the electron in a uniform electric field of intensity E

$$F = QE = -eE = ma$$

$$a = \frac{F}{m} = \frac{-eE}{m}\ \text{m/s}^2$$

where a = Acceleration of electrons in m/s^2
F = Force of electron in N
m = Mass of electron in kg



- An electron entering the field in the positive X-direction with an initial velocity V_{ox} will experience a force.
- As the field acts along Y-axis only, there will be no force acting along Z- or X-axis.
- The acceleration means constant velocity and since the electron enters the field in positive X direction with an initial velocity V_{ox}, it will continue to travel along X-axis at this velocity.

In the direction of Y-axis

$$F = ma_y$$

$$a_y = \frac{F}{m} = \frac{-eE_y}{m}$$

Since $$V = V_o + at$$

$$x = x_o + V_o t + 1/2\ at^2$$

Putting initial conditions, we have

$$V_y = a_y t = \frac{-eE_y t}{m}$$

$$y = 1/2\ a_y t = \frac{-eE_y t^2}{2m}$$

Distance travelled in time t

$$x = x_o + V_{ox} t + 1/2\ a_x t^2$$

At $x_0 = 0$ and $a_x = 0$

$$X = V_{ox}\, t$$

$$\Rightarrow \qquad t = \frac{x}{V_{ox}}$$

Vertical deflection as a function of horizontal distance travelled

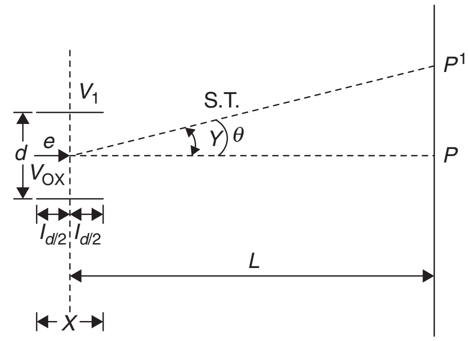
$$y = \left[\frac{-eEy}{2V_{ox}^2\, m}\right] x^2 \text{ m}$$

Hence, path of an electron travelling through an electric field of constant intensity and entering the field at right angles to the lines of force is a parabola.

Consider two parallel deflection plates at a distance d and connected to a source of potential difference V_d.

Hence,

$$E = \frac{V_d}{d} \text{ V/m}$$



Slope of the parabola at a distance $X = l_d$ is defined as

$$\tan\theta = \frac{d_y}{d_x} = \frac{-e\, E_y\, l_d}{mV_{ox}^2}$$

$$X = \frac{y}{\tan\theta} = \frac{\left(\dfrac{e\,E_y\, l_d^2}{2m\, V_{ox}^2}\right)}{\left(\dfrac{e\,E_y\, l_d}{m\, V_{ox}^2}\right)} = \frac{l_d}{2}$$

Deflect on the screen $D = L\tan\theta$

$$D = L\,\frac{e\,E_y\, l_D}{mV_{ox}^2}$$

Kinetic energy of the electrons entering the deflection plate is

$$1/2\ m\ V_{ox}^2 = e\ V_a$$

$$V_{ox}^2 = \frac{2e\ V_a}{m}$$

$$D = \frac{L_e\, E_y\, L_D}{mV_{ox}^2} = \frac{L\, l_D}{2V_a}\cdot\frac{V_D}{d}$$

where V_d = Deflection voltage in volts
V_a = Accelerating voltage in volts

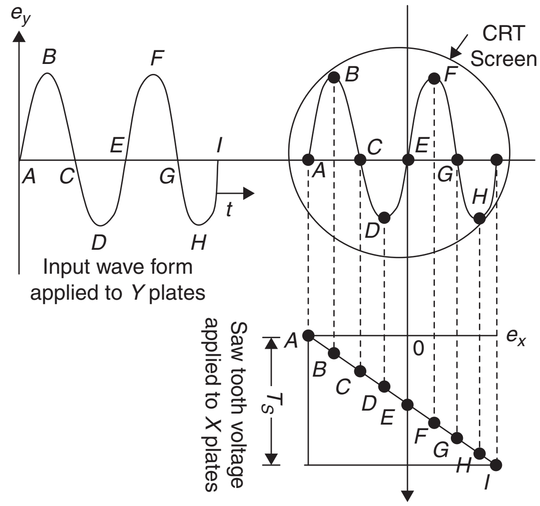
Deflection sensitivity S is defined as the deflection on the screen (in metre) per volts of deflection voltage

$$S = \frac{D}{V_D} = \frac{L\, l_D}{2d\ V_a} \text{(m/V)}$$

Deflection factor $G = \dfrac{1}{s} = \dfrac{2d\ V_a}{L\ l_D}$ V/m

Applications of CRO

Observation of Waveform on CRO



- When horizontal saw-tooth voltage and an input voltage is applied simultaneously to y plates, the beam is under influence of the following two forces.
  1. One in horizontal direction moving the beam at a line or rate from right to left.
  2. Second in vertical direction moving the beam up and down.
- Since deflection is proportional to applied voltage, the horizontal movement is proportional to voltage applied to X plates at any instant and since ramp voltage is linear it traces a straight line on CRT screen.
- The vertical deflection is proportional to input voltage applied to y plates and hence up and down according to the magnitude and polarity of the input voltage.
- At the end of one sweep cycle, the sweep voltage abruptly drops down and the spot is immediately transferred to its original position. The process is repeated again with a result that a stationary image is seen on the screen.

Measurement of Voltage and Currents

- From the expression of electrostatic deflection, deflection is proportional to the deflection plate voltage. Thus CRT measures voltage.
- Direct voltage may be obtained from static deflection of spot. Alternating voltages may be obtained from the length of the line produced when voltage is applied to Y plates when no voltage is applied to X plates. The length of the line corresponds to peak-to-peak voltage.

$$V_{RMS} = \frac{V_{pp}}{2\sqrt{2}}$$

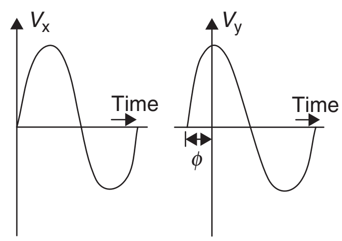
- The y-shift control is adjusted so that positive peak of test voltage coincides with some datum line on the screen, and then the shift control is operated so that negative peak coincides with the datum.
- The movement of control is arranged to read directly V_{pp}.
- The value of current can be obtained by measuring voltage drop across a known resistor connected in the circuit.

Measurement of Phase Difference

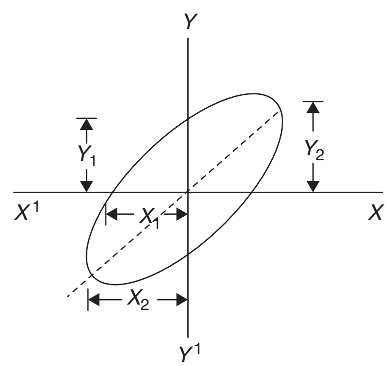
When two sinusoidal voltages are applied to deflection plates of CRO, the phase difference ϕ is determined as follows:

$$V_x = V_x \sin\omega t$$

$$V_y = V_y \sin(\omega t + \phi)$$



Input waveforms



O/P on CRO

$$\sin\phi = \frac{Y_1}{Y_2} = \frac{X_1}{X_2}$$

Measurement of Frequency

Direct Method

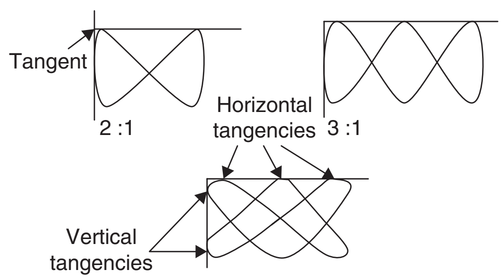
A signal frequency is determined by measuring its time period T and calculating the frequency by $f = \dfrac{1}{T}$.

- The input waveform is fed into the vertical input, with vertical sensitivity sweep speed and triggering controls are adjusted for at least one complete stable cycle of waveform.
- The number of horizontal divisions for a complete cycle is determined and time period is found by

$$T = (\text{Number of horizontal divisions in one cycle}) \times (\text{Sweep speed in s/division})$$

Lissajous Method

Frequency of a signal can be accurately measured by Lissajous patterns. The signal of unknown frequency is applied to *Y* plates. The signal of known frequency is applied to *X* plates. Depending on the frequency, ratio patterns are obtained.



For all the cases of patterns obtained the ratio of the two frequencies is

$$\frac{f_y}{f_x} = \frac{\text{Number of horizontal tangencies}}{\text{Number of vertical tangencies}}$$

f_y = Frequency of signal applied to Y plates
f_x = Frequency of signal applied to X plates

For open Lissajous patterns, free end is treated as 1/2 tangency.

Solved Examples

Example 1: In a CRO, post acceleration is required if the frequency of the signal is
(A) Greater than 10 Hz
(B) Greater than 10 MHz
(C) Greater than 1 MHz
(D) Less than 1 MHz

Solution: (B).

Example 2: The non-viewing side of the CRO phosphorus screen has a thin aluminium film deposited because
(A) It protects the screen from getting negatively charged.
(B) It prevents phosphorus burn by acting as heat sink.
(C) It minimizes light scatters from phosphorus.
(D) All of the above.

Solution: (D).

Example 3: In a CRO, the design of horizontal amplifier should be for signals with
(A) High frequency and fast rise time
(B) High amplitude and fast rise time
(C) High amplitude and slow rise time
(D) Low amplitude and fast rise time

Solution: (C).

Example 4: In a CRO when an unknown signal is applied to the vertical plate is being synchronized with the sweep signal applied to horizontal plates. If the frequency of the signal is lower than that of the unknown signal, then
(A) The pattern on CRO screen moves towards the right.
(B) The pattern on CRO screen moves towards the left.
(C) The pattern on CRO screen moves toward the top.
(D) The pattern non-CRO screen moves towards the bottom.

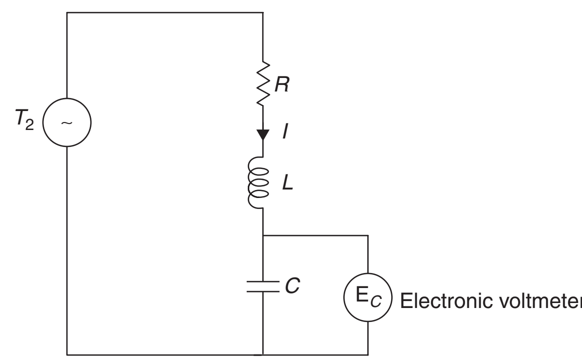
Solution: (A).

Example 5: Focusing anode in a CRO is located
(A) Between accelerating and accelerating anode
(B) Before pre-accelerating anode
(C) After accelerating anode
(D) None of the above

Solution: (C).

Q-meter

It is also called voltage magnifier.



Q-meter works based on the principle of RLC series resonance.

$$\text{Quality factor, } Q = \frac{X_L}{R} = \frac{X_C}{R}$$

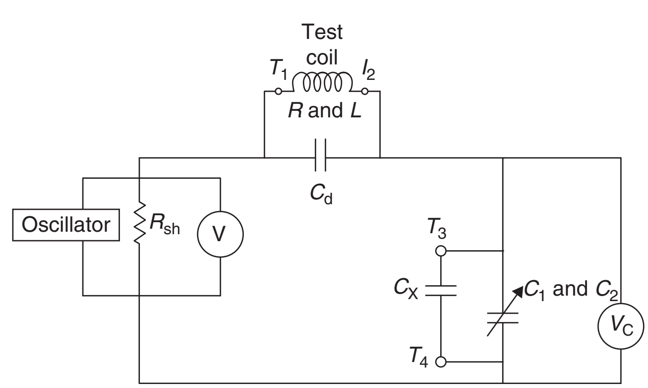
Q-meter is an instrument is designed is very useful in measuring the characteristics of inductive coil and capacitors.

Under resonant condition $I = \frac{V}{R}$

$$V_c = IX_C = \frac{VX_C}{R}$$

$$V_c = VQ$$

Practical Q-meter



Applications of Q-meter

1. Measurement of quality factor of the coil:

$$Q_T = Q_m\left[1+\frac{R_{sh}}{R}\right], \text{since } R_{sh} <<< R$$

$$Q_T = Q_m$$

$$\% \text{ Error} = \frac{-R_{sh}}{R_{sh}+R}$$

2. Measurement of unknown capacitance
If a test capacitance is connected between terminals T_3 and T_4 by varying capacitance C to C_1, the circuit is resonated to a frequency f_1.

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_x)}}$$

after removing C_x between T_3 and T_4, by adjusting capacitance C to the new value C_2

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_x)}} = \frac{1}{2\pi\sqrt{LC_2}}$$

$$C_X = C_2 - C_1$$

3. Measurement of resistance:

At resonant frequency, $Q = \dfrac{\omega_0 L}{R}$

$$R = \frac{\omega_0 L}{Q} = \frac{2\pi f_0 I}{Q}$$

4. Measurement of distributed (or) self-capacitance of an inductive coil:
The internal capacitance of the inductive coil can be measured at resonance by adjusting C to a new value C_1.

Resonant frequency $f_1 = \dfrac{1}{2\pi\sqrt{(C_1+C_d)L}}$

Again the capacitor C is adjusted to C_2 to get the resonant frequency $f_2 = 2f_1$.

$$\frac{1}{2\pi\sqrt{L(C_2+C_d)}} = \frac{2}{2\pi\sqrt{L(C_1+C_d)}}$$

$$C_d = \frac{C_1 - 4C_2}{3}$$

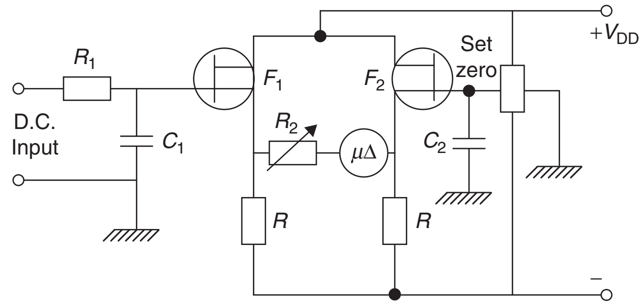
For $\qquad f_2 = nf_1$

$$C_d = \frac{C_1 - n^2 C_2}{n^2 - 1}$$

Analog and Digital Voltmeters

Analog Electronic Voltmeter

- These voltmeters use a moving coil meter in which the torque acting on the movement is proportional to the average current flowing through it.



- A circuit of DC electronic voltmeter is a bridge circuit with the two FETs forming one half of the bridge and source resistor R forming the other half.
- The moving coil meter is coupled between two source resistor R. The circuit R_1C_1 acts as an attenuator to AC signal super imposed on DC voltage.
- The bridge is balanced by set zero control which changes the bias applied to F_2. the capacitor C_2 decouples the gate F_2 to earth.
- If the gate F_1 is raised to a positive potential, the potential of the source is raised by a similar amount and current flow through the meter from F_1 to F_2. A variable resistor R_2 in series with meter is used for calibration

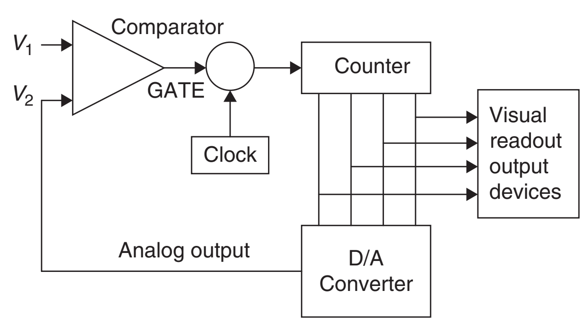
Sensitivity of this instrument = $\dfrac{g_m}{2}$ where g_m is the mutual conductance of FET.
For measuring AC quantities, the instruments are listed as follows.

1. **Rectifier Amplifier:** In which a DC amplifier is used and both AC or DC quantities can be measured.
2. **Amplifier Rectifier Type:** In which an AC amplifier is used and rectification takes place at output. Only AC quantities are measured.

Digital Voltmeters

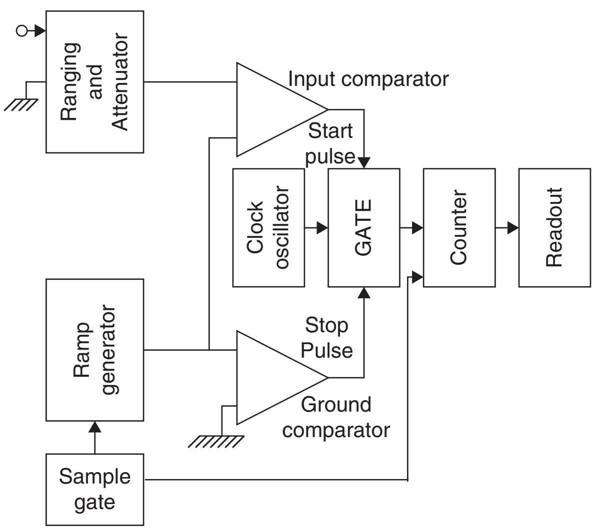
- These display the value of AC or DC voltages being measured directly as discrete numerals in the decimal number system. Analog to digital conversion is used.
- Voltage is changed to a proportional time interval and it starts and stops a clock oscillator. The oscillator output is applied to an electronic counter.

Continuous Balance Type DVM



- Initially the counter is set to zero at the beginning of the measuring process afterwards the counter holds a succession of numbers.
- These are converted into analog signal V_2 by the digital to analog converter. The output is compared with input signal in an electronic comparator.
- If $V_1 > V_2$, output from the comparator is highest. The electronic gate is open and clock pulses are allowed to be fed into the counter.
- The number stored in the counter increases as it counts clock pulses.
- If $V_1 = V_2$, output comparator suddenly falls to zero closing the circuit.

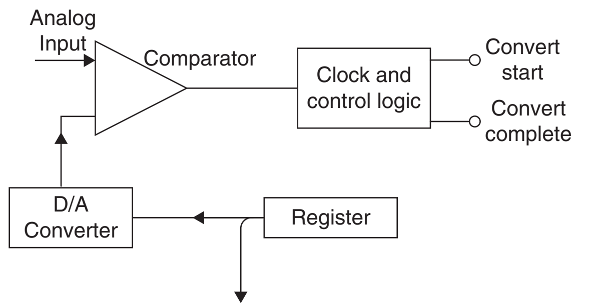
Ramp Type DVM



- The principle is to measure the time that a linear ramp voltage takes to change from the level of input voltage to zero voltage (or vice versa).
- This interval is measured with an electronic time interval counter and the count is displayed as a number of digits on electronic indicating tubes of the output read out.
- At start of measurement, ramp voltage is initiated. The ramp voltage value is continuously compared with the unknown voltage. At the instant the value of ramp voltage is equal to that of unknown voltage, a coincidence circuit called and input comparator generates a pulse which opens a gate.
- The ramp voltage continues to decrease till it reaches ground level. At this instant another comparator called the ground comparator generates a pulse and closes the gate. During the time interval the pulses passing through the gate are counted and displayed.

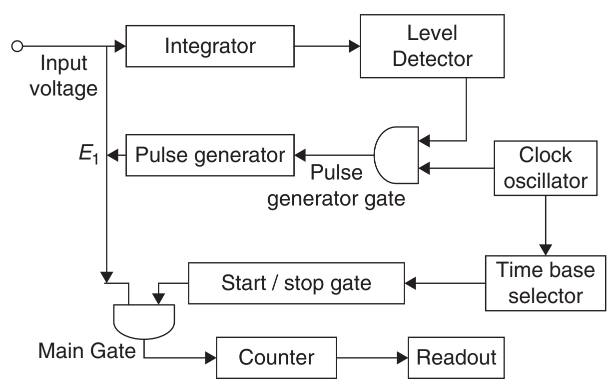
Successive Approximation Type DVM

- The essential difference between the successive approximation type DVM and continuous balance DVM lies in the sequence of test voltages used to balance the voltmeter.



- Let us try the sequence 8, 4, 2, 1. The first clock pulse in the successive approximation type sets the counter to 8. this is compared with V_1 and since $V_1 > V_2$, the comparator allows the count to continue in the up direction.
- The next clock pulse adds another 4 to the count which now becomes 12; this is compared with V_1 and the count continues in the up directions. The next clock pulse adds 2 to the count stored in the counter making it 14. The comparator must then instruct the counter to count down by previous count reducing the number in counter to 12 again.
- The comparator now recognized that $V_2 > V_1$ and the counter then counts up by next sample number, i.e. 1 making the stored number equal to 13.
- At the point after 5 steps DVM balances.
- Clearly this type of DVM is more rapid in operation than the more simple continuous balance DVM, but only at an increase in complexity and cost.

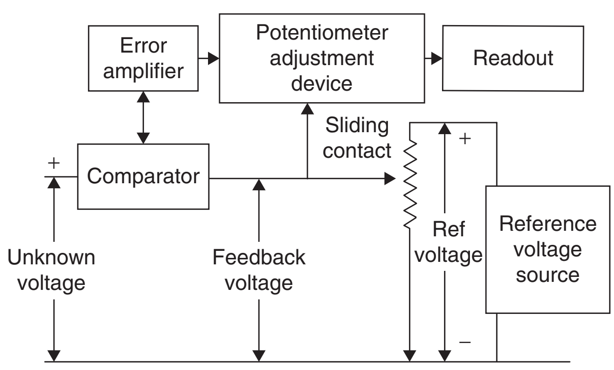
Integrating Type DVM



- It measures the true average value of the input voltage over a fixed measuring period. Here, voltage to frequency conversion is used.
- The voltage frequency conversion function has a feedback control system which controls the rate of pulse generation in proportion to magnitude of the input pulse.
- A train of pulse whose frequency depends on the unknown voltage is generated. The number of pulses appearing in a definite time interval is counted. Since the frequency of these pulses is a function of the unknown voltage, then the number of pulses counted in that period of time is an indication of the unknown voltage.

- The unknown voltage E_i is applied to the input of the integrator and output voltage E_o starts to rise. The slope of E_o is determined by the value of E_i. This voltage is fed to a level detector and when E_o reaches that level, the detector produces an output pulse.
- Greater the value of E_i, sharper will be the slope of E_o and quicker the E_o will reach its reference level. The output pulse of the level detector opens the pulse level gate, permitting pulses from a clock oscillator to pass through pulse generator.
- This generator produces an output pulse of fixed amplitude and width for every pulse it receives. This output pulse, whose polarity is opposite to that of E_i and has greater amplitude, is fed back to the integrator. Hence, the net input to the integrator is now a reversed polarity.
- As a result of this reversed input E_o drops back to its original level and there is no output from the detector to the pulse generator and the gate gets closed.
- When the output voltage pulse from the pulse generator has passed E_i is restored to its original value and E_o starts to rise again. Once again when it reaches the level of reference voltage, the gate is opened, the cycle is repeated.
- Thus the waveform E_o is a saw-tooth wave, whose rise time depends upon E_i and fall time upon width of the output pulse from the pulse generator.
- The frequency of the saw-tooth is measured by coupling the number of pulses in a given interval of time. Pulses from clock oscillator are applied to a time base selector. The first pulse passes through start/stop gate producing an output which is applied to the main gate.
- The same output from the pulse generator also passes through the main gate.
- The next pulse from time base closes the start/stop and main gate. The counter thus counts the number of pulses that have passed during a known interval of time.

Potentiometric Type DVM



- In this, DVM unknown voltage is compared with a reference voltage whose value is fixed by the setting of calibrated potentiometer.
- Under balanced conditions, the value of unknown voltage is indicated by dial setting of the potentiometer. The balance is achieved automatically.
- The unknown voltage is filtered and attenuated to a suitable level. This is applied to a comparator reference voltage is obtained from a fixed voltage source is applied to potentiometer R. The feedback voltage depends upon the position of sliding contact.
- This feedback voltage and unknown voltage are compared in the comparator. The error signal so obtained is amplified and is fed to potentiometer adjustment device which moves sliding contact of the potentiometer proportional to the error signal.
- The sliding contact moves to such a place where feedback signal equals unknown voltage. In such a case, there is no error signal and the movement of sliding contact is stopped.
- The position of potentiometer adjustment device at this point is indicated in numerical form on the digital read out and it is the unknown voltage.

Example 6: Which among the following is a false statement with regard to a potentiometric type DVM?
(A) It is a self-balancing type DVM.
(B) The error detector employed can be a chopper.
(C) The sliding contact moves proportional to the error signal received at the potentiometer adjustment device.
(D) None of the above.

Solution: (D)
Choices a, b, c are true regarding a potentiometric type DVM and hence.

Example 7: Identify the correct matching list I to that in List II.

List I
(P) Ramp type DVM
(Q) Integrating type DVM
(R) Successive approximation type DVM
(S) Potentiometric type DVM

List II
(1) Ground comparator
(2) Level detection
(3) Rapid and simple than continuous balance type DVM

(A) P – 1	Q – 2	R – 3
(B) P – 1	Q – 2	S – 3
(C) P – 2	Q – 1	S – 3
(D) P – 3	Q – 2	S – 1

Solution: (A).

Example 8: In a dual-slope integrating type DVM an input voltage of 1.6 V and reference voltage of 3.2 V are used for a supply frequency of 50 Hz. Calculate the total conversion time if the first integration is carried out for 20 periods.
(A) 0.2 s (B) 0.02 s
(C) 0.05 s (D) 2 s

Solution: (A)

In a dual-slope integrating type

$$\text{DVM}\left(\frac{t_1}{t_2}\right)V_{IN} = V_{ref}$$

First integration time $t_1 = 20 \times \frac{1}{50}$

$$= 0.4 \text{ s}$$

$$V_{IN} = 1.6 \text{ V}; \quad V_{ref} = 3.2 \text{ V}$$

Total conversion time

$$t_2 = \frac{V_{IN}}{V_{ref}} t_1 = \frac{1.6 \times 0.4}{3.2}$$

$$t_2 = 0.2 \text{ s}$$

Example 9: A digital voltmeter has a voltage controlled generator which provides a width of 5 μs/V of unit signal, uses a clock of 20 MHz. The pulse count corresponding to an input signal of 12 V would be
(A) 600 (B) 1200
(C) 1800 (D) 2400

Solution: (B)

$$\text{Pulse count} = (20\times10^6) \times (5\times10^{-6}) \times 12$$

$$= 1200.$$

Example 10: If a 24 V DC voltage is applied to an average response rectifier type electronic AC voltmeter, the meter would read
(A) 24 V (B) 23.34 V
(C) 25.5 V (D) 26.64 V

Solution: (D)
A rectifier type instrument is calibrated to read RMS values for sinusoidal waveforms

The meter would display 1.11 times the average value

$$\text{Readout} = 24 \times 1.11 = 26.64 \text{ V}.$$

Example 11: In a DVM, the number of pulses counted by the counter, when the ramp voltage falls down from 12 V to 0 V in 24 ms and the oscillator frequency of 325 kHz is
(A) 7800 (B) 8000
(C) 288 (D) 3900

Solution: (A)
Assuming the gate opens when ramp is 12 V and closes when ramp reaches 0

$$\text{Number of pulses} = (325\times10^3) \times (24\times10^{-3}) = 7800$$

Example 12: An integrating DVM measures
(A) Peak-to-peak value (B) True average value
(C) RMS value (D) Peak value

Solution: (B)

Exercises

Practice Problems I

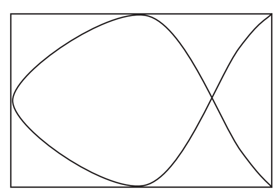
1. The type of converter used in digital meter is
(A) R2R ladder type A–D converter.
(B) Dual-slope integrating type A/D converter.
(C) Any kind of A–D converter.
(D) Flash converter.

2. The electrons in a CRT having a cathode anode voltage of 1000 V leave the cathode with zero velocity. The maximum velocity of the beam of electron in km/s is
(A) 45.6×10^3 (B) 30.6×10^3
(C) 10.5×10^3 (D) 18.7×10^3

3. When two voltages having the same frequency and equal magnitude but with a phase difference of 90° is applied to a CRO, the trace on the screen is a
(A) Circle (B) Ellipse
(C) Oval (D) Straight line

4. A voltage of $10 \sin(314t + 30°)$ is examined on a CRO having 10 divisions on the horizontal scale.
The line base is set to 10 ms/div. The number of cycles of signal displayed on the screen will be
(A) 1 (B) 2.5
(C) 5 (D) 10

5. Two frequencies of value f_h and f_v are applied to the horizontal and vertical plates of a CRO. The Lissajous pattern observed is as shown below. If f_h = 50 Hz, the value of f_v is



(A) 50 Hz (B) 100 Hz
(C) 150 Hz (D) 200 Hz

6. The meter that is suitable for measuring 10 mV at 50 Hz is
(A) VTVM
(B) CRO
(C) Moving iron voltmeter
(D) Electrostatic voltmeter

7. The vertical amplifier of an oscilloscope has a bandwidth of 20 MHz. The fastest rise time that an input may have to be displayed without distortion is
(A) 17.5 μs (B) 17.5 ns
(C) 1.75 μs (D) 1.75 ns

8. A CRT has an anode voltage of 3000 V and parallel deflecting plates 2.5 cm long and 5 mm apart. The screen is 25 cm from the centre of the plates. The input voltage is applied to the deflecting plates through amplifiers having an overall gain of 100. The input voltage required to deflect the beam through 5 cm is.
(A) 100 V (B) 240 V
(C) 2.4 V (D) 2 V

9. By digital voltmeters we can measure
(A) AC voltage
(B) DC voltage
(C) Both A and B
(D) Integrating type is used to measure DC only and the rest are used to measure both AC and DC

10. An average response rectifier type electronic AC voltmeter has DC voltage of 20 V applied to it. The meter reading will be.
(A) 22.2 V
(B) 11.1 V
(C) 10 V
(D) 14.4 V

11. The number of comparators needed in a parallel conversion type 8 bit A to D converter is
(A) 8 (B) 16
(C) 255 (C) 256

12. In a compensated shunt type peak reading VTVM, a bucking battery with a series adjustable resistance is used for
(A) Providing power for the circuit
(B) Zero setting
(C) Purpose of amplifying low level signal
(D) All of these

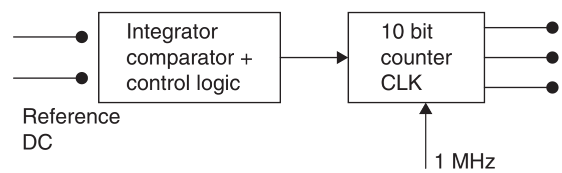
13. In comparison with a conventional VTVM, a balanced bridge vacuum tube voltmeter has
1. Higher input impedance.
2. Effects due to changes in value characteristics are minimized.
3. Meter zero has less tendency to shift.
4. Power supply fluctuation have a smaller effect on measuring circuit.

Select the correct answer using codes below.
(A) 2 and 4 (B) 1 and 3
(C) 1, 2 and 3 (D) 1, 2, 3 and 4

14. Rectifier type electronic voltmeter uses negative feedback. This is done to
(A) Increase the overall gain
(B) Improve the stability
(C) Overcome non-linearity of diodes
(D) None of these

15. The simplified block diagram of a 10 bit A–D converter of dual-slope integrator type is as shown.

The 10-bit counter at the output is clocked by a 1 MHz clock. Assuming negligible timing overhead for the control logic, the maximum frequency of the analog signal that can be converted using this A/D converter is approximately

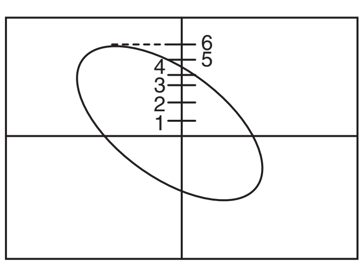


(A) 2 kHz (B) 1 kHz
(C) 500 Hz (D) 250

Practice Problems 2

1. The Lissajous pattern is used to measure
(A) Phase angle
(B) Frequency
(C) Both phase angle and frequency
(D) Does not measure phase angle or frequency

2. Two voltages having the same frequency is applied to a CRO in the X–Y mode. The Lissajous pattern obtained is as shown. The phase difference between the voltages would be.



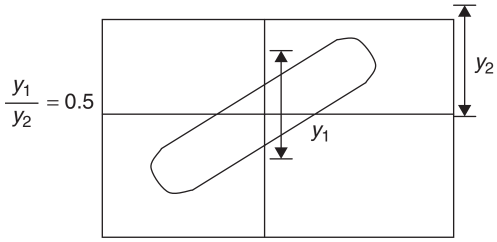
(A) 41.81° (B) 45° (C) 180° (D) 138.2°

3. When the horizontal deflecting plates of a CRO are kept at ground potential and 30 V DC is applied to the vertical defecting plate, the picture observed on the screen would be
(A) A spot approximately 3 cm away from the centre.
(B) A vertical line 2 cm long.
(C) A vertical line approximately 3 cm long.
(D) Two spots 2 cm vertical above each other.

4. A sinusoidal waveform, when observed on an oscilloscope, has a peak-to-peak amplitude of 14 cm. If the vertical resistivity setting is 5 V/cm, the RMS value of voltage will be
(A) 24.8 V (B) 49.6 V
(C) 9.9 V (D) 3.54 V

5. To the y input of a CRO, a signal defined by 10sin 100t is applied. To the x-input the signal 10cos100 t is applied. The gain for both x-channel and y-channel are the same. The screen shows
(A) Sinusoidal (B) A straight line
(C) An ellipse (D) A circle

6. Two sine waves of the same frequency are impressed on the X and Y plates of a CRO and the Lissajous figure seen is shown in the given figure. The phase difference between the signals is



(A) 30° or 330° or 150° or 210°
(B) 30° or 330° or 150°
(C) 30° or 330°
(D) 30°

7. Two inputs of a CRO are fed with two stationary periodic signals. In the X-Y mode, the screen shows a figure which changes from ellipse to circle and back to ellipse with its major axis changing orientation slowly and repeatedly. The following inference can be made from this
(A) The signals are not sinusoidal.
(B) The amplitude of signals are very close but not equal.
(C) The signals are sinusoidal with their frequencies very close but not equal.
(D) There is a constant but small phase difference between the signals.

8. Level detector is used in integrated type DVM circuit. It works much like a
(A) Voltage comparator (B) Pulse generator
(C) Counter (D) None of these

9. The advantage of VTVM over a non-electronic voltmeter is
(A) Lower power consumption
(B) Lower input impedance
(C) Ability to measure wider ranges of voltage and resistance
(D) Greater portability

10. A 10-bit A–D converter is used to digitize an analog signal in the 0–5 V range. The maximum peak to ripple voltage that can be allowed in DC supply voltage is
(A) Nearly 100 mV (B) Nearly 50 mV
(C) Nearly 25 mV (D) Nearly 5 mV

11. In a CRO, a Lissajous pattern of eight keeps on changing the shape when ratio of frequencies is
(A) Not exactly 1:1 (B) Not exactly 2:1
(B) Exactly 3:1 (D) Exactly 4:1

12. The number of base circuits that a dual-trace CRO can have is
(A) 1 (B) 2 (C) 3 (D) 4

13. Group II represents the figures obtained on a CRO screen when the voltage signals $V_x = V_{xm} \sin\omega t$ and $V_y = V_{ym} \sin(\omega t + \phi)$ are given to X and Y plates and ϕ is changed. Choose the correct value of ϕ from group I to match with corresponding figure of group II

Group I

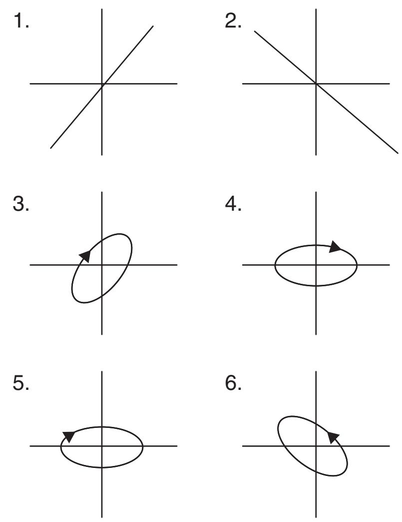
$P \quad \phi = 0$

$Q \quad \phi = \frac{\pi}{2}$

$R \quad \pi < \phi < \frac{3\pi}{\alpha}$

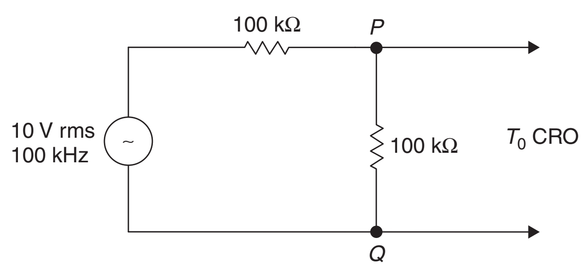
$S \quad \phi = \frac{3\pi}{2}$

Group II



(A) $P = 1, Q = 3, R = 6, S = 5$
(B) $P = 2, Q = 6, R = 4, S = 5$
(C) $P = 2, Q = 3, R = 5, S = 4$
(D) $P = 1, Q = 5, R = 6, S = 6$

14. A CRO probe has an impedance of 500 kΩ in parallel with a capacitance of 10 pF. The probe is used to measure the voltage between P and Q. The measured voltage will be

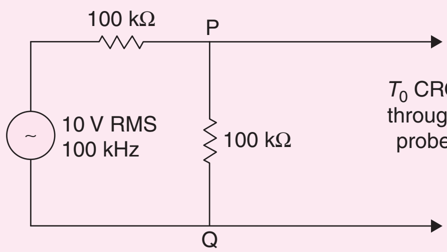


(A) 3.53 V (B) 4.37 V
(C) 4.54 V (D) 5.00 V

15. The simultaneous application of signals $x(t)$ and $y(t)$ to the horizontal and vertical plates, respectively, of an oscilloscope produces a vertical figure of '8' on display. If X and Y are constants and $x(t) = X \sin(4t + 30)$, then $y(t)$ is
(A) $Y\sin(4t - 30)$ (B) $Y\sin(2t + 15)$
(C) $Y\sin(8t + 60)$ (D) $Y\sin(4t + 30)$

Previous Years' Questions

1. A CRO probe has an impedance of 500 kΩ in parallel with a capacitance of 10 pF. The probe is used to measure the voltage between P and Q as shown in figure. The measured voltage will be **[2004]**

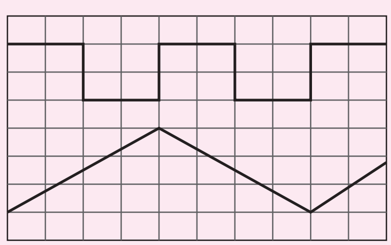


(A) 3.53 V (B) 4.37 V
(C) 4.54 V (D) 5.00 V

2. The Q-meter works on the principle of **[2005]**
(A) Mutual inductance (B) Self-inductance
(C) Series resonance (D) Parallel resonance

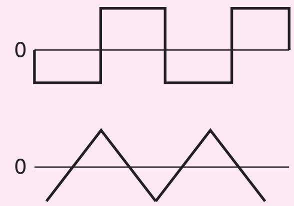
3. The simultaneous application of signals $x(t)$ and $y(t)$ to the horizontal and vertical plates, respectively, of an oscilloscope, produces a vertical figure-of-8 display. If P and Q are constants, and $x(t) = P\sin(4t + 30)$, then $y(t)$ is equal to **[2005]**
(A) $Q\sin(4t - 30)$ (B) $Q\sin(2t + 15)$
(C) $Q\sin(8t + 60)$ (D) $Q\sin(4t + 30)$

4. The time/div and voltage/div axes of an oscilloscope have been erased. A student connects a 1 kHz, 5 V p–p square wave calibration pulse to channel of the scope and observes the screen to be as shown in the upper trace of the figure. An unknown signal is connected to channel 2 (lower trace) of the scope. If the time/div and V/div on both channels are the same, the amplitude (p-p) and period of the unknown signal are, respectively. **[2006]**



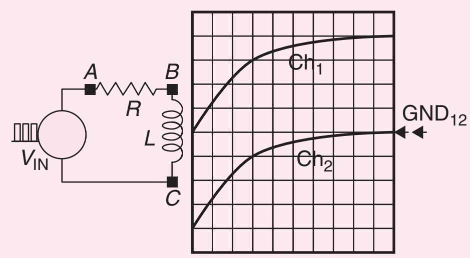
(A) 5 V, 1 ms (B) 5 V, 2 ms
(C) 7.5 V, 2 ms (D) 10 V, 1 ms

5. A sampling wattmeter (that computes power from simultaneously sampled values of voltage and current) is used to measure the average power of a load. The peak-to-peak voltage of the square wave is 10 V and the current is a triangular wave of 5 A p–p as shown in the figure. The period is 20 ms. The reading in W will be **[2006]**



(A) 0 W
(B) 25 W
(C) 50 W
(D) 100 W

6. The probes of a non-isolated, two-channel oscilloscope are clipped to points A, B and C in the circuit of the adjacent figure. V_{IN} is a square wave of a suitable low frequency. The display on Ch_1 and Ch_2 are as shown on the right. Then the 'Signal' and 'Ground' probes S_1, G_1 and S_2, G_2 of Ch_1 and Ch_2, respectively, are connected to points. **[2007]**

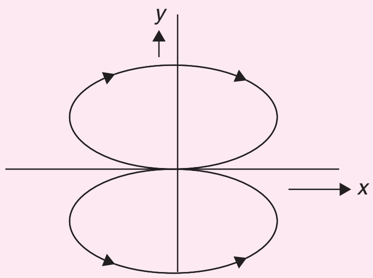


(A) A, B, C, A
(B) A, B, C, B
(C) C, B, A, B
(D) B, A, B, C

7. For a step-input e_i, the overshoot in the output e_0 will be **[2007]**
(A) 0, since the system is not under-clamped
(B) 5%
(C) 16%
(D) 48 %

8. If the above step response is to be observed on a non-storage CRO, then it would be best to have the e_i as a **[2007]**
(A) Step function
(B) Square wave of frequency 50 Hz
(C) Square wave of frequency 300 Hz
(D) Square wave of frequency 2.0 kHz

9. Two sinusoidal signals $p(\omega_1 t) = A\sin\omega_1 t$ and $q(\omega_2 t)$ are applied to X and Y inputs of a dual-channel CRO. The Lissajous figure displayed on the screen is shown below. The signal $q(\omega_2 t)$ will be represented as **[2008]**



(A) $q(\omega_2 t) = A\ \sin\omega_2 t,\ \omega_2 = 2\omega_1$

(B) $q(\omega_2 t) = A\ \sin\omega_2 t,\ \omega_2 = \frac{\omega_1}{2}$

(C) $q(\omega_2 t) = A\ \cos\omega_2 t,\ \omega_2 = 2\omega_1$

(D) $q(\omega_2 t) = A\ \cos\omega_2 t,\ \omega_2 = \frac{\omega_1}{2}$

ANSWER KEYS

EXERCISES

Practice Problems 1

1. B **2.** D **3.** A **4.** C **5.** B **6.** B **7.** B **8.** C **9.** C **10.** A
11. C **12.** C **13.** D **14.** C **15.** B

Practice Problems 2

1. C **2.** D **3.** C **4.** A **5.** D **6.** C **7.** D **8.** A **9.** A **10.** D
11. B **12.** C **13.** D **14.** A **15.** B

Previous Years' Questions

1. B **2.** C **3.** B **4.** C **5.** A **6.** B **7.** C **8.** C **9.** D