Model Answers: AS-2141
M.Sc. (Electronics) III Semester

Section-A **(10 × 2 =20)**

Note: *Attempt all questions. Each question carries 2 marks.*

1. Choose the correct answer:

i. Dynodes is a term used in

a. Photomultiplier

b. Photoconductive cell

c. Photovoltaic cell

d. None of these

Ans: **a**

ii. Prompt photo current in a PN diode

a. Current due to charge carriers in depletion region

b. Current due to charge carriers from neutral n – region

c. Current due to charge carriers from neutral p – region

d. None of these

Ans: **a**

iii. Visible range of electromagnetic spectrum corresponds to

a. 400 – 700 nm

b. 200 – 700 nm

c. 200 – 4000 nm

d. None of these

Ans: **a**

iv. $BaTiO_3$ can be used as _____________

a. Potentiometric transducer

b. Photoelectric transducer

c. Piezoelectric transducer

d. None of these

Ans: **c**

v. The gage factor for most of the metals would be in the range

a. -1.5 to -1.7 b. 2 to 5 c. 1.5 to 1.7 d. -2 to -5

Ans: **c**

vi. Which of the following transducer is having high sensitivity

a. Inductive b. LVDT c. Potentiometric d. Capacitive

Ans: **b**

vii. Quartz crystal is used in

a. Piezoelectric sensor

b. Crystal oscillator

c. Both a & b

d. None of these

Ans: **c**

viii. Which of the following quantities are measured with CRO

a. Voltage b. Frequency c. Phase angle d. all the above

Ans: **d**

ix. Which of the following is correct with respect to CRO

a. It works based on electrostatic deflection of charges

b. It works based on magnetostatic deflection of charges

c. Both a & b

d. None of these

Ans: **c**

x. A flood gun is used in ____________CRTs

a. Storage oscilloscope

b. Sampling oscilloscope

c. Conventional oscilloscope

d. None of these

Ans: **a**

Section – B (5 × 8 =40)

Note: *Answer any* ***five*** *questions. Each question carries 8 marks.*

2. Write a note on optical sensors. Discuss basic characteristics of photo detectors and explain the spectral response and spectral threshold for different optical sensing materials.

Answer:

Optical Sensors:

Optical sensing or detection can be done by using various different types of optical sensors like, photoelectric cell, photovoltaic cell and photoconductive cell. Optical radiation includes ultra violet (UV), infra red (IR) and visible region of electromagnetic spectrum. Radiation energy propagating through space in quanta when collides with matter several different phenomenon happen depending on material characteristics. Photoelectric effect is one of the most common fundamental phenomenon utilized in optical sensing. Radiation effects in photodiodes and light dependent resistors are also utilized as sensing principles for the detection of various different optical and non – optical radiations.

Basic characteristics of photo detectors:

The important characteristic that need to be considered for the photo detectors are i) work function ii) spectral sensitivity and spectral threshold, iii) quantum yield and quantum voltage iv) time lag, v) drift, fatigue and so on. vi) static and dynamic response and vii) linearity

Spectral response and spectral threshold:

The response of different photo sensitive materials to the optical radiation plays an important role in choosing correct material for applications. In photo emissive cells, a critical or threshold frequency decides the possibility of the emission of electrons from metal surfaces. This frequency is called threshold frequency and corresponding wavelength is called threshold wavelength. This depends on a materials property called work function (ϕ_e), energy required to release the electron from the material. The threshold wavelength is now given as,

$$\lambda_0 = hc/(= 1.2395/\phi \ \mu m$$

Thus, the photoelectric emission from metal surface occurs only if the wavelength of the incident radiation is less than the threshold wavelength or in other words, frequency is greater than the threshold frequency. Further the amount of emission is proportional to the intensity of the incident radiation, that is, the number of photons, although the proportionality is not linear for a fixed frequency distribution of the radiant power. It has been observed that for alkali metals the spectral sensitivity increases with increasing atomic weight. The absolute spectral response is often called the quantum efficiency and is expressed as a percentage of the maximum attainable for that particular wavelength.

The spectral response or the spectral sensitivity of the photo emissive cell is different for different cathode coating materials used in the cell. Manufacturers provide the response charts for the cells they produce. The following (Fig.1.) are few example curves for spectral response of some photo emissive materials.

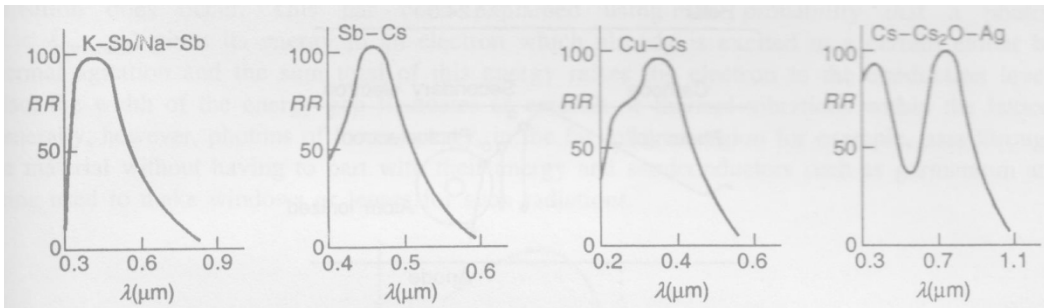

Fig..1. Relative spectral response characteristics of some photoemissive surface materials.

3. Explain the generation of photocurrent in PN diode and write expressions for prompt photo current and total current in neutral region and depletion regions. Explain the working of solar cell and derive expression for conversion efficiency.

Answer:

Photocurrent in a p-n diode

When light impinges upon a semiconductor electron-hole pairs gets generated in the semiconductor channel, some of the carriers are collected at the contact and lead to the photocurrent. Let us consider a long p-n diode in which excess carriers are generated uniformly at a rate G_L. Fig.2 shows a p-n diode with a depletion region of width W. The electron-hole pairs generated in the depletion region are swept rapidly by the electric field existing in the region. Thus the electrons are swept into n-region while the holes are swept into the p-region. The photocurrent arising from the photons absorbed in the depletion region is thus

$$I_{L1} = A.e \int_0^{x} G_L\, dx \qquad (1)$$

where A is the diode area and a uniform generation rate is assumed in the diode. Since the electrons and holes contributing to I_{L1} move under high electric fields, the response is very fast, and this component of the current is called the prompt photocurrent.

In addition to the carriers generated in the depletion region, e-h pairs are generated in the neutral n- and p-regions of the diode. On physical grounds, we may expect that holes generated within a distance Lp (the diffusion length) of the depletion region edge (x = 0 of Fig.2) will be able to enter the depletion region from where the electric field will sweep them into the p-side. Similarly, electrons generated within a distance L_n of the x = 0 to the current. Thus the photocurrent should come from all carriers generated in a region ($W+L_n+L_p$). A quantitative analysis reaches the same conclusion as shown below.

By using diode theory and boundary conditions, the photocurrent due holes and the electrons can be deduced and those are in the form of

hole current:

$$I_{pL} = eG_L L_p \, A \qquad (2)$$

and electron

$$I_{nL} = eG_L L_n \, A \qquad (3)$$

The totral current due to carriers in the neutral region and the depletion region, is

$$I_L = I_{nL} + I_{pL} + I_{L1} = eG_L\,(L_p + L_n + W)A \qquad (4)$$

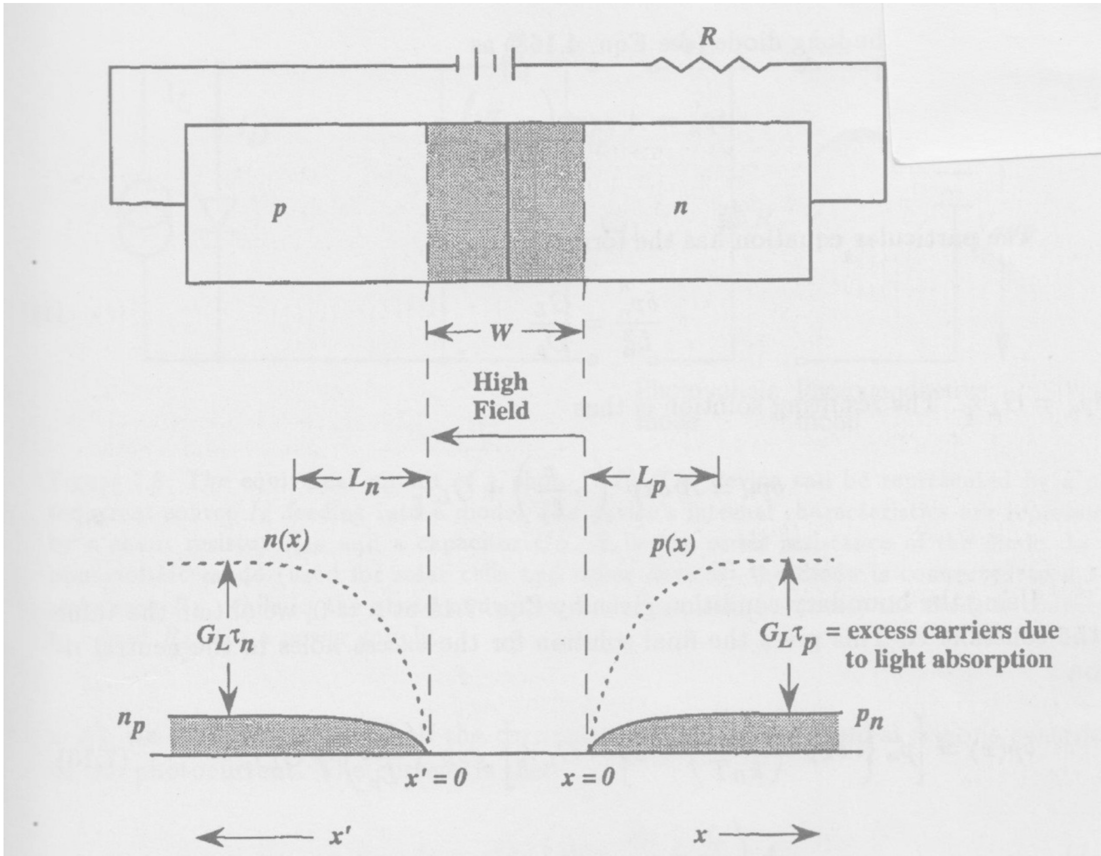

Fig.2 : A schematic of a p-n diode and the minority carrier concentration in absence and presence of light. The minority charge goes to zero at the depletion region due to the high field which sweeps the charge away. The equilibrium minority charge is Pn and Np in the n- and p-sides, respectively.

Working of solar cell and conversion efficiency:

An important application of p-n diode is to convert optical energy to electrical energy as in a solar cell. The solar cell operates without an external power supply and relies on optical power to generate current and voltage. To calculate the important parameters of solar cell consider the case where the diode is used in the open circuit mode so that the current I is zero. This gives for, equation (4)

$$I = 0 = I_L - I_0 \left(e^{(eV_{oc})/(m\,TK_B)} - 1\right) \quad (5)$$

where V_{oc} is the voltage across the diode and is known as the open circuit voltage. We get for this voltage

$$V_{OC} = \frac{mK_BT}{e} ln\left(1 + \frac{I_L}{I_0}\right) \quad (6)$$

At high optical intensities the open circuit voltage can approach the semiconductor band gap. In the case of Si solar cells for solar illumination (without atmospheric absorption), the value of V_{OC} is roughly 0.7 eV.

A second limiting case in the solar cell is the one where the output is short circuited i.e., R = 0 and V = 0. The short circuit current is then

$$I = I_{sc} = I_L \quad (7)$$

A plot of the diode current in the solar cell as a function of the diode voltage then provides the curve shown in the figure below. In general electrical power delivered to the load is given by

$$P = I \times V = I_L V - I_0 \left(e^{\frac{eV_{OC}}{mTK_B}} - 1 \right) V \quad (8)$$

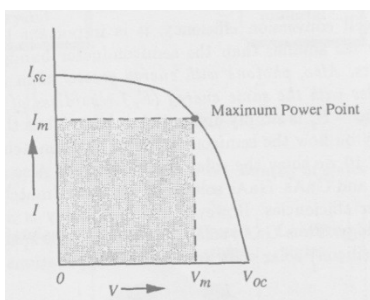

Fig.3. The relationship between the current and voltage delivered by a solar cell. The open circuit voltage (V_{oc}) and the short circuit current (Isc), the maximum power is delivered at the point shown.

The maximum power is delivered at a voltage and current value of V_m and I_m as shown in Fig.3

The conversion efficiency of a solar cell is defined as the rate of the output electrical power to the input optical power. When the solar cell is operating under maximum power conditions, the conversion efficiency is

$$\eta_{conv} = \frac{P_m}{P_{in}} x100 (percent) = \frac{I_m V_m}{P_{in}} \text{x100 (percent)} \quad (9)$$

4. (A) Write a note on metallic strain gages

(B)A resistance strain gage with a gage factor of 2 is fastened to a steel member subjected to a stress of 1,050 Kg/cm^2. The modulus of elasticity of steel is approximately 2.1 x 10^6 Kg/cm^2. Calculate the change in resistance, ΔR, of the strain gage element due to the applied stress

Answer:

(A) **Metallic strain gages:**The Strain gage is an example of a passive transducer that converts a mechanical displacement into a change of resistance. A strain gage is a thin, wafer like device that can be attached to a variety of materials to measure applied strain. Metallic strain gages are formed from thin resistance wire or etched from thin sheets of metal foil. Wire gages are generally small in size, are subject to minimal leakage, and can be used in high temperature applications. Foil elements are somewhat larger in size and are more stable than wire gages. They can be used under extreme temperature conditions and under prolonged loading, and they dissipate self-induced heat easily. Various resistance materials have been developed for use in wire and foil gages. Constanan, Nicrome V, Dynaloy are few examples metallic strain gages. Semiconductor strain gages are often used in high-output tranducers such as load cells. The shape of the sensing element is selected according to the strain to be measured: uniaxial, biaxial, or multidirectional. For example, in the case of uniaxial applications most often use long, narrow sensing elements, as shown in the Fig.4, to maximize the strain sensing material in the direction of interest.

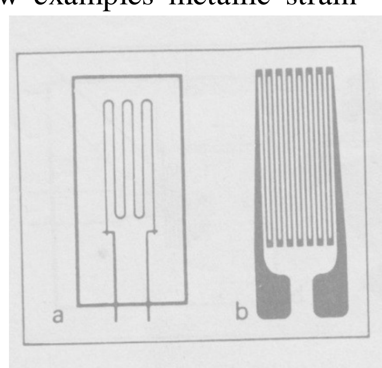

Fig.4. Uniaxial strain gages

The sensitivity of a strain gage is described in terms of a characteristic called the gage factor K, defined as the unit change in resistance per unit change in length, or

$$\text{gage factor } K = \Delta R/R \,/\, \Delta l/l$$

where K is gage factor, ΔR is change in gage resistance, Δl is change in specimen length. For strain gage applications, a high sensitivity is very desirable. A large gage factor means a relatively large sensitivity.

(B) Numerical

By using Hooke's Law, strain (σ) = $\Delta l/l = s/E$

$$= 1.050/2.1\text{x}10^{6} = 5\text{x}10^{-4}$$

The sensitivity of the strain gage, gage factor K = 2

And $K = \Delta R/R \,/\, \Delta l/l \quad \Rightarrow \Delta R/R = K\,\sigma = 2\text{x}5\text{x}10^{-4} = 10^{-3}$ or 0.1%

5. Write a note on

   A) Displacement transducers

   B) Capacitive transducers

   C) Inductive transducers

Answer:

A) **Displacement transducers:** The concept of converting an applied force into a displacement is basic to many types of transducers. The mechanical elements that are used to convert the applied force into a displacement are called a force summing devices. The force summing members generally sued are, diaphragm, bellows, straight tube, twisted tube etc. the displacement created by the action of the force summing device is converted into a change of some electrical parameter. The electrical principles most commonly used in the measurement of displacement are i) capacitive, ii) inductive, iii)differential transformer, iv)oscillation, v) piezoelectric etc.

B) **Capacitive Transducer:** The capacitance of a parallel plate capacitor is given by

$$C = kA\varepsilon/d$$

Where A is area of each plate, d is plate spacing and k is dielectric constant.

Since the capacitance is inversely proportional to the spacing of the parallel plates, any variation in d causes a corresponding variation in the capacitance. This principle is applied in the capacitance transducer, as shown in the Fig.5. A force, applied to a diaphragm that functions as one plate of a simple capacitor, changes the distance between the diaphragm and the static plate. The resultant change in capacitance could be measured with an ac bridge, but it is usually measured with an oscillator circuit. The transducer, as part of the oscillatory circuit, causes a change in the frequency of the oscillator. The capacitance transducer has excellent frequency response and can measure both static and dynamic phenomena. Its disadvantages are sensitivity to temperature variation and possibility of erratic or distorted signals due to long lead length.

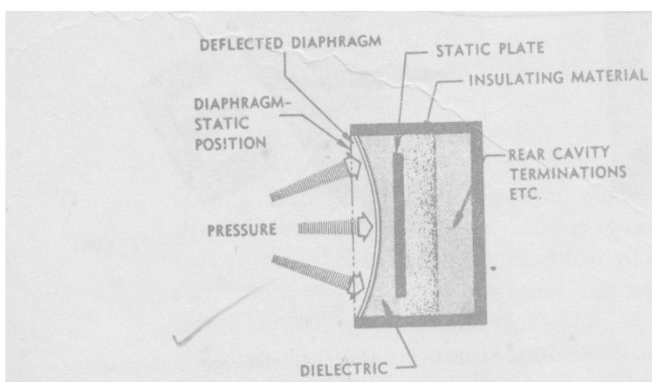

Fig.5. Typical diagram of capacitive transducer

C) **Inductive Transducer:**

In the inductive transducer the measurement of force is accomplished by the change in the inductance ratio of a pair of coils or by the change of inductance in a single coil. In each case, the ferromagnetic armature is displaced by the force being measured, varying the reluctance of the magnetic circuit. Fig.6. shows a single coil system as a inductive transducer.

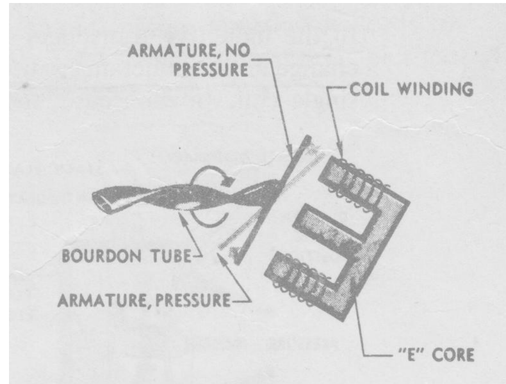

Fig.6. diagram of Iductive transducer

The resultant change in inductance is a measure of the magnitude of the applied force. The coil can be used as a component of an LC oscillator whose frequency then varies with applied force. This type of transducer is used extensively in telemetry system, with a single coil that modulates the frequency of a local oscillator. The inductive transducer responds to static and dynamic measurements, and it has continuous resolution and a fairly high output.

6. What is the difference between photoconductive and photovoltaic cell? Name one application for each cell.

Answer:

Photoconductive cell: The photoconductive cell is the simplest of the detectors and consists of a simple region of semiconductor across which a bias is applied. When light with a proper wavelength impinges upon the semiconductor, e-h pairs are created which are then collected by the electric field. The change in current is detected by a circuit of the form shown in the Fig.7. An important benefit of the photoconductive detector is the gain in the device.

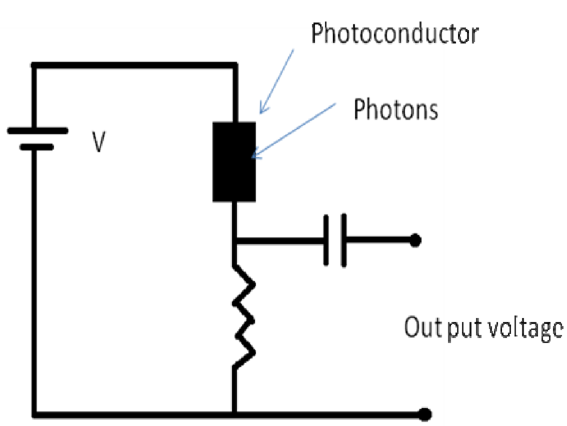

Fig.7. A typical bias circuit for a photo detector. Light causes a change in the resistance of the photoconductor.

An important mode of operation of p-n (p-i-n) diode under illumination is when the diode is under reverse bias conditions. The reverse bias is, however, not so strong that there are breakdown effects as in the avalanche photodiode.

Photovoltaic cell: photovoltaic cells are seen to generate emf when irradiated with radiation of proper range and luminance. The conventional photovoltaic cell consists of a layer of semiconductor on a metal disc. A thin translucent or transparent layer of a precious metal is sputtered on top. The incident radiation on the top layer passes through it and is absorbed by the upper surface of the semiconductor and electrons are freed.

Across a p-n junction, carrier migration occurs and hence, a potential difference is developed. The operation of a p-n junction with or without an impressed electric voltage across it can have three distinct modes of operation. If the p-n junction is reverse biased, small leakage current due to movements of intrinsically generated carriers would flow. Now with photo-irradiation, the rate of generation of intrinsic carriers is enhanced and a set of curve in the third quadrant of Fig.8 below are obtained with increasing illumination. This mode of operation is commonly encountered in photodiodes and they can be called photojunction cells.

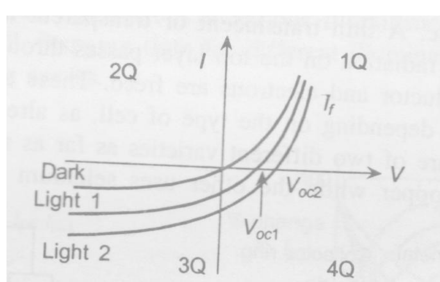

Fig. 8. V-I plot of the p-n junction diode in three quadrants

In the unbiased condition, when the cell is irradiated with photons, a current passes through a load resistance R_L or in the open circuit condition, an open circuit voltage V_{oc} is obtained across the junction diode. This is the photovoltaic mode of operation the corresponding characteristic set of curves is shown in the fourth quadrant of Fig.7.

7. Derive an expression for the vertical deflection on the screen of Cathode Ray Tube (CRT) in terms of length of plates, separation distance, accelerating voltage and distance between screen from the origin.

Answer: It is well known that a force is experienced by an electron when it is kept in a uniform electric field. This principle is the basis for the deflection of electron beam owing to deflection plates. Let us consider an electron having initial velocity u m/s along X-axis at point O in the space between the plates A and B, each of length l metres and separated by a distance d metres (as depicted in Fig.9).

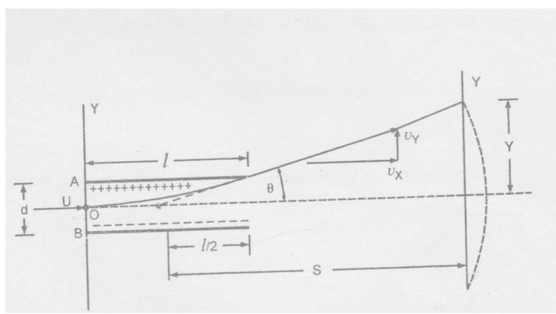

Fig.9. Electrostatic deflection of cathode ray beam

Let the pd across the plates be of V volts. For simplicity, let us assume that the field is uniform and does not extend beyond the ends of the plates. Axial velocity of electron remains unchanged and is equal to u as there is no axial force and, therefore, no axial acceleration.

The period during which an electron remains in the region between the two plates is given by the equation

$$t = l/u \tag{1}$$

there is no initial velocity along Y-axis but has an acceleration along Y – axis given by the equation.

$$a_y = eE/m = e/m .V/d \qquad (2)$$

the velocity of electron along Y-axis after time t is given by the equation

$$v_y = 0 + a_y t = eVl/mdu \qquad (3)$$

after the electron leaves the region between the deflection plates, it travels in a straight line, because there is no field acting on it. A simple extension of this development will show that if this line is extended backward it intercepts the X – axis at the centre of the plates i.e. at x = l/2. Let S be distance along the X – axis from this point to the screen. Then the deflection y can be determined by similar triangles. Thus

$$\frac{y}{S} = \frac{v_y}{v_x} = \frac{\frac{eVl}{mdu}}{u}$$

$$\text{or } y = \frac{elVS}{mdu^2} \qquad (4)$$

If V_a is the accelerating voltage and V_d is the deflecting voltage, then,

$$u = \sqrt{\frac{2eV_d}{m}} \qquad (5)$$

Substituting u in equation 4, we get

$$y = \frac{elSV_d}{md\,\frac{2eV_a}{m}} = \frac{lSV_d}{2dV_a} \qquad (6)$$

8. Write about the following in a CRO

   i. Intensity control

   ii. Horizontal shift

   iii. Sweep

   iv. Triggering

Answer:

Various controls are provided on a panel of cathode ray oscilloscope (CRO) to facilitate its proper functioning. Intensity control is provided for adjustment of brightness of the sport on the screen. It is accomplished by varying the voltage between the first and second anodes. The horizontal and vertical position controls are provided for moving the beam on any part of the screen. It is accomplished by applying a dc voltage to horizontal or vertical deflection plates. Similarly there are other numerous controls in a CRO.

i. Intensity Control: The potential of the control grid with respect to cathode is controlled with the help of potentiometer in order to control the intensity of brightness of the spot. The grid potential determines the amount of electrons leaving the cathode and thus controls the intensity of the beam. A larger number of electrons in the beam cause a brighter sport to appear on the screen.

ii. Horizontal shift:

External signal is applied to horizontal deflection plates through the horizontal amplifier at the sweep selector switch in EXT position. The horizontal amplifier, increases the amplitude of the input signal to the level required by the horizontal deflection plates of CRT. By using horizontal deflection the sport can be moved from left to right on the screen of CRO.

iii. Sweep

The main function of the sweep generator is to produce one cycle of a saw tooth waveform, when it receives a pulse at its input. If the sweep generator receives a trigger pulse during its sweep cycle (i.e., during the trace period Tr), it will simply ignore the pulse and continue with the completion of its sweep cycle. Depending on the selected level and the slope of the input signal, the output of the pulse generator will consist of narrow trigger pulses separated from each other by one period T. Each time the input signal crosses a preselected level (and a preselected slope), the pulse generator emits one narrow trigger pulse. The emitted pulse triggers the sweep generator to begin producing one cycle of the sweep waveform; its duration is the trace period (Tr). At the end of each sweep cycle, the sweep generator stops its output and awaits the arrival of the next trigger pulse before producing a new sweep cycle.

iv. Triggering

The trigger is the event or signal that causes the oscilloscope CRT beam to begin its sweep across the display. Without an adequate trigger, the display starts at unrelated points on the waveform, and the result is a display that is unsynchronized. For the display to be synchronized, or stable, the trigger event should be related in some way to the displayed waveform. Many times it is the waveform itself. Modern oscilloscopes provide versatility in selection of trigger signal, method of coupling the trigger signal into the scope, and positioning of the actual trigger point on the trigger signal waveform.

References:

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