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ESE - 2018
MAINS EXAMINATION
Questions with Detailed Solutions

ELECTRONICS & TELECOMMUNICATION ENGINEERING

PAPER - I

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ELECTRONICS & TELECOMMUNICATION ENGINEERING

ESE _MAINS_2018_PAPER – I

PAPER REVIEW

Except a few out of scope questions from Materials Science, remaining questions in the paper can be easily attempted. Particular in this paper selection of questions plays a vital role in securing a good score. For example Section-A is relatively tougher than Section-B, so choosing 3 questions from Section-B will fetch you a big advantage.

SUBJECT WISE REVIEW

SUBJECT(S)	LEVEL	Marks
Basic Electronics Engineering	Moderate	67
Basic Electrical Engineering	Moderate	12
Materials Science	Hard	39
Electronic Measurements and Instrumentation	Moderate	104
Network Theory	Easy	107
Analog and Digital Circuits	Moderate	151

Subject Experts,

ACE Engineering Academy

SECTION - A

01. (a) Plot the output voltage of the circuit, as shown in Figure (a) below, which has as its input a sawtooth waveform depicted in Figure (b).

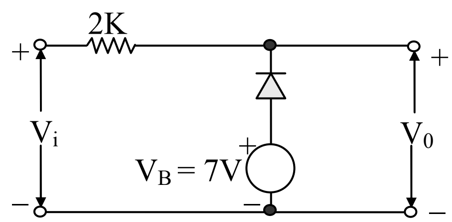


Figure (a)

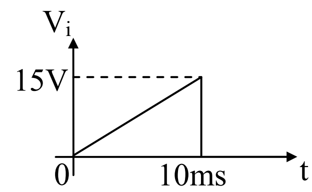
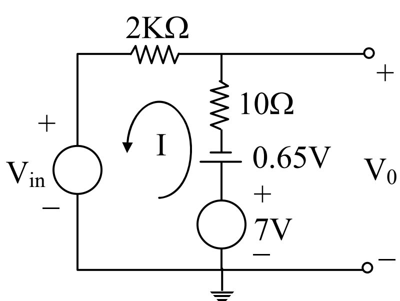


Figure (b)

The diode parameters are $R_f = 10\Omega$, $V_\gamma = 0.65$ V and $I_s = 0$. **(12 M)**

Sol:



The diode is forward biased only when the current I is positive

KVL

$-7 + 0.65 + I(10) + I(2k) + V_{in} = 0$

$$I = \frac{6.35 - V_{in}}{2010}$$

I is positive when $V_{in} < 6.35V$ (diode forward biased)

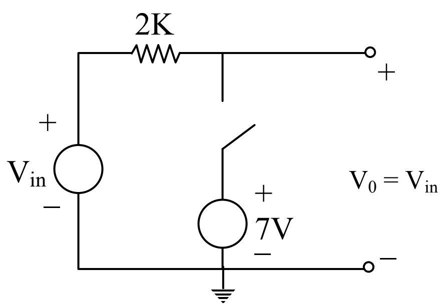
$V_0 = V_{in} + I(2K)$

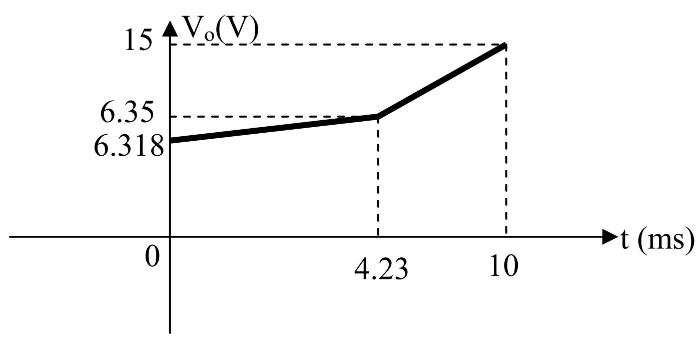
$$V_0 = V_{in} + \left[\frac{6.35 - V_{in}}{2010}\right]2000$$

If $V_{in} = 0 \rightarrow V_0 = 6.318V$

$V_{in} = 6.35 \rightarrow V_0 = 6.35V$

If $V_{in} > 6.35V$, Diode Reverse Bias $\rightarrow V_0 = V_{in}$





01. (b) The electric field in a region of space is given by

$\vec{E} = (yz\hat{x} + xz\hat{y} + xy\hat{z})Vm^{-1}$**.**

Calculate the charge density at the point (x, y, z) = (1, 2, 3)m and the magnetic flux density at the point (1, 2, 3)m. Given that $\vec{B}(5,6,7) = 3T$. (12 M)

Sol: Given $\overline{E} = (yz\hat{x} + xz\hat{y} + xy\hat{z})V/m$

From Gauss's law $\nabla.\overline{E} = \frac{\rho_V}{\varepsilon}$

$$\Rightarrow \frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z} = \frac{\rho_V}{\varepsilon}$$

From the given problem, $E_x = yz$, $E_y = xz$ & $E_z = xy$

$$\nabla.\overline{E} = \frac{\partial(yz)}{\partial x} + \frac{\partial(zx)}{\partial y} + \frac{\partial(xy)}{\partial z} = \frac{\rho_V}{\varepsilon}$$

$$\Rightarrow \vec{E} = 0 = \frac{\rho_V}{\varepsilon}$$

$$\text{(i.e)}\ \frac{\rho_V}{\varepsilon} = 0$$

$$\Rightarrow \boxed{\rho_V = 0}$$

$\because \nabla.\overline{E} = 0$ at any point $\Rightarrow$ the given field is divergence less (or)

Solenoidal at any point in space and hence $\rho_v = 0$ at any point in space.

$\therefore\ \rho_V(1, 2, 3) = 0$

$$\nabla \times \overline{E} = -\frac{\partial \overline{B}}{\partial t}$$

$$-\frac{\partial \overline{B}}{\partial t} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ yz & xz & xy \end{vmatrix}$$

$$-\frac{\partial \overline{B}}{\partial t} = \hat{a}_x(0) - \hat{a}_y(0) + \hat{a}_z(0)$$

$$\frac{\partial \overline{B}}{\partial t} = \overline{0}$$

B = 0 + C

Given B(5, 6, 7,) = 3T

So, C = 3

$\therefore$ B = 3T(everywhere)

01. (c) (i) Compare accuracy and precision with an example of archery target shooting.
(ii) How can time and frequency standards be disseminated? (12 M)

Sol:

(i) Accuracy:

The closeness with which an instrument reading approaches the true value.

Thus accuracy of a measurements means conformity to truth.

Precision:

It is a measure of the reproducibility of the measurement.

The term "precise" means clearly (or) sharply defined.

- Accuracy is a major part of "archery" when shooting a bow.
- Whether a beginner (or) an advanced shooter and keeping a good form is essential.
- Bow hunters are always trying to improve their accuracy in order to get better penetration, and of course to get bragging rights.
- Designed with archer in mind means guaranteed to make more accurate.
- "Having an anchor point is essential to accuracy".
- One of the most important being the archer's non-dominant hand. This hand is used to hold the bow, and coincidently has a tremendous influence on the accuracy of the shot. Basically any kind of pressure that is put on the bow that is not directly on the center point of the riser causes torque, which negatively influences the movement of the string in relation to the position of the bow, decreasing the accuracy of the shot.

The more torque caused by the shooter, the more inaccurate the shot will be.

Precision archery means flawlessly executing every phase of a shot sequence.

(ii) Time Standard:

Time standard is specification for measuring time; either the rate at which time passes (or) points in time, (or) points in time, (or) both.

Several time specifications have been officially recognized as standards.

Eg: Time scale, specifying a method for measuring divisions of time.

Frequency Standard:

Frequency standard is a stable oscillator used for frequency calibration (or) reference.

A frequency standard generates a fundamental frequency with a high degree of accuracy and precision.

A standard clock comprises a frequency standard a device to count off the cycles of the oscillation emitted by the frequency standard and a means of displaying (or) outputting the result.

01. (d) What are Bottom-up and Top-down methods of synthesis of nano materials? (12 M)

Sol: Top down Approach:

- Top down approach refers to slicing or successive cutting of a bulk material to get nano sized particle.
- *Attrition or Milling* is a typical top down method in making nano particles
- The nanomaterials are derived form a bulk substrate and obtained by progressive removal of material, until the desired nanomaterial is obtained.
- This approach leads to the bulk production of nano material. Regardless of the defects produced by top down approach, they will continue to play an important role in the synthesis of nano structures.

Ex: (1) photo lithography
(2) Scanning lithography
(3) E- beam lithography

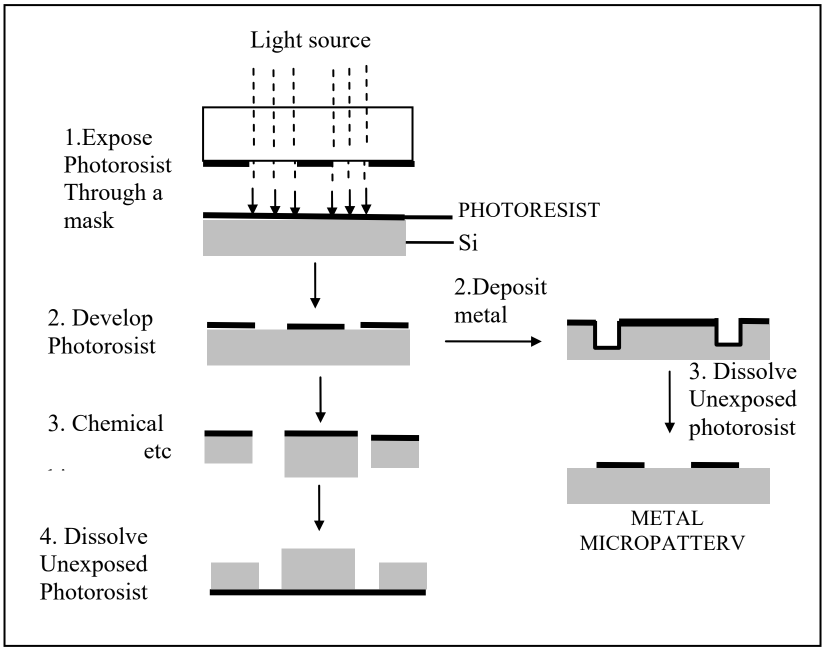
Photo Lithography:

This technique follows the principle of transferring an image from a mask to a receiving substrate.

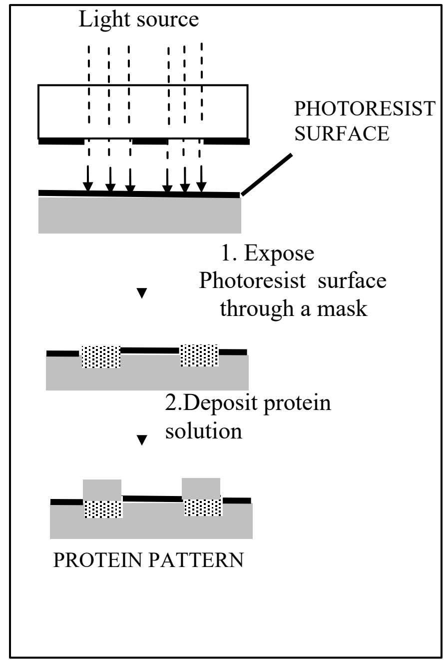
A typical lithographic process consists of three successive steps:

- Coating a substrate (Si wafer or glass) with a sensitive polymer layer (called resist)
- Exposing the resist to light, electrons or ion beams
- Developing the resist image with a suitable chemical(developer), which reveals a positive or negative image on the substrate depending on the type of resist used.(i.e. positive tone or negative tone resist).

(1) PHOTO LITHOGRAPHY



(2) PHOTOLIEOGRAPHY IN BIOPATTERNING



Problems associated with top down approach:

- The biggest problem with top down approach is the imperfection of surface structure and significant crystallographic damage to the processed patterns. Due to these imperfections design and fabrication of devices is difficult.
- The top down approach introduces internal stress, in addition to surface defects and contaminations

Bottom up Approach:

- Bottom up approach refers to the build up of a material from the bottom; atom by atom, molecule by molecule or cluster by cluster.
- The *colloidal dispersion* is a good example of bottom up approach in the synthesis of nano particles.
- This method is not a new concept. All the living beings in nature observe growth by this approach only and also it has been in industrial use for over a century.

  Ex: The production of salt and nitrate in chemical industry.
- Bottom up approach gives a better chance to obtain nano structures with less defects, more homogeneous chemical composition.
- Bottom up methods can be divided into gas-phase and liquid-phase methods.

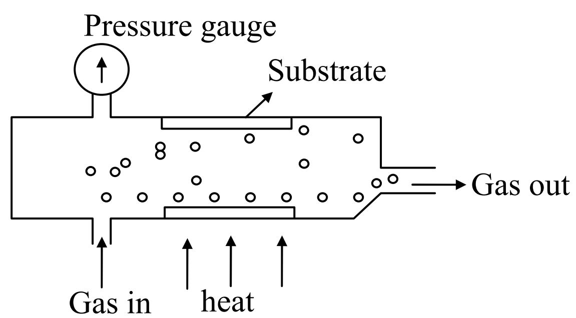
Gas-phase methods:

Plasma arcing and chemical vapour deposition

Liquid phase methods:

Sol-gel synthesis, molecular self-assembly

Chemical vapour deposition:



The material to be deposited is first heated to its gas form and then allowed to deposit as a solid on a surface.

- The method is normally performed under vacuum.
- The deposition can be direct or through a chemical reaction so that the material deposited is different from the one volatilized.
- This process is routinely used to make nanopowders of oxides and carbides of metals if carbon or oxygen are present with the metal.
- The method can also be used to generate nanopowders of pure metals, although not so easily.
- Chemical vapour deposition is often used to deposit a material on a flat surface.
- When a surface is exposed to a chemical vapour, the first layer of atoms or molecules that deposit on the surface can act as a template on which material can grow.

01. (e) An amplifier with an open-loop gain $A_v = 1000 \pm 100$ is available. It is necessary to have an amplifier whose voltage gain varies by no more than ±0.1%

(i) Find the reverse transmission factor, β, of the feedback network used.

(ii) Find the gain with feedback. **(12 M)**

Sol:

(i) $A = 1000 \pm 100$

$$\% \text{ change} = \frac{100}{1000} \times 100 = 10\%$$

$\%$ change in $A_f = 0.1\%$

$$\% \text{ change in Af} = \frac{\% \text{ change in A}}{1 + A\beta}$$

$$0.1 = \frac{10}{1 + 1000(\beta)}$$

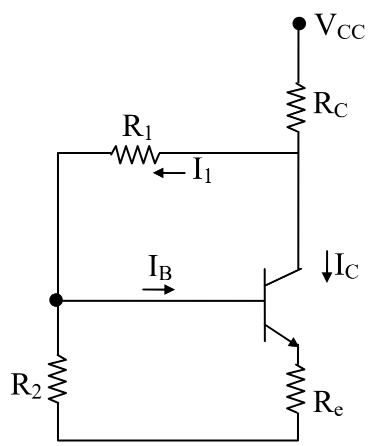
$\beta = 0.099$

(ii) Gain with feedback $(A_f) = \dfrac{A}{1 + A\beta}$

$$= \frac{1000}{1 + 1000[0.099]}$$

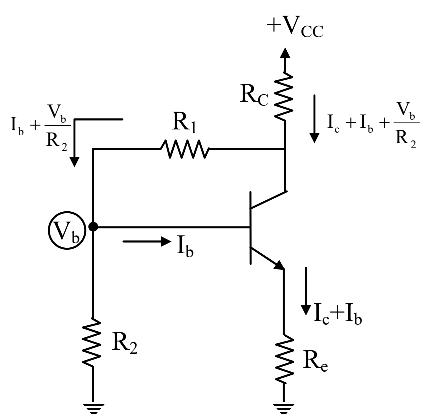
$= 10$

02. (a) Determine the stability factor, S", that is related to the variation of collector current I_C with respect to β, for the circuit shown below.



Assume silicon transistor and also β to be much larger than unity. (20 M)

Sol:



KVL

$$V_{CC} = \left(I_C + I_b + \frac{V_b}{R_2}\right)R_C + \left(I_b + \frac{V_b}{R_2}\right)R_1 + V_b$$

$$= I_C R_C + \frac{I_C R_C}{\beta} + \frac{V_b R_C}{R_2} + \frac{I_C R_1}{\beta} + \frac{V_b R_1}{R_2} + V_b$$

$$= \underbrace{I_C\left[R_C + \frac{R_C}{\beta} + \frac{R_1}{\beta}\right]}_{\text{term1}} + \underbrace{V_b\left[1 + \frac{R_1}{R_2} + \frac{R_C}{R_2}\right]}_{\text{term2}}$$

But $V_b = V_{be} + (I_C + I_b)\, R_e$

$$= V_{be} + I_C R_e + \frac{I_c}{\beta} R_e$$

$$= V_{be} + I_C\left[R_e + \frac{R_e}{\beta}\right]$$

$$\therefore \text{ term2 } = \left[V_{be} + I_c\left[R_e + \frac{R_e}{\beta}\right]\right]\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right]$$

$$= V_{be}\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right] + I_c\left[R_e + \frac{R_e}{\beta}\right]\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right]$$

$$V_{CC} = I_C\left[R_c + \frac{R_c}{\beta} + \frac{R_1}{\beta}\right] + I_c\left[R_e + \frac{R_e}{\beta}\right]\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right] + V_{be}\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right]$$

$$I_c = \frac{V_{cc} - V_{be}\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right]}{R_c + \frac{R_c}{\beta} + \frac{R_1}{\beta} + \left[R_e + \frac{R_e}{\beta}\right]\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right]}$$

Stability factor

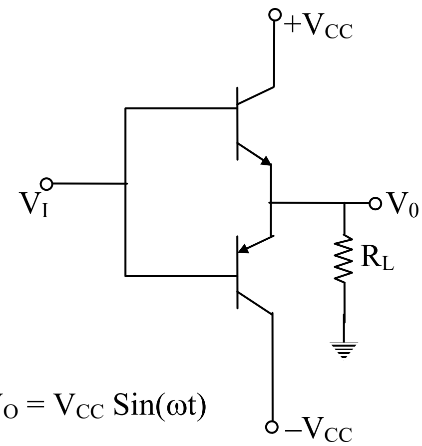
$$\frac{\partial I_c}{\partial \beta} = \frac{-\left[V_{cc} - V_{be}\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right]\right]\left[\frac{-R_c}{\beta^2} - \frac{R_1}{\beta^2} - \left(1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right)\left(\frac{R_e}{\beta^2}\right)\right]}{\left[R_c + \frac{R_c}{\beta} + \frac{R_1}{\beta} + \left[R_e + \frac{R_e}{\beta}\right]\left[1 + \frac{R_1}{R_2} + \frac{R_c}{R_2}\right]\right]^2}$$

02. (b) An output power of 10 W is to be delivered from a class-B push-pull amplifier. What will be the collector dissipation power of each of the transistors used?

Instead, if another configuration of two paralleled transistors, operating in class-A mode are used, what will be the collector dissipation power of each transistor? Derive the equations used.

(20 M)

Sol: Class – B Push Pull Amplifier:



$V_I = V_O = V_{CC}\ \mathrm{Sin}(\omega t)$

$$P_{O,AC} = \frac{V_{CC}^2}{2R_L} = 10W$$

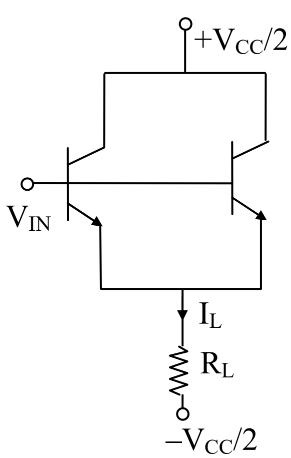
$$P_{DC} = 2V_{CC}\cdot\frac{V_{CC}}{\pi R_L}$$

$$= \frac{4}{\pi}\cdot\frac{V_{CC}^2}{2R_L} = \frac{40}{\pi}W = 12.74W$$

$$P_{TX} = \frac{P_{DC} - P_{O,Ac}}{2} = \frac{12.74 - 10}{2} = 1.37W$$

P_{TX} is the power dissipated by each Transistor.

Class – A with 2 Transistors:



$$V_{IN} = \left(\frac{V_{CC}}{2}\right)\sin(\omega t)$$

$$I_L = \frac{V_{CC}}{2R_L} + \frac{V_{CC}}{2R_L}\sin(\omega t)$$

$$P_{O,Ac} = \frac{V_{CC}^{\ 2}}{8R_L} = 10W$$

$$P_{O,DC} = \frac{V_{CC}^{\ 2}}{4R_L} = 20W$$

$$P_{DC} = \frac{V_{CC}^{\ 2}}{2R_L} = 40W$$

$$P_{TX} = \frac{P_{DC} - P_{O,AC} - P_{O,DC}}{2} = \frac{40-10-20}{2} = 5W$$

02. (c) Hall measurements are conducted on a p-type semiconductor bar 500 μm wide and 20 μm thick. The Hall contacts 'A' and 'B' are displaced 2μm with respect to each other in the direction of current flow of 3mA. The voltage between A and B with a magnetic field of 10^{-5} Wb/cm^2 pointing out of the plane of the sample is 3.2 mV. When the magnetic field direction is reversed the voltage changes to –2.8 mV. Find the value of mobility of holes.

(20 M)

Sol: Hall measurements are made on a p-type semiconductor bar of 500μm wide and 20μm thick. The hall contacts A and B are displaced by 2μm.

Current I = 3mA

V_{AB} when magnetic field is pointing out of the plane is 3.2mV and –2.8mV when magnetic field direction is reversed.

The voltage measured is the Hall voltage plus the ohmic drop.

The sign of V_H changes with the magnetic field, but not the ohmic voltage.

$$V_H = \frac{V_{H1} - V_{H2}}{2} = \frac{3.2-(-2.8)}{2} = 3mV$$

$\Rightarrow$ ohmic drop = 3.2 –3 = 0.2mV

From the equation of hall co-efficient, $p_0 = \frac{I_x B_z}{qt\,V_{AB}}$

$$= \frac{(3\times10^{-3}\,A)(10^{-5}\,Wb/cm^2)}{q(20\times10^{-4}\,cm)(3\times10^{-3}\,V)}$$

$$= 3.125 \times 10^{16}/cm^3$$

$$J = \sigma E \Rightarrow J = \frac{E}{\rho} \Rightarrow \rho = \frac{E}{J}$$

$$= \frac{0.2mV/2\mu m}{3mA/(500\mu m\times 20\mu m)} = 0.033\Omega - cm$$

$$\rho = \frac{1}{q\mu_p p_0} \Rightarrow \mu_p = \frac{1}{q\,p_0\rho}$$

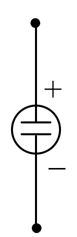
$$\mu_P = \frac{1}{1.6\times10^{-19}\times0.033\times3.125\times10^{16}}$$

$$= 6060.6\ cm^2/V.sec$$

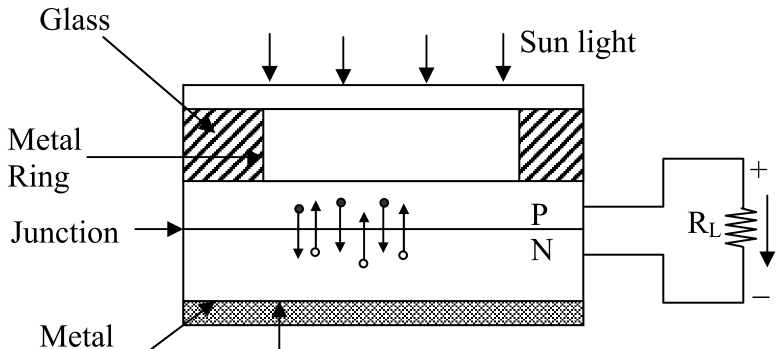
03. (a) Draw a schematic diagram of a solar photovoltaic cell and explain its principle of operation.

(12 M)

Sol:



Solar cell Schematic symbol



Solar cell construction

It is a device which converts the light energy into Electrical energy. When light is allowed to fall on this cell, the cell generate a voltage across it's terminals. This voltage increases with increase in the light intensity. The cell is so designed that a large area is exposed to light which enhances the voltage generation across the two terminals of the cell.

It essentially consists of a silicon PN junction diode with a glass window on top surface layer of P material is made extremely thin so that incident light photons may easily reach the PN junction when there photons collide with valence electrons. They compose them sufficient energy as to leave their parent atoms. In the way free electrons and holes are generated on both sides of the junction. Due to these holes and electrons current is produced. This current is directly proportional to the illumination (mw/cm^2) and also depends on the size of the surface area being illuminates.

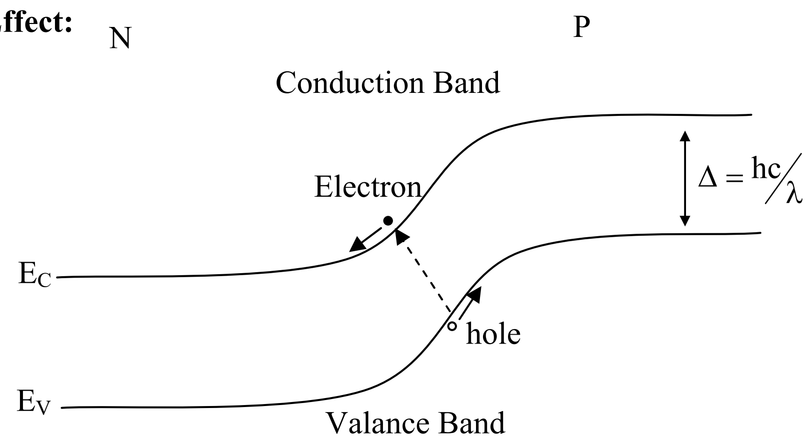
The open circuit voltage is a function of illumination.

As shown in the given diagram the solar cell is like an ordinary diode. It consists of silicon, germanium PN junction with a glass windows on the top surface layer of P–Type, the P–Type material is made very thin and wide so that the incident light photon may easily reach to PN junction.

The P Nickel plated ring around the P layer acts as the positive output terminal's (anode) and the metal contact at the bottom acts as a cathode.

Silicon and germanium are the most widely used semiconductor materials for solar cells although Gallium Arsenide, Indium Arsenide and Cadmium arsenide are also being used now a days.

Photovoltaic Effect:

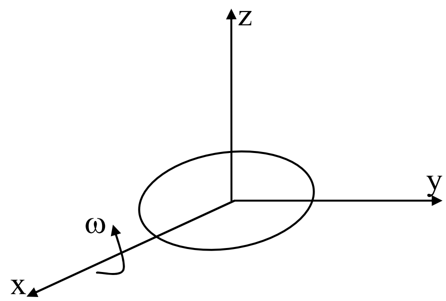


Photovoltaic affect can occur in a material which has a space charge layer.

Eg: In a P–N junction

A Photon of sufficient energy can be absorbed by the detector material to excite an electron from the valence band to the conduction band. The excited electron may be observed through it contribution to the current. A photovoltaic detector can be operated without application of a bias voltage.

03. (b) A rotating circular loop of radius 0.1m and resistance of 10 Ω is placed in a constant magnetic field of $0.2\hat{z}$ T as shown in the figure. If the frequency of rotation is 100 Hz, determine the current through the loop. (12 M)



Sol: From Faraday's law

$$V_{emf} = -\frac{\partial \phi_B}{\partial t}\text{ , where } \phi_B = BA\cos\theta$$

When the loop is rotating about the x–axis ,"θ" is going to change w.r.t time.

(i.e) θ(t) = ωt.

From the given problem magnetic field is constant & area of the loop is also constant .

$$\therefore V_{emf} = -\frac{\partial}{\partial t}\left(BA\cos\theta(t)\right)$$

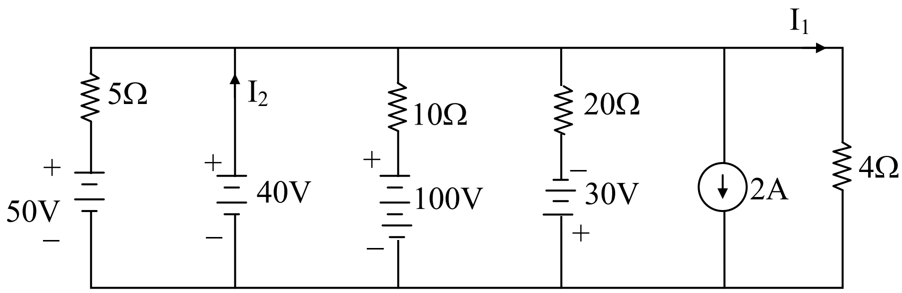
$$V_{emf} = -BA\frac{\partial}{\partial t}\left(\cos\omega t\right) = BA\omega\sin\omega t$$

$$\therefore \text{ Induced current is } I_{ind} = \frac{V_{emf}}{R}$$

$$\therefore I_{ind} = \frac{V_{Emf}}{R} = \frac{BA\omega\sin\omega t}{R} = \frac{(0.2)\left(\pi\times(0.1)^2\right)(2\pi\times100)\sin\omega t}{10}$$

$$\therefore I_{ind} = 0.394\sin\omega t\ (A)$$

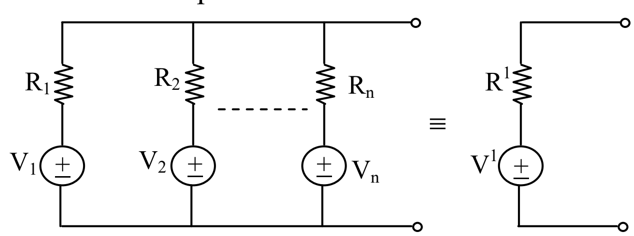
03. (c) State the Millman's Theorem and use it to find the current 'I_1' through the 4Ω resistor. Also, find 'I_2' the current delivered by the 40 V battery.



(12 M)

Sol: Statement:

When a number of voltage sources (V_1, V_2, ….V_n) are in parallel having internal resistances (R_1, R_2, ….R_n) respectively, the arrangement can be replaced by a single equivalent voltage source V in series with an equivalent series resistance R.



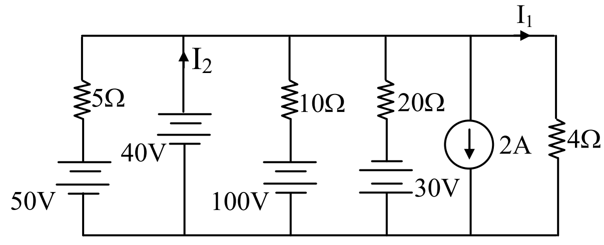
$$V^1 = \frac{V_1G_1 + V_2G_2 + ... + V_nG_n}{G_1 + G_2 + ... + G_n}$$

$$\frac{1}{R^1} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n}$$

$$\Rightarrow G^1 = G_1 + G_2 + ... G_n$$

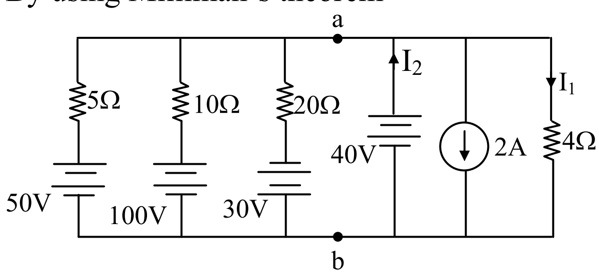
$$\Rightarrow R^1 = \frac{1}{G^1} = \frac{1}{G_1 + G_2 ....G_n}$$

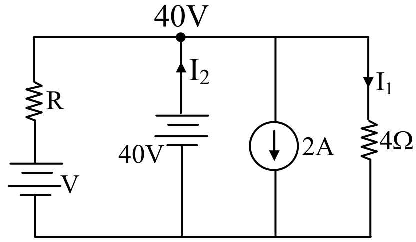
Given Circuit is



Current through the 4Ω resistor is $I_1 = I_{4\Omega} = \frac{40}{4} = 10A$

By using Milliman's theorem





$$V = \frac{50 \times \frac{1}{5} + 100 \times \frac{1}{10} - 30 \times \frac{1}{20}}{\frac{1}{5} + \frac{1}{10} + \frac{1}{20}}$$

$$V = \frac{10 + 10 - 3/2}{\frac{4+2+1}{20}} = \frac{18.5 \times 20}{7} = 52.857 \text{ Volts}$$

$$R = \frac{1}{\frac{1}{5} + \frac{1}{10} + \frac{1}{20}} = \frac{20}{7}\Omega$$

By KCL at 40 V

$$\frac{40 - V}{R} + 2 + \frac{40}{4} = I_2$$

$$\frac{40 - 52.86}{\frac{20}{7}} + 2 + 10 = I_2$$

I_2 = 7.5 Amps

03. (d) The voltage across a 2μF capacitor is given in the transform domain, by

$$V_c(s) = \frac{60s + 8\times 10^4}{s^2 + 10^6}$$

What is the current through the capacitor? (12 M)

Sol: The voltage across 2 μF capacitor

$$V_C(s) = \frac{60s + 8\times 10^4}{s^2 + 10^6}$$

$$V_C(t) = \frac{60s}{s^2 + 10^6} + \frac{80\times 10^3}{s^2 + 10^6}$$

$$= 60\left(\frac{s}{s^2 + 10^6}\right) + 80\left(\frac{10^3}{s^2 + 10^6}\right)$$

$$= 60(\cos 1000\,t) + 80(\sin 1000\,t)$$

$$= 100\,[0.6 \cos 1000\,t + 0.8 \sin 1000\,t] \qquad [\because \cos\phi = 0.8]$$

$$= 100\,[\sin 1000\,t \cos\phi + \cos 1000t\ \sin\phi] \qquad [\because \sin\phi = 0.6]$$

$$V_C(t) = 100\,[\sin(1000\,t + \phi)]$$

$$= 100 \sin(1000\,t + 36.86°)$$

$$i_C(t) = C\frac{dV_C(t)}{dt} \qquad \because\ \phi = \tan^{-1}\left(\frac{3}{4}\right) = 36.86°$$

$$= 2\times 10^{-6}\,(100)\ \frac{d}{dt}\sin(1000\,t + 36.86°)$$

$$= 2\times 10^{-4}\cos(1000\,t + 36.86°)\ 1000$$

$$i_C(t) = 0.2\cos(1000\,t + 36.86°)$$

03. (e) A 4-pole DC generator has 1200 armature conductors and generates 250 V on open circuit when running at a speed of 500 r.p.m. The diameter of the pole-shoe circle is 0.35 m and the ratio of pole arc to pole pitch is 0.7. The length of the shoes is 0.2 m. Find the mean flux density in the air gap. Assume lap-connected armature winding. (12 M)

Sol: Given,

No of poles, $P = 4$

Armature conductors, $Z = 1200$

Generator no-load voltage, $E_0 = 250$ V

No-load speed, $N_0 = 500$ rpm

Diameter of pole shoe circle, $D = 0.35$ m

Length of pole shoe, $L = 0.2$ m

$$\frac{\text{Pole arc}}{\text{Pole pitch}} = 0.7$$

But,

$$\text{Pole pitch} = \frac{\pi D}{P} = \frac{3.14 \times 0.35}{4} = 0.275\,\text{m}$$

Area under each pole = pole arc × length of pole shoe

$\therefore$ Pole arc = 0.7× Pole pitch

$$= 0.7 \times \frac{\pi D}{P}$$

$$= 0.7 \times 0.275 = 0.192\text{ m}$$

Area under each pole = 0.192×0.2 = 0.0385 m^2

From emf equation,

$$E_g = \frac{\phi ZN}{60} \times \frac{P}{A}, \text{where } \phi = \text{flux per pole}$$

At No-load. $E_g = E_0$

$$\therefore\ 250 = \frac{\phi \times 1200 \times 500}{60} \times \frac{4}{4} (\because \text{lap connected } A = P)$$

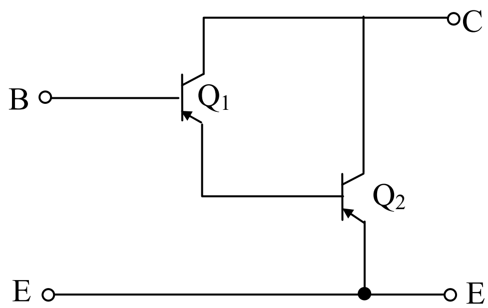
$\phi = 0.025$ Wb

Mean (or) Average flux density, $B_{avg} = \dfrac{\phi}{A}$

$$= \frac{0.025}{0.0385}$$

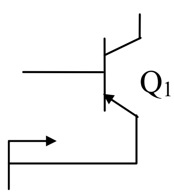
$$= 0.649\ \text{Wb/m}^2 \text{ (or) Tesla}$$

04. (a) Show that the input resistance of the transistor combination shown below is much greater than that of the individual transistors.

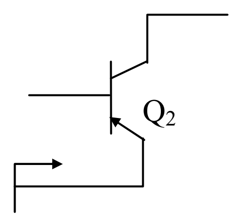


Why is such a combination not preferred, with three or more transistors, to further increases the input resistance? (20 M)

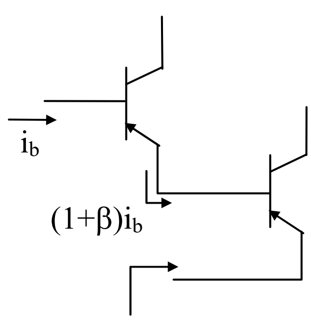
Sol: The small signal model for both npn and pnp transistors is same.



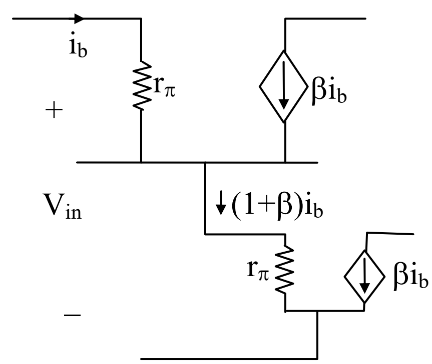
$R_{in}=r_\pi=h_{ie}$



$R_{in}=r_\pi=h_{ie}$



$R_{in}=r_\pi+(1+\beta)r_\pi$



$R_{in} = r_\pi + (1+\beta)\, r_\pi$

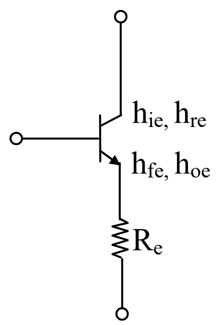
KVL, $V_{in} = i_b\, r_\pi + (1+\beta) i_b\, r_\pi$

$$\frac{V_{in}}{i_b} = R_{in} = r_\pi + (1+\beta) r_\pi$$

$R_{in} = h_{ie} + (1+h_{fe}) h_{ie}$ $[\because r_\pi = h_{ie}, \beta = h_{fe}]$

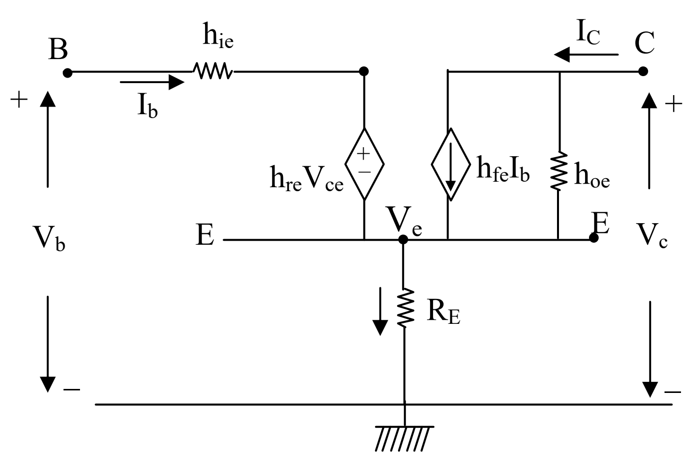
From a Darlington pair to a darlington pair of 3 transistors, the high frequency response is limited and to switch ON, it needs atleast 2.1V.

04. (b) Determine the modified h-parameters of the circuit shown below.



Reduce the expressions derived above for the case if $h_{oe} R_e << 1$. (20 M)

Sol: The equivalent circuit is



$V_1 = h_{11} I_1 + h_{12} V_2$

$I_2 = h_{21} I_1 + h_{22} V_2$

$V_b = h'_{ie} I_b + h'_{re} V_C$

$I_C = h'_{fe} I_b + h'_{oe} V_C$

(i) $h_{ie}' = \left(\frac{V_b}{I_b}\right)\Big|_{V_C=0}$

with $V_C = 0$, $V_{ce} = -(I_c + I_b) R_E$

$V_{ce} = -I_b R_E - I_C R_E$

$= -I_b R_E - (h_{fe} I_b + V_{ce} h_{oe}) R_E$

$V_{ce} = -I_b R_E - h_{fe} I_b R_E - V_{ce} h_{oe} R_E$

$V_{ce} (1 + h_{oe} R_E) = -I_b R_E (1 + h_{fe})$

$\Rightarrow V_{ce} = \frac{-I_b R_E (1 + h_{fe})}{1 + h_{oe} R_E}$

But $V_b = h_{ie} I_b + h_{re} V_{ce} - V_{ce}$

$= h_{ie} I_b + (h_{re} - 1) V_{ce}$

$= h_{ie} I_b + (h_{re} - 1)\left[\frac{-I_b R_E (1 + h_{fe})}{1 + h_{oe} R_E}\right]$

$V_b = I_b\left[h_{ie} + \frac{R_E (1 + h_{fe})}{1 + h_{oe} R_E}(1 - h_{re})\right]$

$\Rightarrow \frac{V_b}{I_b} = h'_{ie} = h_{ie} + \frac{R_E (1 + h_{fe})}{1 + h_{oe} R_e}(1 - h_{re})$

(ii) $h'_{re} = \left(\frac{V_b}{V_c}\right)\Big|_{I_b=0}$

Where $V_b = h_{ie} I_b + h_{re} V_{ce} + V_e$

Since $I_b = 0$, $h_{fe} I_b = 0$, $I_C = h_{oe}, V_{ce} = \frac{V_e}{R_E}$

and $V_C = V_{ce} + V_e$, $V_{ce} = \dfrac{V_e}{h_{oe}R_E}$

$$= \frac{V_e}{h_{oe}R_E} + V_e$$

$$= V_e\left(1 + \frac{1}{h_{oe}R_E}\right) \Rightarrow V_e = V_c\left(\frac{h_{oe}R_E}{1 + h_{oe}R_E}\right)$$

Then $V_b = h_{re} V_{ce} + V_e$

$$= h_{re}\frac{V_e}{h_{oe}R_E} + V_e$$

$$= V_e\left(1 + \frac{h_{re}}{h_{oe}R_E}\right)$$

$$V_b = V_c\left(\frac{h_{oe}R_E}{1 + h_{oe}R_E}\right)\left(\frac{h_{re} + h_{oe}R_E}{h_{oe}R_E}\right)$$

$$\Rightarrow \frac{V_b}{V_c} = h'_{re} = \left(\frac{h_{re} + h_{oe}R_E}{1 + h_{oe}R_E}\right)$$

(iii) $h'_{fe} = \left(\dfrac{I_C}{I_b}\right)\Bigg|_{V_c=0}$ where $I_C = h_{fe} I_b + h_{oe} V_{ce}$

When $V_{ce} = \dfrac{-I_bR_E(1 + h_{fe})}{1 + h_{oe}R_E}$ then

$$I_c = h_{fe}I_b - \frac{I_bR_E(1 + h_{fe})}{1 + h_{oe}R_E}h_{oe}$$

$$\left(\frac{I_c}{I_b}\right) = h'_{fe} = h_{fe} - \frac{R_E(1 + h_{fe})h_{oe}}{1 + h_{oe}R_E}$$

$$= \frac{h_{fe}(1 + h_{oe}R_E) - h_{oe}R_E(1 + h_{fe})}{1 + h_{oe}R_E}$$

$$= \frac{h_{fe} + h_{oe}h_{fe}R_E - h_{oe}R_E - h_{oe}h_{fe}R_E}{1 + h_{oe}R_E}$$

$$h'_{fe} = \frac{h_{fe} - h_{oe}R_E}{1 + h_{oe}R_E}$$

(iv) $h'_{oe} = \left(\dfrac{I_c}{V_c}\right)\Bigg|_{I_b=0}$ when $I_C = \dfrac{V_e}{R_E} = \dfrac{1}{R_E}.V_C\left(\dfrac{h_{oe}R_E}{1+h_{oe}R_E}\right)$

$$\frac{I_C}{V_C} = h'_{oe} = \frac{h_{oe}}{1+h_{oe}R_E}$$

If $h_{oe}R_E << 1$ then $h'_{ie} = h_{ie} + (1+h_{fe})R_E(1-h_{re})$

$h'_{re} = h_{re} + h_{oe}R_E$

$h'_{fe} \approx h_{fe} - h_{oe}R_E$

$h'_{oe} \approx h_{oe}$

04. (c) What is the internal power of an optical source emitting at a peak wavelength of 1310 nm? The radiative and non-radiative recombination times are 40ns and 100ns, respectively. The drive current is 30 mA. (20 M)

Sol: τ_r = Radiative recombination life time

= 40 ns

τ_{nr} = Non - radiative recombination lifetime

= 100 ns

τ = Total recombination life time

$$\frac{1}{\tau} = \frac{1}{\tau_r} + \frac{1}{\tau_{nr}}$$

$$\frac{1}{\tau} = \frac{1}{40} + \frac{1}{100} = \frac{5+2}{200} = \frac{7}{200}$$

$$\tau = \frac{200}{7}\text{ns}$$

P_{int} = Internal optical power

$$= \eta_{int}\cdot\frac{hc}{q\lambda}.I$$

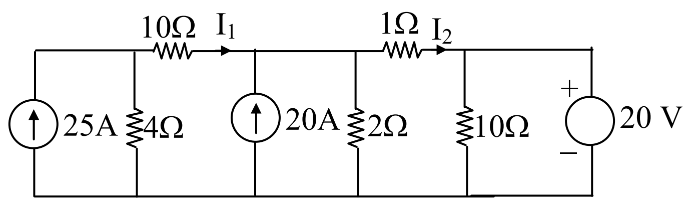
$$= \frac{\tau}{\tau_r}.\frac{hc}{q\lambda}.I$$

$$= \frac{200}{7\times40}\times\frac{6.625\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times1310\times10^{-9}}\times30\times10^{-3}$$

= 20.322mW

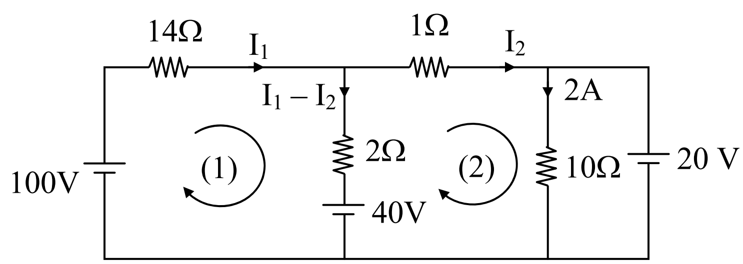
SECTION - B

05. (a) Using mesh analysis and transformation of current sources to voltage sources, determine the currents I_1 and I_2 in the circuit shown below.



(12 M)

Sol:



KVL in loop (1)

$$100 = 14\,I_1 + 2(I_1 - I_2) + 40$$

$$16\,I_1 - 2\,I_2 = 60$$

$$8I_1 - I_2 = 30 \;\ldots\ldots.(1)$$

KVL in loop (2)

$$-40 \;-2\,(I_1 - I_2) + I_2 + 20 = 0$$

$$-2I_1 + 3I_2 = 20 \;\ldots\ldots\ldots.\;(2)$$

Equation (2) × 4 ⇒ $-8I_1 + 12I_2 = 80$ .... (3)

Adding (1) & (3) ⇒ $11I_2 = 110$

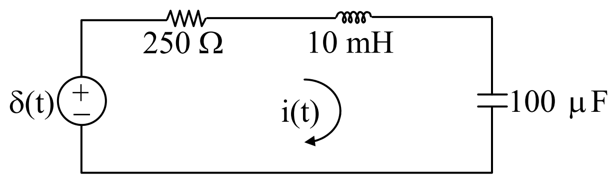
$$I_2 = 10\text{ A}$$

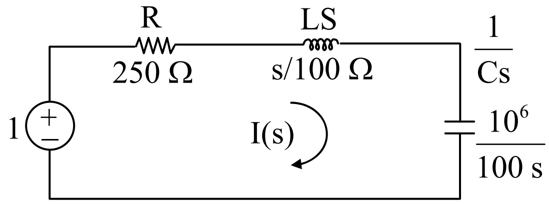
From equation (2) ⇒ $-2I_1 = 20 - 3 \times 10 = 20 - 30 = -10$

$$I_1 = 5\text{A}$$

05. (b) A series R-L-C circuit has R = 250 Ω, L = 10 mH, and C = 100 μF. Assume zero initial conditions and use Laplace Transforms to determine the (natural) current for a unit impulse voltage input. (12 M)

Sol: A series R-L-C circuit has R = 250 Ω, L = 10 mH and C = 100 μF





s–domain

By KVL

$$1 = I(s)\left(R + Ls + \frac{1}{Cs}\right)$$

$$I(s) = \frac{Cs}{RCs + LCs^2 + 1} = \frac{s/L}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$$I(s) = \frac{s/10\times10^{-3}}{s^2 + \frac{250}{10\times10^{-3}}s + \frac{10^6}{10\times10^{-3}\times100}}$$

$$I(s) = \frac{100\,s}{s^2 + 25000\,s + 10^6}$$

$$D_1, D_2 = \frac{-25000 \pm \sqrt{(25000)^2 - 4(1)10^6}}{2(1)}$$

$$= 10^3\left[\frac{-25 \pm \sqrt{621}}{2}\right] = 10^3\left[\frac{-25 \pm 24.92}{2}\right]$$

Then, $D_1 = 40$, $D_2 = 27960$

$$I(s) = \frac{100\ s}{(s+40)(s+24960)} = \frac{A}{(s+40)} + \frac{B}{(s+24960)}$$

$$A = \frac{-4000}{24920} = -0.16 \qquad B = 100 + \frac{4000}{24920} = 100.16$$

$$I(s) = \frac{-0.16}{(s+40)} + \frac{100.16}{(s+24960)}$$

$$I(s) = \frac{100.16}{(s+24960)} - \frac{0.16}{(s+40)}$$

Apply Inverse Laplace transform

$$i(t) = \left(100.16e^{-24960t} - 0.16e^{-40t}\right) \text{ Amps}$$

05. (c) (i) Distinguish between sensors and transducers, with examples.

(ii) What are the different constants of piezo-electric crystals? How are they related?

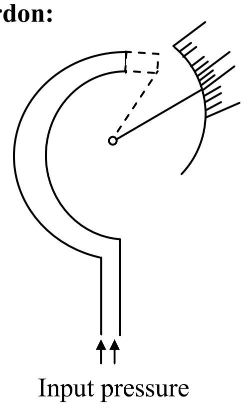
(12 M)

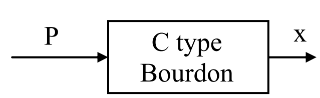
Sol:

(i) **Sensor:** It is which senses the change in physical parameter and makes it as readable but and guaranteed to output

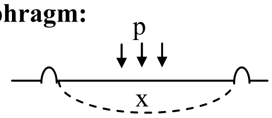
Eg: thermometer, C-type bourdon tube, diaphragm

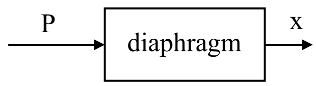
C-Bourdon:



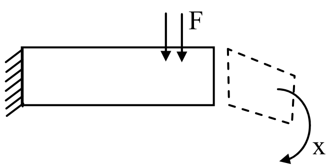


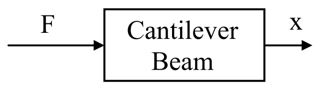
Diaphragm:



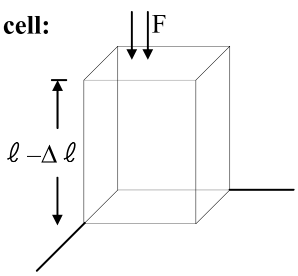


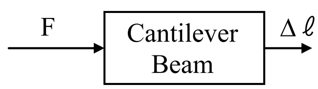
Cantilever Beam:



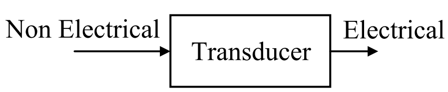


Load cell:



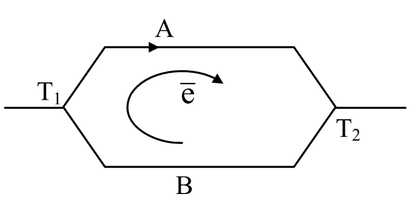


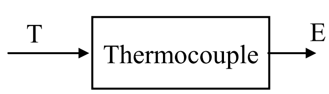
Transducers:

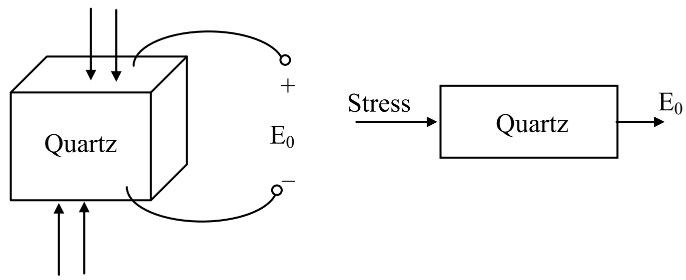


It is a device which converts non electrical quantity to electrical quantity.

Eg: Thermocouple, piezo electric crystal, POT.

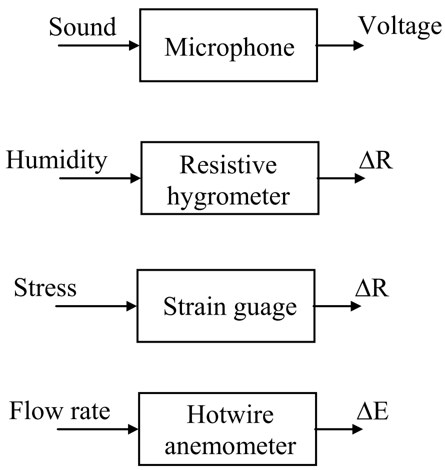




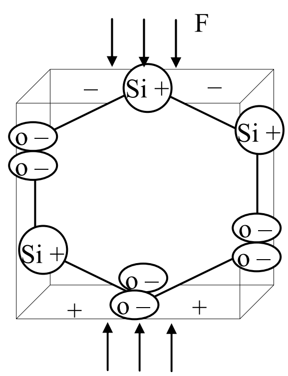


All transducers can be sensor but all sensors may not be necessary transducers.

Some more examples of transducers are:



(ii)



When certain crystals like quartz are under dynamic stress then due to internal molecular displacement a charge (q) is deposited across the plates. By attaching two metal plates this charge can be accumulated and can be formed as capacitance (C_p).As the force is dynamic so is the charge hence the capacitance which induces a potential (E_0) across the plates are to relation Q = CV. This active process of conversion of stress to voltage is called as piezo effect.

$q \propto F$

$= \vec{d}.F$

$$\vec{d} = \frac{q}{F} = \frac{\text{charge developed}}{\text{force applied}}$$

Charge sensitivity

$$C_p = \frac{\varepsilon_0 \varepsilon_r A}{t}$$

$q = C.V$

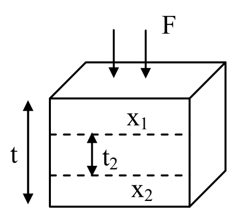
$q = C_p E_0$

$$E_0 = \frac{q}{C_p} = \frac{\vec{d} F}{\varepsilon A} t$$

$$E_0 = \frac{\vec{d}}{\varepsilon} \quad \frac{F}{A} t$$

$$\frac{\varepsilon_0}{t} = \vec{g} \quad \frac{F}{A}$$

$$\vec{g} = \frac{\frac{E_0}{t}}{\frac{F}{A}} = \frac{\text{Electric field}}{\text{Stress}}$$



$$\frac{F}{A} = Y \frac{\Delta t}{t}$$

$$\frac{F}{A} = Y \frac{x}{t}$$

$$x = \frac{F.t}{A.y}$$

displacement sensitivity $= \vec{h} = \frac{E_0}{x} = \frac{\vec{g}\,P\,t}{\left(\frac{F}{A}\right)t} y = \vec{g}.\vec{y}$

$\vec{h} = \vec{g} \quad \vec{y}$

$\vec{g} = \frac{\vec{d}}{\varepsilon}$

$$\text{Sensitivity matrix} = \begin{bmatrix} \vec{d}_{x,x} & \vec{d}_{y,y} & \vec{d}_{z,z} \\ \vec{g}_{x,x} & \vec{g}_{y,y} & \vec{g}_{z,z} \\ \vec{h}_{x,x} & \vec{h}_{y,y} & \vec{h}_{z,z} \end{bmatrix}$$

05. (d) NAND implementation of a circuit is to be designed with three data lines and a control line. When the control line is high, the circuit is to detect when one of the data lines has 1 on it. No more than one data line will have a 1 on it.

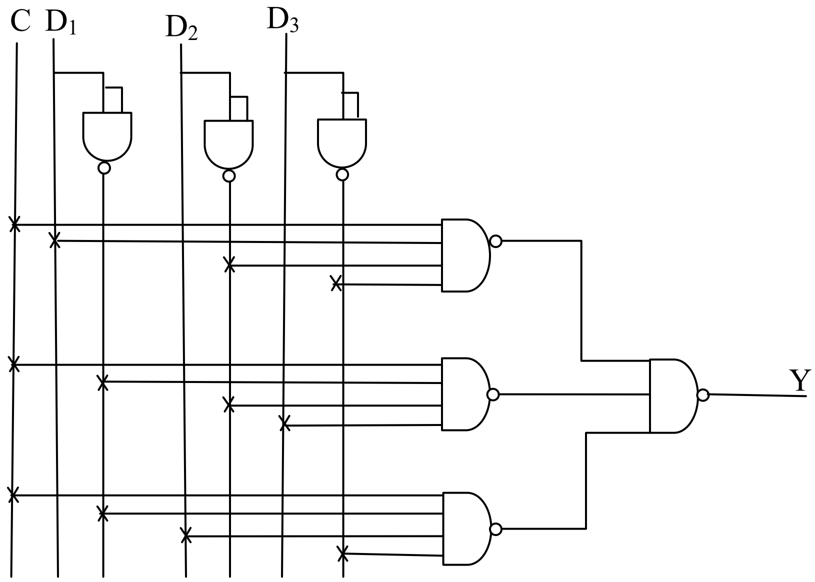
When the control line is low, the circuit will output a 0, regardless of what is on the data line. (12 M)

Sol: Let us consider C is control signal and D_1, D_2 and D_3 are data lines.

According to given data when control signal C = 0, the output is 0 irrespective of data line inputs and when control signal C = 1 and only one data is 1 then output is 1.

Control line	Data lines			Output
C	D_1	D_2	D_3	Y
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	0
1	1	0	0	1
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0
0	X	X	X	0

$$Y = CD_1\overline{D}_2\overline{D}_3 + C\overline{D}_1\overline{D}_2D_3 + C\overline{D}_1D_2\overline{D}_3$$



05. (e) Consider a 'Lead' material has critical temperature 7.19K and critical magnetic flux is 0.0803 tesla. Determine the value of temperature at which 'Lead' material must be cooled in a magnetic filed of 15000 A/m for it to be super conductive. Assume magnetic constant value is $4\pi \times 10^{-7}$ H/m. (12 M)

Sol: Critical Temperature $T_C = 7.19$k

Critical magnetic flux $B_C = 0.0803$ Tesla

Permeability $\mu = 4\pi \times 10^{-7}$ H/m

Magnetic field H = 15000 A/m

$$\mu = \frac{B}{H}$$

$$B = \mu \times H = 4\pi \times 10^{-7} \times 15000 = 0.01884 \text{ Tesla}$$

For super conductor

$$B_t = B_c\left[1-\left(\frac{T}{T_C}\right)^2\right]$$

$$0.01884 = 0.0803\left[1-\left(\frac{T}{7.19}\right)^2\right]$$

$$1-\left(\frac{T}{7.19}\right)^2 = 0.23462$$

$$T = 6.29\ °K$$

ESE / GATE / PSUs - 2019
ADMISSIONS OPEN

CENTER	COURSE	BATCH TYPE	DATE
HYDERABAD - DSNR	GATE + PSUs - 2019	Regular Batch	8th, 22nd July 2018
HYDERABAD - Kukatpally	GATE + PSUs - 2019	Regular Batch	2nd July 2018
HYDERABAD - Abids	GATE + PSUs - 2020	Morning Batch	15th July 2018
HYDERABAD - DSNR	GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - DSNR	GATE + PSUs - 2020	Evening Batch	22nd July 2018
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Evening Batch	22nd July 2018
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HYDERABAD - DSNR	ESE + GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - Kukatpally	ESE + GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - DSNR	ESE + GATE + PSUs - 2020	Evening Batch	22nd July 2018
HYDERABAD - Kukatpally	ESE + GATE + PSUs - 2020	Evening Batch	22nd July 2018
HYDERABAD - Abids	ESE - 2019 (PRELIMS) - G.S	Regular Batch	09th July 2018
DELHI	GATE + PSUs - 2019	Regular Batch	22nd July 2018
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CHENNAI	GATE + PSUs - 2019	Regular Batch	07th July 2018
CHENNAI	GATE + PSUs - 2020	Weekend Batch	07th July 2018
BANGALURU	GATE + PSUs - 2019	Weekend Batch	07th July 2018
BANGALURU	GATE + PSUs - 2020	Weekend Batch	07th July 2018
PATNA	GATE + PSUs - 2020	Weekend Batch	14th July 2018
VISAKHAPATNAM	GATE + PSUs - 2019	Regular Batch	17th July 2018
VISAKHAPATNAM	GATE + PSUs - 2020	Weekend Batch	08th July 2018
TIRUPATI	GATE + PSUs - 2020	Weekend Batch	14th July 2018

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06. (a) (i) Distinguish between thermocouples, thermistor and RTD.

(ii) Why is cold junction of thermocouples required to be compensated and how can it be compensated?

(iii) How can you measure flow of fluid by using ultrasonic flow meter based on change in frequency (Doppler shift)? Explain with necessary diagrams. (25 M)

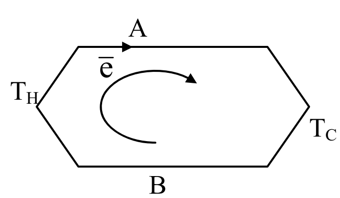
Sol:

(i)

RTD	Thermistor	thermocouple
(1) Principle: + T.C.R	–T.C.R	Seebeck effect
(2) Materials: Metals are used Eg: Pt-RTD	semiconductors Eg: Si- thermistor	alloys Eg: chromel-constantan
(3) Rang of operation range –180° C to +630° C	–100°C to +350°C	–100°C to +200°C
(4) Equation: $R_T = R_0 \{1+\alpha(\Delta T)\}$ $\alpha = +$ T.C.R $= +(1/°C)$	$R_T = R_0 e^{\beta\left[\frac{1}{T}-\frac{1}{T_0}\right]}$ β = Material const $= -(1/k)$	$E = S[T_H - T_C]$ S = sensitivity $= (\mu V/°C)$
(5) Types: Passive type	Passive type	Active type
(6) Linearity: High	Poor	Moderate

(7) Sensitivity: Poor	High	Moderate
(8) Application: Temp m/m of chemical plant	Temp m/m of domestic appliances	Temp m/m of furnace
(9) Signal conditioning: Wheatstone bridge	Op-amp	Chopper amplifier
(10) Limitations: i) Expensive ii) Poor sensitivity	i)Non linear ii)Less temp range	i) Inaccuracy ii)Low output voltage

(ii) **Seebeck effect**: When two different alloys joined together then two different junctions are formed. If two different temperatures are maintained at these junctions such a way $(T_1 - T_2) > 0$ always then flow of electrons will take place from hot junction to cold junction, which can be converted to thermal emf by attaching a high impedance voltmeter



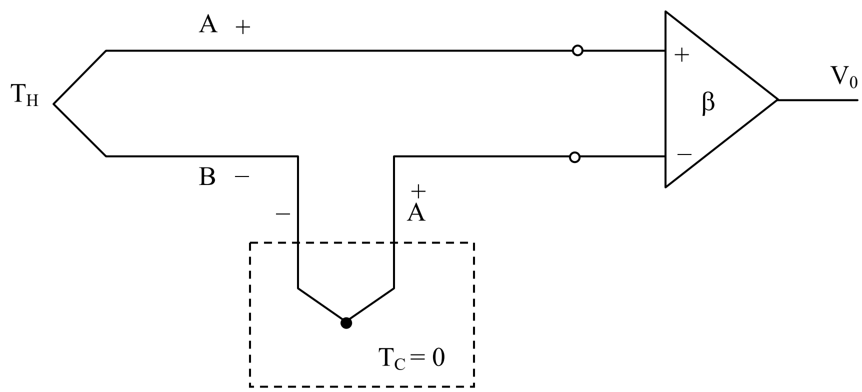
$f(E)\ \alpha (T_H - T_C)$

$E\ \alpha (T_H - T_C)$

$E = s(T_H - T_C)$

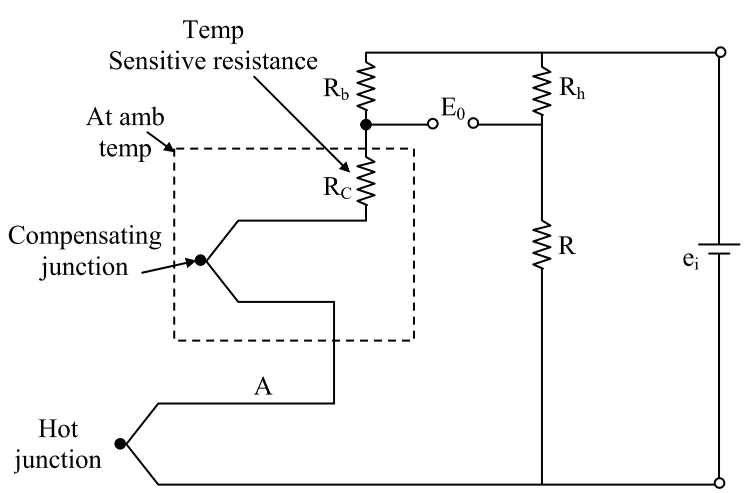
$$s = \frac{E}{(T_H - T_C)} = \frac{E}{\Delta T} (\mu V / ^\circ C)$$

According to seebeck thermocouple output depends on two different functions. But in reality the quantity to be measured is always single like room temperature or furnace temperature since the thermo-electric emf depends upon the difference in temperature between the hot junction and reference junction, the temperature of later should be absolutely constant in order that the calibration holds good and there are no errors on account of change in ambient temperature. The temperature of the reference junction is controlled for this purpose. The reference junction temperature is usually 0°C. this technique is called cold junction compensation.



By keeping one of functions at 0°C like above cold junction compensation can be done

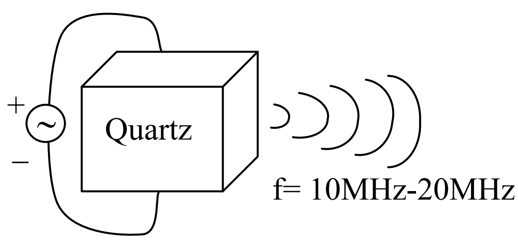
When temperatures near ambient are to be measured with a thermocouple and it is in convenient to use a fixed reference junction and therefore compensating circuits must be employed in the measuring system.



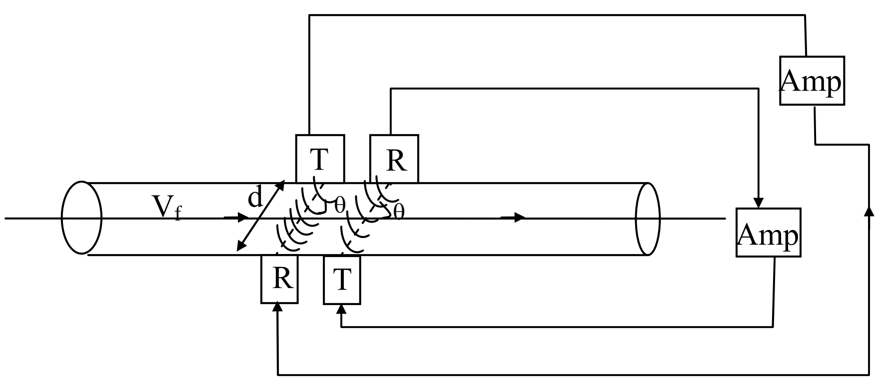
An arrangement for automatic compensating is shown. A temperature sensitive bridge is included in thermocouple circuit such that variations in the ambient temperature are compensate for by the changes in resistance R_c and the compensating junction.

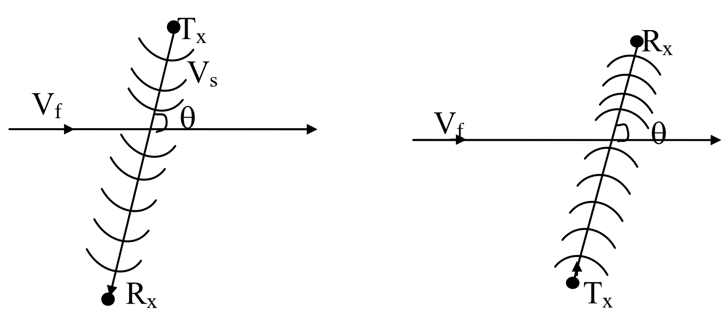
A factor which a important in the use of thermocouple is the requirement of a known reference temperature of the junction. This is because when the reference junction is not at 0°C the observed value must be corrected by adding to it a voltage that has resulted from a temp difference equal to the amount by which the reference junction is above 0°C.

(iii)



When piezo electric crystal is excited by voltage then it generates ultrasonic waves of frequency in the range of MHz, this waves can be used for flow rate measurement





(a) t_1 →down stream (b) t_2→ up stream

An Ultra sonic system based upon frequency may be evolved. The above arrangement shows two self-excited oscillating systems created because of using the received pulses to trigger the transmitted pulses in feed back arrangement The pulse repetition frequency in the forward propagating loop is $\frac{1}{t_1} = f_1$ which that in the back ward loop is $\frac{1}{t_2} = f_2$

For down stream

$$t_1 = \frac{d}{V_s - V_f \cos\theta}$$

$$f_1 = \frac{V_s - V_f \cos\theta}{d}$$

for up stream

$$t_2 = \frac{d}{V_s + V_f \cos\theta}$$

$$f_2 = \frac{V_s + V_f \cos\theta}{d}$$

$\Delta f = f_2 - f_1$

Doppler shift $\Delta f = \frac{2V_f \cos\theta}{d}$

$$V_f = \frac{\Delta f.d}{2.\cos\theta}$$

Doppler shift is more useful than time shift because output is linearly proportional to the flow velocity.

Advantages:

(i) there is no obstruction to the flow

(ii) they are insensitive to variations in viscosity, density, temperature

(iii) The dynamic response is excellent

(iv) bidirectional flow measurement

Disadvantage:

(i) complexity in signal conditioning design

(ii) relatively high cost

06. (b) (i) Five measurements of the resistance of a resistor gave:

101.7Ω

101.0Ω

101.5Ω

101.2Ω

and 101.1Ω

Assume that only random errors are present.

Calculate: (I) the arithmetic mean,

(II) the standard deviation of the readings,

and (III) the probable error.

(ii) Explain the signal conditioning requirements for measurements with strain gauges and how these can be achieved. (20 M)

Sol:

(i) **(I)** The arithmetic mean of readings

$$\bar{x} = \frac{\sum x}{n} = \frac{101.7 + 101.0 + 101.5 + 101.2 + 101.1}{5}$$

$$= 101.3\Omega$$

(II) standard deviation

$$s = \sqrt{\frac{\Sigma d^2}{n-1}} \text{ for less than 20 deviations}$$

$$d_1 = x_1 - \bar{x} = 101.7 - (101.3) = +0.4$$

$$d_2 = x_2 - \bar{x} = 101.0 - (101.3) = -0.3$$

$$d_3 = x_3 - \bar{x} = 101.5 - (101.3) = +0.2$$

$$d_4 = x_4 - \bar{x} = 101.2 - (101.3) = -0.1$$

$$d_5 = x_5 - \bar{x} = 101.1 - (101.3) = -0.2$$

$$s = \sqrt{\frac{(0.4)^2 + (-0.3)^2 + (0.2)^2 + (-0.1)^2 + (-0.2)^2}{5-1}}$$

s = 0.29154

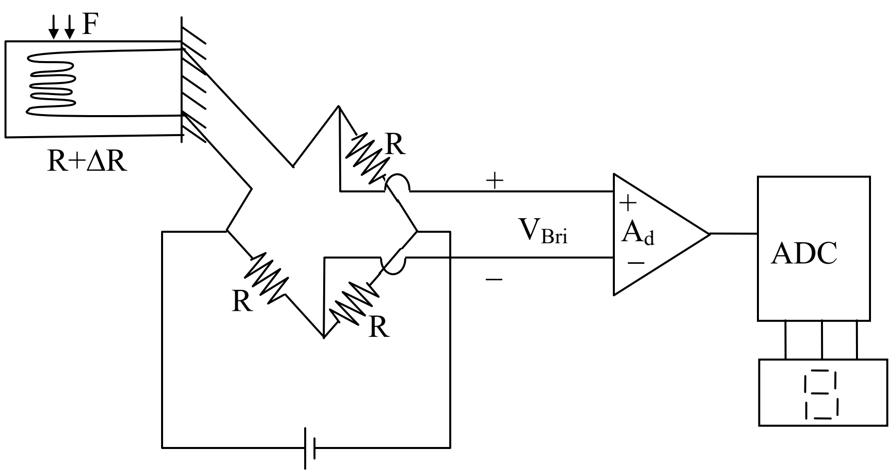
(III) Probable error

$$r = \pm 0.6745\sqrt{\frac{d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2}{n-1}}$$

$$= \pm 0.6745\sqrt{\frac{(0.4)^2 + (-0.3)^2 + (0.2)^2(-0.1)^2 + (-0.2)^2}{(5-1)}}$$

r = ± 0.19664

(ii) **Strain gauge:** It is the resistive transducer used for measurement of force or stress. The basic signal conditioning circuit is Wheatstone bridge.



At no force $R_A = R$; $V_{Bri} = 0V$

At force $R_1 = R + \Delta R$; $R_2 = R_3 = R_4 = R$

$$V_{Bri} = V_s\left\{\frac{R_1}{R_1 + R_2} - \frac{R_3}{R_3 + R_4}\right\} = V_s\left\{\frac{R + \Delta R}{2R + \Delta R} - \frac{1}{2}\right\} = \frac{V_s \Delta R}{4R + 2\Delta R}$$

$$V_{Bri} \cong \frac{V_s \Delta R}{4R}$$

Requirements of Strain Gauge Bridge:

Some times 50MHz or high frequency magnetic field to introduce interfering input to a strain gauge bridge 50Hz magnetic field

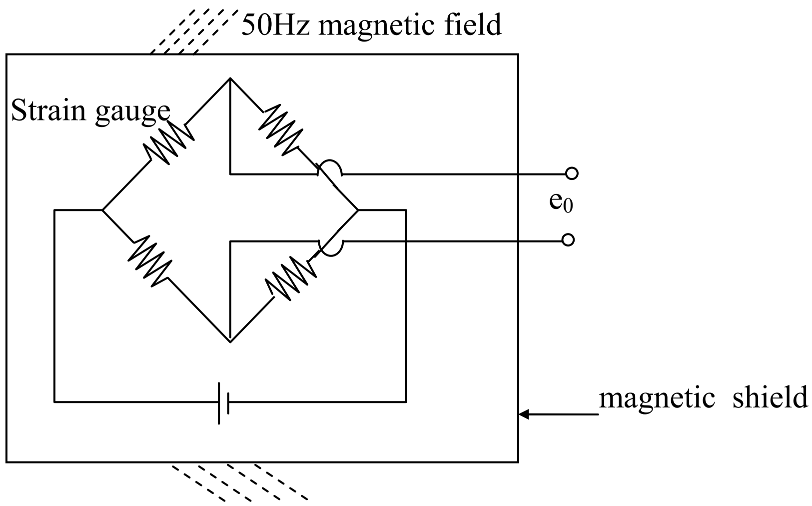
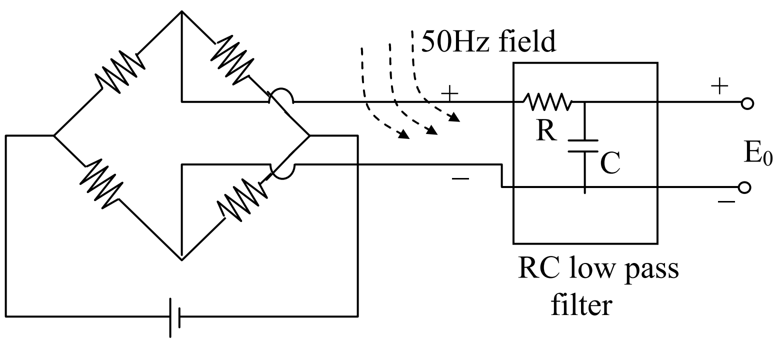
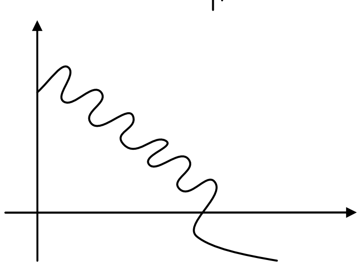
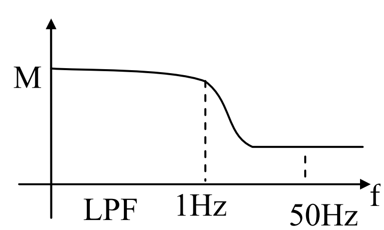


Figure shows magnetic shield for a strain gauge bridge for input filtering of power frequency signals. The interfering magnetic field is prevented from the strain gauge with the help of magnetic shield which magnetic take a shape of box made up of a ferromagnetic material



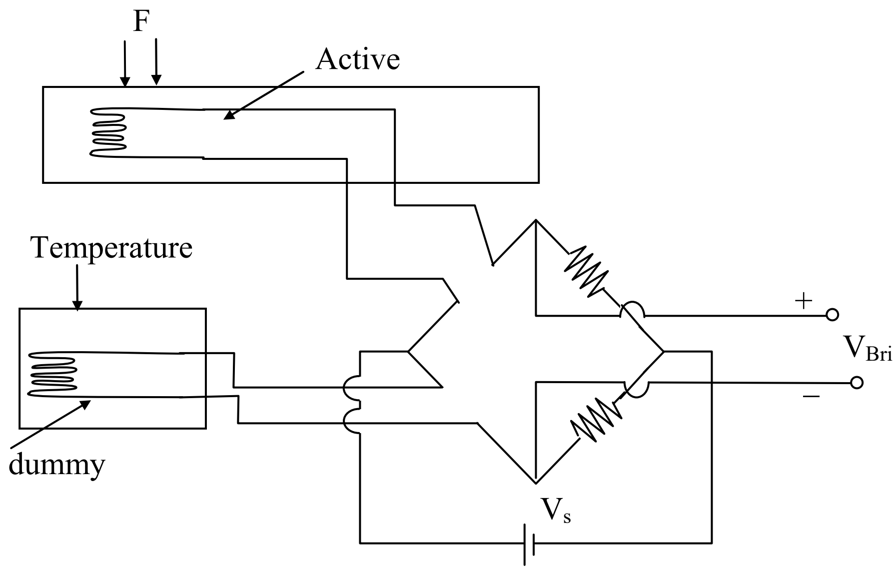


Strain gauge output + Interfering noise



If on the output of strain gauge bridge if a high frequency signal is interfering that can be filtered by LPF allowing low frequency of 1Hz and attenuating 50Hz signal.

Use of dummy gauge for Temp compensation



Temperature can interfere and there is an output an account of changes in ambient temperature even though there is no input strain. This effect can be eliminated by using a dummy gauge in the adjacent of Wheatstone bridge.

$$V_{Bri} = \frac{V_S}{4}\frac{(\Delta R_T + \Delta R_\varepsilon)}{R} - \frac{V_S}{4}\frac{\Delta R_T}{R} = \frac{V_s}{4}\frac{\Delta R_\varepsilon}{R}$$

$\Delta R_T \Rightarrow$ due to temperature

$\Delta R_\varepsilon \Rightarrow$ due to strain

The above problem is predominant especially in semiconductor strain gauges.

06. (c) The quantum efficiency of a particular silicon photo detector is 90% for the detection of radiation at a wavelength of 0.8 μm. When the incident optical power is 0.8μW, the output current from the device is 10μA. Determine the multiplication factor of the photo detector.

(15 M)

Sol: Given that,

Quantum efficiency (η) = 0.9

Radiation wavelength (λ) = 0.8 μm

Incident optical power (P_{opt}) = 0.8×10^{-6}W

Photo detector output current with gain $(I_M) = 10\mu A$

Multiplication factor M = ?

$$M = \frac{I_M}{I_p}$$

$$\eta = \frac{\frac{I_p}{q}}{\frac{P_{opt}}{hf}} = \frac{I_p hf}{P_{opt} q} = \frac{I_p hc}{P_{opt} q.\lambda}$$

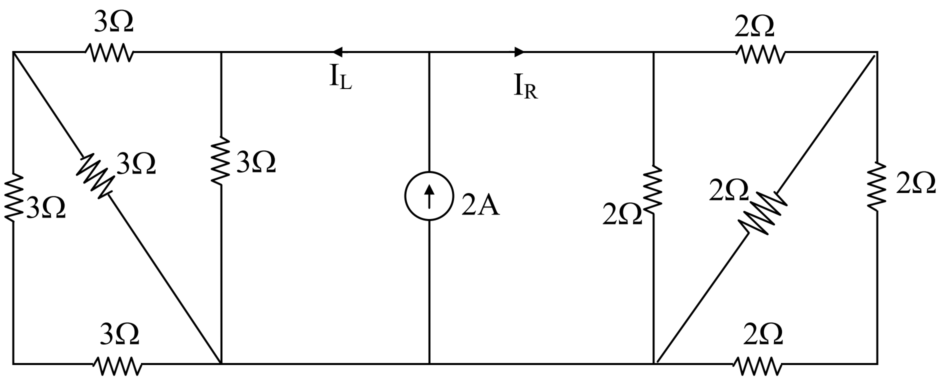
$$\Rightarrow I_p = \frac{\eta I_p q.\lambda}{P_{opt} hc}$$

$$I_p = \frac{0.9 \times 0.8 \times 10^{-6} \times 1.6 \times 10^{-19} \times 0.8 \times 10^{-6}}{6.626 \times 10^{-34} \times 3 \times 10^{8}} = \frac{0.9216}{19.878} \times 10^{-5}$$

$I_p = 0.4636\mu A$

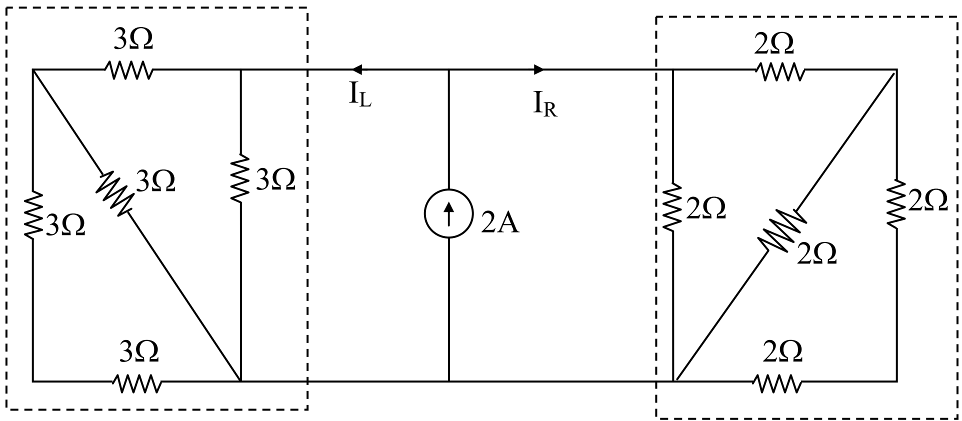
$$M = \frac{I_M}{I_p} = \frac{10\mu A}{0.4636\mu A} = 21.57$$

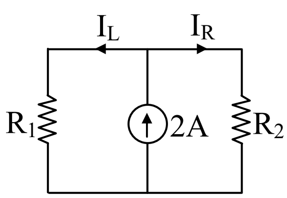
07. (a) For the circuit shown below, calculate the currents I_L and I_R



(15 M)

Sol:





$$R_1 = \left(((3+3)\|3)+3\right)\|3 = \frac{15}{8}\Omega$$

$$R_2 = \left(((2+2)\|2)+2\right)\|2 = \frac{10}{8}\Omega$$

By current division rule

$$I_L = \frac{2\times R_2}{R_1+R_2} = \frac{2\times\frac{10}{8}}{\frac{10}{8}+\frac{15}{8}} = \frac{20}{25} = \frac{4}{5} = 0.8\text{A}$$

$I_R = 2 - I_L = 2 - 0.8 = 1.2$Amps

07. (b) Design a counter to go through states 0, 2, 4, 5, 0…., using type D Flip Flops. (15 M)

Sol: Sequence of states given as 0, 2, 4, 5, 0….

Assume initial state is 0 and the remaining states never occurs.

Present states			Next states			D-FF inputs		
Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	D_2	D_1	D_0
0	0	0	0	1	0	0	1	0
0	1	0	1	0	0	1	0	0
1	0	0	1	0	1	1	0	1
1	0	1	0	0	0	0	0	0

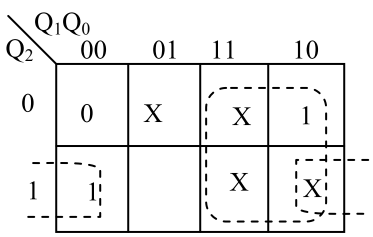
$\Sigma m\,(1,3,6,7)$ are don't care conditions.

$D_2 = \Sigma m\,(2,4) + \Sigma m\,(1,3,6,7)$

$D_1 = \Sigma m\,(0) + \Sigma m\,(1,3,6,7)$

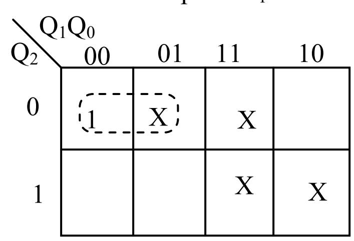
$D_0 = \Sigma m\,(4) + \Sigma m\,(1,3,6,7)$

K-Map for D_2



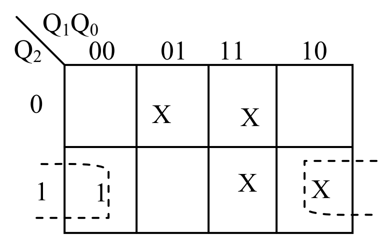
$D_2 = Q_1 + Q_2\overline{Q}_0$

K-Map for D_1

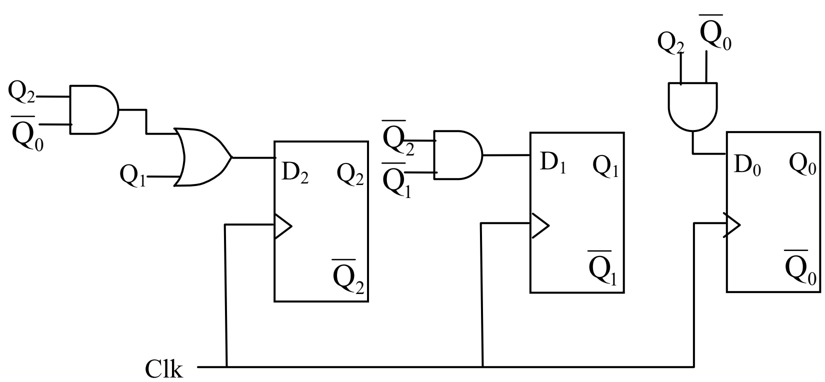


$D_1 = \overline{Q}_2\,\overline{Q}_1$

K-Map for D_0



$D_0 = Q_2\overline{Q}_0$



07. (c) (i) What is Spintronics ? Discuss two examples of spintronic devices.

(ii) Find the relation between unit cell edge length 'a' and atomic radius 'r' for a body-centred crystal. (15 M)

Sol:

(i) Spintronics is an emerging field of nanoscale electronics involving the detection & manipulation of electron spin.

Electron spin can be detected as a magnetic field having one of two orientation known as down & up. This provides an additional two binary states to the conventional low and high logic values which are represented by simple currents..

Example of spintronics devices are GMR (Giant Magneto Resistance) and MRAM.

GMR is the change in electrical resistance of some materials in response to an applied magnetic field.

The application of a magnetic field to magnetic metallic multilayer such as Fe/Cr & Co/Cu, in which ferrormagnetic layers are separated by non magnetic layers of a few nm thick, result in a significant reduction of the electrical resistance of multilayer.

MRAM (Magnetic Random Access Memory) used magnetism rather than electric power to store data. It has the potential to store more data, access that data faster and use less power than current memory technologies.

(ii) Body centered cubic structure (B.C.C):

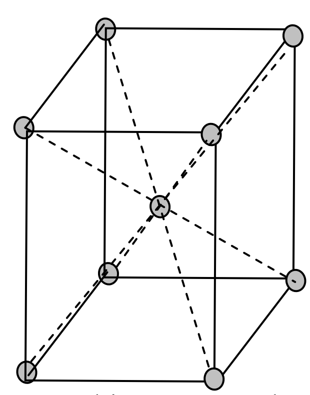


Figure shows the unit cell of B.C.C. structure. In this structure the eight corners of the cube are occupied by eight atoms and the centre of the cube is occupied by one atom. Metals that crystallize into B.C.C. structure are chromium, tungsten, iron, vanadium, molybdenum and sodium.

Number of atoms in the unit cell of B.C.C Structure:

In B.C.C. structure, the unit cell contains eight atoms at each corner of the cube and one atom in the centre of the cube. Since each corner atom is shared by eight surrounding cubes and the atom in the centre can not be shared by any other cube, the unit cell of the B.C.C. structure contains:

8 atoms at the corners $\times \frac{1}{8} = 1$ atom

1 centre atom = 1 atom

$\therefore$ Total = 2 atoms

Therefore the unit cell of B.C.C. structure contains two atoms.

From the figure

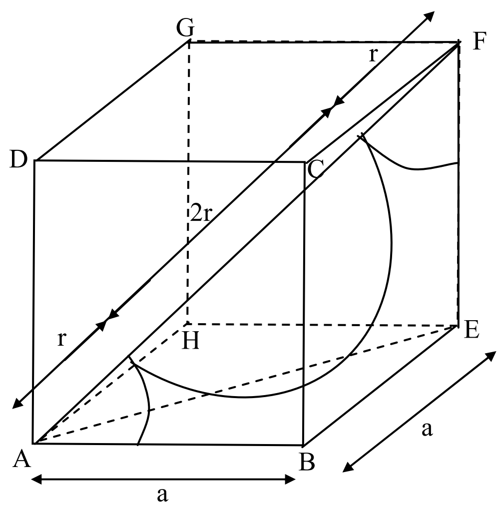
$(AE)^2 = (AB)^2 + (BE)^2$

$= a^2 + a^2 = 2a^2$

And $(AF)^2 = (AE)^2 + (EF)^2$

$= 2a^2 + a^2 = 3a^2$

$\Rightarrow$ AF = $a\sqrt{3}$



We have from the figure

AF = 4r

$\therefore \quad 4r = a\sqrt{3}$

$\Rightarrow r = \frac{a\sqrt{3}}{4}$

07. (d) (i) The charge sensitivity of a piezo-electric transducer is 40 pC/N. A charge amplifier is connected with the piezo-electric transducer such that the combination of the transducer and amplifier is to have an overall gain of 100mV/N.

Find (I) the gain of the amplifier,

(II) the value of the feedback capacitor required to have this gain.

(ii) What is telemetry? Classify the telemetering systems. (15 M)

Sol:

(i)

(I) Overall sensitivity = 100mV/N

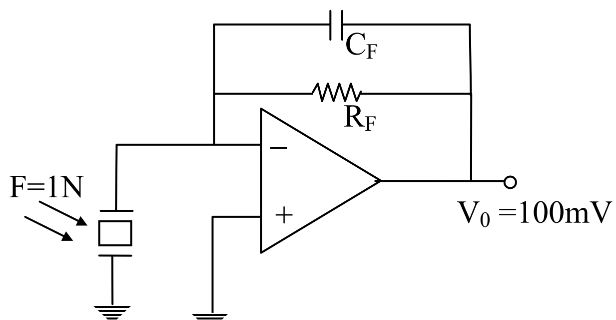
Charge sensitivity = 40pC/N

Overall sensitivity = Op-amp gain × charge sensitivity

100mV/N = 40pC/N × Op-amp gain

Gain of the Op-Amp = 2.5 (mV/pC)

(II)



$$\text{Charges sensitivity (d)} = \frac{q}{F} = 40(\text{pC/N})$$

$$\frac{V_0}{F} = \frac{k\tau S}{1+\tau S}$$

$$\left|\frac{V_0}{F}\right| = \frac{k}{\sqrt{1+\frac{1}{(\tau\omega)^2}}}$$

$$k = \frac{d}{C_F} \text{ at } f_F = \infty$$

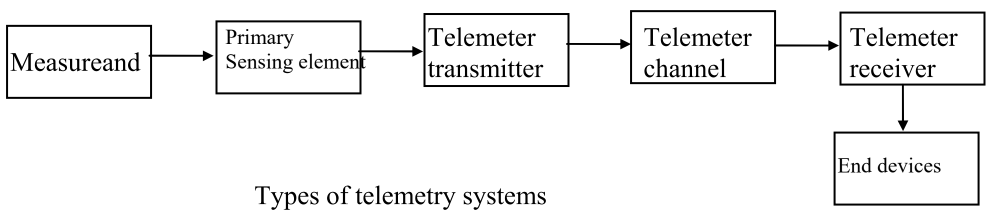
$$k = 100\frac{\text{mV}}{\text{N}}$$

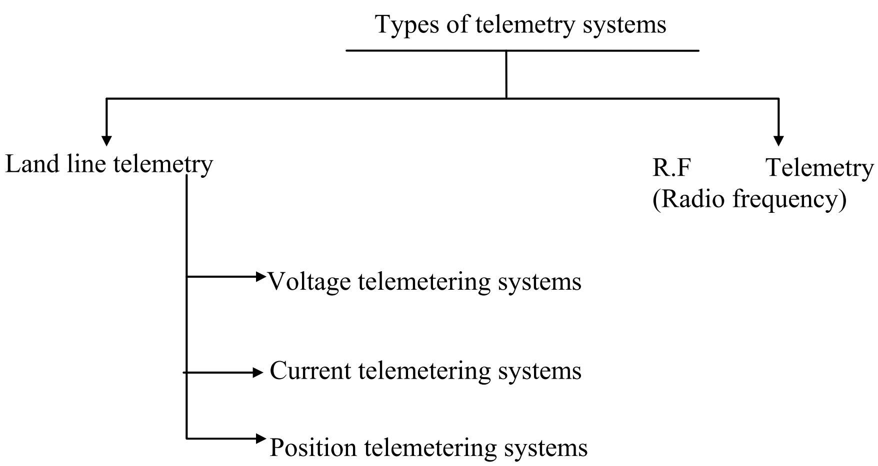
$$100\frac{\text{mV}}{\text{N}} = \frac{\text{d}}{\text{C}_\text{F}} = \frac{40(\text{pC}/\text{N})}{\text{C}_\text{F}}$$

$$C_F = \frac{40(pC/N)}{100mV}$$

$C_F = 0.4\times 10^{-9}$ F

(ii) **Telemetry:** It is the technology which enables a user to collect data from several measurement points at inaccessible or inconvenient locations, transmit that data to a convenient location and present the several individual measurements in a usable form

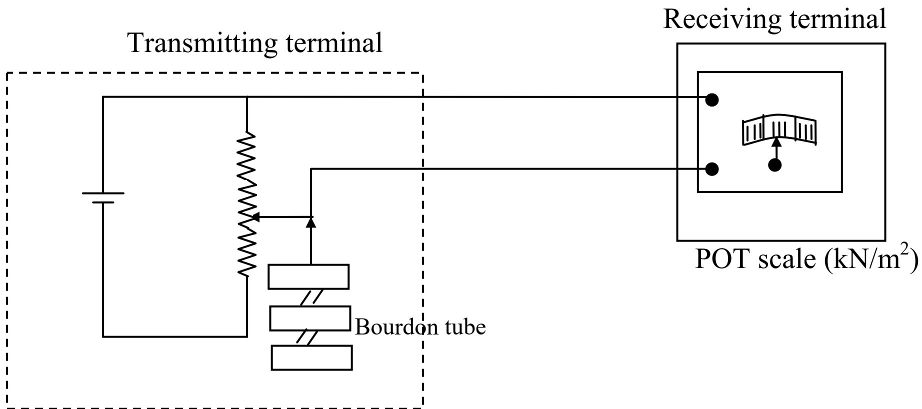




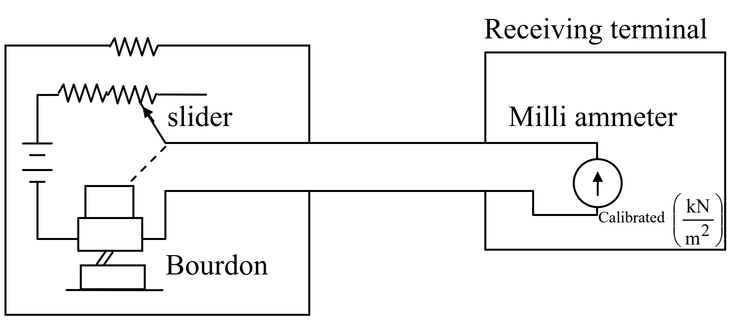
Land line telemetry system

A landline telemetering system requires a telemetering channel which is a physical link between the telemetering transmitter and receiver. The land line telemetering system is a direct transmission of information through cables and transmission lines.

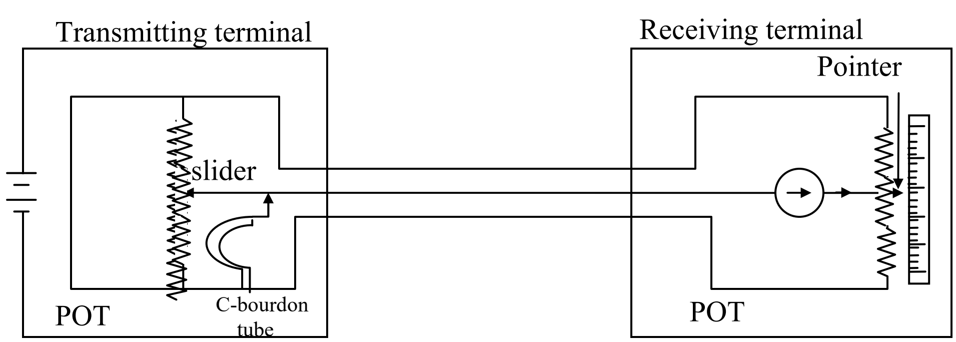
(1) **Voltage telemetering system:**



(2) **Current telemetering system:**

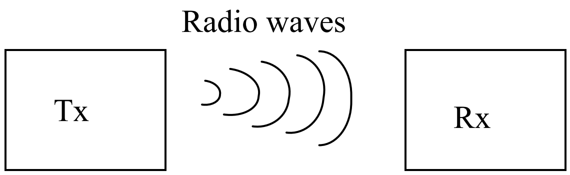


Position telemetry system:



A position telemetering system transmits and reproduces the measured variable by positioning variable resistors or other electrical components in a bridge circuit form so that to produce proportional changes at both the transmitter and receiver ends. This is known as bridge type system

R.F. Telemetry system:



→ There is no physical link between the transmission station and the receiving station (through radio links)

→ **Eg:** Air craft on a test flight (i.e), fuel flow, amount of fuel, engine performance, vibrations of critical parts, performance of avionic systems, Temp of various components.

→ The best way is to locate the team of engineers on a land based station and the test data be transmitted through radio links from the aircraft to land station.

→ R.F telemetry useful if the data transmission over 1Km

→ R.F telemetry system based vehicles use PDM & FM

→ PDM = Pulse Duration Modulation
FM = Frequency Modulation

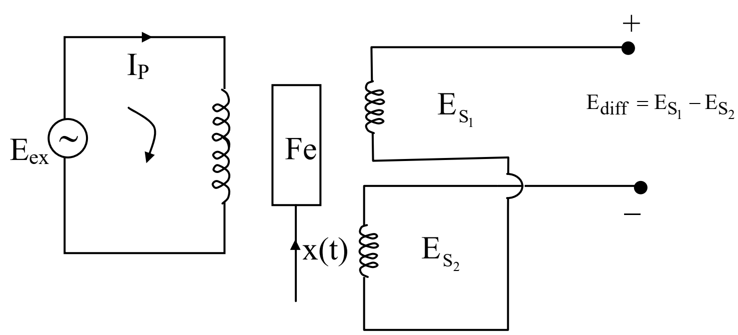
08. (a) (i) What are the requirements for the processing of signals using LVDT? Show a complete scheme to explain the displacement measurements with LVDT.

(ii) A 12A dynamometer ammeter has a full scale deflection of 90°. The rate of mutual inductance with deflection is constant and its value is 0.006 μH per degree. Find the deflection, if the current to be measured is 6A. (20 M)

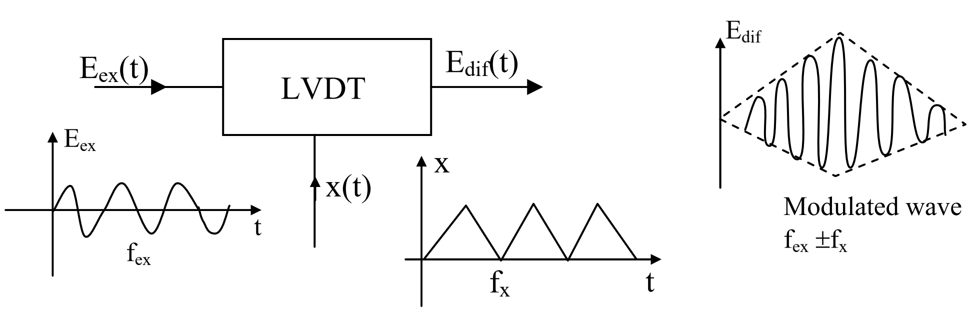
Sol:

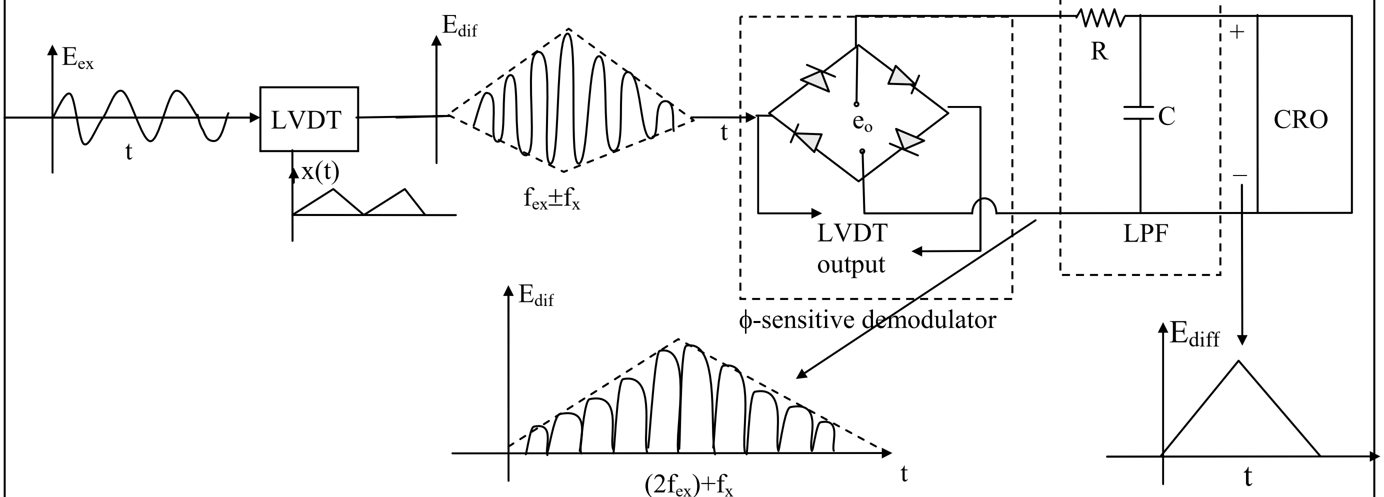
(i)

LVDT : Linear Variable Differential Transformer



According to the movement of core LVDT generate O/P voltage some times (+e) or (–e).





Explanation:

The modulated signal of LVDT containing ($f_{ex} \pm f_x$) given to phase sensitive diode bridge demodulator circuit, then it generates rectified full signal, then after to a low pass filter which eliminates high frequency AC carrier wave and contains only low frequency message signal

Like this by using signal conditioning modules like demodulator, low pass filler LVDT signals can be processed.

(ii) Given,

$I_{fsd} = 12A$,

Full scale deflection = 90°

$\frac{dM}{d\theta} = \text{constant} = 0.006\mu H/\text{degree}$

at I = 6A, $\Rightarrow \theta = ?$

For dynamometer ammeter, $T_d = I^2 \frac{dM}{d\theta}$

As $\frac{dM}{d\theta}$ is constant

$\therefore T_d \times I^2$

$\Rightarrow \frac{T_{d_1}}{T_{d_2}} = \frac{I_1^2}{I_2^2}$

At steady state, $T_d = T_c = K_c\, \theta$

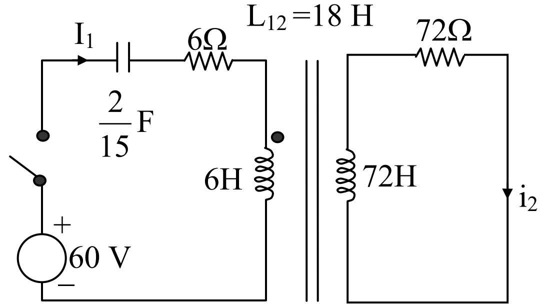
$$\therefore \frac{K_c\theta_1}{K_c\theta_2} = \frac{I_1^2}{I_2^2}$$

$$\frac{90^\circ}{\theta_2} = \frac{12^2}{6^2} \quad \left(I_{FSD} = I_1 = 12A, \theta_{FSD} = \theta_1 = 90^\circ\right)$$

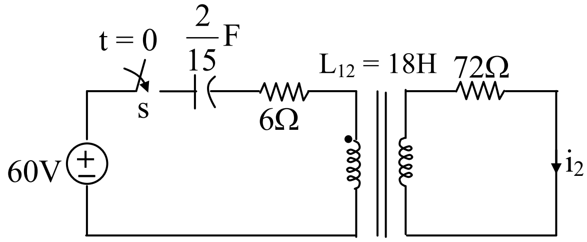
$$\therefore \theta_2 = 90^\circ \times \frac{36}{144} = 22.5^\circ$$

$$\therefore \theta_2 = 22.5^\circ$$

08. (b) An inductively coupled circuit is shown below. The switch is closed at t = 0. Assuming zero initial condition, determine the current $i_2(t)$. (20 M)

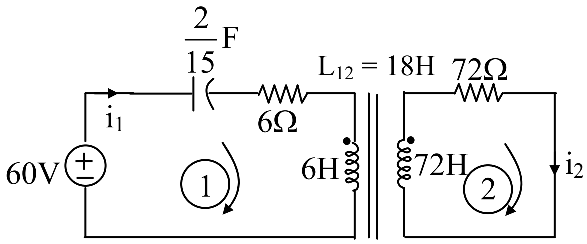


Sol:



Dot in the secondary is not given

By assuming that current $i_2(t)$ in the secondary is leaving then for $t > 0$



Here L_{12} is Mutual inductance M = 18 H

By KVL for Loop (1)

$$60 = \frac{15}{2}\int I_1 dt + 6I_1 + 6\frac{dI_1}{dt} - 18\frac{dI_2}{dt}$$

Apply Laplace transform

$$\frac{60}{s} = 7.5\frac{I_1(s)}{s} + 6I_1(s) + 6sI_1(s) - 18sI_2(s)$$

$$60 = 7.5I_1(s) + 6sI_1(s) + 6s^2I_1(s) - 18s^2I_2(s)$$

$$60 = I_1(s)[6s^2 + 6s + 7.5] - 18s^2I_2(s) \quad \text{-------- (1)}$$

By KVL for loop (2)

$$72\frac{dI_2}{dt} - 18\frac{dI_1}{dt} + 72I_2 = 0$$

Apply Laplace transform

$$72sI_2(s) - 18sI_1(s) + 72I_2(s) = 0$$

$$I_1(s) = \frac{I_2(s)}{s}(4s+4) \quad \text{-------- (2)}$$

From (1) & (2)

$$60 = I_2(s)\left[\frac{4s+4}{s}\right](6s^2 + 6s + 7.5) - 18s^2I_2(s)$$

$$60 = I_2(s)\left[\frac{24s^3 + 24s^2 + 30s + 24s^2 + 24s + 30 - 18s^3}{s}\right]$$

$$I_2(s) = \frac{60s}{6s^3 + 48s^2 + 54s + 30}$$

$$I_2(s) = \frac{10s}{s^3 + 8s^2 + 9s + 5}$$

$$I_2(s) = \frac{10s}{(s+6.78)(s^2 + 1.22s + 0.744)}$$

$$I_2(s) = \frac{A}{(s+6.78)} + \frac{Bs+C}{(s^2+1.22s+0.744)}$$

A = –1.763, B = 1.763, C = 0.193

$$I_2(s) = \frac{-1.763}{(s+6.78)} + \frac{1.763s+0.193}{(s+0.61)^2+(0.61)^2}$$

$$I_2(s) = \frac{-1.763}{(s+6.78)} + \frac{1.763(s+0.61)-0.88}{(s+0.61)^2+(0.61)^2}$$

$$I_2(s) = \frac{-1.763}{s+6.78} + \frac{1.763(s+0.61)}{(s+0.61)^2+(0.61)^2} - \frac{1.45(0.61)}{(s+0.61)^2+(0.61)^2}$$

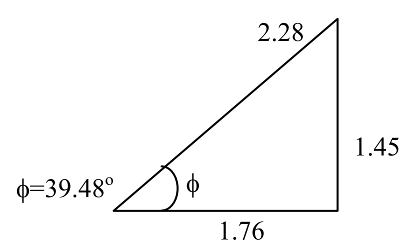
Apply Inverse Laplace transform

$$i_2(t) = -1.763e^{-6.78t} + 1.76e^{-0.61t}\cos(0.61t) - 1.45e^{-0.61t}\sin(0.61t)$$

$$= -1.763e^{-6.78t} + 2.28e^{-0.61t}\left[\frac{1.76}{2.28}\cos(0.61t) - \frac{1.45}{2.28}\sin(0.61t)\right]$$

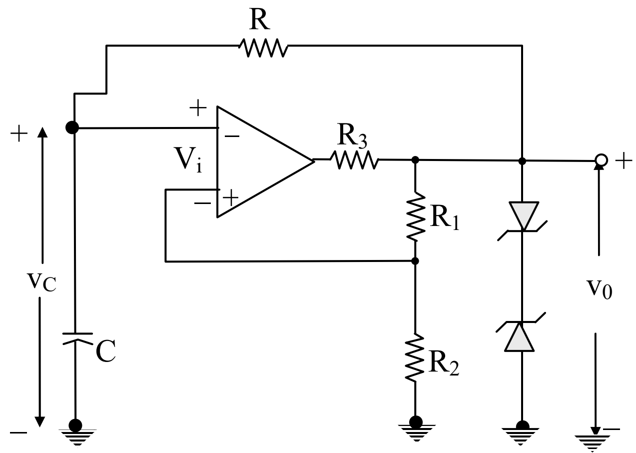
$$= -1.763e^{-6.78t} + 2.28e^{-0.61t}\left[\cos\phi\cos(0.61t) - \sin\phi\sin(0.61t)\right]$$

$$= -1.763e^{-6.78t} + 2.28e^{-0.61t}\left[\cos\left(0.61t + 39.48^\circ\right)\right]$$



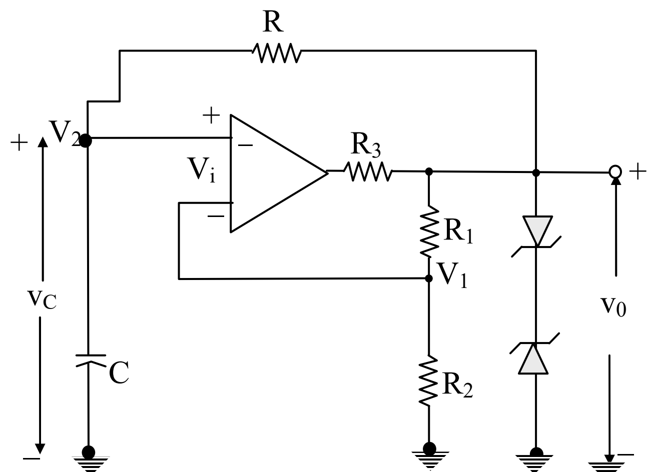
$$i_2(t) = -1.763e^{-6.78t} + 2.28e^{-0.61t}\cos\left(0.61t + 39.48^\circ\right) \text{ Amps} \quad (t \geq 0)$$

08. (c) How does the circuit shown below generate square wave? Calculate the time period of the generated wave and plot the voltages v_c and v_o.



How can the time period of the generated square wave be varied? (20 M)

Sol: Given circuit is an astable multivibrator



Operation:

Case 1:

- Since the output of comparator is either HIGH ($+V_{sat}$) or LOW ($-V_{sat}$), let us assume that the output is HIGH to begin with:

  i.e $V_0 = +V_{sat} = V_\gamma + V_z$ -----(1)

$$\Rightarrow V_1 = \frac{R_1}{R_1+R_2}(+V_{sat}) = +\beta V_{sat}$$

$$\& \ V_2 = V_C \ --(2)$$

Where $\beta = \frac{R_1}{R_1+R_2}$ is the feedback ratio and

V_C is the voltage across the capacitor.

- As the initial voltage across the capacitor is less than $+\beta V_{sat}$, V_1-V_2 remains positive and hence the output of astable multivibrator is at $+V_{sat}$ and the capacitor start charging towards $+V_{sat}$.
- As long as voltage across the capacitor is less than $+\beta V_{sat}$, the output of astable multivibrator remains at $+V_{sat}$.
- As soon as voltage across the capacitor is slightly more than $+\beta V_{sat}$, the output of astable multivibrator changes from $+V_{sat}$ to $-V_{sat}$.

Case 2:

- At present, the output is at $-V_{sat} = -(V_\gamma + V_z)$

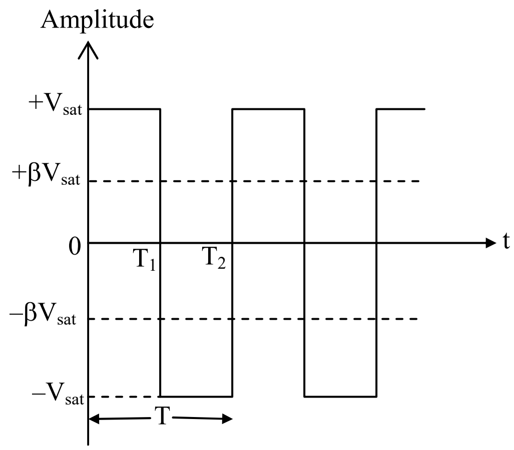
$$V_1 = \frac{R_1}{R_1+R_2}(-V_{sat}) = -\beta V_{sat} \ \& V_2 = V_C \ --(3)$$

The capacitor start discharging towards $-V_{sat}$

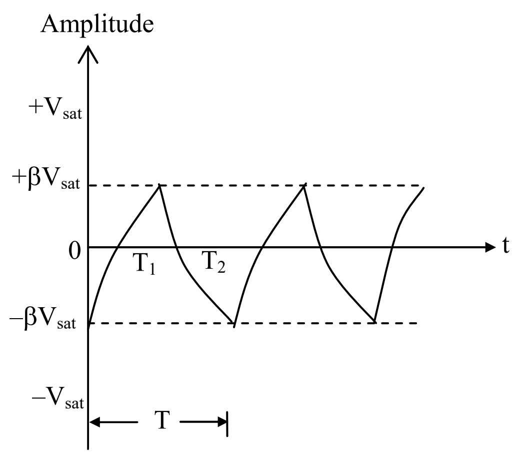
- As long as voltage across the capacitor is more than $+\beta V_{sat}$, the output of astable multivibrator remains at $-V_{sat}$.
- As soon as voltage across the capacitor is slightly less than $-\beta V_{sat}$, the output of astable multivibrator changes from $-V_{sat}$ to $+V_{sat}$.

Note: Since the duration of positive and negative half cycles of an astable multivibrator are controlled by the charging and discharging periods of the capacitor, there are no stable states but there are two Quasi (temporary) stable states in an astable multivibrator.

Waveforms for the output, V_0:



Voltage across capacitor V_C



Time period:

(a) Charging period of capacitor:

$$V_C(t) = V_{final} + [V_{initial} - V_{final}]e^{-t/RC} \text{ ----- (1)}$$

Here $V_{final} = V_{sat}$

$$\therefore V_C(t) = V_{sat} + [-\beta V_{sat} - V_{sat}]e^{-t/RC} \text{ ----- (2)}$$

At $t = T_1$, $V_C(t) = \beta V_{sat}$ ---(3)

$$\therefore \beta V_{sat} = V_{sat}\left[1-(1+\beta)e^{-T_1/RC}\right]$$

$$(1+\beta)e^{-T_1/RC} = 1-\beta$$

$$e^{-T_1/RC} = \ln\left(\frac{1-\beta}{1+\beta}\right)$$

$$-T_1/RC = \ln\left(\frac{1-\beta}{1+\beta}\right)$$

$$T_1 = RC\ln\left(\frac{1+\beta}{1-\beta}\right) --- (4)$$

(b) Discharging period of capacitor:

$V_{final} = -V_{sat}$

$V_{initial} = \beta V_{sat}$

$\therefore V_C(t) = -V_{sat} + [\beta V_{sat} + V_{sat}]e^{-t/RC}$

At $t = T_2$, $V_C(t) = -\beta V_{sat}$

$$\therefore \beta V_{sat} = -V_{sat}\left[1-(1+\beta)e^{-\frac{T_2}{RC}}\right]$$

$$(1+\beta)e^{-\frac{T_2}{RC}} = 1-\beta$$

$$e^{-\beta\frac{T_2}{RC}} = \frac{1-\beta}{1+\beta}$$

$$-\frac{T_2}{RC} = \ln\left(\frac{1-\beta}{1+\beta}\right)$$

$$T_2 = RC\ln\left(\frac{1+\beta}{1-\beta}\right)$$

$\Rightarrow$Total time period, $T = T_1 + T_2$

$$= 2RC\ln\left(\frac{1+\beta}{1-\beta}\right) \text{----- (6)}$$

So, time period can be varied by varying R_1, R_2, R and C.