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ESE – 2019
(MAINS)

Questions with Detailed Solutions

ELECTRONICS & TELECOMMUNICATION ENGINEERING

PAPER – I

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ELECTRONICS & TELECOMMUNICATION ENGINEERING

ESE _MAINS_2019_PAPER – I

SUBJECT WISE REVIEW

SUBJECT(S)	LEVEL	Marks
Basic Electronics Engineering	Moderate	27
Basic Electrical Engineering	Moderate	20
Materials Science	Easy	84
Electronic Measurements and Instrumentation	Moderate	84
Network Theory	Moderate	124
Analog and Digital Circuits	Moderate	141

Subject Experts,

ACE Engineering Academy

SECTION-A

01. (a) (i) Calculate the temperature at which silicon (Si) semiconductor tends to behave like a metal **(6 M)**

(ii) Prove that reverse saturation current approximately doubles for every 10°C rise in temperature in a semiconductor diode. **(6 M)**

Sol:

(i) $E_G(T) = E_{G0} - \beta T$

$0 = 1.21 - 3.60 \times 10^{-4}. T$

$\Rightarrow T = 3361.1°K$

Explanation:

Energy Band gap $\cong$ 6 eV For Insulator

$\cong$ 1 eV For Semiconductor

$\cong$ 0 eV For Metal

$\rightarrow$ Energy Band is Dependent on temperature. As temperature increases energy band gap decreases. As temperature increases Valence electrons gain energy and get excited, hence making such excited electron, free is possible easily i.e., gap between conduction & valence band decreases.

$\rightarrow$ The above equations relates energy gap versus temperature

E_{G0} = Energy Gap At 0°K

β = Constant

T = Temperature in °K

$E_G(T)$ = Energy Gap at T°K

(ii) $I_{02} = 2^{\left(\frac{T_2 - T_1}{10}\right)}.I_{01}$

where, I_{01} is reverse saturation current at temperature T_1

I_{02} is reverse saturation current at temperature T_2

$I_{02} = 2^{\frac{\Delta T}{10}}.I_{01}$

$\Delta T = 10°C$

$$I_{02} = 2^{\frac{10}{10}}.I_{01} \quad = 2^1.I_{01}$$

$I_{02} = 2\ I_{01}$

$\therefore$ For every 10^oC rise in temperature, reverse saturation current approximately double.

01. (b) (i) Prove that when two resistors are connected in parallel, the equivalent resistance of the combination is always smaller than that of smaller resistor. (6 M)

(ii) A conductor has resistance 5.4Ω at 20°C and 7Ω at 100°C. Determine the resistance of the conductor at 0°C. (6 M)

Sol:

(i) $$\frac{1}{R_{eq(n)}} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n}$$

If n = 2 then $\dfrac{1}{R_{eq(2)}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} \Rightarrow R_{eq(2)} = \dfrac{R_1 R_2}{R_1 + R_2}$

$$R_{eq(2)} = \frac{R_1}{1+\dfrac{R_1}{R_2}} = \frac{R_2}{1+\dfrac{R_2}{R_1}}$$

Since $\dfrac{R_1}{R_2} > 0$, we see $R_{eq(2)} < R_1$

& $R_{eq(2)} < R_2$

So, $R_{eq(2)} < \min(R_1 R_2)$

Now suppose it is true that

$R_{eq(n)} < \min(R_1, R_2, ...R_n)$

Consider, $\dfrac{1}{R_{eq(n+1)}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + ... + \dfrac{1}{R_n} + \dfrac{1}{R_{n+1}} \quad = \dfrac{1}{R_{eq(n)}} + \dfrac{1}{R_{n+1}}$

Using above result for n = 2, we find $R_{eq(n+1)} < \min[R_{n+1}, R_{eq(n)}] < \min[R_{n+1}, \min(R_1....R_n)]$

But $\min[R_{n+1}, \min(R_1,.....R_n)] = \min[R_{n+1}, R_1....R_n]$.

So, $R_{eq(n+1)} < \min(R_1, R_2, ..., R_n, R_{n+1})$

(ii) Let us consider the following equation

$R_1 = R_0[1 + \alpha\,(\Delta T_1)]$

Where, R_1 = Resistance at 20°C (5.4Ω)

R_0 = Resistance at 0°C

$\Delta T_1 = (20^\circ C - 0^\circ C) = 20^\circ C$

α = Temperature coefficient of resistance

$\Rightarrow 5.4 = R_0[1 + 20\alpha]$ - - - - - (1)

$R_2 = R_0[1 + \alpha\,(\Delta T_2)]$

Where, R_2 = Resistance at 100°C (7Ω)

$\Delta T_2 = 100^\circ C - 0^\circ C = 100^\circ C$

$\Rightarrow 7 = R_0[1 + 100\alpha]$ - - - - - (2)

∴ By solving above equation (1) and (2)

$R_0 = 5\Omega$ and $\alpha = \left(\dfrac{1}{50}\right)$

∴ Resistance of the conductor at 0°C is 5Ω.

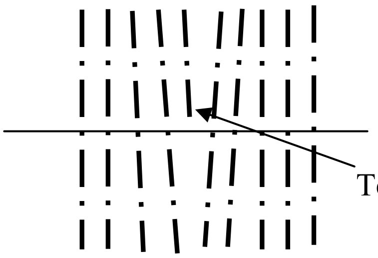
01. (c) What is 'line imperfection defect' in crystal? How does it affect the properties of a metal? (12 M)

Sol: Line imperfection defects:

- If the defect is confined to more number of atoms in a lattice is known as line defect.
  Ex; Crack formation in a material, where along the line of crack, the atoms are missing. Hence it is a line defect.
- A *dislocation* may be defined as a disturbed region between two substantially perfect parts of a crystal.

(a) Edge Dislocation

- By applying force on the lattice along the line of defect the lattice can break or crack easily known as edge dislocation.
- At the edge of a material, if any defects are created, then it acts as a line defect in the material.



- Edge dislocations are caused by the termination of a plane of atoms in the middle of a crystal.
- In such a case, the adjacent planes are not straight, but instead bend around the edge of the terminating plane so that the crystal structure is perfectly ordered on either side.

(b) Screw Dislocation

- If the movement of atom planes is following a translation motion followed by rotational motion is known as screw dislocation.
- In this phenomenon the arrangement of atoms in the lattice will be in the form of circular fashion at different planes.
- Therefore screw dislocation defects will change the surface properties of the material significantly.

(1) Material properties depends on number of line defect and there movement.

(2) The dislocation (line defect) always moves in a direction and on a plane that require low energy. Combination of direction and plane is known as slip system.

Structure	**Number of slip systems**
HCP	` 8
BCC	48
FCC	12

(3) If the number of slip system in a material is more than 5 then those materials are ductile in nature with low strength , otherwise material is brittle.

(4) Based on strain hardening mechanism, by deforming material plastically, dislocation density increased and due to that dislocation – dislocation interaction takes place, so strength of material decreases.

01. (d) (i) Enumerate the different performance indices based on which an engineer selects an instrument. (5 M)

(ii) What is the SI system of units? Mention some (at least four) well-defined units maintained by the international System of Units. (7 M)

Sol: (i) Different performance indices on which engineer selects an Instrument

(1) Accuracy Grade (Class) of an Instrument: If instrument has more Accuracy grade, then error in Instrument reading is less.

(2) Sensitivity of an Instrument:

If instrument has high sensitivity then loading by instrument on measuring quantity is less.

So loading error in instrument reading less

(3) Resolution of an Instrument:

If instrument has high resolution even a small variation in measuring quantity can be measured.

(4) Dynamic Error/fidelity:

If dynamic error is less, output of instrument follows similar to the input quantity.

So, instrument should be preferred more fidelity (mean less dynamic error)

(5) Speed of response:

If an instrument has more speed of response, settling time is less, with more speed of response measuring lag/delay time is less

(ii) The seven base units which from the basis of the now universally accepted international systems of Units, in their present status are defined below:

1. Metre (m): It is the unit of length. The metre is the length equal to 1,650,763.73 wavelengths in vacuum of radiation corresponding to the transition between the level 2_{p10} and 5_{d5} (orange red line) of the krypton 86 atom (excited at the triple point of nitrogen 63.15^{o} kelvin).

2. Kilogramme (kg): It is the unit of mass. A kilogramme is equal to the mass of the international prototype of mass. This prototype is a cylinder of platinum iridium alloy.

3. Second (s): It is the unit of time. A second is defined as the duration of 9,192,631,770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium atom.

4. Ampere (A): It is the unit of electric current. The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible cross-section, and placed one metre apart in vacuum, would produce between them a force equal to 2×10^7 Newton per metre length.

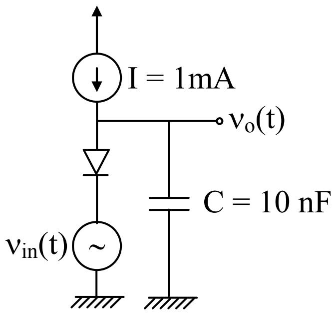
5. Kelvin (K): It is the unit of temperature. The Kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of triple point of water.

6. Candela (Cd): it is the unit of luminous intensity. It is the luminous intensity, in a perpendicular direction, of a surface of 1/600,000 square metre of a blackbody at the temperature of freezing platinum under a pressure of 101,325Newton per square metre.

7. Mole (mol): The mole is the amount of substance of a system which contains as many elementary entities as there are a toms in 0.012 kg of carbon 12. it should be noted that whenever mole is used, the elementary entities must be specified, which may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

These definitions are adopted all over the world for purposes of science, technology, industry and commerce. The Eleventh General Conference of Weights and Measures which met in October, 1960 recommended a unified systematically constituted, coherent system of fundamental, supplementary and derived units for international use. This system, called the International system of units and designated by the abbreviation SI, system internaitonale 'd' units is now legally compulsory in about twenty countries. It consists of six base units, two supplementary units and 27 derived units. Principles for the use of prefixes for forming the multiples and sub-multiples of units were also laid down. The six base units have already been adopted in the standards of weights and Measures Act, 1956.

01. (e) In the circuit shown in the figure below, I = 1mA is a DC current and $v_{in}(t)$ is a sinusoidal voltage with small amplitude:

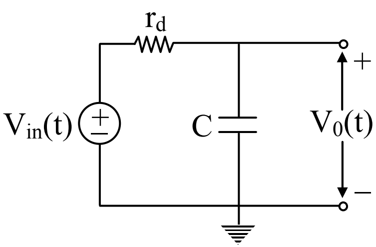


Representing the diode by its small signal resistance r_d, which is a function of I, sketch the circuit for determining $v_o(t)$ and thus find out cutoff frequency f_H. (Assume V_T = 25mV at room temperature) **(12 M)**

Sol: Step (1): r_d (the diode small-signal resistance) is given by.

$$r_d = \frac{V_T}{I} = \frac{25mV}{1mA} = 25\Omega \text{ ---------(1)}$$

Step (2): For determining $V_0(t)$, all the dc sources in the circuit should be considered as zero. i.e the current source I should be open from the circuit shown in bellow.



$$V_0(t) = \frac{\frac{1}{j\omega C} V_i(t)}{r_d + \frac{1}{j\omega C}} \text{ ----------(2)}$$

$$\frac{V_0(t)}{V_i(t)} = \frac{\frac{1}{j\omega C}}{\frac{1 + j\omega r_d C}{j\omega C}} = \frac{1}{1 + j2\pi f r_d C} \text{ ------------(3)}$$

$$= \frac{1}{1+\frac{jf}{f_H}} \text{ ----------------(4)}$$

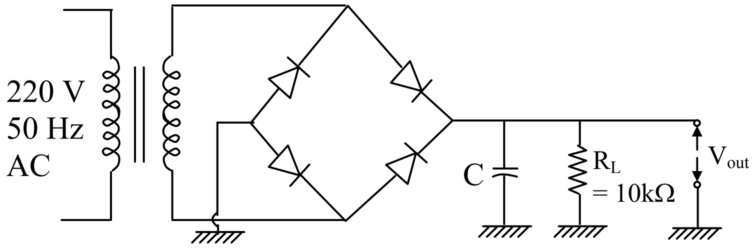
where f_H = Upper cutoff frequency $= \frac{1}{2\pi r_d C}$

$$\therefore \left|\frac{V_0(t)}{V_i(t)}\right| = \frac{1}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}} \text{ ------------(6)}$$

Step (3): cutoff frequency $f_H = \frac{1}{2\pi r_d C} = \frac{1}{2\pi \times 25\Omega \times 10\text{nF}} = 636.94\text{kHz} = 0.63694\text{MHz}$ -------(7)

02. (a)(i) Find the equilibrium hole concentration p_0 at 300 K of Si sample doped with phosphorus impurity if Fermi level energy (E_F) of doped Si is 0.407 eV more than intrinsic level energy (E_i). Given $n_i = 1.5\times10^{10}$ atoms/cm^3 and kT = 0.0259 eV. (10 M)

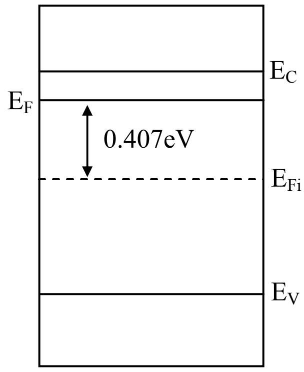
(ii) A filter capacitor C is used to smooth out the pulses from the full-wave rectifier as shown in the figure below:



Find the value of C so that the steady current supply to load R_L can be maintained. (10 M)

Sol:

(i) $$E_F - E_{Fi} = KT\ell n\left(\frac{N_D}{n_i}\right) = KT\ell n\left(\frac{n}{n_i}\right)$$



$$\frac{E_F - E_{Fi}}{KT} = \ell n\left(\frac{n}{n_i}\right)$$

$$\Rightarrow \frac{n}{n_i} = e^{\frac{E_F - E_{Fi}}{KT}}$$

$$n = n_i e^{\left(\frac{E_F - E_{Fi}}{KT}\right)}$$

$$= 1.5\times10^{10}.e^{\frac{0.407}{0.0259}}$$

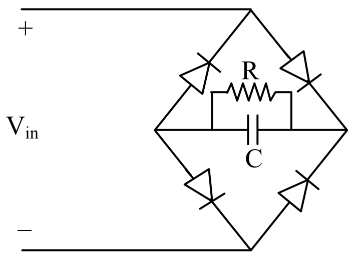
$$= 1 \times 10^{17}/\text{cm}^3$$

$\therefore$ The equilibrium hole concentration, $p_o = \dfrac{n_i^2}{n}$

$$\Rightarrow p_o = \frac{(1.5\times10^{10})^2}{1\times10^{17}}$$

$$\Rightarrow p_o = 2246.279 \text{ cm}^{-3}$$

(ii)



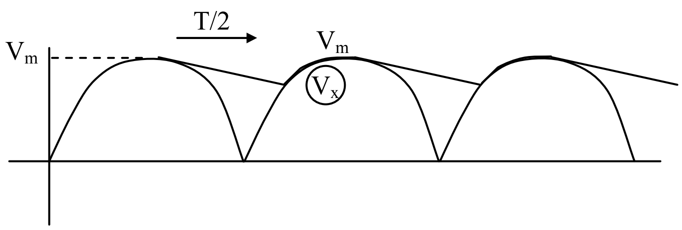
$V_m = 220\sqrt{2} = 311.12$

$T = \dfrac{1}{f} = 0.02$

R = 10K

For a steady current supply

Diodes are ideal



$V_x = V_m e^{-t/RC}$ $\quad \Big| \begin{array}{l} t = T/2 \\ RC >> T \end{array}$

$= V_m\left(1 - \dfrac{T}{2RC}\right)$

Ripple (r) = $V_m - V_x$

$r = \dfrac{V_m T}{2RC} = \dfrac{0.00031}{C}$

'r' should be small

$\therefore$ C should be large, If $r = 0.01V_m$

C = 0.1mF

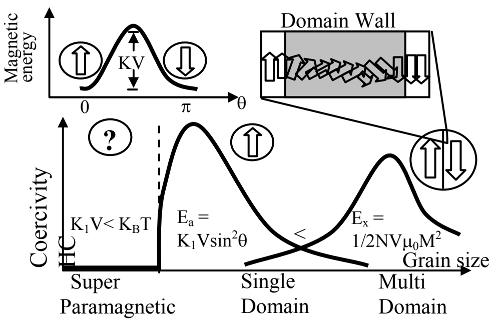
$\therefore$ C = 0.1mF

02. (b) (i) What is the principle of nanomagnetism? Based on the specific properties of nanomagnetism, write its applications in engineering field. (12 M)

(ii) Classify insulating materials according to their temperature stability limit and give few examples of each grade. (8 M)

Sol:

(i) When reducing the size of the magnetic material the number of domains within the material will be reduced until only a single domain is obtained. By having only single domains it is possible to produce strong permanent magnets. However if the size is reduced beyond a certain limit the sample becomes superparamagnetic and does no longer hold any ferromagnetism.



The figure illustrates the coercivity as function of magnetic particle size. As the particle shrinks fewer domains are present in the particle. At a certain size - depending in the material the magnetic particle becomes a single domain - typically in the range from 10 - 100 nm. At sizes below 10nm the particles becomes superparamagnetic. The spin is constantly changing within the particle.

To produce high performance permanent magnetic the particle size should be chosen so that the coercivity is maximized together with the remanence.

engineering application of nanomagnetisim:-

(1) MRI contrast equipment.

(2) Biosensors.

(3) Magnetic relaxation switches.

(4) energy conversion.

(5) electronic devices.

(ii) Maximum allowable temperatures of various types of insulation

Insulation Classes	**Maximum Permissible temperature (^oC)**
Y	90
A	105
E	120
B	130
F	155
H	180
C	Over 180

(i) Class-Y Insulation: Withstands a temperature of up to 90^{o}C; typically made of cotton, silk, or paper.

(ii) Class-A Insulation: Withstands a temperature of up to 105^{o}C; reinforced Class-Y materials with impregnated varnish or insulation oil.

(iii) Class-E Insulation: Withstands a temperature of up to 120^{o}C.

(iv) Class-B Insulation: Withstands a temperature of up to 130^{o}C; This has a form that inorganic material is hardened with adhesives. This is the first insulator using this structure.

(v) Class-F Insulation: Withstands a temperature of up to 155^{o}C; for example, made of Class-B materials that are upgraded with adhesives, silicone, and alkyd-resin varnish of higher thermal endurance.

(vi) Class-H Insulation: Withstands a temperature of up to 180^{o}C; for example, made of inorganic material glued with silicone resin or adhesives of equivalent performance

(vi) Class-C Insulation: Withstands a temperature of up to 180^{o}C or higher; made of 100% inorganic material.

Temperature classes of insulating material.

3Insulation type	Main	Insulation material	Adhesive, impregnant, or coating material used together with the insulator specified in column 3	Target Insulator
Y	Main	Cotton, silk, or other natural plant or animal fibers . Regenerated celluslose. Cellulose acetate. Polyamide fiber. Paper and paper goods. Press board.	None	None

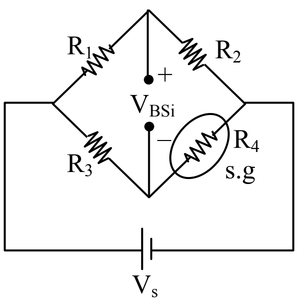
02. (c) (i) What are the signal conditioning requirements for measurements with strain gauges? How can you compensate errors due to temperature in strain gauge measurements?

(10 M)

(ii) A piezoelectric transducer is subjected to force of 6 N. The dimension of the transducer is given as 6 mm × 6 mm × 1.3 mm. The charge sensitivity and the dielectric constant of the transducer are given as 160 pC/N and 1250×10^{-11} F/m respectively. Calculate the voltage generated and the deflection caused to the surface. The Young's modulus of elasticity of the material is given as 12×10^{6} N/m^2. **(10 M)**

Sol:

(i)



$R_m = \infty$

Strain gauge is a resistive transducer so the best signal conditioning is done by wheatstone bridge circuit.

$R_1 = R_2 = R_3 = R$

$R_4 = R + \Delta R$ after stress applied

$$V_{Bsi} = V_s\left\{\frac{R_2}{R_1+R_2} - \frac{R_4}{R_3+R_4}\right\}$$

$$= V_s\left\{\frac{R}{R+R} - \frac{(R+\Delta R)}{R+(R+\Delta R)}\right\}$$

$$= V_s\left\{\frac{1}{2} - \frac{R+\Delta R}{2R+\Delta R}\right\}$$

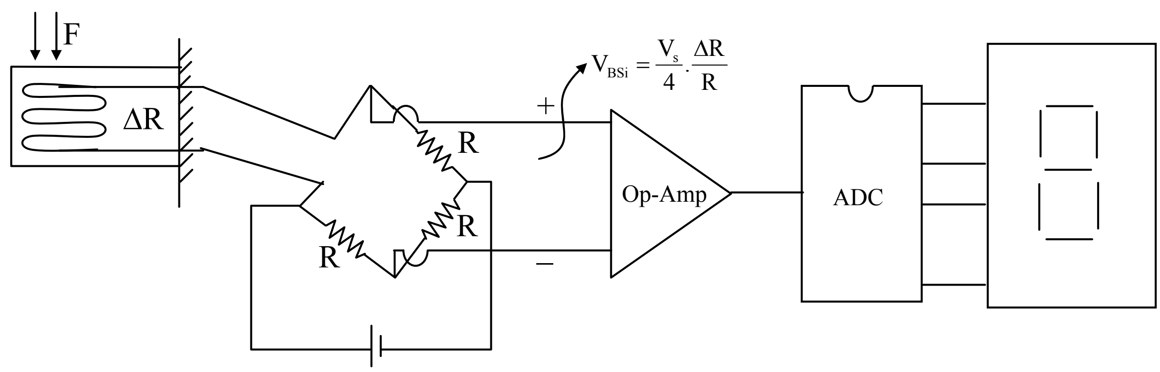
$$= V_s\left\{\frac{2R+\Delta R-2R-\Delta R}{4R+2\Delta R}\right\}$$

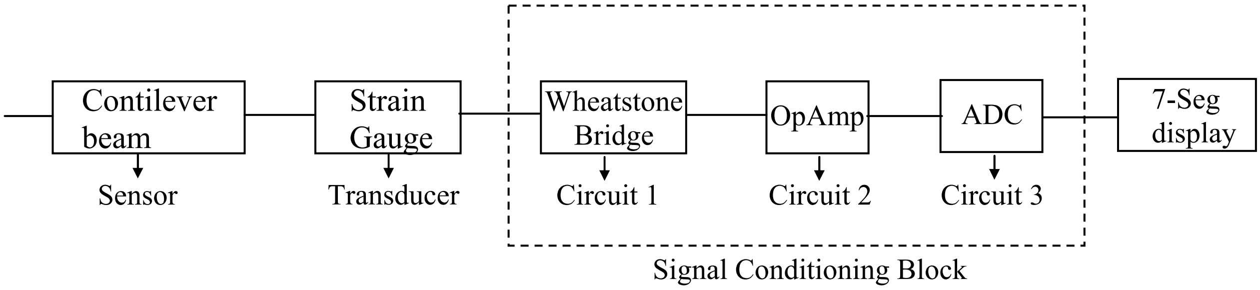
$$= V_s\left\{\frac{-\Delta R}{4R+2\Delta R}\right\}$$

$$|V_{Bsi}| = \frac{V_s.\Delta R}{4R} \; [\because 4R >> 2\Delta R]$$

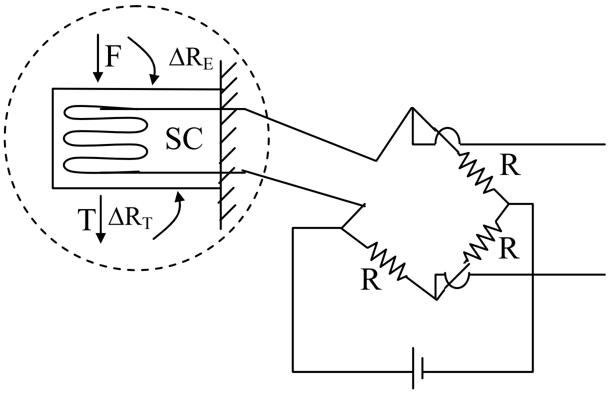
$V_{Bsi} \; \alpha \; \Delta R \; \alpha \; \Delta L \; \alpha \; F$

The signal conditioning blocks for strain gauge





<u>Temperature effect on Strain Gauge</u>



$$V_{Bsi} = \left[\frac{V_s}{L_1}.\frac{\Delta R_E}{R}\right] + \left[\frac{V_s}{L_1}.\frac{\Delta R_T}{R}\right]$$

Semiconductor strain gauges are extremely sensitive for stress m/m as their gauge factor is high due to resistivity effect. But they're sensitive to temperature also; they've negative temperature coefficient of resistance,

$$V_{Bsi} = \frac{V_s}{4}.\frac{\Delta R}{R}$$

$$= \frac{V_s}{4}\frac{[\Delta R_E + \Delta R_T]}{R} \qquad \Delta R_E = \text{due to strain}$$

$$V_{Bsi} = \left[\frac{V_s}{4}.\frac{\Delta R_E}{R}\right] + \frac{V_s}{4}.\frac{\Delta R_T}{R} \qquad \Delta R_T = \text{due to temperature}$$

True value Temperature induced error

To eliminate this error dummy strain gauges of semiconductor material have to be used as compensation element that strain gauge has to be placed on other surface and that surface has to be subjected to temperature but not to force; that's why that strain gauge is called dummy strain gauge

(ii) $F_{i/p} = 6N$

$\ell \times b \times h = 6mm \times 6mm \times 1.3$ mm

$\vec{d}$ [charge sensitivity] = 160pC/N

$\in$ [dielectric constant] = 1250×10^{-11} F/m

$Y_{crystal} = 12 \times 10^6$ N/m^2

(1) $E_0 = ?$

$$E_0 = \vec{g}.p.t$$

$$= \left[\frac{\vec{d}}{\in}\right].\frac{F}{A}.t$$

$$\Rightarrow \frac{160\times10^{-12}}{1250\times10^{-11}}\times\frac{6}{6\times6\times10^{-6}}\times1.3\times10^{-3}$$

$$\Rightarrow \frac{1248\times10^{-15}}{45000\times10^{-17}}$$

$$\Rightarrow 0.0277 \times 10^{+2}$$

$E_0 = 2.77$ volts

(2) x(deflection) = ?

$$\frac{F}{A} = Y.\frac{(\Delta t)}{t} \to x$$

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

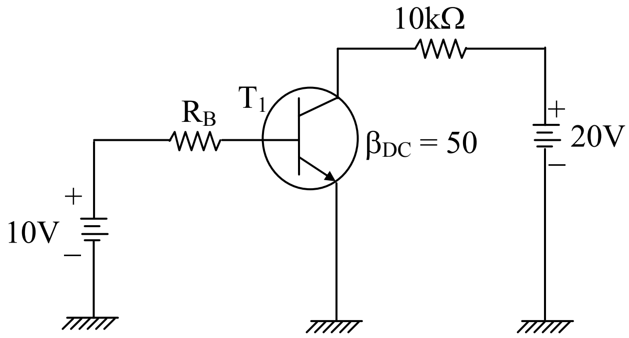
$$\frac{F}{A}.\frac{t}{Y} = x$$

$$x = \frac{6}{6\times6\times10^{-6}}\times\frac{1.3\times10^{-3}}{12\times10^{6}}$$

$$\Rightarrow \frac{7.8}{432}\times\frac{10^{-3}}{1}$$

x = 0.018 mm

03. (a)(i) Calculate the range of base resistance (R_B) so that transistor T_1 never operates in saturation region:

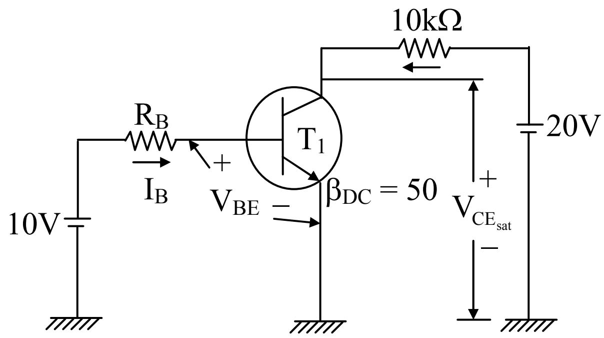


(10 M)

(ii) An amplifier has bandwidth of 500kHz and voltage gain of 100. What should be the amount of negative feedback if the amplifier bandwidth is extended to 5MHz? What will be the new gain after negative feedback is introduced? (10 M)

Sol:

(i) Case (i): Let $V_{CE_{sat}} = 0.2V$ and $V_{BE} = 0.7V$



Step (1): KVL for output section

$20V - I_{C_{sat}} 10k\Omega - V_{CE_{sat}} = 0$ ________(1)

$\Rightarrow I_{C_{sat}} = \dfrac{20V - 0.2V}{10k\Omega} = 1.98mA$ ________(2)

$\therefore I_{B_{min}}$ to saturate $'T_1' = \dfrac{I_{C_{sat}}}{\beta_{DC}} = \dfrac{1.98mA}{50} = 0.0396mA$ ________(3)

NOTE: The actual value of I_B should be less than $I_{B_{min}}$ to ensure the transistor never operates in saturation region.

i.e., $I_B < I_{B_{min}} \Rightarrow I_B < 0.0396mA$ ________(4)

Step (2) KVL for input section

$10V - I_B R_B - V_{BE} = 0$ _____(5)

$\Rightarrow R_B = \dfrac{10V - 0.7V}{I_B}$ ________(6)

$R_B > \dfrac{9.3\text{V}}{0.0396\text{mA}}$ ________(7)

$\therefore\ R_B > 234.85\text{k}\Omega$_______(8)

i.e. For $R_B > 234.85\text{k}\Omega$ T_1 never operates in saturation

(ii) Given

Bandwidth before feedback, BW = 500kHz

Voltage gain before feedback $A_V = 100$

Step (1) The general formula for the bandwidth with negative feedback,

$BW_f = BW\,[1+A_V\beta]$

$\Rightarrow$ 5MHz = 500kHz [1+100β]

$$\Rightarrow 1 + 100\beta = \frac{5\times10^6\,\text{Hz}}{500\times10^3\,\text{Hz}} = 10$$

$\Rightarrow 100\,\beta = 9$

$$\therefore \beta = \frac{9}{100} = 0.09 \qquad [\text{i.e } 9\%]$$

Step (2): Gain with negative feedback,

$$A_{V_f} = \frac{A_V}{1+A_V\beta}$$

$$= \frac{100}{1+100\times\frac{9}{100}}$$

$$\therefore\ A_{V_f} = 10$$

03. (b) (i) What are HTSC? Write the important applications of superconducting materials and HTSC. (10 M)

(ii) "A ceramist can alter the properties of ceramic." Justify the statement. (10 M)

Sol:

(i) High temperature superconductors:- Some of the cuprate ceramics are becoming superconductor at high temperature nearly about 100K.

Example:- Yttrium barium copper oxide-94K

Application of superconductor:

(1) Maglev trains

(2) loss less power transmission line.

(3)cryotron switch

(4)MRI scanning

(5) Nuclear power plant.

Application of HTSC:-

(1) Current limiter

(2) Fusion magnets

(3) NMR- spectrometer.

(4) Transformers.

(ii) In general density of ceramics are lighter than metal and heavier than polymers.

A ceramist can alter the properties of ceramic by the following method

→ Make starting materials more uniform.

→Decrease grain size in polycrystalline ceramic products.

→Minimize porosity.

→introduce compressive surface stresses.

→Use fibre reinforcement.

→ Heat treat.

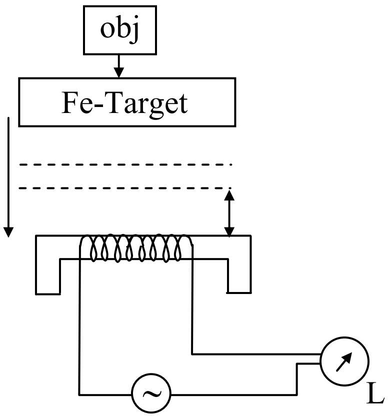
03. (c) (i) Explain, with necessary diagrams, how you can detect the proximity of an object.(12 M)

(ii) The spring constant and seismic mass of an accelerometer are 3300 N/m and 5×10^{-2} kg respectively. The maximum displacement is ± 0.25m(before the mass hits the stops). Calculate (1) the maximum measurable acceleration in g and (2) the natural frequency. (8 M)

Sol:

(i) The proximity of an object can be detected by several sensor technologies such as ultrasonic sensors, capacitive, photo electric, inductive.

Inductive proximity:



x = 0 ; gap↑

Reluctance ↑

$\phi\downarrow$

L ↓

$V_L\downarrow$

If object approaches

x ↓ , gap ↓

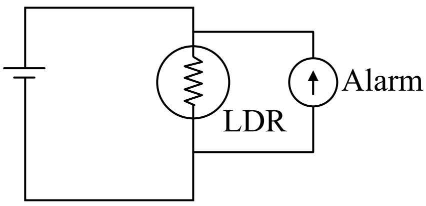
Reluctance ↓

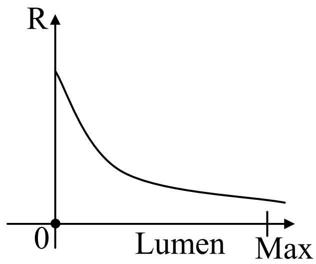
$\phi\uparrow$

L ↑

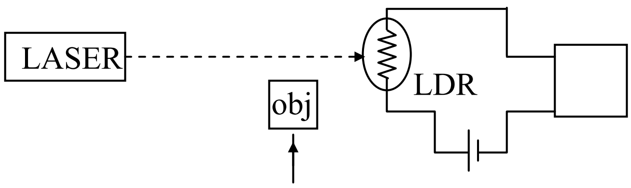
$V_L\uparrow$

Optical proximity:



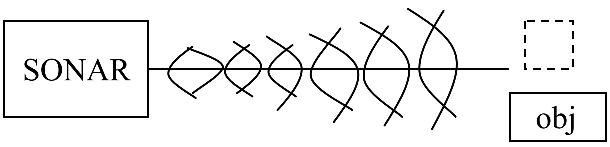


LDR is a photo resistor whose resistance will decrease as the light is incident on it; when a object enters in between light source and LDR then alarm rings.



If object is not there then light hits LDR then R is less current increases, when object comes in the middle then LDR, resistance increases current decreases.

Ultrasonic proximity:



Piezo electric acts like transducer and inverse transducer also. When stress applied voltage generated and when voltage applied it generates ultrasonic waves; when object is not there will not be any echo; if a object is present in the middle of the wave propagation then there will be echo.

(ii) K(spring constant) = 3300 N/m

M (Mass) = 5×10^{-2} kg

X_0 (dispersion) = ± 0.25 m

(1) Steady state sensitivity $= \dfrac{X_0}{acc_{i/p}} = \dfrac{M}{K}$

$$X_0 = \left(\frac{M}{K}\right) acc_{i/p}$$

$$(0.25m) = \frac{5\times10^{-2}}{3300} acc_{i/p}$$

$$acc_{i/p} = \frac{0.25\times3300}{5\times10^{-2}} = 16{,}500\ m/s^2$$

In terms of 'g' ⇒ 1683.67g

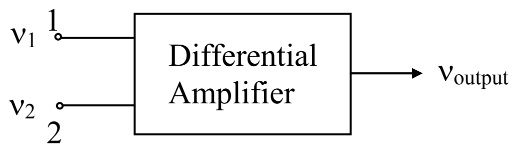
(2) Natural frequency $(\omega_n) = \sqrt{\dfrac{K}{M}}$

$$= \sqrt{\frac{3300}{5\times10^{-2}}} = \sqrt{\frac{330000}{5}} = \sqrt{\frac{33}{5}}\times100$$

= 256.904 rad/sec

f_n = 40.908 Hz

04. (a) (i) Consider a differential amplifier as shown in the figure



Where the first set of signals is v_1 = 50 μV, v_1 = –50 μV and the second set of signals is v_1 = 1050 μV, v_2 = 950 μV. If the common-mode rejection ratio is 100, calculate the percentage difference in output voltage obtained for the two sets of input signals.

(10 M)

(ii) (1) Repeat part (a)(i), if the common-mode rejection ratio is 10^5. **(3 M)**

(2) Draw the conclusion by comparing part (a)(i) and part (a)(ii)(1). **(2 M)**

(iii) Explain photovoltaic potential in short. **(5 M)**

Sol:

(i) Case (i): consider the first set of input signals:

$V_1 = 50\mu V$ and $V_2 = -50\mu V$

Step (1): $V_{id} = V_1 - V_2 = 50\mu V - (-50\mu V) = 100\mu V$________(1) [Differential mode input]

common mode input, $V_C = \dfrac{V_1 + V_2}{2} = \dfrac{50\mu V - 50\mu V}{2} = 0$

Step (2): Total output voltage of the differential amplifier,

$$V_0^1 = A_d V_{id} + A_C V_C$$

$$= A_d V_{id}\left[1 + \frac{A_C}{A_d}\left(\frac{V_C}{V_{id}}\right)\right]$$

$$= A_d 100\mu V\left[1 + \frac{1}{CMRR}\left(\frac{V_C}{V_{id}}\right)\right]$$

$= A_d\ 100\mu V\ [1 + 0] - (6)\ [\because\ V_C = 0]$

$\therefore\ V_0^1 = A_d 100\mu V$

Case (ii): Consider the second set of input signals $V_1 = 1050\mu V$ and $V_2 = 950\mu V$

Step (1): Differential mode input, $V_{id} = V_1 - V_2 = 1050\mu V - 950\mu V = 100\mu V$

common mode input, $V_C = \dfrac{V_1 + V_2}{2} = \dfrac{1050\mu V + 950\mu V}{2} = 1000\mu V$

Step (2): $V_0^{11} = A_d V_{id}\left[1 + \dfrac{1}{CMRR}\left(\dfrac{V_C}{V_{id}}\right)\right]$

$$= A_d 100\mu V\left[1 + \frac{1}{100}\left(\frac{1000}{100}\right)\right]$$

$= A_d\ 100\mu V\ [1 + 0.1]$

$\therefore\ V_0^{11} = A_d 100\mu V + A_d 10\mu V = A_d\ [110\mu V]$

Step (3): % change in the output,

$$\%\Delta V_0 = \frac{V_0^{11} - V_0^{1}}{V_0^{1}} \times 100 \ = \frac{A_d 10\mu V}{A_d 100\mu V} \times 100$$

% change in output = 10%

(ii) (1) Case(i): $V_{id} = 100\mu V$ and $V_C = 0$

$$V_0^1 = A_d V_{id} = A_C V_C = A_d 100\mu V$$

Case (ii) $V_{id} = 100\mu V$ and $V_C = 1000\mu V$

$$V_0^{11} = A_d V_{id}\left[1 + \frac{1}{CMRR}\left(\frac{V_C}{V_{id}}\right)\right]$$

$$= A_d 100\mu V\left[1 + \frac{1}{10^5}\left(\frac{1000}{100}\right)\right]$$

$$= A_d 100\mu V + A_d 100\mu V \times \frac{1}{10000}$$

$$V_0^{11} = A_d 100\mu V + A_d 0.01\mu V = A_d\ 100.01\ \mu V$$

Case (iii) % change in output voltage $= \frac{V_0^{11} - V_0^{1}}{V_0^{1}} \times 100 \ = \frac{A_d \times 0.01\mu V}{A_d \times 100\mu V} \times 100$

$\therefore\ \%\ \Delta\ V_0 = 0.01\%$

(2) **Observation**

1. In part (a) (i), the percentage change in the output voltage is 10% when the CMRR value is 100.
2. In part (a)(ii) (1), when the CMRR is 10^5, the percentage change in output voltage is just 0.01% only.

Conclusion: The error in the output of a differential amplifier due to common mode can be minimized by having high CMRR value in the amplifier (or) A differential amplifier with high CMRR value will have the less tendency to enter into common mode of operation and hence the error in the output of such an amplifier will be almost zero.

(iii) The Photovoltaic potential is the actual usable solar energy or power once it has been transformed into electricity by photovoltaic systems.

Photovoltaic is the most direct way to convert solar radiation into electricity and is based on the phtovoltaic effect. It is quite generally defined as the emergence of an electric voltage between two electrodes attached to a solid or liquid system upon shining light onto this system. Practically all photovoltaic devices incorporate a p-n junction in a semiconductor across which the photovoltage is developed. These devices are also known as solar cells. Light absorption occurs in a semiconductor material. The semiconductor material has to be able to absorb a large part of the solar spectrum. Dependent on the absorption properties of the material, the light is absorbed in a region more or less close to surface.

04. (b) (i) What is polarization mechanism in dielectric material? Explain active and passive dielectrics with suitable example. (10 M)

(ii) Explain cermets. How are they different from fibre reinforced composites? Write four applications of each. (10 M)

Sol:

(i) Polarization occurs due to several microscopic mechanisms and is of four types

(1) Electronic polarization, α_e

(2) Ionic polarization, α_i

(3) Orientational polarization, α_o

(4) Space - charge polarization, α_s

1) Electronic polarization, α_e:

It is defined as the electric strain produced in an atom due to the relative displacement of electron cloud and the positive nucleus in electric field.

Electronic polarizability $\alpha_e = 4\pi\epsilon_0 R^3$

F-m^2 (R – Radius of the atom)

Thus it is proportional to the volume of the atom and is independent of temperature. It is present in all materials and is fastest of all polarizabilities.

2) Ionic polarization, α_i :

It occurs in ionic solids only and is due to the displacement of cations and anions in opposite directions to the applied field.

$$\alpha_i = \frac{\mu}{E} = \frac{e^2}{\omega_0^2}\left[\frac{1}{M} + \frac{1}{m}\right]$$

OR $\alpha_i = \dfrac{e^2}{\omega_0^2\, m^*}$

α_i is inversely proportional to the square of the natural frequency of the ionic molecule and to its reduced mass and is independent of temperature.

3) Orientational polarization, α_o:

This occurs in polar solids only and is due to the presence of polar molecules in the dielectric. These molecules posses permanent dipole moments even without field. But they are randomly oriented. When an external field is applied these dipoles try to align themselves in the direction of the field giving rise to Orientational Polarization.

$$\alpha_o = \frac{\mu^2}{3kT}$$

Where μ is dipole moment of each atom.

Thus it is inversely proportional to absolute temperature.

4) Space - charge polarization, α_S:

Space - charge polarization occurs due to the accumulation of charges at the electrodes or at the interfaces in a multi phases material. The ions diffuse over appreciable distances in response to the applied field, giving rise to redistribution of charges in the dielectric medium. It is found in ferrites and semiconductors and is negligibly small.

Therefore, total polarizability of the material is

$$\alpha = \alpha_e + \alpha_i + \alpha_o$$

$$= 4\pi\varepsilon_0 R^3 + \frac{e^2}{\omega_0^2}\left[\frac{1}{M} + \frac{1}{m}\right] + \frac{\mu^2}{3KT}$$

We have $\mu_e = \alpha_e E$

where α_e is the electronic polarizability.

$$\alpha_e = 4\pi\varepsilon_0 R^3$$

Polarization, $P_e = N\mu_e = N\alpha_e E$

Where 'N' is the number of atoms/ m^3

$P_e = \epsilon_0 E(\epsilon_r - 1) = N\alpha_e E$

$$(\varepsilon_r - 1) = \frac{N\alpha_e}{\varepsilon_0}$$

$$\alpha_e = \frac{\varepsilon_e(\varepsilon_r - 1)}{N}$$

S.No	Active dielectric	Passive dielectric
1.	Dielectric which can easily adapt itself to store the electrical energy in it is called active dielectric	Dielectric which restricts the flow of electrical energy in it are called passive dielectrics.
2.	Examples: Piezo electric, Ferro electrics	Examples: Glass, mica, plastic
3.	It is used in the production of ultrasonics.	It is used in the production of sheets pipes, etc.,

(ii) Cermets:- cermets are compounds of ceramics and metals. cermets are composite material. A cermet is designed to have the optical properties of both a ceramics, such as high temperature resistance and hardness, and those of a metal, such as ability to undergo plastic deformation.

Application of cermets:

(1) resistor, capacitor and vacuum tubes.

(2) space craft shields

(3) transport vehicle breaks and clutches.

(4) storage of nuclear waste, fabrication of nuclear reactor.

Fiber reinforced composites:- In fiber reinforced composites, the reinforcement phase materials are in the form of wires, fibers and whiskers surrounded by these fibers polymer matrix phase present.

Application of Fiber reinforced composites:

(1) optical fiber (GFRP)

(2) Transportation vehicle glasses (GFRP)

(3) Sports goods (CFRP)

(4) bullet proof jackets (AFRP)

04. (c) (i) What are the elements of a generalized data acquisition system? Draw a multi-channel data acquisition system using single A/D converter and briefly explain its working. (14 M)

(ii) Explain, with a diagram, the operation of a force balance current telemetering system. (6 M)

Sol:

(i) **DAQ:** Data Acquisition is a process of achieving the information of a process variable (like temperature, press, flows etc) in the required format.

A DAQ system typically consists of there following elements

(1) Transducers

(2) Signal conditioning equipment

(3) Multiplexer

(4) Signal converter

(5) A/D converter

(6) Auxillary equipment

(7) Digital recorders

(8) Digital printers.

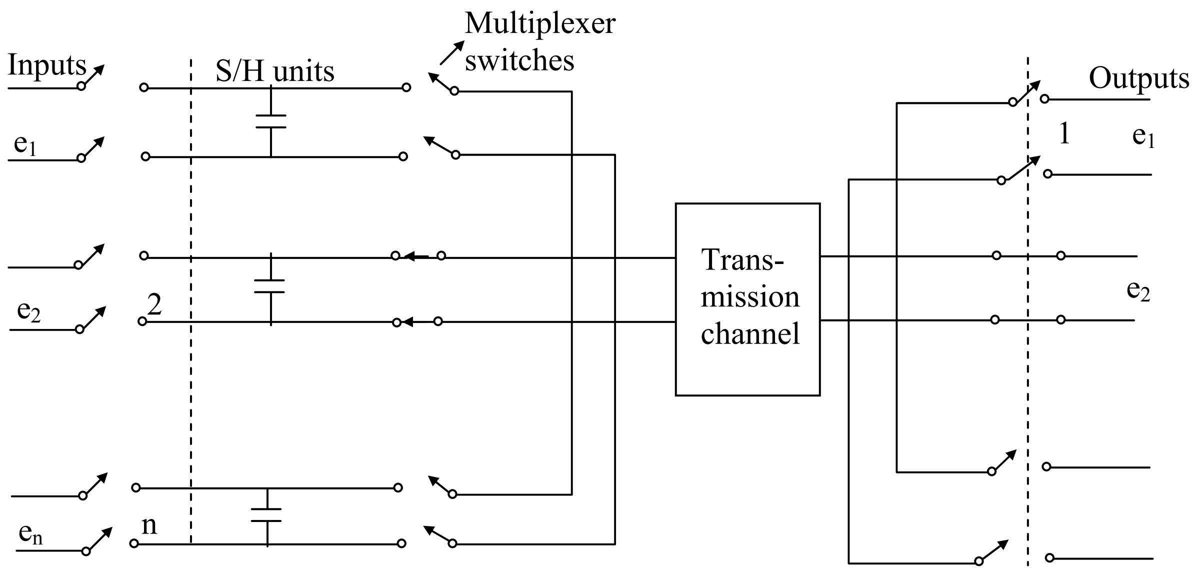
(1) **Transducers:** They convert a physical quantity into an electrical signal which is acceptable by the data acquisition system.

Eg: Thermocouple, strain gauge

(2) **Signal conditioning equipment:** Signal conditioning equipment provides any equipment that assists in transforming the output of transducers to the desired magnitude or form required by the next stage of the DAQ system. They may include devices for amplifying, refining, attenuation, altering.

Eg: Op-Amp, Divider, Filter

(3) Multiplexer: Multiplexing is the process of sharing a single channel with more than one output. Thus a multiplexer accepts analog inputs and connects them sequentially to one measuring instrument another name for a multiplexer is "scanner".



(4) A/D converter: ADC will convert analog voltage to its equivalent digital form.

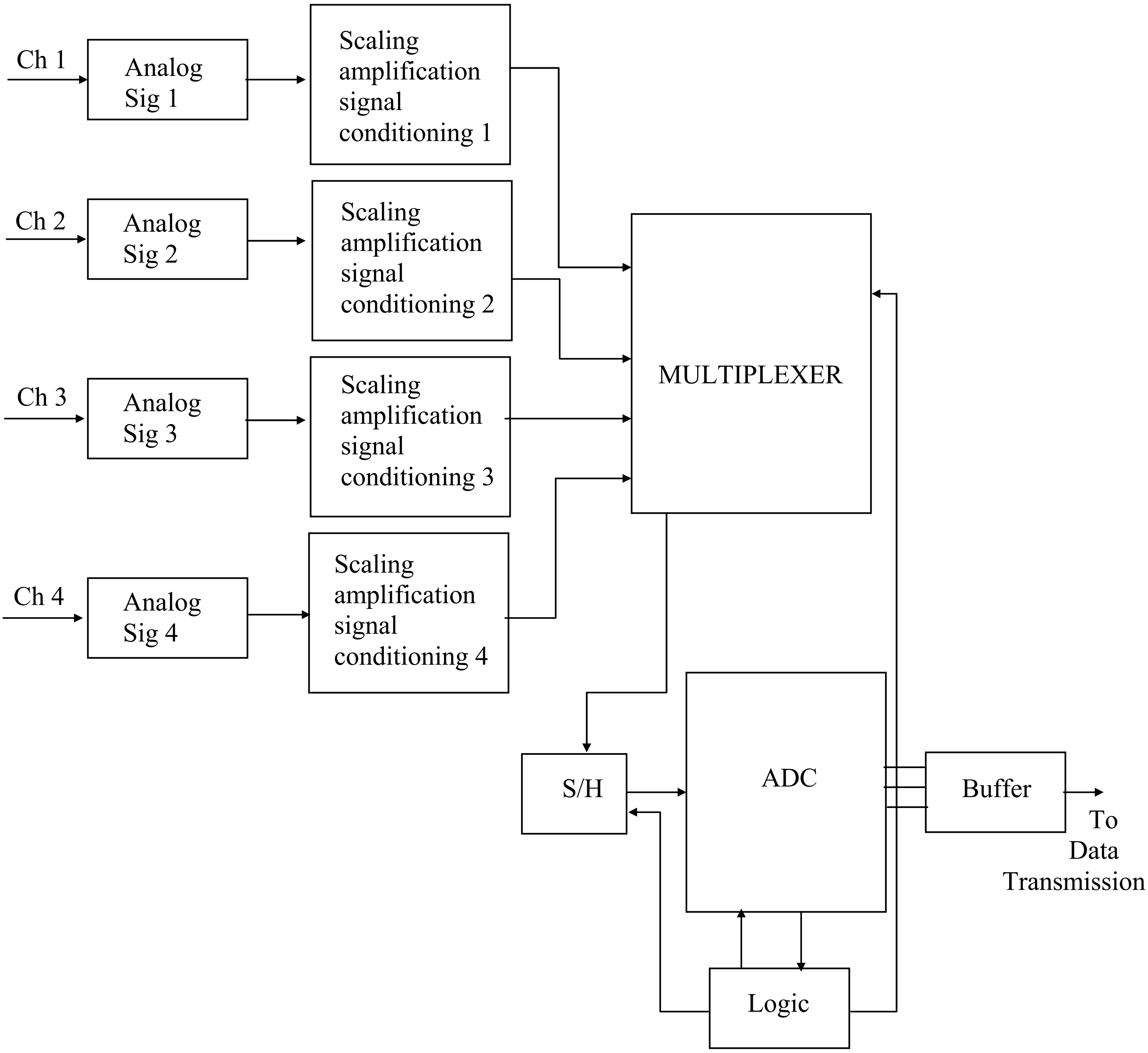
(5) Auxiliary equipment: This contains devices for system programming functions and digital processing. Some of typical functions done by auxiliary equipment are linearization and limit comparison of signals.

(6) Digital recorders: Records information in digital form.

Eg: Floppy disks, magnetic tapes

(7) Digital printers: A digital printer can be specified to interface with an electronic instrumentation system in codes to perform this work.

Multichannel DAQ system:



There will be many systems in DAQ. They can be time shared by two or more input devices.

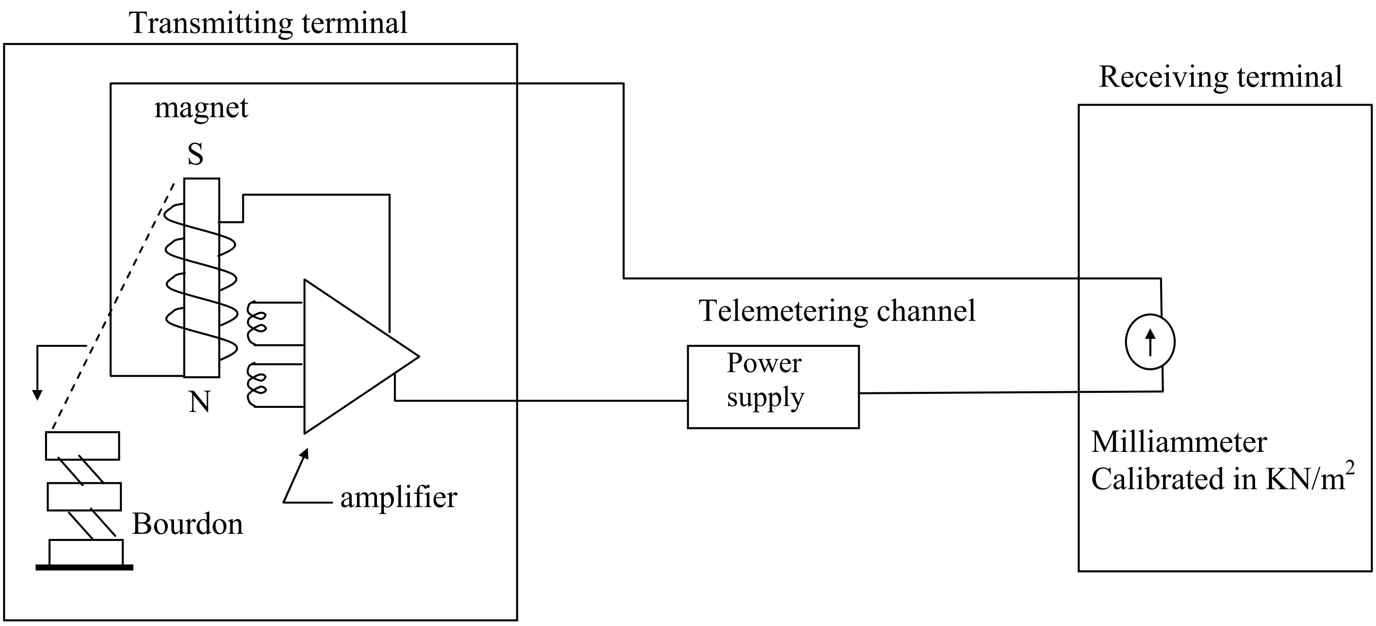
The above figure shows a multichannel DAQ system. It has a signal ADC preceeded by multiplexer.

As shown in figure, there are 4 channels analog in nature. There can be number of input's. Each signal is given to individual amplifiers. The output of the amplifiers is given to signal condition circuits. From the output of signal conditioning circuits the signals go to the multiplexer. The multiplexer output is converted into digital signals by A/D converter sequentially.

The multiplexer stores the data say of the first channel in the sample hold circuit. It then seeks the second channel. During this interval the data of the first channel will be converted into digital form. This permits utilization of time more efficiently.

When once conversion is complete the status line from the converter causes the sample/hold circuit to return to the sample mode. It then accepts the signal of next channel. After acquisition of data either immediately or on a command the S/H circuit will be switched to hold mode. Now conversion begins and MUX selects the next channel.

(ii) Force Balance Current Telemetry System:

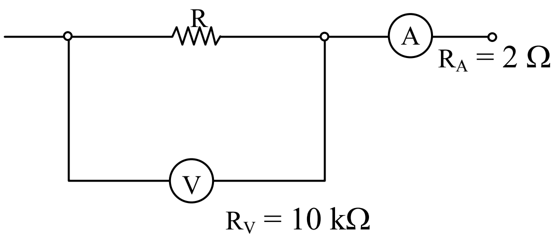


A Force Balance System, in this system a part of the current output is feedback to oppose the motion of the input variable. The system is operated by the bourdon tube which rotates the feedback coil which in turn changes the flux linkages between the primary and secondary coils. The change in flux linkages varies the amplitude of amplifier. The output signal is connected to the feedback force coil which produces a force opposing the bourdon tube input.

A force balance system increases the accuracy as smaller motions are required which result in better linearity.

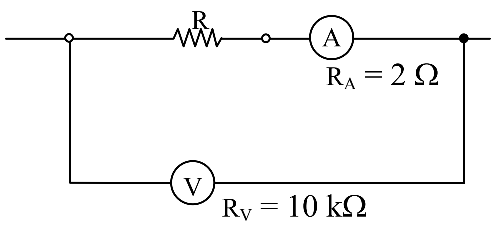
SECTION-B

05. (a) (i) Find the value of resistance R in the figure below if the voltmeter reads 12 V and ammeter reads 0.100 A:



(6 M)

(ii) Repeat part (a)(i) for the circuit arrangement given in the figure below



(6 M)

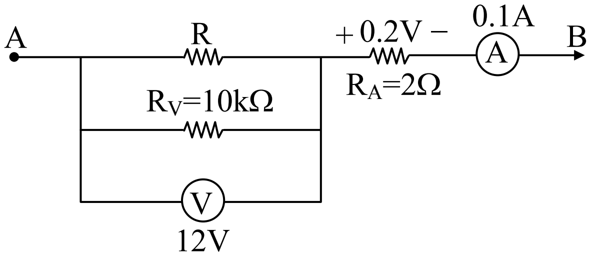
Sol:

(i) Given data,

Voltmeter reading = 12V

ammeter reading = 0.100A

The given circuit can be redraw as



$\therefore$ Total voltage drop across the terminal AB = 12 + 0.2 = 12.2V

Total resistance across the terminal AB = (R//10k) + 2

$\therefore$ Current flowing through terminal $AB = \dfrac{\text{Voltage drop}}{\text{Total Resistance}}$

$$\Rightarrow 0.1 = \frac{12.2}{2+(R//10k)}$$

$$\Rightarrow 2 + \frac{10^4 R}{10^4 + R} = 122$$

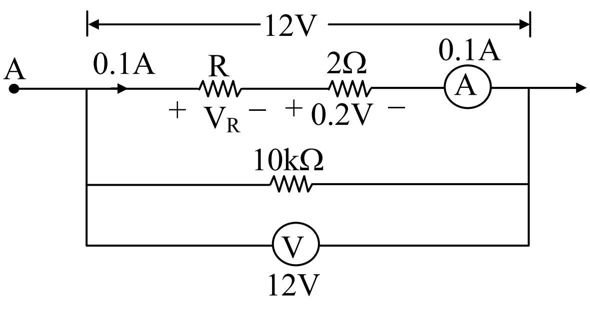
$$\Rightarrow \frac{10^4 R}{10^4 + R} = 120$$

$$\Rightarrow \frac{10^4 + R}{R} = \frac{10^4}{120}$$

$$\Rightarrow \frac{10^4}{R} + 1 = \frac{10^4}{120}$$

$$\Rightarrow \frac{10^4}{R} = \frac{10^4}{120} - 1 \Rightarrow R = 121.45\Omega$$

(ii) Redraw the given circuit



$\therefore\ V_R = 12 - 0.2$

$\Rightarrow V_R = 11.8V$

$\therefore\ R = \dfrac{V_R}{0.1A}$

$\Rightarrow R = \dfrac{11.8}{0.1}$

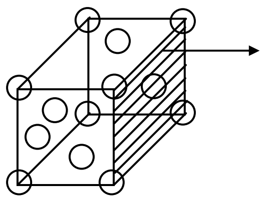
$\Rightarrow R = 118\Omega$

05. (b) Copper has an atomic radius of 0.1278 nm. Calculate the atomic density (number of atoms per unit) in (1 0 0) plane of copper (FCC). (12 M)

Sol: Cu is FCC structure material .

$4R = \sqrt{2}\,a$

$$a = \frac{4R}{\sqrt{2}} = \frac{4\times 0.1278}{\sqrt{2}}\text{nm} = 0.36147\,\text{nm}$$



Number of atoms in (100) = 2

$$\text{Planar density} = \frac{2}{a^2} = \frac{2}{(0.3614)^2} = \frac{2}{0.13066} = 15.306\,\text{atoms/nm}^2$$

05. (c) How can you convert a galvanometer into an ammeter and a voltmeter? A PMMC galvanometer of 6 Ω resistance reads up to 60 mA. Determine the value of the resistance (i) when connected in parallel to enable the instrument to read up to 1.20 A and (ii) when connected in series to enable it to read 12 V. (12 M)

Sol: A Galvanometer can be converted into an ammeter by connecting a small value resistance in parallel.

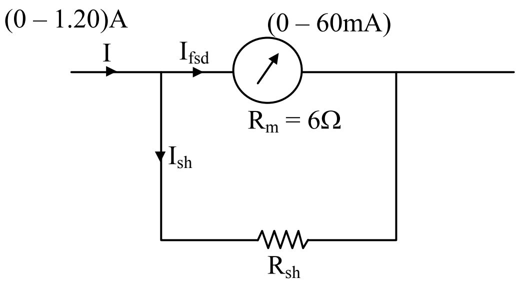
A Galvanometer can be converted into a voltmeter by connecting a high value resistance in series.

Galvanometer resistance (R_m) = 6Ω

Current (I_{fsd}) = 60 mA (0 - 60mA)

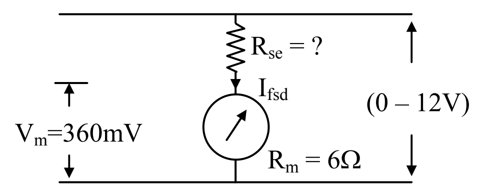
Galvanometer Voltage (V_m) = I_{fsd} R_m = 60 mA × 6 = 360 mV (0 - 360 mV)

(i) As a Ammeter Conversion



$$R_{sh} = \frac{R_m}{(m-1)} = \frac{6\Omega}{\left(\frac{1.2\,A}{60mA} - 1\right)} = \frac{6\Omega}{19} = 0.316\Omega$$

(ii) As a Voltmeter Conversion



$$R_{se} = R_m(m-1) \Rightarrow R_{se} = 6\Omega\left(\frac{12\,V}{360mV} - 1\right) = 194\Omega$$

05. (d) In the circuit below, $v_C(0^-) = v_0$, while the inductor is no charged. The switch that is initially open is closed at t = 0. Also L = C in terms of numerical value. Find R (positive value) so that the circuit is critically damped (12 M)

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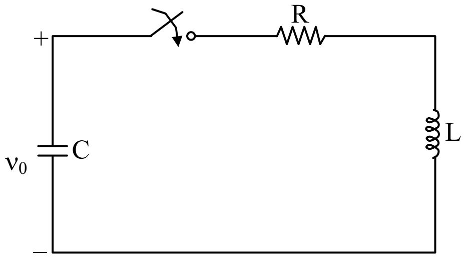
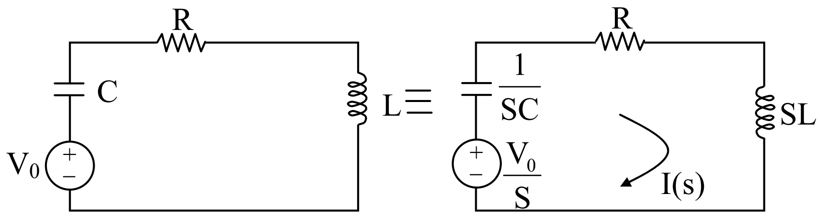


Sol: Given data,

$$V_0(0^-) = V_0$$

$$L = C$$

The given circuit for t > 0 is shown below



$$\therefore\ I(s) = \frac{V_0/S}{R + SL + \frac{1}{SC}}$$

$$= \frac{V_0}{SR + S^2L + \frac{1}{C}}$$

$$= \frac{V_0}{LS^2 + SR + \frac{1}{C}}$$

$$= \frac{V_0}{L\left(S^2 + S\frac{R}{L} + \frac{1}{LC}\right)}$$

$$\Rightarrow I(S) = \frac{V_0/L}{S^2 + \frac{R}{L}S + \frac{1}{LC}} \quad \ldots\ldots(1)$$

$\therefore$ The characteristics equation for equation (1) is $S^2 + \frac{R}{L}S + \frac{1}{LC} = 0$

Now if we compare equation (1) with standard equation $S^2 + 2\xi\omega_n S + \omega_n^2 = 0$

$\omega_n^2 = \frac{1}{LC}$ and $2\xi\omega_n = \frac{R}{L} \Rightarrow \xi = \frac{R}{L(2\omega_n)}$

$\Rightarrow \omega_n = \frac{1}{\sqrt{LC}}$

$\therefore \xi = \frac{R}{L} \times \frac{\sqrt{LC}}{2}$

$\Rightarrow \xi = \frac{R}{2}\sqrt{\frac{C}{L}}$ ……..(2)

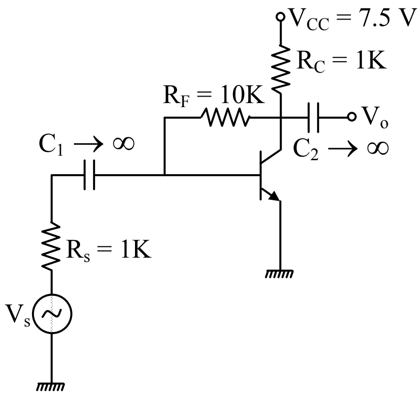
$\therefore$ for critically damped, $\xi = 1$

$\therefore$ From equation (2)

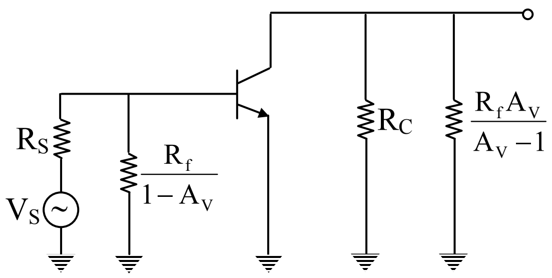
$\frac{R}{2}\sqrt{\frac{C}{L}} = 1$

$\Rightarrow R = 2\sqrt{\frac{L}{C}}$ $\Rightarrow R = 2\Omega$ ($\because$ L = C)

05. (e) In the feedback circuit shown in the figure below, h_{fe} is very large. Identify the type of feedback, and (i) find the feedback factor β and overall transresistance with feedback and (ii) overall voltage gain, $A_{vs} = \frac{V_o}{V_s}$: **(12 M)**



Sol: The given circuit can be redrawn as shown below using miller's theorem: (AC model)



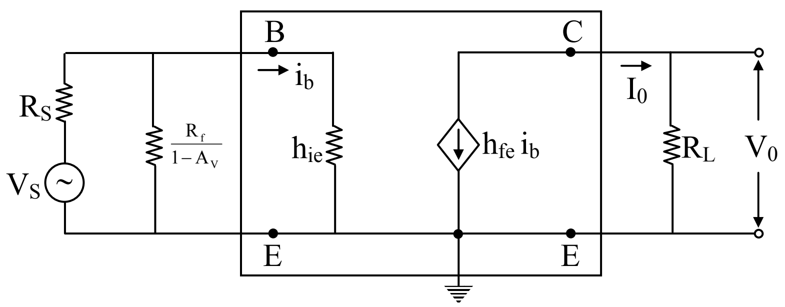
NOTE: In the given circuit output is voltage and feedback signal is current.

Hence it is voltage-shunt (or) shunt-shunt type of feedback

(i) Step (1) $R_L = R_C // R_f \frac{A_V}{A_V - 1} = R_C // R_f$ ________(1) [∵ h_{fe} is large, A_V is large]

$\Rightarrow R_L = 1k // 10k = 0.9k\Omega$ ______(2)

Step (2): small signal model



Transresistance gain without feedback,

$$R_M = \frac{V_0}{i_b} = -\frac{h_{fe} i_b R_L}{i_b} = -h_{fe} R_L \text{\_\_\_\_\_\_\_\_(3)}$$

Feed back factor, $\beta = \dfrac{I_f}{V_0}$ ________(4)

KVL for (Base) B to (Collector)C loop of BJT

$V_i - I_f R_f - V_0 = 0$_____(5)

$I_f R_f = V_i - V_0 \approx - V_0$ ______(6) [$\because V_i << V_0$

$$\therefore \frac{I_f}{V_f} = \beta = -\frac{1}{R_f} = -\frac{1}{10k\Omega} \text{\_\_\_\_\_\_(7)}$$

Step (3):

Overall transresistance with feedback, $R_{M_f} = \dfrac{R_M}{1 + R_M \beta}$ ________(8)

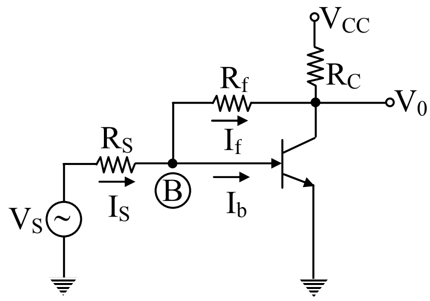
$$= \frac{-h_{fe} R_L}{1 + \left(-h_{fe} R_L \left(-\frac{1}{R_f}\right)\right)} \text{\_\_\_\_\_\_(9)}$$

$$= \frac{-h_{fe} R_L}{h_{fe} \frac{R_L}{R_f}} \text{\_\_\_\_\_\_\_\_(10)} \qquad [\because h_{fe} \text{ is large}]$$

$$= -\frac{0.9k\Omega}{\frac{0.9k\Omega}{10k\Omega}} \text{\_\_\_\_\_\_(11)}$$

$$\therefore R_{M_f} = \frac{V_0}{I_S} = -10k\Omega \text{\_\_\_\_\_(12)}$$

(ii) Consider the given circuit



Method (1):

Step (1) KCL at node (B):

$I_S = I_f + i_b \approx I_f$ ______(1) [$\because$ h_{fe} is large $i_b \approx 0$]

$$\Rightarrow \frac{V_S - V_b}{R_S} = \frac{V_b - V_0}{R_f} \text{ ________(2)}$$

step (2): In a BJT, the AC voltage at base and Emitter is always equal i.e $V_b = V_e$ ________(3)

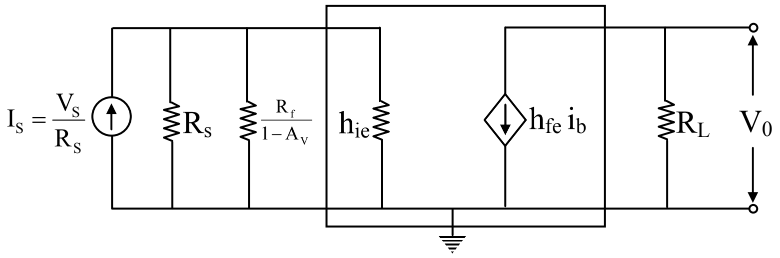
in the given circuit, $V_b = V_e = 0$ ________(4) [$\because$ Emitter is grounded]

Step (3): Equation (4) in equation (2)

$$\frac{V_S - 0}{R_S} = \frac{0 - V_0}{R_f} \text{ _________(5)}$$

$$\frac{V_0}{V_S} = A_{V_S} = -\frac{R_f}{R_S} = \frac{-10k\Omega}{1k\Omega} = -10 \text{ ________(6)}$$

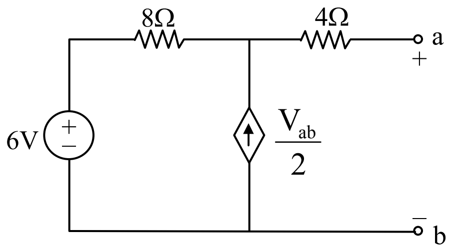
Method: (2)



$$A_{V_S} = \frac{V_0}{V_S} = \left(\frac{V_0}{I_S R_S}\right) = \frac{R_{M_f}}{R_S} = \frac{-10k\Omega}{1k\Omega} = -10 \text{ ______(1)} \left[\because R_{M_f} = \frac{V_0}{I_S} = -10k\right]$$

06. (a) (i) A voltage source delivers 4 A when the load connected is 5 Ω and 2 A when the load is 20 Ω. What is the maximum power it can deliver? Also calculate power transfer efficiency with R_L = 5 Ω and power transfer efficiency when it delivers 50 W. (10 M)

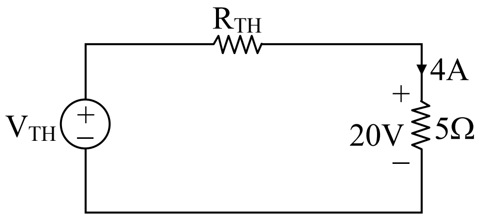
(ii) Find the thevenin equivalent of the circuit at a-b :



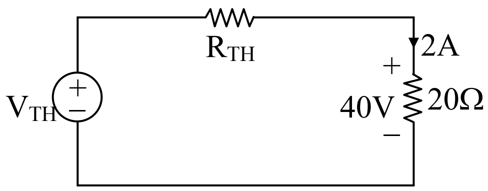
(10 M)

Sol:

(i)



$V_{TH} = 4R_{TH} + 20$ -----(1)



$V_{TH} = 2R_{TH} + 40$ ----(2)

equation (2) – equation (1)

$$-2R_{TH} + 20 = 0 \Rightarrow 2R_{TH} = 20$$

$$R_{TH} = 10\Omega$$

Now, put the value of $R_{Th} = 10\Omega$ in equation (1)

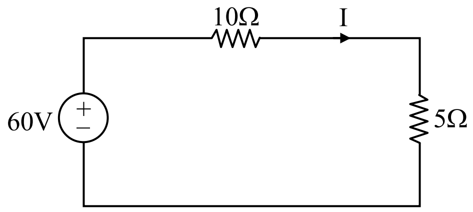
$\therefore\ V_{Th} = 4(10) + 20$

$\Rightarrow V_{Th} = 60$ Volts

The maximum power that can be deliver, $P_{max} = \dfrac{V_{Th}^2}{4R_{Th}}$

$$\Rightarrow P_{max} = \frac{(60)^2}{4\times10} = 90\text{Watts}$$

Power transfer efficiency with $R_L = 5\Omega$:-



$$I = \frac{60}{15} = 4A$$

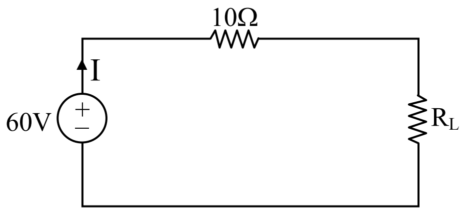
$P_{in} = (60)(4) = 240$

$P_{out} = (4)^2(5) = 80$

Power transfer efficiency $(\eta) = \frac{P_{out}}{P_{in}} \times 100 = \frac{80}{240} \times 100$

$\eta = 33.33\%$

Power transfer efficiency for 50W delivery:-



$P_{deli} = 50W$ ($P_{in} = 50W$)

$\Rightarrow 50 = 60\ I$

$$\Rightarrow I = \frac{5}{6} A$$

By KVL, $60 - 10I - R_L I = 0$

$$\Rightarrow 60 = \frac{50}{6} + \frac{5R_L}{6}$$

$\Rightarrow 360 = 50 + 5R_L$

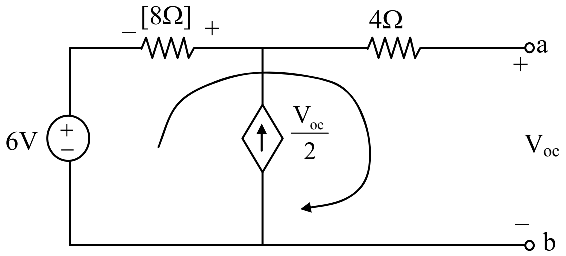
$\Rightarrow R_L = 62\Omega$

$$\therefore P_{out} = I^2 R_L = \left(\frac{5}{6}\right)^2 \times 62$$

$\Rightarrow P_{out} = 43.05$ Watts

$\therefore$ Power transfer efficiency $(\eta) = \dfrac{P_{out}}{P_{in}} \times 100 = \dfrac{43.05}{50} \times 100 = 86.11\%$

(ii) Calculation of V_{OC}:-

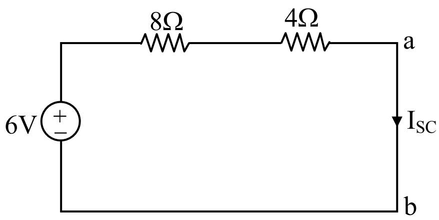


KVL, $-6 - \dfrac{V_{oc}}{2}(8) + V_{oc} = 0$

$V_{oc} - 4V_{oc} = 6$

$-V_{oc} = 6 \Rightarrow V_{oc} = -2$ volts

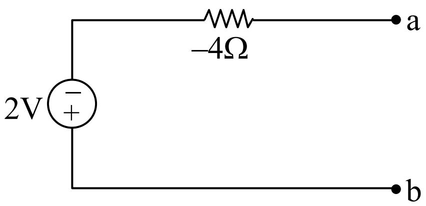
Calculation of I_{SC}:-



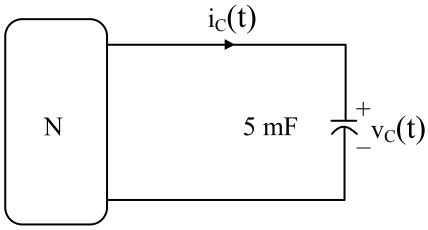
$I_{SC} = \dfrac{6}{12} = \dfrac{1}{2}$ A

$R_{TH} = \dfrac{V_{oc}}{I_{SC}} = \dfrac{-2}{1/2} = -4\Omega$

Thevenin equivalent circuit:-

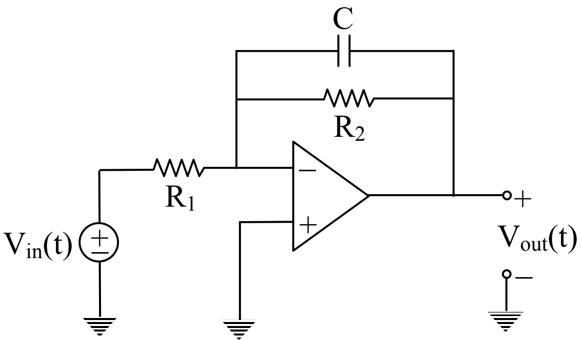


06 (b) (i) For the circuit shown in the figure below, it is known that the voltage across the capacitor is $v_C(t) = 20\sin\left(2t + \frac{\pi}{6}\right)$V for $t \geq 0$. Compute and plot the instantaneous power absorbed by the capacitor and energy stored by the capacitor over [0, t] :



(8 M)

(ii) The op-amp in the figure assumed to be ideal R_1 = 20 kΩ, R_2 = 40 kΩ and C = 10 μF:



(1) Use nodal to construct a first-order differential equation describing the input-output relationship of the voltage.

(2) Laplace transform your equation of (1) and solve $V_{out}(s)$ in terms of $V_{in}(s)$ and $V_C(0^-)$.

(3) If $V_{in}(t) = 2e^{-2t}u(t)$ V and $V_C(0) = 0$, find $V_{out}(t)$.

(12 M)

Sol:

(i) $v_c(t) = 20.\sin\left(2t + \frac{\pi}{6}\right)$ for $t \geq 0$

c = 5 mF

$$i_c(t) = c.\frac{dv_c(t)}{dt}$$

$$= 5\times10^{-3}\times\frac{d}{dt}\left(20\sin\left(2t+\frac{\pi}{6}\right)\right)$$

$$= 10^{-1}\times\cos\left(2t+\frac{\pi}{6}\right)\ (2)$$

$$i_c(t) = 0.2\ \cos\left(2t+\frac{\pi}{6}\right)$$

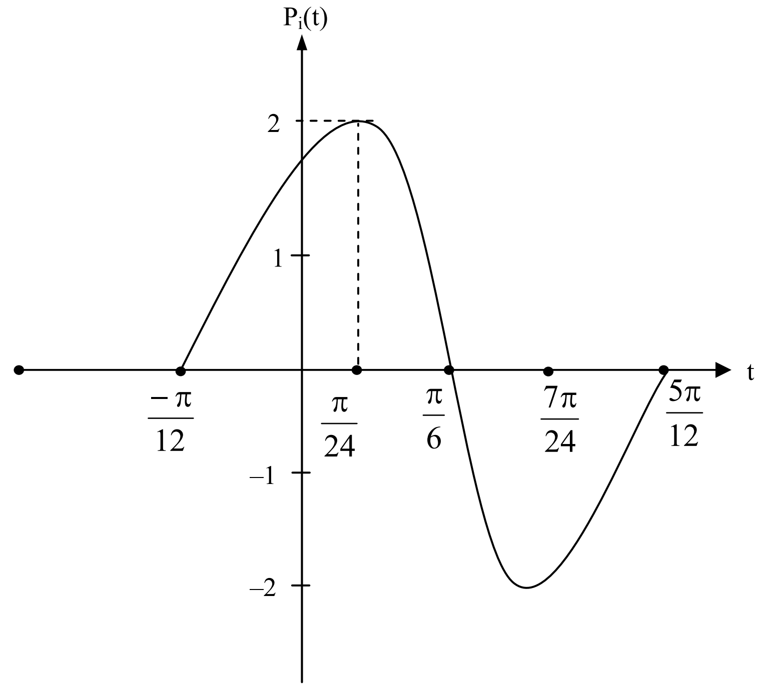
Instantaneous power $P_i(t) = v_c(t).\ i_c(t) = 20\ \sin\left(2t+\frac{\pi}{6}\right)\times 0.2\cos\left(2t+\frac{\pi}{6}\right)$

$$= 4\sin\left(2t+\frac{\pi}{6}\right).\cos\left(2t+\frac{\pi}{6}\right)$$

$$= 2\left(2\sin\left(2t+\frac{\pi}{6}\right).\cos\left(2t+\frac{\pi}{6}\right)\right)$$

$$= 2\left(\sin\left(4t+\frac{\pi}{3}\right)\right)$$

$$P_i(t) = 2\ \sin\ \left(4t+\frac{\pi}{3}\right)$$



$$E = \frac{1}{2}CV^2(t)$$

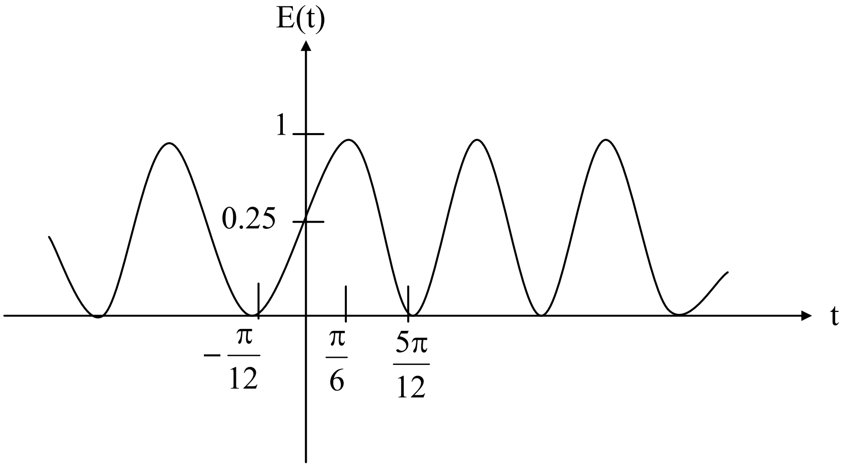
$$= \frac{1}{2} \times 5 \times 10^{-3} \quad \left\{20\sin\left(2t + \frac{\pi}{6}\right)\right\}^2$$

$$= \frac{5 \times 10^{-3}}{2} \times 20 \times 20 \times \sin^2\left(2t + \frac{\pi}{6}\right)$$

$$= 1\sin^2\left(2t + \frac{\pi}{6}\right)$$

$$= \frac{1 - \cos\left(4t + \frac{\pi}{3}\right)}{2}$$

$$= 0.5 - 0.5\cos\left(4t + \frac{\pi}{3}\right)$$



(ii) (1) Step (1): KCL at (V_2)

$$I_i + I_{f_1} + I_{f_2} = 0 \text{ \_\_\_\_\_\_\_\_\_(1)}$$

$$\Rightarrow \frac{V_i(t)}{R_1} + \frac{V_0(t)}{R_2} + \frac{CdV_0(t)}{dt} = 0 \text{ \_\_\_\_\_\_\_(2)}[\because V_1 = 0 \Rightarrow V_2 = 0]$$

$$\Rightarrow \frac{CdV_0(t)}{dt} + \frac{V_0(t)}{R_2} = -\frac{V_i(t)}{R_1}$$

$$\Rightarrow \frac{d}{dt}V_0(t) + \frac{1}{CR_2}V_0(t) = -\frac{1}{R_1C}V_i(t)$$

This is first order linear differential equation describing input-output relationship of the voltage.

NOTE:

The solution for the above first order linear differential equation

$$V_0(t) = -\frac{e^{\frac{-t}{CR_2}}}{CR_1}\int \frac{t}{e^{CR_2}} V_i(t)dt + Ke^{-t/CR_2}$$

(2) From the circuit given

$$\frac{V_i(s)}{R_1} + \frac{V_0(s)}{R_2} + CSV_0(s) = 0$$

$$\Rightarrow V_0(s)\left[sC + \frac{1}{R_2}\right] = -\frac{V_i(s)}{R_1}$$

$$\Rightarrow V_0(s)\left[\frac{1 + sCR_2}{R_2}\right] = -\frac{V_i(s)}{R_1}$$

$$\therefore V_0(s) = -\frac{R_2}{R_1}\frac{V_i(s)}{1 + sCR_2}$$

(3) Consider the equation for output voltage obtained in (1) [equation (5)]

$$V_0(t) = -\frac{e^{-\frac{t}{R_2C}}}{R_1C}\int e^{\frac{t}{R_2C}} V_i(t)dt + Ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_\_\_(9)}$$

$$= -\frac{e^{-\frac{t}{R_2C}}}{R_1C}\int e^{\frac{t}{R_2C}}\left[2e^{-2t}\right]dt + Ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_(10)}$$

$$= -\frac{2e^{-\frac{t}{R_2C}}}{R_1C}\int e^{\left(\frac{t}{R_2C}-2\right)t}dt + Ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_\_(11)}$$

$$= -\frac{2e^{-\frac{t}{R_2C}}}{R_1C}\left[\frac{e^{\left(\frac{1}{R_2C}-2\right)t}}{\left(\frac{1}{R_2C}-2\right)}\right] + Ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_\_(12)}$$

$$= -\frac{2e^{-\frac{t}{R_2C}}}{R_1C}\frac{e^{\left(\frac{t}{R_2C}-2\right)t}}{\frac{1-2R_2C}{R_2C}} + Ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_\_(13)}$$

$$\therefore\ V_0(t) = -\frac{2R_2}{R_1}\left[\frac{e^{-2t}}{1-2R_2C}\right] + Ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_\_(14)}$$

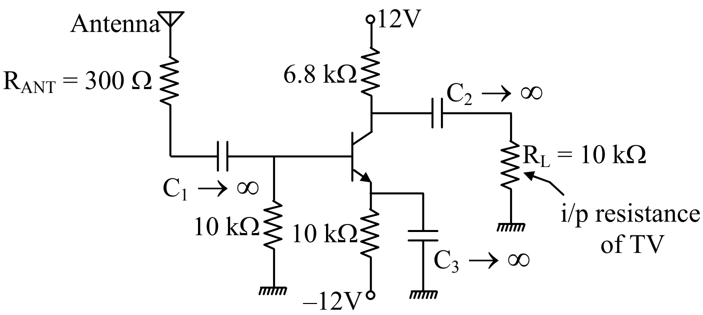
$$= -2\left(\frac{40k}{20k}\right)\left[\frac{e^{-2t}}{1-2\times 40k\times 10\mu F}\right] + Ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_\_(15)}$$

$$= -\frac{4e^{-2t}}{1-0.8} + ke^{-t/R_2C} \text{ \_\_\_\_\_\_\_\_(16)}$$

$\therefore\ V_0(t) = -20e^{-2t} + ke^{-t/R_2C}$ _______(17)

$\Rightarrow V_0(t) = -10\ V_i(t)$ _______(18) [$\because\ V_i(t) = 2e^{-2t}$ and $V_C(0) = 0$]

06. (c) A certain person with poor television reception and no access to cable TV intends to use the amplifier in the figure shown below as booster amplifier between his antenna and his television:



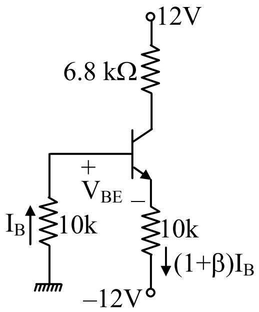
The transistor has high frequency capacitances with C_{bc} = 4 pF, C_{be} = 2 pF, C_{ce} = 1pF and $\beta \cong 100$. Calculate low-pass dominant pole frequency and determine whether this amplifier performs adequately. (Assume V_T = 26 mV at room temperature) **(20 M)**

Sol: Case (i):

DC model

1. All Ac sources = 0

2. $X_C = \infty$ (All capacitors open)



KVL for input loop

$0 - I_B\, 10k - V_{BE} - (1+\beta)\, I_B\, 10k + 12V = 0$ ——(1)

$\Rightarrow\ I_B = \dfrac{12V - 0.7V}{10k + 101 \times 10k} = 0.011mA$ ________(2)

$\Rightarrow I_E = (1 + \beta)\, I_B = 1.11mA$ ______(3)

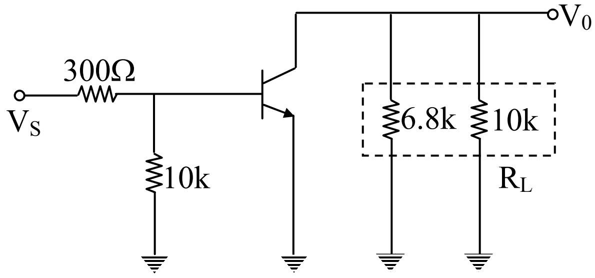
$\Rightarrow\ g_m = \dfrac{I_E}{V_T} = \dfrac{1.11mA}{26mV} = 0.0427\,\mho$ ______(4)

$\therefore\ h_{ie} = r_\pi = \dfrac{\beta}{g_m} = 2.34k\Omega$ _______(5)

Case (ii): AC model

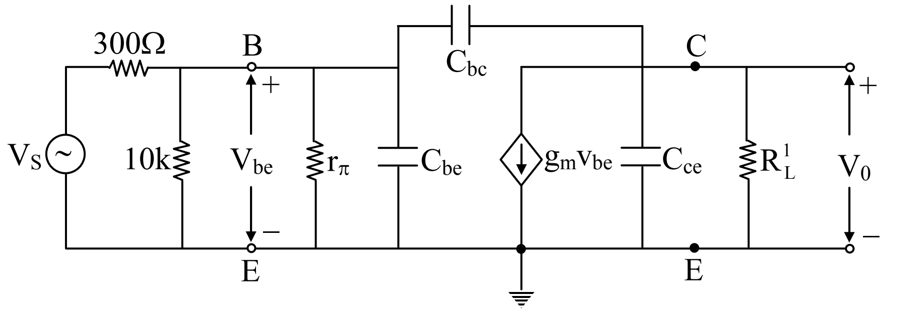
1. All DC sources = 0

2. $X_C = 0$

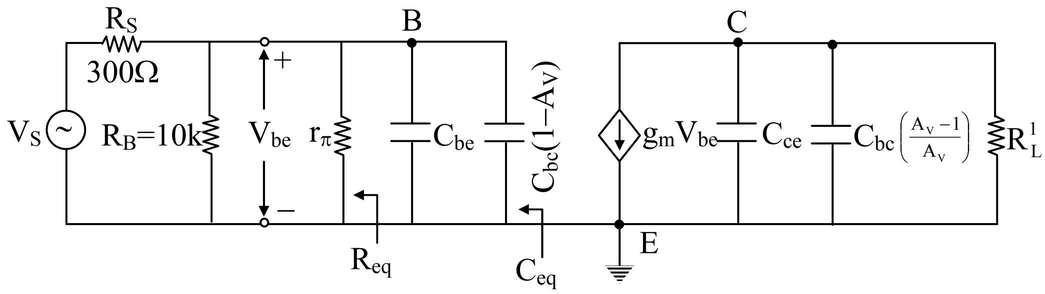


Step (1): $R_L^1 = 6.8k // 10k = 4.0476k$

Small-signal model at high frequencies:



Modified Small-Signal model using Millers theorem:



Step (2): $C_{eq} = C_{be} + C_{bc}\left[1 + g_m R_L^1\right]$ ______(2)

$= 2pF + 4pF\ [1+0.0427℧ \times 4.0476 \times 10^3\Omega]$ ______(3)

$= 697.33pF$ _______(4)

Step (3): $R_{eq} = 300\Omega\ //\ 10k\ //\ r_\pi$ _______(5)

$= 0.3k\Omega\ //\ 10k\ //\ 2.34k\Omega$ _______(6)

$= 259\Omega$

Step (4): Low pass dominant pole frequency

$$f_H = \frac{1}{2\pi R_{eq} C_{eq}} \text{ \_\_\_\_\_(8)}$$

$$= \frac{1}{2\pi \times 259\Omega \times 697.33 \times 10^{-12} F} \text{ \_\_\_\_\_\_\_(9)}$$

$f_H = 0.88166MHz$_______(10)

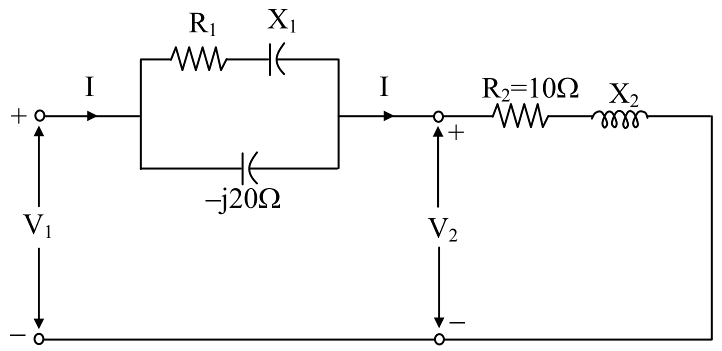
Step (5): $\left|A_{V_M}\right| = \frac{R_B}{R_B + R_S}\left[\frac{r_\pi}{r_\pi + R_B // R_S}\right]\left(g_m R_L^1\right)$_______(11)

$$= \left(\frac{10k}{10k + 0.3k}\right)\left(\frac{2.34k}{2.34k + 10k // 0.3k}\right)(0.0427℧ \times 4.0476 \times 10^3\Omega)\_\_\_\_\_\_(12)$$

$$= 149.154 \_\_\_\_\_\_\_(13)$$

Conclusion: The amplifier used between antenna and TV can amplifier the signals upto 0.88166 MHz by 149.154 times approximately. As the frequency of signals received through cable TV is in the range of 41MHz to 250MHz, the amplifier used will not perform adequately.

07. (a) In the circuit shown in the figure below, $|V_1|$ = 200 V, $V_2 = 200\ \angle 0^o$ V and $|I|$ = 12 A. The total power absorbed by the circuit is 1.8 kW. Find R_1, X_1 and X_2 :



(20 M)

Sol: $V_1 = 200$ V

$V_2 = 200$ V

Power absorbed by 10 Ω resistor = $R \times |I|^2 = 10 \times (12)^2 = 1440$ W

$P = V_2 \times I \cos\phi_2$

$1440 = 200 \times 12 \times \cos\phi_2$

$\cos\phi_2 = 0.6 \qquad \Rightarrow \sin\phi_2 = 0.8$

$\phi_2 = 53.13^o$

Angle between I and V_2 is 53.13^o. Since $V_2 = 200\angle 0^o$, $I = 12\angle -5.3.13^o$

We know that $X_2 = Z_2.\sin\phi_2$ -----(1)

$R_2 = Z_2.\cos\phi_2$

$$Z_2 = \frac{R_2}{\cos\phi_2} = \frac{10}{0.6} = 16.66\Omega$$

From (1) $\Rightarrow X_2 = Z_2.\sin\phi_2 = 16.66 \times 0.8$

$X_2 = 13.328\Omega$

$P_1 = V_1 \times I \times \cos\phi_1$ $(\because P_1 = 1.8\text{kW})$

$$\cos\phi_1 = \frac{1800}{200\times 12}$$

$\cos\phi_1 = 0.75$

$\phi_1 = 41.4^o$ $(\sin\phi_1 = \sin 41.4^o)$

That is angle between current I and voltage V_1 is 41.4^o

$V_1 = 200\angle{-11.73^o}$ V $(\because -53.13^o + 41.4^o = 11.73^o)$

$V_1 - V_2 = 200\angle{-11.73^o} - 200\angle 0^o$

$V_1 - V_2 = 40.87\angle{-95.86^o}$

Current through the capacitor $I_c = \dfrac{V_1 - V_2}{j.x_c} = \dfrac{40.87\angle -95.86^o}{20\angle -90^o}$

$I_c = 2.0436\angle{-5.86^o}$

Now, current through R_1 & $X_1$are $I_1 = I - I_c = 12\angle{-53.13^o} - 2.04\angle{-5.86^o}$

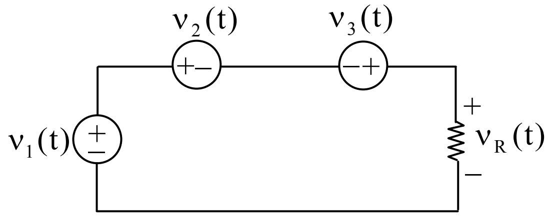
$I_1 = 10.718\angle 61.18^o$

$$Z_1 = \frac{V_1 - V_2}{I_1} = \frac{40.87\angle -95.86^o}{10.718\angle -61.18^o}$$

$Z_1 = 3.13 - j\,2.119 \Rightarrow R_1 - j1$

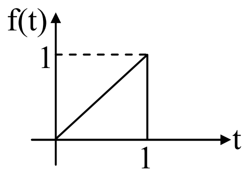
$R_1 = 3.13\Omega$ $X_1 = 2.169\Omega$

07. (b) (i) Determine the voltage across the resistor in the circuit of the figure shown below using phasor concept for $v_1(t)$ = 20 cos(ωt + 53.13°)V, $v_2(t)$ = 19.68 sin(ωt + 152.8°)V and $v_3(t)$ = 4.215cos (ω t + 71.61°)V.:



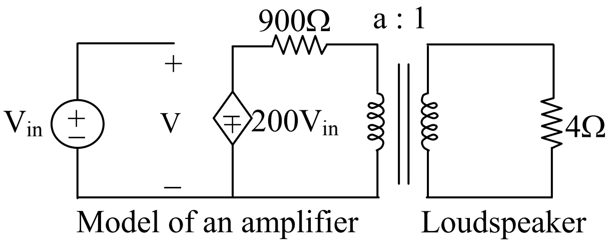
(6 M)

(ii) Find the Laplace transform of the sawtooth sketched in the figure below:



(4 M)

(iii) The figure below shown a simplified model of an audio amplifier containing an ideal transformer. The input voltage is at 2kHz with a magnitude 1V r.m.s. The load is a loudspeaker, represented by 4Ω resistance:



(1) Find the average power delivered to the 4Ω load if it is directly connected to the amplifier (i.e., with the transformer removed)

(2) With the transformer connected and with turns ratio a = 5, find the average power delivered to the load. (10 M)

Sol:

(i) $\overline{V}_1 = 20\angle 90^\circ + 53.13^\circ = 20\angle 143.13^\circ$ V

$\overline{V}_2 = 19.68\angle 152.8^\circ$ V

$\overline{V}_3 = 4.215\angle 90^\circ + 71.61^\circ = 4.215\angle 161.61^\circ$ V

KVL

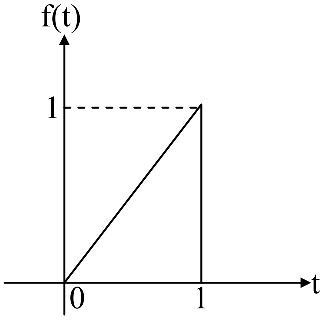
$$-\overline{V}_1 + \overline{V}_2 - \overline{V}_3 + \overline{V}_R = 0$$

$$\overline{V}_R = \overline{V}_1 - \overline{V}_2 + \overline{V}_3$$

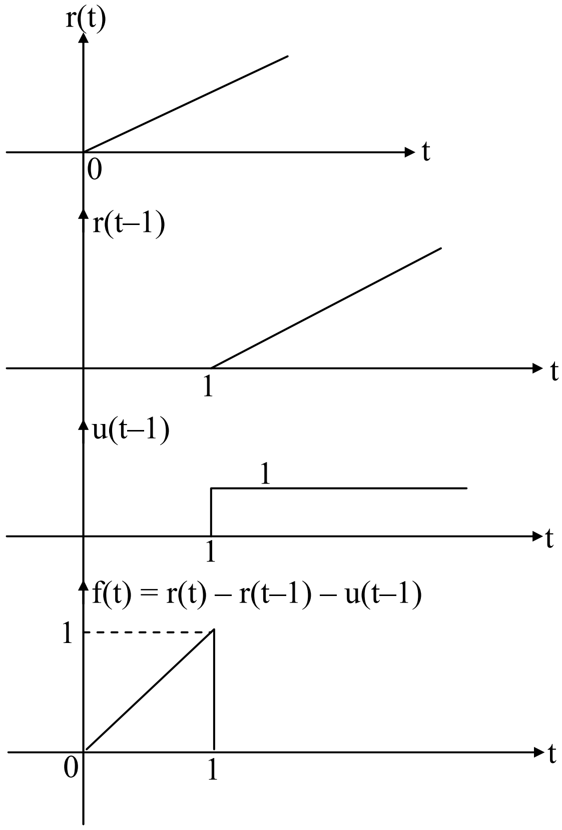
$\overline{V}_R = [20\angle 143.13^\circ] - [19.68\angle 152.8^\circ] + 4.215\angle 161.6$V

$\overline{V}_R = 5\angle 119.93^\circ$

(ii)



f(t) = r(t) – r(t – 1) – u(t – 1)



$r(t) \leftrightarrow 1/s^2$

$r(t-1) \leftrightarrow \dfrac{e^{-s}}{s^2}$ (From time shifting property)

$u(t) \leftrightarrow \dfrac{1}{s}$

$u(t-1) \leftrightarrow \dfrac{e^{-s}}{s}$ (From time shifting property)

$$F(s) = \frac{1}{s^2} - \frac{e^{-s}}{s^2} - \frac{e^{-s}}{s}$$

(OR)

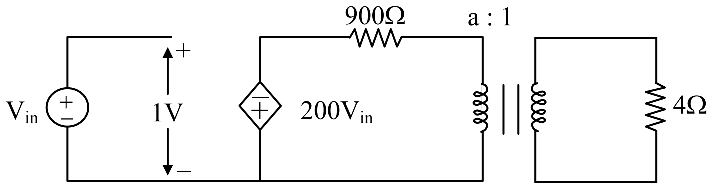
f(t) = t[u(t) – u(t – 1)] = tu(t) – tu(t – 1)

= tu(t) – (t – 1 + 1) u(t – 1)

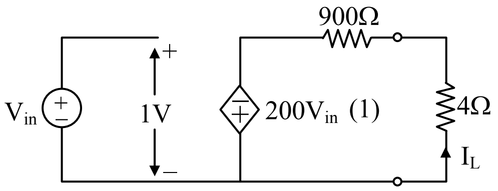
= tu(t) – (t – 1) u(t – 1) – u(t – 1)

$$F(s) = \frac{1}{s^2} - \frac{e^{-s}}{s^2} - \frac{e^{-s}}{s}$$

(iii)



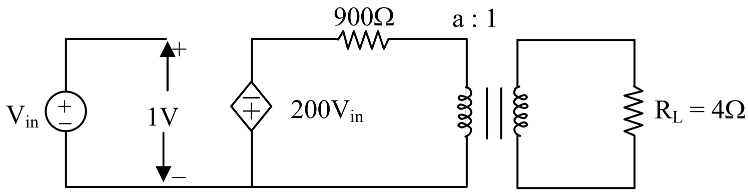
(1) The average power delivered to the 4Ω load if it is directly connected



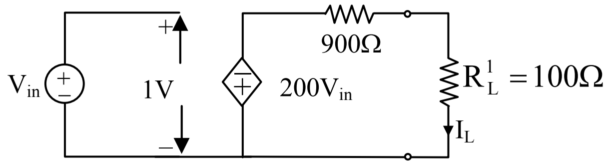
$$I_L = \frac{200(1)}{900+4} = \frac{200}{904} = 0.2214$$

$$P_{avg} = I_L^2(4) = 0.1957 = 195.8\,\text{mW}$$

(2) With the transformer Connected and with turns ratio a = 5



$$K = \frac{1}{a} = \frac{1}{5} \qquad R_L^1 = \frac{R_L}{K^2} = \frac{4}{\left(\frac{1}{5}\right)^2} = 100\Omega$$



$$I_L = \frac{200(1)}{900+100} = \frac{1}{5}\text{A}$$

$$P_{avg} = I_L^2(100) = \left(\frac{1}{5}\right)^2 100 = 4\text{W}$$

07. (c) (i) Implement the logic function shown below with a static CMOS gate

$$\text{Out} = \overline{AB\overline{C} + ABC + \overline{A}BC}.$$

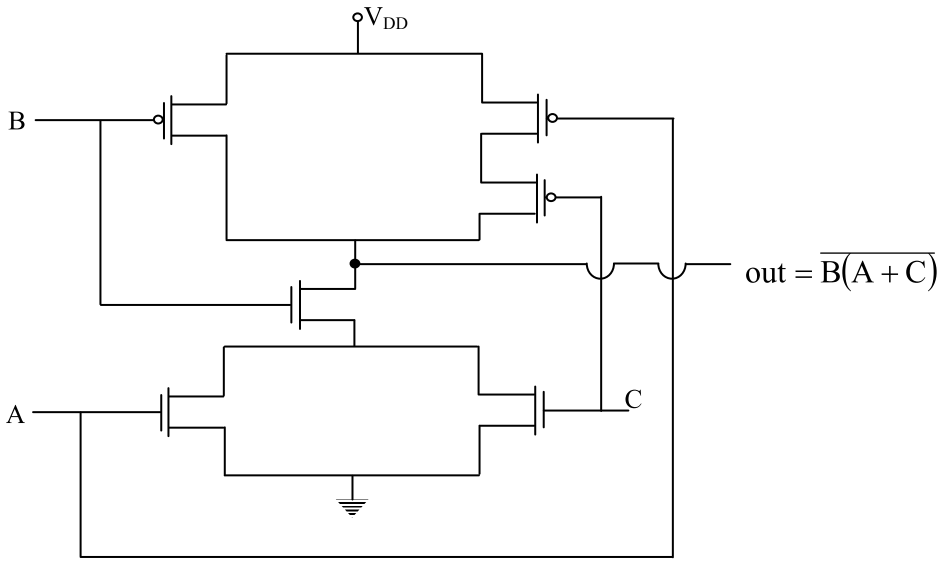
(ii) A certain counting type 12-bit ADC operates with FSR = 0 to 10 V, clock frequency f_{clk} = 1MHz. Determine the dynamic range of converter, conversion time, conversion rate and Nyquist frequency of converter. (20 M)

Sol: (i) $\text{Out} = \overline{AB\overline{C} + ABC + \overline{A}BC}$

$$= \overline{AB\overline{C} + ABC + ABC + \overline{A}BC}$$

$$= \overline{AB + BC}$$

$$\text{Out} = \overline{B(A + C)}$$



(ii) Given 12-bit counter Type ADC $\Rightarrow$ N = 12

FSR = 0 to 10V

$$f_{clock} = 1\text{MHz} \Rightarrow \text{Clock period } T = \frac{1}{f_{clock}} = 1\mu s$$

$$\text{(a) Dynamic range} = 20 \log\left[\frac{\text{max voltage}}{\text{min voltage other than 0}}\right]$$

$$= 20\log\left[\frac{(2^N-1)\times \text{stepsize}}{\text{stepsize}}\right]$$

$$= 20\log 2^N$$

$$= 20\,N\log 2$$

$$= 20(N)\,0.301$$

$$= 6.02N = 6.02(12)$$

$$= 72.247\text{ dB}$$

(b) Max convertion time = $(2^N-1)T$

$$= (2^{12}-1)\,1\mu s = (2047)\,(1\mu s) \approx 2\text{ ms}$$

(c) Sampling period Ts ≥ max convertion time

$$Ts \geq 2\times 10^{-3}\text{ Sec}$$

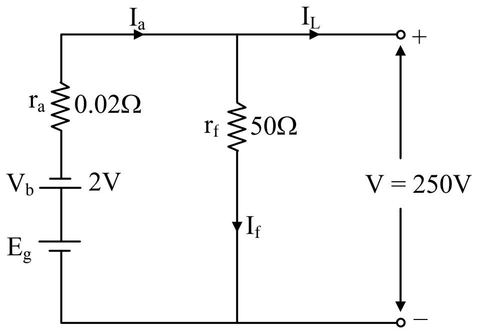
(d) Conversion rate $f_s = \frac{1}{Ts} = \frac{1}{2\times 10^{-3}s} \Rightarrow f_s = 500\text{Hz}$

(e) As $f_s = 500\text{Hz}$

Nyquist frequency of the converter = $\frac{f_s}{2} = 250\text{Hz}$

08. (a) A shunt generator delivers 50kW at 250V when running at 400 r.p.m. The armature and field resistance are 0.02Ω and 50Ω respectively. Calculate the speed of the machine when running as a shunt motor and taking 50kW, 250V. Given, total voltage drop in the brushes is 2V. (20 M)

Sol: Generating mode:-



$P_{out} = VI_L = 50kW$

$= (250)I_L = 50kW$

$I_L = 200A$

$$I_f = \frac{V}{r_f} = \frac{250}{50} = 5A$$

$I_a = I_L + I_f = 200A + 5A = 205A$

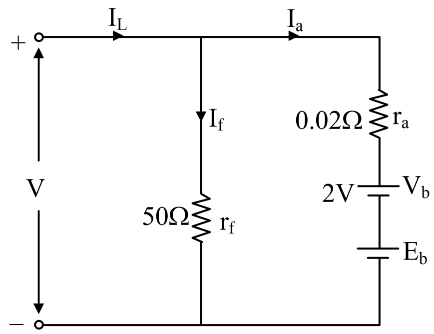
$E_g = V_b + V + I_a r_a$

$= 2 + 250 + (205)(0.02)$

$E_g = 256.1$ V

$N_1 = 400$ rpm $= N_s$

Motoring mode:-



$I_f = 5A$

$P_{in} = 50kW$

$V.I_L = 50kW$

$(250)I_L = 50kW$

$I_L = 200A$

$I_a = I_L - I_f = 195A$

$I_a = 195A$

$E_b = V - I_a r_a - V_b$

$= 250 - (195)(0.02) - 2$

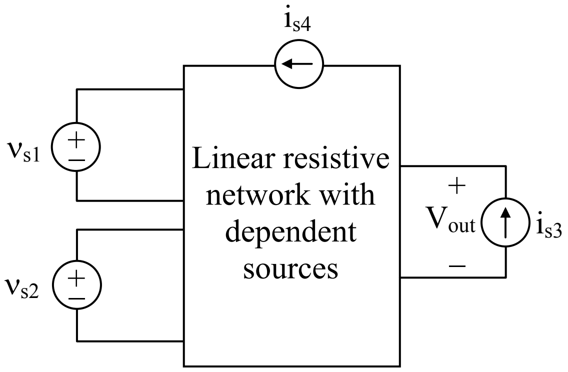
$E_b = 244.1V$

$$\frac{E_g}{E_b} = \frac{N_s}{N_m}$$

$$\frac{256.1}{244.1} = \frac{400}{N_m}$$

$N_m = 381.26$ rpm

08. (b) (i) The linear resistive circuit shown in the figure below has four independent sources. Three of them have fixed value, only one, i_{s3} is adjustable:

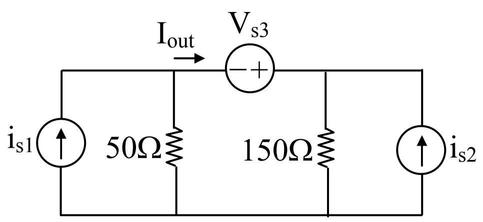


The table shows the four sets of measurements taken in a laboratory:

i_{s3} (mA)	V_{out} (V)
1	6
2	10
5	?
?	0

Complete the last two rows of the table. For the data in row 3, find the power delivered by the current source i_{s3}. **(12 M)**

(ii) Consider the three-source circuit of the figure below:



Compute I_{out} using superposition theorem. **(8 M)**

Sol:

(i) $V_{out} = \underbrace{k_1 v_{s1} + k_2 v_{s2} + k_3 i_{s4}}_{\text{Constant} \rightarrow k_o} + k_4 i_{s3}$

$V_{out} = k_0 + k_4 i_{s3}$

$10 = k_0 + k_4\,(2m)$

$6 = k_0 + k_4\,(1m)$

$- \quad - \quad -$

$4 = k_4\,(1m)$

$\Rightarrow k_4 = 4000$

So, $6 = K_0 + 4 \rightarrow k_0 = 2$

So, $V_{out} = 2 + (4000)i_{s3}$

Now from table

if $\quad i_{s3} = 5mA,\ V_{out} = 2+(4k)(5m)$

$V_{out} = 22$ volts

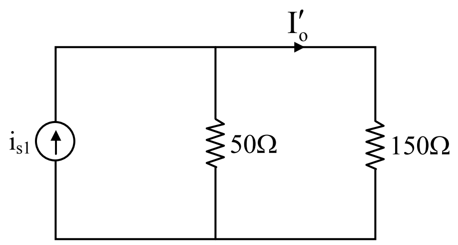
If $\quad V_{out} = 0,\ 0 = 2 + 4k(i_{s3})$

$i_{s3} = -\,0.5mA$

Now for data in Row - 3, $i_{s3} = 5mA$ & $V_{out} = 22$ V

Power delivered is, $(V_{out})(i_{s3}) = 110mW$

(ii) Consider source 'i_{s1}' (V_{s3} = short circuited, i_{s2} = open circuited)

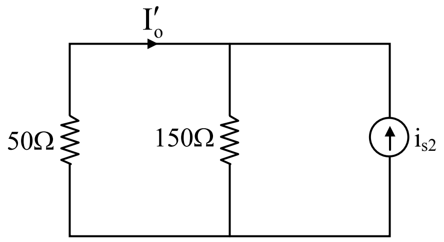


$$\therefore I_o' = \frac{i_{s1} \times 50}{50+150}$$

$$\Rightarrow I_o' = \frac{50 i_{s1}}{200}$$

$$\Rightarrow I_o' = 0.25 i_{s1}$$

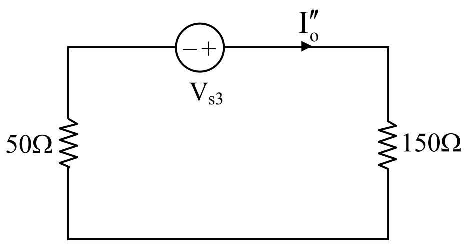
Consider source 'i_{s2}' (V_{s3} = S.C., i_{s1} = 0.C.)



$$\therefore I_o'' = \frac{-i_{s2} \times 150}{50+150}$$

$$\Rightarrow I_o'' = -0.75 i_{s2}$$

Consider source V_{s3} (i_{s1} = 0.C., i_{s2} = 0.C.)



$$\therefore I_o''' = \frac{V_{s3}}{200}$$

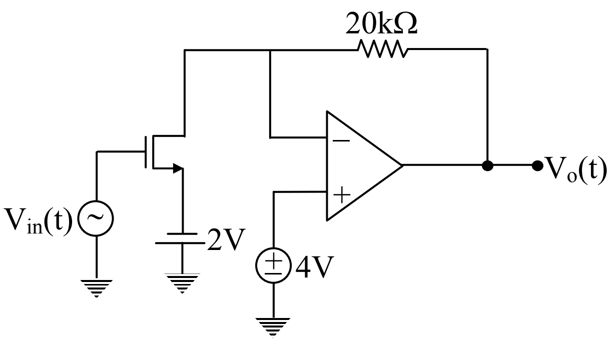
$$\Rightarrow I_o''' = 0.005 V_{s3}$$

$\therefore$ using superposition theorem

$$I_{out} = I_o' + I_o'' + I_o'''$$

$$\Rightarrow I_{out} = 0.25 i_{s1} - 0.75 i_{s2} + 0.005 V_{s3}$$

08. (c) (i) For the circuit shown in the figure below, determine the output voltage if the input $V_{in}(t) = 100 \sin(2\pi \times 10^3 t)$ mV. Assume that the op-amp is an ideal op-amp and MOSFET parameters are $\mu_n C_{ox} = 100\ \mu A/V^2$, $V_{tn} = 1V$, W = 10μm and L = 2.5μm:

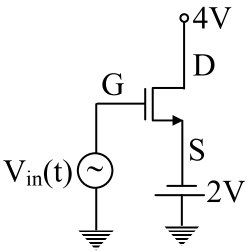


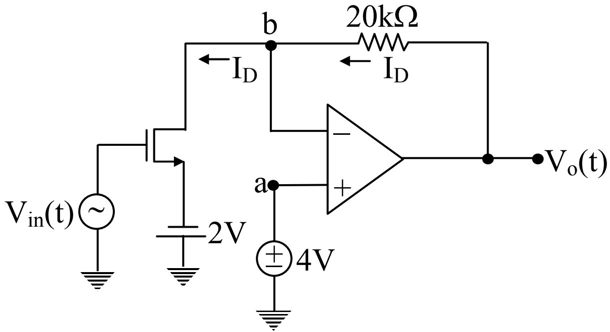
(15 M)

(ii) Draw a block diagram of a 4 to 2 encoder. Label all inputs and outputs. How is the 4 to 2 encoder different from 4 to 1 multiplexer? (5 M)

Sol:

(i)





Since $V_d = 0$

$V_a = V_b = 4V$

$V_D = 4V,\ V_s = -2V,\ V_G = V_{in}(t)$

$V_{DS} = 6V,\ V_{DS(sat)} = V_{GS} - V_{tn} = V_{in}(t) + 2 - 1 = V_{in}(t) + 1$ (range ⇒ 1.1V to 0.9V)

As $V_{DS} > V_{DS(sat)} \rightarrow$ MOSFET in saturation regain then $I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)[V_{GS} - V_{tn}]^2$

$$= \frac{1}{2}\left(100\times10^{-6}\right)\left(\frac{10}{2.5}\right)[V_{GS} - V_{tn}]^2$$

$I_D = 200 \times 10^{-6}\ [V_{in}(t) + 1]^2$

Then from op-amp circuit

$V_0(t) - V_b = 20 \times 10^3\ I_D$

$V_0(t) = V_b + 20 \times 10^3 \times 200 \times 10^{-6}\ (V_{in}(t)+1)^2$

$= 4 + 4\ (V_{in}(t)+1)^2$

$= 4 + 4\ [0.1\sin\omega t+1]^2$

$= 4 + 4\ [0.01\sin^2\omega t + 0.2\sin\omega t + 1]$

$V_0(t) = 8 + 0.8\sin(2\pi 10^3 t) + 0.04\sin^2(2\pi \times 10^3 t)$

(ii) 4 to 2 Encoder

Encoder produces a binary code for the selected input, the relation between n and m is $2^m = n$

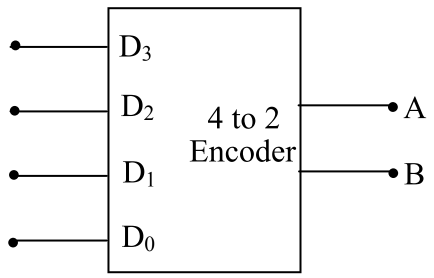


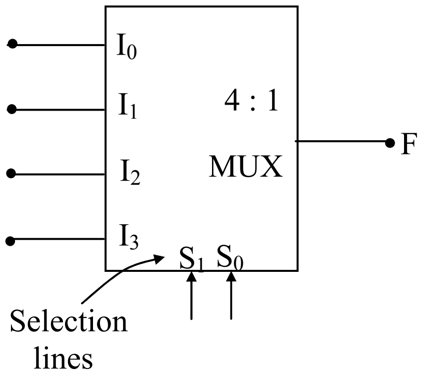
Table: Encoder Function:

D_3	D_2	D_1	D_0	A	B
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1

The limitation of encoder is the coding process is incorrect if more than one input is selected. To overcome this, we use priority encoder, where inputs are given with priorities.

* A multiplexer is a many to one circuit. It selects one of the inputs based on the selection line value. For a N:1 MUX, the number of selection lines are '$\log_2 N$'.

Consider a 4:1 MUX. It has 4 inputs, 2 selection lines and one output.



S_1 S_0	F
0 0	I_0
0 1	I_1
1 0	I_2
1 1	I_3

$$F = \overline{S}_1\,\overline{S}_0\,I_0 + \overline{S}_1\,S_0 I_1 + S_1\overline{S}_0\,I_2 + S_1 S_0 I_3$$