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ESE - 2025

MAINS EXAMINATION

QUESTIONS WITH DETAILED SOLUTIONS

ELECTRONICS & TELECOMMUNICATION ENGINEERING

(Paper-1)

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ELECTRONICS & TELECOMMUNICATION ENGINEERING

ESE_MAINS_2025_PAPER – I

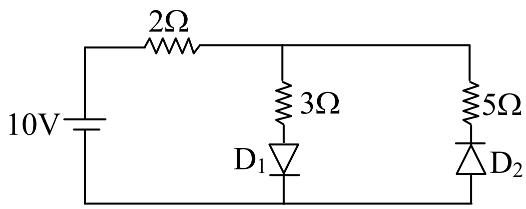
Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

S.No	NAME OF THE SUBJECT	Marks
01	BASIC ELECTRICAL ENGINEERING	20
02	BASIC ELECTRONICS ENGINEERING	32
03	MATERIALS SCIENCE	54
04	ELECTRONIC MEASUREMENTS & INSTRUMENTATION	72
05	NETWORK THEORY	124
06	ANALOG ELECTRONICS	106
07	DIGITAL ELECTRONICS	52
08	CONTROL SYSTEMS	20
	Total Marks	**480**

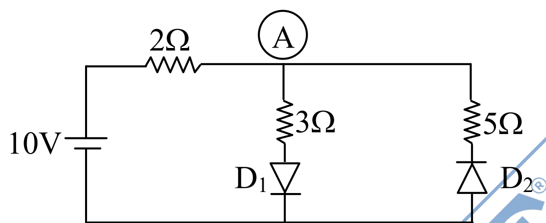
SECTION - A

01. (a) Find the current flowing in the circuit as given in the figure, where two ideal diodes are connected in parallel :



(12 M)

Sol:



Very Clear → D_1 ON

D_2 OFF

$$\Rightarrow \frac{10 - V_A}{2} = \frac{1V_A - 0}{3} \Rightarrow V_A = 6V$$

$$\Rightarrow I_{D_1} = I_{3\Omega} = \frac{6-0}{3} = 2\,\text{Amp}$$

$$I_{D_2} = I_{5\Omega} = 0$$

$$\therefore\ I_{2\Omega} = \frac{10 - V_A}{2} = 2\,\text{Amp}$$

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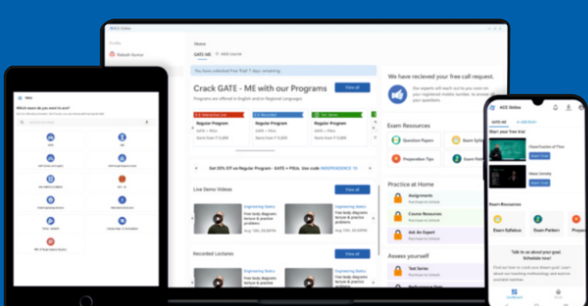

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01. (b) A certain d.c. motor has R_A = 1.3 Ω , I_A = 10 A, and produces a back e.m.f. E_A = 240 V, while operating at a speed of 1200 r.p.m. Determine the voltage applied to the armature, the developed torque and the developed power. (12 M)

Sol: **DC Motor:**

$R_a = 1.3\ \Omega;\ \ I_a = 10$ A

$E_b = 240$ V, N= 1200 rpm

$V = E_b + I_a R_a = 240 + 10\,(1.3) = 253$ V

Torque developed

$$T = 9.55\left(\frac{E_b I_a}{N}\right)$$

$$T = 9.55\left(\frac{240\times 10}{1200}\right) = 19.1\ \text{N-m}$$

$P_{developed} = E_b\ I_a = 240 \times 10 = 2400$ W

01. (c) Consider a unit cell of simple cubic structure. Find the angle between the normals to pair of planes whose Miller indices are (i) [1 0 1] and [0 1 0], and (ii) [2 1 1] and [1 0 1]. (12 M)

Sol: Given data, simple cubic structure

The angle between two crystallographic plane

$$\cos\theta = \frac{h_1h_2 + k_1k_2 + l_1l_2}{\sqrt{h_1^2 + k_1^2 + l_1^2}\sqrt{h_2^2 + k_2^2 + l_2^2}}$$

(i) [1 0 1] and [0 1 0]

$$\cos\theta = \frac{(1)(0) + (0)(1) + (1)(0)}{\sqrt{1^2 + 0^2 + 1^2}.\sqrt{0^2 + 1^2 + 0^2}} = 0$$

$\theta = 90^\circ$

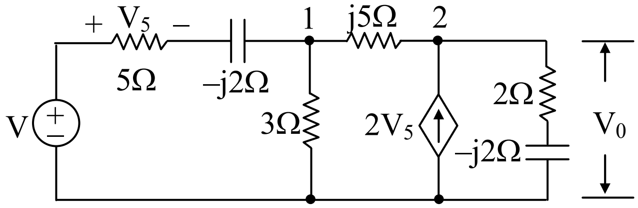
(ii) [2 1 1] and [1 0 1]

$$\cos\theta = \frac{(2)(1) + (1)(0) + (1)(1)}{\sqrt{2^2 + 1^2 + 1^2}.\sqrt{1^2 + 0^2 + 1^2}} = \frac{2+1}{\sqrt{6}.\sqrt{2}} = \frac{3}{\sqrt{12}}$$

$$\cos\theta = \frac{3}{\sqrt{3.2}} = \frac{\sqrt{3}}{2}$$

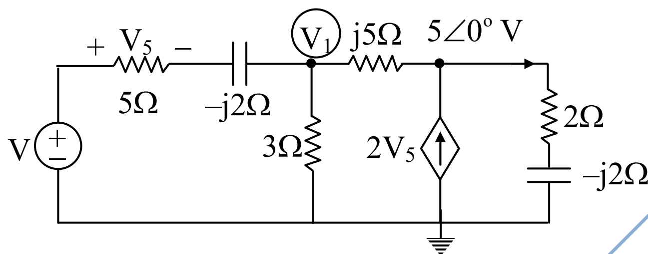
$\theta = 30^\circ$

01. (d) For the circuit shown in the figure, calculate the value of the voltage V which gives $V_0 = 5\angle 0°$ volts:



(12 M)

Sol: Since given $V_0 = 5\angle 0^o$ V, then



Using Nodal Analysis

$$\frac{[V_1 - V]}{(5-j2)} + \frac{V_1}{3} + \frac{[V_1 - 5]}{j5} = 0$$

$$\frac{[V_1 - V][5+j2]}{29} + \frac{V_1}{3} + \frac{-j[V_1 - 5]}{5} = 0$$

$$\frac{[V_1 - V][75 + j30] + 145V_1 - j87[V_1 - 5]}{29 \times 3 \times 5} = 0$$

$$75V_1 + j30V_1 - 75V - j30V + 145V_1 - j87V_1 + j435 = 0$$

$$V_1[220 - j57] - V[75 + j30] = -j435 \quad ----(1)$$

Also Voltage division Rule

$$V_5 = [V - V_1]\left[\frac{5}{5-j2}\right]$$

$$V_5 = [V - V_1]\left[\frac{25+j10}{29}\right] \quad ----(2)$$

Also KCL

$$\frac{[V_1 - 5]}{j5} + 2V_5 = \frac{5}{(2-j2)}$$

$$\frac{-j[V_1-5]}{5}+2V_5=\frac{5}{2-j2}\times\frac{2+j2}{2+j2}=\frac{5}{8}[2+j2]$$

$$2V_5=\frac{[10+j10]}{8}+\frac{j[V_1-5]}{5}$$

$$V_5=\frac{5+j5}{8}+\frac{j[V_1-5]}{10} \quad ----(3)$$

Sub (3) in (2)

$$\left[\frac{5+j5}{8}\right]+\frac{j[V_1-5]}{10}=[V-V_1]\left[\frac{25+j10}{29}\right]$$

$$\left[\frac{5+j5}{8}\right]+\frac{jV_1}{10}-\frac{j5}{10}=V\left[\frac{25+j10}{29}\right]-V_1\left[\frac{25+j10}{29}\right]$$

$$V_1\left[\frac{j}{10}+\frac{25+j10}{29}\right]-V\left[\frac{25+j10}{29}\right]=\frac{j}{2}-\frac{[5+j5]}{8}$$

$$V_1\left[\frac{j29+250+j100}{10\times29}\right]-\frac{V[25+j10]}{29}=\frac{j8-10-j10}{2\times8}$$

$$V_1\left[\frac{250}{290}+\frac{j129}{290}\right]-V\left[\frac{25}{29}+j\frac{10}{29}\right]=\left[\frac{-5}{8}-\frac{j}{8}\right]$$

$$V_1[0.862+j0.445]-V[0.862+j0.345]=[-0.625-j0.125] \quad ----(4)$$

Now solve (1) & (4)

$(1)\times[0.862+j\,0.445]$

$$[215+j48.766]V_1-[51.3+j59.235]V=[193.575-j374.97] \quad ----(5)$$

$(4)\times[220-j\,57]$

$$[215+j48.766]V_1-[209.3+j26.766]V=[-144.625+j8.125] \quad ----(6)$$

$(5)-(6)$

$$[158-j32.469]V=[338.2-j383.0]$$

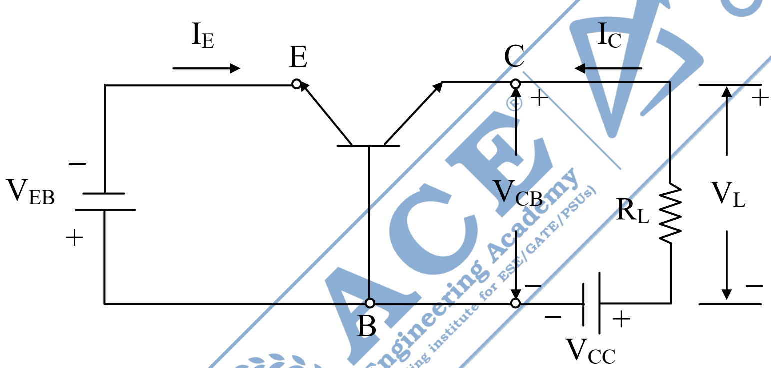
Finally

$$V = \frac{[338.2 - j383]}{[158 - j32.469]}$$

$$V = [2.532 - j1.904]$$

$$V = 3.2\angle -37.46^\circ \text{ V}$$

01. (e) Shown below is an n-p-n transistor biased in the active region :



Assume that the emitter is much more heavily doped than the base.

(i) Plot the potential variation across the emitter and collector junction

(ii) Plot the minority cacrier concentration in each section of the transistor

(iii) Show how this transistor configuration works as an amplifier

(iv) Plot the collctor current against base to emitter voltage for a silicon transistor when it is varied from –0.4 V to + 0.8 V. Indicate the cutoff, active and saturation regions.

(v) From the transistor characteristics, write the analytical expressions for the collector current and the emitter current.

vi) Show how these equations are used to replace the n-p-n transistor with two back diodes in shunt with two dependent current Sources.

(12 M)

Sol:

(i) Since $[E\text{-}B]_J$ is f, biased $\Rightarrow (V_0)_{EB_J}$ is low ($\cong$ 0.6V $\rightarrow$ 0.8V)

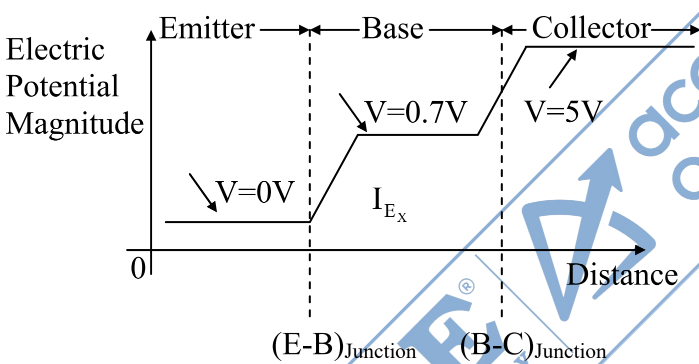
Also base is light doping than emitter and thin base

$\Rightarrow$ Potential is nearly uniform (or) has only a slight slope as concentration of carriers is changing slowly

Also as base collector junction is Reverse biased

$\Rightarrow$ Potential increases sharply at B.C junction (depletion region).

Hence, variation of potential across n-p-n transistor (active region)

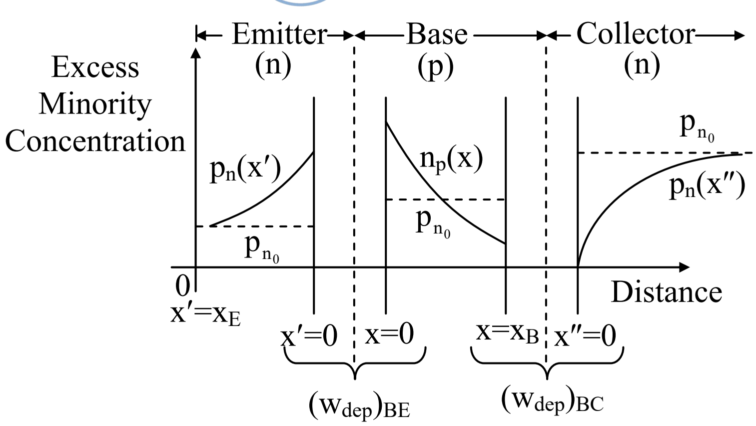


IF $V_E \rightarrow$ Grounded

$\Rightarrow V_{BE} = 0.7V \Rightarrow V_B = 0.7V$ (F. bias)

If $V_C = 5V \Rightarrow V_{CB} = V_C - V_B = 4.3V$ (R.Bias)

(ii) Minority (or) excess minority carrier profile in forward active $\rightarrow$



(iii) Clearly given npn transistor,

$$\left.\begin{matrix}(E-B)_J \rightarrow F.Bias \\ (C-B)_J \rightarrow R.Bias\end{matrix}\right\} F.Active$$

$\downarrow$

Small AC signal + DC bias applied at the BE

$\downarrow$

Small V_{BE} charge will give large I_C change [$\because\ I_C = \beta_F\, I_B$]

$\downarrow$

Due to E_J F.bias and C_J R.Bias $\Rightarrow$ most of injected electrons from E reach B then to collector,

$$\alpha_{dc} = \alpha_F = \overset{*}{\gamma}\overset{*}{\beta}$$

$\downarrow$

Now as $V_L = I_C R_L$, where as $V_C = V_{CC} - V_L$

$\Rightarrow$ Output voltage at the collector varies in the opposite phase $\Rightarrow$ 180° phase shift if input is given at the base.

$\downarrow$

Now transistor producer as voltage gain,

$$A_V \cong \frac{-\beta R_L}{r_e}$$

Where $r_e \cong \dfrac{26mV}{I_{EQ}}$

Hence the above flow chart gives an idea that how above design could be used for amplification.

(iv) Let $I_S \cong 10^{-15}$A

$V_T = 26$mV

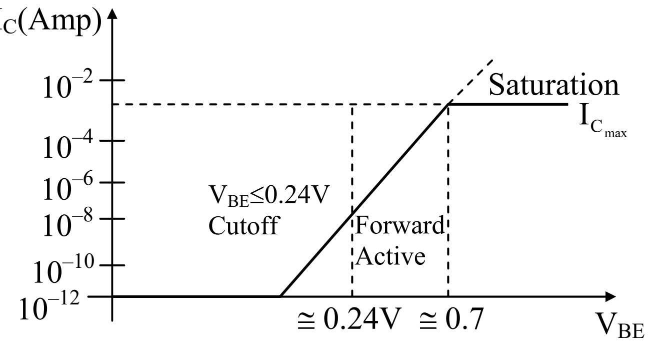
$\beta_F = 100$ and $V_{CC} = 5$V

$R_L = 2$k

$\Rightarrow (V_{CE})_{sat} = 0.2$V

$$I_{C_{max}} = \frac{5-0.2}{2000} \cong 2.4\times10^{-3}\text{amp}$$

Since $I_C \cong \beta I_S \left[\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right] + I_{CE0}$



Under cutoff only leakage currents pas in the device

Under active region, the step nearly straight line on a log plot, where transistor act as an amplifier.

In saturation I_C cannot glow beyond, it is limited by supply and resistor.

(v) As active mode $\Rightarrow I_C = \beta_F I_B + I_{CEO}$ (or) $I_C = \alpha_F I_E + I_{CBO}$

Also, $I_C = I_{C_0} \exp\left(\frac{V_{BE}}{V_T}\right) \to$ by Ebbers moll equation

$I_C = I_{C_0} \exp\left(\frac{V_{BE}}{V_T}\right)(1 + \lambda V_{CE}) \to$ In C.Emitter

$I_C = I_{C_0} \exp\left(\frac{V_{BE}}{V_T}\right)(1 + \lambda V_{CB}) \to$ In C.Base

With early effect.

As $I_E = I_B + I_C$ and $I_B = \frac{I_C}{\beta_F} \Rightarrow I_E = I_C\left(1 + \frac{1}{\beta_F}\right)$

$\Rightarrow$ without early effect,

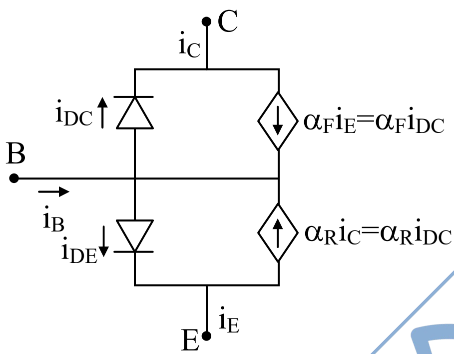
$I_E = I_{C_0} \exp\left(\frac{V_{BE}}{V_T}\right)\left(1 + \frac{1}{\beta_F}\right)$

With early effect,

$$I_E = I_{C_0}\exp\left(\frac{V_{BE}}{V_T}\right)\left(1+\frac{1}{\beta_F}\right)\left(1+\frac{V_{CE}}{V_A}\right)$$

(vi) Since two diodes connected back to back is ebbers moll model

$\alpha_F I_{SE} = I_S = \alpha_R I_{SC}$ where $I_S \rightarrow 10^{-12}$ to 10^{-18}Amp



KCL at the E $\rightarrow i_E = i_{DE} - \alpha_R i_C$, where $i_{DE} = i_{SE}\left[\exp\left(\frac{V_{BE}}{V_T}\right)-1\right]$

$$i_{DC} = i_{SC}\left[\exp\left(\frac{V_{BC}}{V_T}\right)-1\right]$$

$$\therefore\ i_E = i_{SE}\left[\exp\left(\frac{V_{BE}}{V_T}\right)-1\right] - i_{SC}\left[\exp\left(\frac{V_{BC}}{V_T}\right)-1\right]\alpha_R$$

$$= \frac{I_S}{\alpha_F}\left[\exp\left(\frac{V_{BE}}{V_T}\right)-1\right] - \frac{I_S}{\alpha_R}\left[\exp\left(\frac{V_{BC}}{V_T}\right)-1\right]\alpha_R$$

$$\therefore\ i_E = \frac{I_S}{\alpha_F}\left[\exp\left(\frac{V_{BE}}{V_T}\right)-1\right] - I_S\left[\exp\left(\frac{V_{BC}}{V_T}\right)-1\right] \text{\_\_\_\_\_\_\_\_}(1)$$

For forward active, V_{BE} = (+) Ve, V_{BE} = (–) Ve

$$\therefore\ i_E = \frac{I_S}{\alpha_F}\left[\exp\left(\frac{V_{BE}}{V_T}\right)-1\right] + I_S$$

$$\therefore\ I_E = \frac{I_S}{\alpha_F}\exp\left[\frac{V_{BE}}{V_T}\right] - \frac{I_S}{\alpha_F} + I_S$$

$$\therefore\ I_E = \frac{I_S}{\alpha_F}\exp\left[\frac{V_{BE}}{V_T}\right] + I_S\left(1 - \frac{I}{\alpha_F}\right)$$

$\alpha_F \rightarrow 0.95 \rightarrow 0.98$
$\alpha_R \rightarrow 0.01 \rightarrow 0.5$
$\beta_F \rightarrow 49 \rightarrow 300$
$\beta_R \rightarrow 0.01 \rightarrow 1$

KCL at the C $\rightarrow$

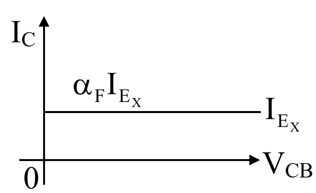
$i_C = \alpha_F I_{DE} - i_{DC}$

$$= \alpha_F \cdot \frac{I_S}{\alpha_F}\left[\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right] - \frac{I_S}{\alpha_R}\left[\exp\left(\frac{V_{BC}}{V_T}\right) - 1\right]$$

$$\therefore\ i_C = I_S\left[\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right] - \frac{I_S}{\alpha_R}\left[\exp\left(\frac{V_{BC}}{V_T}\right) - 1\right] \quad \text{———— (2)}$$

At the forward active, V_{BE} = (+)Ve, V_{BC} = (–)Ve

$\Rightarrow i_C = I_S \exp\left[\frac{V_{BE}}{V_T} + I_S\left[\frac{1}{\alpha_R} - 1\right]\right] \Rightarrow$ 'I_C' is independent of V_{BC}.



Commonly neglected as I_S is very very small.

* Now in sat region,

V_{CB} = (–)Ve $\Rightarrow CB_J \rightarrow F_B \rightarrow V_{CB}$ knee = 0.4V $\rightarrow$ 0.5V

$\Rightarrow$ from (2),

$$i_C = I_S\left[\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right] - \left[\frac{I_S}{\alpha_R}\right]\left[\exp\left(\frac{V_{BC}}{V_T}\right) - 1\right]$$

$$\therefore\ i_C \approx I_S \exp\left(\frac{V_{BE}}{V_T}\right) - \left[\frac{I_S}{\alpha_R}\right]\left[\exp\left(\frac{V_{BC}}{V_T}\right) - 1\right]$$

As V_{BC} ↑↑ at the V_{BE} = constant $\rightarrow i_C$ ↓↓ exponentially in SAT region.

$\therefore\ i_{C_{SAT}} < i_{C_{F.Active}} \Rightarrow i_{C_{SAT}} < \alpha_F i_E$.

02. (a) (i) The magnetic field of the earth is approximately 3×10^{-5} T (tesla). At what distance from a long-distance wire carrying a steady current of 10 A is the field equal to 10 percent of the earth's field? Suggest at least two ways to help reduce the effect of electric circuits on the navigation compass in a boat or an airplane. (12 M)

Sol: Given data

$B = 3\times10^{-5}$ T

$I = 10$ A

Magnetic field due to long straight rod

$B = \dfrac{\mu_0 I}{2\pi r}$ B = 10% of earth $= 0.1\times3\times10^{-5} = 3\times10^{-6}$

$3\times10^{-6} = \dfrac{4\pi\times10^{-7}\times10}{2\pi r}$

$r = 0.67$ m

Methods of reducing effects on navigation compass

(1) use magnetic shielding

(2) Increase physical separation from electrical circuits

(3) Use twisted wires cancel field

02. (a) (ii) A typical deep cycle battery (used for electric trolling motors for fishing boats) is capable of delivering 12.6 V and 10 A for a period of 10 hours. How much charge flows through the battery in this interval? How much energy does the battery deliver? (8 M)

Sol: $V_d =$ 12.6 V

$I_d =$ 10 A

$T_d =$ 10 hours

$Q = I_d T_d = 10\times10 = 100$ Ah $= (100\text{ A})(3600\text{ sec}) = 36\times10^4$ A sec

$E_d = V_d I_d T_d$

$= 12.6\times10\times10$

$= 1260$ Wh

02. (b) During a laboratory experiment, a student tried to build an inverting amplifier as shown in Fig. (i). The student accidentally reversed the connection of the two input terminals and obtained the circuit of Fig. (ii). The student was greatly surprised that the circuit no longer behaved as expected. Calculate the gain in both the cases and explain the stability of both the circuits. Assume open-loop gain of op-amp as 2×10^5, $R_i = \infty$, $R_0 = 0$ and stray capacitance of 1 pF across the input terminals:

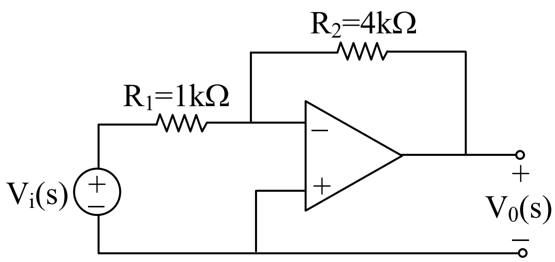


Fig. (i)

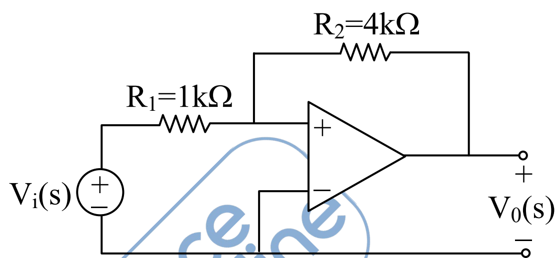
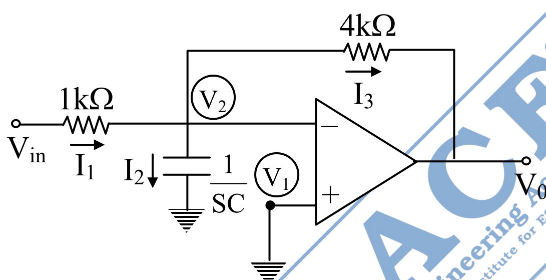


Fig (ii)

(20 M)

Sol:



Given C = 1PE

$A = 2 \times 10^5$

$V_0 = A(V_1 - V_2)$

$= 2 \times 10^5 (0 - V_2)$

$V_0 = -2 \times 10^5 V_2$ ________(1)

KCL at the V_2

$I_1 = I_2 + I_3$

$$\frac{V_{in} - V_2}{1k} = V_2(SC) + \frac{V_2 - V_0}{4k}$$

$$\frac{4V_{in} - 4V_2}{4k} = \frac{V_2(4k)SC + V_2 - V_0}{4k}$$

$V_2 (1 + (4k)CS + 4) = 4V_{in} + V_0$

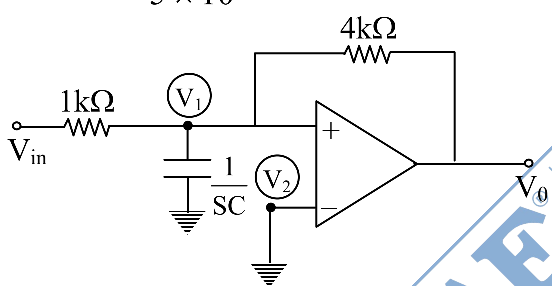
$$V_2 = \frac{4V_{in} + V_0}{5 + (4k)CS} \quad \text{——— (2)}$$

Sub (2) in (1)

$$V_0 = -2\times10^5\left[\frac{4V_{in} + V_0}{5+(4k)CS}\right] \quad \because [C = 1pF]$$

$$\frac{V_0}{V_{in}} = \frac{-8\times10^5}{(2\times10^5+5)+(4k)(1pF)s}$$

$$\frac{V_0}{V_{in}} = \frac{-4}{1+\frac{s}{5\times10^{13}}} = \frac{k}{1+s\tau} \text{ (low pass filter)}$$



$V_0 = A(V_1 - V_2)$

$= 2 \times 10^5 V_1$ ——— (3)

Similarly, $V_1 = \frac{4V_{in} + V_0}{5+(4k)CS}$ ——— (4) from equation (2)

Sub (4) in (3)

$$\frac{V_0}{V_{in}} = \frac{-4}{1-\frac{s}{5\times10^{13}}} = \frac{k}{1-s\tau}$$

The transfer function in the first case $\frac{k}{1+s\tau}$ is stable.

But the transfer function is the second case $\frac{k}{1-s\tau}$ is unstable.

The stability of the feedback system is determined by the location of poles of its closed loop transfer function.

02. (c) The state equation of a linear time-invariant system is expressed by

$$\begin{bmatrix}\dot{x}_1(t)\\ \dot{x}_2(t)\end{bmatrix}=\begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}[r(t)]$$

(i) Calculate the state transition matrix.

(ii) Find the state vector x(t) for $t \geq 0$, when r(t) = u(t).

Assume the initial state to be zero. **(10 + 10 = 20 M)**

Sol:
$$\begin{bmatrix}\dot{x}_1(t)\\ \dot{x}_2(t)\end{bmatrix}=\begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}r(t)$$

$$\Rightarrow A=\begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}\Rightarrow [sI-A]=\begin{bmatrix}s & -1\\ +1 & s+2\end{bmatrix}$$

(i) State transition matrix:

$$\phi(t)=e^{At}=L^{-1}\left[[sI-A]^{-1}\right]=L^{-1}\left[\frac{\text{Adj}[sI-A]}{|sI-A|}\right]$$

$$\phi(t)=L^{-1}\begin{bmatrix}\frac{s+2}{(s+1)^2} & \frac{1}{(s+1)^2}\\ \frac{-1}{(s+1)^2} & \frac{s}{(s+1)^2}\end{bmatrix}=L^{-1}\begin{bmatrix}\frac{s+1}{(s+1)^2}+\frac{1}{(s+1)^2} & \frac{1}{(s+1)^2}\\ \frac{-1}{(s+1)^2} & \frac{s+1-1}{(s+1)^2}\end{bmatrix}$$

$$\phi(t)=L^{-1}\begin{bmatrix}\frac{1}{s+1}+\frac{1}{(s+1)^2} & \frac{1}{(s+1)^2}\\ \frac{-1}{(s+1)^2} & \frac{1}{s+1}+\frac{-1}{(s+1)^2}\end{bmatrix}=\begin{bmatrix}e^{-t}+te^{-t} & te^{-t}\\ -te^{-t} & e^{-t}-te^{-t}\end{bmatrix}$$

$$\Rightarrow \text{State transition matrix } \phi(t)=\begin{bmatrix}e^{-t}+te^{-t} & te^{-t}\\ -te^{-t} & e^{-t}-te^{-t}\end{bmatrix}$$

(ii) State Vector :

$x(t) = e^{At}X(0) + L^{-1}[\phi(s)\,BU(s)]$

$X(0)=\begin{bmatrix}0\\ 0\end{bmatrix}$ initial condition are zero [given]

$x(t) = L^{-1}[\phi(s)\,BU(s)]$

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$$= L^{-1}\left[\begin{bmatrix} \dfrac{(s+2)}{(s+1)^2} & \dfrac{1}{(s+1)^2} \\ \dfrac{-1}{(s+1)^2} & \dfrac{s}{(s+1)^2} \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix}\begin{bmatrix} \dfrac{1}{s} \end{bmatrix}\right]$$

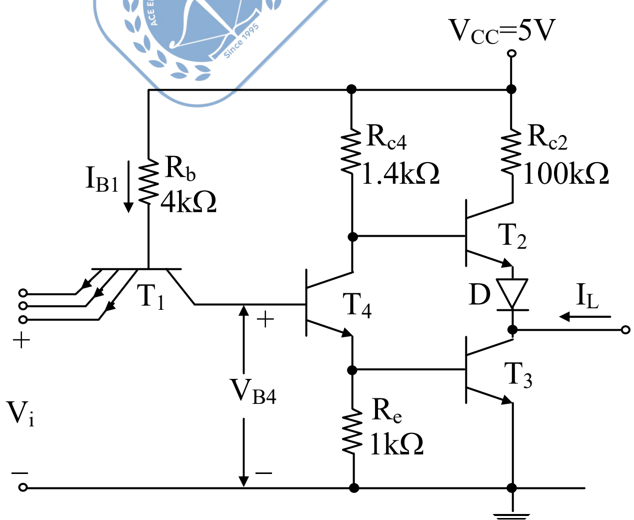
$$x(t) = L^{-1}\left[\begin{bmatrix} \dfrac{1}{(s+1)^2} \\ \dfrac{s}{(s+1)^2} \end{bmatrix}\begin{bmatrix} \dfrac{1}{s} \end{bmatrix}\right] = L^{-1}\begin{bmatrix} \dfrac{1}{s(s+1)^2} \\ \dfrac{1}{(s+1)^2} \end{bmatrix}$$

$$x(t) = L^{-1}\begin{bmatrix} \dfrac{1}{s} - \dfrac{1}{s+1} - \dfrac{1}{(s+1)^2} \\ \dfrac{1}{(s+1)^2} \end{bmatrix}$$

$$x(t) = \begin{bmatrix} 1 - e^{-t} - te^{-t} \\ te^{-t} \end{bmatrix} \Rightarrow x(t) = \begin{bmatrix} 1 - e^{-t}(1+t) \\ te^{-t} \end{bmatrix}$$

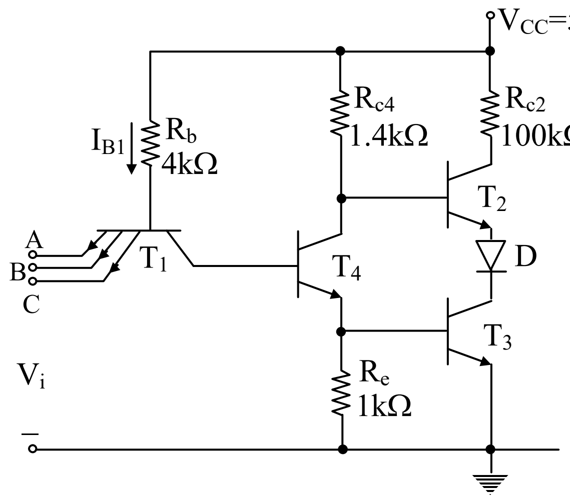
03. (a) Explain the operation of the TTL gate circuit shown below, clearly mentioning the roles of the transistors T_2 and T_4, and the diode D.

Assume that when all the inputs are at logic 1, the transistors T_3 and T_4 are both in saturation:



(20 M)

Sol:



Transistor-transistor logic belongs to the digital logic family. It consists of transistor at both input and output side, diodes and few resistors. Unlike resistor-transistor logic and diode-transistor logic, both the logic function and amplifying function are performed by the transistors. In the given circuit of 3 input TTL NAND gate, it has four transistors T_1, T_2, T_3 and T_4. Transistor T_1 has 3 inputs on the emitter side. Transistors T_2 and T_3 form the output side, called totem pole output.

When all the three inputs A, B and C are low, the three diodes are forward biased. So the current due to the supply V_{CC} = 5V will go to the ground through R_b and it will not be sufficient to turn ON the transistor T_4, with T_4 open, the transistor T_3 will also cutoff. But the transistor T_2 is pulled high. Since T_2 is an emitter follower, the output will also be HIGH i.e., logic 1.

When any one input is low, the diode with low input will be forward biased. The same operation will take place as explained above. In this case output is high.

When all the inputs A, B and C are HIGH then all the three diodes at the emitter base junction will be reverse biased. The diode at collector base junction is forward biased. It will turn on the transistor T_4. with T_4 turned ON, transistor T_3 will also be tuned ON. So the output will be logic low which is considered as logic 0.

In the circuit shown the transistors T_2, T_3, diode D and current limiting resistor R_{C2} from the totem-pole output configuration of TTL.
There are few advantages of this configuration, when the output switches from low the HIGH state, the output transistor T_3 goes from saturation to cutoff. During this transition the load capacitance across T_2 charges exponentially from low to high.

Due to the low output impedance of both T_2 and T_3, the output voltage can change quickly from Low to HIGH as the capacitance charge and discharge quickly.

A	B	C	Y
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

03. (b) (i) A thermistor, having $\beta = 3100K$, has a resistance of 1050 Ω at $20^{\circ}C$. The thermistor is used for the measurement of temperature and the resistance measured is 2300 Ω. Find the measured temperature if the thermistor is described by the relation $R = R_0 \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$ where the symbols have their standard meanings.

(10 M)

(ii) The following are the data for a Hay's bridge :

$R_i = 1\ k\Omega \pm 1$ part in 10 K, $R_2 = 16.8\ k\Omega \pm 1$ part in 10 K,

$R_3 = 833 \pm 0.25\ \Omega$, $C = 1.43\ \Omega \pm 0.001\ \mu F$

The supply frequency is 50 ± 01 Hz and the bridge's balanced conditions are

$$L = \frac{CR_1R_2}{1+\omega^2C^2R_3^2} \quad \textbf{and} \quad R = \frac{R_1R_2R_3C^2\omega^2}{1+\omega^2C^2R_3^2}$$

Calculate the values of L and R of the coil, and their limits of error. (10 M)

Sol:

(i) $\beta = 3100\,k$

$R_0 = 1050\Omega$ at 20° C $\Rightarrow T_0 = 273 + 20 = 293$

$R_t = 2300\ \Omega$

$$R_t = R_0\, e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

$$\frac{R_t}{R_0} = e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

$$\ln\left(\frac{R_t}{R_0}\right) = \beta\left(\frac{1}{T} - \frac{1}{T_0}\right)$$

$$\ln\left(\frac{2300}{1050}\right) = 3100\left(\frac{1}{T} - \frac{1}{293}\right)$$

$$2.529\times10^{-4} = \frac{1}{T} - \frac{1}{293}$$

$$\frac{1}{T} = 3.6659\times10^{-3}$$

$$T = 272.78\,k$$

(ii) $R_1 = 1000 \pm 0.1 = 1000 \pm 0.01\%$

$$R_2 = 16800 \pm 0.01\%$$

$$R_3 = 833 \pm 0.25\,\Omega = 833 \pm 0.03\%$$

$$C = 1.43 \pm 0.001\,\mu F = 1.43\,\mu F \pm 0.07\%$$

$$f = 50 \pm 0.1\,Hz = 50 \pm 0.2\%$$

$$R = \frac{R_1R_2R_3C^2\omega^2}{1+\omega^2C^2R_3^2}$$

$$= \frac{(1000\pm0.01\%)(16800\pm0.01\%)(833\pm0.03\%)(1.43\times10^{-6}\pm0.07\%)^2[4\pi^2(50\pm0.2\%)^2]}{1+4\pi^2(50\pm0.2\%)^2(1.43\times10^{-6}\pm0.07\%)^2(833\pm0.03\%)^2}$$

$$= \frac{2824.39\pm0.59\%}{1+0.13998\pm0.6\%}$$

$$= \frac{2824.39\pm0.59\%}{1.13998\pm0.0736\%}$$

$$= 2477.57 \pm 0.6636\%$$

$$= 2477.57 \pm 16.44$$

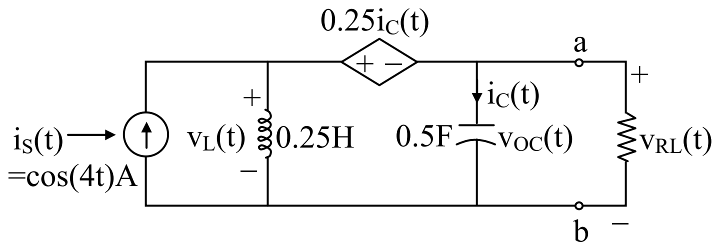
$$L_1 = \frac{CR_1R_2}{1+\omega^2C^2R_3^2} = \frac{(1.43\times10^{-6}\pm0.07\%)(1000\pm0.01\%)(16800\pm0.01\%)}{1.13998\pm0.0736\%}$$

$$= \frac{24\pm0.09\%}{1.13998\pm0.0736\%}$$

$$= 21.05 \pm 0.1636\%$$

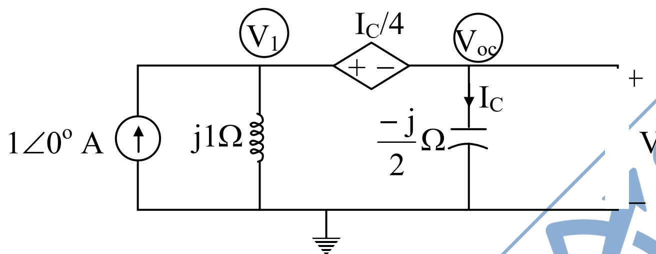
$$= 21.05 \pm 0.0344$$

03. (c) Find the Thevenin's equivalent of the circuit shown in the figure if ω = 4 rad/s. Also determine the voltage $V_{R_L}(t)$, when a 1.2 Ω load is connected to terminals a-b:



(20 M)

Sol: V_{OC} :



$$-[1\angle 0^\circ] + \frac{V_1}{j1} + \frac{V_{oc}}{-j/2} = 0$$

$$-jV_1 + j2V_{oc} = 1 \quad ----(1)$$

$$[V_1 - V_{oc}] = \frac{I_C}{4} \quad ----(2)$$

$$I_C = \frac{V_{oc}}{-j/2} = +j2V_{oc} \quad ----(3)$$

(3) in (2)

$$V_1 - V_{oc} = +\frac{j2V_{oc}}{4}$$

$$V_1 - V_{oc} = +\frac{j}{2}V_{oc} \quad ----(4)$$

Equation (4) × j, we get

$$+jV_1 - jV_{oc} = -\frac{V_{oc}}{2} \quad ----(5)$$

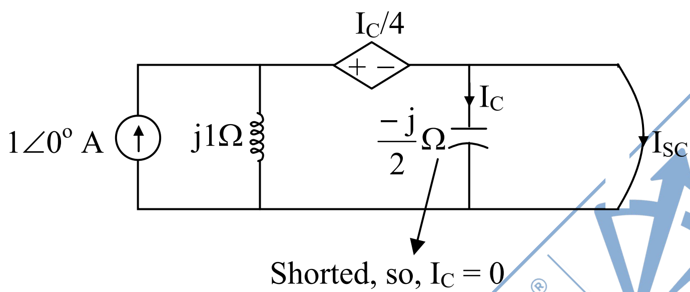
(1) + (5)

$$jV_{oc} = 1 - \frac{V_{oc}}{2} \Rightarrow V_{oc}\left[\frac{1}{2} + j\right] = 1$$

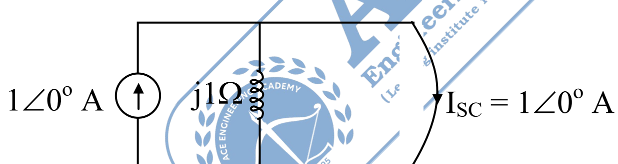
$$V_{oc} = \left[\frac{2}{1+j2}\right]V = [0.4 - j0.8]V = 0.894\angle -63.43^\circ \text{ V}$$

$$= 0.894\cos(4t - 63.43^\circ)\text{ V}$$

S-II: $\mathbf{I_{SC}}$

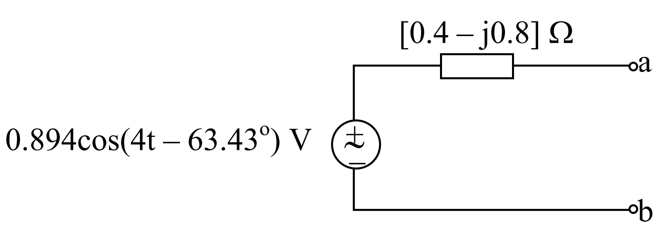


Then dependent voltage source is also zero, so short it

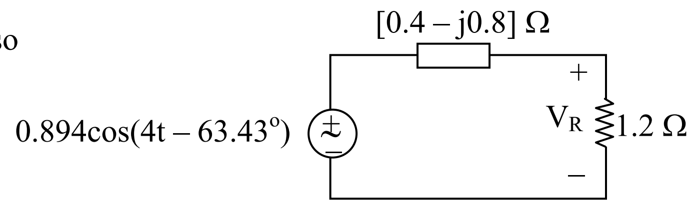


$$Z_{TH} = \frac{V_{oc}}{I_{SC}} = \left[\frac{2}{1+j2}\right]\Omega = [0.4 - j0.8]\Omega$$

Thevenin's Equivalent Circuit becomes



Also



$$V_R = [0.894\angle -63.43]\left[\frac{1.2}{1.6 - j0.8}\right]$$

$$V_R = [0.894\angle -63.43^\circ][0.6 + j0.3]$$

$$V_R = [0.894\angle -63.43^\circ][0.67\angle 26.56^\circ]$$

$$V_R = 0.6\angle -36.87^\circ$$

$$V_R = 0.6\cos(4t - 36.87^\circ)\,V$$

04. (a) Consider that a double-heterojunction LED emitting at a peak wavelength 1400 nm has radiative and non-radiative recombination times of 20 ns and 80 ns respectively. The drive current is 30 mA and the refractive index of the light source material is 3.0. Calculate the power emitted from the device. (20 M)

Sol: Given Peak wave length, λ = 1400 nm

τ_{rad} = 20 ns

$\tau_{non-rad}$ = 80 ns

Drive current, I = 30 mA

Refractive Index, n = 3.0

Since internal quantum efficiency, $\eta_e = \theta_e = \dfrac{\tau_{non-rad}}{\tau_{rad} + \tau_{non-rad}} = \dfrac{80\,ns}{20\,ns + 80\,ns} = 0.8$

Now, to calculate internal optical power, $P_{internal} = \eta_e \times I \times \dfrac{hC}{q\lambda} \cong 11.3\,mW$

Now emitter power, $P_{Emitted} = \dfrac{P_{internal}}{n^2} = \dfrac{11.3\,mW}{(3)^2} = \dfrac{11.3\,mW}{9} \cong 1.2\,mW$

$\Rightarrow$ Power Emitter $\cong 1.2\,mW$

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04. (b) A spherical nanoparticle has diameter of 10 nm. Determine the surface area to volume ratio and explain how this property affects the behaviour of nanomaterials compared to bulk materials. (20 M)

Sol: **Calculate Surface Area to Volume Ratio**

For a **sphere**:

- **Surface Area** $A = 4\pi r^2$
- **Volume** $V = 4\pi r^3/3$

So, the **surface area to volume ratio** is:

$A/V = 3/r = 3/5\text{nm} = 6 \times 10^8$

At the **nanoscale**, the **surface area to volume ratio is extremely high**. This has significant consequences:

◈ **Increased Reactivity**

- More atoms are exposed at the surface.
- Surface atoms are less tightly bound → more reactive.

◈ **Enhanced Mechanical Properties**

- Higher surface energy contributes to strength and hardness.

◈ **Changes in Electrical & Thermal Properties**

- Electron transport may occur via surface or quantum effects.
- Thermal conductivity can decrease due to boundary scattering.

◈ **Quantum Confinement**

- Electrons are confined in small volumes → changes in optical/electronic properties.
- Example: Quantum dots emitting different colors based on size.

04. (c) (i) A CR tube has an anode-screen distance of 30 cm. The accelerating potential is 1 kV. The tube is placed with its axis vertical. Find the maximum deflection of the spot due to the earth's magnetic field having $B = 0.018\times10^{-3}$ Wb/m^2. (10 M)

Sol: Speed of Electron beam

$$v = \sqrt{\frac{2qv}{m}} = \sqrt{\frac{2ev}{m}} = \sqrt{\frac{2\times1.602\times10^{-9}\times1000}{9.1\times10^{-31}}}$$

$v = 1.8755 \times 10^7$ m/s

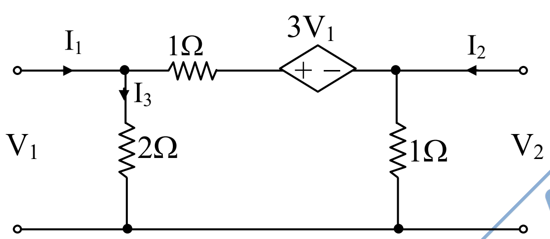
Radius of curvature of magnitude filed

$$r = \frac{mv}{eB} = \frac{9.1\times10^{-31}\times1.8755\times10^{7}}{1.602\times10^{-19}\times1.8\times10^{-5}} = 5.92\ \mu m$$

The beam follows a circular path of radius of arc length 'L'

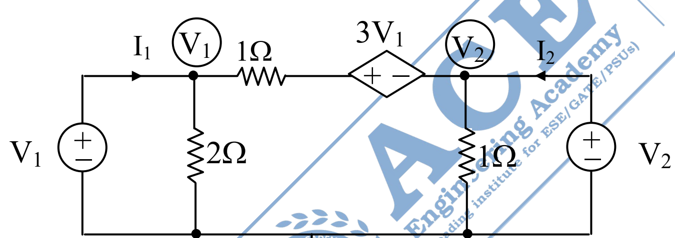
$$y = \frac{L^2}{2r} = \frac{(0.3)^2}{2\times5.92\,\mu m} = 7.6\,mm$$

04. (c) (ii) Calculate the Y-parameters for the network shown in the figure:



(10 M)

Sol: Here for Y-parameters just write Nodal Equations



KCL at V_1

$$-I_1 + \frac{V_1}{2} + \frac{[V_1 - V_2 - 3V_1]}{1} = 0$$

$$-2I_1 + V_1 + 2V_1 - 2V_2 - 6V_1 = 0$$

$$-2I_1 - 3V_1 - 2V_2 = 0$$

$$-2I_1 = 3V_1 + 2V_2$$

$$I_1 = -\frac{3}{2}V_1 - V_2 \quad ----(1)$$

KCL at (V_2)

$$-I_2 + \frac{V_2}{1} + \frac{(V_2 - V_1 + 3V_1)}{1} = 0$$

$I_2 = 2V_1 + 2V_2 \quad ---- (2)$

So, from (1) & (2)

$I_1 = -\frac{3}{2}V_1 - V_2$

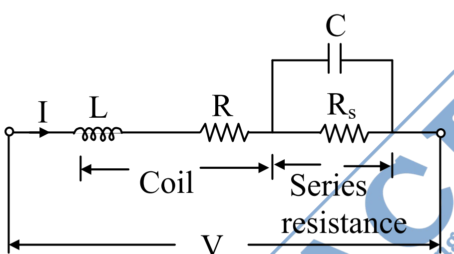
$I_2 = 2V_1 + 2V_2$

So, $[Y] = \begin{bmatrix} -\frac{3}{2} & -1 \\ 2 & 2 \end{bmatrix} \mho$

SECTION - B

05. (a) Derive a relation for the value of the capacitor for frequency error compensation of a moving-iron voltmeter in terms of its parameters and the series resistance. (12 M)

Sol:



Frequency Compensation for M.I voltmeters

Now $Z = j\omega L + \frac{R_s}{1 + j\omega CR_s} = j\omega L + \frac{R_s - j\omega CR_s^2}{1 + \omega^2 C^2 R_s^2}$

Since $\omega CR_s << 1$, we can write

$Z = j\omega L + (R_s - j\omega CR_s^2)(1 - \omega^2 C^2 R_s^2)$

$= j\omega L + R_s - j\omega CR_s^2 - \omega^2 C^2 R_s^3 + j\omega^3 C^3 R_s^4$

$= R_s - \omega^2 C^2 R_s^3 + j[\omega L - \omega CR_s^2(1 - \omega^2 C^2 R_s^2)]$

$= R_s - \omega^2 C^2 R_s^2 + j[\omega L + \omega CR_s^2]$

$= R_s(1 - \omega^2 C^2 R_s^2)^2 + j\omega(L - CR_s^2)$

Or

$Z^2 = R_s^2(1 - \omega^2 C^2 R_s^2)^2 + \omega^2(L - CR_s^2)^2$.

This must equal R_s^2 in order that the a.c. calibration at all frequencies and d.c calibration is the same.

$$\therefore\ R_s^2 = R_s^2(1-\omega^2C^2R_s^2)^2 + \omega^2(L-CR_s^2)^2$$

$$= R_s^2(1-2\omega^2C^2R_s^2+\omega^4C^4R_s^4)+\omega^2(L-CR_s^2)^2$$

$$= R_s^2(1-2\omega^2C^2R_s^2)+\omega^2(L-CR_s^2)$$

$$\text{as } \omega^4C^4R_s^2 << 1$$

$$= R_s^2 - 2\omega^2C^2R_s^4+\omega^2L^2+\omega^2C^2R_s^4-2\omega^2LCR_s^2$$

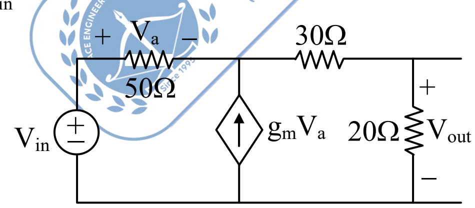
or $L^2-2LCR_s^2-C^2R_s^4=0$ or $L=2.41CR_s^2$

$$\therefore\ C=\frac{1}{2.41}\frac{L}{R_s^2}=0.41\frac{L}{R_s^2}$$

It should be understood that the above analysis is valid for a limited range of frequency which in practical cases is upto 125 Hz.

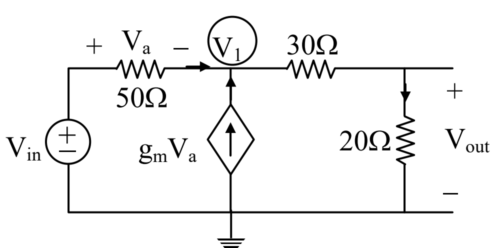
05. (b) For the circuit shown in the figure, find $\frac{V_{out}}{V_{in}}$ in terms of the parameter g_m.

Then find $\frac{V_{out}}{V_{in}}$, when g_m = 2:



(12 M)

Sol:



KCL + OHM'S LAW

$$V_{out} = 20\left[g_m V_a + \frac{V_a}{50}\right]$$

$$V_{out} = 20V_a\left[g_m + \frac{1}{50}\right] \quad \text{-----}(1)$$

Also $V_a = [V_{in} - V_1]$ -----(2)

Also $V_{out} = V_1\left[\frac{20}{20+30}\right] \Rightarrow V_{out} = \frac{2}{5}V_1$ -----(3)

Sub (2) in (1)

$$V_{out} = 20[V_{in} - V_1]\left[g_m + \frac{1}{50}\right] \quad \text{-----}(4)$$

Sub (3) in (4)

$$V_{out} = 20\left[V_{in} - \frac{5}{2}V_{out}\right]\left[g_m + \frac{1}{50}\right]$$

$$V_{out} = [20V_{in} - 50V_{out}]\left[\frac{50g_m + 1}{50}\right]$$

$$V_{out} = [20V_{in}]\left[\frac{50g_m + 1}{50}\right] - [50V_{out}]\left[\frac{50g_m + 1}{50}\right]$$

$$V_{out} = \left[\frac{2}{5}V_{in}\right]\left[\frac{50g_m + 1}{1}\right] - V_{out}[50g_m + 1]$$

$$V_{out}[1 + 1 + 50g_m] = \frac{2}{5}V_{in}[50g_m + 1]$$

$$V_{out} = V_{in}\frac{2}{5}\left[\frac{[50g_m + 1]}{[50g_m + 2]}\right]$$

$$\frac{V_{out}}{V_{in}} = \frac{2}{5}\left[\frac{[50g_m + 1]}{[50g_m + 2]}\right]$$

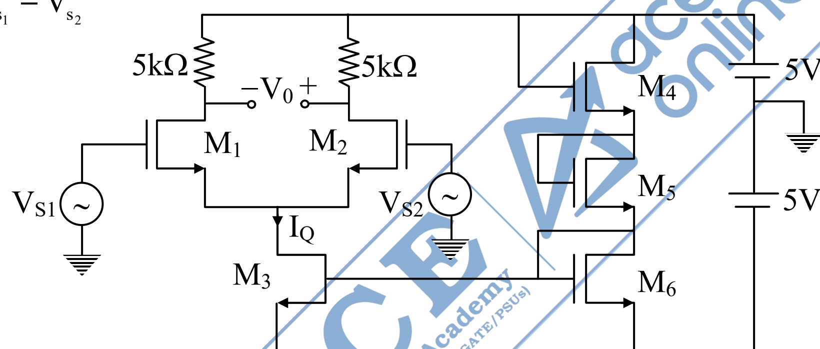
if $g_m = 2$

$$\frac{V_{out}}{V_{in}} = \frac{2}{5}\frac{[101]}{[102]} = 0.4 \times 0.9901$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = 0.396$$

05. (c) For the circuit shown in the figure, all the MOSFETs are identical. Assume $\mu_n C_{ox} = 0.1 mA/V^2$, $V_{tn} = 1V, \lambda = 0$ and $I_Q = 1mA$. Calculate $\frac{W}{L}$ ratio and voltage gain

$$A_d = \frac{V_0}{V_{s_1} - V_{s_2}}:$$



(12 M)

Sol: Given I_Q = mA so $I_6 = I_5 = I_4 = 1mA \rightarrow V_{GS6} = V_{GS5} = V_{GS4}$______(1)

$\mu.C_{ox} = 0.1mA/V^2$

$V_{GS4} + V_{GS5} + V_{GS6} = 5 - (-5) = 10V$______(2)

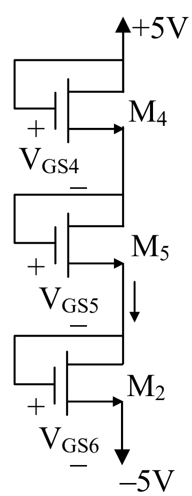
$\therefore V_{GS4} = V_{GS5} = V_{GS6} = 3.33$

Assuming MOS in saturation

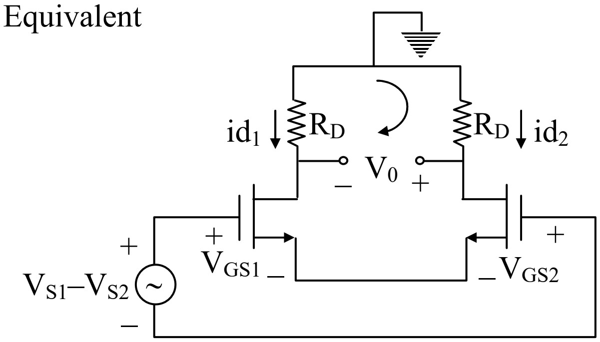
$$I_D = \frac{1}{2}\mu.C_{ox}\left(\frac{W}{L}\right)[V_{GS} - V_{tn}]^2$$

$$\rightarrow \frac{1m}{2} = \frac{1}{2}0.1m\left(\frac{W}{L}\right)[3.33-1]^2$$

$$\rightarrow \left(\frac{W}{L}\right) = \frac{3.6745}{2} = 1.8367 \text{ (for } M_4, M_5, M_6)$$



AC Equivalent



KVL $V_{S1} = V_{S2} - Vg_{S2}$ $\quad$ ($V_{gs1} = -V_{gs2}$ and $i_{d1} = -i_{d2} = i_d$)

$= 2V_{gs}$

KVL $i_{d2}\,R_D + V_0 - i_{d2}\,R_D = 0$

$V_0 = (i_{d1} - i_{d2})\,R_D = 2i_dR_D$

Differential gain

$$\frac{V_0}{V_d} = \frac{V_0}{V_{S1} - V_{S2}} = \frac{2i_dR_D}{2V_{gs}} = +g_mR_D$$

$= (0.42856)\ 5k$

$= 2.1428$

Where $g_m = \sqrt{2kI_D}$

$$= \sqrt{2(\mu.C_{ox})\left(\frac{W}{L}\right)[I_D]}$$

$$= \sqrt{2(0.1m)\frac{[3.6745]}{2}(0.5m)}$$

$$= \sqrt{0.2m(1.8367)(0.5m)}$$

$= 0.42856$

05. (d) Design a JK counter for states 1, 2, 4, 5, 7, 8, 10, 11, ... What would happen if the circuit were turned ON and the first state it entered was a don't care state? (12 M)

Sol:

	PS				NS				FF i/p's							
	Q_3	Q_1	Q_2	Q_0	Q_3	Q_1	Q_2	Q_0	J_3	K_3	J_2	K_2	J_1	F_1	J_0	K_0
1	0	0	0	1	0	0	1	0	0	×	0	×	1	×	×	1
2	0	0	1	0	0	1	0	0	0	×	1	×	×	1	0	×
4	0	1	0	0	0	1	0	1	0	×	×	0	0	×	1	×
5	0	1	0	1	0	1	1	1	0	×	×	0	1	×	×	0
7	0	1	1	1	1	0	0	0	1	×	×	1	×	1	×	1
8	1	0	0	0	1	0	1	0	×	0	0	×	1	×	0	×
10	1	0	1	0	1	0	1	1	×	0	0	×	×	0	1	×
11	1	0	1	1	0	0	0	1	×	0	0	×	×	1	×	0

$J_3 = \Sigma m(7) + d(0, 3, 6, 8, 9, 10, 11, 12, 13, 14, 15)$

$K_3 = \Sigma m(11) + d(0, 1, 2\ 3, 4, 5, 6, 7, 9, 12, 13, 14, 15)$

$J_2 = \Sigma m(2) + d(0, 3, 4, 5, 6, 7, 9, 12, 13, 14, 15)$

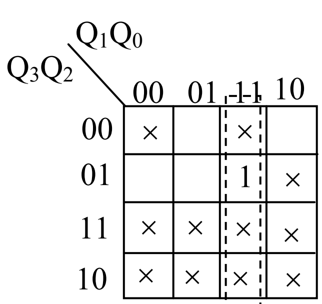
$K_2 = \Sigma m(7) + d(0, 1, 2, 3, 6, 8, 9, 10, 11, 12, 13, 14, 15)$

$J_1 = \Sigma m(1, 5, 8) + d(0, 2, 3, 6, 7, 9, 10, 11, 12, 13, 14, 15)$

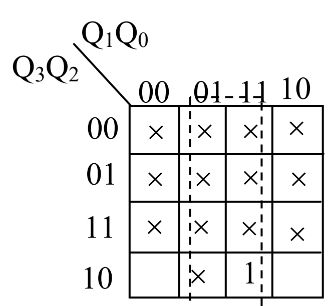
$K_1 = \Sigma m(2, 7, 11) + d(0, 1, 3, 4, 5, 6, 8, 9, 12, 13, 14, 15)$

$J_0 = \Sigma m(4, 10) + d(0, 1, 3, 5, 6, 7, 9, 11, 12, 13, 14, 15)$

$K_0 = \Sigma m(1, 7) + d(0, 2, 3, 4, 6, 8, 9, 10, 12, 13, 14, 15)$



$J_3 = Q_1Q_0$



$K_3 = Q_0$

Q_3Q_2 \ Q_1Q_0	00	01	11	10
00	×		×	1
01	×	×	×	×
11	×	×	×	×
10		×		

$J_2 = \overline{Q}_3 Q_1$

Q_3Q_2 \ Q_1Q_0	00	01	11	10
00	×	×	×	×
01			1	×
11	×	×	×	×
10	×	×	×	×

$K_2 = Q_1$

Q_3Q_2 \ Q_1Q_0	00	01	11	10
00	×	1	×	×
01		1	×	×
11	×	×	×	×
10	1	×	×	×

$J_1 = Q_3 + Q_0$

Q_3Q_2 \ Q_1Q_0	00	01	11	10
00	×	×	×	1
01	×	×	1	×
11	×	×	×	×
10	×	×	1	

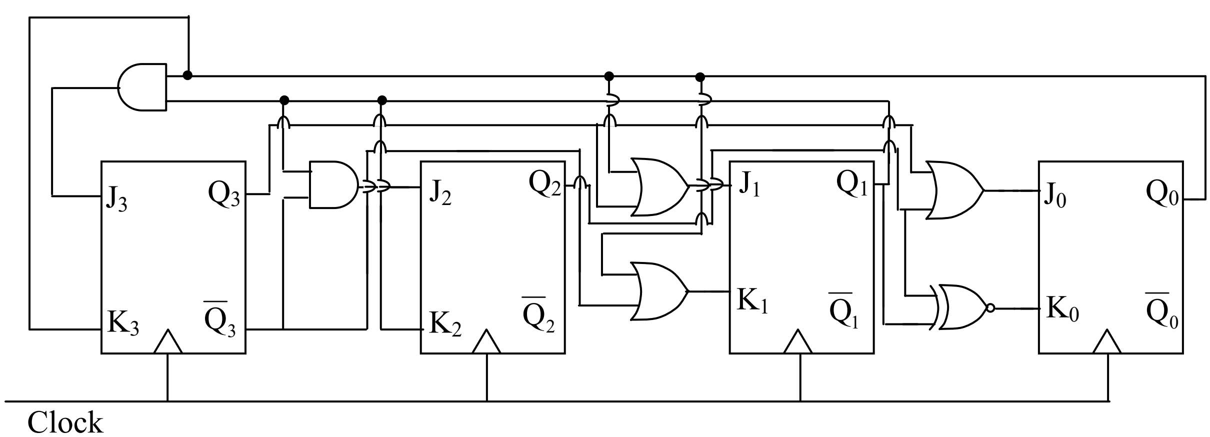
$K_1 = \overline{Q}_3 + Q_0$

Q_3Q_2 \ Q_1Q_0	00	01	11	10
00	×	×	×	
01	1	×	×	×
11	×	×	×	×
10		×	×	1

$J_0 = Q_3 + Q_2$

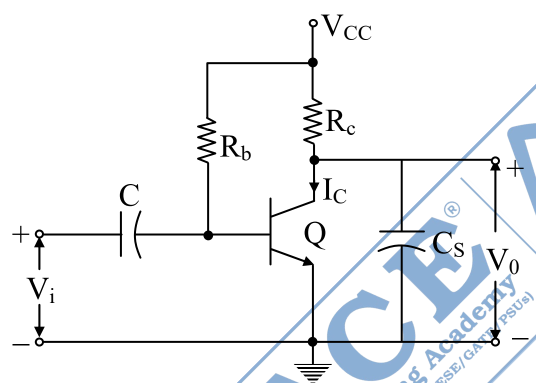
Q_3Q_2 \ Q_1Q_0	00	01	11	10
00	×	1	×	×
01	×		1	×
11	×	×	×	×
10	×	×		×

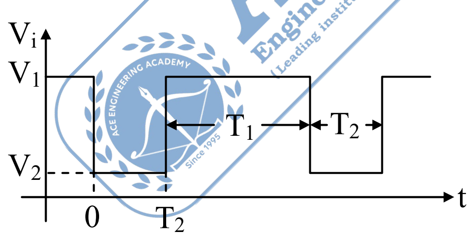
$K_0 = \overline{Q}_2\overline{Q}_1 + Q_2Q_1 = Q_2 \odot Q_1$



If a counter is entering into unused state and it is used as a don't care, then depending on utilization of don't cares in flip flop input expression may result input is 1 or 0. So the next state may be either used or unused state. Then there is a possibility for forming a loop in unused states only and it is called lockout.

05. (e) The transistor Q acts as a switch in the given circuit for the applied input V_i that varies with time as shown below:



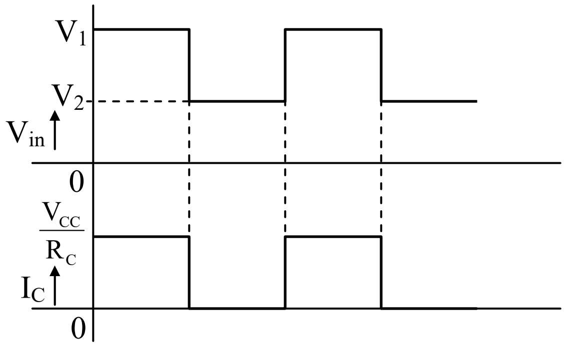


Plot the variation of the collector current: I_c and the output voltage v_0, assuming that the time constants are small compared to T_1 or T_2. (12 M)

Sol: The given transistor acts as a switch. Consider the input V_1 is high and V_2 is low. The transitions are instantaneous as the time constants are negligible.

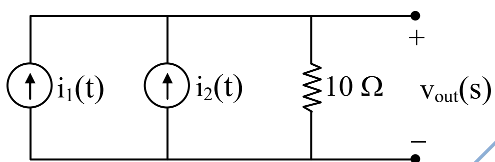
Case 1: Let $V_{in} = V_1$ (high), the BJT is ON and $I_C = \dfrac{V_{CC} - V_{CC(sat)}}{R_C} \approx \dfrac{V_{CC}}{R_C}$

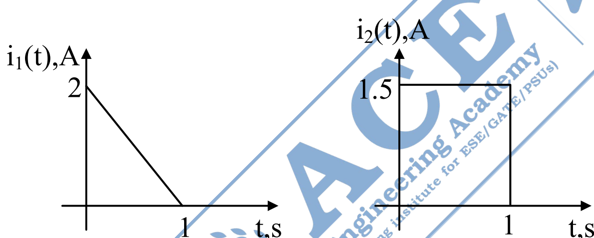
Case 2: Let $V_{in} = V_2$ (low), the BJT is OFF and $I_C = 0$, $V_0 = V_{CC}$



The given transistor toggles between cutoff and saturation.

06. (a) The circuit of the figure has two sources of excitation $i_1(t)$ and $i_2(t)$. Compute $v_{out}(s)$:





(20 M)

Sol: $V_{out} = [i_1(t) + i_2(t)]10$ Volts

At t = 0

$i_1(t = 0) = 2\,A$

$i_2(t = 0) = 1.5\,A$

$i_1 + i_2 = 3.5\,A$

So, $V_{out}(t = 0) = 3.5 \times 10 = 35$ volts

At $t = 1^-$

$i_1(t = 1^-) = 0\,A$

$i_2(t=1^-) = 1.5\,A$

$i_1 + i_2 = 1.5\,A$

So, $V_{out}(t=1^-) = 1.5 \times 10 = 15$ volts

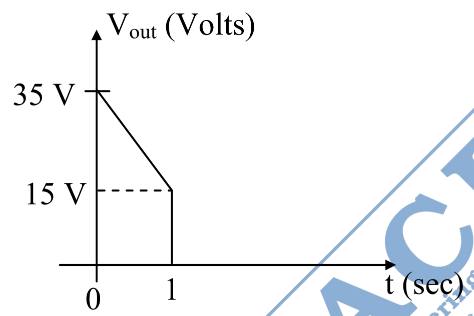
At $t = 1^+$

$i_1(t=1^+) = 0\,A$

$i_2(t=1^+) = 0\,A$

$i_1 + i_2 = 0\,A$

So, $V_{out}(t=1^+) = 0\,V$



Using Laplace Transform

$i_1 = -2tu(t) + 2(t-1)u(t-1)$

$$I_1(s) = -\frac{2}{s^2} - \frac{2}{s^2}e^{-s} = -\frac{2}{s^2}[1+e^{-s}]A$$

$i_2(t) = 1.5tu(t) - 1.5u(t-1)$

$$I_2(s) = \frac{1.5}{s} - \frac{1.5}{s}e^{-s} = \frac{1.5}{s}[1-e^{-s}]A$$

$V_{out}(s) = [I_1(s) + I_2(s)]10$

$$= 10\left[-\frac{2}{s^2}[1+e^{-s}] + \frac{1.5}{s}[1-e^{-s}]\right]V$$

06. (b) Consider the circuit given below with the following parameters:

$R_{c_1} = 3K, R_{c_2} = 500\Omega, R_e = 50\Omega, R' = R_s = 1.2K, h_{fe} = 50, h_{ie} = 1.1K$

and $h_{re} = h_{oe} = 0$

Analyze the circuit for —

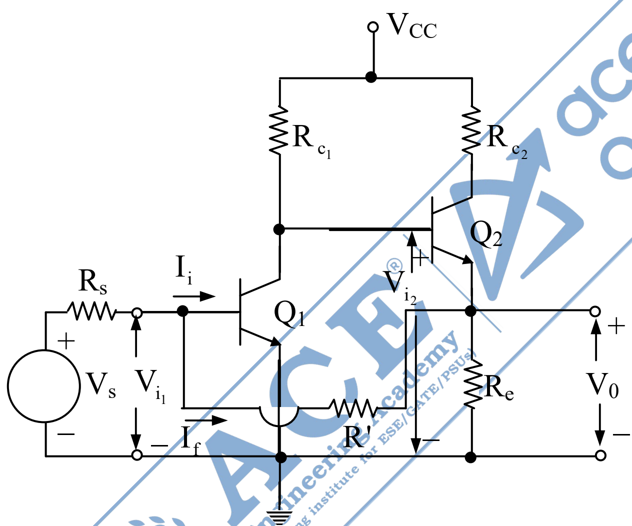
(i) reverse transmission factor, β;

(ii) transfer gain;

(iii) voltage gain with feedback;

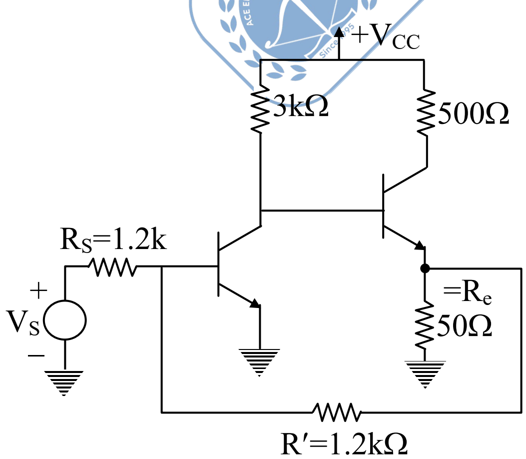
(iv) input resistance with feedback;

(v) output resistance with feedback.



(20 M)

Sol:

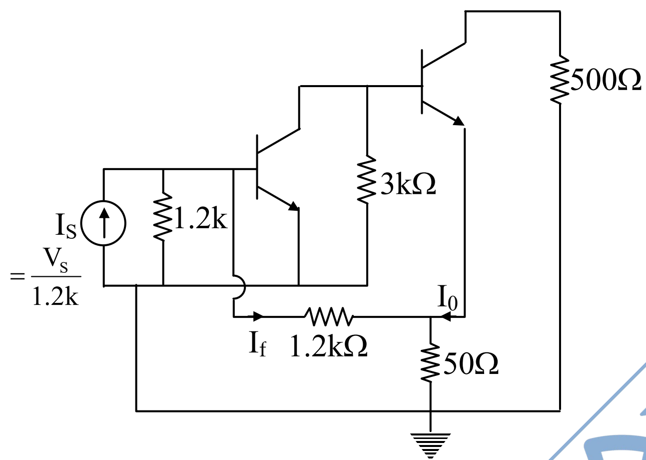


$h_{fe} = \beta = 50$

$h_{ie} = r_\pi = 1.1k\Omega$

$h_{re} = h_{oe} = 0$

The given amplifier is a current amplifier with shunt-series feedback



(i) $i_{b1} = \dfrac{I_S[612.244]}{612.244+110}$

$\dfrac{i_{b1}}{I_S} = \dfrac{612.244}{1712.244} = 0.357568$

(ii) $A_{open} = \dfrac{i_0}{i_s} = \dfrac{i_0}{i_{b2}}.\dfrac{i_{b2}}{i_{b1}}.\dfrac{i_{b1}}{i_s}$

$= (51)\ (-22.9077)\ (0.357568)$

$= -417.7443$

(iii) Desensitivity factor = $1 + A_{open}.\ \beta$

$= 1 + (-417.7443)\ (-0.04)$

$= 17.70977$

(iv) Input resistance with feedback $R_{inf} = \dfrac{R_{in\,open}}{1+A_{open}.\beta} = \dfrac{612.244\,//\,1.1k\Omega}{17.70977}$

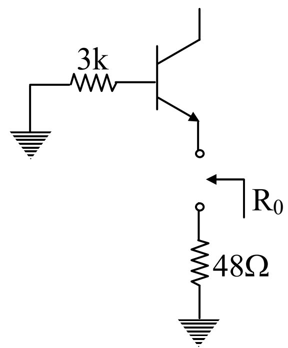
$= \dfrac{393.325}{17.70977} = 22.2094\Omega$

(v) Output resistance with feedback $R_{0f} = R_{0(\text{Basic Amp})}\,[1 + A\beta]$

$$= 128392\ (17.7097)$$

$$R_{0f} = 2273.79\Omega$$

$\because$



$$\underset{(\text{Basic})}{R_o} = \left(\frac{r_\pi}{1+\beta} + \frac{3k}{1+\beta}\right) + 48\Omega$$

$$= \frac{h_{ie}}{1+h_{fe}} + \frac{3k}{1+h_{fe}} + 48\Omega$$

$$= \frac{1.1k}{51} + \frac{3k}{51} + 48$$

$$= 21.568 + 58.82 + 48$$

$$= 128.392$$

Overall current gain with feedback

$$\left(\frac{i_0}{i_{in}}\right) = A_f = \frac{A}{1+A\beta} = \frac{-417.7443}{17.70977} = -23.58835$$

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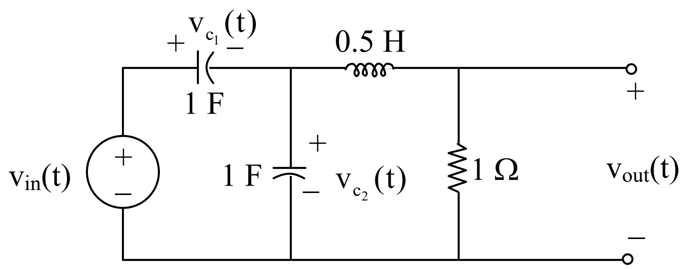
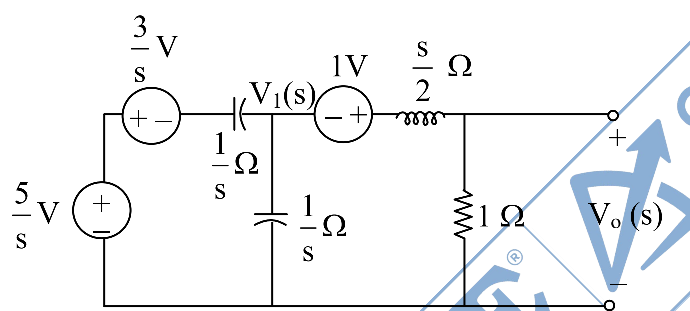
06. (c) Consider the circuit in which $v_{in}(t) = 5u(t)\,V,\ v_{c_1}(0^-) = 3\,V, v_{c_2}(0^-) = 0\,V$ **and** $i_L(0^-) = 2\,A.$

Find $v_{out}(t)$:



(20 M)

Sol: **Using Laplace Transform**



By Nodal

$$\frac{\left[V_1(s) - \frac{5}{s} + \frac{3}{s}\right]}{\frac{1}{s}} + \frac{V_1(s)}{\frac{1}{s}} + \frac{[V_1(s)+1]}{\left[1+\frac{s}{2}\right]} = 0$$

$$V_1(s)\left[s + s + \frac{2}{s+2}\right] = 5 - 3 - \frac{2}{(s+2)}$$

$$V_1(s)\left[\frac{s^2 + 2s + s^2 + 2s + 2}{s+2}\right] = 2 - \frac{2}{s+2} = \frac{2s+4-2}{s+2} = \frac{2s+2}{s+2}$$

$$V_1(s) = \frac{2(s+1)}{2s^2 + 4s + 2} = \frac{2(s+1)}{2(s^2+2s+1)}$$

But

$$V_0(s) = [V_1(s)+1]\left[\frac{1}{1+\frac{s}{2}}\right] = [V_1(s)+1]\left[\frac{2}{s+2}\right]$$

$$V_0(s) = \left[\frac{s+1}{s^2+2s+1}+1\right]\left[\frac{2}{s+2}\right]$$

$$V_0(s) = \left[\frac{s+1+s^2+2s+1}{s^2+2s+1}\right].\left[\frac{2}{s+2}\right]$$

$$V_0(s) = \frac{2(s^2+3s+2)}{(s+2)(s^2+2s+1)} = \frac{2(s+2)(s+1)}{(s+2)(s+1)^2} = \frac{2}{s+1}$$

Do Inverse Laplace transform to get

$$V_0(t) = L^{-1}[V_0(s)]$$

$$V_0(t) = 2e^{-t}u(t) \text{ Volts}$$

07. (a) (i) A first-order thermometer is used for the measurement of temperature of air cycling at a rate of 1 cycle every 5 minutes. The time constant of the thermometer is 20 seconds. Calculate the attenuation of the indicated temperature in percent. If the temperature undergoes a sinusoidal variation of 20 °C, calculate the indicated variation in temperature. (10 M)

Sol: $f = \frac{1}{5\times 60} = \frac{1}{300}\text{Hz}$

$\omega = 2\pi f = 0.02094 \text{ rad/sec}$

$\tau = 20$ sec

$$(AR)\text{ ratio} = \frac{1}{\sqrt{1+(\omega\tau)^2}} = 0.923$$

$\therefore$ Attenuation % = 0.923×100 = 92.3 %

Indicated amplitude = (AR) × 20 = 0.923 × 20 = 18.46 ^{o}C

07. (a) (ii) Compare and contrast Type-1 and Type-II superconductors based on the following parameters:

(1) Magnetic field behaviour

(2) Critical magnetic field

(3) Material examples

(4) Meissner effect

(5) Applications. **(10 M)**

Sol: Comparison: Type-I vs Type-II Superconductors

Parameter	Type-I Superconductors	Type-II Superconductors
1. Magnetic field behaviour	Exhibit perfect diamagnetism (complete expulsion of magnetic field) below critical field. Transition is abrupt.	Allow partial penetration of magnetic field through vortex state between two critical fields.
2. Critical magnetic field (Bc)	Have a single critical magnetic field (Bc). Superconductivity is lost completely above this value.	Have two critical fields: lower (Bc1) and upper (Bc2). Between Bc1 and Bc2, mixed state exists.
3. Material examples	Elements like Lead (Pb), Mercury (Hg), Tin (Sn), Aluminium (Al).	Alloys and complex oxides like Niobium-Titanium (NbTi), YBCO (Yttrium Barium Copper Oxide).
4. Meissner effect	Show **complete Meissner effect** (perfect expulsion of magnetic field).	Show **partial Meissner effect** in the mixed state. Magnetic flux penetrates in quantized vortices.
5. Applications	Limited use due to low critical magnetic fields and current density.	Widely used in magnets, MRI, particle accelerators due to high critical fields and current capacity.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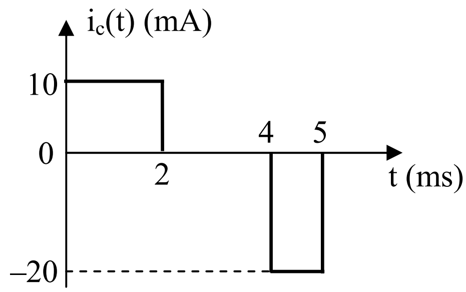
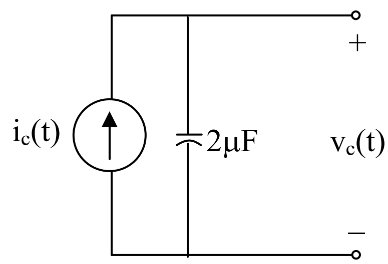
07. (b) The current through a 2 μF capacitor is shown in the figure. At t = 0, the voltage is zero. Sketch the voltage and power waveform with respect to the time (scaled voltage and power):





(20 M)

Sol: $V_c(t) = V(0) + \frac{1}{C}\int i(t)dt \text{ V}$

$0 \le t \le 2$ msec

$$V_c(t) = V(0) + \frac{1}{2\mu}\int_0^{2m} 10\,m\ dt$$

$$= 0 + \frac{10\,m}{2\,\mu}.t\Big|_0^{2m}$$

So, at $t = 0 \rightarrow V_c = 0$ V
at $t = 2m \rightarrow V_c = 10$ V } Ramp Voltage

$2m \le t \le 4$ m

$$V_c(t) = V(0) + \frac{1}{2\mu}\int_{2m}^{4m} 0\ dt$$

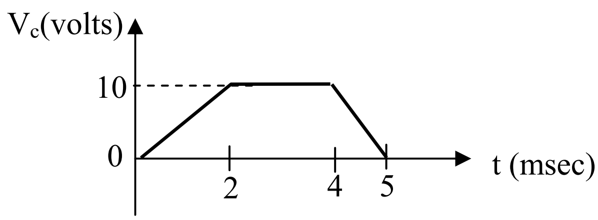
Voltage remains at 10 Volts

$4m \le t \le 5$ msec

$$V_c(t) = V(0) + \frac{1}{2\mu}\int_{4m}^{5m} -20\,m\,dt$$

$$= 10 - \frac{20\,m}{2\,\mu}.t\Big|_{4m}^{5m}$$

So, at $t = 4m \rightarrow V_c = 10$ V
at $t = 5m \rightarrow V_c = 0$ V
} Ramp function

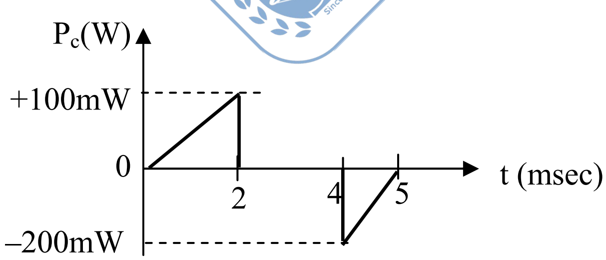


$$P_c(t) = V_c(t)i_c(t)\ W$$

$0 \le t \le 2$ m
at $t = 0 \rightarrow 0W$
at $t = 2m \rightarrow 10V \times 10mW = 100$ mW
} Ramp

$2m \le t \le 4$ m
$\because i_c = 0 \rightarrow P = 0W$

$4m \le t \le 5$ m
at $t = 4m \rightarrow 10\ V \times -20\ m = -200$ mW
at $t = 5m \rightarrow 0\ W$

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AIR 10 ME Ashutosh kumar
AIR 10 ME Jetti Ganateja
AIR 10 ME Pitchika Kumar Vasu
AIR 10 CE Adnan Quasain
& mamy more....

07. (c) (i) A piezoclectric ceramic disc of thickness t = 2mm and area = 1.5×10^{-4} m^2 is subjected to a compressive force of F = 50N applied perpendicular to its faces. The material has the following properties:

- **Piezoelectric coefficient = 300×10^{-12} C/N**
- **Relative permittivity = 1200**
- **Volume permittivity = 8.854×10^{-12} F/m**

Determine the following :

(1) Charge generated on electrodes due to applied force

(2) Capacitance of the piezoelectric disc

(3) Voltage generated across the ceramic disc **(10 M)**

Sol:

Charge $Q = dF = 300\times10^{-12}\times50 = 15\times10^{-9}$ col

$$C = \frac{\varepsilon_0.\varepsilon_R.A}{t} = \frac{8.854\times10^{-12}\times1200\times1.5\times10^{-4}}{0.002} = 7.97\times10^{-10}\text{ F}$$

$$V = \frac{Q}{C} = \frac{15\times10^{-9}}{7.97\times10^{-10}} = 18.8\text{ V}$$

(or)

$$V = \frac{d}{\varepsilon_0\varepsilon_r}\frac{E}{A}t = \frac{300\times10^{-12}}{8.854\times10^{-12}\times1200}\times\frac{50}{1.5\times10^{-4}}\times2\times10^{-3} = 18.8\text{ V}$$

07. (c) (ii) For a 2-port network, express Z-parameters in terms of inverse hybrid parameters. **(10 M)**

Sol: g-parameters

$$I_1 = g_{11}V_1 + g_{12}I_2$$

$$V_2 = g_{21}V_1 + g_{22}I_2$$

Z-parameters

$$V_1 = z_{11}I_1 + z_{12}I_2$$

$$V_2 = z_{21}V_1 + z_{22}I_2$$

For z_{11} & $z_{21} \Rightarrow I_2 = 0$

$I_2 = 0:$

$I_1 = g_{11}V_1 \qquad z_{11} = \frac{V_1}{I_1} = \frac{1}{g_{11}} \quad ----(1)$

$V_2 = g_{21}V_1 \qquad z_{21} = \frac{V_2}{I_1} = \frac{g_{21}}{g_{11}} \quad ----(2)$

For z_{22} & $z_{12} \Rightarrow I_1 = 0$

$I_1 = 0:$

$g_{11}V_1 = -g_{12}I_2$

$V_2 = g_{21}V_1 + g_{22}I_2$

$$V_2 = g_{21}\left[-\frac{g_{12}}{g_{11}}\right]I_2 + g_{22}I_2 = \frac{\Delta g}{g_{11}}I_2$$

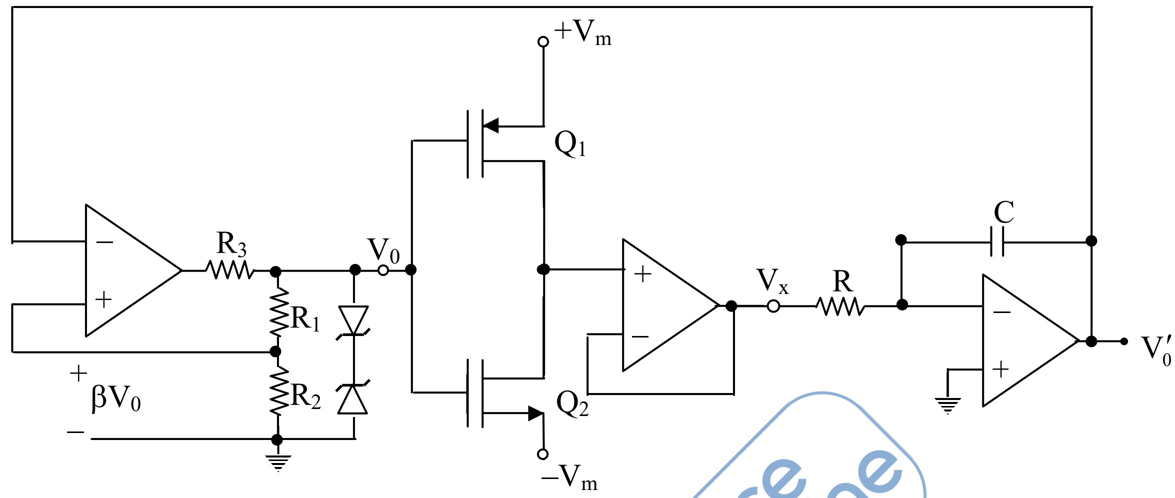
$$z_{22} = \frac{V_2}{I_2} = \frac{\Delta g}{g_{11}}$$

$$z_{12} = \frac{V_1}{I_2} = -\frac{g_{12}}{g_{11}}$$

So,

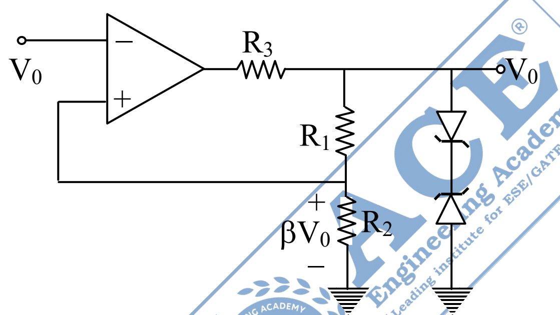
$$[z] = \begin{bmatrix} \frac{1}{g_{11}} & \frac{-g_{12}}{g_{11}} \\ \frac{g_{21}}{g_{11}} & \frac{\Delta g}{g_{11}} \end{bmatrix}$$

08. (a) Explain the working of each stage of the voltage-controlled oscillator circuit shown below :



Evaluate the effect of change in modulating voltage V_m to the output frequency. (20 M)

Sol: **Stage 1:** Schmitt trigger



The given circuit is a Schmitt trigger with positive feedback. So the output V_0 can have two states, $V_z + V_{D_{ON}}$ or $-\left(V_z + V_{D_{ON}}\right)$

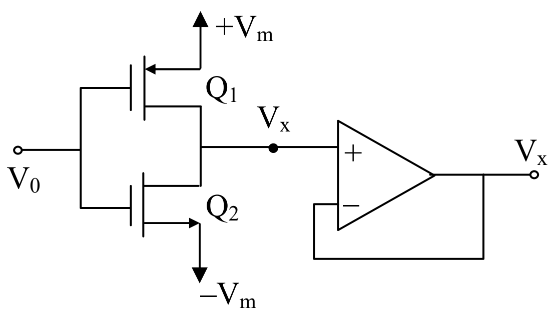
→ The feedback factor $\beta = \dfrac{R_2}{R_1 + R_2}$

So a portion of V_0 which is βV_0 is fed back to the non inverting terminal for comparison

→ If $V_{01} > \beta V_0$ then $V_0 = -\left(V_z + V_{D_{ON}}\right)$

If $V_{01} < \beta V_0$ then $V_0 = +\left(V_z + V_{D_{ON}}\right)$

Stage 2:



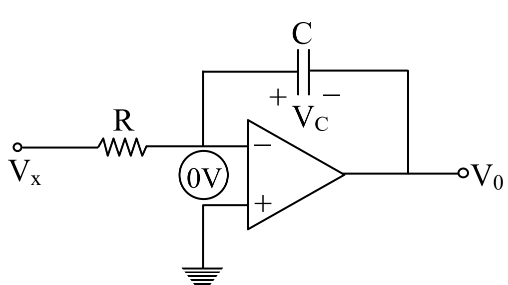
→ The given MOS in the above diagram as used as switch.

→ If $V_0 = V_z + V_{D_{ON}}$ then Q_2 is ON and $V_x = -V_m$

→ If $V_0 = -\left(V_z + V_{D_{ON}}\right)$ then Q_1 is ON and $V_x = +V_m$

→ The buffer (voltage follower) is used for Isolation as it has to drive the (inverting terminal) integrator

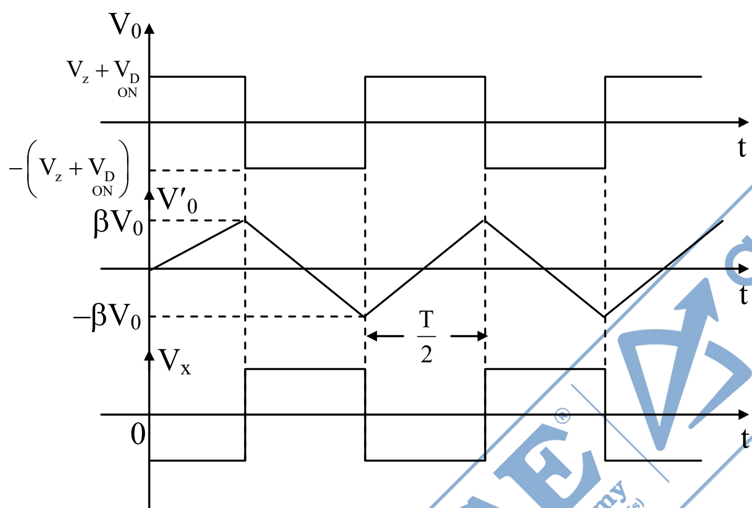
Stage 3: (Integrator)



$\rightarrow$ If $V_x = V_m$ then $V_{01} = \left(\frac{-V_m}{RC}\right)t$ and the output is a negative ramp

$$V_{01} = -V_C = -\frac{1}{C}\int I dt = -\left(\frac{I}{C}\right)t = \left(\frac{-V_m}{RC}\right)t$$

$\rightarrow$ If $V_x = -V_m$ then $V_{01} = \left(\frac{V_m}{RC}\right)t$ then output is a positive ramp



Calculation of frequency

$$slope = \frac{\Delta y}{\Delta x}$$

$$\frac{V_m}{RC} = \frac{\beta V_0 - (-\beta V_0)}{\left(\frac{T}{2}\right)}$$

$$\frac{V_m}{RC} = \frac{4\beta V_0}{T}$$

$$\rightarrow \frac{1}{T} = f = \frac{V_m}{4\beta V_0 RC}$$

Sub $\beta = \frac{R_2}{R_1 + R_2}$ and $V_0 = V_z + V_{D_{ON}}$

$$\therefore f = \frac{V_m (R_1 + R_2)}{4R_2 RC\left(V_z + V_{D_{ON}}\right)}$$

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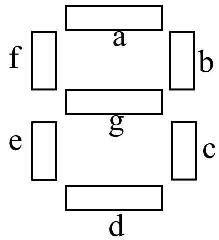
TOTAL 36 SELECTIONS IN TOP 10 CE: 09 | ME: 10 | EE: 08 | E&T: 09

08. (b) Use a decoder to design a binary-to-hexadecimal character generator. The outputs of the character generator are to be connected via current limiting resistors to a common anode seven-segment display. Assume that the inputs are positive logic signals. (20 M)

Sol: Binary to hexa character generation with 7 segment display.



	B_3	B_2	B_1	B_0	a b c d e f g
0	0	0	0	0	1 1 1 1 1 1 0
1	0	0	0	1	0 1 1 0 0 0 0
2	0	0	1	0	1 1 0 1 1 0 1
3	0	0	1	1	1 1 1 1 0 0 1
4	0	1	0	0	0 1 1 0 0 1 1
5	0	1	0	1	1 0 1 1 0 1 1
6	0	1	1	0	1 0 1 1 1 1 1
7	0	1	1	1	1 1 1 0 0 0 0
8	1	0	0	0	1 1 1 1 1 1 1
9	1	0	0	1	1 1 1 0 1 1 1
10	1	0	1	0	1 1 1 1 0 1 1
11	1	0	1	1	1 1 1 1 1 1 1
12	1	1	0	0	0 0 0 1 1 1 0
13	1	1	0	1	1 1 1 1 1 1 0
14	1	1	1	0	1 0 0 1 1 1 1
15	1	1	1	1	1 0 0 0 1 1 1

$a = \Sigma m(0,2,3,5,6,7,8,9,10,11,13,14,15)$

$b = \Sigma m(0,1,2,3,4,7,8,9,10,11,13)$

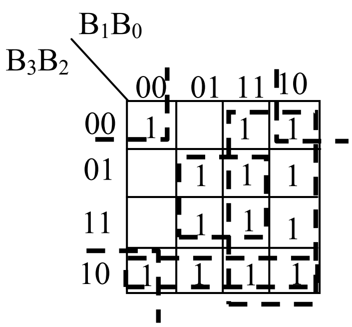
$c = \Sigma m(0,1,3,4,5,6,7,8,9,10,11,13)$

$d = \Sigma m(0,2,3,5,6,8,10,11,12,13,14)$

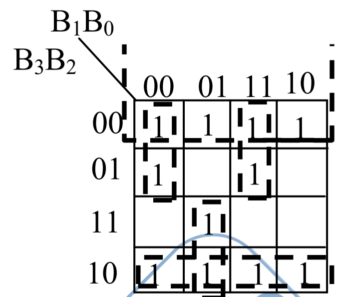
$e = \Sigma m(0,2,6,8,9,11,12,13,14,15)$

$f = \Sigma m(0,4,5,6,8,9,10,11,12,13,14,15)$

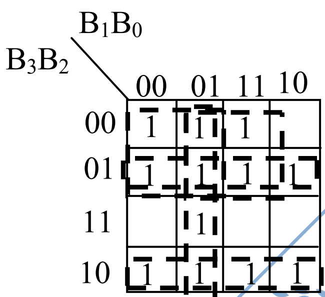
$g = \Sigma m(2,3,4,5,6,8,9,10,11,14,15)$



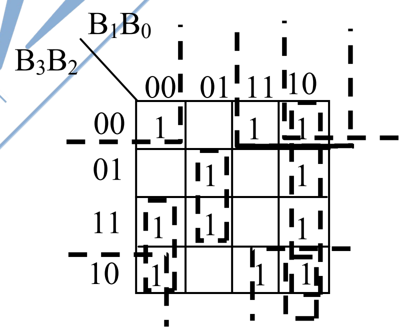
$a = B_1 + B_2B_0 + B_3\overline{B}_2 + \overline{B}_2\overline{B}_0$



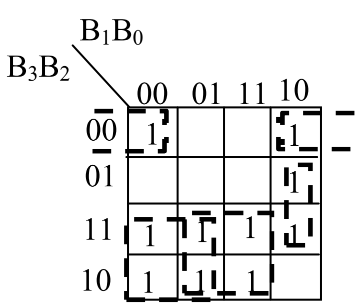
$b = \overline{B}_2 + \overline{B}_3\overline{B}_1\overline{B}_0 + \overline{B}_3B_1B_0 + B_3\overline{B}_1B_0$



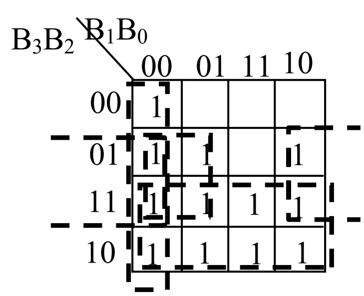
$c = \overline{B}_3B_2 + B_3\overline{B}_2 + \overline{B}_3\overline{B}_0 + \overline{B}_3B_0 + B_1\overline{B}_0$



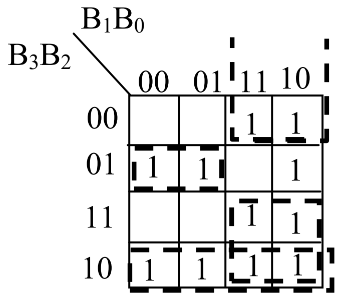
$d = \overline{B}_1\overline{B}_0 + \overline{B}_2B_1 + \overline{B}_2\overline{B}_0 + B_3\overline{B}_1\overline{B}_0 + B_2\overline{B}_1B_0$



$e = B_3\overline{B}_1 + B_3B_0 + B_2B_1\overline{B}_0 + \overline{B}_3\overline{B}_2\overline{B}_0$



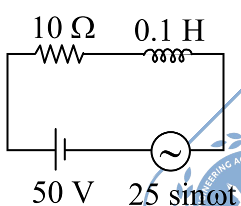
$f = B_3 + B_1\overline{B}_0 + B_2\overline{B}_1 + B_2\overline{B}_0$



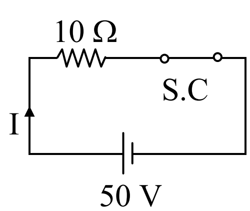
$$g = B_3\overline{B}_2 + B_1\overline{B}_0 + B_3B_1 + \overline{B}_2B_1 + \overline{B}_3B_2\overline{B}_1$$

08. (c) (i) A voltage 50 + 25sinωt volts is applied to a series R-L circuit having a resistance of 10 Ω and inductance of 0.1 H. A wattmeter is connected in the circuit to measure power. Calculate the reading of the wattmeter if ω = 100 π rad/s. **(10 M)**

Sol:



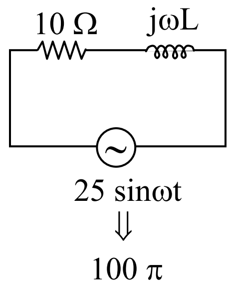
DC:



$$I = \frac{50}{10} = 5\,A$$

$$P_{dc} = I^2R = (5)^2 10 = 250\ W$$

AC:



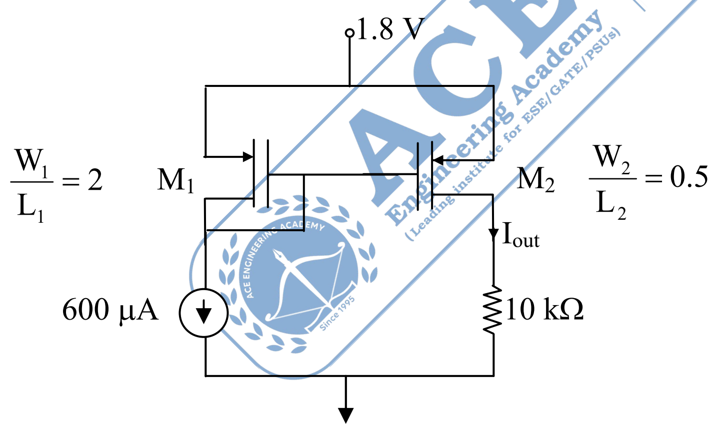
$j\omega L = 100\pi\,(0.1) = 10\pi = 31.4\ \Omega$

$$I_{rms} = \frac{V_m/\sqrt{2}}{z} = \frac{25/\sqrt{2}}{10 + j31.4} = 0.5355\angle -72.366\ A$$

$$P_{ac} = (0.5355)^2 10 = 2.8676\ W$$

$$\therefore\ P_{Total} = P_{dc} + P_{ac} = 250 + 2.8676 = 252.8676\ W$$

08. (c) (ii) For the circuit shown in the figure, find I_{out}. Assume $\mu_n C_{ox} = 250\,\mu A/V^2$ and $V_{tn} = 0.4\,V$ for both the MOSFETs: (10 M)



Sol: Circuit given is a current mirror

$$\frac{I_{out}}{\left(\frac{W}{L}\right)_2} = \frac{I_{in}}{\left(\frac{W}{L}\right)_1}$$

$$I_{out} = \frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1}.I_{in} = \left(\frac{0.5}{2}\right)600\mu \ = 150\mu A$$