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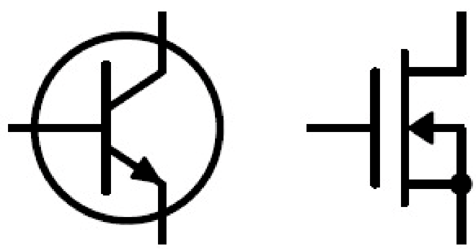
Analog Circuits

Text Book : Theory with worked out Examples and Practice Questions



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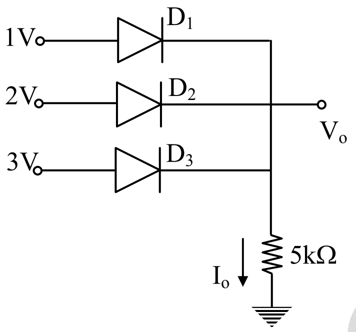
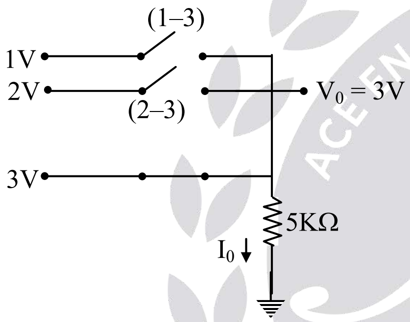
Analog Circuits

(Solutions for Text Book Practice Questions)

01.
Sol:



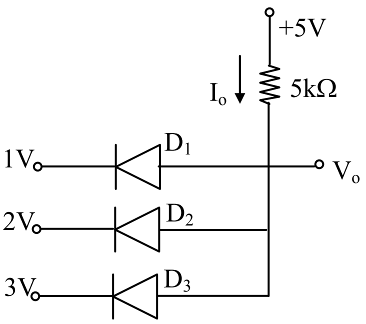


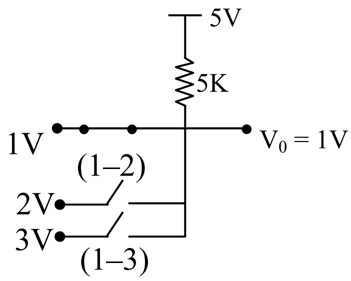
⇒ D_1, D_2 are reverse biased and D_3 is forward biased.

i.e., D_3 only conducts.

∴ $I_0 = 3/5K = 0.6mA$

02.
Sol:





⇒ D_2 & D_3 are reverse biased and 'D_1' is forward biased.

i.e., D_1 only conduct

$$\therefore I_0 = \frac{5-1}{5K} = 0.8mA$$

03.
Sol: Let diodes D_1 & D_2 are forward biased.

⇒ $V_0 = 0$ volt

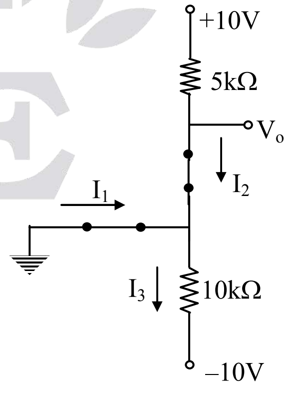
$$I_2 = \frac{10-0}{5K} = 2mA$$

$$I_3 = \frac{0-(-10)}{10K} = 1mA$$

Apply KVL at nodes 'V_0':

$-I_1 + I_3 - I_2 = 0$

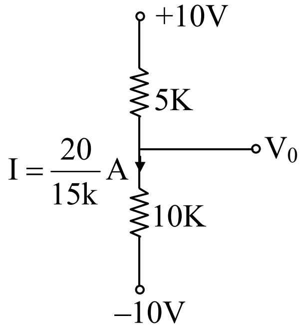
$\Rightarrow I_1 = -(I_2 - I_3) = -1mA$



So, D_1 is reverse biased & D_2 is forward biased

⇒ 'D_1' act as an open circuit & D_2 is act as short circuit.

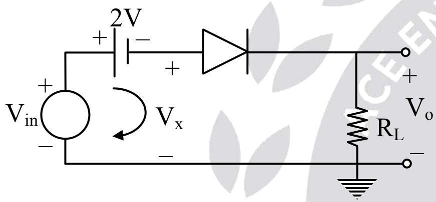
Then circuit becomes



$$\Rightarrow V_0 = 10k \times \left(\frac{20}{15k}\right) - 10$$

$\therefore$ $V_0 = 3.33V$

04.
Sol:



Apply KVL to the loop:

$V_{in} - 2 - V_x = 0$

$\Rightarrow V_x = V_{in} - 2$ ----- (1)

Given, V_{in} range = –5V to 5V

$\Rightarrow V_x$ range = –7V to 3V [$\because$ from eq (1)]

Diode ON for $V_x > 0V$

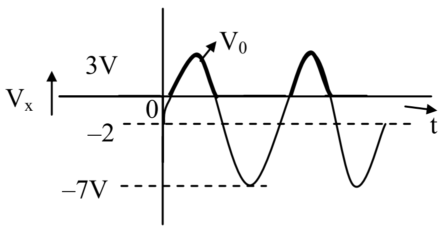
$\Rightarrow V_0 = V_x$

Diode OFF for $V_x < 0V$

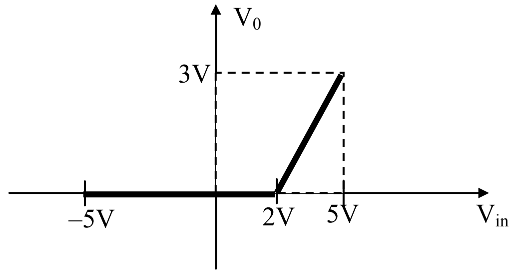
$\Rightarrow V_0 = 0$ V

$\therefore V_0$ range = 0 to 3V

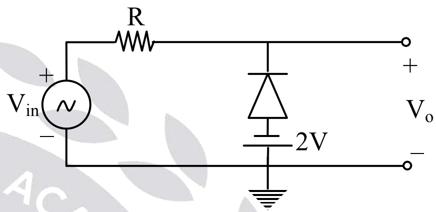
Output wave form:



Transfer characteristics:



05.
Sol:

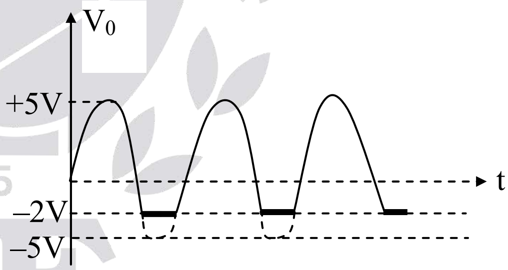


For $V_i < -2$Volt, Diode ON

$\Rightarrow V_0 = -2$Volt

For $V_i > -2$Volt, Diode OFF

$\Rightarrow V_0 = V_i$



06.

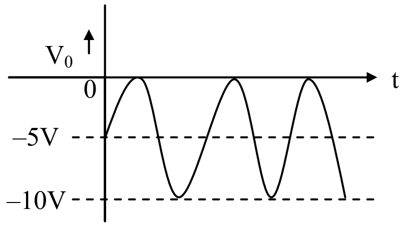
Sol: For positive half cycle diode Forward biased and Capacitor start charging towards peak value.

$\Rightarrow V_C = V_m = 5V$

$\Rightarrow V_0 = V_{in} - V_C = V_{in} - 5$

V_{in} range = – 5V to +5V

$\therefore$ V_0 range = – 10V to 0V



07.

Sol: For +ve cycle, diode 'ON', then capacitor starts charging

$\Rightarrow V_C = V_m - 7 = 10 - 7 = 3V$

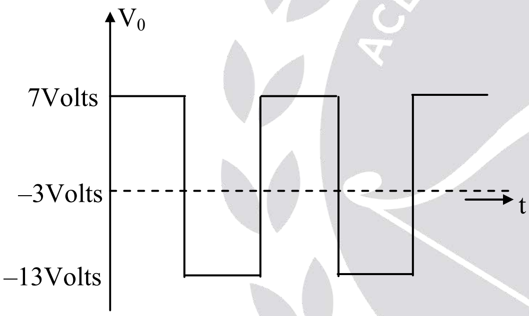
Now diode OFF for rest of cycle

$\Rightarrow V_0 = -V_C + V_{in}$

$= V_{in} - 3$

V_{in} range : –10V to +10V

$\therefore$ V_0 range: –13V to 7V



08.

Sol: Always start the analysis of clamping circuit with that part of the cycle that will forward bias the diodes this diode is forward bias during negative cycle.

For negative cycle diode ON, then capacitor starts charging

$\Rightarrow V_C = V_P + 9$

$= 12 + 9 = 21V$

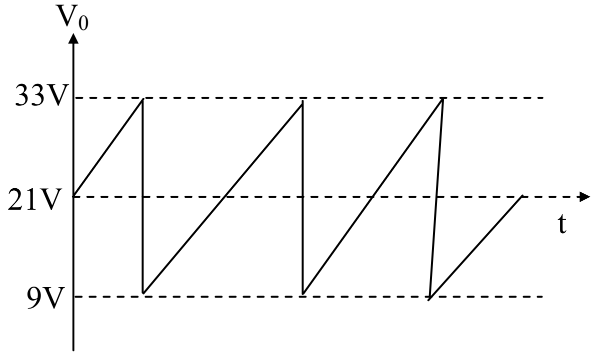
Now diode OFF for rest of cycle.

$\Rightarrow V_0 = V_C + V_{in}$

$= 21 + V_{in}$

V_{in} range: –12 to +12V

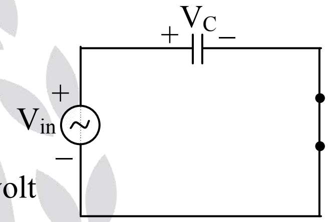
V_0 range: 9V to 33V



09.

Sol: During positive cycle,

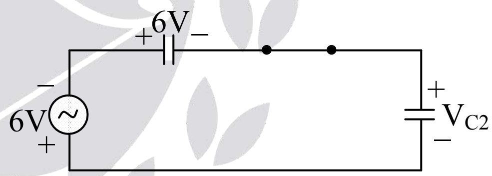
D_1 forward biased & D_2 Reverse biased.



$V_{C_1} = V_{in} = 6$volt

During negative cycle,

D_1 reverse biased & D_2 forward biased.

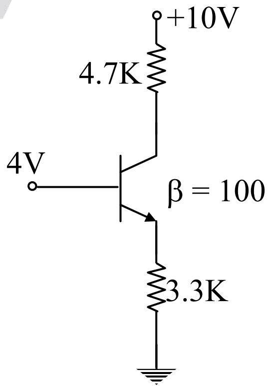


$V_{C2} = -6 - 6 = -12V$

Capacitor C_2 will charge to negative voltage of magnitude 12V

10.

Sol:



Given,

$V_B = 4V$

$V_{BE} = 0.7$

$V_B - V_E = 0.7$

$V_E = V_B - 7 = 3.3V$

$\Rightarrow I_E = \dfrac{3.3}{3.3K\Omega} = 1mA$

Let transisotr in active region

$\Rightarrow I_C = \beta/(\beta+1) \cdot I_E = 0.99mA$

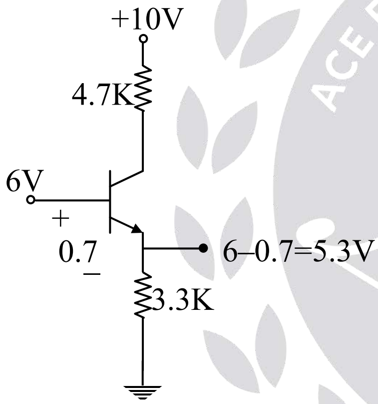
$I_B = I_C/\beta = 9.9\mu A$

$V_C = 10 - 4.7\times10^3\times0.99\times10^{-3} = 5.347V$

$\Rightarrow V_C > V_B$

$\therefore$ Transistor in the active region.

11.
Sol:



$V_E = V_B - V_{BE} = 6 - 0.7 = 5.3V$

$I_E = \dfrac{5.3}{3.3K} = 1.6mA$

Let transistor is active region

$\Rightarrow I_C = \dfrac{\beta}{(1+\beta)} I_E$

$I_C = 1.59mA$

$V_C = 2.55V$

$\Rightarrow V_C < V_B$

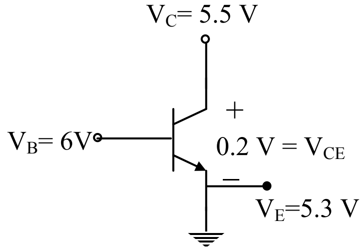
$\therefore$ Transistor in saturation region

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

$V_C - V_E = 0.2$

$V_C = 5.3+0.2$

$\Rightarrow V_C = 5.5V$



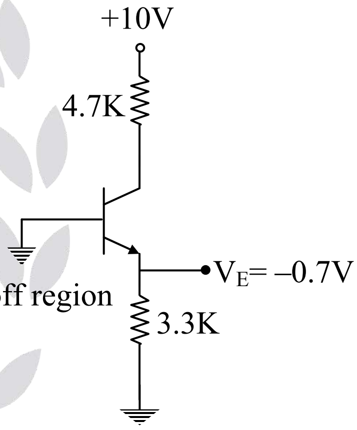
$\Rightarrow I_C = \dfrac{10-5.5}{4.7K} = 0.957mA$

$I_B = 1.6 - 0.957 = 0.643mA$

$\beta = \dfrac{I_C}{I_B} = \dfrac{0.957\ mA}{0.643\,mA} = 1.483$

$\beta_{forced} < \beta_{active}$

12.
Sol:



$V_E = -0.7V$

Transistor in cut off region

$I_C = I_B = I_E = 0A$

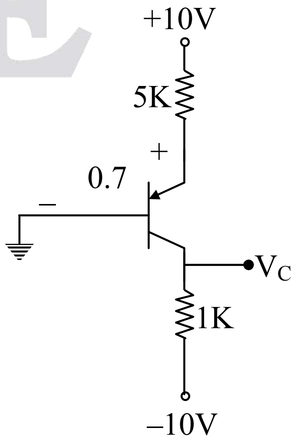
$V_{CE} = 10V$

$V_E = 0V$

$V_C = 10V$

$V_B = 0V$

13.
Sol:



$V_E = 0.7V$ [$\because V_B = 0V$]

$\Rightarrow I_E = \dfrac{10 - 0.7}{5K} = 1.86mA$

Let transistor in active region.

$\Rightarrow I_C = \dfrac{\beta}{(\beta+1)} I_E = 1.84mA$

$\Rightarrow V_C = -10 + 1K \times 1.84m$

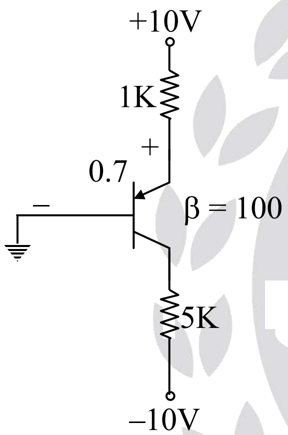
$V_C = -8.16V$

$V_{EC} = V_E - V_C = 8.86V$

$V_{EC} > V_{EB}$

$\therefore$ Transistor in active region

14.
Sol:



Let transistor in active region

$V_E = 0.7V$ [$\because V_B = 0V$]

$I_E = \dfrac{10 - 0.7}{1k} = 9.3mA$

$I_C = \dfrac{\beta}{\beta+1}.I_E = 9.2mA$

$\Rightarrow V_C = -10 + 5K \times 9.2m$

$V_C = 36V$

$V_{EC} < V_{EB}$

Transistor in saturation region

$\Rightarrow V_{EC} = 0.2$

$V_E - V_C = 0.2 \Rightarrow V_C = 0.5V$

$\Rightarrow I_C = \dfrac{0.5 + 10}{5K} = 2.1mA$

$I_B = I_E - I_C = 7.2mA$

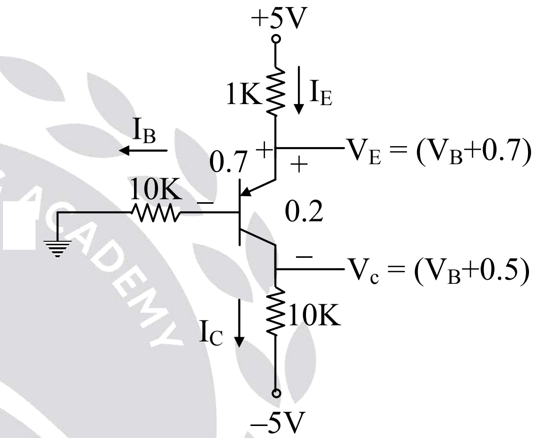
$\beta_{forced} = \dfrac{I_{c(sat)}}{I_B}$

$= \dfrac{2.1}{7.2}$

$= 0.29$

$\beta_{forced} < \beta_{active}$ i.e., saturation region

15.
Sol:



$I_E = I_C + I_B$

$\Rightarrow \dfrac{5 - (V_B + 0.7)}{1k} = \dfrac{(V_B + 0.5) + 5}{10k} + \dfrac{V_B}{10k}$

$10(5 - V_B - 0.7) = V_B + 0.5 + 5 + V_B$

$43 - 10V_B = 2V_B + 5.5$

$V_B = \dfrac{43 - 5.5}{12} = 3.125V$

$I_B = \dfrac{3.125}{10K} = 0.3125mA$

$V_C = V_B + 0.5 = 3.625V$

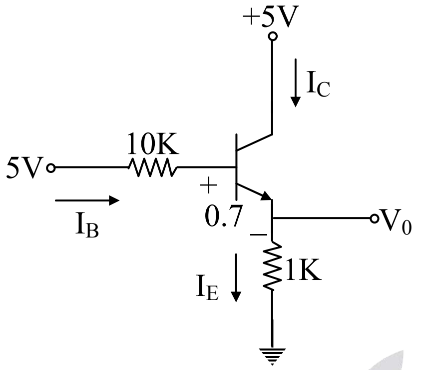
$V_E = 3.825V$

$\therefore I_E = 1.175mA$

$\therefore I_C = 0.862mA$

16.

Sol: Here the lower transistor (PNP) is in cut off region.



Apply KVL to the base emitter loop:

$5 - 10K.\ I_B - 0.7 - 1K.\ (1+\beta)I_B = 0$

$\Rightarrow I_B = \dfrac{4.3}{(101)K + 10K}$

$= 38.73\mu A$

$I_C = 3.87mA$

$I_E = 3.91mA$

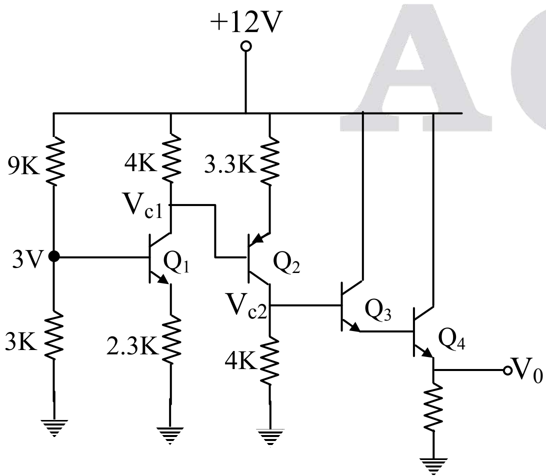
$\Rightarrow V_E = V_0 = I_E(1k) = 3.91\ V$

$V_C = 5V$

$V_B = 5 - 10\ k\ (I_B) = 4.61\ V$

17.

Sol:



$$I_{C_1} = I_{\varepsilon_1} = \frac{2.3V}{2.3k} = 1m\,Amp$$

$$V_{C_1} = 12V - 4\times10^3 \times 1\times10^{-3} = 8V$$

$$V_{\varepsilon_2} = 8 + 0.7V = 8.7V$$

$$I_{\varepsilon_2} = \frac{12V - V_{\varepsilon 2}}{3.3k} = \frac{12V - 8.7}{3.3k} = 1m\,Amp$$

$$V_{C_2} = 4k\times 1mA = 4V$$

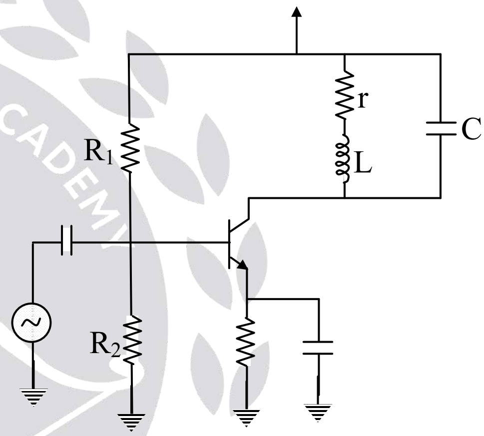
$$V_{\varepsilon 3} = 4V - 0.7 = 3.3V$$

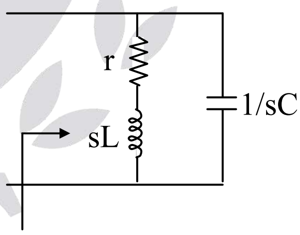
$$V_{\varepsilon_4} = 3.3 - 0.7 = 2.6V$$

$V_0 = 2.6\ V$

18.

Sol:





$$Z_{eq} = \frac{1}{sC + \dfrac{1}{r + sL}}$$

$$= \frac{r + sL}{srC + s^2LC + 1}$$

$$= \frac{r + j\omega L}{(1 - \omega^2 LC) + j\omega rC}$$

$$Z_{eq} = \frac{(r + j\omega L)\left[1 - \omega^2 LC - j\omega rC\right]}{\left(1 - \omega^2 LC\right)^2 + \left(\omega rC\right)^2}$$

$$= \frac{\omega^2 rLC + r - \omega^2 rLC + j\omega L[1-\omega^2 LC] - j\omega r^2 C}{(1-\omega^2 LC)^2 + (\omega rC)^2}$$

Equate Imaginary terms:

$\omega L - \omega^3 L^2 C - \omega r^2 C = 0$

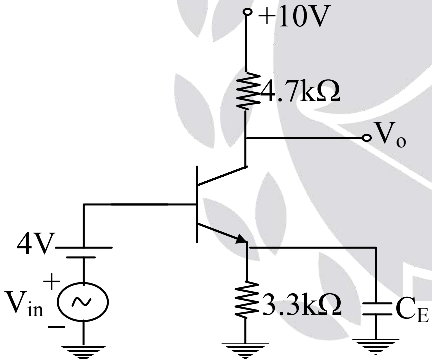
$L - \omega^2 L^2 C - r^2 C = 0$

$\omega^2 L^2 C = L - r^2 C$

$$\omega = \sqrt{\frac{1}{LC} - \frac{r^2 C}{L^2 C}}$$

$$\omega = \sqrt{\frac{1}{LC} - \left(\frac{r}{L}\right)^2}$$

19.
Sol:



For D.C Analysis:

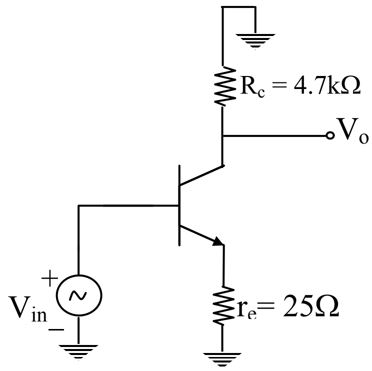
$V_B = 4$ V

$V_B - V_E = 0.7 \Rightarrow V_E = 4 - 0.7 = 3.3$ V

$$I_E = \frac{3.3}{3.3k} = 1\text{mA}$$

$$r_e = \frac{V_T}{I_E} = \frac{25\,\text{mV}}{1\text{mA}} = 25\,\Omega$$

To apply small signal analysis set D.C source equal to zero.



$\Rightarrow V_0 = -i_c R_c$

$V_{in} = i_b r_\pi = i_b \beta r_e = i_c r_e$

$$\therefore A_V = \frac{V_0}{V_i}$$

$$= \frac{-i_c R_c}{i_c r_e} = \frac{-R_c}{r_e} = \frac{-4.7\,k}{25}$$

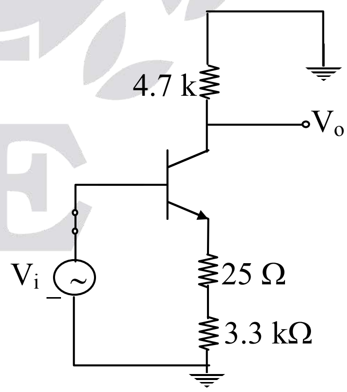
$= -188$

20.
Sol: D.C calculation is same as previous question

$I_E = 1$ mA

$r_e = 25\ \Omega$

Apply small signal analysis:



$$\frac{V_0}{V_i} = \frac{-R_c}{r_e + R_E} = \frac{-4700}{25 + 3300}$$

$$\therefore A_V = \frac{V_0}{V_i} = -1.413$$

21.

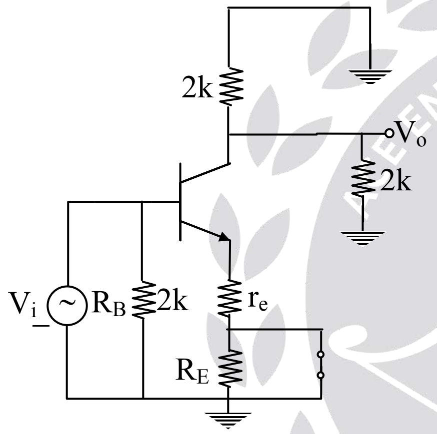
Sol: To calculate r_e value apply D.C analysis

$$I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta + 1}}$$

$$= \frac{3 - 0.7}{2.3k + \frac{2k}{101}} = 0.991mA$$

$$r_e = \frac{V_T}{I_E} = \frac{25}{0.991} = 25.22\Omega$$

Now apply small signal analysis:



$$A_V = \frac{V_0}{V_i} = \frac{-R_C}{r_e} = \frac{-(2k \parallel 2k)}{25.22} = -39.65$$

$R_i = R_B \parallel \beta r_e$

$R_i = 1.116k\Omega$

$$A_I = \frac{i_0}{i_i} = \frac{V_0}{R_L} \times \frac{R_i}{V_i} = A_V \times \frac{R_i}{R_L}$$

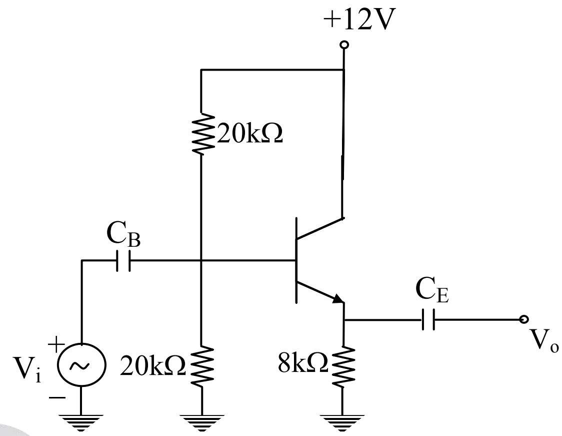
$$= \frac{-39.5 \times 1.116 \times 10^3}{2 \times 10^3}$$

$$= -22.322$$

$R_o = R_C = 2k\Omega$

22.

Sol:



Apply KVL at input Loop:

$6 - 10k\,(I_B) - 0.7 - 8\,k(1+\beta)I_B = 0$

$$I_B = \frac{6 - 0.7}{10k + 8k \times 101} = 6.47\,\mu A$$

$I_E = 0.65$ mA

$$r_e = \frac{V_T}{I_E} = \frac{25}{0.65} = 38.5\,\Omega$$

Apply small signal analysis

$$A_v = \frac{V_0}{V_i} = \frac{R_E}{r_e + R_E}$$

$= 0.995$

$R_i = R_B \parallel \beta R_{E_{Total}}$

$R_{E_{Total}} = (R_E + r_e)$

$R_i = 10\,k \parallel 803.85k$

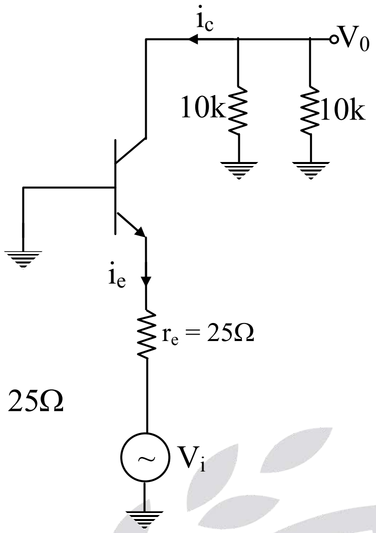
$= 9.87\,k\Omega$

$R_0 = R_E \parallel r_e = 38.3\,\Omega$

23.

Sol: $V_0 = -i_c R_C$

$$i_e \approx i_c = \frac{-V_i}{r_e}$$



$$V_0 = \left(\frac{V_i}{r_e}\right) R_C$$

$$\frac{V_0}{V_i} = \frac{R_C}{r_e}$$

Given $I_E = 1mA$

$$\Rightarrow r_e = \frac{25mV}{1mA} = 25\Omega$$

$$A_V = \frac{R_C}{re}$$

$$A_V = \frac{10k // 10k}{25} = \frac{5000}{25} = 200$$

$$R_0 = R_C = 10k\Omega$$

$$R_i = r_e = 25\Omega$$

$$A_I = \frac{i_0}{i_i} = \frac{v_0}{R_L} \times \frac{R_i}{v_i}$$

$$= A_V \times \frac{R_i}{R_L} = \frac{200 \times 25}{10^4} = 0.5$$

24.

Sol: For the given differential amplifier,

$I_E = 1mA$

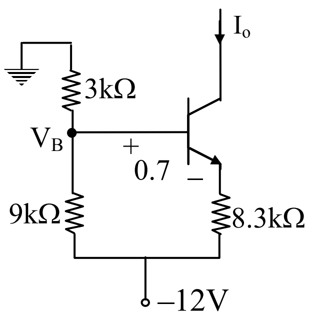
$$r_e = \frac{V_T}{I_E} = 25\Omega$$

$$A_d = \frac{V_0}{V_i} = \frac{-R_c}{r_e} = \frac{-3000}{25} \text{ (or) } -g_m R_c$$

$A_d = -120$

25.

Sol:



$$I_1 = \frac{0-(-12)}{12k} = 1mA$$

$$I_1 = \frac{0 - V_B}{3K}$$

$V_B = -3V$

$V_B - V_E = 0.7$

$V_E = V_B - 0.7$

$V_E = -3.7$ Volt

$$I_0 = \frac{-3.7 + 12}{8.3k}$$

$$I_o = 1mA$$

$$I_E = 0.5mA$$

$$r_e = \frac{25mV}{0.5mA} = 50\Omega$$

$$A_d = \frac{-R_C}{r_e} = \frac{-2000}{50}$$

$$A_d = -40$$

26.

Sol: Voltage shunt feedback amplifier and

$$\frac{V_0}{V_{in}} = \frac{-R_f}{R_S} = \frac{-10k}{1k} \approx -10$$

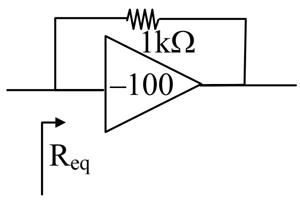
27.

Sol: Current – series feedback amplifier and

$$A_V \approx \frac{-R_C}{R_E} = \frac{-4.7k}{3.3k} = 1.4242$$

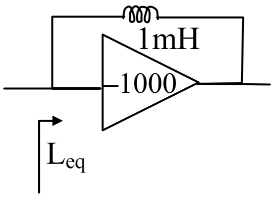
28.

Sol:



Using millers effect,

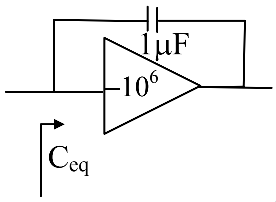
$$R_{eq} = \frac{1k}{1+100} = 9.9\Omega$$



$$L_{eq} = \frac{1mH}{1+1000} \approx 1\mu H$$

29.

Sol:



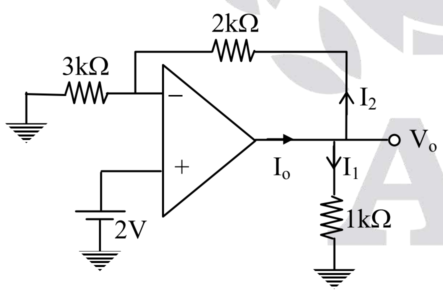
$$C_{eq} = 1\mu F\left(1+10^6\right) \approx 1F$$

30.

Sol: $V_0 = \left(1+\frac{R_f}{R_1}\right)V_i$

$$V_0 = \left(1+\frac{2k}{3k}\right)2$$

$$V_0 = \frac{10}{3}\text{volt}$$



$$I_1 = \frac{V_0}{1k} = \frac{10}{3}mA \ \&$$

$$I_2 = \frac{V_0-2}{2k} = \frac{\frac{10}{3}-2}{2k} = \frac{2}{3}mA$$

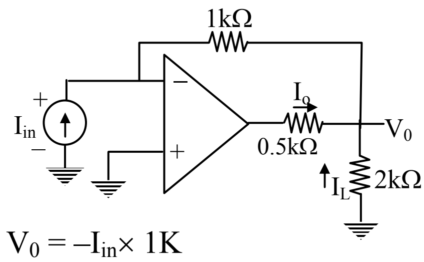
$$\therefore I_0 = I_1 + I_2 = 4mA$$

31.

Sol: $V_0 = \frac{-R_2}{R_1}V_{in}$

32.

Sol:



$$V_0 = -I_{in}\times 1K$$

$$I_L = \frac{I_i\times 1K}{2K} = \frac{I_{in}}{2}$$

$$I_0 + I_{in} + I_L = 0$$

$$I_0 + I_{in} + \frac{I_{in}}{2} = 0$$

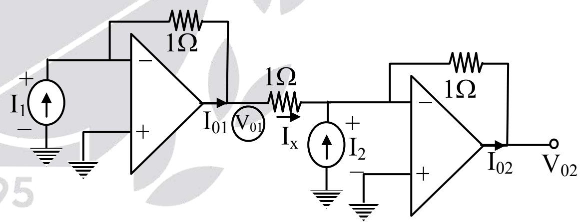
$$2I_0 + 2I_{in} + I_{in} = 0$$

$$2I_0 = -3I_{in}$$

$$\frac{I_0}{I_{in}} = \frac{-3}{2} = -1.5$$

33.

Sol:



$$V_{01} = -I_1$$

Apply KCL:

$$I_x + I_2 = \frac{0-V_{0_2}}{1}$$

$$\frac{V_{01}}{1} + I_2 = -V_{02}$$

$$V_{01} + I_2 = -V_{02}$$

$$-I_1 + I_2 = -V_{02}$$

$$V_{02} = (I_1 - I_2)\text{volt}$$

$$I_{01} + I_1 = I_x$$

$$I_{01} + I_1 = V_{01} \qquad \left[\because I_x = \frac{V_{01}}{1}\right]$$

$$I_{01} = V_{01} - I_1$$

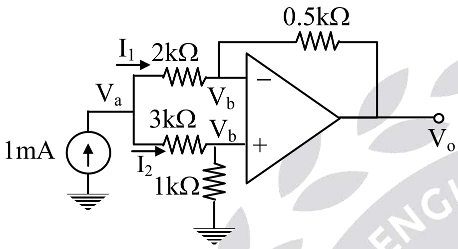
$$I_{01} = -2I_1 \qquad [\because V_{01} = -I_1]$$

$$I_{02} = -(I_2 + I_x)$$

$$I_{02} = -(I_2 + V_{01})$$

$$I_{02} = (I_1 - I_2)A$$

34.
Sol:



Apply KCL at V_a:

$$1m = \frac{V_a - V_b}{2k} + \frac{V_a - V_b}{3K}$$

$$1m = \frac{3V_a - 3V_b + 2V_a - 2V_b}{6k}$$

$$6 = 5V_a - 5V_b$$

$$V_a - V_b = \frac{6}{5}$$

$$V_a - V_b = 1.2\text{Volt}$$

$$I_1 = \frac{V_a - V_b}{2k} = \frac{1.2}{2k} = 0.6\text{mA}$$

$$I_2 = \frac{1.2}{3k} = 0.4\text{mA}$$

$$V_b = 0.4m \times 1k = 0.4 \text{ Volt}$$

$$I_1 = \frac{V_b - V_0}{0.5k}$$

$$0.6m = \frac{0.4 - V_0}{0.5k}$$

$$0.3 = 0.4 - V_0$$

$$\therefore V_0 = 0.1 \text{ Volt}$$

35.

Sol: $V_C = \frac{-I}{C}.t = \frac{-10\times10^{-3}}{10^{-6}}\times0.5\times10^{-3}$

$$V_C = -5\text{Volt}$$

36.

Sol: Given open loop gain = 10

$$\frac{V_0}{V_i} = \frac{\left(1+\frac{R_f}{R_1}\right)}{1+\left(1+\frac{R_f}{R_1}\right)\times\frac{1}{A_{0L}}}$$

$$\frac{V_0}{V_i} = \frac{(1+3)}{1+\frac{4}{10}}$$

$$V_0 = V_i \times \frac{4}{1+\frac{4}{10}}$$

$$V_0 = \frac{2\times4}{1+\frac{4}{10}} = 5.715\text{Volt}$$

37.

Sol: $\frac{V_0}{V_i} = \frac{-R_f/R_1}{1+\frac{(1+R_f/R_1)}{A_{OL}}}$

$$\frac{V_0}{V_i} = \frac{-9}{1+\frac{10}{10}}$$

$$\frac{V_0}{V_i} = \frac{-9}{2}$$

$$V_0 = -4.5\text{Volt}$$

38.

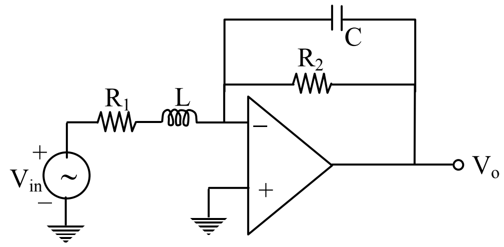
Sol: $SR = 2\pi f_{max} V_{0max}$

$$V_{0\max} = \frac{SR}{2\pi f_{max}} = \frac{10^6}{2\pi\times20\times10^3} = 7.95\text{Volt}$$

$$V_0 = A\times V_i \Rightarrow V_i = \frac{V_0}{A} = 79.5\text{mV}$$

39.

Sol:



$$z_2 = R_2 || \frac{1}{sC} = \frac{R_2}{sCR_2 + 1}$$

$$z_1 = R_1 + sL$$

$$\left|\frac{V_0}{V_i}\right| = \frac{\frac{R_2}{sCR_2+1}}{R_1 + sL}$$

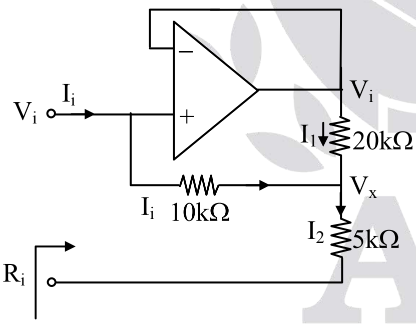
$$\left|\frac{V_0}{V_i}\right| = \frac{R_2}{(sCR_2+1)(R_1+sL)}$$

It represent low pass filter with

D.C gain $= \frac{R_2}{R_1}$

40.

Sol: (i)



Apply KCL at V_x :

$$\frac{V_x}{5k} = I_i + I_1$$

$$\frac{V_x}{5k} = \frac{V_i - V_x}{10k} + \frac{V_i - V_x}{20k}$$

$$\frac{V_x}{5} = \frac{3V_i - 3V_x}{20}$$

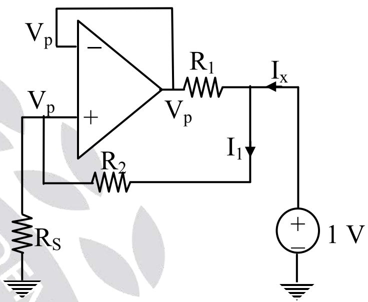
$$V_x = \frac{3}{7}V_i$$

$$I_i = \frac{V_i - V_x}{10k}$$

$$I_i = \frac{V_i - \frac{3}{7}V_i}{10k}$$

$$\frac{V_i}{I_i} = 17.5\,k\Omega$$

(ii)



$$R_0 = \frac{1}{I_x}$$

$$V_p = \frac{R_s}{R_2 + R_s}$$

$$I_x = \frac{1 - V_p}{R_2} + \frac{1 - V_p}{R_1}$$

$$I_x = (1 - V_p)\left(\frac{1}{R_2} + \frac{1}{R_1}\right)$$

$$I_x = \left(1 - \frac{R_s}{R_2 + R_s}\right)\left(\frac{R_1 + R_2}{R_1R_2}\right)$$

$$I_x = \frac{R_2}{R_2 + R_s}\left(\frac{R_1 + R_2}{R_1R_2}\right)$$

$$\therefore R_0 = \frac{1}{I_x} = \left(\frac{R_s + R_2}{R_1 + R_2}\right)R_1$$

41.

Sol: $V_E = V_{in}$

$V_{CE} = V_C - V_E$

$V_{CE} = 15 - V_{in}$

given V_{in} 0 to 5 Volt

$\Rightarrow$Transistor is in active region

$I_E = I_0 = \frac{V_{in}+15}{10} = \frac{17}{10} = 1.7\text{ A}$ $[\because V_{in} = 2V]$

$I_B = \frac{I_0}{1+\beta} = \frac{1.7}{100}$ A

$V_B = V_{in} + 0.7 = 2.7V$

$I_B = \frac{V_{op} - V_B}{100}$

$\frac{V_{op} - 2.7}{100} = \frac{1.7}{100}$

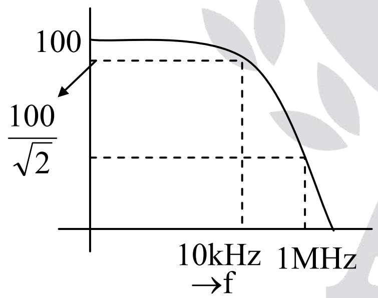
$V_{op} = 4.4$ Volt

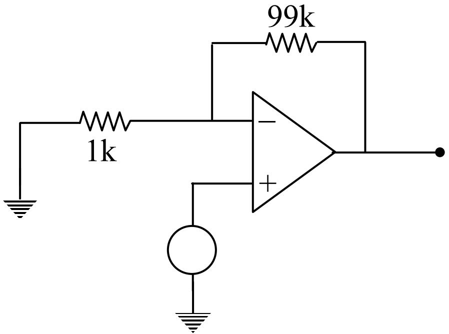
42.

Sol: Single stage:

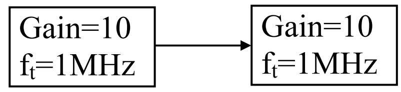
Gain = 40dB = 100, f_T = 1MHz = Gain BW

$$BW \rightarrow f_{3dB} = \frac{f_T}{Gain} = \frac{10^6}{100} = 10kHz$$



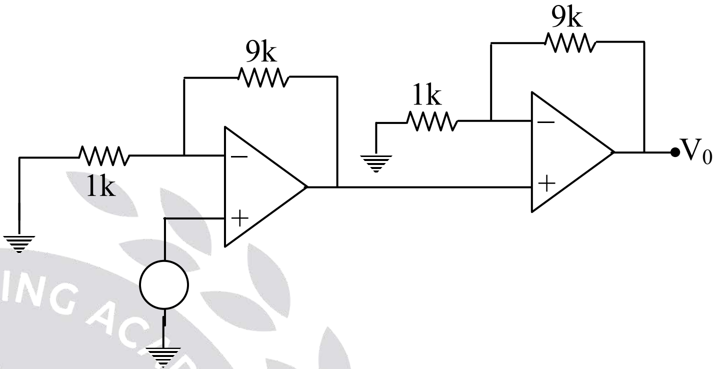


Two stages:



$f_{3dB} = \frac{1M}{10} = 100kHz$, f_{3dB} = 100kHz(for single stage)

Two stages (Overall):



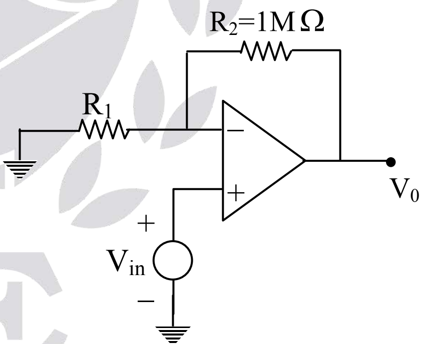
Overall BW = $f_{3dB}\sqrt{2^{1/2}-1}$

= 100k (0.65)

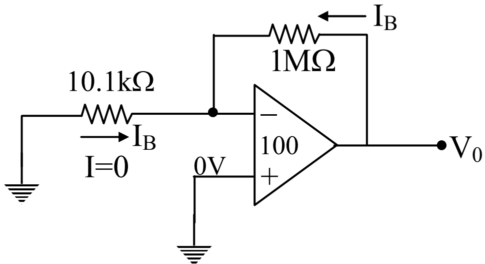
= 65 kHz

43.

Sol: (a)



$$Gain = \frac{V_0}{V_{in}} = 1 + \frac{1M}{R_1} = 100 \Rightarrow R_1 = 10.1k\Omega$$

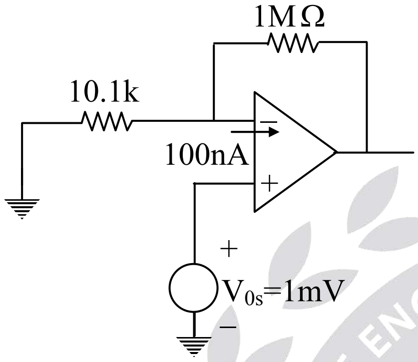


$V_0 = I_B(1M)$
$= 100nA(1M)$
$= 0.1V$

(b)

→ op-amp draws current

→ op-amp CKT the curve doesn't pass through '0' (transfer characteristics)



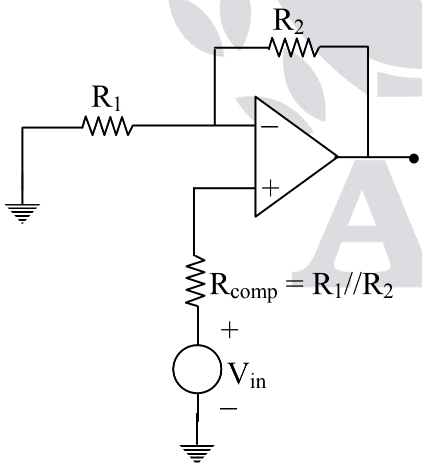
$$V_0 = \left|V_{0_{\text{Bios current}}}\right| + \left|V_{0_{\text{Offset Voltage}}}\right|$$

$$= 1M(I_B) + \left(1 + \frac{R_2}{R_1}\right)V_{os}$$

$= 1M\ (100nA) + 100(1mV)$

$= 0.2V$

(c)



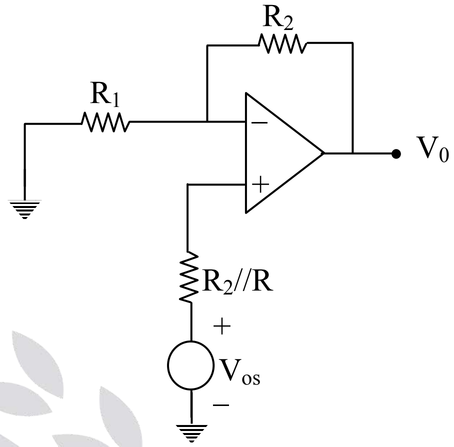
→ $R_{comp} = R_1//R_2$, then $V_0 = (I_{B1} - I_{B2})\ R_2$
$= I_{os}\ R_2$

$V_0 = (I_{B1} - I_{B2})\ R_2$
$= I_{os}\ R_2$
$= 1/10\ (I_B R_2)$

$$= \frac{1}{10} 100nA(1M)$$

$= 0.01V$

(d)



$$V_0 = \left|V_{0_{\text{Offset Voltage}}}\right| + \left|V_{0_{\text{Bios current}}}\right|$$

$= 0.1 + 0.01$

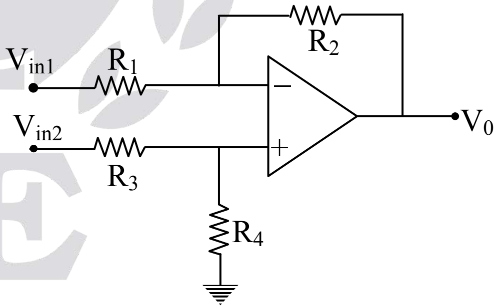
$= 0.11$

44.

Sol: Given

$R_1 = R_3 = 10k\Omega$

$R_2 = R_4 = 1M\Omega$



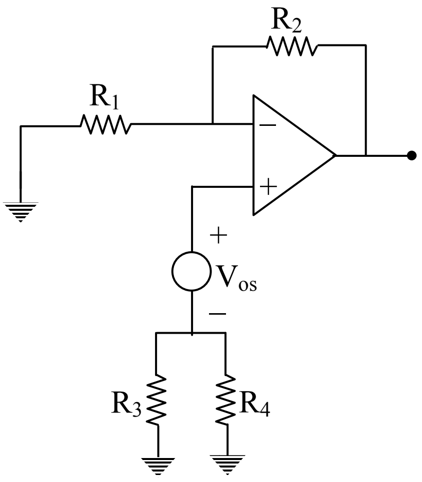
$$V_0 = \frac{R_2}{R_1}(V_{in2} - V_{in1})$$

$$= \frac{1M}{10k}(V_{in2} - V_{in1})$$

Given $V_{os} = 4mV$

$I_B = 0.3\ \mu A$

$I_{os} = 50\ nA$

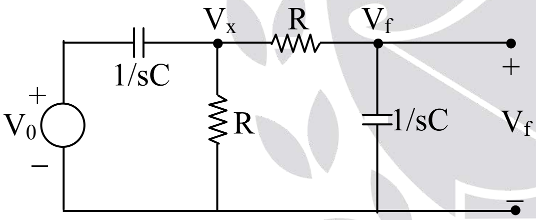


$$V_0 = \left[1+\frac{R_2}{R_1}\right]V_{os} + I_{os}R_2$$

$$= \left[1+\frac{1M}{10k}\right]4mV + 50nA[1M]$$

$$= 454mV$$

45.
Sol:



KCL

$$\frac{V_x - V_0}{(1/SC)} + \frac{V_x}{R} + \frac{V_x - V_f}{R} = 0 \text{ -------(1)}$$

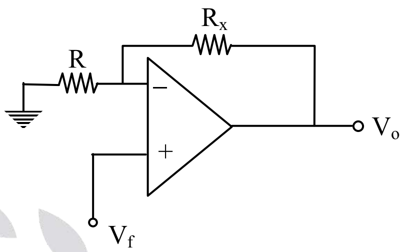
$$\frac{V_f - V_x}{R} + \frac{V_f}{(1/SC)} = 0 \text{ -------(2)}$$

From (1) and (2) eliminate V_x

$$\beta = \frac{V_f}{V_0} = \frac{SCR}{[S^2C^2R^2 + 3SCR + 1]}$$

$$\beta = \frac{1}{[3 + SCR + \frac{1}{SCR}]}$$

$$\beta = \frac{1}{3 + j\left(\omega RC - \frac{1}{\omega RC}\right)} \quad (S = j\omega)$$



$$A = \frac{V_0}{V_f} = 1 + \frac{R_x}{R}$$

Loop gain =1 → A = 1/β

$$A\beta = 1$$

$$1 + \frac{R_x}{R} = 3 + j\left(\omega RC - \frac{1}{\omega RC}\right)$$

Equate imaginary parts

$$0 = \omega RC - \frac{1}{\omega RC}$$

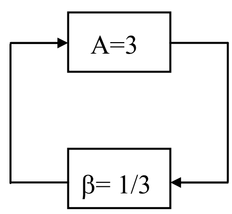
$$\omega^2 = \frac{1}{R^2C^2}$$

$$f = \frac{1}{2\pi RC} \text{ frequency of oscillation}$$

Equate

$$1 + \frac{R_x}{R} = 3$$

$$R_x = 2R$$



46.

Sol: $\omega_0 = \dfrac{1}{\sqrt{LC}}$

$\dfrac{V_F}{V_0} = \beta = \dfrac{0.5k}{R_x + 0.5}$

$A = 1 + \dfrac{9k}{1k} = 10$

$A\beta = 1$ for sustained oscillations

$\dfrac{0.5k}{R_x + 0.5k} \times 10 = 1$

$\therefore R_x = 4.5\ k\Omega$

47.

Sol: Given $\beta = \dfrac{1}{6}$

$A = 1 + \dfrac{R_2}{R_1}$

$A\beta = 1$ for sustained oscillations

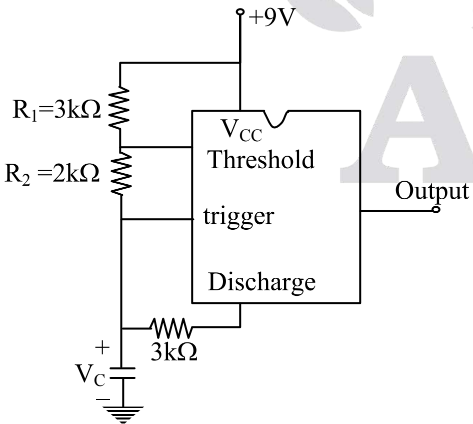
$\left(1 + \dfrac{R_2}{R_1}\right).\dfrac{1}{6} = 1$

$\dfrac{R_2}{R_1} = 5$

$R_2 = 5\ R_1$

48.

Sol:



$V_{th} = \dfrac{2}{3}V_{CC} = \dfrac{2}{3} \times 9 = 6\ V$

$V_{th} - V_C = 2\times10^3\times I \qquad \left(I = \dfrac{9-6}{3k}\right)$

$V_{th} - V_C = 2\ V$

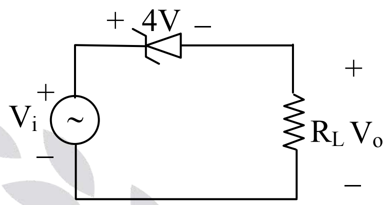
$V_C = V_{th} - 2 = 4\ V$

$V_{trigger} = \dfrac{1}{3}V_{CC} = 3\ V$

$V_C = 3\ V$ to $4\ V$

49.

Sol:



$V_i = 8$ sint V

During –Ve cycle, Zener is Forward biased and act as short circuit.

$\Rightarrow V_0 = V_i$

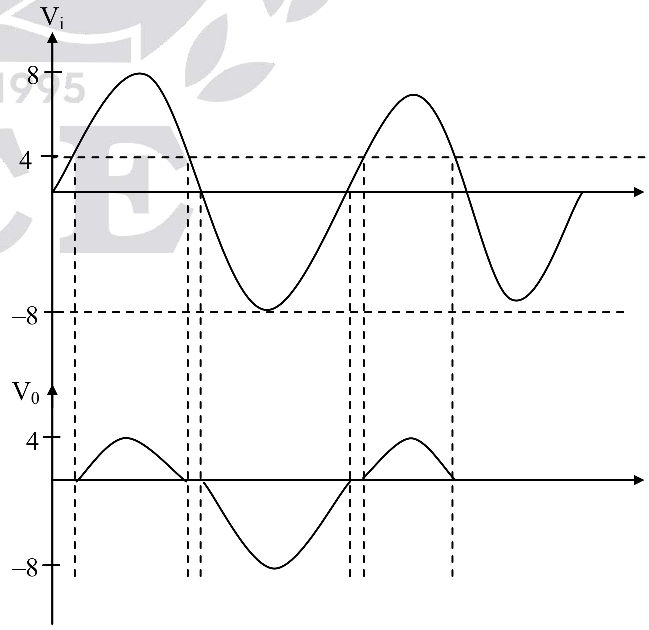
During + Ve cycle,

For $0 < V_i < 4$, Zener OFF Since Zener is not in break down

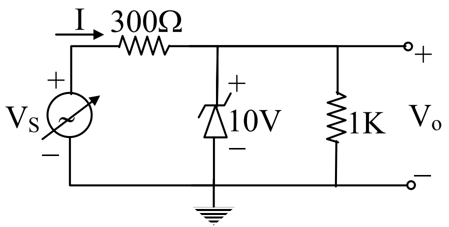
$\Rightarrow V_0 = 0$

For $V_i > 4$, Zener is in break down.

$\Rightarrow V_0 = V_i - 4$



50.
Sol:



I_z = 1mA to 60mA

$$I = \frac{V_s - V_z}{300}$$

$$I_{min} = \frac{V_{s\,min} - 10}{300} \_\_\_\_\_\_\_\_(I)$$

$$I_{max} = \frac{V_{smax} - 10}{300} \_\_\_\_\_\_(II)$$

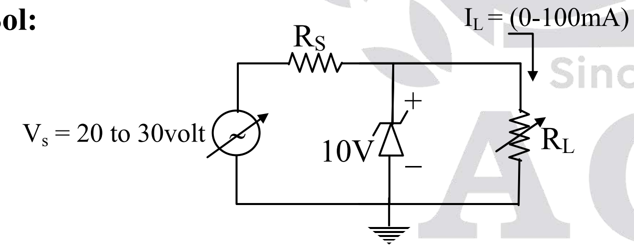
$$I_{min} = I_{zmin} + I_L \left[\because I_L + \frac{V_z}{1k} = 10mA\right]$$

I_{min} = 1mA + 10mA = 11mA

I_{max} = 60mA + 10mA = 70mA

From equation (1) and (2) required range of V_S is 13.3 to 31 volt.

51.
Sol:



The current in the diode is minimum when the load current is maximum and v_s is minimum.

$$R_s = \frac{V_{s\,min} - V_z}{I_{z\,min} + I_{L\,max}}$$

$$R_s = \frac{20 - 10}{(10 + 100)mA}$$

R_s = 90.9Ω

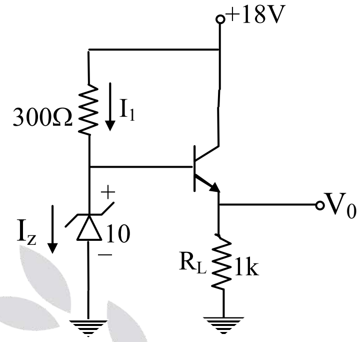
$$I_{z\,max} = \frac{30 - 10}{90.9} = 0.22A\left[\because I_{L\,min} = 0A\right]$$

$P_z = V_z\, I_{zmax}$

$P_z = 10 \times 0.22$

P_z = 2.2W

52.
Sol:



V_B = 10volt

V_E = 10 – 0.7 = 9.3volt

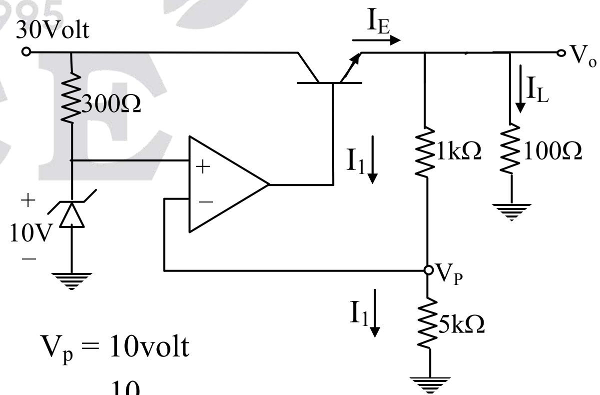
I_E = 9.3mA

$$I_B = \frac{I_E}{1+\beta} = \frac{9.3mA}{101} = 92.07\mu A$$

$$I_1 = \frac{18 - 10}{300} = 26.67mA$$

$$I_z = I_1 - I_B = 26.57mA$$

53.
Sol:



V_p = 10volt

$$I_1 = \frac{10}{5k} = 2mA$$

$\Rightarrow V_0 = (6k)\, I_1 = 12V = V_E$

V_C = 30volt

$\Rightarrow V_{CE} = V_C - V_E = 18$ volt.

$I_E = I_1 + I_L$

$I_E = 2m + \dfrac{12}{100} = 122mA$

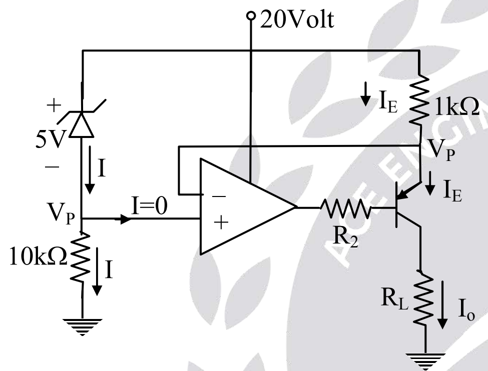
$\Rightarrow I_C = \dfrac{\beta}{1+\beta} I_E$

$\Rightarrow I_C = 0.120Amp$

$\Rightarrow P_T = I_C \times V_{CE}$

$\therefore\ P_T = 2.17W$

54.
Sol:



$I = \dfrac{20-5}{10k} = \dfrac{15}{10} mA$

$V_P = 10k \times I = 15volt$

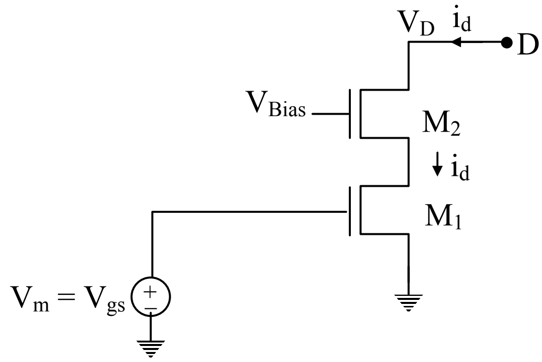
$I_C = \dfrac{20 - V_P}{1k} = \dfrac{20-15}{1k} = 5mA$

β large $\Rightarrow I_B \approx 0A$

$\therefore\ I_C = I_0 = 5mA$

55. Ans: (c)

Sol: The circuit given is the MOS cascode amplifier, Transistor M_1 is connected in common source configuration and provides its output to the input terminals (i.e., source) of transistor M_2. Transistor M_2 has a constant dc voltage , V_{bias} applied at its gate. Thus the signal voltage at the gate of M_2 is zero and M_2 is operating as a CG amplifier. Which is current Buffer.



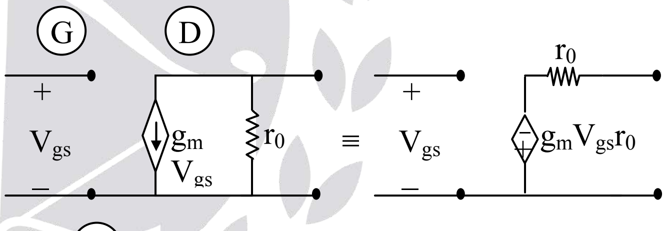
Overall transconductance

$$g_m = \frac{i_d}{V_{gs}} = \left[\frac{\partial i_D}{\partial V_{GS}}\right] = \frac{i_{d_1}}{V_{gs_1}}$$

$$= g_{m_1}$$

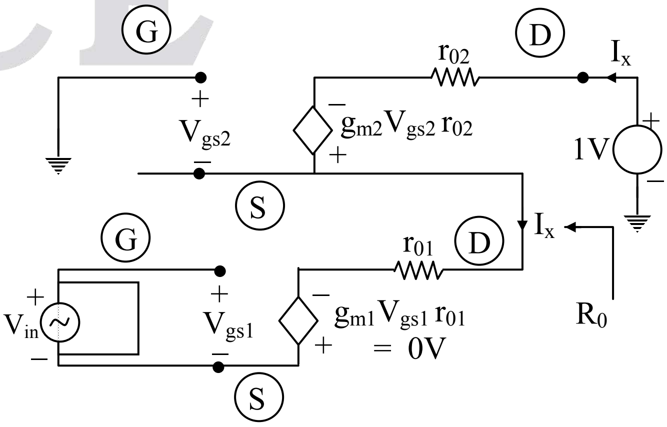
The overall (approximate) transconductance of the cascode amplifier is equal to the transconductance of common source amplifier g_{m_1}

AC model of MOSFET



Thevenin equivalent

Let us find the output resistance $R_0 = \dfrac{1V}{I_x}$



By KVL $V_{gs2} + I_x r_{01} = 0$

$V_{gs2} = -I_x r_{01}$ ------(1)

By KVL

$-1 + I_x r_{02} - g_m r_{02} V_{gs2} + I_x r_{01} = 0$

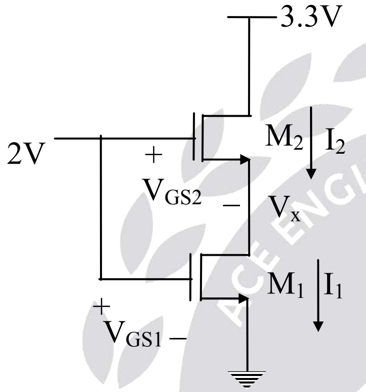
$-1 + I_x r_{02} + g_{m2} r_{02} I_x r_{01} + I_x r_{01} = 0$

$$\therefore I_x = \frac{1}{r_{01} + r_{02} + g_{m2} r_{02} r_{01}} \approx \frac{1}{g_{m2} r_{01} r_{02}}$$

$$R_0 = \frac{1}{I_x} = g_{m2} r_{01} r_{02}$$

56.

Sol:



$$\left(\frac{W}{L}\right)_2 = 2\left(\frac{W}{L}\right)_1$$

$V_{TH} = 1$V for both M_1 and M_2

For M_2 to be in saturation:

$V_D > V_G - V_{TH}$

$3.3 > 2 - 1$

$3.3 > 1$

So M_2 will be in saturation if it is ON.

For M_1 to be in saturation:

$V_D > V_G - V_{TH}$

$V_X > 2 - 1$

$V_X > 1$V but if V_X is more than 1V, V_{GS2} becomes less than 1V, Which means M_2 will be off so M_1 can not be in saturation.

Now, We can conclude that M_1 is in triode and M_2 is in saturation

$V_{GS1} = 2$V

$V_{DS1} = V_X$

$V_{GS2} = 2 - V_X$

Now, $I_1 = I_2$

$$\mu_n C_{ox}\left(\frac{W}{L}\right)_1\left[(V_{GS1} - V_{TH})V_{DS1} - \frac{1}{2}V_{DS1}^{\;2}\right]$$

$$= \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TH})^2$$

$$V_x - \frac{1}{2}V_x^2 = (1 - V_x)^2$$

$$3V_x^2 - 6V_x + 2 = 0$$

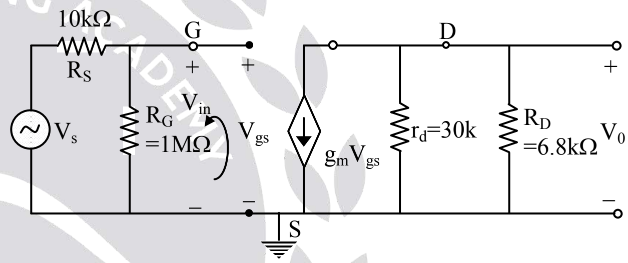
$V_x = 0.42$V, -1.58V

V_x cannot be more than 1V, since M_2 will become off

So, $V_x = 0.42$ V

57.

Sol: Given $I_{DSS} = 10$ mA, $V_P = -5$V, $V_{GG} = -2$V and $r_d = 30$ kΩ



$V_0 = -g_m V_{gs} (r_d || R_D)$

$\therefore A_V = -g_m (r_d || R_D)$

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$$

$V_G = -2$V

$V_{GS} = -2 - 0 = -2$V ($\therefore V_S = 0$V)

$$I_D = 10m\left[1 - \frac{-2}{-5}\right]^2$$

$I_D = 3.6$ mA

$$g_m = \frac{2\sqrt{I_D I_{DSS}}}{V_P}$$

$$= \frac{2\sqrt{(3.6m)(10m)}}{5} = \frac{2 \times 6m}{5} = 2.4\text{ms}$$

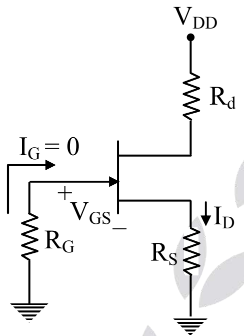
$\therefore A_V = -(2.4 \times 10^{-3})[30\text{ k} || 6.8\text{ k}]$

$$\frac{V_0}{V_{gs}} = A_V = -13.3$$

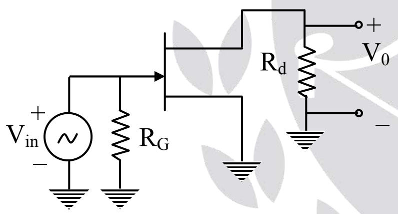
$$V_{gs} = \frac{10^6}{10^6 + 10^4} V_s$$
$$= 0.99\ V_s$$
$$\frac{V_0}{V_s} = A_{Vs}$$
$$= -13.3 \times 0.99$$
$$= -13.16$$

58.

Sol: **DC Equivalent**



AC Equivalent



Device equation

(i) $I_{DS} = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$

$$\Rightarrow 0.8\text{ mA} = 1.65\text{ mA}\left[1 - \frac{V_{GS}}{-2}\right]^2$$

$$\Rightarrow V_{GSQ} = -0.607\text{ V}$$

(ii) $g_m = \frac{\partial I_{DS}}{\partial V_{GS}} = 2I_{DSS}\left[1 - \frac{V_{GSQ}}{V_P}\right]\left[-\frac{1}{V_P}\right]$

$$= 2(1.65\text{ mA})\left[1 - \frac{0.607}{2}\right]\left[\frac{1}{2}\right]$$

$$= 1.149\text{ ms}$$

(iii) $V_G = V_{GS} + I_{DS}R_S = 0$

$$\Rightarrow -0.607 + 0.8\text{ mA}(R_S) = 0$$

$$R_S = \frac{-0.607}{-0.8\text{ mA}} = 758.75\Omega$$

(iv) Voltage gain $(A_V) = -g_mR_d$

Gain (dB) = 20 log A_V

$20 = 20 \log A_V$

$\Rightarrow A_V = 10$

$\Rightarrow 10 = g_mR_d$

$\Rightarrow 10 = (1.149\text{ m})R_d$

$\therefore R_d = 8.7\text{ k}\Omega$