



INSTRUMENTATION ENGINEERING



GATE | PSUs

**ANALOG
ELECTRONICS**

Volume - I : Study Material with Classroom Practice Questions

Classroom Practice solutions

To

Analog Electronics

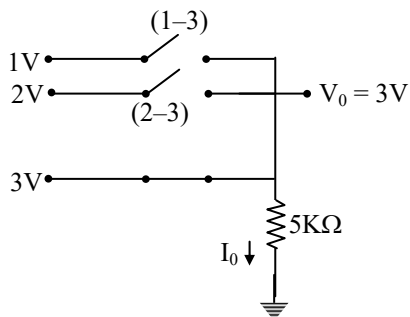
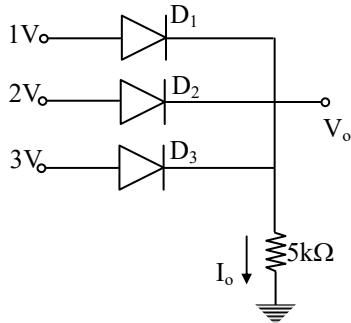
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Analog Electronics

Class Room Practice Solutions

01.
Sol:

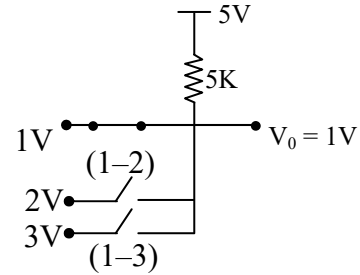
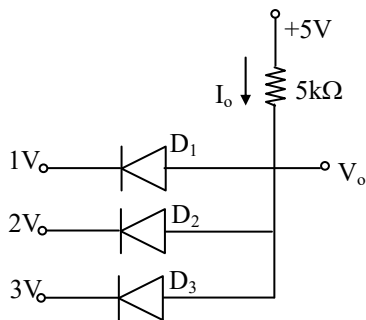


⇒ D_1, D_2 are reverse biased and D_3 is forward biased.

i.e., D_3 only conducts.

$$\therefore I_0 = 3/5K = 0.6\text{mA}$$

02.
Sol:



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

i.e., D_1 only conduct

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

03.

Sol: Let diodes D_1 & D_2 are forward biased.

⇒ $V_0 = 0$ volt

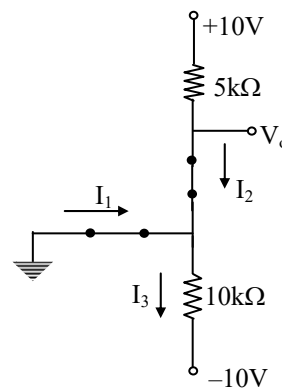
$$I_2 = \frac{10-0}{5K} = 2\text{mA}$$

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

Apply KVL at nodes ' V_0 ':

$$-I_1 + I_3 - I_2 = 0$$

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

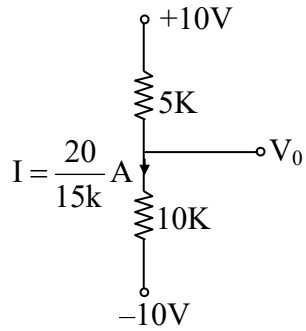


So, D_1 is reverse biased & D_2 is forward biased

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



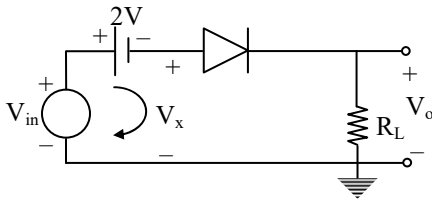
Then circuit becomes



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

$$\therefore V_0 = 3.33V$$

04.
Sol:



Apply KVL to the loop:

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

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

Given, V_{in} range = $-5V$ to $5V$

$$\Rightarrow V_x \text{ range} = -7V \text{ to } 3V \quad [\because \text{from eq (1)}]$$

Diode ON for $V_x > 0V$

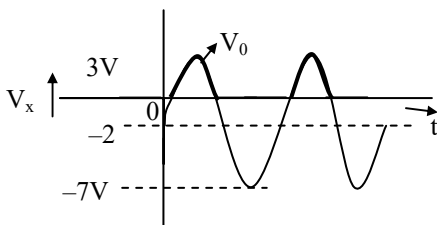
$$\Rightarrow V_0 = V_x$$

Diode OFF for $V_x < 0V$

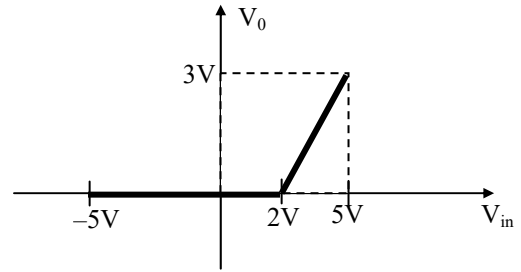
$$\Rightarrow V_0 = 0V$$

$$\therefore V_0 \text{ range} = 0 \text{ to } 3V$$

Output wave form:

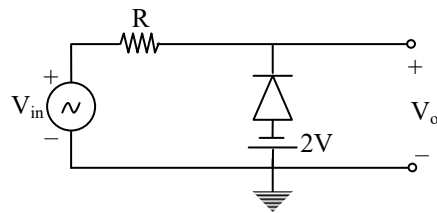


Transfer characteristics:



05.

Sol:

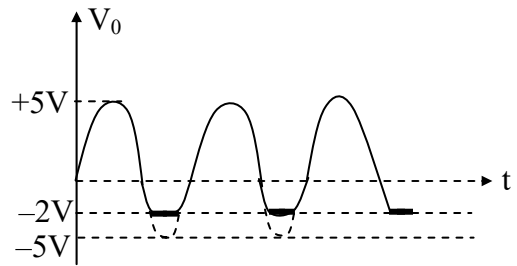


For $V_i < -2V$ olt, Diode ON

$$\Rightarrow V_0 = -2V$$

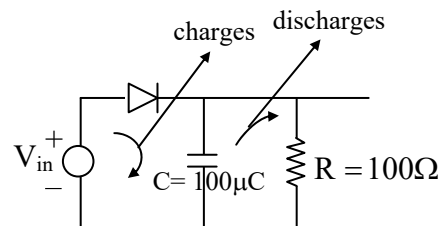
For $V_i > -2V$ olt, Diode OFF

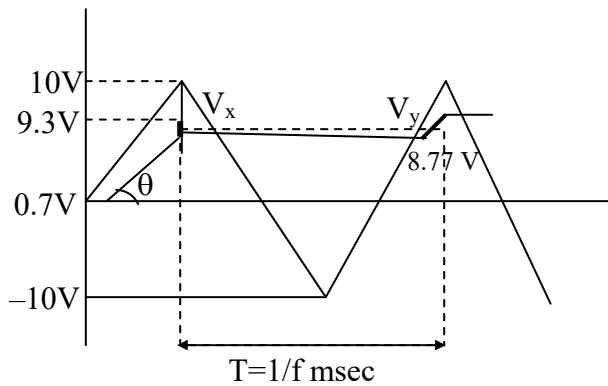
$$\Rightarrow V_0 = V_i$$



06.

Sol: Consider a half wave peak detector the calculate average value for triangular waveform



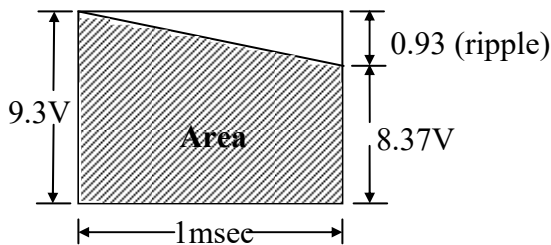


When diode is OFF, the capacitor discharges through the resistor

$$V_y = V_x e^{-t/RC} \Big|_{t=T}$$

$$V_y = 9.3 \left[1 - \frac{1m}{100\mu \times 100} \right] = 8.37 \text{ V}$$

$$\text{Ripple amplitude, } V_r = V_x - V_y = 9.3 - 8.77 = 0.93 \text{ V}$$



$$(a) V_{\text{Avg}} = \frac{\text{Area}}{\text{Base}} = \frac{9.3(1m) - \frac{1}{2}(0.93)(1m)}{1m}$$

$$= 9.3 - \frac{0.93}{2} = 8.84 \text{ V}$$

$$(b) \tan\theta = \frac{10}{(T/4)} \left[\frac{V_r}{\Delta t} \right]$$

$$= \frac{10}{0.25m} = \frac{0.93}{\Delta t}$$

$$\Delta t = 0.023 \text{ msec}$$

$$(c) I_{C(\text{avg})} = C \frac{\Delta V}{\Delta t}$$

$$= 100\mu \frac{0.93}{0.023m}$$

$$I_{C(\text{avg})} = 4 \text{ A}$$

$$(d) I_R = \frac{V_p}{R} = \frac{9.3}{100}$$

$$\text{Total } I_D(\text{max}) = I_C + I_R$$

$$= 4 + \frac{9.3}{100}$$

$$= 4.093 \text{ A}$$

07.

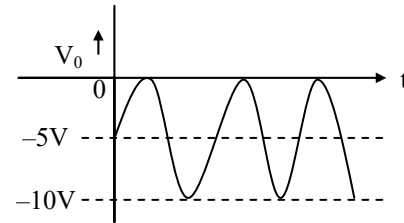
Sol: For positive half cycle diode Forward biased and Capacitor start charging towards peak value.

$$\Rightarrow V_C = V_m = 5 \text{ V}$$

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

$$V_{\text{in}} \text{ range} = -5 \text{ V to } +5 \text{ V}$$

$$\therefore V_0 \text{ range} = -10 \text{ V to } 0 \text{ V}$$



08.

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

$$\Rightarrow V_C = V_m - 7 = 10 - 7 = 3 \text{ V}$$

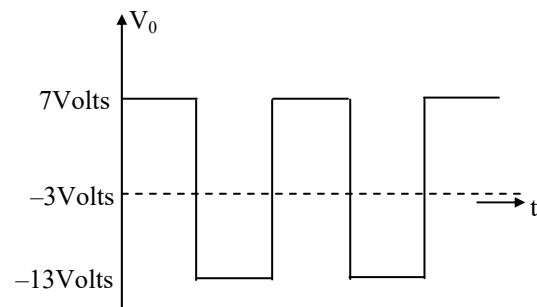
Now diode OFF for rest of cycle

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

$$= V_{\text{in}} - 3$$

$$V_{\text{in}} \text{ range} : -10 \text{ V to } +10 \text{ V}$$

$$\therefore V_0 \text{ range} : -13 \text{ V to } 7 \text{ V}$$





09.

Sol: For +ve cycle, diode ON, then capacitor starts charging $\Rightarrow V_C = V_P + 9$
 $= 12 + 9 = 21V$

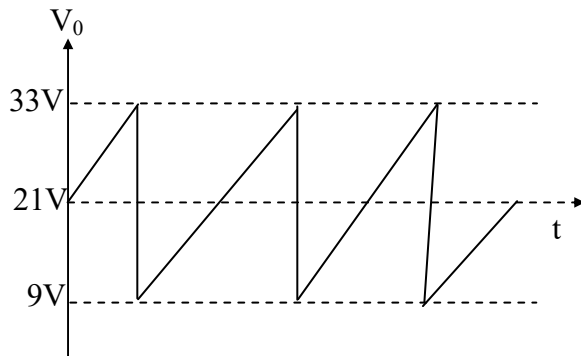
Now diode OFF for rest of cycle.

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

$$= 21 + V_{in}$$

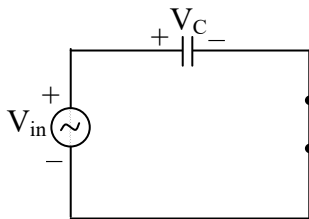
V_{in} range: -12 to $+12V$

V_0 range: $9V$ to $33V$



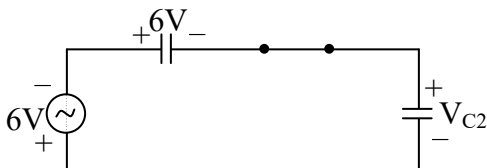
10.

Sol: During positive cycle,
 D_1 forward biased & D_2 Reverse biased.



$$V_{C1} = V_{in} = 6\text{volt}$$

During negative cycle,
 D_1 reverse biased & D_2 forward biased.

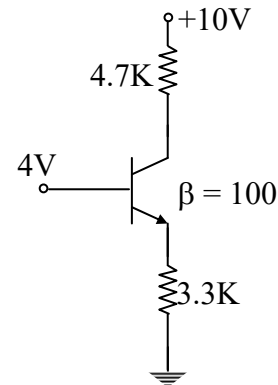


$$V_{C2} = -6 - 6 = -12V$$

Capacitor C_2 will charge to negative voltage of magnitude $12V$

11.

Sol:



Given,

$$V_B = 4V$$

$$V_{BE} = 0.7$$

$$V_B - V_E = 0.7$$

$$V_E = V_B - 0.7 = 3.3V$$

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

Let transistor in active region

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

$$I_B = I_C / \beta = 9.9\mu\text{A}$$

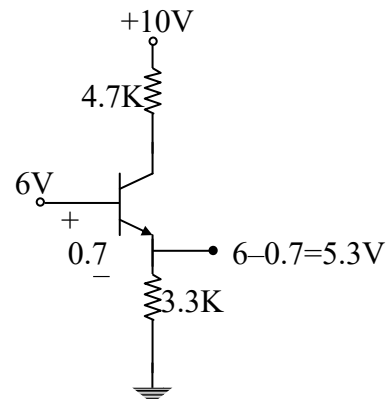
$$V_C = 10 - 4.7 \times 10^3 \times 0.99 \times 10^{-3} = 5.347V$$

$$\Rightarrow V_C > V_B$$

\therefore Transistor in the active region.

12.

Sol:



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

$$I_E = \frac{5.3}{3.3K} = 1.6\text{mA}$$



Let transistor is active region

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

$$I_C = 1.59\text{mA}$$

$$V_C = 2.55\text{V}$$

$$\Rightarrow V_C < V_B$$

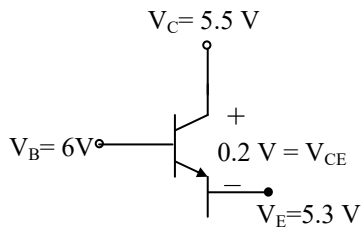
\therefore Transistor in saturation region

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

$$V_C - V_E = 0.2$$

$$V_C = 5.3 + 0.2$$

$$\Rightarrow V_C = 5.5\text{V}$$



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

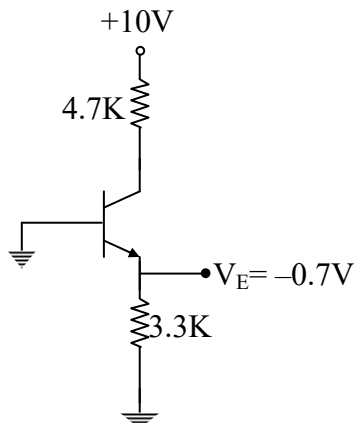
$$I_B = 1.6 - 0.957 = 0.643\text{mA}$$

$$\beta = \frac{I_C}{I_B} = \frac{0.957\text{mA}}{0.643\text{mA}} = 1.483$$

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

13.

Sol:



$$V_E = -0.7\text{V}$$

Transistor in cut off region

$$I_C = I_B = I_E = 0\text{A}$$

$$V_{CE} = 10\text{V}$$

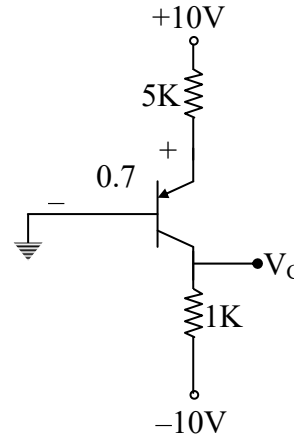
$$V_E = 0\text{V}$$

$$V_C = 10\text{V}$$

$$V_B = 0\text{V}$$

14.

Sol:



$$V_E = 0.7\text{V} [\because V_B = 0\text{V}]$$

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

Let transistor in active region.

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

$$\Rightarrow V_C = -10 + 1\text{K} \times 1.84\text{mA}$$

$$V_C = -8.16\text{V}$$

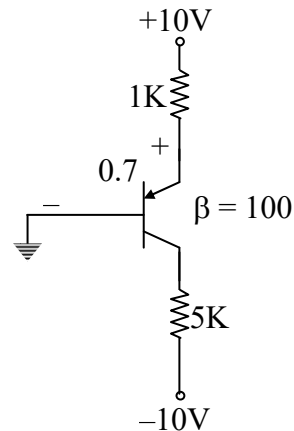
$$V_{EC} = V_E - V_C = 8.86\text{V}$$

$$V_{EC} > V_{EB}$$

\therefore Transistor in active region

15.

Sol:





Let transistor in active region

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

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

$$I_C = \frac{\beta}{\beta + 1} \cdot I_E = 9.2mA$$

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

$$V_C = 36V$$

$$V_{EC} < V_{EB}$$

Transistor in saturation region

$$\Rightarrow V_{EC} = 0.2$$

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

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

$$I_B = I_E - I_C = 7.2mA$$

$$\beta_{\text{forced}} = \frac{I_{C(\text{sat})}}{I_B}$$

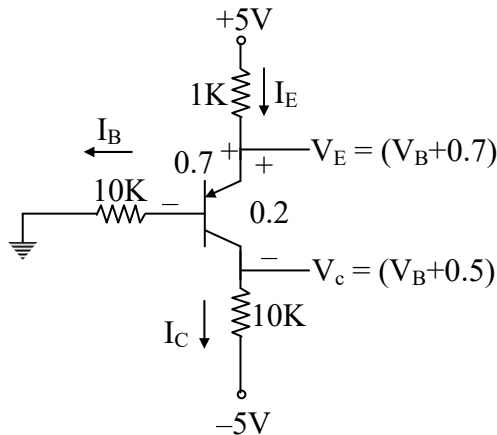
$$= \frac{2.1}{7.2}$$

$$= 0.29$$

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

16.

Sol:



$$I_E = I_C + I_B$$

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

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

$$43 - 10V_B = 2V_B + 5.5$$

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

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

$$V_C = V_B + 0.5 = 3.625V$$

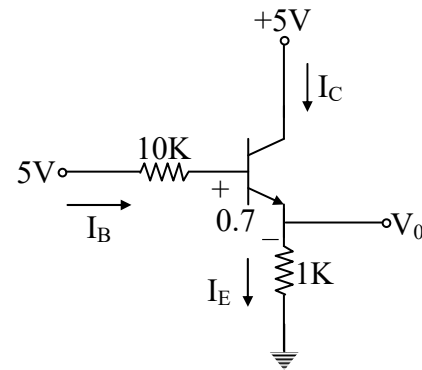
$$V_E = 3.825V$$

$$\therefore I_E = 1.175mA$$

$$\therefore I_C = 0.862mA$$

17.

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



Apply KVL to the base emitter loop:

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

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

$$= 38.73\mu A$$

$$I_C = 3.87mA$$

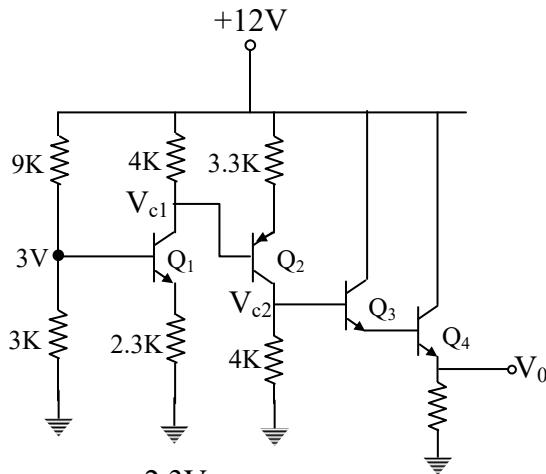
$$I_E = 3.91mA$$

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

$$V_C = 5V$$

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

18.
Sol:



$$I_{C_1} = I_{E_1} = \frac{2.3V}{2.3k} = 1\text{mA}$$

$$V_{C_1} = 12V - 4 \times 10^3 \times 1 \times 10^{-3} = 8V$$

$$V_{E_2} = 8 + 0.7V = 8.7V$$

$$I_{E_2} = \frac{12V - V_{E_2}}{3.3k} = \frac{12V - 8.7}{3.3k} = 1\text{mA}$$

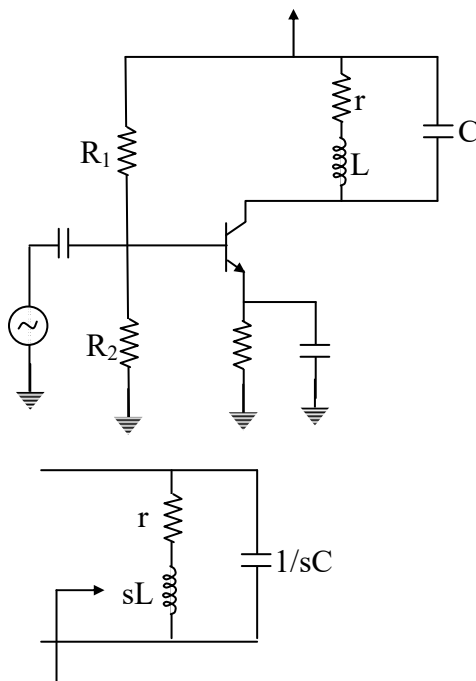
$$V_{C_2} = 4k \times 1\text{mA} = 4V$$

$$V_{E_3} = 4V - 0.7 = 3.3V$$

$$V_{E_4} = 3.3 - 0.7 = 2.6V$$

$$V_0 = 2.6V$$

19.
Sol:



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

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

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

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

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

Equate Imaginary terms:

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

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

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

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

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

Equate real:

$$Z_{eq} = \frac{r - \omega^2 LCr + \omega^2 LCr}{(1 - \omega^2 LC)^2 + \omega^2 r^2 C^2}$$

$$= \frac{r}{\left(\frac{r^2 C}{L}\right)^2 + \left[\frac{1}{LC} - \frac{r^2}{L^2}\right] r^2 C^2}$$

$$= \frac{r}{\frac{r^4 C^2}{L^2} + \frac{r^2 C^2}{LC} - \frac{r^4 C^2}{L^2}}$$

$$Z = \frac{L}{rC}$$

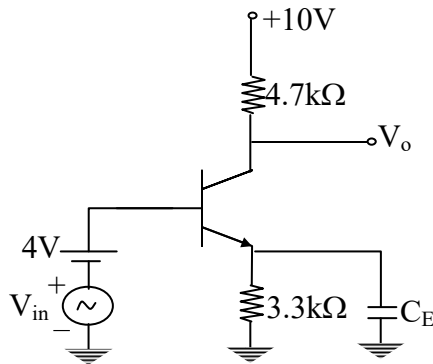
$$(ii) A_V = -g_m Z$$

$$= -g_m \left[\frac{L}{rC} \right]$$



20.

Sol:



For D.C Analysis:

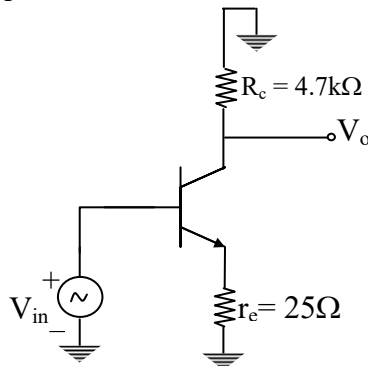
$$V_B = 4 \text{ V}$$

$$V_B - V_E = 0.7 \Rightarrow V_E = 4 - 0.7 = 3.3 \text{ V}$$

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

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

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



$$\Rightarrow V_0 = -i_c R_c$$

$$V_i = i_c r_e$$

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

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

$$= -188$$

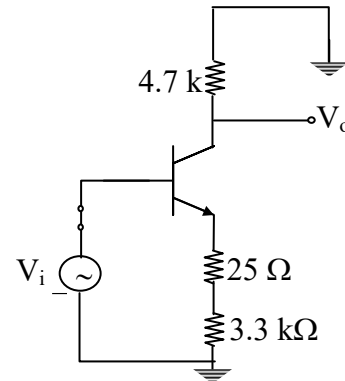
21.

Sol: D.C calculation is same as previous question

$$I_E = 1 \text{ mA}$$

$$r_e = 25 \Omega$$

Apply small signal analysis:



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

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

22.

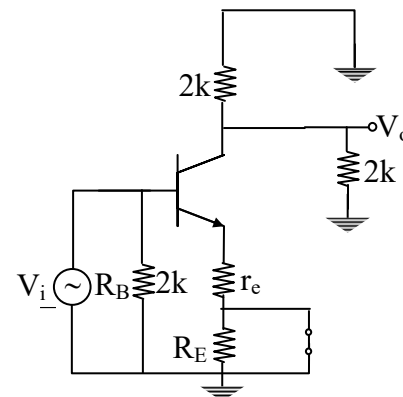
Sol: To calculate r_e value apply D.C analysis

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

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

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

Now apply small signal analysis.:



$$A_V = \frac{v_0}{v_i} = \frac{-R_C}{r_e} = \frac{-(2\text{k} \parallel 2\text{k})}{25.22} = -39.65$$



$$R_i = R_B \parallel \beta r_e$$

$$R_i = 1.116 \text{ k}\Omega$$

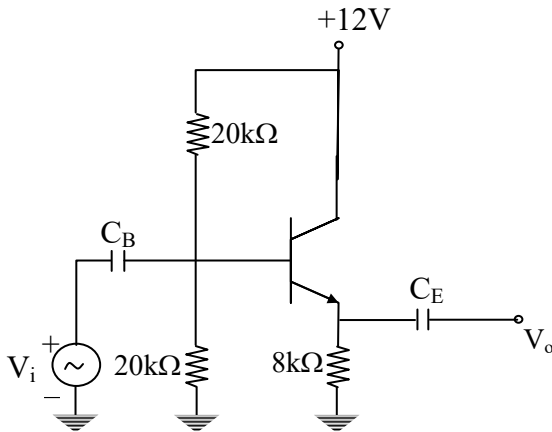
$$A_I = \frac{i_o}{i_i} = \frac{v_o}{R_L} \times \frac{R_i}{v_i} = A_V \times \frac{R_i}{R_L}$$

$$= \frac{-39.5 \times 1.116 \times 10^3}{2 \times 10^3} = -22.322$$

$$R_o = R_C = 2 \text{ k}\Omega$$

23.

Sol:



Apply KVL at input Loop:

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

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

$$I_E = 0.65 \text{ mA}$$

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

Apply small signal analysis

$$A_V = \frac{V_o}{V_i} = \frac{R_C}{r_e + R_E} = 0.995$$

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

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

$$R_i = 10 \text{ k} \parallel 803.85 \text{ k} = 9.87 \text{ k}\Omega$$

$$R_o = R_E \parallel r_e = 38.3 \Omega$$

24.

Sol: $V_o = -i_c R_C$

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

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

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

Given $I_E = 1 \text{ mA}$

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

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

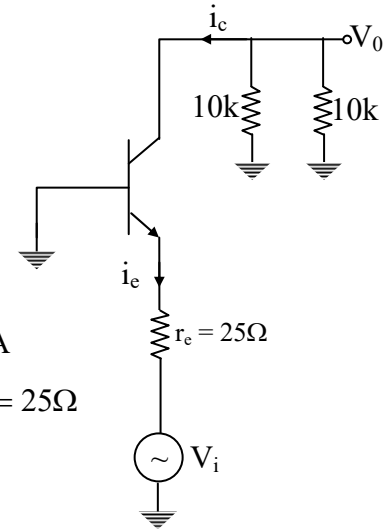
$$A_V = \frac{10 \text{ k} \parallel 10 \text{ k}}{25} = \frac{5000}{25} = 200$$

$$R_o = R_C = 10 \text{ k}\Omega$$

$$R_i = r_e = 25 \Omega$$

$$A_I = \frac{i_o}{i_i} = \frac{v_o}{R_L} \times \frac{R_i}{v_i}$$

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



25.

Sol: For the given differential amplifier,

$$I_E = 1 \text{ mA}$$

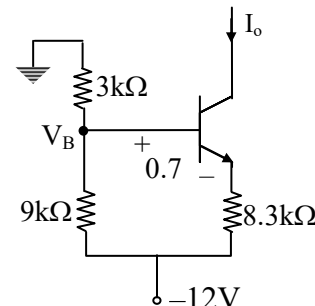
$$r_e = \frac{V_T}{I_E} = 25 \Omega$$

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

$$A_d = -120$$

26.

Sol:





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

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

$$V_B = -3V$$

$$V_B - V_E = 0.7$$

$$V_E = V_B - 0.7$$

$$V_E = -3.7 \text{ Volt}$$

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

$$I_o = 1\text{mA}$$

$$I_E = 0.5\text{mA}$$

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

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

$$A_d = -40$$

27.

Sol: Voltage shunt feedback amplifier and

$$\frac{V_o}{V_{in}} = \frac{-R_f}{R_s} = \frac{-10k}{1k} \approx -10$$

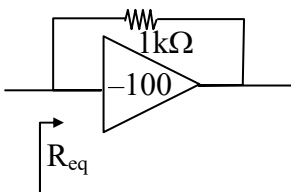
28.

Sol: Current – series feedback amplifier and

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

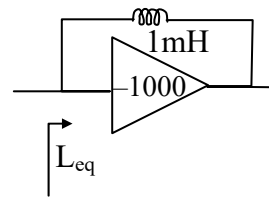
29.

Sol:

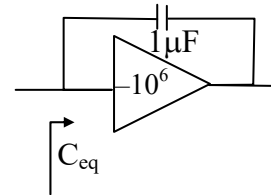


using millers effect,

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



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



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

30.

Sol: Maximum power across the Transistor will be at the middle of active region

$$\text{Ideally at } V_{CE} = \frac{V_{CC}}{2}$$

$$V_{CE} = 12\text{V}$$

$$I_C = \frac{24-12}{8k} = 1.5\text{mA}$$

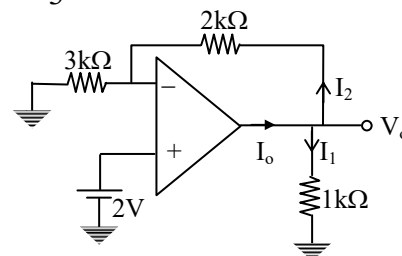
$$\begin{aligned} P_{Tmax} &= V_{CE} \times I_C \\ &= 12 \times 1.5 \\ &= 18\text{mW} \end{aligned}$$

31.

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

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

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





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

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

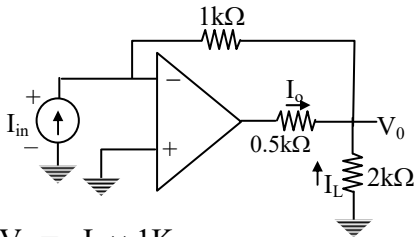
$$\therefore I_0 = I_1 + I_2 = 4 \text{ mA}$$

32.

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

33.

Sol:



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

$$I_L = \frac{I_1 \times 1K}{2K} = \frac{I_{in}}{2}$$

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

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

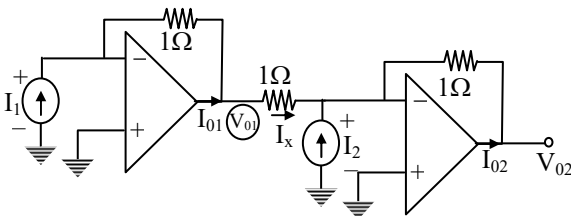
$$2I_0 + 2I_{in} + I_{in} = 0$$

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

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

34.

Sol:



$$V_{01} = -I_1$$

Apply KCL:

$$I_x + I_2 = \frac{0 - V_{02}}{1}$$

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

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

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

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

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

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

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

$$I_{01} = -2I_1 \quad \left[\because V_{01} = -I_1 \right]$$

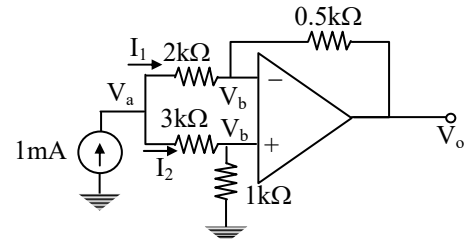
$$I_{02} = -(I_2 + I_x)$$

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

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

35.

Sol:



Apply KCL at V_a :

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

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

$$6 = 5V_a - 5V_b$$

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

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

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

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

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



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

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

$$0.3 = 0.4 - V_0$$

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

36.

$$\text{Sol: } V_C = \frac{-I}{C} \cdot t = \frac{-10 \times 10^{-3}}{10^{-6}} \times 0.5 \times 10^{-3}$$

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

37.

Sol: Given open loop gain = 10

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

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

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

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

38.

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

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

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

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

39.

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

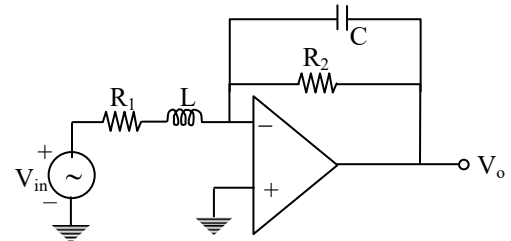
$$V_{0\max} = \frac{SR}{2\pi f_{\max}}$$

$$= \frac{10^6}{2\pi \times 20 \times 10^3} = 7.95 \text{ Volt}$$

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

40.

Sol:



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

$$z_1 = R_1 + sL$$

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

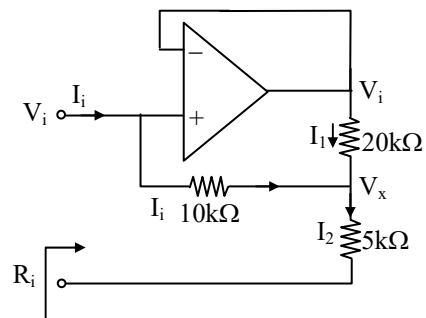
$$\left| \frac{V_0}{V_i} \right| = \frac{R_2}{(sCR_2 + 1)(R_1 + sL)}$$

It represent low pass filter with

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

41.

Sol: (i)





Apply KCL at V_x :

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

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

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

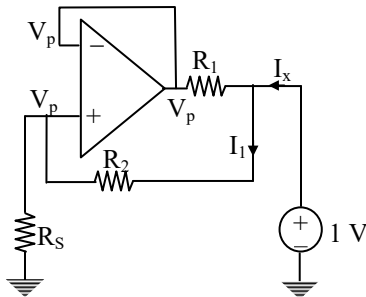
$$V_x = \frac{3}{7} V_i$$

$$I_1 = \frac{V_i - V_x}{10k}$$

$$I_1 = \frac{V_i - \frac{3}{7} V_i}{10k}$$

$$\frac{V_i}{I_1} = 17.5k\Omega$$

(ii)



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

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

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

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

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

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

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

42.

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

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

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

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

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

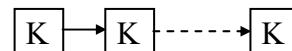
$$\frac{V_{op} - 2.7}{100} = \frac{1.7}{100}$$

$$V_{op} = 4.4 \text{ Volt}$$

43

Sol:

(a) n-stage



$$\text{LPF single stage gain} = \frac{K}{1 + j \frac{f}{f_c}}$$

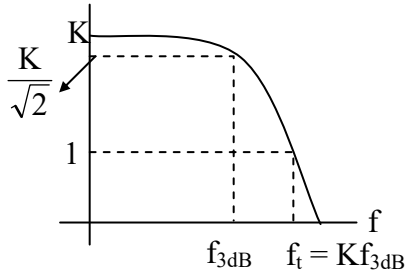
$$\text{For n stages gain} = \left[\frac{K}{1 + j \frac{f}{f_c}} \right]^n$$

3dB cut-off frequency (f_{3dB}) is given by



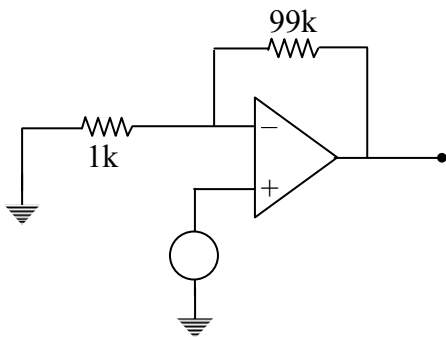
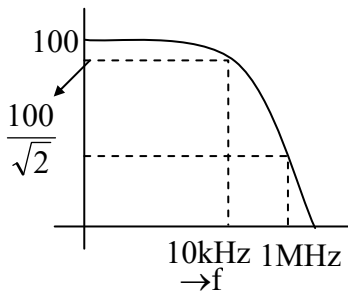
$$\frac{K^n}{\sqrt{2}} = \left[\frac{K}{\sqrt{1 + \left(\frac{f_{3dB}}{f_c}\right)^2}} \right]^n$$

$$\Rightarrow f_{3dB} = f_c \sqrt{2^{1/n} - 1}$$



(b) Gain = 40dB = 100, $f_t = 1\text{MHz} = \text{Gain BW}$

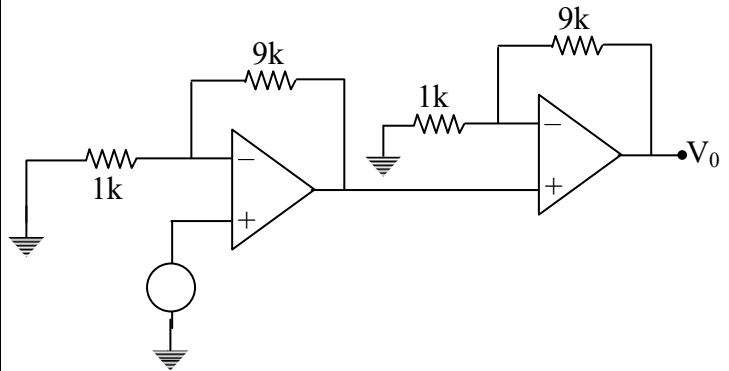
$$\text{BW} \rightarrow f_{3dB} = \frac{f_t}{\text{Gain}} = \frac{10^6}{100} = 10\text{kHz}$$



(c)



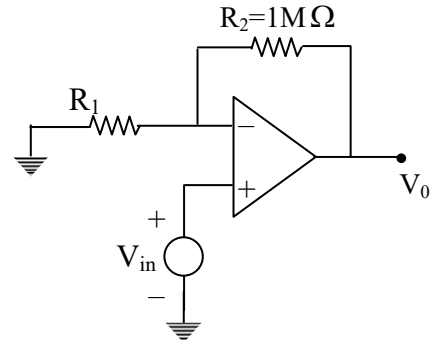
$$f_{3dB} = \frac{1\text{M}}{10} = 100\text{kHz}, \quad f_{3dB} = 100\text{kHz (for single stage)}$$



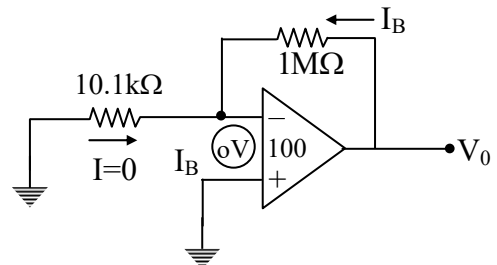
$$\begin{aligned} \text{Overall BW} &= f_{3dB} \sqrt{2^{1/2} - 1} \\ &= 100\text{k} (0.04) \\ &= 64\text{ kHz} \end{aligned}$$

44
Sol:

(a)



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

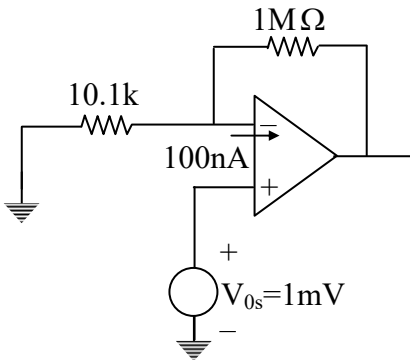




$$\begin{aligned} V_0 &= I_B(1M) \\ &= 100nA(1M) \\ &= 0.1V \end{aligned}$$

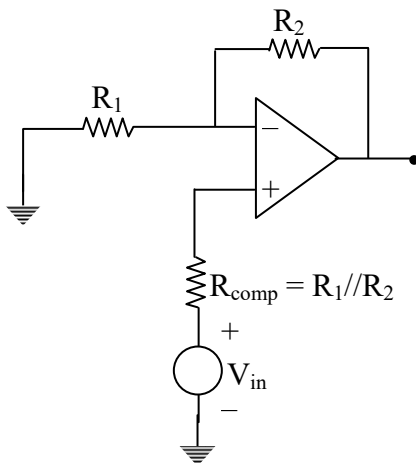
(b)

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



$$\begin{aligned} V_0 &= |V_{0 \text{ Bios current}}| + |V_{0 \text{ Offset Voltage}}| \\ &= 1M(I_B) + \left(1 + \frac{R_2}{R_1}\right) V_{os} \\ &= 1M(100nA) + 100(1mV) \\ &= 0.2V \end{aligned}$$

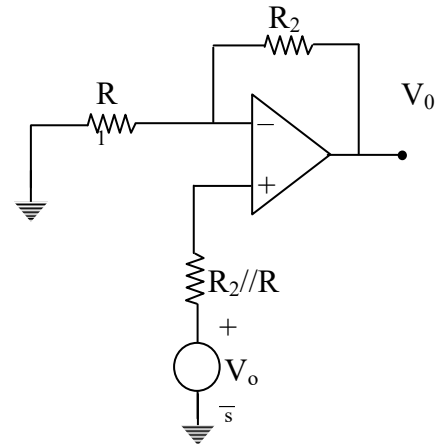
(c)



$$\begin{aligned} \rightarrow R_{comp} &= R_1/R_2, \text{ then } V_0 = (I_{B1} - I_{B2}) R_2 \\ &= I_{os} R_2 \\ V_0 &= (I_{B1} - I_{B2}) R_2 \\ &= I_{os} R_2 \\ &= 1/10 (I_B R_2) \end{aligned}$$

$$\begin{aligned} &= \frac{1}{10} 100nA(1M) \\ &= 0.01V \end{aligned}$$

(d)



$$\begin{aligned} V_0 &= |V_{0 \text{ Offset Voltage}}| + |V_{0 \text{ Bios current}}| \\ &= 0.1 + 0.01 \\ &= 0.11 \end{aligned}$$

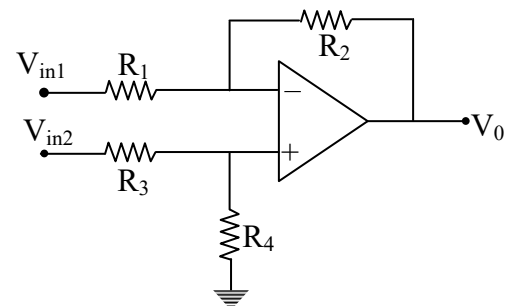
45.

Sol:

Given

$$R_1 = R_3 = 10k\Omega$$

$$R_2 = R_4 = 1M\Omega$$

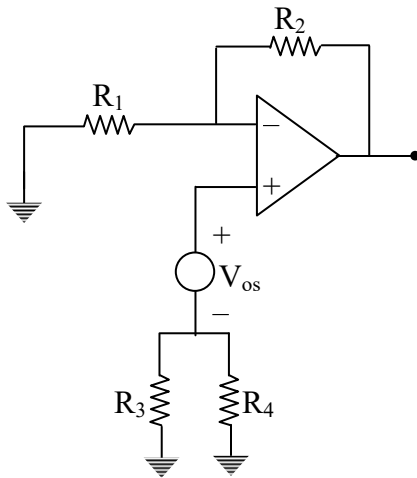


$$\begin{aligned} V_0 &= \frac{R_2}{R_1} (V_{in2} - V_{in1}) \\ &= \frac{1M}{10k} (V_{in2} - V_{in1}) \end{aligned}$$

Given $V_{os} = 4mV$

$$I_B = 0.3 \mu A$$

$$I_{os} = 50 nA$$

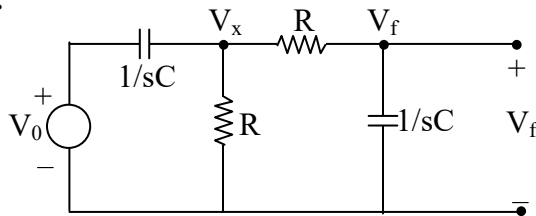


$$V_o = \left[1 + \frac{R_2}{R_1} \right] V_{os} + I_{os} R_2$$

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

$$= 454mV$$

46.
Sol:



KCL

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

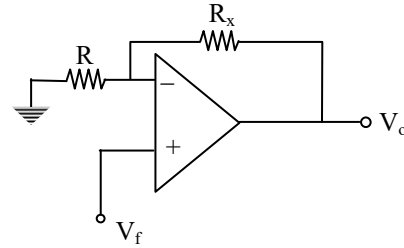
$$\frac{V_f - V_x}{R} + \frac{V_f}{(1/SC)} = 0 \text{ -----(2)}$$

From (1) and (2) eliminate V_x

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

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

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



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

Loop gain = 1 $\rightarrow A = 1/\beta$

$$A\beta = 1$$

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

Equate img. parts

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

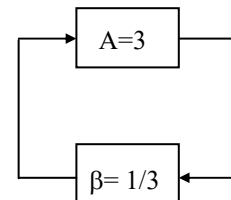
$$\omega^2 = \frac{1}{R^2C^2}$$

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

Equate

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

$$R_x = 2R$$





47.

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

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

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

$A\beta = 1$ for sustained oscillations

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

$$\therefore R_x = 4.5 \text{ k}\Omega$$

48.

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

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

$A\beta = 1$ for sustained oscillations

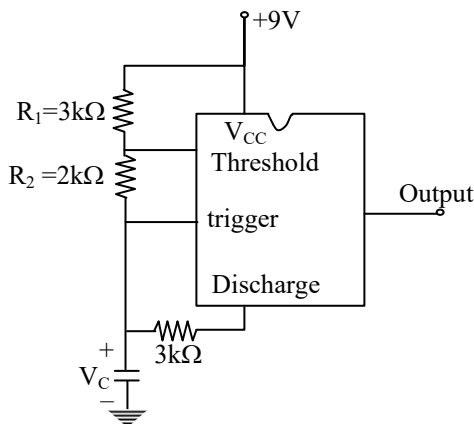
$$\left(1 + \frac{R_2}{R_1}\right) \cdot \frac{1}{6} = 1$$

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

$$R_2 = 5 R_1$$

49.

Sol:



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

$$V_{th} - V_C = 2 \times 10^3 \times I \quad \left(I = \frac{9-6}{3k} \right)$$

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

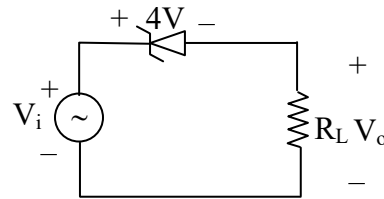
$$V_C = V_{th} - 2 = 4 \text{ V}$$

$$V_{trigger} = \frac{1}{3} V_{CC} = 3 \text{ V}$$

$$V_C = 3 \text{ V to } 4 \text{ V}$$

50.

Sol:



$$V_i = 8 \sin t \text{ V}$$

During $-V_e$ cycle, Zener is Forward biased and act as short circuit.

$$\Rightarrow V_0 = V_i$$

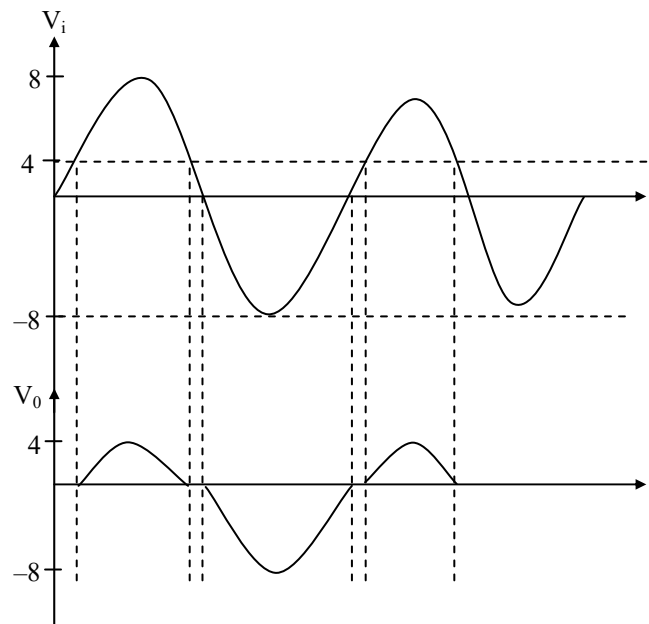
During $+V_e$ cycle,

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.

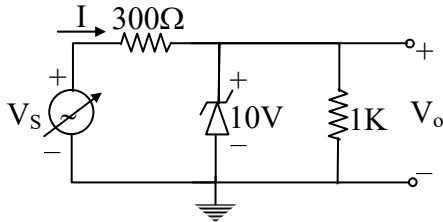
$$\Rightarrow V_0 = V_i - 4$$





51.

Sol:



$$I_z = 1\text{mA to } 60\text{mA}$$

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

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

$$I_{\max} = \frac{V_{s\max} - 10}{300} \quad \text{--- (II)}$$

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

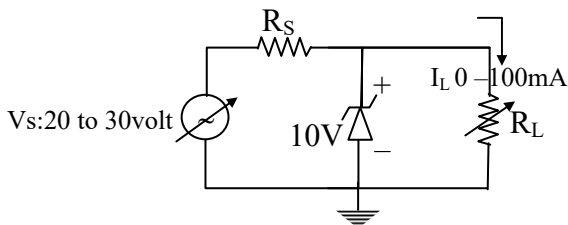
$$I_{\min} = 1\text{mA} + 10\text{mA} = 11\text{mA}$$

$$I_{\max} = 60\text{mA} + 10\text{mA} = 70\text{mA}$$

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

52.

Sol:



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

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

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

$$R_s = 90.9\Omega$$

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

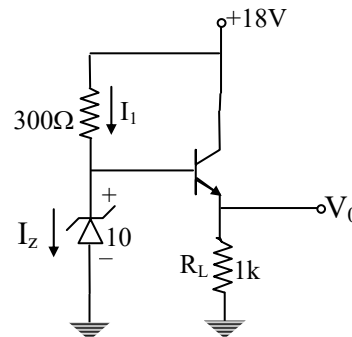
$$P_z = V_z I_{z\max}$$

$$P_z = 10 \times 0.22$$

$$P_z = 2.2\text{W}$$

53.

Sol:



$$V_B = 10\text{volt}$$

$$V_E = 10 - 0.7 = 9.3\text{volt}$$

$$I_E = 9.3\text{mA}$$

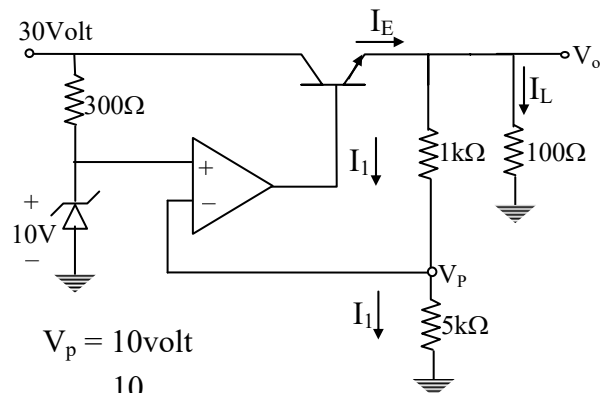
$$I_B = \frac{I_E}{1 + \beta} = \frac{9.3\text{mA}}{101} = 92.07\mu\text{A}$$

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

$$I_z = I_1 - I_B = 26.57\text{mA}$$

54.

Sol:



$$V_p = 10\text{volt}$$

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

$$\Rightarrow V_o = (6k) I_1 = 12\text{V} = V_E$$

$$V_C = 30\text{volt}$$



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

$$I_E = I_1 + I_L$$

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

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

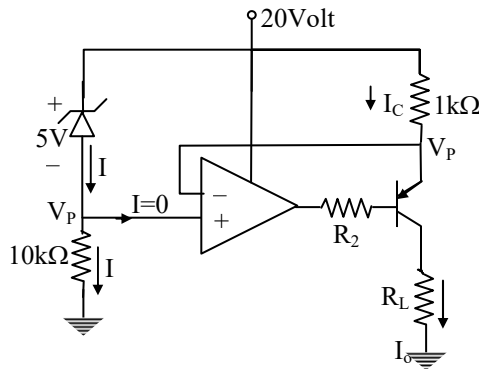
$$\Rightarrow I_C = 0.120\text{Amp}$$

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

$$\therefore P_T = 2.17\text{W}$$

55.

Sol:



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

$$V_P = 10\text{k} \times I = 15\text{volt}$$

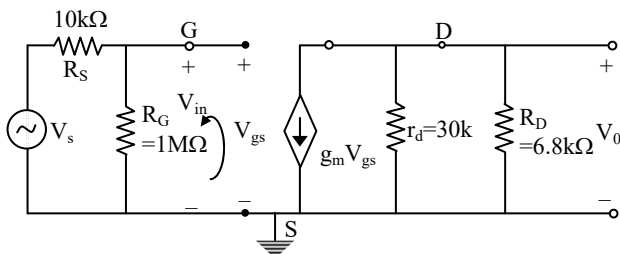
$$I_C = \frac{20 - V_P}{1\text{k}} = \frac{20 - 15}{1\text{k}} = 5\text{mA}$$

$$\beta \text{ large} \Rightarrow I_B \approx 0\text{A}$$

$$\therefore I_C = I_0 = 5\text{mA}$$

56.

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



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

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

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

$$V_G = -2\text{V}$$

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

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

$$I_D = 3.6 \text{ mA}$$

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

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

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

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

$$V_{gs} = \frac{10^6}{10^6 + 10^4} V_s$$

$$= 0.99 V_s$$

$$\frac{V_0}{V_s} = A_{Vs}$$

$$= -13.3 \times 0.99$$

$$= -13.16$$

$$V_G = -2\text{V}$$

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

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

$$I_D = 3.6 \text{ mA}$$

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

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

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

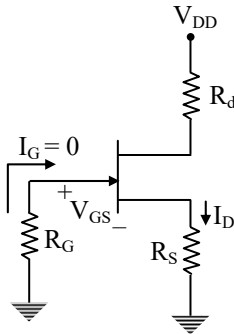
$$\frac{V_0}{V_{gs}} = A_V = -13.3$$

$$V_{gs} = \frac{10^6}{10^6 + 10^4} V_s$$

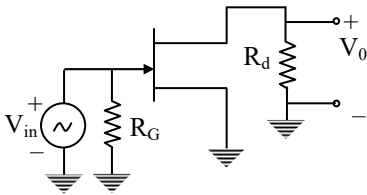


57.

Sol: **DC Equivalent**



AC Equivalent



Device equation

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

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

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

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

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

$$= 1.149 \text{ ms}$$

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

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

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

$$(iv) \quad \text{Voltage gain } (A_V) = -g_m R_d$$

$$\text{Gain (db)} = 20 \log A_V$$

$$20 = 20 \log A_V$$

$$\Rightarrow A_V = 10$$

$$\Rightarrow 10 = g_m R_d$$

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

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