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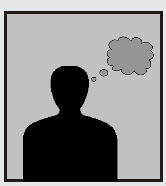


Detailed Explanations of Try Yourself *Questions*

ELECTRICAL ENGINEERING

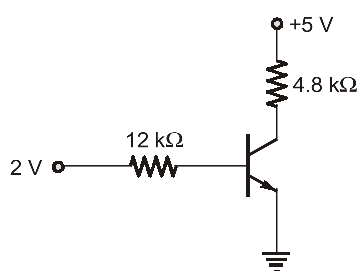
Analog Electronics

MADE EASY Publications

2 Testing of BJT in Different Operating Regions

Detailed Explanation of Try Yourself Questions

T1. (0.902)



$$I_B = \frac{2-0.7}{12} = 0.10833 \text{ mA}$$

$$I_{C(\text{sat})} = \frac{5-0.2}{4.8} = 1 \text{mA}$$

$$I_B \geq I_{B(\text{min})}$$

$$= \frac{I_{C(\text{sat})}}{\beta}$$

$$I_B \geq \frac{1\text{mA}}{\beta}$$

$$\beta \geq \frac{1}{0.10833} \quad \text{and} \quad \beta_{\text{min}} = 9.23$$

$$\alpha_{\text{min}} = \frac{\beta_{\text{min}}}{1+\beta_{\text{min}}} = 0.902$$

T2. (c)

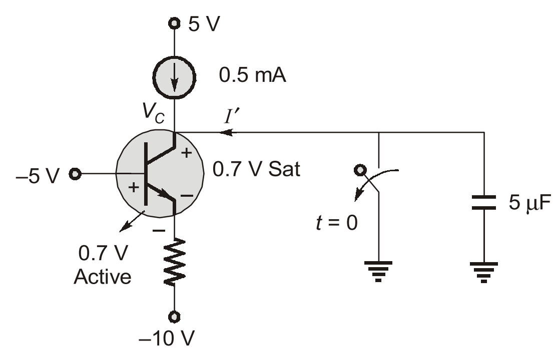
In active region

$-5 - 0.7 - 4.3\, I_E = -10$

$$I_E = \frac{10-5.7}{4.3} = \frac{4.3}{4.3} = 1 \text{ mA}$$

$$I_C = I_E = I' + 0.5 \text{ mA} = 1 \text{ mA}$$

$$\Rightarrow \quad I' = 0.5 \text{ mA}$$



In saturation region ⇒

$V_C - 0.7 - 4.3 \times 1 = -10$

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

$$q = CV_C = -5 \times 10^{-6} \times 5 \text{ V}$$

$$= -25 \times 10^{-6}$$

and $q = it$

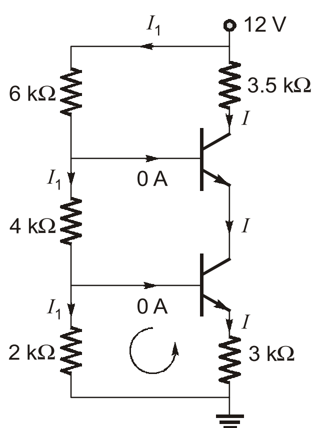
$$I'(0-t) = -25 \times 10^{-6}$$

$$t = \frac{25\times10^{-6}}{0.5\times10^{-3}} = 50 \text{ m sec}$$

3 BJT Biasing

Detailed Explanation of Try Yourself Questions

T1. Sol.



$$I_1 = \frac{12}{6+4+2}\text{ mA}$$

$$I_1 = 1\text{ mA}$$

Applying KVL in loop L

$$I_1 \times 2\text{ k}\Omega - I \times 3\text{ k}\Omega = V_{BE}$$

$$2 - I \times 3k = 0.5$$

$$-I \times 3\text{ k} = -1.5$$

$$I = \frac{-1.5}{-3} \times 10^{-3} = 0.5\text{ mA}$$

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4 BJT Current Mirrors

Detailed Explanation of Try Yourself Questions

T1. (a)

$$I_{ref} = \frac{9-0.7}{30\times10^3} = 0.277 \text{ mA}$$

at node 'a' $\quad I_{ref} = I_C + 3I_B$

(I_{B3} is assumed negligible)

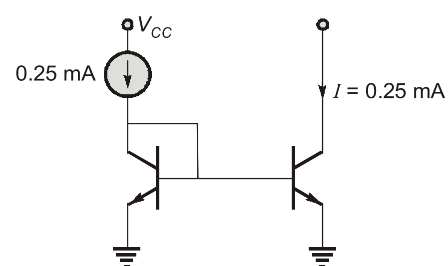
$$= I_C\left(1+\frac{3}{\beta}\right)$$

$$I_C = I_{ref}\left(\frac{\beta}{3+\beta}\right)$$

$$= 0.277\times10^{-3}\left(\frac{125}{128}\right)$$

$$I_{C_1} = 0.27 \text{ mA}$$

T2. (c)



Using current mirror concept,

For large 'β',

$$I = I_{ref}$$

so,

$$I_y = (0.25 + 0.25 + 0.25) \text{ mA}$$

$$I_x = (0.25 + 0.25) \text{ mA}$$

$$I_x + I_y = (0.25)\,5 \text{ mA}$$

$$= 1.25 \text{ mA}$$

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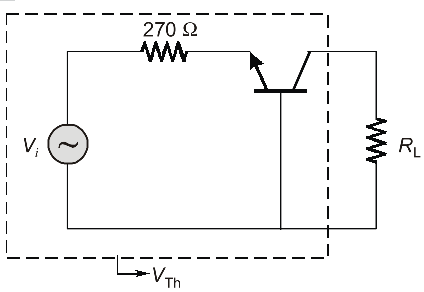
5 Small Signal Analysis of BJT Amplifiers

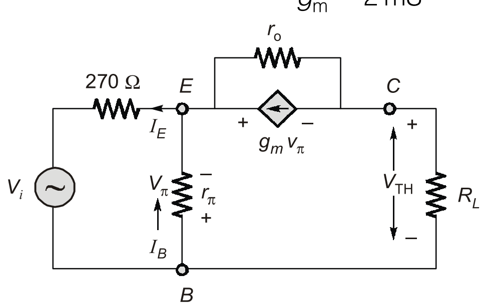
Detailed Explanation of Try Yourself Questions

T1. (d)



$$g_m = 2 \text{ mS} \; ; \; r_o = 250 \text{ k}\Omega$$

$$r_\pi = \beta r_e = \frac{\beta}{g_m} = \frac{100}{2 \text{ mS}} = 50 \text{ k}\Omega$$



$$V_\pi = -v_i \times \frac{r_\pi}{r_\pi + 270}$$

$$= \frac{-50 \text{ k}}{50 \text{ k} + 270} V_i = -0.994 \, v_i$$

$$V_{Th} + r_o g_m v_\pi - v_\pi = 0$$

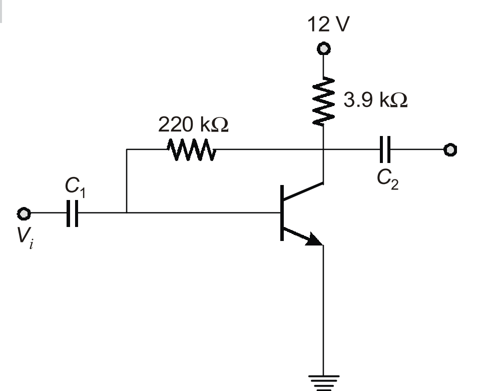
$$V_{Th} = -r_o g_m v_\pi - v_\pi$$

$$= -(1 + g_m r_o)(-0.994 v_i)$$

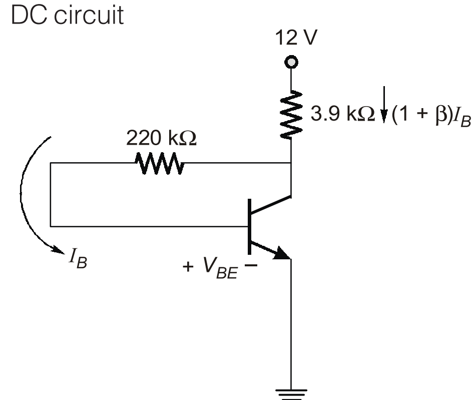
$$= -(1 + 2\text{mS} \times 250 \text{ k}\Omega) \times 0.994 v_i$$

$$V_{Th} = 497.9 \, v_i$$

T2. (d)



DC circuit

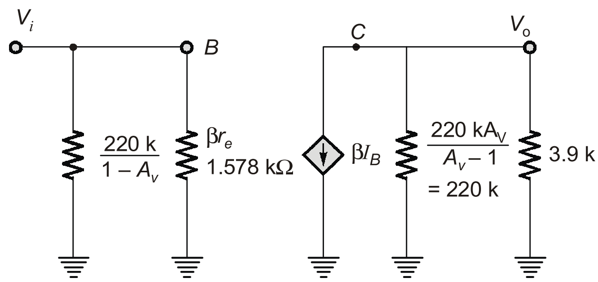


$$I_B = \frac{12 - 0.7}{(1+\beta)3.9 \text{ k} + 220 \text{ k}}$$

$$= 0.0163 \text{ mA}$$

$$I_E = (1 + \beta)I_B = 1.97 \text{ mA}$$

$$r_e = \frac{V_T}{I_E} = \frac{26 \text{ mV}}{1.97 \text{ mA}} = 13.15 \, \Omega$$



$$V_o = -(220\text{ k} \,||\, 3.9\text{ k})\,\beta I_B$$

$$A_v = \frac{-R_C \,||\, R_L}{r_e} = \frac{-3.83\text{ k}}{13.15}$$

$$= -291.41$$

$$Z_i = \frac{V_i}{I_i} = \frac{220\text{ k}}{1-A_v} \,||\, \beta re$$

$$= 0.752\text{ k} \,||\, 1.578\text{ k}$$

$$= 0.509\text{ k}\Omega = 509.4\ \Omega$$

T3. (b)

$$A_I = \frac{-h_{fe}}{1+h_{oe}R_L} = \frac{-50}{1+\frac{1}{40}\times 10}$$

$$\Rightarrow \quad A_I = \frac{-50}{1.25}$$

$$A_v = \frac{A_I \cdot Z_L}{Z_{in}} = \frac{A_I R_L}{h_{ie}}$$

$$A_v = \frac{-50}{1.25} \times \frac{10}{1}$$

$$\Rightarrow \quad A_v = -400$$

T4. (c)

$$R_E = 0.5\text{ k}\Omega \quad ; \quad \beta = 100$$

$$R_C = 5\text{ k}\Omega$$

The voltage gain

$$= A_v = \frac{g_m R_C}{1+g_m R_E} \quad \left(\because R_E >> \frac{1}{g_m}\right)$$

Thus, $|A_v| \simeq \frac{R_C}{R_E} \simeq \frac{5}{0.5} \simeq 10$

T5. (b)

$$g_m = \frac{I_c}{V_T} = \frac{100\ \mu\text{A}}{25\times 10^{-3}\text{ V}} = 4\text{ mA/V}$$

Input resistance

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{4\times 10^{-3}}$$

$$\Rightarrow \quad R_i = r_\pi = 25\text{ k}\Omega$$

T6. (c)

$$h_{oe}\times R_L < 0.1$$

$\Rightarrow$ Approximate analysis can be used

$$A_I \approx -h_{fe} = -30$$

$$A_V \approx \frac{-h_{fe}R_L}{h_{ie}} = \frac{-30\times 2.5}{1} = 75$$

$$A_P = A_V \times A_I = 2250$$

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6 Testing of MOSFET in Different Operating Regions

Detailed Explanation of Try Yourself Questions

T1. (d)

Given : $V_{Th} = 0.4$ V

$V_{GS} = V_G - V_S = 0.5 - 1.5$

$= -1$ V

If $V_{GS} < V_{Th}$ in PMOS, M_1 will be ON

$V_{DS} = V_D - V_S = 0 - 1.5 = -1.5$ V

$V_{GS} - V_t = -1 - 0.4$

$= -1.4$ V

If $V_{DS} \le V_{GS} - V_t$, M_1 is in current saturation.

T2. (b)

Given : $V_{Th} = 0.4$ V

$V_{GS} = V_G - V_S$

$= 0 - 0.9 = -0.9$ V

If $V_{GS} < V_{Th}$ PMOS M_2 will be ON.

$V_{DS} = V_D - V_S = 0.9 - 0.9 = 0$

If $V_{DS} = 0$ V or mV, M_2 will be in ohmic.

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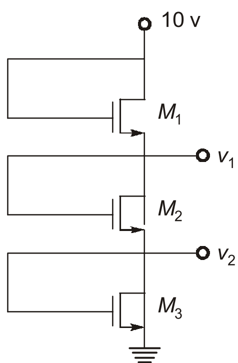
7 MOSFET Biasing

Detailed Explanation of Try Yourself Questions

T1. (a)

If $V_D = V_G$ ∴ we conclude that each MOSFET is in saturation.



$$I_D = k_{n1}(V_{GS} - V_T)^2$$

MOSFET M_1

$$I_D = k_{n1}(V_{GS1} - V_T)^2$$

$$V_{GS1} = 10 - 5 = 5 \text{ v}$$

$$0.5 \text{ mA} = 36\mu \times \frac{1}{2} \cdot \left(\frac{W}{L}\right) \times (5-1)^2$$

$$\left(\frac{W}{L}\right)_1 = 1.73$$

MOSFET M_2

$$I_D = k_{n2}(V_{GS2} - V_T)^2$$

$$0.5 \text{ mA} = 36\mu \times \frac{1}{2}\left(\frac{W}{L}\right)_2 (3-1)^2$$

$$\left(\frac{W}{L}\right)_2 = 6.94$$

MOSFET M_3

$$I_D = k_{n3}(V_{GS3} - V_T)^2$$

$$0.5 \text{ mA} = 36\mu \times \frac{1}{2}\left(\frac{W}{L}\right)_3 (2-1)^2$$

$$\left(\frac{W}{L}\right)_3 = 27.8$$

T2. (a)

To calculate the value of V_{DS}, we require the voltage of both drain and source terminal.

Now, assuming the transistor to be in saturation region, the value of V_{GS} can be calculated as

$$I_D = \frac{\mu_n C_{ox} W}{2L}(V_{GS} - V_T)^2$$

$$1 \times 10^{-3} = 0.5 \times 10^{-3} \times (V_{GS} - V_T)^2$$

$$\sqrt{2} + 1.2 = V_{GS}$$

$$V_{GS} = 1.414 + 1.2$$

$$V_{GS} = 2.614 \text{ V}$$

Now, $V_{GS} = V_G - V_S$

∵ $V_G = 0$

Thus $V_S = -2.614$ V

And $V_D = 5$ V

Thus, $V_{DS} = V_D - V_S = 5 - (-2.614)$

$V_{DS} = 7.614$ V

$V_{DS} > V_{GS} - V_T$, so our assumption is correct.

9 Small Signal Analysis of MOSFET Amplifiers

Detailed Explanation of Try Yourself Questions

T1. (b)

It is common drain amplifier.

$$A_v = \frac{g_m R_s}{1+g_m R_s} = \frac{g_m\ 4\ \text{k}\Omega}{1+g_m\ 4\ \text{k}\Omega} = 0.95$$

$$g_m = 4.75\ \text{m}\mho$$

$$g_m = 2\,k_n\,(V_{GS} - V_T)$$

$$= 2\,k_n\left(\sqrt{\frac{I_D}{k_n}} + V_T - V_T\right)$$

$$g_m = 2\sqrt{I_D\,k_n}$$

$$g_m = 2\sqrt{I_D \times \frac{1}{2}\mu_n\,C_{ox}\left(\frac{W}{L}\right)}$$

$$\frac{W}{L} = 47$$

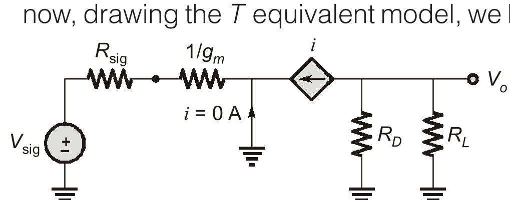
T2. (c)

$$g_m = 2\sqrt{k_n I_D}$$

$$= 2\sqrt{10\times10^{-3}\times10\times10^{-3}}$$

$$g_m = 20\ \text{mA/V}$$

now, drawing the T equivalent model, we have



$$i = -\frac{V_{sig}}{\dfrac{1}{g_m} + R_{sig}}$$

and

$$V_{out} = \frac{(R_D \parallel R_L)\cdot V_{sig}}{\dfrac{1}{g_m} + R_{sig}}$$

$$V_{out} = \frac{g_m (R_D \parallel R_L)}{1+g_m R_{sig}}\cdot V_{sig}$$

$$\therefore\quad V_{out} = \frac{20\times10^{-3}(2\times10^3 \parallel 2\times10^3)\times1\times10^{-3}}{1+20\times10^{-3}\times50}$$

$$V_{out} = 10\ \text{mV}$$

T3. (b)

$$g_m = 2\left[\frac{\mu_n C_{ox} W}{2L}\right](V_{GS} - V_{TN})$$

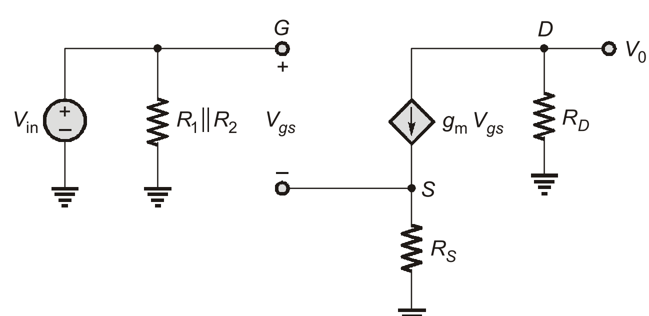
or

$$g_m = 2\sqrt{\frac{\mu_n C_{ox} W}{2L}\times I_{DQ}}$$

$$= 2\sqrt{1\times10^{-3}\times0.5\times10^{-3}}$$

$$= 1.414\ \text{mA/V}$$

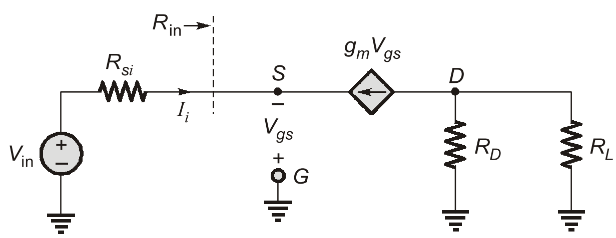
Thus, considering small signal model, we get,



Thus,
$$V_0 = -g_m V_{gs} R_D$$
$$V_{in} = V_{gs} + (g_m V_{gs}) R_S$$
$$V_{in} = V_{gs}(1 + g_m R_S)$$
$$A_v = \frac{V_0}{V_{in}} = \frac{-g_m R_D}{1 + g_m R_S}$$
$$A_v = \frac{-(1.414)(7)}{1+(1.414)(0.5)} = -5.80$$

T4. (b)

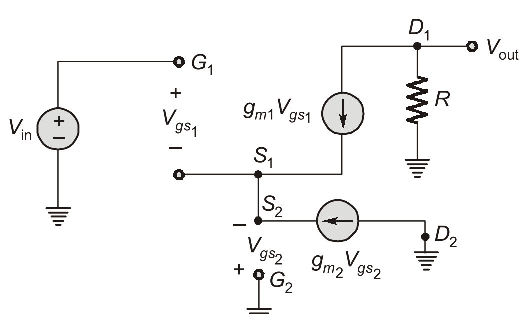
By drawing the small signal equivalent circuit by deactivating all the D.C. supplies, we get,



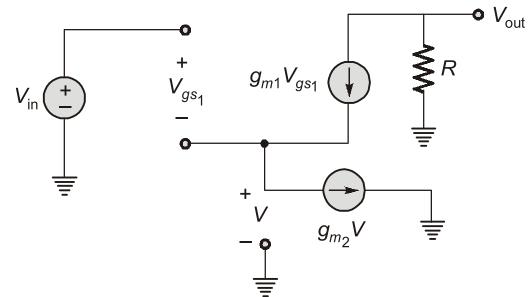
Now, from the figure,
$$R_{in} = \frac{-V_{gs}}{I_i}$$
and
$$I_i = -g_m V_{gs}$$
$$\therefore \quad R_{in} = \frac{-V_{gs}}{-g_m V_{gs}} = \frac{1}{g_m}$$

T5. (a)

By drawing the small signal equivalent circuit, we get



the above circuit can be redrawn as



Substituting $V = -V_{gs_2}$

now, $V_{in} = V_{gs_1} + V$ ...(i)

and $g_{m_1} V_{gs_1} = g_{m_2} \cdot V$

($\because$ from KCL at node S_1) ...(ii)

thus $V_{out} = -\left[g_{m_1} V_{gs_1} R\right]$ ...(iii)

$$V_{out} = -g_{m_1} R(V_{in} - V) \quad \text{(from (i))}$$
$$= -g_{m_1} R V_{in} + g_{m_1} VR$$

now, $V = \dfrac{g_{m_1} V_{gs_1}}{g_{m_2}}$ (from equation (ii))

$$V_{out} = -g_{m_1} R V_{in} + \frac{g_{m_1} R V_{gs_1}}{g_{m_2}} \cdot g_{m_1}$$

now from (3), we get

$$V_{out} = -g_{m_1} R V_{in} - \frac{g_{m_1}}{g_{m_2}} V_{out}$$
$$\left(1 + \frac{g_{m_1}}{g_{m_2}}\right) V_{out} = -g_{m_1} R V_{in}$$
$$V_{out} = \frac{-g_{m_1} R}{1 + \dfrac{g_{m_1}}{g_{m_2}}} V_{in}$$
$$\frac{V_{out}}{V_{in}} = \frac{-R}{\dfrac{1}{g_{m_1}} + \dfrac{1}{g_{m_2}}}$$

Hence, option (a) is correct.

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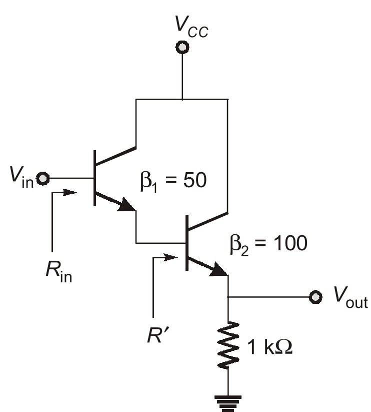
10 Multistage Amplifiers

Detailed Explanation of Try Yourself Questions

T1. (b)

The input resistance will be



$$R' = r_\pi + (\beta_2 + 1)R_E$$
$$= 1\text{k} + (101)(1\text{k}) = 102\ \text{k}\Omega$$
$$R_{in} = r_\pi + (\beta_1 + 1)R'$$
$$= 1\text{k} + (51)(102\text{k}) = 5.203\ \text{M}\Omega$$

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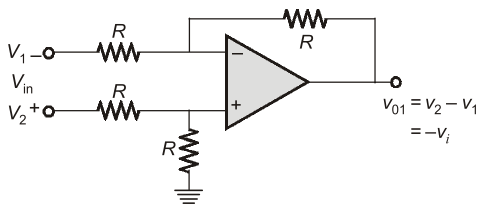
11 Differential Amplifiers & Operational Amplifiers

Detailed Explanation of Try Yourself Questions

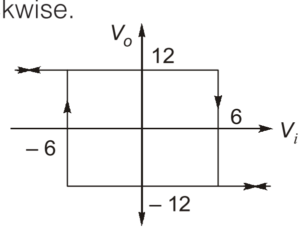
T1. **(b)**

Output of op-amp 1



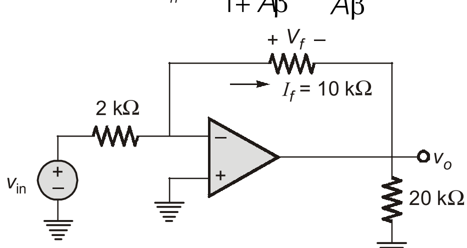
It is connected to schmitt trigger (inverting mode) $\rightarrow$ clockwise.

But inverting amplifier + inverting schmitt trigger $\rightarrow$ anticlockwise.

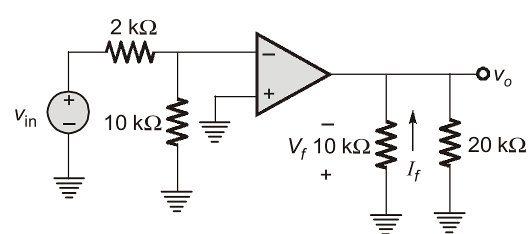


T2. **(b)**

$$R_{if} = \frac{R_i}{1 + A\beta} = \frac{R_i}{A\beta} \qquad A\beta >> 1$$



voltage shunt



$$\beta = \frac{V_f}{V_0} = -1$$

$$\beta = \frac{I_f}{V_0} = -\frac{1}{10\text{k}}$$

$$|\beta| = \frac{1}{10\text{k}}$$

$$R_{if} = \frac{R_i}{A\beta} = \frac{10\text{k}}{10^5 \times \frac{1}{10\text{k}}}$$

$$= \frac{10 \times 10 \times 10^6}{10^5}$$

$$R_{if} = 1\ \text{k}\Omega$$

T3. **(0.5)**

Applying the concept of virtual ground, we get,

$$V_o = -\frac{R_2}{R_1} \cdot V_{in}$$

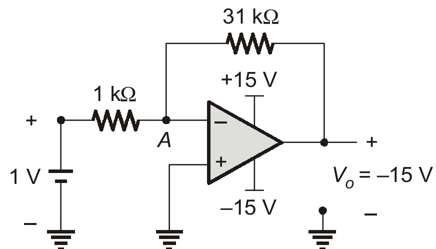
[∵ non-inverting amplifier]

$$\therefore \quad V_o = -\frac{31\text{k}\Omega}{1\text{k}\Omega} \times 1\text{V}$$

$$V_o = -31 \text{ V} < -15 \text{ V}$$

which is not possible

Hence, the output voltage of the op-amp is equal to –15 V.



Now applying KCL of node 'A', we get,

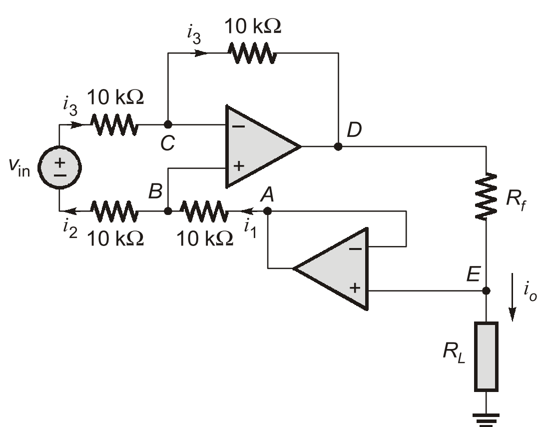
$$\frac{V_A - (-15)}{31\text{k}\Omega} + \frac{V_A - 1}{1\text{k}\Omega} = 0$$

$$\frac{V_A}{31\text{k}\Omega} + \frac{V_A}{1\text{k}\Omega} = \frac{-15}{31\text{k}\Omega} + \frac{1}{1\text{k}\Omega}$$

$$V_A\left[\frac{1}{31} + \frac{1}{1}\right] = -\frac{15}{31} + 1$$

$$V_A = 0.5 \text{ V}$$

T4. (b)



From the circuit,

$$V_E = i_o R_L$$

$$V_E = V_A \text{ (Virtual short concept)}$$

$$i_1 = i_2 = i_3$$

If we apply KVL between node B and C,

$$\therefore \quad V_B = V_C \text{ (Virtual short concept)}$$

$$i_1 = i_2 = i_3 = \frac{V_{in}}{20\text{ k}\Omega}$$

$$V_C - V_D = i_3 \times 10 \text{ k}\Omega = \frac{V_{in}}{2}$$

$$\text{and} \quad V_A - V_B = i_1 \times 10 \text{ k}\Omega = \frac{V_{in}}{2}$$

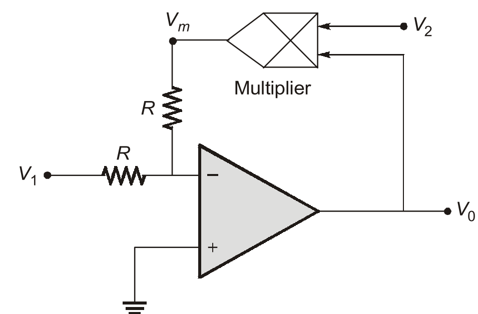
$$\therefore \quad V_B = V_C$$

$$\Rightarrow \quad V_D - V_E = -V_{in}$$

$$\because \quad i_o = \frac{-V_{in}}{R_f}$$

T5. (b)

From the given figure



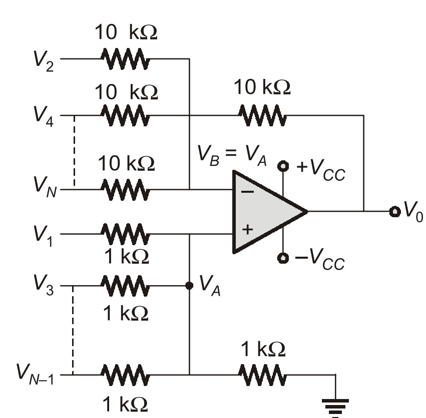
$$V_m = V_2 \times V_0$$

$$\text{and} \quad V_m = -V_1\left(\frac{R}{R}\right) = -V_1$$

$$\text{Thus,} \quad -V_1 = V_2 \times V_0$$

$$V_0 = -\frac{V_1}{V_2} = \frac{-15}{3} = -5 \text{ Volts}$$

T6. (15)



Node A:

$$\frac{V_A - V_1}{1\text{K}} + \frac{V_A - V_3}{1\text{K}} + \ldots\ldots \frac{V_A - V_{N-1}}{1\text{K}} + \frac{V_A}{1\text{K}} = 0$$

$$V_A\left(\frac{N}{2}+1\right) = V_1 + V_3 + \dots + V_{N-1}$$

$$V_B = V_A \quad \because \text{ Virtual short}$$

Node B:

$$\frac{V_A - V_2}{10\,K} + \frac{V_A - V_4}{10\,K} + \dots + \frac{V_A - V_N}{10K} + \frac{V_A - V_0}{10K} = 0$$

$$V_0 = V_A\left(\frac{N}{2}+1\right) - (V_2 + V_4 + V_6 + \dots + V_N)$$

$$= \left(\frac{N}{2}+1\right)\cdot\frac{(V_1 + V_3 + \dots + V_{N-1})}{\left(\frac{N}{2}+1\right)} - (V_2 + V_4 + \dots + V_N)$$

$$= V_1 - V_2 + V_3 - V_4 + \dots$$

$$= 1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} \dots$$

$$= \Sigma\frac{1}{N} = \infty$$

$\Rightarrow$ Output of op-amp goes to saturation

$$V_0 = V_{sat} = V_{CC} = 15\text{ V}$$

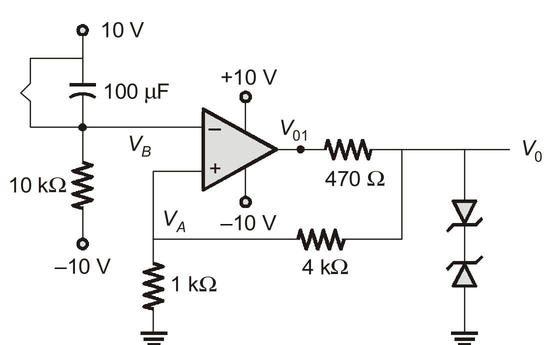
T7. (0.798)

Initially switch is closed and $V_B = 10$ V

$\Rightarrow \quad V_{01} = -10$ V

$\Rightarrow \quad V_0 = -V_2 = -5$ V

$\Rightarrow \quad V_A = \frac{V_0}{4\,k + 1\,k} \times 1k = -1$ V



At $t = 0$;

The switch is opened and as $t \to \infty$, V_B approaches –10 V.

Let at $t = T_1$,

V_B exceeds V_A (–1 V) so that V_{01} changes from –10 V to 10 V

$\Rightarrow V_0$ charges from –5 V to 5 V

$$V_B = V_f + (V_i - V_f)e^{-t/\tau}$$

$$= -10 + [10 - (-10)]\, e^{-t/RC}$$

At $t = T_1 \quad V_B = -1$

$$-1\text{ V} = -10 + 20\, e^{-T1/RC}$$

$$\Rightarrow \quad T_1 = RC\, ln\frac{20}{9}$$

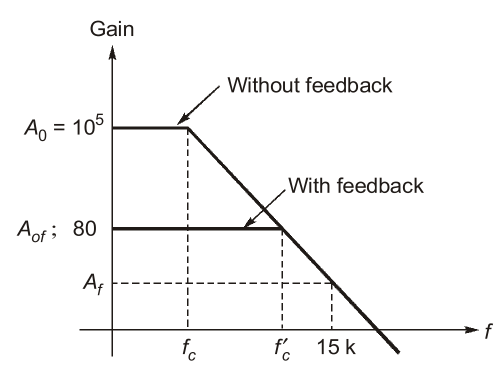
$$= 10 \times 10^3 \times 100 \times 10^{-6} \times 0.798$$

$$= 0.798\text{ sec}$$

T8. (44.4)

- In the given circuit,

Feedback factor, $\beta = \frac{R_1}{R_1 + R_2} = \frac{1}{80}$



- $A_{of} = \frac{A_o}{1 + A_o\beta} \simeq 80$

- $f'_c = f_c(1 + A_o\beta) = 8\left(1 + \frac{10^5}{80}\right)\text{Hz} = 10{,}008\text{ Hz}$

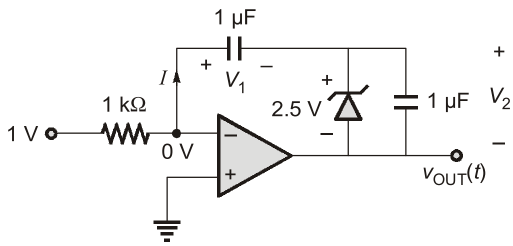
- Gain at f = 15 kHz = 15000 Hz is,

$$A_f = \frac{A_{of}}{\sqrt{1 + \left(\frac{f}{f'_c}\right)^2}}$$

$$= \frac{80}{\sqrt{\left(1 + \left(\frac{15000}{10008}\right)^2\right)}} \simeq 44.4$$

T9. (c)

For $t > 0$,



$$I = \frac{1\text{V}}{1\text{k}\Omega} = 1\text{mA}$$

The capacitor charges with constant current I and both V_1 and V_2 will increase till V_2 reaches 2.5 V. Thereafter, $V_2 = 2.5$ V and V_1 increases with time.

When $v_{out}(t) = -10$ V,

$$V_1 = 7.5 \text{ V}$$

So,

$$\frac{1}{1\mu\text{F}}\int_0^t (1\text{mA})dt = 7.5 \text{ V}$$

$$10^3 t = 7.5$$

$$t = 7.5 \text{ msec}$$

■■■■

12 Negative Feedback Amplifiers & Oscillators

Detailed Explanation of Try Yourself Questions

T1. (a)

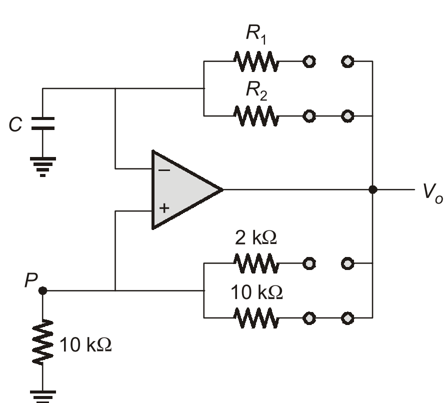
The overall forward gain is 1000 and close loop gain is 100. Thus, $\beta = 0.009$.
Now, when gain of each stage increase by 10% then overall forward gain will be 1331 and using the previous value of β the close loop will be 102.55.
$\Rightarrow$ Close loop Voltage gain increase by 2.55%.

T2. (b)

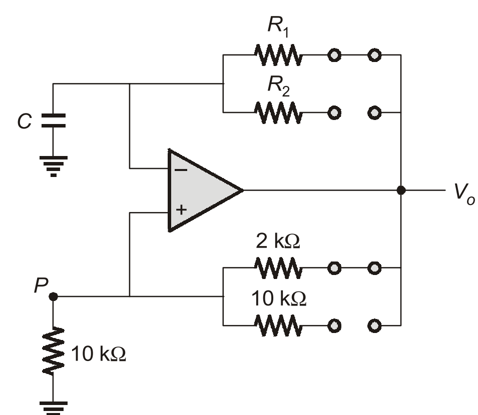
The feedback element is R_f it samples voltage and mix current so shunt-shunt feedback.

T3. (a)

The output can be ±12 V only, when output is 12 V then



So, $V_p = 6$ V
when output is –12 V then



So, $V_p = -10$ V

T4. (d)

Since their are 3 capacitors the maximum phase shift that can be provided will be 270° but due to the presence of the RC circuit the phase shift is equal to 60° for the individual RC circuit, making the phase shift of the feedback network equal to 180°. Thus the amplifier should be an inverting amplifier so that it can be a positive feedback circuit and because the amplifier is a practical amplifier thus $|A\beta| > 1$ for the circuit to work.

■■■■

14 Bipolar Junction Transistor

Detailed Explanation of Try Yourself Questions

T1. (c)

$$\because \quad (\beta + 1) = \frac{I_{CEO}}{I_{CBO}} = \frac{0.6 \times 10^{-3}}{3 \times 10^{-6}} = 200$$

$$\therefore \quad \beta = 199$$

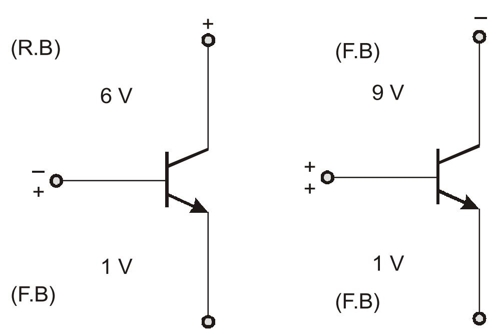
T2. (d)

$$\because \quad I_B = 0$$

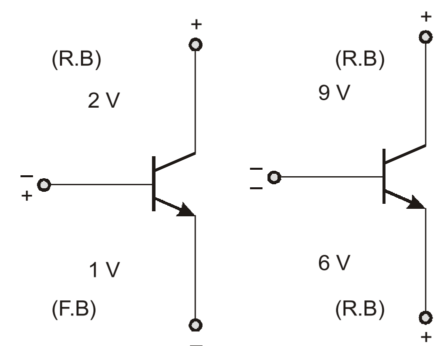
then only emitter to collector current will flow

$$\therefore \quad I_{CEO} = (\beta + 1) I_{CBO}$$
$$= 101 \times 15 \times 10^{-6}$$
$$= 1515\ \mu\text{A} = 1.515\ \text{mA}$$

T3. (c)



(Active) (Saturation)



(Active) (Cut off)

T4. (c)

If base length > length of diffusion then the carriers will not enter the collector.

T5. Sol.

$$I_C = \beta I_C + (\beta + 1) I_{CO}$$

Now, $$\beta + 1 = \frac{I_{CEO}}{I_{CBO}} = \frac{0.6 \times 10^{-3}}{3 \times 10^{-6}} = 200$$

$$\therefore \quad \beta = 199$$

$$\therefore \quad I_C = 199(10\ \mu\text{A}) + (1 + 199) \times 3 \times 10^{-6}$$
$$= 2.59 \times 10^{-3}\ \text{Amp}$$

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