ESE GATE PSUs
State Engg. Exams

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WORKBOOK 2025

Detailed Explanations of Try Yourself *Questions*

ELECTRICAL ENGINEERING
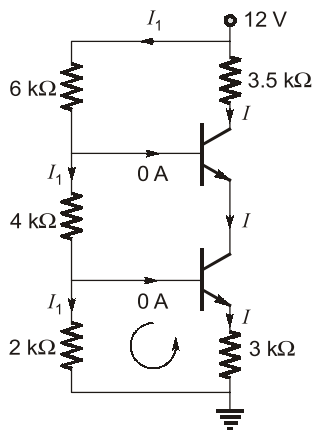## Analog Electronics

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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 $\Rightarrow$

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

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

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

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

and $q = it$

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

$$t = \frac{25 \times 10^{-6}}{0.5 \times 10^{-3}} = 50 \text{ m sec}$$

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BJT Biasing

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)**

$$I_{\text{ref}} = \frac{9 - 0.7}{30 \times 10^3} = 0.277 \text{ mA}$$

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

(I_{B3} is assumed negligible)

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

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

$$= 0.277 \times 10^{-3}\left(\frac{125}{128}\right)$$

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

T2. **(c)**
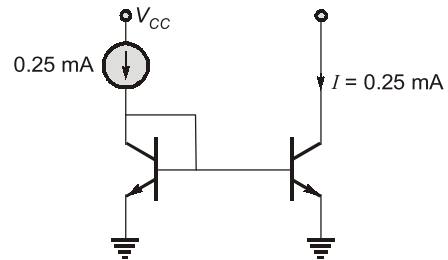
Using current mirror concept,

For large 'β',

$$I = I_{\text{ref}}$$

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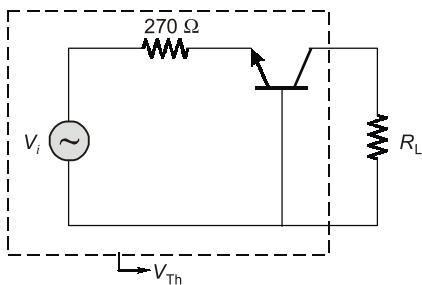
$$g_m = 2 \text{ mS} \; ; \; r_o = 250 \text{ k}\Omega$$

$$r_\pi = \beta r_e = \frac{\beta}{g_m} = \frac{100}{2 \text{ mS}} = 50 \text{ k}\Omega$$
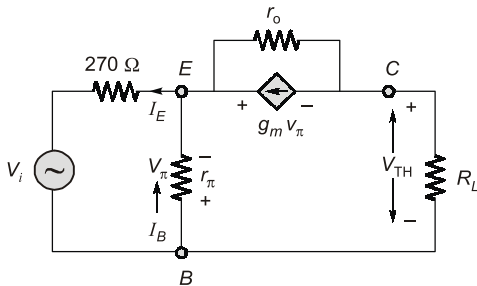
$$V_\pi = -v_i \times \frac{r_\pi}{r_\pi + 270}$$

$$= \frac{-50 \text{ k}}{50 \text{ k} + 270} v_i = -0.994 \, v_i$$
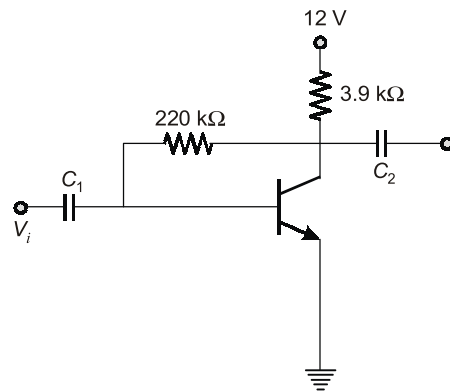
$$V_{Th} + r_o g_m v_\pi - v_\pi = 0$$
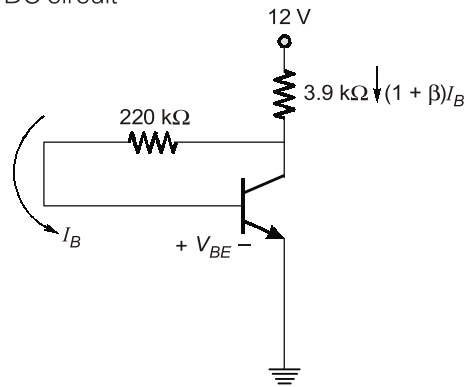
$$V_{Th} = -r_o g_m v_\pi - v_\pi$$

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

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

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

T2. (d)

DC circuit

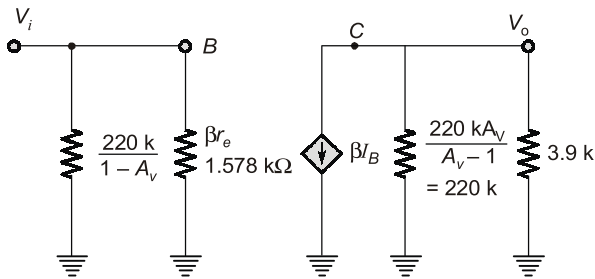$$I_B = \frac{12 - 0.7}{(1+\beta)3.9 \text{ k} + 220 \text{ k}}$$

$$= 0.0163 \text{ mA}$$

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

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

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

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

$$= -291.41$$

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

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

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

T3. (b)

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

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

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

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

$$\Rightarrow \qquad A_v = -400$$

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, $\quad |A_v| \simeq \dfrac{R_C}{R_E} \simeq \dfrac{5}{0.5} \simeq 10$

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

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

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

T6. (c)

$$h_{oe}\times R_L < 0.1$$
$$\Rightarrow \text{ Approximate analysis can be used}$$
$$A_I \approx -h_{fe} = -30$$
$$A_V \approx \frac{-h_{fe}R_L}{h_{ie}} = \frac{-30\times 2.5}{1} = 75$$
$$A_P = A_V\times A_I = 2250$$

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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 $V_{DS} \leq V_{GS} - V_t$, 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 $V_D = V_G \therefore$ we conclude that each MOSFET is in saturation.
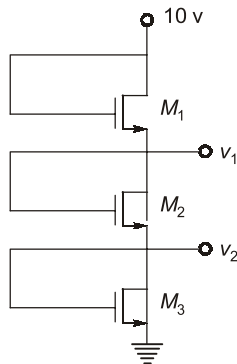
$$I_D = k_{n1} (V_{GS} - V_T)^2$$

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,	$V_{GS} = V_G - V_S$
$\because$	$V_G = 0$
Thus	$V_S = -2.614 \text{ V}$
And	$V_D = 5 \text{ V}$
Thus,	$V_{DS} = V_D - V_S = 5 - (-2.614)$
	$V_{DS} = 7.614 \text{ V}$

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

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9   Small Signal Analysis of MOSFET Amplifiers

T1. **(b)**

It is common drain amplifier.

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

$$g_m = 4.75\ m\mho$$

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

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

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

$$g_m = 2\sqrt{I_D \times \frac{1}{2} \mu_n\ C_{ox} \left(\frac{W}{L} \right)}$$
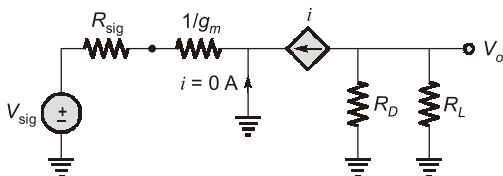
$$\frac{W}{L} = 47$$

T2. **(c)**

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

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

$$g_m = 20\ mA/V$$

now, drawing the *T* equivalent model, we have

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

and

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

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

$$\therefore \quad V_{out} = \frac{20 \times 10^{-3}(2 \times 10^3 \,\|\, 2 \times 10^3) \times 1 \times 10^{-3}}{1 + 20 \times 10^{-3} \times 50}$$

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

T3. **(b)**

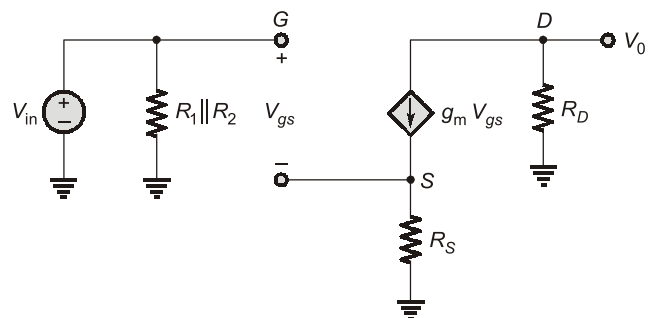$$g_m = 2\left[\frac{\mu_n C_{ox} W}{2L} \right](V_{GS} - V_{TN})$$

or

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

$$= 2\sqrt{1 \times 10^{-3} \times 0.5 \times 10^{-3}}$$

$$= 1.414\ mA/V$$

Thus, considering small signal model, we get,

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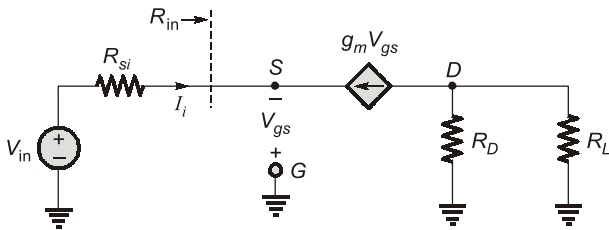$$V_{in} = V_{gs} (1 + g_m R_S)$$
$$A_v = \frac{V_0}{V_{in}} = \frac{-g_m R_D}{1 + g_m R_S}$$
$$A_v = \frac{-(1.414)(7)}{1 + (1.414)(0.5)} = -5.80$$

T4. (b)

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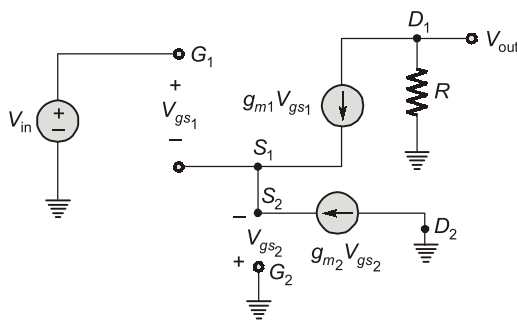

Now, from the figure,
$$R_{in} = \frac{-V_{gs}}{I_i}$$
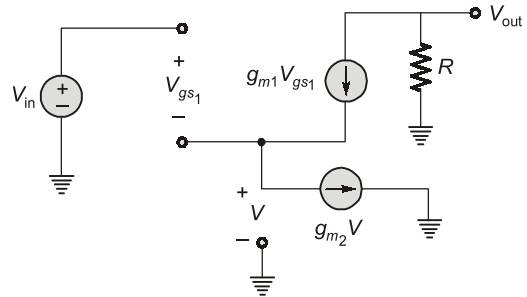and
$$I_i = -g_m V_{gs}$$
$$\therefore \quad R_{in} = \frac{-V_{gs}}{-g_m V_{gs}} = \frac{1}{g_m}$$

T5. (a)

By drawing the small signal equivalent circuit, we get

the above circuit can be redrawn as

Substituting $V = -V_{gs_2}$
now,
$$V_{in} = V_{gs_1} + V \qquad \text{...(i)}$$
and
$$g_{m_1} V_{gs_1} = g_{m_2} \cdot V$$
($\because$ from KCL at node S_1) $\qquad$ ...(ii)

thus
$$V_{out} = -\left[g_{m_1} V_{gs_1} R \right] \qquad \text{...(iii)}$$
$$V_{out} = -g_{m_1} R (V_{in} - V) \qquad \text{(from (i))}$$
$$= -g_{m_1} R V_{in} + g_{m_1} V R$$

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

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

now from (3), we get
$$V_{out} = -g_{m_1} R V_{in} - \frac{g_{m_1}}{g_{m_2}} V_{out}$$

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

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

$$\frac{V_{out}}{V_{in}} = \frac{-R}{\dfrac{1}{g_{m_1}} + \dfrac{1}{g_{m_2}}}$$
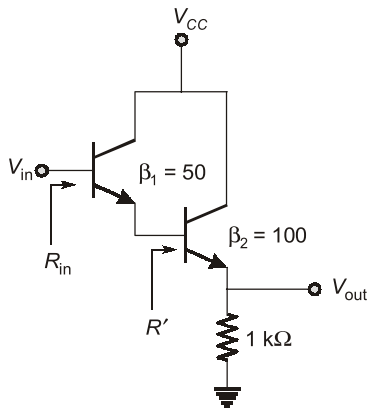
Hence, option (a) is correct.

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10 Multistage Amplifiers

T1. **(b)**

The input resistance will be

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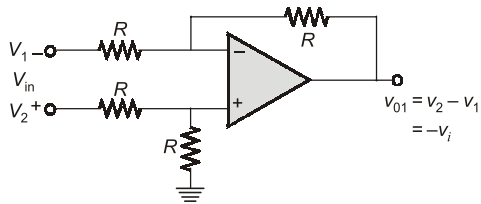$$= 1\text{k} + (51)(102\text{k}) = 5.203\text{ M}\Omega$$

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11 Differential Amplifiers & Operational Amplifiers
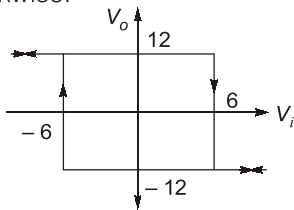

Detailed Explanation
of
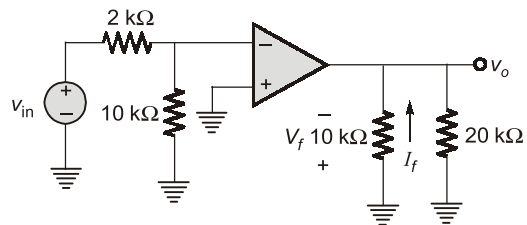**Try Yourself Questions**

T1. (b)

Output of op-amp 1

It is connected to schmitt trigger (inverting mode) → clockwise.

But inverting amplifier + inverting schmitt trigger → anticlockwise.

T2. (b)

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

voltage shunt

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

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

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

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

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

$$R_{if} = 1 \text{ k}\Omega$$
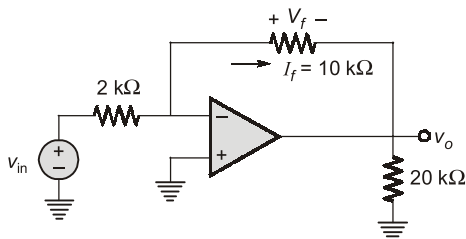
T3. (0.5)

Applying the concept of virtual ground, we get,

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

[∵ non-inverting amplifier]

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

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

which is not possible

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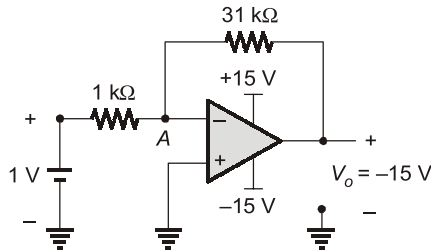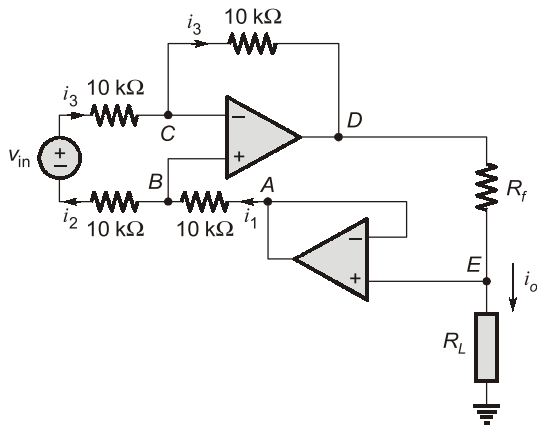

Now applying KCL of node 'A', we get,

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

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

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

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

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,

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

$$i_1 = i_2 = i_3 = \frac{v_{in}}{20\,k\Omega}$$

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

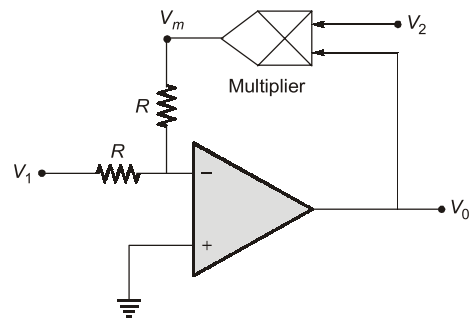and $\qquad V_A - V_B = i_1 \times 10 \text{ k}\Omega = \frac{v_{in}}{2}$

$$\therefore \qquad V_B = V_C$$
$$\Rightarrow \qquad V_D - V_E = -v_{in}$$

$$\therefore \qquad i_o = \frac{-v_{in}}{R_f}$$

T5. (b)
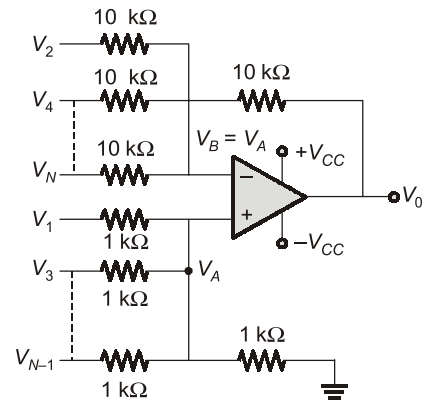
From the given figure

$$V_m = V_2 \times V_0$$

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

Thus, $\qquad -V_1 = V_2 \times V_0$

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

T6. (15)

Node A:

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

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

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

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

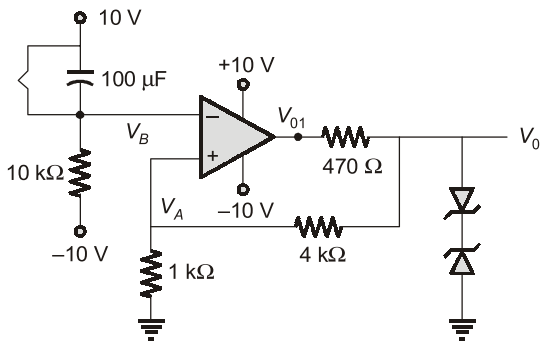$$V_0 = V_{\text{sat}} = V_{CC} = 15\text{ V}$$

T7. (0.798)

Initially switch is closed and $V_B = 10$ V

$$\Rightarrow \qquad V_{01} = -10\text{ V}$$
$$\Rightarrow \qquad V_0 = -V_2 = -5\text{ V}$$

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

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 $t = T_1$ $\quad V_B = -1$
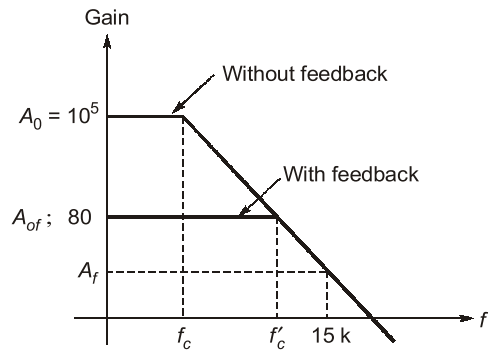$$-1\text{ V} = -10 + 20\,e^{-T_1/RC}$$

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

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

T8. (44.4)

• In the given circuit,

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

• $A_{of} = \dfrac{A_o}{1 + A_o\beta} \simeq 80$

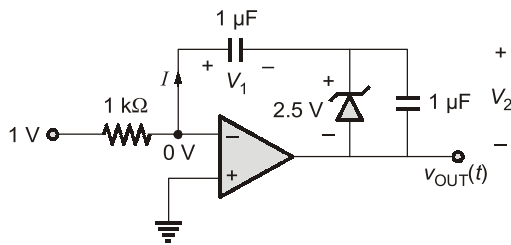• $f_c' = f_c(1 + A_o\beta) = 8\left(1 + \dfrac{10^5}{80}\right)\text{Hz} = 10{,}008\text{ Hz}$

• Gain at $f = 15$ kHz = 15000 Hz is,

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

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

T9. **(c)**

For $t > 0$,

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

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,

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

$$10^3 t = 7.5$$

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

■■■■

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, β = 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.

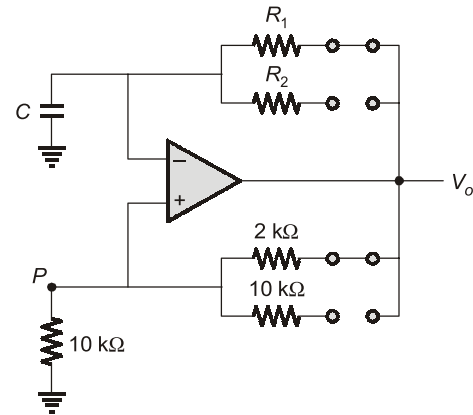⇒ Close loop Voltage gain increase by 2.55%.

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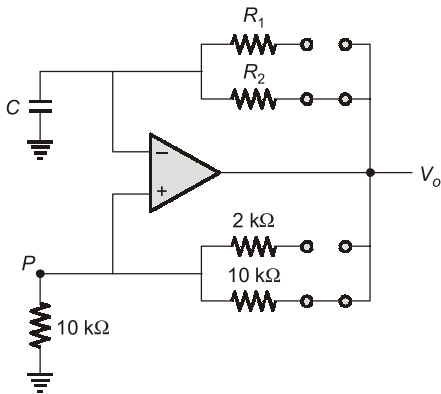
So, $V_p = 6$ V
when output is −12 V then

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)

$$\because \quad I_B = 0$$

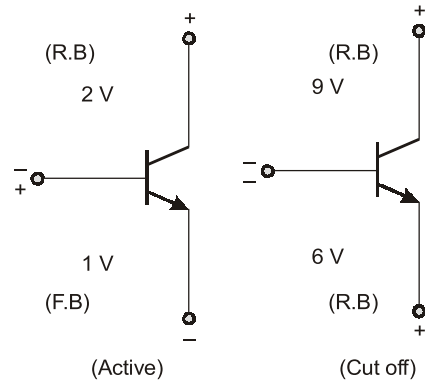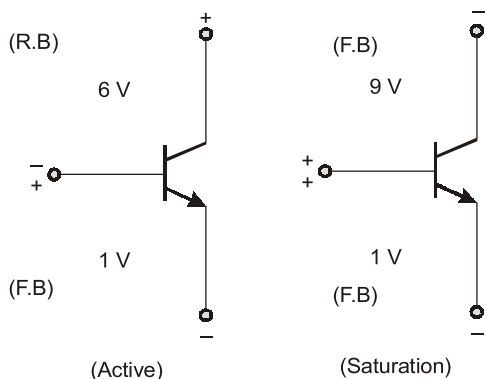then only emitter to collector current will flow

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

T3. (c)

(R.B) 6 V

1 V
(F.B)

(Active)

(F.B) 9 V

1 V
(F.B)

(Saturation)

(R.B) 2 V

1 V
(F.B)

(Active)

(R.B) 9 V

6 V
(R.B)

(Cut off)

T4. (c)

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

T5. Sol.

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

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

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

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