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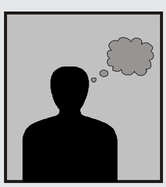


Detailed Explanations of Try Yourself *Questions*

Instrumentation Engineering
Analog Electronics

MADE EASY PUBLICATIONS

2 Bipolar Junction Transistor

Detailed Explanation of Try Yourself Questions

T1. (c)

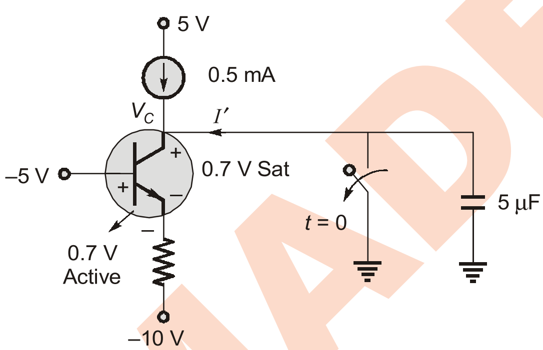
In active region

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

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

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

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



In saturation region ⇒

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

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

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

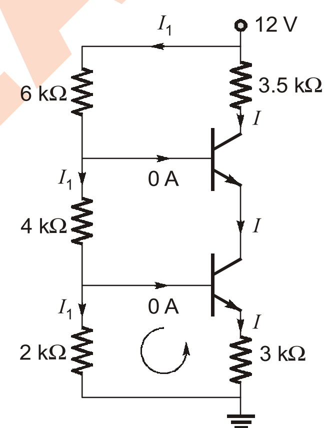
$$= -25 \times 10^{-6}$$

and $q = it$

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

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

T2. Sol.



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

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

Applying KVL in loop L

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

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

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

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

T3. (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)

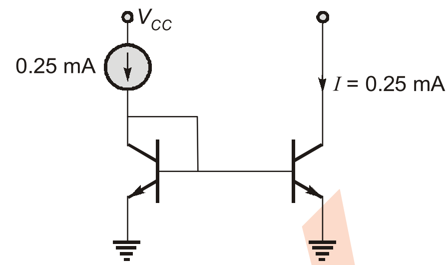
$$= I_C\left(1+\frac{3}{\beta}\right)$$

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

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

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

T4. (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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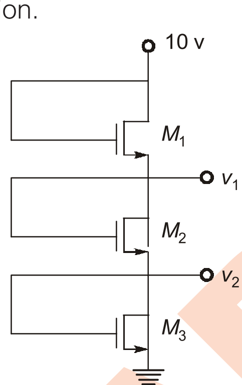
3 MOSFET

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 $V_S = -2.614$ V

And $V_D = 5$ V

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

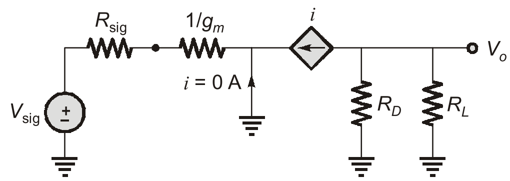
$V_{DS} = 7.614$ V

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

T3. (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



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

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

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

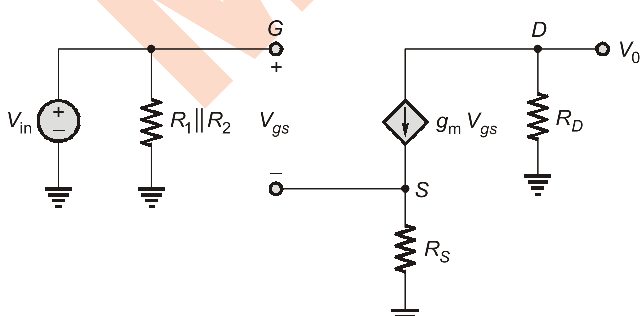
$$\therefore \quad V_{out} = \frac{20\times10^{-3}(2\times10^3 \| 2\times10^3)\times1\times10^{-3}}{1+20\times10^{-3}\times50}$$
$$V_{out} = 10 \text{ mV}$$

T4. (b)

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

or
$$g_m = 2\sqrt{\frac{\mu_n C_{ox} W}{2L}\times I_{DQ}}$$
$$= 2\sqrt{1\times10^{-3}\times0.5\times10^{-3}}$$
$$= 1.414 \text{ mA/V}$$

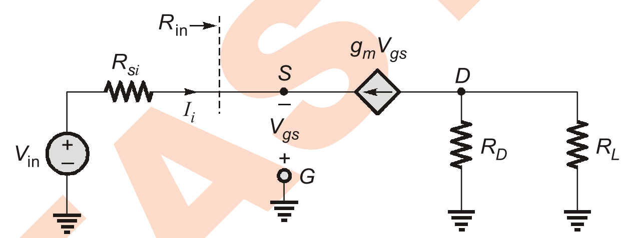
Thus, considering small signal model, we get,



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

T5. (b)

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



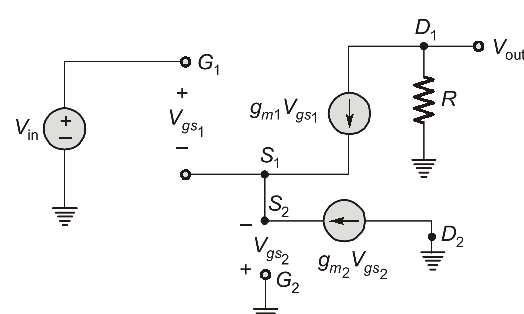
Now, from the figure,
$$R_{in} = \frac{-V_{gs}}{I_i}$$

and
$$I_i = -g_m V_{gs}$$

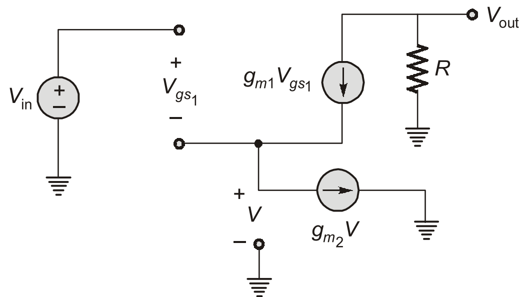
$$\therefore \quad R_{in} = \frac{-V_{gs}}{-g_m V_{gs}} = \frac{1}{g_m}$$

T6. (a)

By drawing the small signal equivalent circuit, we get



the above circuit can be redrawn as



Substituting $V = -V_{gs2}$

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)

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

$$= -g_{m_1}RV_{in} + g_{m_1}VR$$

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

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

now from (3), we get

$$V_{out} = -g_{m_1}RV_{in} - \frac{g_{m_1}}{g_{m_2}}V_{out}$$

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

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

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

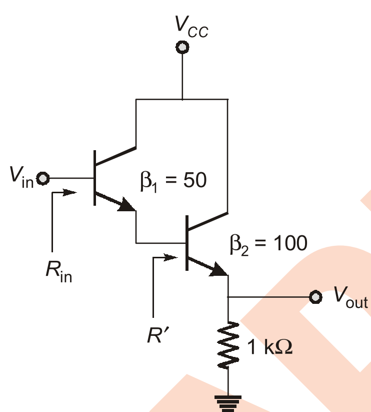
Hence, option (a) is correct.

4 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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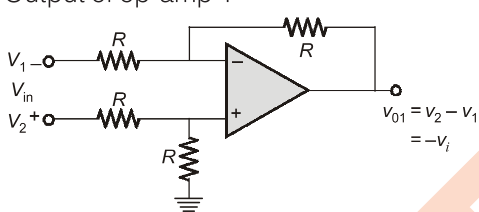
6 Application of Op-amp

Detailed Explanation of Try Yourself Questions

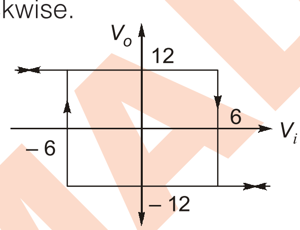
T1. **(b)**

Output of op-amp 1



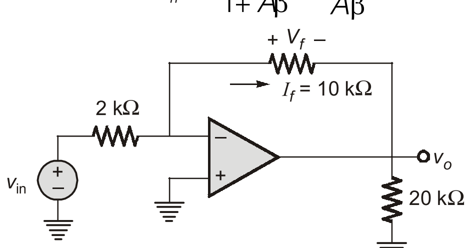
It is connected to schmitt trigger (inverting mode) $\rightarrow$ clockwise.

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

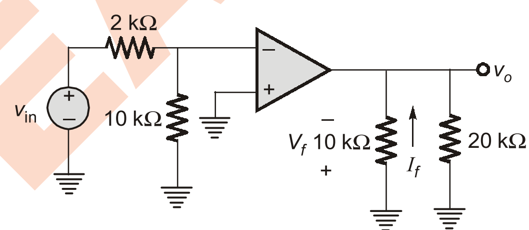


T2. **(b)**

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



voltage shunt



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

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

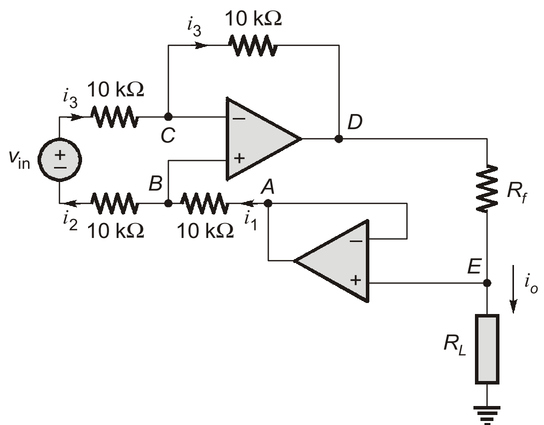
$$|\beta| = \frac{1}{10\text{k}}$$

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

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

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

T3. (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,

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

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

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

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

$$\therefore \quad V_B = V_C$$

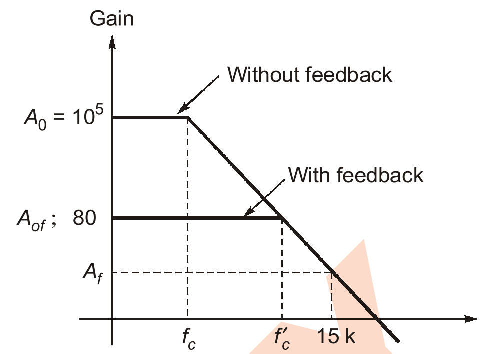
$$\Rightarrow \quad V_D - V_E = -v_{in}$$

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

T4. (44.4)

- In the given circuit,

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

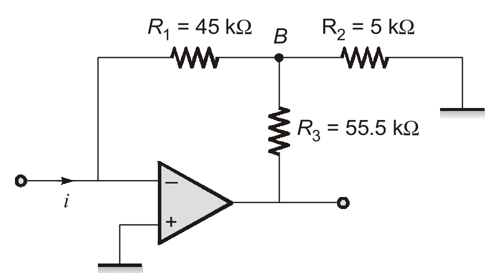


- $A_{of} = \dfrac{A_o}{1 + A_o\beta} \simeq 80$
- $f'_c = f_c(1 + A_o\beta) = 8\left(1 + \dfrac{10^5}{80}\right)\text{Hz} = 10{,}008\text{ Hz}$
- Gain at f = 15 kHz = 15000 Hz is,

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

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

T5. (0.6)



$$V_A = 0 \text{ (By virtual ground)}$$

$$\frac{V_B - 0}{45} + \frac{V_B - V_o}{55.5} + \frac{V_B - 0}{5} = 0$$

$$i = \frac{-(V_B - 0)}{45}$$

$$\therefore \quad V_B = -45\,i$$

$$\frac{-45\,i}{45} + \frac{(-45\,i) - V_o}{55.5} + \frac{(-45\,i)}{5} = 0$$

$$-i - \frac{45i + V_o}{55.5} - 9i = 0$$

$$10i = -\frac{45i + V_o}{55.5}$$

$$600i = V_o$$

$$\frac{V_o}{i} = 600\text{ k}\Omega = 0.6\text{ M}\Omega$$

T6. **(–2.5)**

$$\frac{V_{in} - 0}{R} = 0 + I_C$$

$$\frac{V_{in}}{R} = C\frac{dV_C}{dt} = C\frac{d}{dt}(0 - V_{out})$$

$$-\frac{V_{in}}{RC} = \frac{dV_{out}}{dt}$$

$$V_{out} = \frac{-1}{RC}\int V_{in}\,dt$$

$$V_{out} = \frac{-1}{10^3 \times 2 \times 10^{-6}}\int V_{in}dt$$

$$V_{out} = \frac{-10^3}{2}\int V_{in}dt \text{ Volt}$$

$0 < t < 1$ ms :

$$V_{in} = 5 \text{ volt}$$

$$V_{out} = -\frac{10^3}{2} \times 5(t)$$

at $t = 1$ ms

$$V_{out} = -10^3 \times 2.5 \times 1 \times 10^{-3}$$

$$= -2.5 \text{ volt}$$

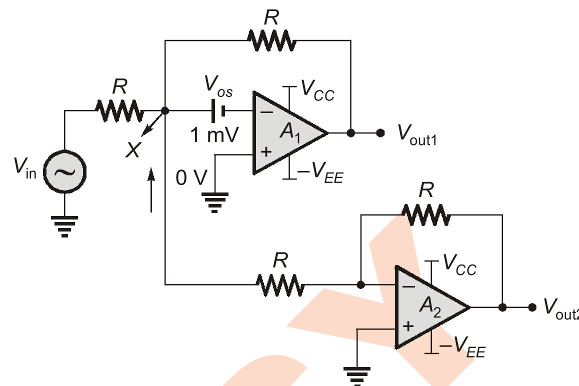
1 ms $< t < 2$ ms:

$$V_{in} = 0 \text{ volt}$$

$$V_{out} = -2.5 \text{ volt}$$

$\therefore$ at $t = 2$ ms, $V_{out} = -2.5$ volt

T7. **(a)**



$\Rightarrow$ applying KCL at node X—

$$\frac{1}{2} + \frac{1 - V_{01}}{R} + \frac{1 - 0}{R} = 0$$

$$V_{01} = 3 \text{ mV}$$

and $\quad V_{out2} =$

$$1 \times \left(\frac{-R}{R}\right) = -1\text{ mV}$$

T8. **15.39**

$$f = \frac{1}{2\pi RC} = \frac{1}{2 \times 22 \times 10^3 \times 0.47 \times 10^6}$$

$$= 15.39 \text{ Hz}$$

T9. **8.109**

$$V_{sat} = 5\text{ V}, \quad \text{UTP} = 3\text{ V}, \quad \text{LTP} = 2\text{ V}$$

$$v_c(t) = V_{final} + (V_{initial} + V_{final})\,e^{-t/\tau}$$

$$\therefore \quad \text{UTP} = V_{sat} + (\text{LTP} - V_{sat})\,e^{-T_1/RC}$$

$$e^{-T_1/RC} = \left[\frac{V_{sat} - \text{UTP}}{V_{sat} - \text{LTP}}\right]$$

$$\therefore \quad \text{Total, } T = 2T_1 = 2RC\,ln\left[\frac{5-2}{5-3}\right]$$

$$\therefore \quad T = 8.109 \text{ m-sec.}$$

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7 Negative Feedback Amplifiers

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.

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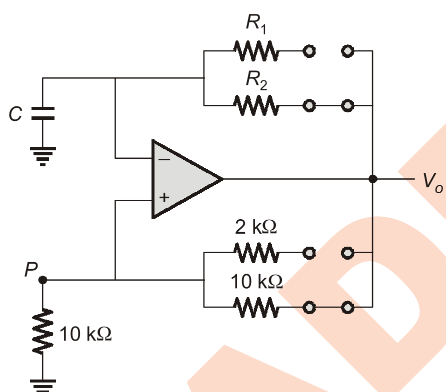
8 Oscillators

Detailed Explanation of Try Yourself Questions

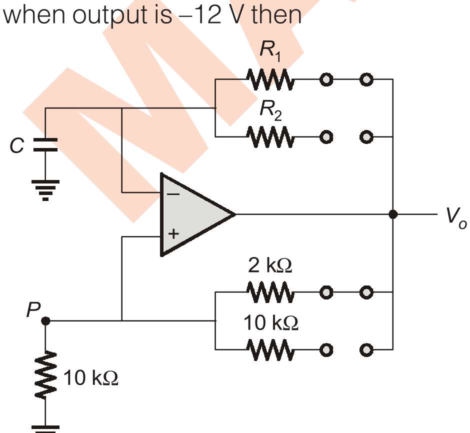
T1. (a)

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

T2. (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.

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