2017

MADE EASY WORKBOOK

Detailed Explanations of Try Yourself Questions

Electrical Engineering

Analog Circuits

MADE EASY Publications

2 Diode Applications

Detailed Explanation of Try Yourself Questions

T3 : Solution

(a)

In this question we need to determine which diode is on and which diode is OFF, clearly diode D_3 is OFF because if it is on then current from current source will flow from *n* to *p* terminal of the diode D_3 and this is not possible, hence D_3 is OFF.

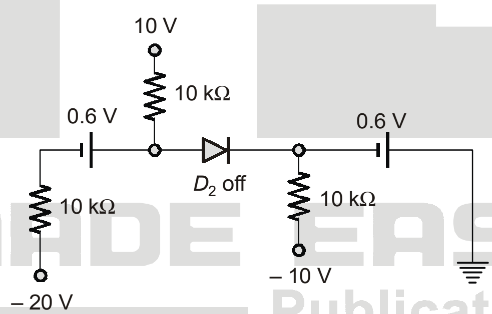
Applying the same concept, we can say diode D_2 is also OFF.

Diode D_1 is on because it is forced by the battery of 10 V.

T2 : Solution

(c)

Assume D_1on, D_2off, D_3on



$$I_{D1} = \frac{10-0.6-(-20)}{20\,k} = 1.47 \text{ mA}$$

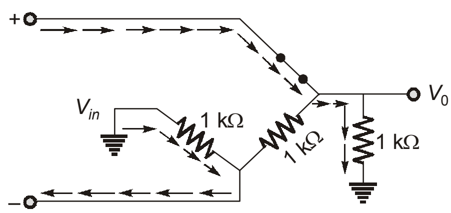
$$I_{D2} = 0$$

$$I_{D3} = \frac{0-0.6(-10)}{10k} = 0.94 \text{ mA}$$

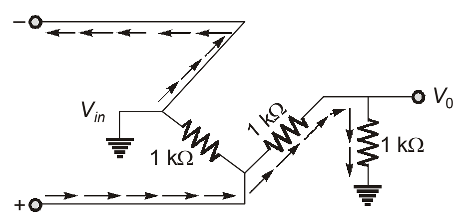
(c)
Since all the voltage are positive all the diodes will try to be forward biased but only the diode with highest voltage will be switched on rest will be in off state.

T4 : Solution

(b)



For positive cycle of input



For negative cycle of input

Thus the V_{in} will appear across the series combination of the two 1 kΩ resistors and we are taking output across 1 kΩ resistance only hence the output will be reduced by 50 % and the above circuit will work as a full wave rectifier with an attenuation of 1/2.

T5 : Solution

(b)
Since there is a D.C level shift in the output waveform thus the circuit must be a clamper circuit and when the diode is conducting then the voltage at the output must be 5 V as seen from the output waveform hence option (b).

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3 Bipolar Junction Transistor

Detailed Explanation *of* Try Yourself Questions

T1 : Solution

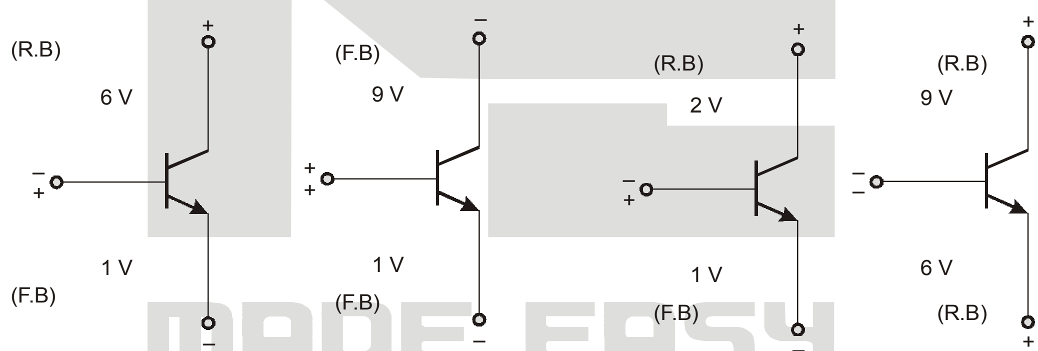
(c)

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

$\therefore \quad \beta = 199$

T2 : Solution

(c)



(Active) (Saturation) (Active) (Cut off)

T3 : Solution

(d)

$\because \quad I_B = 0$

then only emitter to collector current will flow

$\therefore \quad I_{CEO} = (\beta + 1)I_{CBO}$

$= 101 \times 15 \times 10^{-6}$

$= 1515\ \mu A = 1.515\ mA$

T4 : Solution

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

T5 : Solution

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

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

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

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

$$= 2.59 \times 10^{-3} \text{ Amp}$$

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4 BJT Biasing

Detailed Explanation of Try Yourself Questions

T1 : Solution

$$V_{CC} - I_{C1}R_2 - V_{CE1} = 0$$

$$6 - 1.5 \text{ mA} \times R_2 - 3 = 0$$

$$R_2 = 2 \text{ k}\Omega$$

$$I_{B1} = \frac{IC_1}{\beta_1} = \frac{1.5mA}{150} = 0.01 \text{ mA}$$

I_{B2} will be equal to I_{B1} as there is no change in R_1

$$I_{C2} = \beta_2 I_{B2}$$

$$= 200 \times 0.01 \text{ mA} = 2 \text{ mA}$$

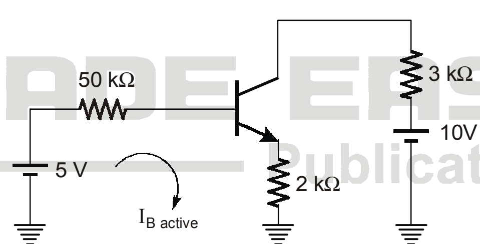
$$V_{CE2} = V_{CC} - I_{C2}R_2$$

$$= 6 - 2 \text{ mA} \times 2\text{k}\Omega = 2 \text{ V}$$

The new operating point is Q(2 V, 2 mA).

T2 : Solution

Assume Q is in active region

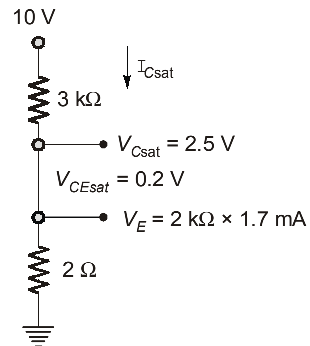


$$I_{Bactive} = \frac{5 - 0.7}{50k + 101 \times 2k}$$

$$= \frac{4.3}{252} = 17 \text{ µA}$$

$$I_{Cactive} = \beta I_{Bactive}$$
$$= 100 \times 17\ \mu A = 1.7\ mA$$

KVL in output loop,



$$V_{Csat} = 3.6\ V$$
$$V_{CEsat} = 0.2\ V$$
$$V_E = 2\ k\Omega \times 1.7\ mA = 3.4\ V$$
$$I_{Csat} = \frac{10 - 3.6}{3k\Omega} = 2.13\ mA$$
$$I_{Csat} > I_{Cactive} \qquad \text{(Active region)}$$

T3 : Solution

Since I_1 = 0.2 mA and I_2 = 0.3 mA. So n_1 = 2 and n_2 = 3, because we need to find minimum number of BJT required.

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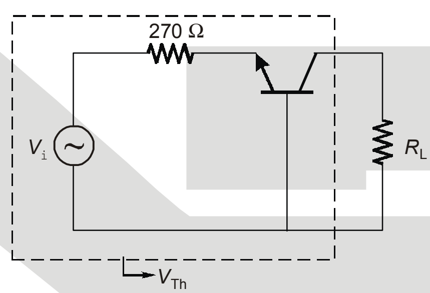
5 Small Signal Analysis of BJT

Detailed Explanation of Try Yourself Questions

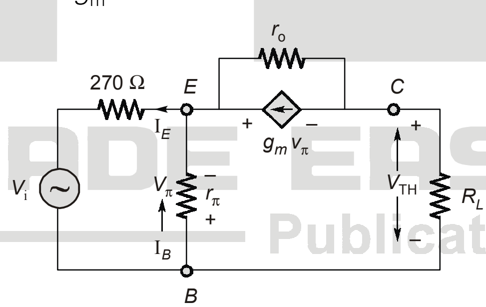
T1 : Solution

(d)



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

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



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

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

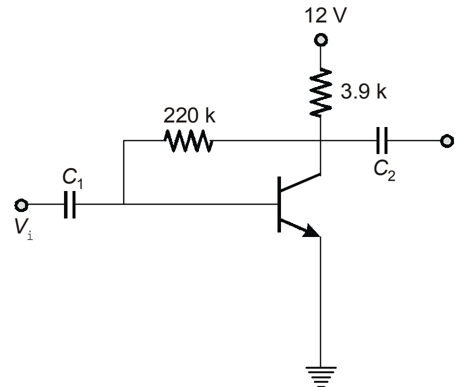
$$V_{Th} = -r_o g_m v_\pi - v_\pi = -(1 + g_m r_o)(-0.994 v_i)$$

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

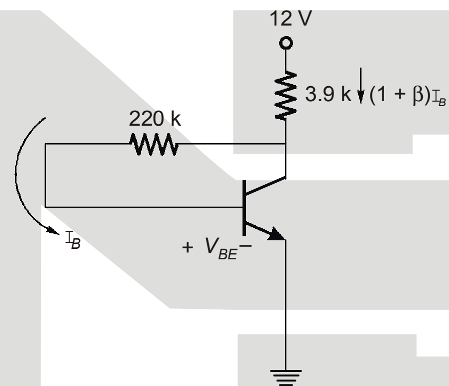
$$V_{Th} = 497.9\, v_i$$

T2 : Solution

(d)



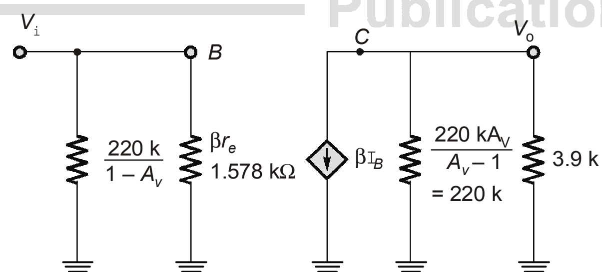
DC circuit:



$$I_B = \frac{12 - 0.7}{(1+\beta)3.9\text{ k} + 220\text{ k}} = 0.0163\text{ mA}$$

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

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



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

$$A_v = \frac{-R_C \,||\, R_L}{r_e} = \frac{-3.83\text{ k}}{13.15} = -291.41$$

$$Z_i = \frac{V_i}{I_i} = \frac{220\text{ k}}{1 - A_v} \,||\, \beta re = 0.752\text{ k} \,||\, 1.578\text{ k} = 0.509\text{ k}\Omega = 509.4\ \Omega$$

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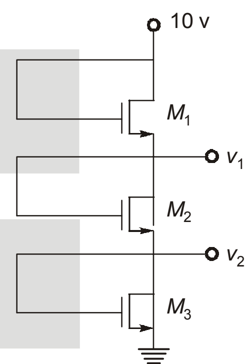
6 FET Biasing

Detailed Explanation of Try Yourself Questions

T1 : Solution

(a)

Ad $V_D = V_G$ ∴ 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

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

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

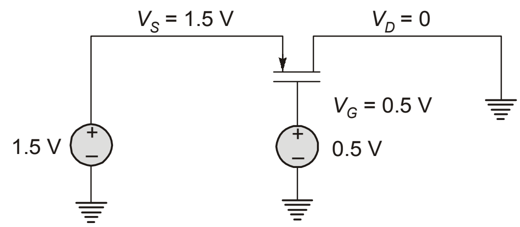
$$\left(\frac{W}{L}\right)_3 = 27.8$$

T2 : Solution

(c)

If $V_{TH} = 0.4$ v

PMOS in depletion mode



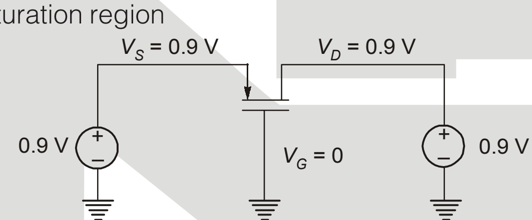
$V_{SD} > V_{SG} + V_{TH} \rightarrow$ current saturation

$V_{SD} < V_{SG} + V_{TH} \rightarrow$ Triode region

$V_{SD} = V_S - V_G = 1.5 - 0.5 = 1$ v

$V_{SD} = V_S - V_D = 1.5 - 0 = 1.5$ v

1.5 > 1 V + 0.4 current saturation region



PMOS in depletion mode.

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

$$V_{SG} = V_S - V_G = 0.9 - 0 = 0.9$$

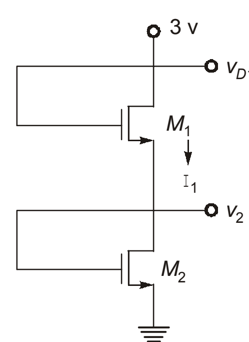
$$0 < 0.9 + 0.4 \text{ triode region}$$

T3 : Solution

(b)

Given: $V_{TH} = 1$ V

So MOSFET is an *n* channel enhancement MOSFET in both transistors



$$V_D = V_G$$

M_1 and M_2 are in current saturation

$$3 - V_{DS1} - V_{DS2} = 0$$

$$V_{DS1} + V_{DS2} = 3 \text{ V}$$

$$V_{DS2} = \frac{3}{2} = 1.5 \text{ v} \quad (V_{DS1} = V_{DS2})$$

$$V_{GS2} = V_{DS2} = 1.5 \text{ v} = V_2$$

$$V_{GS1} = V_{DS1} = 1.5 \text{ v}$$

$$I_1 = I_{D1} = I_{D2}$$

$$= \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS1} - V_{TH})^2 = \frac{1}{2} \times 20 \times 3(1.5 - 1)^2 \, \mu\text{A} = 7.5 \, \mu \text{ A}$$

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7 Small Signal Analysis of FET

Detailed Explanation of Try Yourself Questions

T1 : Solution

(b)

It is common drain amplifier.

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

$$g_m = 4.75 \text{ m℧}$$

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

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

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

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

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

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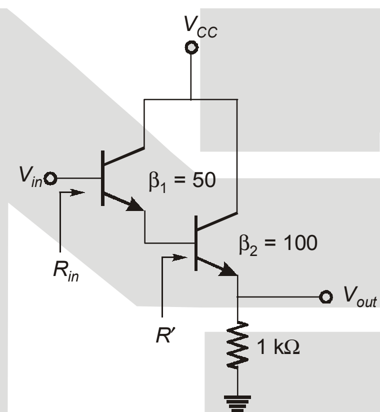
8 Multistage Amplifiers

Detailed Explanation of Try Yourself Questions

T1 : Solution

(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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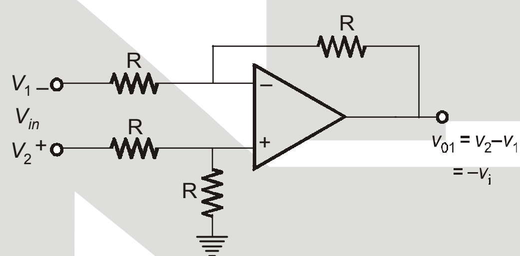
9 Op-Amps and 555 Timer

Detailed Explanation of Try Yourself Questions

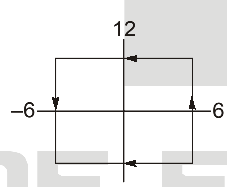
T1 : Solution

(b)

Output of op-amp 1



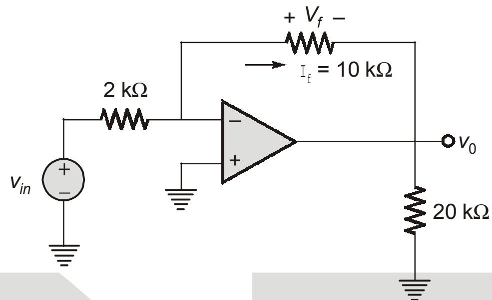
It is connected to schmitt trigger (inverting mode) → clockwise.
But inverting amplifier + inverting schmitt trigger → anticlockwise.



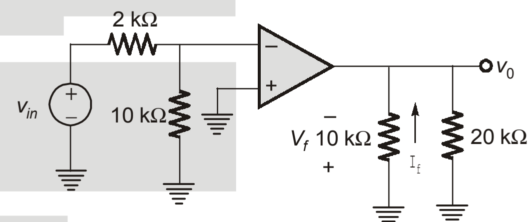
T2 : Solution

(b)

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



Voltage shunt:



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

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

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

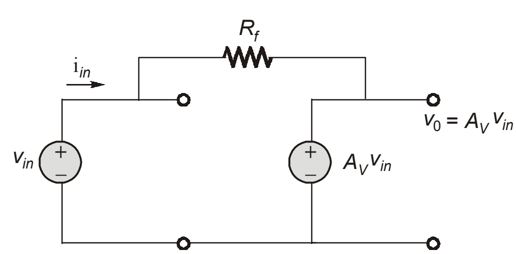
$$R_{if} = \frac{R_i}{A\beta} = \frac{10k}{10^5 \times \frac{1}{10k}} = \frac{10 \times 10 \times 10^6}{10^5}$$

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

T3 : Solution

(b)

Redrawing the circuit by replacing amplifier with its block diagram from the given properties $R_i = \infty$; $R_0 = 0$; voltage gain = A_V



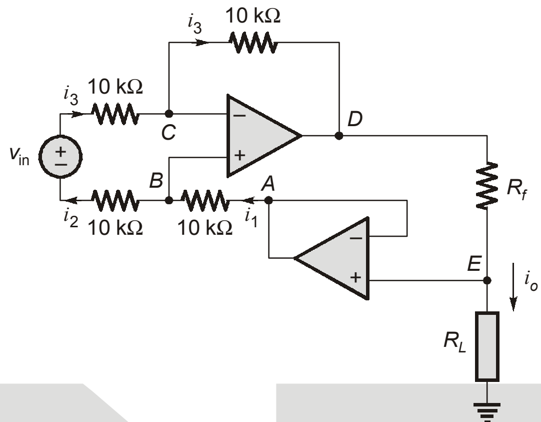
$$i_{in} = \frac{V_{in} - V_0}{R_f}$$

$$i_{in} = \frac{V_{in} - A_v V_{in}}{R_f} = \frac{V_{in} - [1 - A_v]}{R_f}$$

$$R_{in} = \frac{V_{in}}{i_{in}} = \frac{R_f}{1 - A_v}$$

T4 : Solution

(b)



From the circuit,

$$V_E = i_o R_L$$

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

$$i_1 = i_2 = i_3$$

If we apply KVL between node B and C,

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

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

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

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

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

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

T5 : Solution

(a)

The duty cycle of the above astable multivibrator (designed using 555 timer) is

$$\because \quad \frac{T_{on}}{T} = \frac{R_A + R_B}{R_A + 2R_B}$$

Thus duty cycle > 50%.

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10 Negative Feedback Amplifiers and Oscillators

Detailed Explanation of Try Yourself Questions

T1 : Solution

(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 : Solution

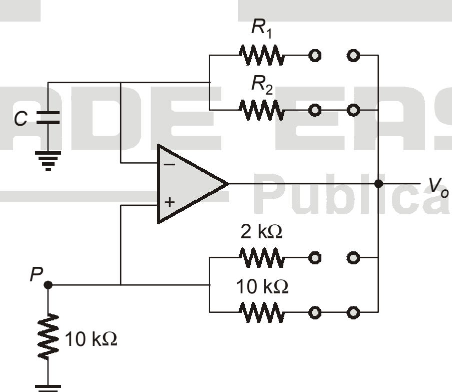
(b)

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

T3 : Solution

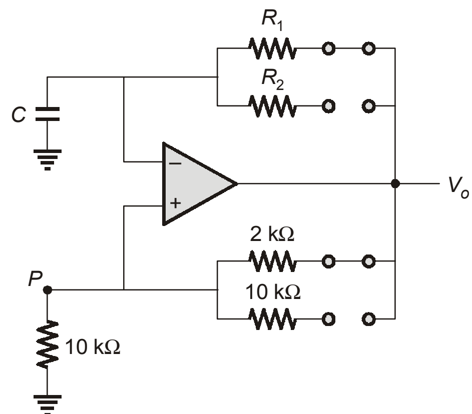
(a)

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 : Solution

(a)

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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