RIB RANK IMPROVEMENT BATCH
ELECTRONICS ENGINEERING

RIB-R | T6

Session 2019 -20 | S.No. : 230819_LS1A

ANSWER KEY ➤ Analog Electronics

1.	(d)	7.	(a)	13.	(c)	19.	(c)	25.	(c)
2.	(a)	8.	(d)	14.	(b)	20.	(b)	26.	(a)
3.	(b)	9.	(b)	15.	(c)	21.	(d)	27.	(c)
4.	(a)	10.	(c)	16.	(a)	22.	(d)	28.	(d)
5.	(c)	11.	(c)	17.	(c)	23.	(b)	29.	(c)
6.	(b)	12.	(d)	18.	(d)	24.	(d)	30.	(c)

DETAILED EXPLANATIONS

1. (d)

$$V = 11V_1$$
$$V_{o_1} = V = 11V_1$$
$$V_{o_2} = -V = -11V_1$$
$$V_{o_1} - V_{o_2} = 22V_1$$
$$V_{o_1} + V_{o_2} = 0$$

2. (a)

For op-amp $V_+ = V_- = 6.2\text{ V}$

For non inverting configuration,

$$V_0 = V_+\left(1+\frac{R_2}{R_1}\right)$$

$$V_0 = 6.2\left[1+\frac{30\times10^3}{10\times10^3}\right] = 24.8\text{ V}$$

3. (b)

$$\text{CMRR} = \frac{A_{dm}}{A_{cm}}$$

$$10^5 = \frac{10^5}{A_{cm}}$$

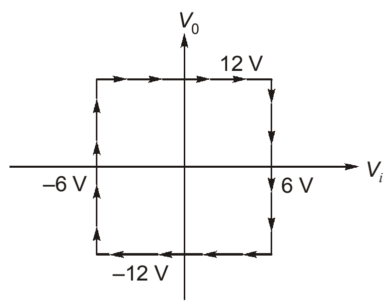
$$A_{\text{cm}} = 1$$

4. (a)

$$V^+ = \frac{V_0 \cdot 2}{2+2} = \frac{V_0}{2}$$

when $V^+ > V^- \Rightarrow V_0 = V_{CC} = 12\text{ V}$

when $V^+ < V^- \Rightarrow V_0 = -V_{CC} = -12\text{ V}$



$$V_H = 6 - (-6) = 12\text{ V}$$

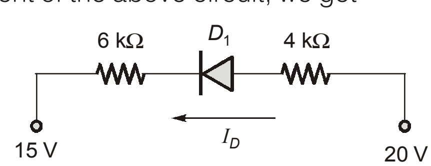
5. (c)

Transistor M_F senses the output voltage and returns a current to the input. Thus its a transresistance amplifier (or) a voltage - current feedback (voltage shunt feedback).

$$\beta = \frac{I_F}{V_{\text{out}}} = \frac{V_{\text{in}}}{V_{\text{out}}}$$

6. (b)

Taking the Thevenins equivalent of the above circuit, we get



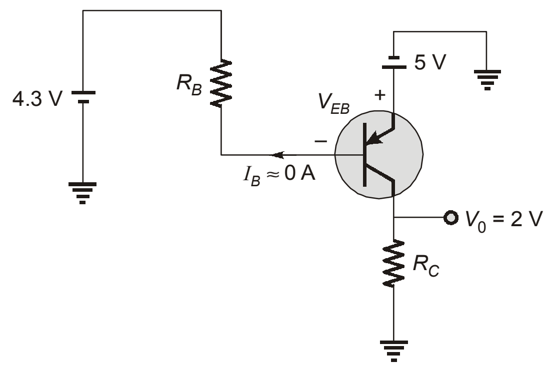
D_1 is on

$$I_D = \frac{20-15}{10\text{k}\Omega} = 0.5\text{ mA}$$

7. (a)

Since β is very large, base current I_B can be neglected.

Thus



Applying KVL in base loop, we get,

$$V_{EB} + 4.3 = 5 \text{ V}$$

$\therefore$ $$V_{EB} = 0.7 \text{ V}$$

Thus $$V_B = 0.7$$

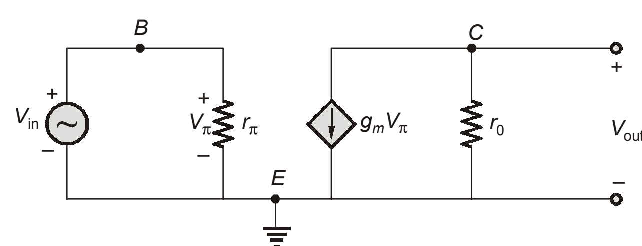
Now $$V_C = 2 \text{ V}$$

Hence $$V_{CB} = 2 - 0.7 = 1.3 \text{ V}$$

Hence, emitter base junction $\Rightarrow$ forward biased and collector base junction $\Rightarrow$ reverse biased.
Thus the transistor is working in forward active region or active region.

8. (d)
Option (a) and (c) are wrong and option (b) does not include the resistance r_0.

9. (b)
Since the current source is ideal, the collector resistance $R_C \to \infty$.
Small signal model,



$$V_\pi = V_{in}$$

$$\frac{V_{out}}{V_{in}} = -g_m r_0$$

$$g_m = \frac{I_C}{V_T}$$

$$r_0 = \frac{V_A}{I_C}$$

$$\frac{V_{out}}{V_{in}} = -\frac{V_A}{V_T} = \frac{-10000}{25}$$

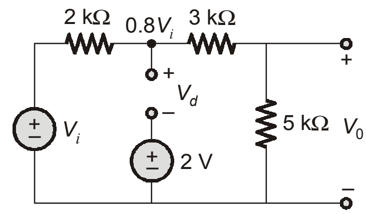
$$\frac{V_{out}}{V_{in}} = -400 \text{ V/V}$$

10. (c)

$$f_\beta = \frac{1}{2\pi r_\pi (C_\pi + C_\mu)} = \frac{1}{2\pi \times 2.6 \times 10^3 \times (2 + 0.1) \times 10^{-12}}$$

$$f_\beta = 29.15 \text{ MHz}$$

11. (c)



$$V_d = 0.8V_i - 2$$

for $V_d < 0,$ diode acts open circuit

$$0.8V_i < 2$$

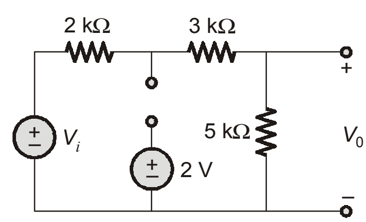
$$\Rightarrow \quad V_i < \frac{2}{0.8} = 2.5 \text{ Volts}$$

for $V_i > 0,$ diode acts shorts circuit

$$0.8V_i > 2$$

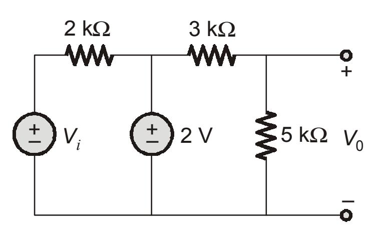
$$\Rightarrow \quad V_i > 2.5 \text{ V}$$

Case - I (when $V_i < 2.5$ V) :



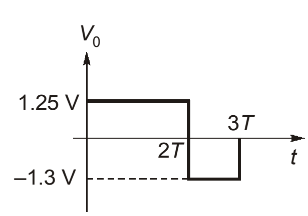
$$V_0 = \frac{V_i}{2}$$

Case - II (when $V_i > 2.5$ V) :



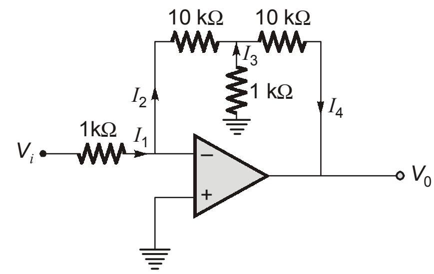
$$V_0 = \frac{2 \times 5}{8}$$

$$V_0 = 1.25 \text{ V}$$



12. (d)

Since the two port network is symmetric thus converting it into T network we get the circuit as shown below.



$$I_1 = I_2 = \frac{V_i}{1\text{k}\Omega}$$

and
$$I_3 = \frac{10V_i}{1\text{k}\Omega}$$

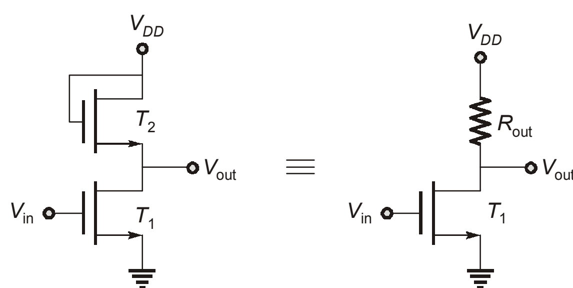
and
$$I_4 = I_2 + I_3 = \frac{11V_i}{1\text{k}\Omega}$$

$\Rightarrow$
$$V_0 = -120\ V_i$$

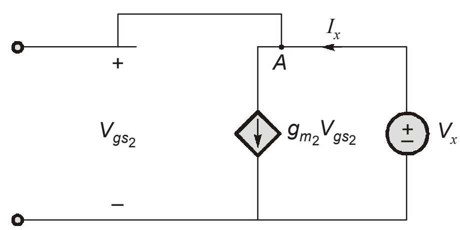
or,
$$\frac{V_0}{V_i} = -120\text{ V/V}$$

13. (c)

MOS T_2 serve as drain resistance for T_1



Calculating R_{out} of T_2

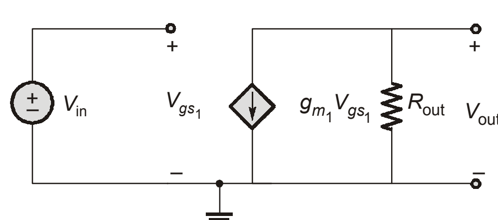


Applying KCL at node, A

$$I_x = g_m V_{gs}$$
$$V_{gs_2} = V_x$$

Thus
$$\frac{V_x}{I_x} = \frac{1}{g_{m_2}} = R_{out}$$

for transistor T_1



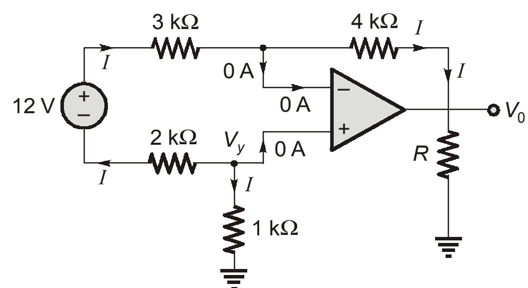
$$V_{out} = -g_{m_1}V_{gs_1}R_{out}$$

$$V_{gs_1} = V_{in}$$

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

$$A_v = -\frac{g_{m_1}}{g_{m_2}} \qquad \left(\because R_{out} = -\frac{1}{g_{m_2}}\right)$$

14. (b)



Let I be I (mA)

$$V_x - V_0 = 4I \qquad \text{...(i)}$$

$$V_y + 12\text{ V} - V_x = 5I \qquad \text{...(ii)}$$

$$V_x = V_y \qquad \text{(Virtual short)}$$

so, from equation (ii)

$$5I = 12\text{ V}$$

$$V_y = -I = V_x$$

so, from equation (i)

$$V_y - V_0 = 4I$$

$$V_0 = V_y - 4I$$

$$= -5I$$

$$V_0 = -12\text{ V}$$

15. (c)

Given $k_n = 20\text{ mA/V}^2$, $R_D = 5\text{ k}\Omega$

$$V_{DS} = 1.1 - I_D R_D$$

$$I_D = k_n(V_g - V_T)^2$$

$$= k_n(V_g - 1)^2$$

for saturation region of operation,

$$V_{DS} \geq V_{gs} - V_T$$

$$V_{DS} \geq (V_{gs} - 1\text{ V})$$

$$(1.1 - I_D R_D) \geq (V_{gs} - 1)$$

$$1.1 - R_D k_n (V_{gs} - 1)^2 \geq (V_{gs} - 1)$$

$$1.1 - (5 \times 10^3)(20 \times 10^{-6})(V_{gs} - 1)^2 \geq (V_{gs} - 1)$$

$$1.1 - (0.1)(V_{gs} - 1)^2 \geq (V_{gs} - 1)$$

$$1.1 - (0.1)(V_g^2 - 2V_g + 1) \geq (V_{gs} - 1)$$

$$1.1 - \frac{V_g^2}{10} + \frac{2V_g}{10} - 0.1 \geq (V_{gs} - 1)$$

$$-\frac{V_g^2}{10} + \frac{2V_g}{10} - V_g + 2 \geq 0$$

$$-V_g^2 - 8V_g + 20 \geq 0$$

at the edge of saturation, $V_g = V_{g\,max}$

so, $$-V_{g\,max}^2 - 8V_{g\,max} + 20 = 0$$

$$V_{g\,max}^2 + 8V_{g\,max} - 2 = 0$$

$$V_{g\,max} = \frac{-8 \pm \sqrt{64+80}}{2}\ \text{V}$$

$$= \frac{-8 \pm 12}{4}\ \text{V} = -10\ \text{V}, 2\ \text{V}$$

valid $$V_{g\,max} = 2\ \text{V}$$

16. (a)

$$I_x = I_{C_1} + I_{C_2}$$

$$I_x = I_{S_1} \exp\left(\frac{V_{BE}}{V_T}\right) + I_{S_2} \exp\left(\frac{V_{BE}}{V_T}\right) \quad \because \text{both the transistors have same } V_{BE}$$

$$I_x = I_{C_1} + \frac{I_{C_1}}{2} \quad \because I_{S_2} = \frac{I_{S_1}}{2}$$

$$I_x = \frac{3I_{C_1}}{2}$$

$$\Rightarrow \quad I_{C_1} = \frac{2I_x}{3} = \frac{2}{3}(1.2\ \text{mA}) = 0.8\ \text{mA}$$

$$0.8\ \text{mA} = 4 \times 10^{-16} \exp\left(\frac{V_{BE}}{V_T}\right) \text{A} \quad \because V_{BE} = V_B$$

$$V_T \ln\left(\frac{0.8 \times 10^{-3}}{4 \times 10^{-16}}\right) = V_B = mV_T$$

$$m = \ln\left(\frac{8 \times 10^{-4}}{4 \times 10^{-16}}\right)$$

$$m = \ln(2 \times 10^{+12})$$

$$m = 28.32$$

17. (c)

The above circuit is a summer, where V_0 can be is given as

$$V_0 = -\frac{R_F}{R}\left(V_{S_1} + V_{S_2} + V_{S_3} + \ldots + V_{S_n}\right)$$

$$V_0 = -\frac{2 \times 10^3}{5 \times 10^3}(5 + 10 + 15 + 20 + \ldots + 5n)\ \text{V}$$

$$V_0 = -(0.4)5\ (1 + 2 + 3 + \ldots + n)\ \text{V}$$

$$= -2\frac{n(n+1)}{2}\ \text{V}$$

$$-72\ \text{V} = -n(n+1)\ \text{V}$$

$$n(n+1) = 72$$

$$n^2 + n - 72 = 0$$

$$n = \frac{-1 \pm \sqrt{1 + 4(72)}}{2}$$

$$= \frac{-1 \pm \sqrt{289}}{2}$$

$$= \frac{-1 \pm 17}{2}$$

$$= -9, 8$$

valid value of $n = 8$

18. (d)

$\because$ The drain and gate of transistor T_1 is shorted, thus the transistor will always remain in saturation region, and $V_{GS} = V_{DS} - V_o = 5 - 0.1 = 4.9$ V.

For transistor M_2

$$V_{GS} = 5 \text{ V}$$

$$V_{DS} = 0.1 \text{ V}$$

$$V_T = 0.8 \text{ V}$$

Thus, $V_{DS} < V_{GS} - V_T$ and $V_{GS} < V_T$

Hence, the transistor will be working in linear region.

The current flowing through the two transistors must be equal because they are connected in series to each other. Thus, current flowing through transistor M_1 is equal to

$$I_{D1} = \frac{\mu_n C_{ox} W_1}{2L_1}(V_{GS1} - V_T)^2$$

and current flowing through transistor M_2 is equal to

$$I_{D2} = \frac{\mu_n C_{ox} W_2}{L_2}\left[(V_{GS2} - V_T)V_{DS2} - \frac{V_{DS2}^2}{2}\right]$$

thus, $I_{D1} = I_{D2}$

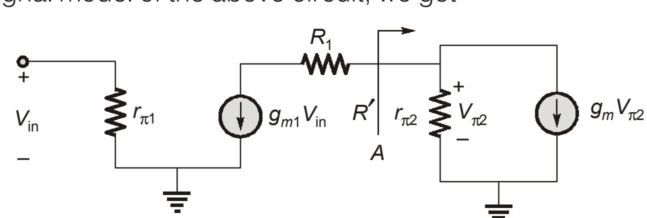
$$\left(\frac{W}{L}\right)_2\left[(V_{GS2} - V_T)V_{DS2} - \frac{V_{DS2}^2}{2}\right] = \frac{1}{2}\left(\frac{W}{L}\right)_1(V_{GS1} - V_T)^2$$

$$\left(\frac{W}{L}\right)_2\left[(5-0.8)(0.1) - \frac{(0.1)^2}{2}\right] = \frac{1}{2} \times 1 \times (5 - 0.1 - 0.8)^2$$

$$\therefore \quad \left(\frac{W}{L}\right)_2 = 20.253$$

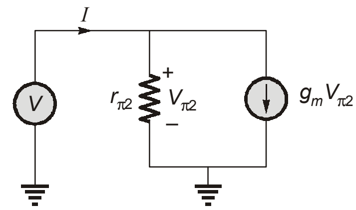
19. (c)

Drawing the small signal model of the above circuit, we get



Let R' be the input resistance as seen in from point A.

Thus, to calculate R' we can draw the diagram separately



$$\therefore \qquad R' = \frac{V}{I} = \left(\frac{1}{g_{m_2}} \bigg\| r_{\pi_2}\right)$$

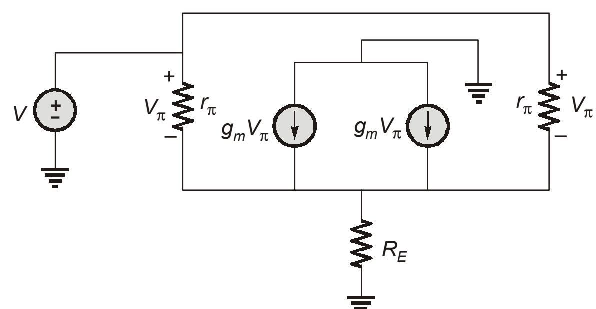
Thus, the value of the output voltage

$$V_o = -g_{m_1} V_{in} (R_1 + R')$$

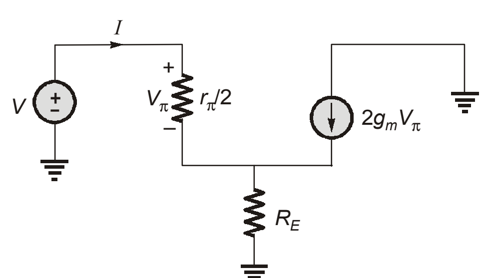
$$\frac{V_o}{V_{in}} = -g_{m_1}\left(R_1 + \left(\frac{1}{g_{m_2}} \bigg\| r_{\pi_2}\right)\right)$$

20. (b)

Drawing the small signal equivalent model of the circuit, we get



Thus, the equivalent circuit can be drawn as



now, $$I = \frac{V_\pi}{r_\pi/2} = \frac{2V_\pi}{r_\pi} \qquad \text{...(i)}$$

and $$V_{in} = V_\pi + (I + 2g_m V_\pi) R_E$$

$$= V_\pi + \frac{R_E(2V_\pi)}{r_\pi} + 2g_m R_E V_\pi$$

$$= \left(1 + \frac{2R_E}{r_\pi} + 2g_m R_E\right) V_\pi$$

$$V_{in} = (r_\pi + 2R_E + 2g_m r_\pi R_E)\frac{V_\pi}{r_\pi}$$

$$V_{in} = (r_\pi + 2(1+\beta) R_E)\frac{V_\pi}{r_\pi} \qquad (\because g_m r_\pi = \beta)$$

$\therefore \quad V_\pi = \dfrac{V_{in}\, r_\pi}{(r_\pi + 2(1+\beta)R_E)}$ ...(ii)

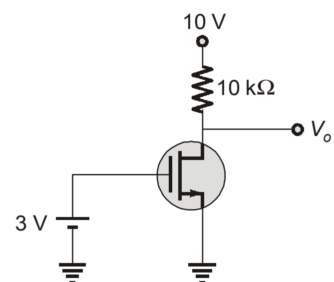
now, substituting equation (ii) in (i), we get

$$I = \frac{2V_{in}}{(r_\pi + 2(1+\beta)R_E)}$$

$$\therefore \quad R_{in} = \frac{V_{in}}{I} = \frac{r_\pi + 2(1+\beta)R_E}{2}$$

21. (d)

First applying the D.C. analysis, we have



now, assuming MOS to be in saturation region.

$$\therefore \quad I_D = \frac{\mu_n C_{ox} W}{2L}(V_{GS} - V_T)^2 = 0.5 \times 10^{-3}\,(3-2)^2$$

$$I_D = 0.5 \times 10^{-3} \text{ mA}$$

now, $\quad V_{DS} = 10 - 10 \times 10^3 \times 0.5 \times 10^{-3} = 10 - 5 = 5$ V

thus, $\quad V_{DS} > V_{GS} - V_T$

$5 > 3 - 2$ (true)

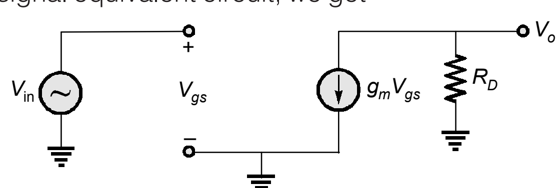
Hence, our assumption was true.

now, $\quad g_m = 2\sqrt{\dfrac{\mu_n C_{ox} W}{2L} \cdot I_D}$

$$= 2\sqrt{0.5 \times 0.5 \times 10^{-6}}$$

$$g_m = 1 \text{ mA/V}$$

Now, drawing the small signal equivalent circuit, we get



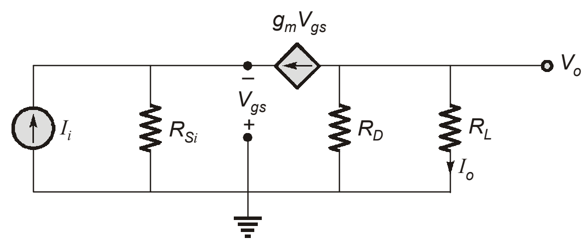
$$\therefore \quad V_0 = -g_m V_{gs} R_D$$

$$V_0 = -(g_m R_D) V_{in} = -[1 \times 10^{-3} \times 10 \times 10^3] \times 3 \sin(\omega t) \times 10^{-3}$$

$$V_0 = -30 \sin(\omega t) \text{ mV}$$

22. (d)

Drawing the small signal equivalent of the below circuit, we get



now, $$I_o = -\left[\frac{R_D}{R_D + R_L}\right](g_m V_{gs}) \quad \text{...(i)}$$

Applying KCL at the input, we have

$$I_i + g_m V_{gs} + \frac{V_{gs}}{R_{Si}} = 0$$

$$\Rightarrow \quad V_{gs} = -I_i\left(\frac{R_{Si}}{1 + g_m R_{Si}}\right) \quad \text{...(ii)}$$

Substituting (ii) in (i), we get

$$A_i = \frac{I_o}{I_i} = \left(\frac{R_D}{R_D + R_L}\right) \times g_m\left(\frac{R_{Si}}{1 + g_m R_{Si}}\right)$$

Now $R_D = R_L$ and $R_{Si} = \dfrac{1}{g_m}$

Thus, $$A_i = \frac{I_o}{I_i} = \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{4} = 0.25$$

23. (b)

Applying superposition at the output, we have

$$V_o = -\frac{R_2}{R_1} \cdot V_1 + \left(\frac{R_4}{R_3 + R_4}\right) \cdot \left(1 + \frac{R_2}{R_1}\right) \cdot V_2 = -10\,V_1 + 10.0833\,V_2$$

Now, the differential input voltage is given as

$$V_d = V_2 - V_1$$

and $$V_c = \frac{V_1 + V_2}{2}$$

Thus, $$V_1 = V_c - \frac{V_d}{2}$$

$$V_2 = V_c + \frac{V_d}{2}$$

$$\therefore \quad V_o = (10.0833)\left[V_c + \frac{V_d}{2}\right] - 10\left[V_c - \frac{V_d}{2}\right]$$

$$V_o = 10.042\,V_d + 0.0833\,V_c$$

Comparing the equation from the standard result.

i.e. $$V_o = A_d V_d + A_c V_c$$

We get, $$A_d = 10.042$$

$$A_c = 0.0833$$

$$\therefore \quad (\text{CMRR})_{\text{dB}} = 20\log_{10}\left[\frac{10.042}{0.0833}\right] = 41.63 \text{ dB}$$

24. (d)

For RC phase shift oscillator, the frequency of oscillation is,

$$f_{osc} = \frac{1}{2\pi\sqrt{6}RC}$$

$$\therefore \quad R = \frac{1}{2\pi\sqrt{6}f_{OSC}\cdot C} = \frac{1}{2\pi\sqrt{6}\times 10^{-7}\times 100} = 6.49\text{ k}\Omega$$

now $|A| \geq 29$

$$\therefore \quad \frac{R_F}{R} = 29 \text{ for minimum value of } R$$

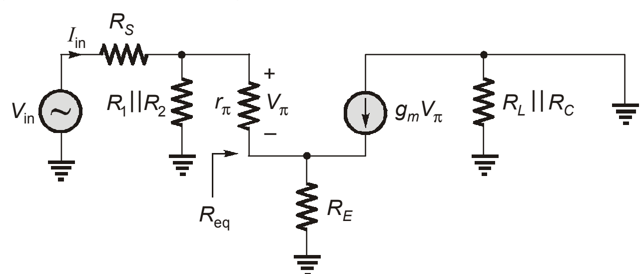
$$R_F = 29 \times R$$
$$= 29 \times 6.49 \times 10^3$$
$$= 188.21\text{ k}\Omega$$

25. (c)

We know $g_m r_\pi = \beta$

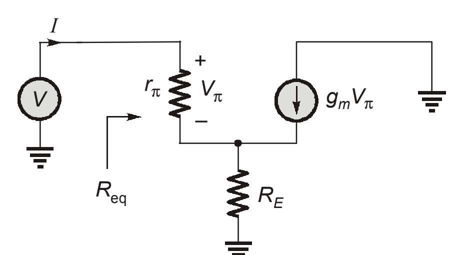
$$r_\pi = \frac{\beta}{g_m} = \frac{100}{10}\times 10^3 = 10\text{ k}\Omega$$

Drawing the small signal equivalent, we get



$$\therefore \quad \frac{V_{in}}{I_{in}} = R_{in} = R_S + (R_1 || R_2 || R_{eq})$$

now, to calculate R_{eq}, we can use another model



$$V = Ir_\pi + (I + g_mV_\pi)R_E$$

now, $\quad V_\pi = Ir_\pi$

$$\Rightarrow \quad V = Ir_\pi + R_EI + g_mr_\pi R_EI$$

$$g_mr_\pi = \beta$$

$$\therefore \quad V = (r_\pi + (\beta + 1)R_E)I$$

$$R_{eq} = \frac{V}{I} = r_\pi + (\beta+1)R_E$$

$$\therefore \quad R_{in} = R_S + [R_1 || R_2 || (r_\pi + (\beta + 1)R_E]$$

putting the values

$$R_{eq} = 10\text{ k}\Omega + 101 \times 500$$
$$= 60.5\text{ k}\Omega$$

$$\therefore \quad R_{in} = 1\text{ k}\Omega + 4.62\text{ k}\Omega$$
$$= 5.62\text{ k}\Omega$$

26. (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 $V_S = -2.614 \text{ V}$

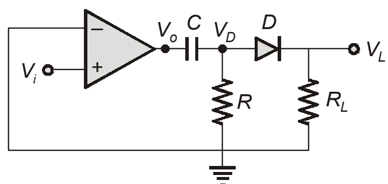
And $V_D = 5 \text{ V}$

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

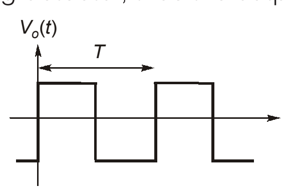
$$V_{DS} = 7.614 \text{ V}$$

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

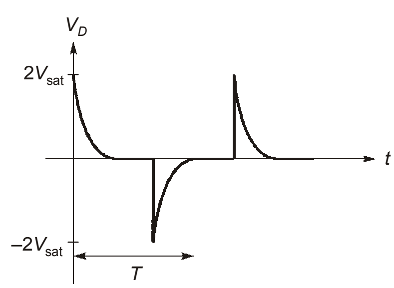
27. (c)



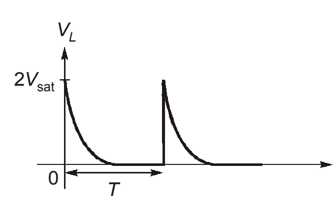
The op-amp will work as a zero crossing detector, thus the output at node V_o is equal to



Now, at differentiator $RC << T$, thus the output V_D can be represented as

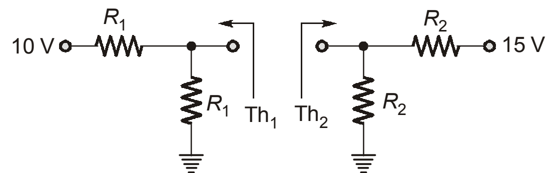


Now, at last state the diode circuit will acts as a negative clipper and the output waveform will look like



28. (d)

Assuming the diode to be considered as load, the Thevenin's equivalent circuit can be drawn for diode *D*.



Thus, $V_{Th_1} = \frac{V_1}{2}$ and $R_{Th_1} = \frac{R_1}{2}$

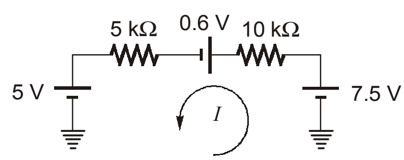
$V_{Th_2} = \frac{V_2}{2}$ and $R_{Th_2} = \frac{R_2}{2}$

$V_{Th_1} = \frac{10}{2} = 5\text{ V}$ $\quad R_{Th_1} = \frac{10}{2} = 5\text{ k}\Omega$

$V_{Th_2} = \frac{15}{2} = 7.5\text{ V}$ $\quad R_{Th_2} = \frac{20}{2} = 10\text{ k}\Omega$

$\because V_{th_2} > V_{th_1}$, thus the diode will be forward biased.

Hence the equivalent circuit can be drawn as,



Thus, $I = \frac{7.5-0.6-5}{15} \times 10^{-3}$

$= 0.1266\text{ mA} \approx 0.127\text{ mA}$

29. (c)

The minimum value of load resistance can be calculated when maximum current flows through the load.

Thus, $I_{L(\max)} = I_{in} - I_{Z(\min)}$

Now, $I_{Z(\min)} = 0$ $\quad \because$ knee current nearly equal to zero

$\therefore$ $I_{L(\max)} = I_{in}$

$I_{in} = \frac{50-10}{1\text{k}\Omega} = 40\text{ mA}$

$\therefore$ $R_{L(\min)} = \frac{10}{40} \times 10^3 = \frac{1}{4} \times 10^3 = 250\ \Omega$

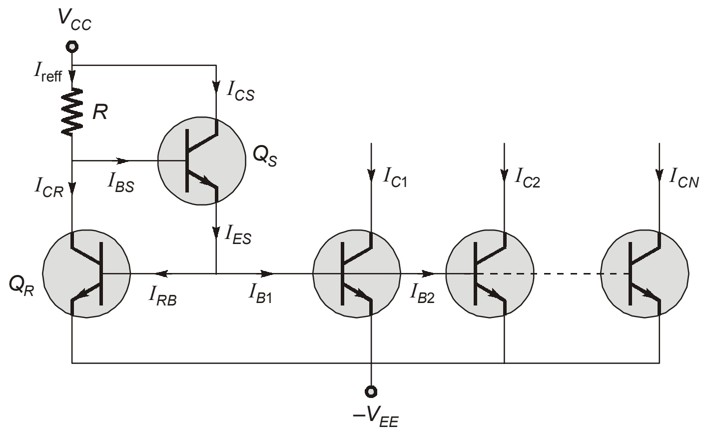
Now, for maximum value of load resistance, there should be minimum value of current through the load

$\therefore$ $I_{L(\min)} = I_{in} - I_{Z(\max)}$

$I_{L(\min)} = (40 - 20) \times 10^{-3} = 20\text{ mA}$

$\therefore$ $R_{L(\max)} = \frac{10}{20} \times 10^3 = 500\ \Omega$

30. (c)



From the figure, we can see that,

$$I_{\text{reff}} = I_{\text{CR}} + I_{\text{BS}}$$

$$I_{\text{reff}} = I_{\text{CR}} + \frac{I_{\text{ES}}}{(\beta+1)}$$

now, $I_{\text{ES}} = I_{\text{RB}} + I_{\text{B1}} + I_{\text{B2}} + \ldots\ldots + I_{\text{BN}}$

$$I_{\text{ES}} = (1+N)\, I_B \qquad (\because \text{ all transistors are matched})$$

$$I_{\text{ES}} = (1+N)\frac{I_C}{\beta} \qquad (\because I_{C1} = I_{C2} = I_{CN} = I_C)$$

$\therefore$

$$I_{\text{reff}} = I_{\text{CR}} + \frac{I_{\text{ES}}}{(\beta+1)}$$

$$I_{\text{reff}} = \left[1 + \frac{(1+N)}{\beta(\beta+1)}\right] I_{CR}$$

$$I_{\text{reff}} = I_C\left[1 + \frac{(1+N)}{\beta(\beta+1)}\right]$$

now, $I_C = 99$ mA, $I_{\text{reff}} = 100$ mA and $\beta = 50$

thus,

$$100 = 99\left[1 + \frac{(1+N)}{50(51)}\right]$$

$$\left(\frac{100}{99} - 1\right) = \frac{1+N}{50(51)}$$

$$1 + N = 50(51)\left[\frac{1}{99}\right]$$

$$1 + N = 25.75$$

$$N = 24.75$$

$\because$ We have to maintain minimum value of 99 mA, thus

$$N = 24$$

■■■■