CLASS TEST

S.No.: 01SKEC_ABCDEFG_110724

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# ANALOG ELECTRONICS

## ELECTRONICS ENGINEERING

**Date of Test : 11/07/2024**

## ANSWER KEY

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

## Detailed Explanations

**1. (b)**

**Case-I**

For positive input voltage when $V_i$ > 5.7 V, the diode $D_1$ will turn ON, thus voltage at the output = 5 + 0.7 = 5.7 V.

**Case-II**

For negative input voltage when $V_i$ < –0.7 V, then diode $D_2$ will enter into forward region and thus will start conducting with a drop of 0.7 V on it.

Thus, $V_0 = V_{in}$ for $-0.7\text{ V} < V_i < 0$ and $V_0 = 0.7$ V for $V_i < -0.7$ V.

**2. (a)**

∵ The feedback is series-series feedback, so the amplifier will be a voltage amplifier.

**3. (a)**

The above circuit is a positive half-wave precision rectifier.

Case 1: If $V_{in} > 0$, then diode will conduct thus, $V_{out} = V_{in}$ (∵ the op-amp will work as a buffer.)

Case 2: If $V_{in} < 0$, then diode will be OFF hence $V_{out} = 0$.

**4. (c)**

For a fixed biased circuit,

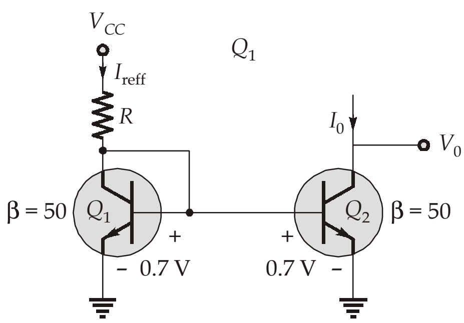
$$I_C = \beta I_B + (\beta + 1)I_{co}$$

$$\therefore \quad \frac{\partial I_c}{\partial I_{co}} = (\beta + 1) \qquad \left[\because I_B = \frac{V_{CC} - V_{BE}}{R_B} = \text{constant}\right]$$

$$\therefore \quad S = \frac{\partial I_c}{\partial I_{co}} = 100 + 1 = 101$$

**5. (d)**

The circuit can be redrawn as,



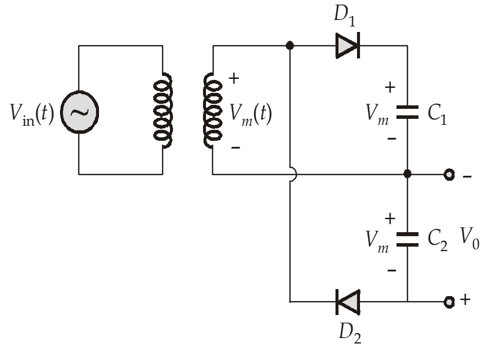

For current mirror circuit,

$$I_{reff} = \frac{V_{CC} - V_{BE}}{R} = \frac{10 - 0.7}{37 \times 10^3} = 0.251 \text{ mA}$$

now,
$$I_0 = \frac{I_{reff}}{\left(1 + \frac{2}{\beta}\right)} = \frac{0.251}{\left(1 + \frac{2}{50}\right)} = 0.241 \text{ mA}$$

**6. (d)**

The circuit can be redrawn as,




The circuit represents a voltage doubler circuit, if the voltage was taken by adding voltages of both the capacitors, but to calculate $V_0$ we have to find the voltage stored on a single capacitor. Thus, comparing from the above figure,

$$V_0 = -V_m$$

**7. (b)**

The early voltage $V_A$ can be calculated as

$$V_A = r_0 I_C$$

where $r_0$ = output resistance = $\dfrac{1}{\text{slope of } I_C - V_{CB} \text{ curve}}$

$$r_0 = \frac{1}{3\times10^{-5}}$$

thus, $$V_A = \frac{1}{3\times10^{-5}}\times3\times10^{-3} = 100 \text{ V} \qquad (\because I_C = 3\times10^{-3} \text{ A})$$

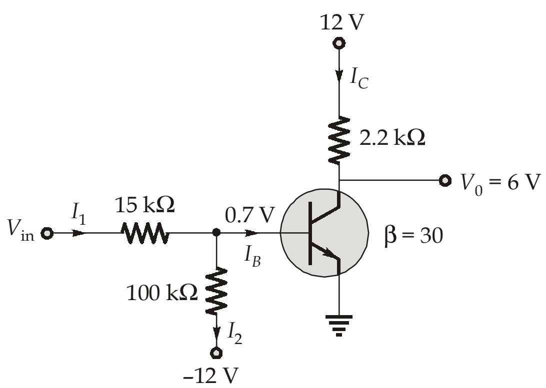
**8. (a)**

Since, the op-amp represents a closed loop unity gain amplifier.

Thus, $$A_{CL} = \frac{A_{OL}}{1+A_{OL}}$$

$$= \frac{999}{1+999} = 0.999$$

**9. (c)**




Now, $$I_C = \frac{12-6}{2.2}\times10^{-3} = 2.727 \text{ mA}$$

$\therefore \quad I_B = \frac{I_C}{\beta} = \frac{2.727}{30} = \frac{1}{11}$ mA

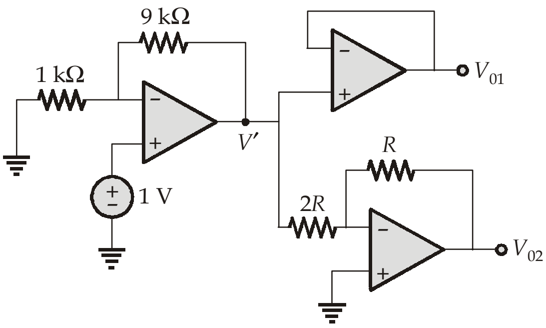
Now, $\quad I_2 = \frac{0.7-(-12)}{100\text{ k}\Omega} = 0.127$ mA

$\therefore \quad I_1 = I_2 + I_B = 0.218$ mA

thus, $\quad V_{in} = I_1 \times 15 \times 10^3\ \Omega + 0.7$

$V_{in} = 3.968\text{ V} \approx 3.97\text{ V}$

**10.** **(c)**




$$V' = \left(1 + \frac{9\text{ k}\Omega}{1\text{ k}\Omega}\right) \times 1\text{ V} \qquad (\because \text{ non-inverting amplifier})$$

$V' = 10$ V

now, $\quad V_{01} = V' = 10$ V $\qquad (\because$ it is a voltage buffer)

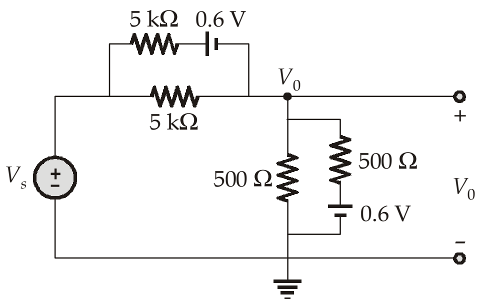
and $\quad V_{02} = -\frac{R}{2R}V' \qquad (\because$ inverting amplifier)

$V_{02} = -\frac{1}{2}V' = -\frac{10\text{ V}}{2} = -5$ V

$\therefore \quad V_{02} - V_{01} = -5\text{ V} - 10\text{ V} = -15$ V

**11.** **(a)**

Assume both the diode to be ON.




Applying the KCL at node $V_0$, we get,

$$\frac{V_0 + 0.6 - V_s}{5\text{ k}} + \frac{V_0 - V_s}{5\text{ k}} + \frac{V_0}{500} + \frac{V_0 - 0.6}{500} = 0$$

$\therefore \quad V_0 = \frac{2}{22}V_s + \frac{5.4}{22}$

$$V_0 = \frac{1}{11}V_s + \frac{54}{220}$$

For diode $D_1$ to be ON.

$$\therefore \quad V_{D1} = \frac{5\text{ k}\Omega}{5\text{ k}\Omega + 0.5\text{ k}\Omega} \times V_s$$

$$= \frac{5}{5.5} \times V_s > 0.6\text{ V}$$

For diode $D_2$ to be ON.

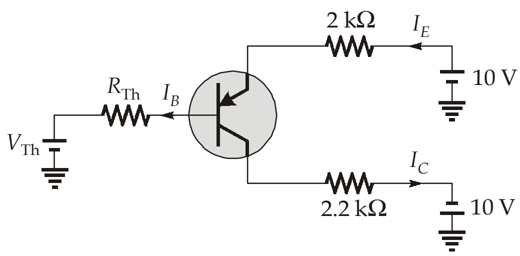
$$V_0 > 0.6\text{ V}$$

$$\frac{2V_s + 5.4}{22} > 0.6$$

$$V_s > 3.9\text{ V}$$

**12. (d)**

The above circuit can be redrawn as




$$V_{Th} = 6.67\text{ V}$$

$$R_{Th} = 10\text{ k}\Omega \,||\, 20\text{ k}\Omega = 6.67\text{ k}\Omega$$

Applying KVL in the emitter base loop.

$10 - (1 + \beta)\, I_{BQ}(2\text{ k}\Omega) - V_{EB} - I_{BQ}(6.67\text{ k}\Omega) - V_{Th} = 0$

$$I_{BQ} = \frac{10 - 6.67 - 0.7}{6.67 + 122} \times 10^{-3} = 20.44\ \mu\text{A}$$

$$\therefore \quad I_{CQ} = \beta I_{BQ} = 1.226\text{ mA}$$

$$I_{EQ} = (\beta + 1)I_{BQ} = 1.247\text{ mA}$$

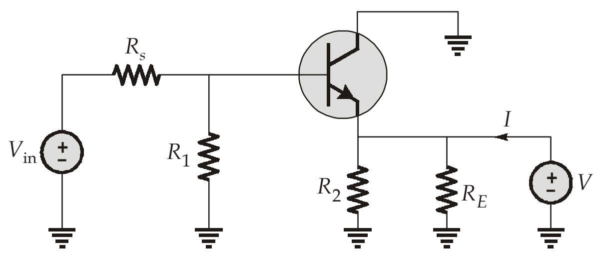
Applying KVL in emitter-collector loop, we get,

$10 - I_E \times (2\text{ k}\Omega) - V_{ECQ} - (2.2\text{ k}\Omega)I_C + 10 = 0$

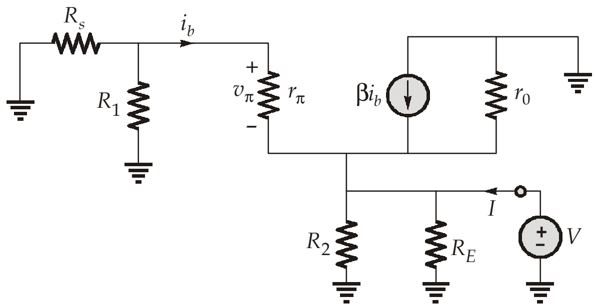
$$V_{ECQ} = 20 - 1.247 \times 2 - 2.2 \times 1.226 = 14.81\text{ V}$$

$$\therefore \quad V_{CEQ} = -14.81\text{ V}$$

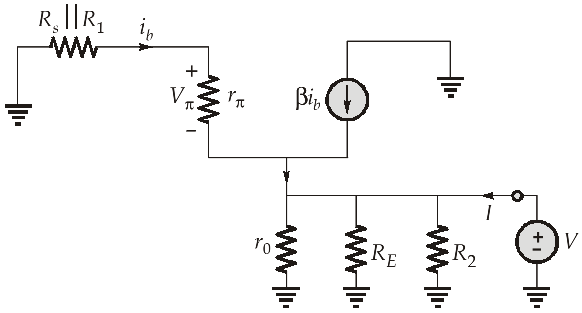
**13. (d)**



Drawing small signal equivalent circuit,




thus, the circuit can be further reduced to




$$\therefore \qquad I = \frac{V}{R_2} + \frac{V}{R_E} + \frac{V}{r_0} - (\beta+1)\,i_b$$

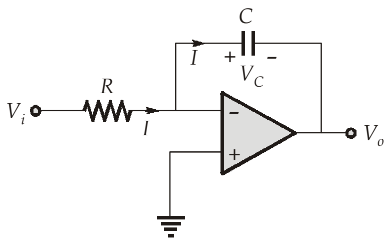
now,
$$i_b = -\frac{V}{r_\pi + R_s \| R_1}$$

$$\therefore \qquad I = V\left[\frac{1}{R_2} + \frac{1}{R_E} + \frac{1}{r_0}\right] + \frac{V}{\dfrac{r_\pi}{\beta+1} + \dfrac{R_s \| R_1}{\beta+1}}$$

$$\therefore \qquad \frac{V}{I} = \left(R_2 \| r_0 \| R_E\right) \Big\| \left[\frac{1}{g_m} + \frac{R_s \| R_1}{\beta+1}\right]$$

$$\because \qquad g_m r_\pi = (\beta + 1)$$

**14. (b)**




$$I = \frac{V_i}{R}$$

Thus,
$$V_c(t) = \frac{1}{C}\int_0^t I dt = \frac{1}{C}\int_0^t \frac{V_i}{R} dt$$

$$= \frac{V_i}{CR}\cdot t \qquad (\because V_i \text{ is constant})$$

$$\therefore \qquad V_o(t) = -\frac{1\,V\times(nT_p)}{10^3\times10^{-5}} = -1\text{ V}$$

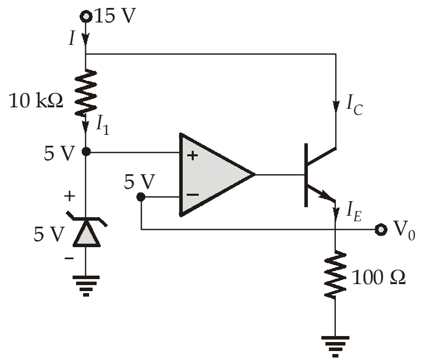
$$nT_p = 10^{-2} \text{ and } T_p = 10\ \mu\text{sec}$$

$$n = \frac{10^{-2}}{10^{-5}} = 1000$$

Thus, minimum number of pulses required to reach the value of $|V_o| = 1$ V is 1000.

**15. (c)**

Redrawing the circuit



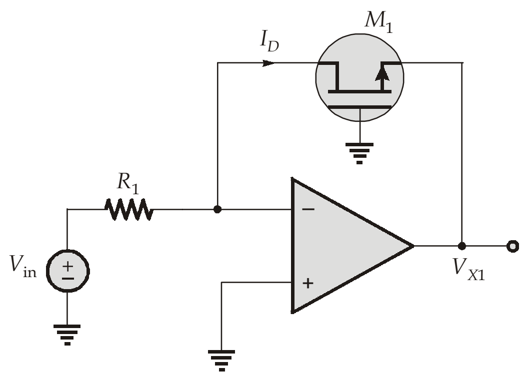

$$I_1 = \frac{15-5}{10\text{ k}\Omega} = 1\text{ mA}$$

$$I_E = \frac{5-0}{100} = 50\text{ mA}$$

$$I_E \approx I_C$$

$$I = I_1 + I_C = (50 + 1)\text{ m} = 51\text{ mA}$$

**16. (d)**




For the circuit in fig. 1 the value of output voltage.

$V_{\text{out}}$ can be given as $\quad V_{\text{out}} = V_{X1} + V_{Th}$

and $\quad V_{X1} = -V_{GS}$

where $\quad I_D = K_n(V_{GS} - V_{Th})^2$

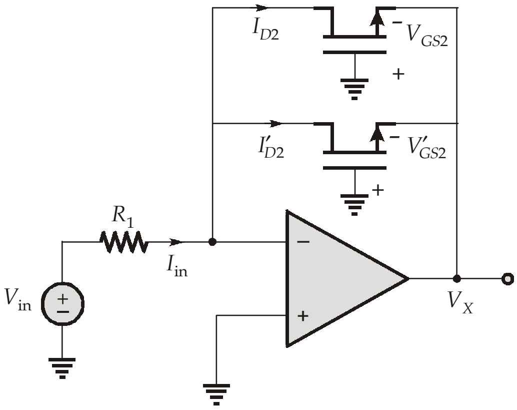
$$\sqrt{\frac{I_D}{K_n}} = V_{GS} - V_{Th}$$

$$-V_{GS} = -\sqrt{\frac{I_D}{K_n}} - V_{Th}$$

$$-V_{GS} + V_{Th} = -\sqrt{\frac{I_D}{K_n}}$$

$$V_{\text{out1}} = V_{X1} + V_{Th} = -\sqrt{\frac{I_D}{K_n}} = -\sqrt{\frac{I_{in}}{K_n}}$$

now, for figure 2, since the two MOS circuit are in parallel thus,




$$I'_{D2} = I_{D2} = \frac{I_{in}}{2}$$

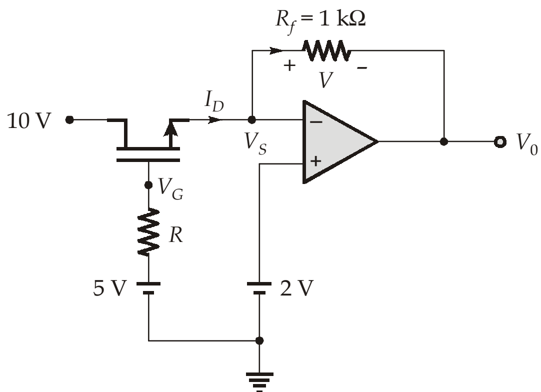
and $$V_{\text{out2}} = -\sqrt{\frac{I_{D2}}{K_n}} = -\sqrt{\frac{I_{in}}{2K_n}}$$

now for both transistors

$$I_{\text{in}} = \frac{V_{in}}{R_1}$$

$$\therefore \quad \frac{V_{out2}}{V_{out1}} = \frac{1}{\sqrt{2}} = 0.707$$

**17. (b)**




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

$$V_{GS} = V_G - V_S = 5\text{ V} - 2\text{ V} = 3\text{ V} \qquad (\because V_S = 2\text{V due to virtual ground})$$

Now, $$I_D = 10^{-3}(3-1)^2$$

$$I_D = 4\text{ mA}$$

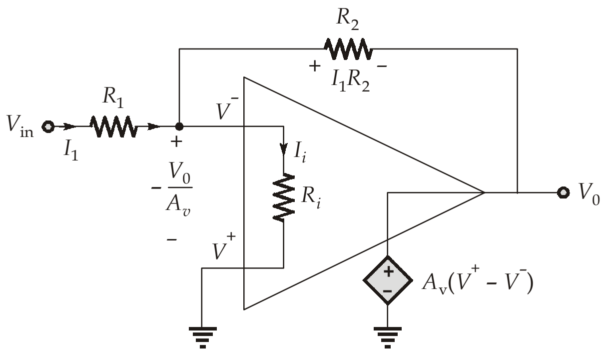
$$\therefore \quad V_0 = V_S - I_DR_f = 2 - I_DR_f$$

$$= 2 - 4 \times 10^{-3} \times 1 \times 10^3$$

$$= -2\text{V}$$

**18. (a)**

$\because R_i \neq \infty$ thus concept of virtual ground is not applicable for this circuit.




$$V_0 = -\frac{R_2}{R_1}\left[V_{in} + \frac{V_0}{A_v}\right] - \frac{V_0}{A_v}$$

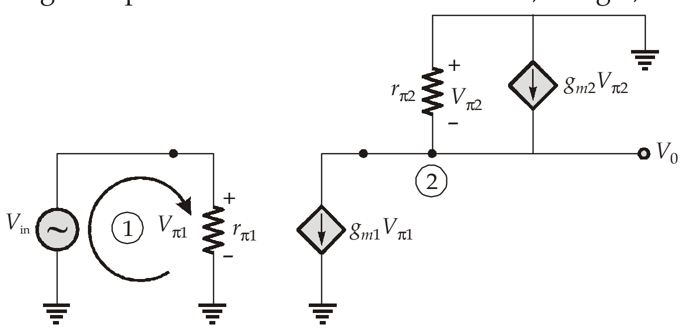
$$V_0 = -\frac{R_2}{R_1}V_{in} - \frac{1}{A_v}\left[1 + \frac{R_2}{R_1}\right]V_0$$

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

Thus,
$$\frac{V_0}{V_{in}} = \frac{-100/1}{1 + \frac{1}{10^3}\left(1 + \frac{100}{1}\right)} = \frac{-100}{1.1} = -90.83 \text{ V/V}$$

**19. (c)**

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




Now, $V_{in} = V_{\pi 1}$

and $V_0 = -V_{\pi 2}$

Applying KCL at node-2 we get

$$g_{m1}V_{\pi 1} + \frac{V_0}{r_{\pi 2}} = g_{m2}V_{\pi 2}$$

$$\Rightarrow \quad g_{m1}V_{in} + \frac{V_0}{r_{\pi 2}} = -g_{m2}V_0$$

$$V_0\left[\frac{1}{r_{\pi 2}} + g_{m2}\right] = -g_{m1}V_{in}$$

$$|A_v| = \left|\frac{V_0}{V_{in}}\right| = \frac{g_{m1} r_{\pi 2}}{1 + g_{m2} r_{\pi 2}}$$

Since β >> 1 for both the transistors.
Thus, the above expression can be approximated as

$$|A_v| \approx \frac{g_{m1}}{g_{m2}}$$

**20. (a)**

In the circuit, the capacitor starts charging from 0 V (as the switch was initially closed) towards the steady state value of 20 V.

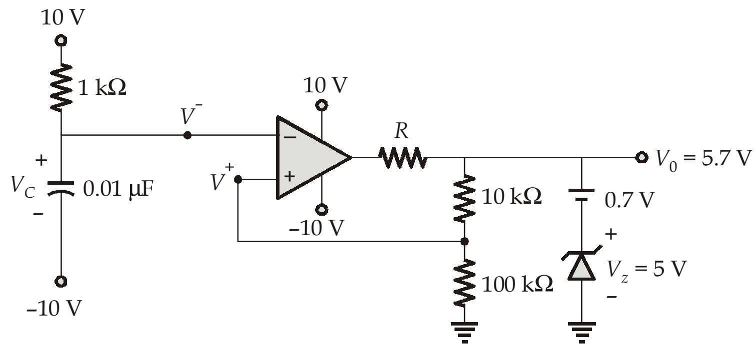
Now, when the switch is flipped open, the capacitor will charge upto 20 V.

$\therefore \quad V_c(t) = V_c(\infty) - [V_c(0) - V_c(\infty)]e^{-t/RC}$

$RC = 1 \times 10^3 \times 0.01 \times 10^{-6} = 10\ \mu\text{sec}$

$\therefore \quad V_c(t) = 20\,(1 - e^{-t/RC})$

Voltage at non-inverting amplifier is obtained as




$$V^+ = V_0 \times \frac{100\ \text{k}\Omega}{(10+100)\ \text{k}\Omega}$$

$$V^+ = V_0 \times \frac{100}{110} = \frac{V_0 \times 10}{11}$$

$\because$ Initially $V^-$ was equal to –10 V, thus $V_0 = +5.7$ V.

Thus, now capacitor will start charging as soon as the switch is opened.

Thus, $\quad V^- = V_C - 10$ V

or, $\quad V_C = V^- + 10$ V

now, $\quad V^- = V^+ = \dfrac{5.7\ \text{V} \times 10}{11} \quad$ [$\because$ the op-amp will switch]

thus, $\quad V_C = \dfrac{10 \times 5.7}{11} + 10$

now, $\quad V_C = 20(1 - e^{-t/RC})$

$\therefore \quad 20(1 - e^{-t/RC}) = 10 + \dfrac{57}{11}$

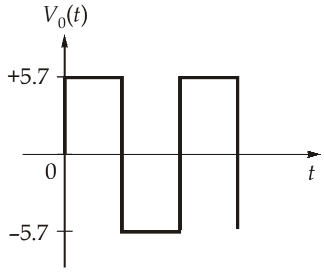
$$1 - e^{-t/RC} = \frac{1}{2} + \frac{57}{220}$$

$$1 - e^{-t/RC} = 0.7590$$

$$e^{-t/RC} = 0.2409$$

$$T = 14.23\ \mu\text{sec}$$

Hence, the output voltage wave will be,

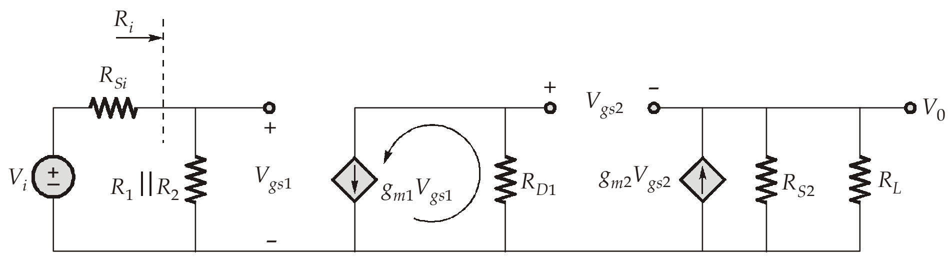



**21. (c)**

Now, $$g_{m1} = 2\sqrt{k_{n1}I_{D_1}} = 2\sqrt{0.5\times0.2\times10^{-6}} = 0.632 \text{ mA/V}$$

and $$g_{m2} = 2\sqrt{k_{n2}I_{D_2}} = 2\sqrt{(0.2)(0.5)\times10^{-6}} = 0.632 \text{ mA/V}$$

Now, drawing the small signal equivalent circuit, we get,




Now, $$V_0 = g_{m2}(R_{S2}||R_L).V_{gs2} \quad \text{. . . (i)}$$

Also, $$V_{gs2} + V_0 = -g_{m1}V_{gs1}R_{D1} \quad \text{. . . (ii)}$$

and $$V_{gs1} = \frac{R_1||R_2}{R_1||R_2 + R_{Si}} \times V_i \quad \text{. . . (iii)}$$

Putting values of $V_{gs1}$ and $V_{gs2}$ from equation (i) and (iii) in equation (ii), we get

$$\frac{V_0}{g_{m_2}(R_{S2}||R_1)} + V_0 = -g_{m1}R_{D1}\left[\frac{R_1||R_2}{R_1||R_2 + R_{Si}}\right]\cdot V_i$$

$$\therefore \quad A_V = \frac{V_0}{V_i} = \frac{-g_{m1}\,g_{m2}R_{D1}(R_{S2}||R_L)}{1+g_{m2}(R_{S2}||R_L)} \times \left[\frac{R_1||R_2}{R_1||R_2 + R_{Si}}\right]$$

Now, $$R_{S2}\ ||R_L = \frac{8}{3}\text{k}\Omega$$

$$R_1\ ||R_2 = 99.8 \text{ k}\Omega \approx 100 \text{ k}\Omega$$

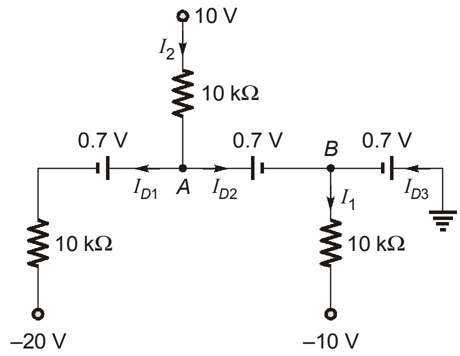
$$\therefore \quad A_v = \frac{V_0}{V_i} = \frac{-(0.632)(0.632)(16.1)(8/3)}{1+(0.632)(8/3)} \times \left[\frac{100}{104}\right]$$

$$\approx -6.14$$

**22. (c)**

Assuming all the diodes are forward biased,

$$V_B = -0.7 \text{ V}$$
$$V_A = 0 \text{ V}$$




$\therefore$ $$I_2 = \frac{10-0}{10\text{ k}} = 1\text{ mA}$$

and $$I_1 = \frac{-0.7-(-10)}{10\text{ k}} = 0.93\text{ mA}$$

$\because$ $$I_2 = I_{D_1} + I_{D_2}$$

and $$I_1 = I_{D_2} + I_{D_3}$$

applying KVL in the outer loop, we get,

$$10\text{k}I_2 + 0.7 + 10\text{k}\,I_{D_1} - 20 = 10$$

$$10\text{ k}(I_{D_1} + I_{D_2}) + 10\text{ k}\,I_{D_1} = 30 - 0.7 = 29.3$$

$$20\text{ k}I_{D_1} + 10\text{k}\,I_{D_2} = 29.3$$

$$2I_{D_1} + I_{D_2} = 2.93\text{ mA} \quad \text{...(i)}$$

also, $$I_{D_1} + I_{D_2} = I_2 = 1\text{ mA} \quad \text{...(ii)}$$

from (i) and (ii)

$$I_{D_1} = 1.93\text{ mA and } I_{D_2} = -0.93\text{ mA}$$

$\because$ $$I_{D_2} + I_{D_3} = 0.93\text{ mA}$$

$\Rightarrow$ $$I_{D_3} = -I_{D_2} + 0.93\text{ mA} = 1.86\text{ mA}$$

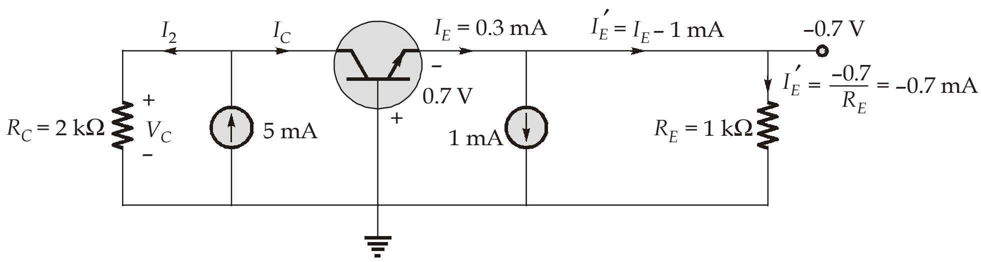
Here $I_{D_2}$ is negative, Hence, our assumption is incorrect.

Therefore, $D_2$ is reverse biased

and $\because$ $I_{D_1}$ and $I_{D_3}$ are positive,

$D_1$, $D_3$ are forward biased.

**23.** **(a)**




now, $$I_E = I'_E + 1\text{ mA}$$

$$I_E = 1\text{ mA} - 0.7\text{ mA} = 0.3\text{ mA}$$

now, $$I_C = \alpha I_E$$

$$\alpha = \frac{\beta}{1+\beta} = \frac{99}{1+99} = 0.99$$

$\therefore$ $$I_C = 0.99 \times 0.3 = 0.297\text{ mA}$$

$\therefore$ $$I_2 + I_C = 5\text{ mA}$$

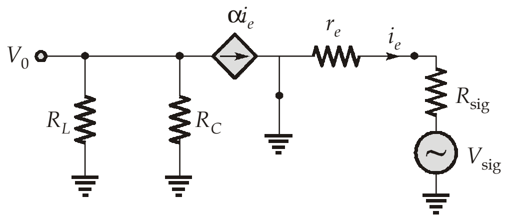
$$I_2 = 5\text{ mA} - I_C$$
$$= 4.703\text{ mA}$$

$\therefore$ $$V_C = I_2 \cdot R_C = 4.703 \times 2$$
$$V_C = 9.406$$

$\therefore$ $$V_{CE} = 9.406 + 0.7 = 10.1\text{ V}$$

**24. (b)**

The small signal $r_e$ equivalent circuit can be drawn as




$$V_0 = -\alpha(R_C \parallel R_L)i_e \quad \text{...(i)}$$

and
$$i_e = \frac{-V_{sig}}{R_{sig}+r_e} \quad \text{...(ii)}$$

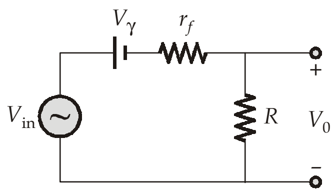
Combining equation (i) and (ii), we get,

$$V_0 = \frac{\alpha(R_C \parallel R_L)}{R_{sig}+r_e} \cdot V_{sig}$$

thus,
$$\frac{V_0}{V_{sig}} = \frac{\alpha(R_C \parallel R_L)}{R_{sig}+r_e}$$

**25. (c)**

The small signal equivalent model can be drawn as




∴ The output can be expressed as,

$$V_0 = \frac{R}{R+r_f}V_{in} - \frac{R}{R+r_f}V_\gamma \quad \text{...(i)}$$

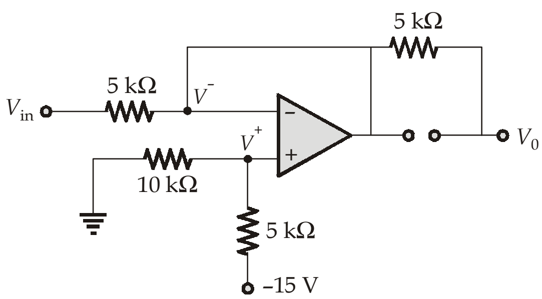
Thus, the slope of line in the graph of the input output curve can be written

$$\text{Slope} = \frac{R}{R+r_f} = \frac{1.2}{2-0.7} = \frac{1.2}{1.3} \quad \text{...from equation (i)}$$

Thus,
$$r_f = 83.33\ \Omega$$

**26. (b)**

**Case -I :** When $V_{in} > -10$ V, then the voltage across diode $D_1$ is positive so diode $D_1$ is in ON state, and therefore the equivalent circuit can be drawn as




$$V^+ = -15\times\frac{10}{15} = -10\text{ V}$$

Due to virtual ground, $V^+ = V^- = -10$ V

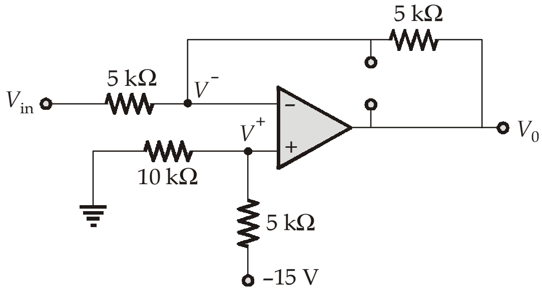
and $V_0 = V^- = -10$ V

∴ $V_0 = -10$ V

**Case -II :** When $V_{in} < -10$ V

$$V_0 = +V_{sat}$$

Thus,




$$\therefore \quad V_0 = -\frac{5}{5} \times V_{in} = -V_{in} \text{ (for } V_{in} < -10 \text{ V)}$$

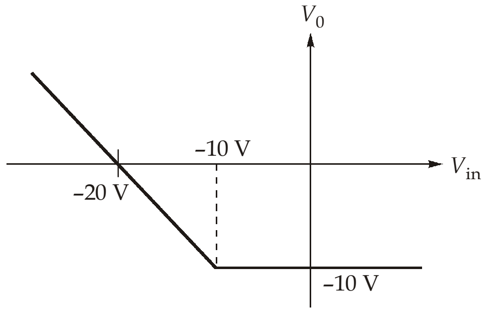
Alternately, we can write the equation of the graph by applying KCL at node $V^-$

$$\because \quad V^- = V^+ = -10 \text{ V}$$

$$\frac{-10 - V_{in}}{5\text{ k}\Omega} + \frac{-10 - V_0}{5\text{ k}\Omega} = 0$$

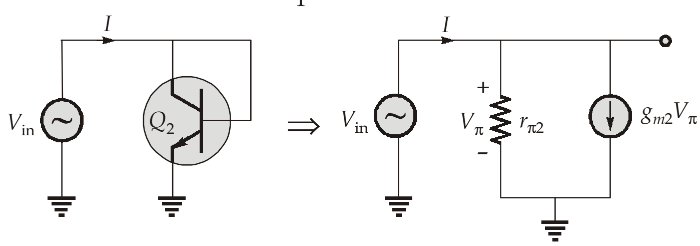
$$-20 - V_{in} - V_0 = 0$$

$$V_0 = -V_{in} - 20$$




**27. (b)**

For transistor $Q_2$, we can calculate the equivalent resistance as



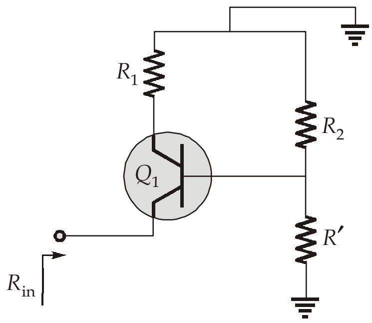

$$\therefore \quad I = \frac{V_\pi}{r_{\pi 2}} + g_{m2}V_\pi$$

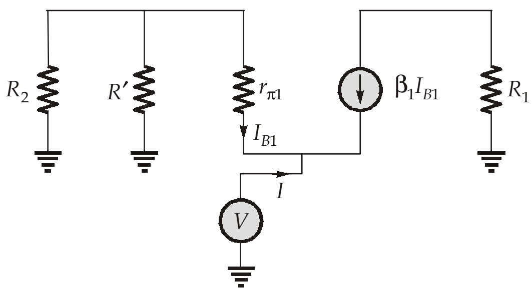
Now, $\quad V_{in} = V_\pi$

$$\therefore \quad \frac{I}{V_{in}} = \frac{1}{r_{\pi 2}} + g_{m2}$$

or $\quad R' = r_{\pi 2} \,||\, \frac{1}{g_{m2}}$

Now, the circuit can be redrawn as




$$I = -I_{B1} - \beta_1 I_{B1}$$
$$I = -(1 + \beta_1)\, I_{B1}$$

Now,
$$I_{B1} = \frac{-V}{r_{\pi 1} + R' || R_2}$$

$$\therefore \quad \frac{V}{I} = \frac{r_{\pi 1} + R' || R_2}{\beta_1 + 1}$$

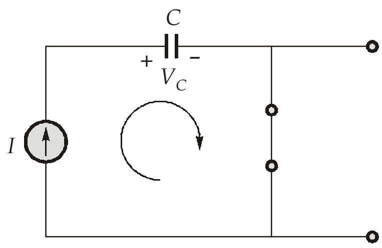
$$\therefore \quad R_{in} = \frac{1}{\beta_1 + 1}\left(r_{\pi 1} + \frac{1}{g_{m2}} || r_{\pi 2} || R_2\right)$$

$\because$ where, $\beta_1 = 99$

$$\therefore \quad R_{in} = \frac{1}{100}\left(r_{\pi 1} + \frac{1}{g_{m2}} || r_{\pi 2} || R_2\right)$$

**28. (c)**

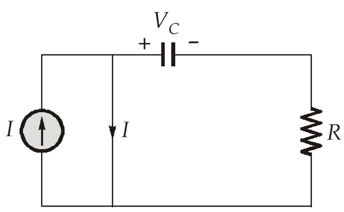
For negative cycle $V_{in} < 3.2$ V always, thus the MOSFET $M_1$ will be OFF and diode $D_1$ will be ON




$$\therefore \quad V_C = \frac{I}{C}.t$$

$$\Rightarrow \quad V_C = \frac{I}{C}.T_{off} = \frac{I}{C}(1 - D)T$$

Now, when $V_{in} > 3.2$ V, thus the MOSFET transistor will be switched ON and hence




Now, since $R$ is very large, thus, $V_c$ will not reduce substantially and thus, $V_C$ will not change during the positive going pulse.

Hence, after 5 clock pulse value of $V_c$

$$V_c = \frac{5I}{C}(1-D)T$$

**29. (d)**

$$I_D = k_n(V_{GS} - V_{th})^2 (1 + \lambda V_{DS})$$

$$r_0 = \frac{\Delta V_{DS}}{\Delta I_D} = \frac{1}{(\partial I_D / \partial V_{DS})}$$

$$\frac{\partial I_D}{\partial V_{DS}} = k_n(V_{GS} - V_{th})^2 \lambda$$

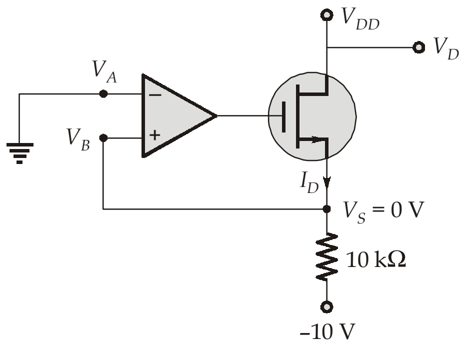
at $V_{GS} = 0.5, \quad I_D = 1 \text{ mA}$

so, $1 \text{ mA} = k_n(V_{GS} - V_{th})^2 (1 + 0.05)$

$$k_n(V_{GS} - V_{th})^2 = \frac{1}{1.05} \text{m℧}$$

$$r_0 = \frac{1.05}{0.1} \text{k}\Omega = 10.5 \text{ k}\Omega$$

**30. (b)**




For the transistor

$$V_S = V_B = V_A$$

due to virtual ground,

thus, $V_S = 0$ V

Hence, $$I_D = \frac{0-(-10)}{10\times 10^3} = 1 \text{ mA}$$

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

$$\therefore \quad V_{GS} - V_T = \sqrt{\frac{I_D}{\frac{\mu_n C_{ox} W}{2L}}}$$

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

$$V_{GS} - V_T = 2 \text{ V}$$

For the MOSFET to be in saturation region

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

$\therefore$ at the edge of saturation

$$V_{DS} = V_{GS} - V_T = 2 \text{ V}$$

$\because \quad V_S = 0$

$\therefore \quad V_D = V_G - V_T$

$\Rightarrow \quad V_{DD} = 2$ V

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