CLASS TEST

Sl. 01 SK_EC_ABCD_100722 [G]

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ANALOG ELECTRONICS

ELECTRONICS ENGINEERING

Date of Test : 10/07/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

When D_2 is ON then the value of V_0 will be

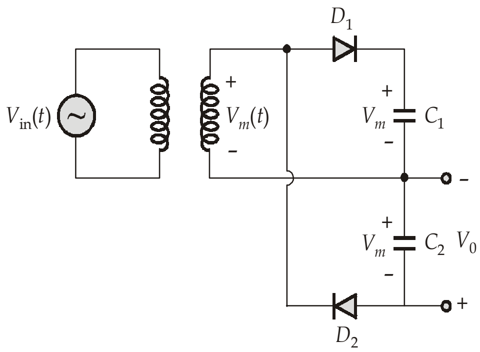
$$V_0 = 3 - 0.7\text{ V} = 2.3\text{ V}$$

Hence, D_1 will be OFF.

Thus, The current, $I = \frac{2.3-(-3)}{5} \times 10^{-3} = \frac{5.3}{5} \times 10^{-3} = 1.06\text{ mA}$

2. (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,

$$V_0 = -V_m$$

3. (b)

The early voltage V_A can be calculated as

$$V_A = r_0 I_C$$

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

$$r_0 = \frac{1}{3\times 10^{-5}}$$

thus, $V_A = \frac{1}{3\times10^{-5}} \times 3\times10^{-3} = 100\text{ V}$ $\quad(\because I_C = 3 \times 10^{-3}\text{ A})$

6. (a)

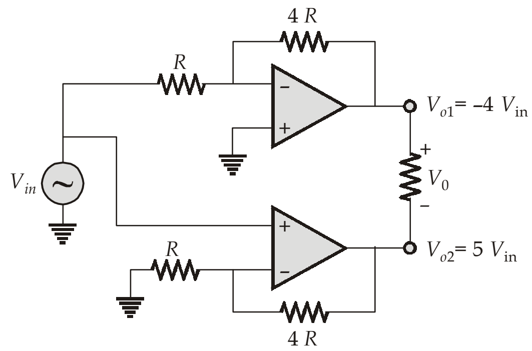
Since, the op-amp represents a closed loop unity gain amplifier.

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

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

7. (c)

In the given circuit

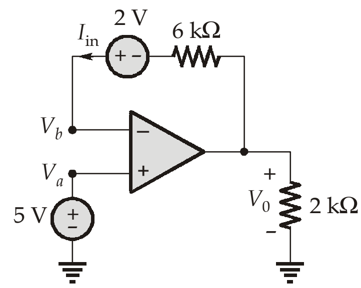


$$\therefore \quad V_o = V_{o_1} - V_{o_2}$$
$$= -4\ V_{in} - 5\ V_{in}$$
$$= -9\ V_{in}$$

$$\therefore \quad \frac{V_o}{V_{in}} = -9$$

8. (b)

Since, negative feedback is applied to the op-amp, thus the concept of virtual ground is applicable.



Thus, $V_a = V_b$

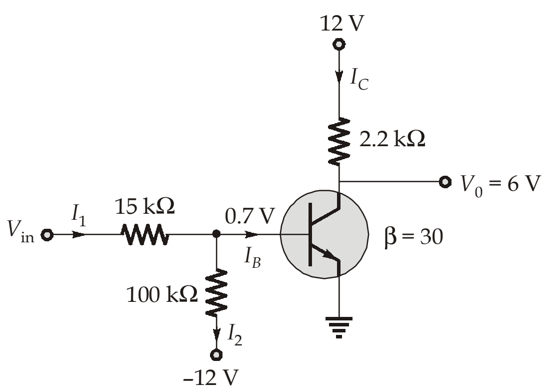
now, since the op-amp is ideal thus $I_{in} = 0$

Hence $V_0 = V_b - 2\text{ V}$

$= 5\text{ V} - 2\text{ V}$

$= 3\text{ V}$

9. (c)



Now, $I_C = \dfrac{12-6}{2.2}\times 10^{-3} = 2.727 \text{ mA}$

$\therefore$ $I_B = \dfrac{I_C}{\beta} = \dfrac{2.727}{30} = \dfrac{1}{11} \text{ mA}$

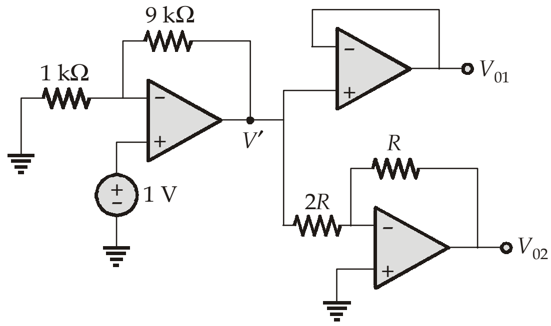
Now, $I_2 = \dfrac{0.7-(-12)}{100 \text{ k}\Omega} = 0.127 \text{ mA}$

$\therefore$ $I_1 = I_2 + I_B = 0.218 \text{ mA}$

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

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

10. (c)



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

$V' = 10 \text{ V}$

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

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

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

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

11. (a)

The current of both the transistors are equal since they are perfectly matched.

Thus, $\dfrac{I}{2} = \dfrac{1}{2}\mu_n C_{ox}\left(\dfrac{W}{L}\right)(V_{GS1} - V_t)^2$

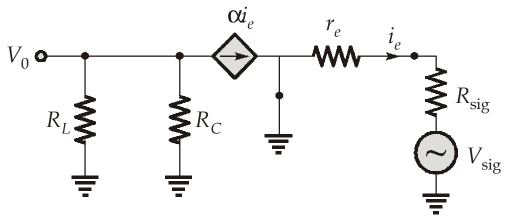
$10 \times 10^{-3} = \dfrac{1}{2}\times 500\times 10^{-6}\times 100(V_{GS1}-0.5)^2$

$\therefore$ $V_{GS1} = V_{GS2} = 1.132 \text{ V}$

Thus, $V_S = V_{cm} - V_{GS1} = 3 - 1.132 = 1.868 \text{ V}$

12. (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,
$$\frac{V_0}{V_{sig}} = \frac{\alpha(R_C \parallel R_L)}{R_{sig} + r_e}$$

13. (a)

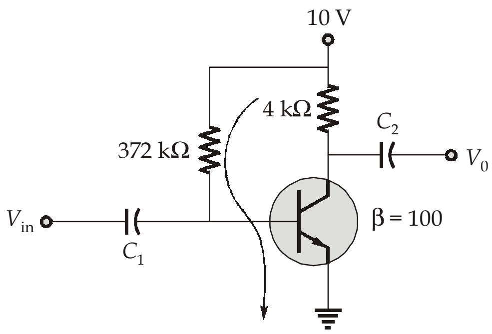
$$\frac{V_0}{V_i} = -g_m R_C$$

now,
$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{2V_T} = \frac{1\times10^{-3}}{2\times25\times10^{-3}} = 20 \text{ mA/V}$$

$\therefore$
$$\frac{V_0}{V_{in}} = -20 \times 10^{-3} \times 1 \times 10^{3} = -20 \text{ V/V}$$

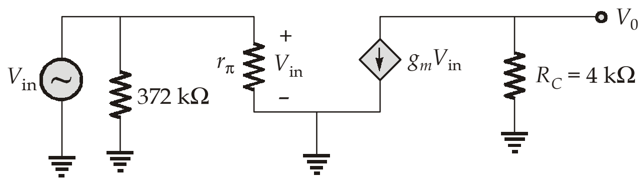
14. (c)

Applying KVL in base-emitter loop, we get,



$$I_B = \frac{10 - 0.7}{372 \text{ k}\Omega} = 25 \text{ μA}$$

To draw the small signal we need to calculate r_π



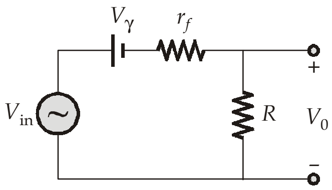
$\therefore$ $$r_\pi = \frac{V_T}{I_{B_{DC}}} = \frac{25\times10^{-3}}{25\times10^{-6}} = 10^3\ \Omega$$

now, $$g_m = \frac{\beta}{r_\pi} = \frac{100}{10^3} = 0.1\ \text{A/V}$$

now, $$A_v = \frac{V_0}{V_{in}} = -g_mR_C = -0.1\times4\times10^3 = -400$$

15. **(c)**

The small signal equivalent model can be drawn as



$\therefore$ 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, $$r_f = 83.33\ \Omega$$

16. **(b)**

In the transistor $V_{GS} = V_{DS}$

Since, the gate and drain terminals are shorted,

the transistor will always be in saturation mode.

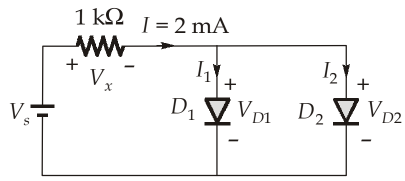
thus, $$I_D = \frac{\mu_nC_{ox}}{2}\left(\frac{W}{L}\right)(V_{GS}-V_t)^2$$

now, $$I_D = \frac{V_0}{R} = \frac{3}{3}\times10^{-3} = 1\ \text{mA}$$

thus, $$1\times10^{-3} = \frac{50\times10^{-3}}{2}\left(\frac{W}{L}\right)\times(2-1)^2$$

$$\left(\frac{W}{L}\right) = \frac{1}{25} = 0.04$$

17. (c)



$$V_s = V_x + V_{D1} \qquad (\because V_{D1} = V_{D2})$$

and $$I = I_1 + I_2$$

thus $$2 \times 10^{-3} = 10^{-12}\left[e^{\frac{V_{D1}}{26\times 10^{-3}}} - 1\right] + 10^{-10}\left[e^{\frac{V_{D1}}{26\times 10^{-3}}} - 1\right]$$

$$2 \times 10^{-3} \approx 10^{-10}(1.01)\cdot e^{\frac{V_{D1}}{26\times 10^{-3}}}$$

$$\frac{V_{D1}}{26\times 10^{-3}} = \ln(1.9801 \times 10^{7}) = 16.801$$

$\therefore$ $$V_{D1} = 0.437 \text{ V}$$

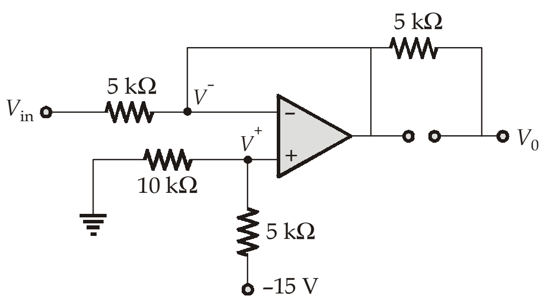
Now, $$V_x = 2 \times 10^{-3} \times 1 \times 10^{3} = 2 \text{ V}$$

$$V_s = V_x + V_{D1} = 2 + 0.437$$

$$= 2.437 \text{ V}$$

18. (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

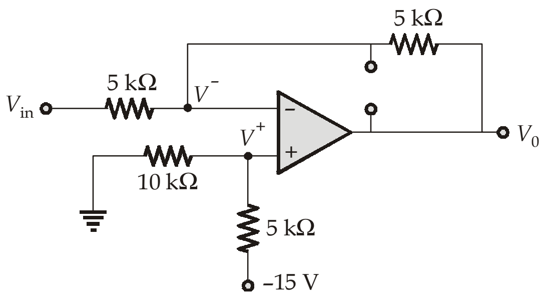
and $V_0 = V^- = -10$ V

$\therefore$ $V_0 = -10$ V

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

$$V_0 = +V_{sat}$$

Thus,



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

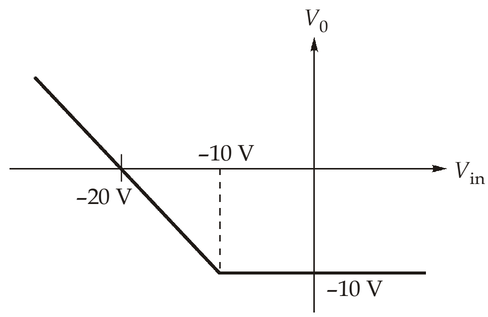
Alternately, we can write the equation of the graph by applying KCL at node V⁻

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

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

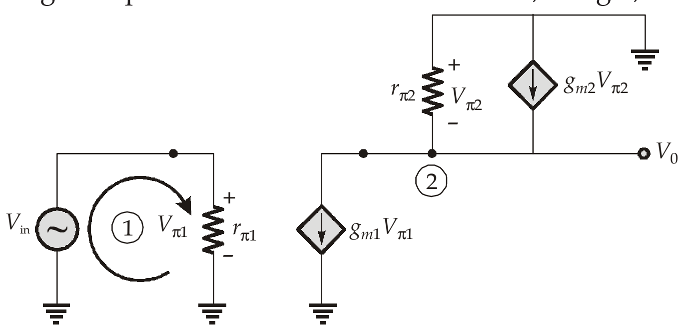
$$-20 - V_{in} - V_0 = 0$$

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



19. (c)

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



Now, $\quad V_{in} = V_{\pi1}$

and $\quad V_0 = -V_{\pi2}$

Applying KCL at node-2 we get

$$g_{m1}V_{\pi1} + \frac{V_0}{r_{\pi2}} = g_{m2}V_{\pi2}$$

$$\Rightarrow \quad g_{m1}V_{in} + \frac{V_0}{r_{\pi2}} = -g_{m2}V_0$$

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

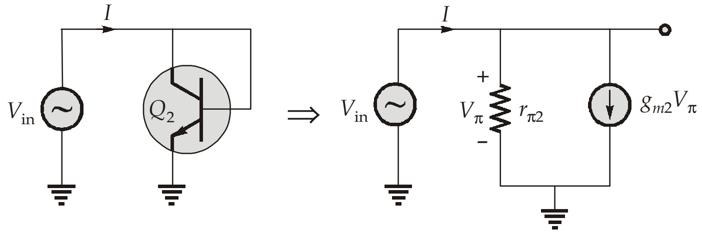
$$|A_v| = \left|\frac{V_0}{V_{in}}\right| = \frac{g_{m1}r_{\pi 2}}{1 + g_{m2}r_{\pi 2}}$$

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

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

20. (b)

For transistor Q_2, we can calculate the equivalent resistance as



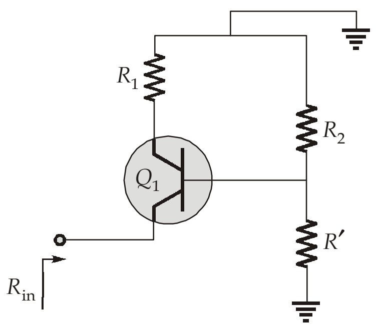
$$\therefore \quad I = \frac{V_\pi}{r_{\pi 2}} + g_{m2}V_\pi$$

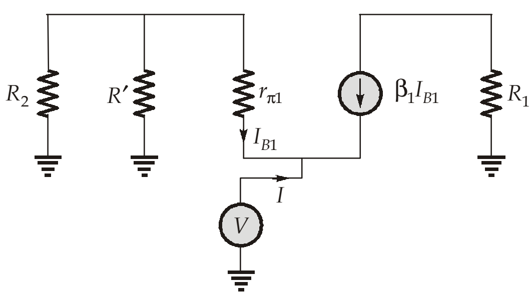
Now, $\quad V_{in} = V_\pi$

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

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

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

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

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

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

21. (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.

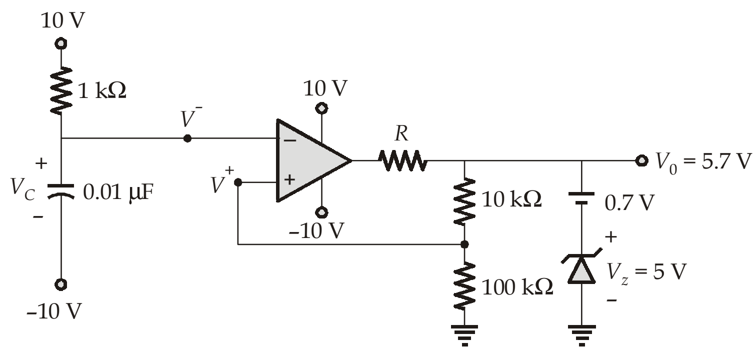
Now, when the switch is flipped open, the capacitor will charge upto 20 V.

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

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

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

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, $$V^- = V_C - 10\ \text{V}$$

or, $$V_C = V^- + 10\ \text{V}$$

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

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

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

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

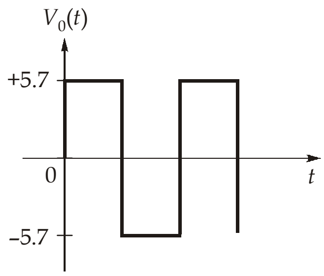
$$1 - e^{-t/RC} = \frac{1}{2} + \frac{57}{220}$$

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

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

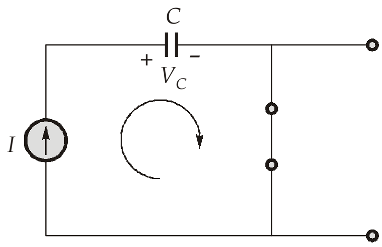
$$T = 14.23\ \mu\text{sec}$$

Hence, the output voltage wave will be,



22. (c)

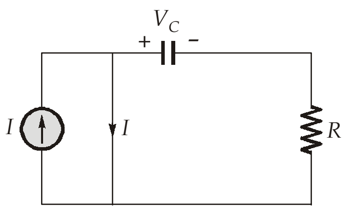
For negative cycle V_{in} < 3.2 V always, thus the MOSFET M_1 will be OFF and diode D_1 will be ON



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

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

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

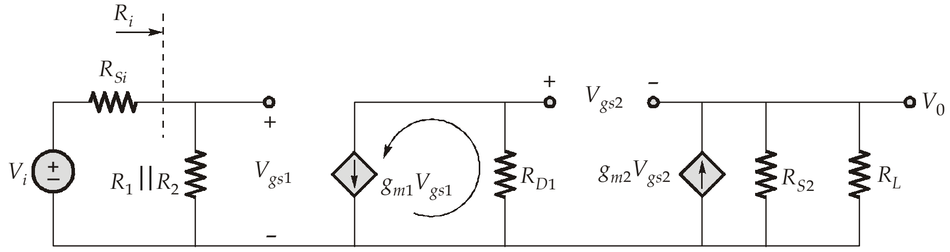
$$V_c = \frac{5I}{C}(1-D)T$$

23. (c)

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

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

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

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

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

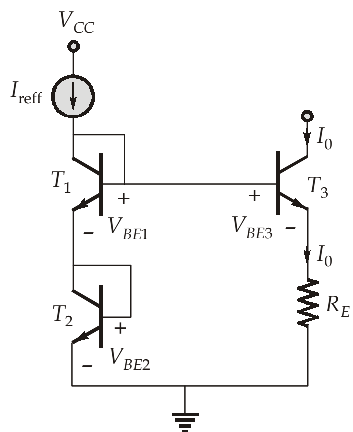
$$\approx -6.14$$

24. (b)

Applying KVL in the circuit shown below, we get,

$$2V_{BE1} = V_{BE3} + I_0R_E$$

($\because$ both the transistor are matched with negligible base current thus $V_{BE1} = V_{BE2}$ for same I_{reff}).



Now, $$V_{BE1} = V_T \ln\left(\frac{I_{reff}}{I_s}\right)$$

$$V_{BE3} = V_T \ln\left(\frac{I_0}{I_s}\right)$$

$$2V_T \ln\left(\frac{I_{reff}}{I_s}\right) - V_T \ln\left(\frac{I_0}{I_s}\right) = I_0R_E$$

$$V_T \ln\left(\frac{I_{reff}^2}{I_0I_s}\right) = I_0R_E$$

$$R_E = \frac{V_T}{I_0}\ln\left(\frac{I_{reff}^2}{I_0I_s}\right) = 0.208\ln\left(\frac{625}{10\times120\times10^{-3}}\right) = 15.638 \text{ k}\Omega$$

25. (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 $V_{GS} = 0.5, \quad I_D = 1 \text{ mA}$

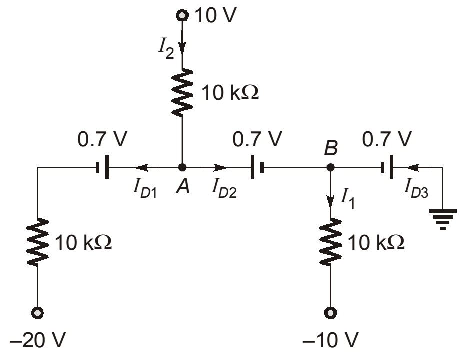
so, $1 \text{ mA} = k_n(V_{GS} - V_{th})^2 (1 + 0.05)$

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

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

26. (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,

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

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

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

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

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

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.

27. (d)

By applying superposition theorem, we get,
When V_1 at non-inverting terminal is shorted

$$V_{01} = -\frac{40}{20}V_1 = -2V_1 \quad ...(i)$$

When V_1 at inverting terminal is shorted, then

$$V_{02} = \left[1+\frac{40}{20}\right]\times\left[\frac{30}{30+30}\right]V_1 = 3\times\frac{3}{6}V_1 = 1.5\,V_1 \quad ...(ii)$$

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

$$V_0 = V_{01} + V_{02} = -2V_1 + 1.5V_1$$

$$= -\frac{V_1}{2}$$

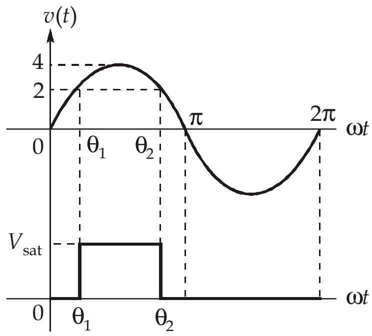
28. (b)

$$V_{P-P} = 8\text{ V}$$

Thus, $v(t) = 4\sin(\omega t)$

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

∴ Duty cycle $= \frac{T_{on}}{T_{total}} = \frac{\theta_{on}}{\theta_{total}}$



now, $\theta_1 = \sin^{-1}\left(\frac{2}{4}\right)$

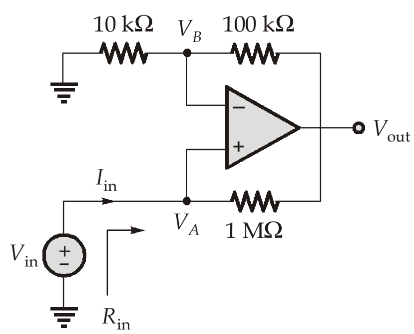
$$\theta_1 = \frac{\pi}{6}$$

and $\theta_2 = \pi - \frac{\pi}{6} = \frac{5\pi}{6}$

thus, $\theta_{on} = \frac{5\pi}{6} - \frac{\pi}{6}$ and $\theta_{total} = 2\pi$

∴ Duty cycle $= \frac{\frac{5\pi}{6}-\frac{\pi}{6}}{2\pi}\times 100 = 33.33\%$

29. (c)



now, $I_{in} = \frac{V_A - V_0}{1\,\text{M}\Omega} \quad ...(i)$

Applying KCL at inverting terminal, we get,

$$\frac{V_B - 0}{10\,\text{k}\Omega} + \frac{V_B - V_0}{100\,\text{k}\Omega} = 0$$

$$\frac{V_B}{10\text{ k}\Omega} = \frac{V_0 - V_B}{100\text{ k}\Omega} \quad \text{...(ii)}$$

now $V_B = V_A$ due to virtual ground

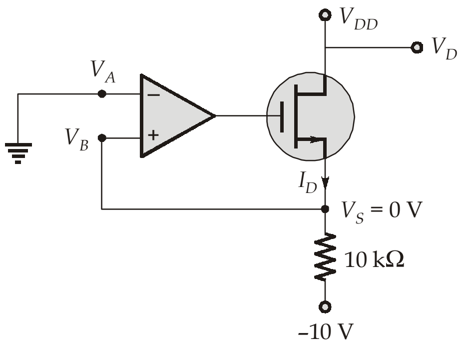
thus, $$\frac{V_A}{10\text{ k}\Omega} = -\left[\frac{V_A - V_0}{100\text{ k}\Omega}\right]$$

∴ $$\frac{V_A}{10\text{ k}\Omega} = \frac{-I_{in} \times (1\text{ M}\Omega)}{100\text{ k}\Omega}$$

$$\frac{V_{in}}{I_{in}} = -100\text{ k}\Omega \qquad \{\because V_A = V_{in}\}$$

30. **(b)**

For the transistor



$$V_S = V_B = V_A$$

due to virtual ground,

thus, $$V_S = 0\text{ V}$$

Hence, $$I_D = \frac{0-(-10)}{10\times10^3} = 1\text{ mA}$$

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

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

$$V_{GS} - V_T = \sqrt{\frac{1\times10^{-3}}{\frac{0.5\times10^{-3}}{2}}}$$

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

For the MOSFET to be in saturation region

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

∴ at the edge of saturation

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

∵ $$V_S = 0$$

∴ $$V_D = V_G - V_T$$

⇒ $$V_{DD} = 2\text{ V}$$

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