VLSI

HW-01

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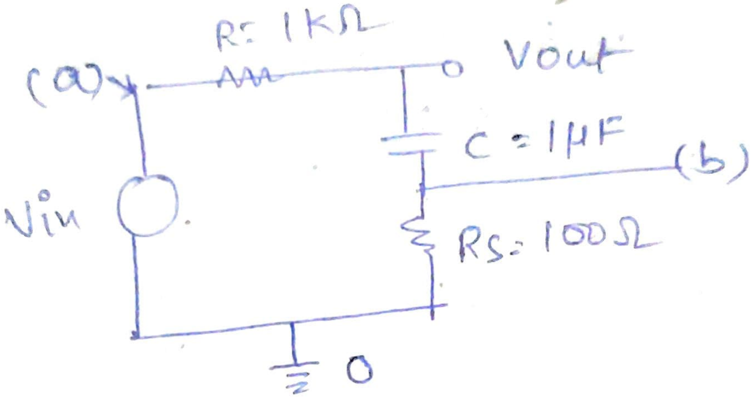
EE18BTECH11026

1). 

a) Operating point:

$V_{in} = 2.5\,V$

$V_b = 0V$

$V_{out} = 2.5V$

→ $I_{in\,c} = 0A$

b) Transient Analysis :-

* $V_{in} = \sin\omega t$, $\omega \in \{100Hz, 1MHz\}$

Analytical Expression:

Finding Frequency Analysis

$$V_{in} = I\left(R + R_s + \frac{1}{sC}\right)$$

$$V_{out} = V_{in}\left(\frac{\frac{1}{sC}+R_s}{R+R_s+1/sC}\right) \sim I\left(R_s+\frac{1}{sC}\right)$$

$$\Rightarrow \boxed{V_{out} = \frac{1+R_s sC}{1+(R+R_s)sC}\cdot V_{in}(s)}$$

↳ Let $s = j\omega \Rightarrow$ freq. analysis

$$V_{out} = \underbrace{\left(\frac{1+(j\omega)R_s C}{1+(j\omega)(R+R_s)C}\right)}_{H(\omega)} 1\angle 0^\circ$$

Considering $V_{in} = 1\sin(\omega t)$

* b.1 For $\omega = 2\pi \times 100$

$H(j\omega) = 0.824\angle -31.055$

$\therefore \boxed{V_{out} = 0.824\angle -31.055}$

$\therefore$ Attenuated to 0.824 ratio.

Phase shift by -31.055°

$$\boxed{V_{out} = 0.824\sin(\omega t - 31.05)}$$

b.2 For $\omega = 2\pi \times 1MHz$

$H(j\omega) = 0.091 \angle -0.083$

$\Rightarrow V_{out} = 0.091 \angle -0.083$

$\therefore \boxed{V_{out} = 0.091 \sin(\omega t - 0.083)}$

1.(C) As derived before.

Sol

$$\frac{V_{out}}{V_{in}} = H(j\omega) = \left(\frac{1+(j\omega)R_sC}{1+(j\omega)(R+R_s)C}\right)$$

$\Rightarrow$ For 3dB point $\Rightarrow$ $\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\sqrt{2}}$

$R_s = 100\Omega$, $R = 1k\Omega$, $C = 1\mu F$

$$\Rightarrow \left|\frac{V_{out}}{V_{in}}\right|^2 = \frac{(\omega R_sC)^2+1}{1+(\omega(R+R_s)C)^2} = \frac{1}{2}$$

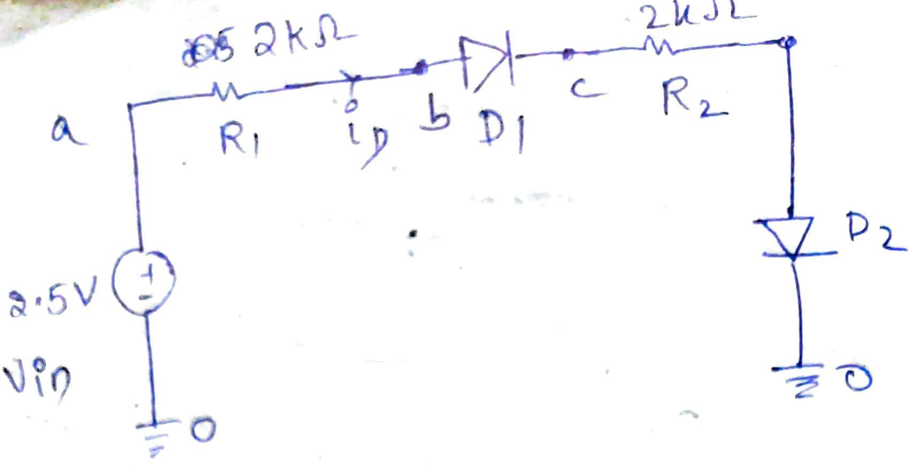
$$\Rightarrow 2\omega^2(R_sC)^2+2 = 1+\omega^2(R+R_s)^2C^2$$

$$\Rightarrow 1 = \omega^2\left((R+R_s)^2C^2 - 2R_s^2C^2\right)$$

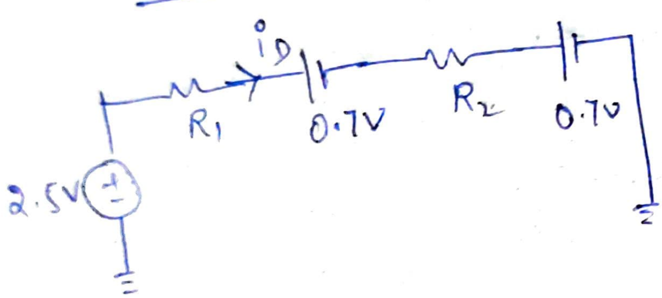
$$\rightarrow \omega = \frac{1}{C\sqrt{(R+R_s)^2-2R_s^2}} \sim \frac{10^4}{\sqrt{119}} \text{ rad/sec}$$

$$\rightarrow \text{freq. } f = \frac{10^4}{\sqrt{119}\times 2\pi} \sim 146 \text{ Hz}$$

2Q)



a) Simple model



$$i_D = \frac{2.5 - 2(0.7)}{R_1 + R_2} = \cancel{3.1 \times 10^{-4}} A$$

$\cancel{I_D = 3.1 \times 10^{-4} A}$

$\boxed{I_D = 2.7 \times 10^{-4} A}$

(b) Ideal diode model

Diode eq: $I_D = I_s \left(e^{\frac{V_D}{V_T}} - 1 \right)$

$V_T = \frac{1kT}{q} = 0.026V$

$= (k = 1.38 \times 10^{-23} J/K,$
$T = 300K)$

$I_S = 10^{-14} A$

$\Rightarrow \boxed{I_D = 10^{-14}\left(e^{\frac{V_D}{0.026}} - 1\right)}$ //

$\rightarrow \quad 2.5 = i(2k) + 2V_D + i(2k)$

$\Rightarrow \quad 2.5 = 2V_D + 4\times10^{3}(i_D)$

$\Rightarrow \quad \underbrace{2.5 = 2V_D + 10^{-14}\left(e^{V_D/0.026} - 1\right)\times 4\times10^{3}}$

$\Downarrow$

Non-linear Eqn.

↳ Solved using MATLAB.

$\boxed{V_D = 0.628 V}$

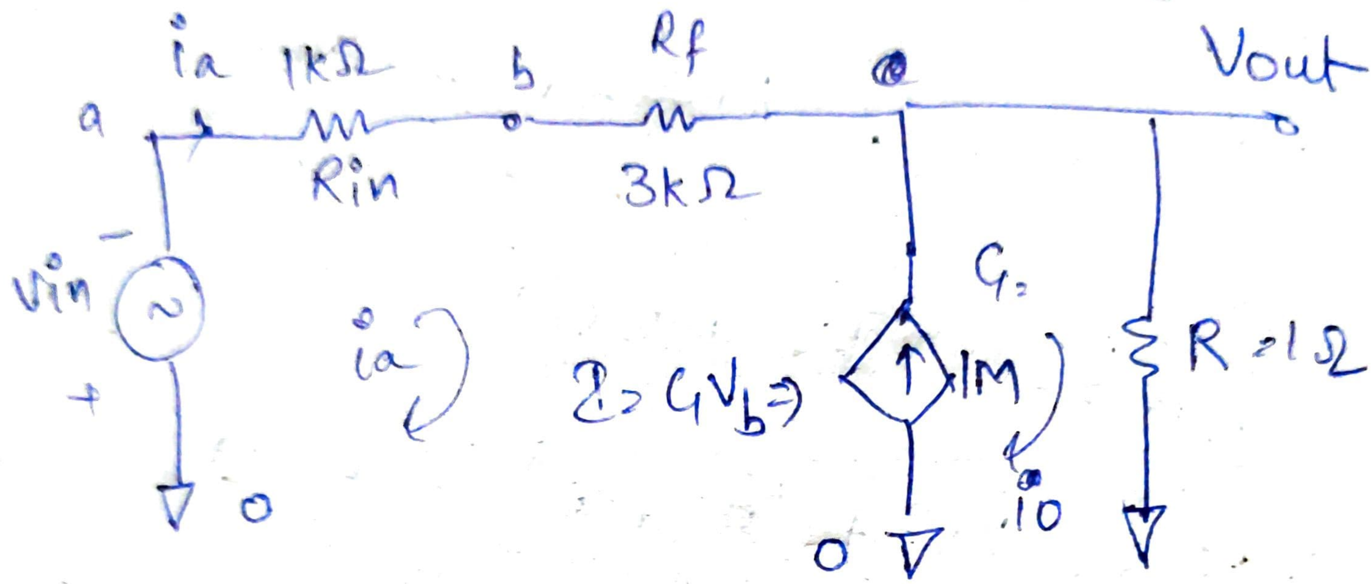
$\rightarrow \quad i.\ I_D = \frac{2.5 - 2V_D}{4\times10^{3}} = 3.1\times10^{-4} A$

$\rightarrow \quad \boxed{I_D = 3.1\times10^{-4} A}$ //

3Q) VCCS

Sol

$v_{in} = 1\,V_{pp}$, 1kHz



Analytical Soln:

$i_a \rightarrow$ current is left loop

$i_o \rightarrow$ " " right loop

$\Rightarrow$ ①: $-v_{in} - i_a(R_{in} + R_f) - i_o R = 0$

②: $V_{out} = i_o \cdot R = i_o$.

③: $G V_b = i_o - i_a$

Solving to find $\frac{V_{out}}{V_{in}} = ?$

(4) $v_b = -v_{in} - i_a R_{in}$

$\Rightarrow$ From; (3) (4)

$$\Rightarrow v_{in} + i_a R_{in} = \frac{i_a - i_o}{G}$$

$$\Rightarrow i_a\left(\frac{1}{G} - R_{in}\right) = \frac{i_o}{G} + v_{in}$$

$$\Rightarrow \boxed{i_a = \frac{i_o + G \cdot v_{in}}{1 - G R_{in}}} \rightarrow (6)$$

Sub. in (1):

$$-v_{in} - \left(\frac{i_o + G v_{in}}{1 - G R_{in}}\right)(R_{in} + R_f) = i_o R$$

$$\Rightarrow -v_{in}\left(1 + \frac{G(R_{in} + R_f)}{1 - G R_{in}}\right) = i_o\left(R + \left(\frac{R_{in} + R_f}{1 - G R_{in}}\right)\right)$$

$V_{out} = i_0 R \Rightarrow i_0$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{-1(1+GR_f)}{(R - GR_{in}R + R_{in} + R_f)}$$

For $G = 1M$ mho.

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{-G\left(R_f + \cancel{1/G}^{\,0}\right)}{-G\left(R_{in}R - \cancel{\frac{(R+R_{in}+R_f)}{G}}^{\,0}\right)}$$

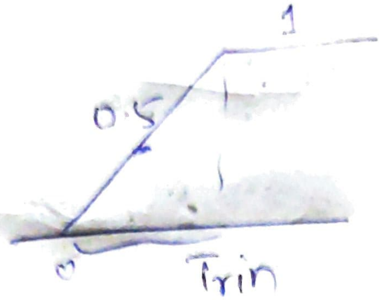
$$= \frac{R_f}{R_{in}R}$$

$$\boxed{\frac{V_{out}}{V_{in}} = 3}$$

Q5) Emperical Soln.

c.

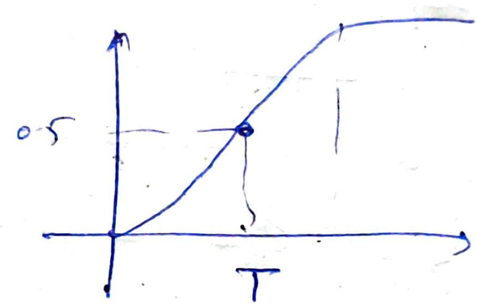
→ Trin



→ $V_{in}(0.5) = \frac{T_{rin}}{2}$

#

$V_{out}(0.5) = T$



∴ $t_p = T + \frac{T_{rin}}{2}$

Since $10ps < T_{rin} < 10ns$

$0.69RC \sim 0.69ns$.

∴ At start $T >> T_{rin} \Rightarrow t_p = T \sim 0.69RC$

At $T_{rin} \sim 1ns \Rightarrow T \sim T_{rin}. \Rightarrow t_p = 0.69RC + \frac{t_{rin}}{2}$

∴ Hence $t_p = 0.69RC + \frac{t_{rin}}{2}$

Explanation of Graph :-

→ for $10p < t_{rin} < 250ps$ → $0.69RC >> \frac{t_{rin}}{2}$

$t_p = 0.69RC.$

for $500ps < t_{rin} < 8ns$ ⇒ $0.69RC \sim \frac{t_{rin}}{2}$

$t_p = 0.69RC + \frac{t_{rin}}{2}$

for $8ns < t_{rin} < 10ns$ ⇒ $0.69RC << \frac{t_{rin}}{2}$

$\cancel{t_p = \frac{t_{rin}}{2}}$

Here, since, trin is high, so it slowly increases, hence capacitor also gets time to charge up., so hence delay 'tp' ~ 1ns