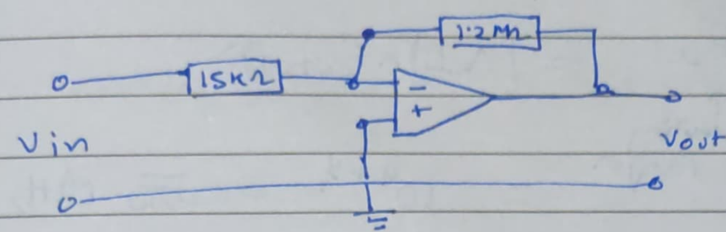
Basic Electronics
(ECE113)

Assignment-4

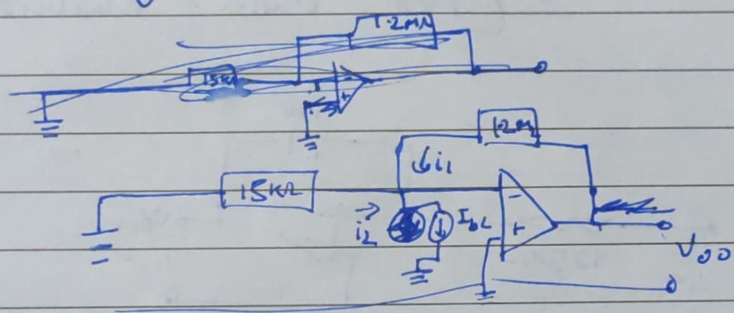
A1) (a) $V_g = -\frac{R_F}{R_{in}} = -\frac{1.2M\Omega}{15k\Omega} = -\frac{4}{5}\times 10^2 = -80$

(b)



$\downarrow$ at Vin=0

$I_{bc} = 90nA$



$\downarrow$

Now $V_{oo} = i_1 \times 1.2M\Omega$

but $i_1 + i_2 = I_{bc}$ and $\frac{i_1}{i_2} = \frac{15k\Omega}{1.2M\Omega}$

$\downarrow$

$i_1 = I_{bc}\left(\frac{15k\Omega}{1.2M\Omega + 15k\Omega}\right)$

$\therefore V_{oo} = \frac{1.2M\Omega \times 15k\Omega \times 90\,nA}{1.2\times 10^6\Omega + 15k\Omega}$

$= \frac{12\times 15\times 9}{1215}$ mV

$= \frac{4}{3}$ mV $= 1.333$ mV

A2) (a) $(V_g)_{dB} = 20\log_{10}(V_g)_{normal} \Rightarrow (V_g)_{normal} = 10^{9/4}$

$\therefore |(V_g)_{normal}| = |R_f/R_{in}|$

$R_f = 2\times 10^{4+\frac{1}{4}}$

$= (2\times\sqrt{\sqrt{10}})\,M\Omega$

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(b) $f_{cutoff} = 10\,KHz$ (CL B)

Now $|A_{CL}| = 10^{9/4}$

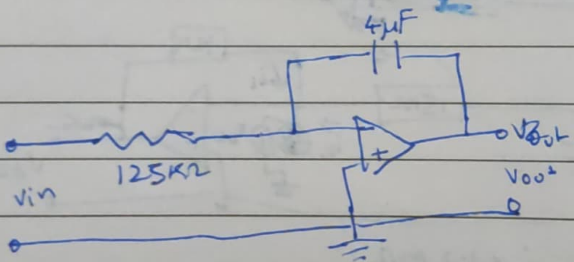
$\therefore f_u = |A_{CL}| \times f_{cutoff}$

↑ Limiting freq^n

$= 10^{4+\frac{1}{4}} = \sqrt{\sqrt{10}}\ MHz$

$\because$ (freq = Gain × Bandwidth)

A3)



$$\int \left(\frac{V_{in}-0}{R}\right) dt = d(V_{out} \times C)$$

at $t=0$, $q=0$ $\therefore V_{out}=0$

$$\therefore \int_0^{V_{out}} dV_{out} = -\int_0^{0.12} \frac{V_{in}}{RC} \cdot dt$$

500×10^{-3}

$$\Rightarrow V_{out} = -(0.12) \times \frac{-1.25}{0.5}$$

$= (0.12) \times 2.5$

$= 5 \times 0.06$

$= 0.3\ V$

$\therefore$ $V_{out} = 0.3\ V$ at $t = 120\ ms$ (0.12 s)

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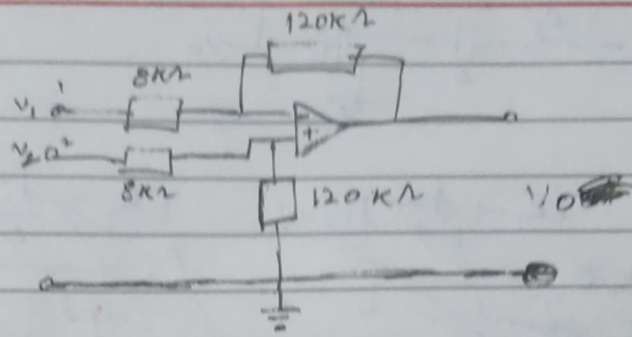
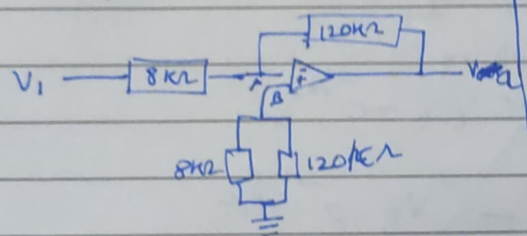
A4)



by using superposition therem ?

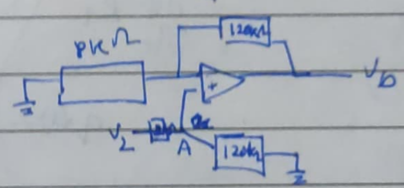
for V_1



$V_A = V_B = 0 \quad \therefore V_a = \frac{-\overset{15}{120}}{8} V_1$

$= -15 V_1$

for V_2



$\frac{V_2 - V_A}{8 k\Omega} = \frac{V_A}{\underset{15}{120 k\Omega}}$

$15 V_2 = 16 V_A$

$\frac{15}{16} V_2 = V_A$

$V_b = \left(1 + \frac{120 k\Omega}{8 k\Omega}\right) V_A$

$\therefore V_b = 16 \times \frac{15}{16} V_2$

$= 15 V_2$

$\therefore V_{out} = 15 (V_2 - V_1)$

(a) $V_1 = 4mV$, $V_2 = 0 \Rightarrow V_{out} = -60mV$

(b) $V_1 = 40mV$ and $V_2 = 30mV \Rightarrow V_{out} = -150 mV$

(c) $V_1 = 23 mV$ $V_2 = 40mV \Rightarrow V_{out} = 255mV$

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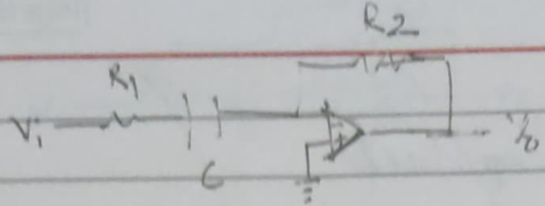
A5)



$$i = \frac{-V_0}{R_2} \Rightarrow \frac{dq}{dt} = \frac{-V_0}{R_2} \quad (2)$$

$$iR_1 + \frac{q}{C} = V_i \quad (1)$$

$$\downarrow$$

$$R_1\frac{dq}{dt} + \frac{q}{C} = V_i$$

$$\frac{-V_0 R_1}{R_2} + \int_0^t \frac{-V_0}{R_2 C}\,dt = V_i$$

$$\downarrow$$

$$\frac{-R_1}{R_2}\frac{dV_0}{dt} + \frac{-V_0(t)}{R_2 C} = \frac{dV_i}{dt}$$

$$\frac{dV_0(t)}{dt} + \frac{V_0(t)}{R_1 C} = \frac{-R_2}{R_1}\frac{dV_i}{dt}$$

$$\downarrow$$

$$\left[V_0(t)\, e^{t/R_1 C}\right]_{t=0}^{t=t} = \left\{\int_0^t e^{t/R_1 C}\left(\frac{-R_2}{R_1}\right)\frac{dV_i}{dt}\,dt\right.$$

$$\downarrow$$

at $t=0$ $\quad V_0(t) = 0$

$\therefore \quad V_0(t)$

$$\frac{0 - V_0}{R_2} = \frac{V_i - 0}{R_1 + \frac{1}{j\omega C}}$$

where $s = j\omega$

Transfer function $= H(s) = \frac{V_0}{V_{in}} = \frac{-R_2}{R_1 + \frac{1}{sC}}$

$$\therefore \boxed{H(j\omega) = \frac{-R_2}{R_1 + \frac{1}{j\omega C}}}$$

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at $\omega \to \infty$ (High freq^n)

$$\frac{V_o}{V_i} = \frac{-R_2}{R_1}$$

at critical frequency I

$$\left(\frac{V_o}{V_i}\right)_{f_c} = \frac{\left(\frac{V_o}{V_i}\right)_\infty}{\sqrt{2}}$$

$$\frac{-R_2}{R_1 + \frac{1}{j\omega C}} = \frac{-R_2}{R_1\sqrt{2}}$$

$$\downarrow$$

$$R_1 + \frac{1}{j\omega C} = R_1\sqrt{2}$$

$$\downarrow$$

$$\left|R_1 + \frac{1}{j\omega C}\right|^2 = \left|R_1\sqrt{2}\right|^2$$

$$R_1^2 + \left(\frac{1}{\omega^2 C^2}\right) = 2R_1^2$$

$$\downarrow$$

$$\frac{1}{R_1} = \omega C$$

$$\downarrow$$

$$\boxed{f_c = \frac{1}{2\pi R_1 C}}$$

~~at f_c $\frac{V_o}{V_i}$ $(V_g) = -3d$~~

$(V_g)_\infty = 20\text{dB} \Rightarrow \frac{R_2}{R_1} = 10$ $\quad (20 = 20\log_{10}(V_g))$

at high freq^n $\quad X_c \approx 0 \quad \therefore \quad R_{in} = R_1$

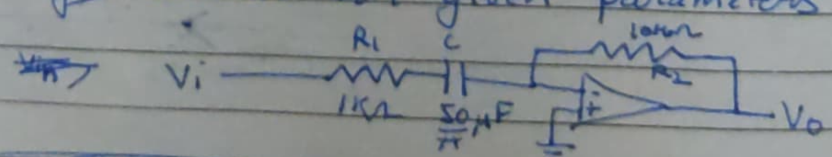
$$\therefore R_1 = 1K\Omega$$

$$\therefore R_2 = 10K\Omega$$

$$\therefore f_c = \frac{1}{2\pi C}$$

$$\therefore C = \frac{1}{2\pi \times 10KH_z} = \frac{50}{\pi}\mu F$$

$\therefore$ The circuit for given parameters becomes



~~Now the unity gain bandwidth~~

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Now the unity gain bandwidth is

$$\cancel{f_0} \quad 1 = \left| \frac{R_2}{R_1 + \frac{1}{j\omega C}} \right|$$

$$R_2^2 = R_1^2 + \frac{1}{\omega^2 C^2}$$

$$\Downarrow$$

$$\cancel{R} \quad \omega^2 C^2 = \frac{1}{R_2^2 - R_1^2}$$

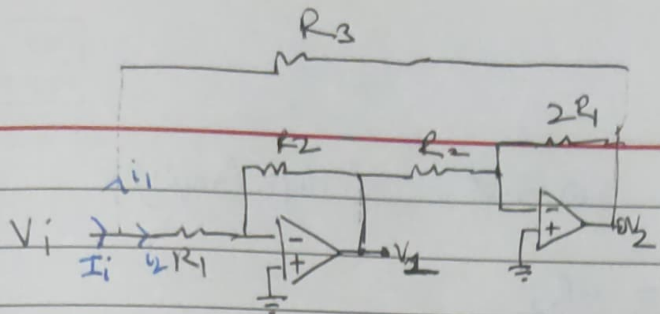
$$\Downarrow$$

$$f_0 = \frac{1}{2\pi C \sqrt{R_2^2 - R_1^2}}$$

$$f_0 = \frac{10^4}{10^3\sqrt{100-1}} = \frac{10}{\sqrt{99}} \text{ Hz}$$

$$\therefore f_0 = 1.00503782 \text{ Hz}$$

A6)



$$v_1 = V_i\left(-\frac{R_2}{R_1}\right)$$

$$V_2 = v_1\left(-2\frac{R_1}{R_2}\right) = 2\times V_i$$

$$i_1 = \frac{V_i - 2V_i}{R_3} = \frac{-v_i}{R_3}$$

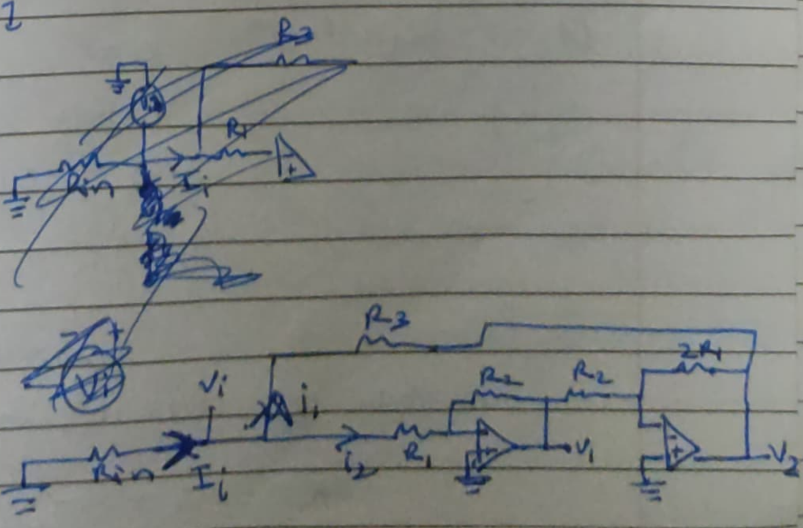
$$i_2 = \frac{\cancel{V_2}\ 0 - V_2}{2R_1} = \frac{-V_i}{R_1}$$

$$\therefore I_i = i_1 + i_2 = -V_i\left(\frac{1}{R_1} + \frac{1}{R_3}\right)$$

$$\text{Now, } R_{in} = \frac{-V_i}{I_i} = \frac{R_1R_3}{R_1+R_3}$$

$$\therefore R_{in} = \boxed{\frac{R_1R_3}{R_1+R_3}}$$

↳ circuit 1



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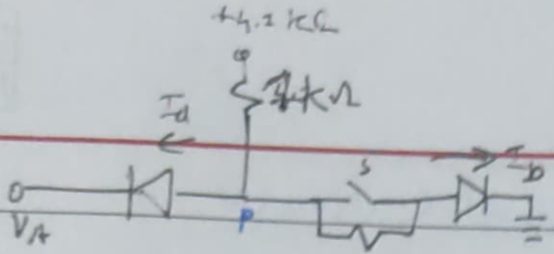
A7)



(a) S → closed

$$I_a = R_D \cdot (V_p - V_a)$$

$$I_b = R_D (V_p)$$

$$\therefore \frac{I_a}{I_b} = \frac{V_p - V_a}{V_p}$$

$$\frac{4.7 - V_p}{10^3} = ~~1k/I~~ \; I_a + I_b$$

(for silicon diodes
↳ vol. drop = 0.7)

~~for I_a to exist,~~ ~~4.7 =~~

$4.7 - V_a > 0.7$

for both to exist

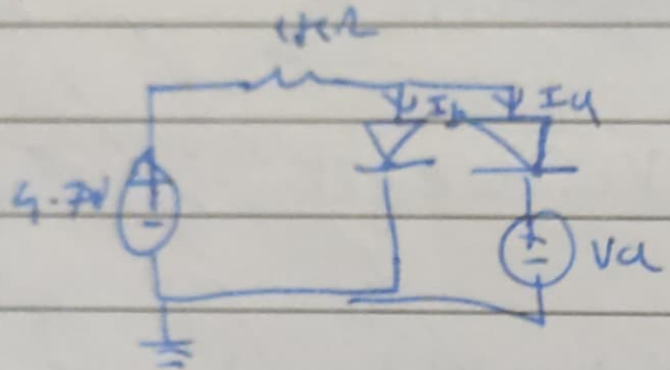
for I_b to exist → $4.7 > 0.7$

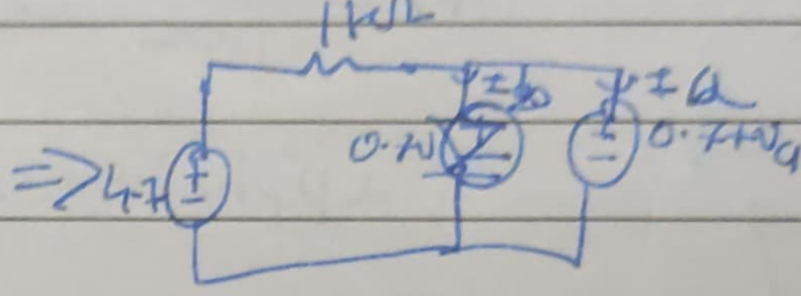
$4 > V_a$

else $I_a = 0$

∴ for $V_a = -1V$ = 0.1V

(a) contn





for $V_a < 0$, $\begin{pmatrix} -0.1V \\ -1V \end{pmatrix}$

$I_b = 4\,mA$

$I_a = 0$

else $\rightarrow$ $I_b = 0$

$I_a = (4 - V_a)\,mA$

V_a	I_a	I_b
−1V	0	4mA
−0.1V	0	4mA
1V	3mA	0
2V	2mA	0

(S → closed)

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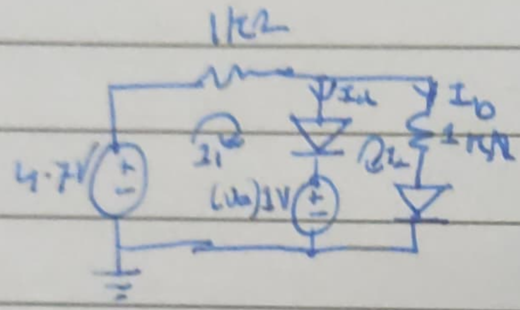
(b) for S - opened & $V_o = 1V$



$I_1 \times 1k\Omega + 0.7V + 1V = 4.7V$

$I_1 = 3\,mA$

$I_2 \times 1k\Omega + 0.7 = 1 + 0.7$

$I_2 = 1\,mA$

$\therefore I_b = 1\,mA$

and $I_u = I_1 - I_2 = 3 - 1 = 2\,mA$

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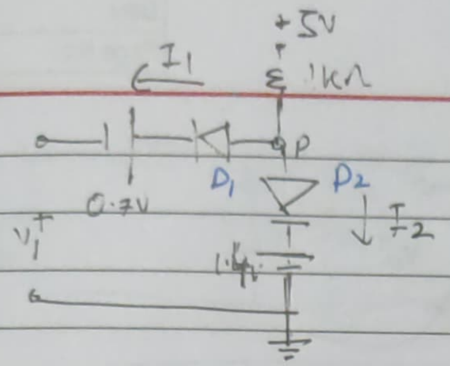
A8)



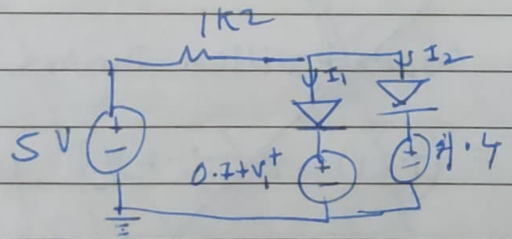
~~when v_1~~

~~when $v_1^+ > 0 \Rightarrow I_2 = \frac{4-0.4}{1k\Omega} = 3.6mA$~~

~~D_1~~

D_1 does not conduct

If $(v_1^+ + 0.7) > V_P \Rightarrow I_2 = 3.6\,mA$



$\therefore I_2 = 0$ when $0.7 + v_1^+ > 1.4\,V$

$\Rightarrow v_1^+ > 0.7V$

$I_1 = (4.3 - v_1^+)\,mA$

and $\rightarrow I_1 = 0$

$I_2 = (5-1.4)\,mA$ when $0.7+v_1^+ < 1.4$

and when $v_1^+ = 0.7V$

$I_1 = I_2 = (5-1.4)\,mA$

$$\therefore \boxed{I_2 = \begin{cases} 0\,mA ; & v_1^+ > 0.7V \\ 3.6\,mA ; & \text{otherwise} \end{cases}}$$

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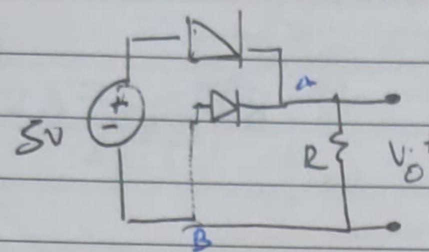
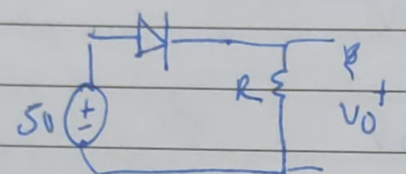
A9) (a)



A — B

pd > 0.7V or pd = −4.3V

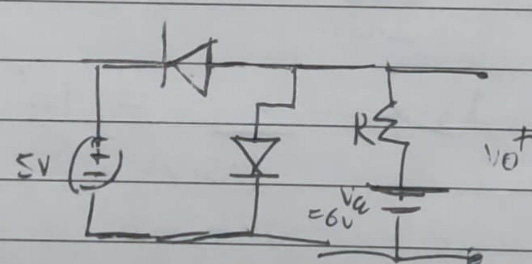
⇓ equivalent to



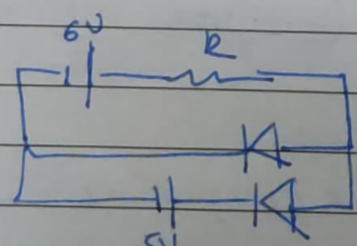
⇓

$\therefore V_0^+ = 5 - 0.7V = 4.3V$

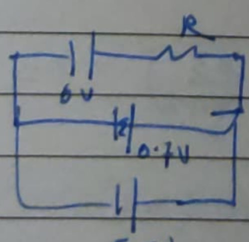
(b)



⇓

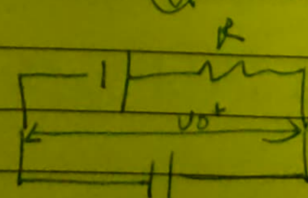


⇓ equivalent to



Now, This is equivalent to

⇓



$\therefore V_0^+ = 5.7V$

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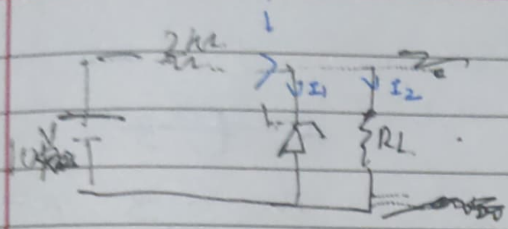
A10)



$BV_{ZD} = 6V$

~~V accross the $R_L = 6V$~~

V accross the $R_L = 6V$

when $R_L = 2.5k\Omega$

$i = \frac{4}{2k\Omega} = 2mA$

$I_2 = \frac{6}{2.5k\Omega} = \frac{12}{5} = 2.4mA$

$I_1 = -0.4\,mA$

$(P)_{R_L} = \cancel{(2.4)}\ \cancel{(2.5)k\Omega}\quad \frac{V^2}{R} = \frac{36}{2.5\times10^3}$

$= 14.4\,mW$

$(P)_{ZD} = (-0.4mA)\times(6V) = -2.4\,mV$

when $R_L = 4k\Omega$

$i_1 = 2mA - \left(\frac{6}{4k\Omega}\right) = 0.5\,mA$

$\therefore (P)_{ZD} = (6V)\times(0.5\,mA) = 3\,mW$