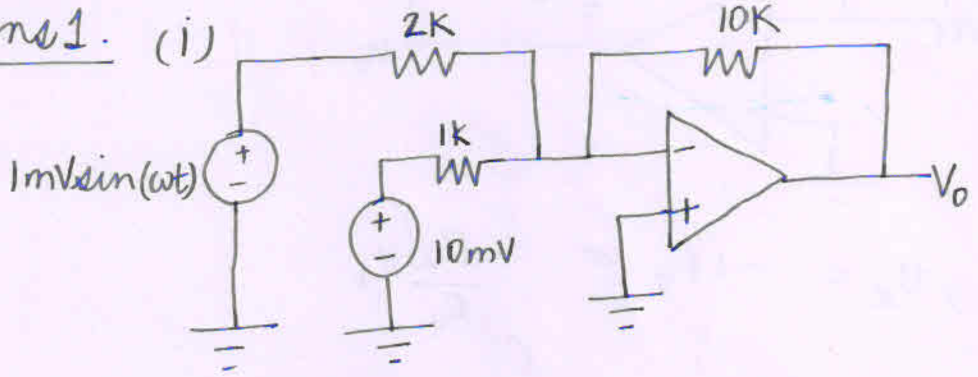
ESC 201 Assignment 8 Solutions

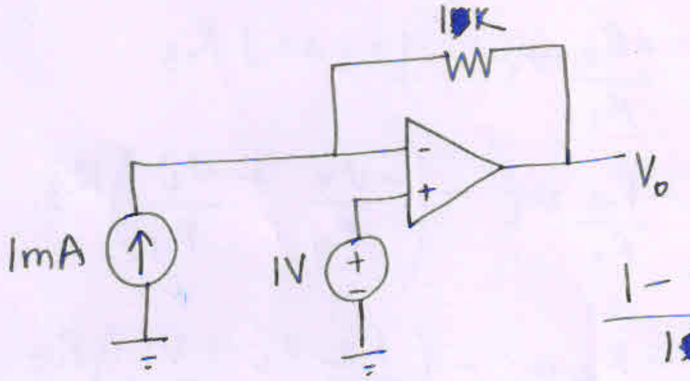
Ans 1. (i)



$$v_o = -\left\{ \frac{10k}{1K} \times 10mV + \frac{10k}{2K}\ 1mV \sin(\omega t) \right\}$$

$$= -\left(0.1 + 5\times10^{-3} \sin(\omega t)\right) V$$

(ii)

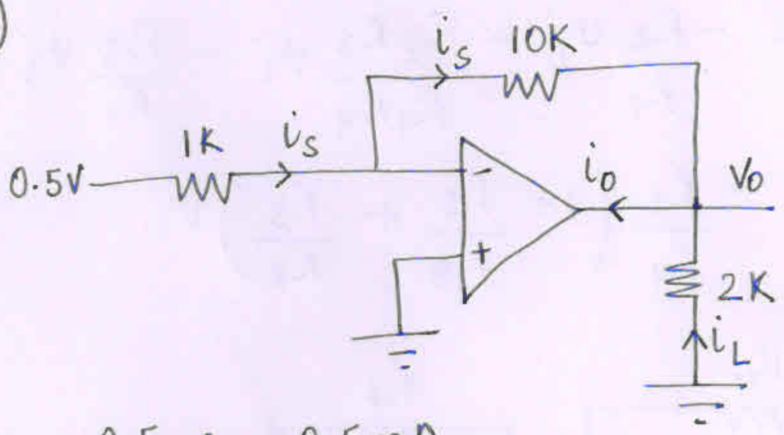


$$v_+ = v_- = 1V$$

$$\frac{1 - V_o}{1K} = 1mA$$

$$\Rightarrow v_o = 0V$$

(iii)



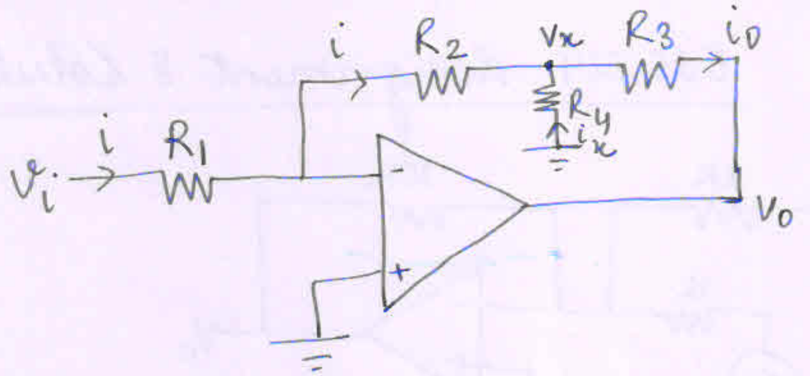
$$i_s = \frac{0.5}{1K} A = 0.5mA$$

$$v_o = -i_s \times 10k = -0.5\times10^{-3} \times 10\times10^{3} V = -5V$$

$$i_L = \frac{-V_o}{2k} = \frac{5}{2k} A = 2.5mA$$

$$i_o = i_s + i_L = 0.5mA + 2.5mA = 3mA$$

(iv)



$$i = \frac{v_i}{R_1}, \quad v_x = -iR_2 = -\frac{R_2}{R_1} v_i$$

$$i_x = \frac{-v_x}{R_4}$$

$$i_0 = i_x + i$$

$$v_0 = v_x - i_0 R_3$$

$$\Rightarrow v_0 = \frac{-R_2}{R_1} v_i - (i_x + i) R_3$$

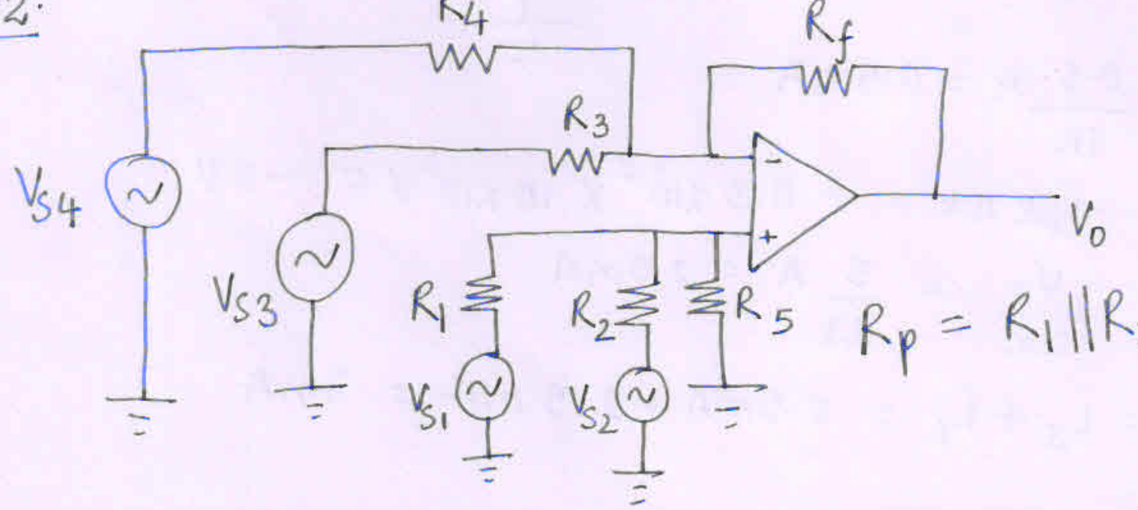
$$\Rightarrow v_0 = -\frac{R_2}{R_1} v_i - \left(\frac{-v_x}{R_4} + \frac{v_i}{R_1} \right) R_3$$

$$\Rightarrow v_0 = -\frac{R_2}{R_1} v_i - \left(\frac{R_2}{R_1 R_4} v_i + \frac{v_i}{R_1} \right) R_3$$

$$\Rightarrow v_0 = -\frac{R_2}{R_1} v_i - \frac{R_2 R_3}{R_1 R_4} v_i - \frac{R_3}{R_1} v_i$$

$$\Rightarrow v_0 = -\frac{R_2}{R_1} \left(1 + \frac{R_3}{R_4} + \frac{R_3}{R_2} \right) v_i$$

Ans 2.



$R_p = R_1 || R_2 || R_5$

$$v_o = -\left(\frac{R_f}{R_3}\right)v_{S3} - \left(\frac{R_f}{R_4}\right)v_{S4} + \left(1+\frac{R_f}{R_3\|R_4}\right)\times\frac{R_p}{R_1}v_{S1}$$
$$+\left(1+\frac{R_f}{R_3\|R_4}\right)\times\frac{R_p}{R_2}v_{S2}$$

$$V_o = 2v_{S1} + 4v_{S2} - 8v_{S3} - 10v_{S4}$$

Let $R_f = 10K$

$$\therefore \frac{R_f}{R_3} = 8$$

$$\frac{10K}{R_3} = 8 \rightarrow R_3 = 1.25k\Omega$$

$$\frac{R_f}{R_4} = 10$$

$$\therefore \frac{10k}{R_4} = 10 \Rightarrow R_4 = 1k\Omega$$

$$\frac{R_f}{R_3\|R_4}\times\frac{R_p}{R_1} = 2 \Rightarrow \frac{10K}{(1.25k\|1k)}\times\frac{R_p}{R_1} = 2$$

$$\Rightarrow \frac{R_p}{R_1} = 0.105$$

$$\frac{R_f}{R_3\|R_4}\times\frac{R_p}{R_2} = 4 \Rightarrow \frac{10K}{(1.25k\|1k)}\times\frac{R_p}{R_2} = 4$$

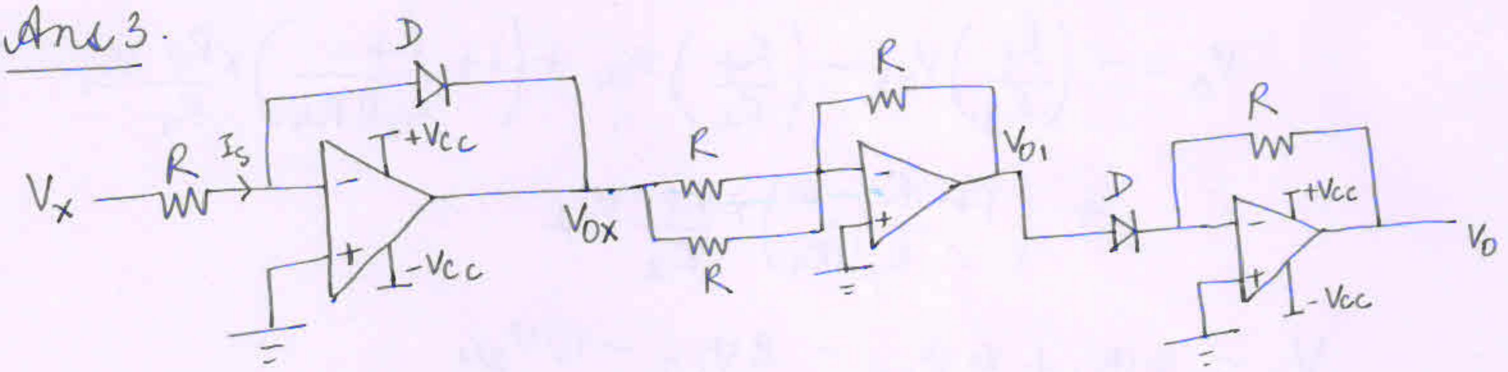
$$\Rightarrow \frac{R_p}{R_2} = 0.211$$

$$\frac{R_1}{R_p}\times\frac{R_p}{R_2} = \frac{1}{0.105}\times 0.211 \rightarrow \frac{R_1}{R_2} = 2$$

Let $R_2 = 1k\Omega \Rightarrow R_1 = 2k\Omega \Rightarrow R_p = 0.211k\Omega$

$\therefore R_5 = 0.308k\Omega$

Ans 3.



$$V_{OX} = -V_T \ln\left(\frac{V_x}{RI_s}\right)$$

$$V_{01} = V_T \times \left[\ln\left(\frac{V_x}{RI_s}\right) + \ln\left(\frac{V_x}{RI_s}\right)\right]$$

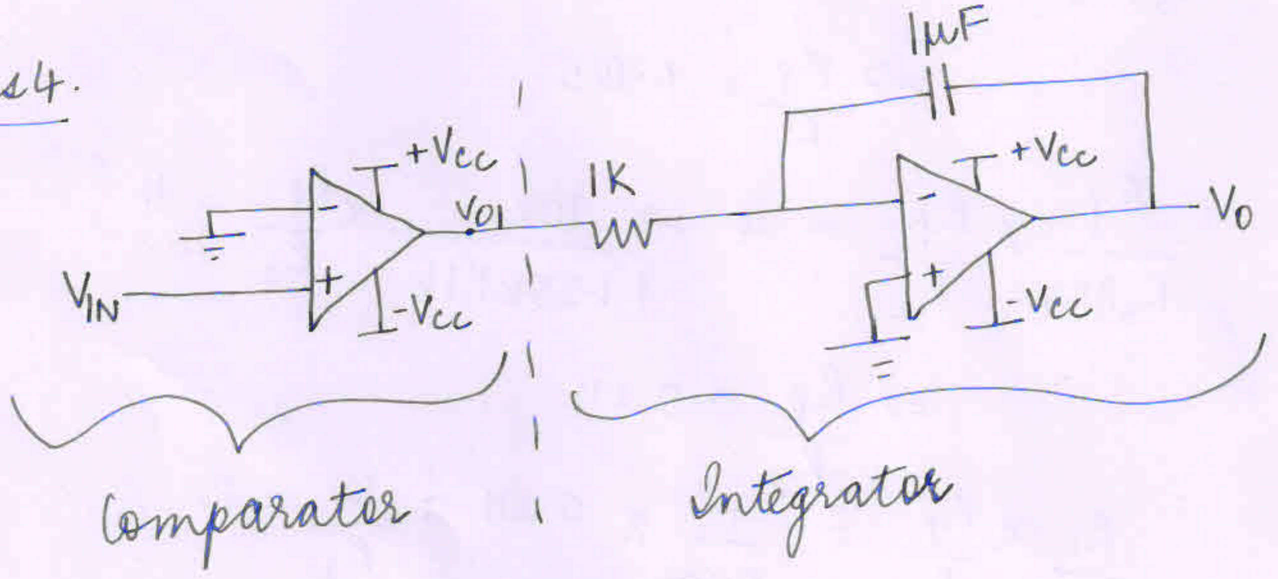
$$\Rightarrow V_{01} = V_T \times \ln\left(\frac{V_x^2}{R^2 I_s^2}\right)$$

$$V_0 \simeq -RI_s \times e^{V_{01}/V_T}$$

$$= -RI_s \times \left(\frac{V_x^2}{R^2 I_s^2}\right)$$

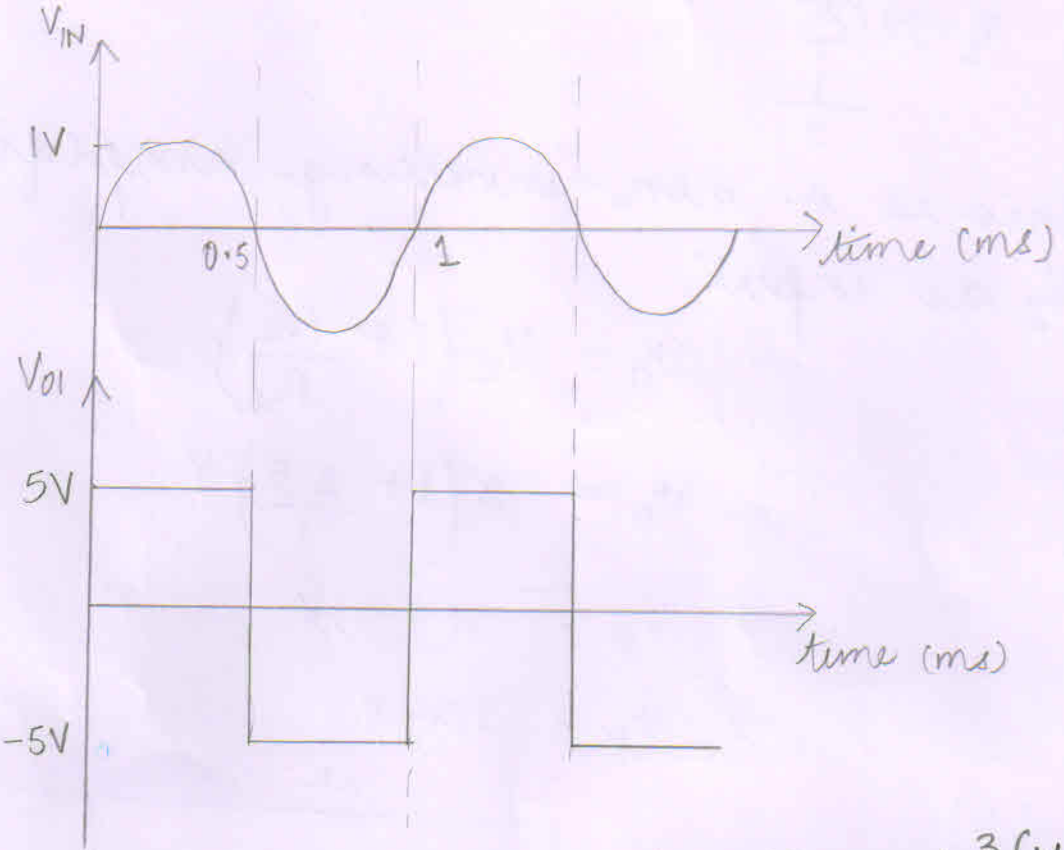
$$= \frac{-V_x^2}{RI_s} \qquad \left[\text{Here, } K = -\frac{1}{RI_s}\right]$$

Ans 4.



for the comparator,

$$V_{O1} = +5\,V \text{ if } V_{IN} > 0$$
$$= -5\,V \text{ if } V_{IN} < 0$$

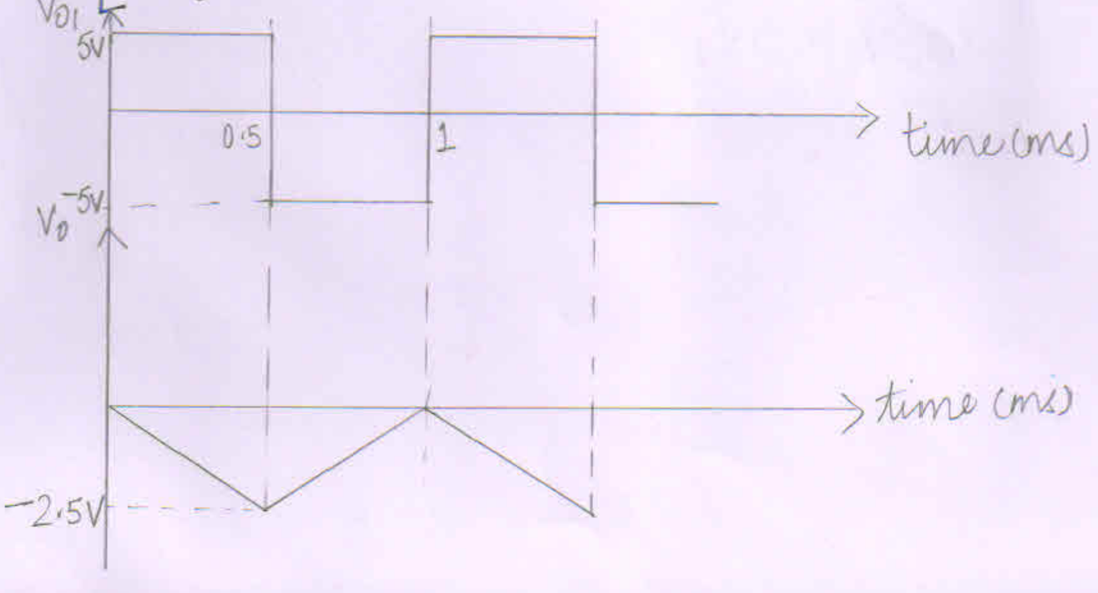


For the integrator, $V_O(t) = \frac{-1}{RC}\int V_{O1}\,dt = -10^3 \int V_{O1}\,dt$

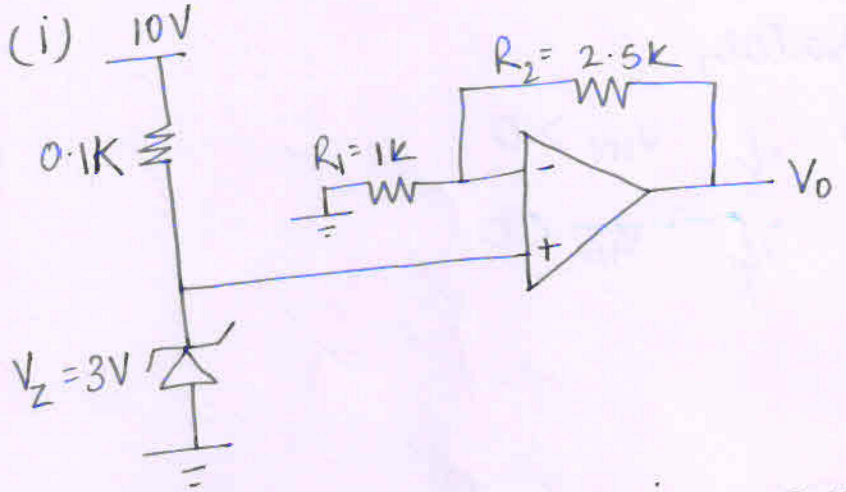
for $V_{IN} > 0$, $V_0 = -5 \times 10^3 \times t$

for $V_{IN} < 0$, $V_0 = -2.5 + 5 \times 10^3 (t - 0.5\,ms)$

$[\because V_0 (t = 0.5\,ms) = -2.5\,V]$



Ans5. (i)



This is a non-inverting amplifier with V_Z as input.

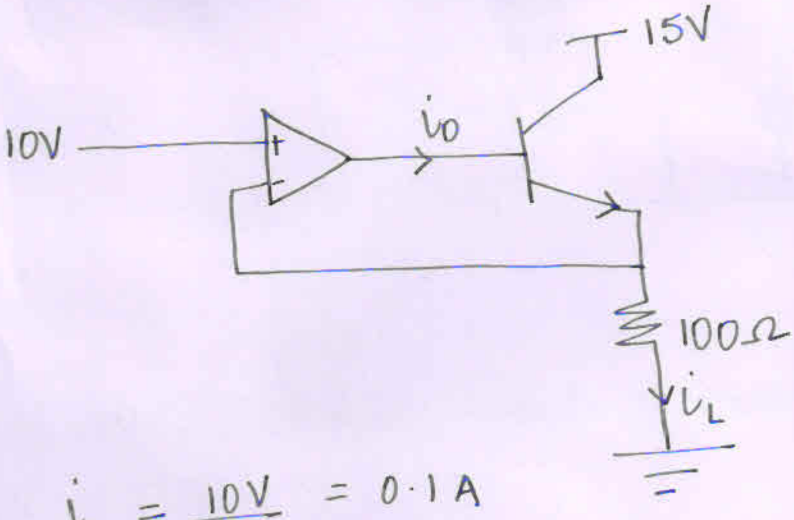
$$v_0 = V_Z\left(1 + \frac{R_2}{R_1}\right)$$

$$\therefore v_0 = 3\left(1 + \frac{2.5}{1}\right) V$$

$$\Rightarrow v_0 = 3(3.5) V$$

$$\Rightarrow v_0 = 10.5 V$$

(ii)



$$i_L = \frac{10V}{100\Omega} = 0.1 A$$

$$\cancel{I_A}\, i_0 = I_B = \frac{I_E}{\beta+1} = \frac{i_L}{\beta+1} = \frac{0.1 A}{101} = 0.99mA.$$

The circuit can supply load current that is much larger than op-amp output current.