3rd October, 2016

# Home Assignment –10

1. An **Instrumentation Amplifier** is shown in **Fig. 1**. If $v_1 = 3 + 0.04\ \sin(\omega t)$ and $v_2 = 3 - 0.04\ \sin(\omega t)$, find the voltages $v_a$, $v_b$, $v_c$ and $v_d$. Also find the **voltage gain** of this circuit. Assume all op-amps are ideal.

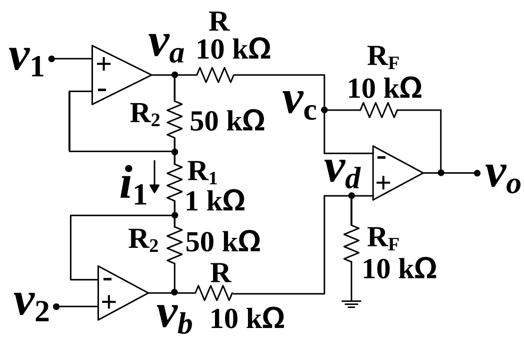



**Fig. 1**

2. A **square wave generator** is shown in **Fig. 2**. If the period of the square wave is 400 μs and the capacitor voltage is 8 $V_{p\text{-}p}$, find '**C**' and '**$R_2$**'. Assume $\mathbf{V_{osat}}$ = ±10 V and the op-amp is ideal.

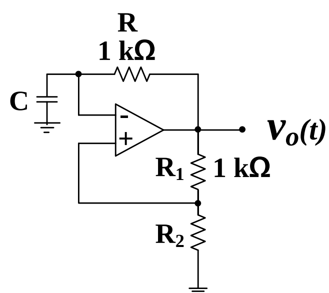



**Fig. 2**

3. A triangular wave shown in **Fig. 3(a)** is fed to a **Schmitt trigger** circuit shown in **Fig. 3(b)**. Assuming $\mathbf{V_{osat} = \pm 12\ V}$, sketch the output voltage $v_o(t)$ and $v_o$ vs $v_i$ with relevant information.

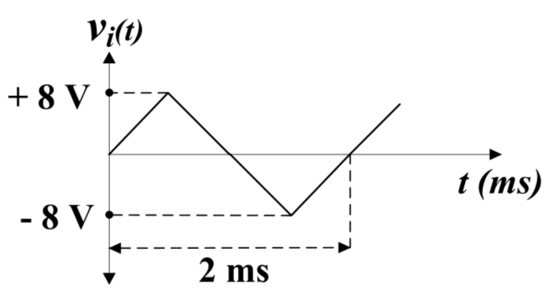



**Fig. 3(a)**

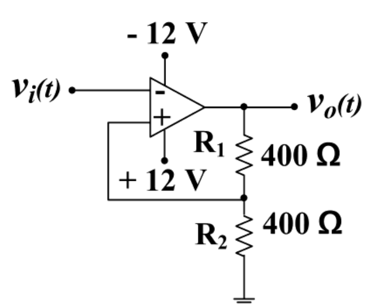



**Fig. 3(b)**

4. A **difference amplifier** is shown in **Fig. 4**. If $\boldsymbol{v_o = K\,(v_2 - v_1)}$, determine **'$K$'.** Assume all op-amps are ideal.

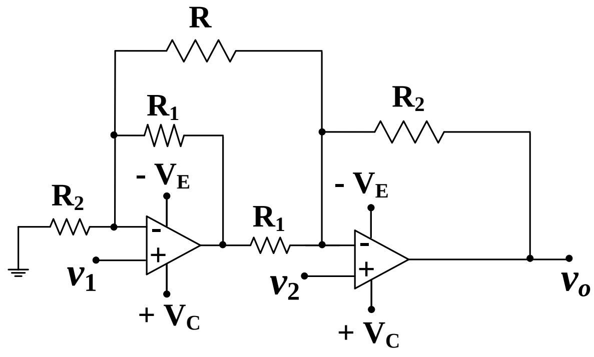



**Fig. 4**

5. For the ideal op-amp shown in **Fig. 5**, sketch $\boldsymbol{v_o}$ as a function of $\boldsymbol{v_i}$. Assume that both diodes have cut-in voltages (**$V_\gamma$**) of 0.7 V and Zener voltages (**$V_Z$**) of 6 V.

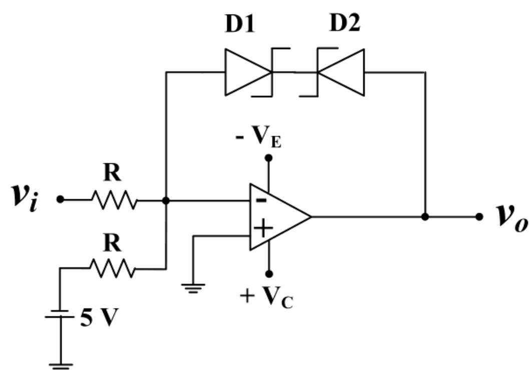
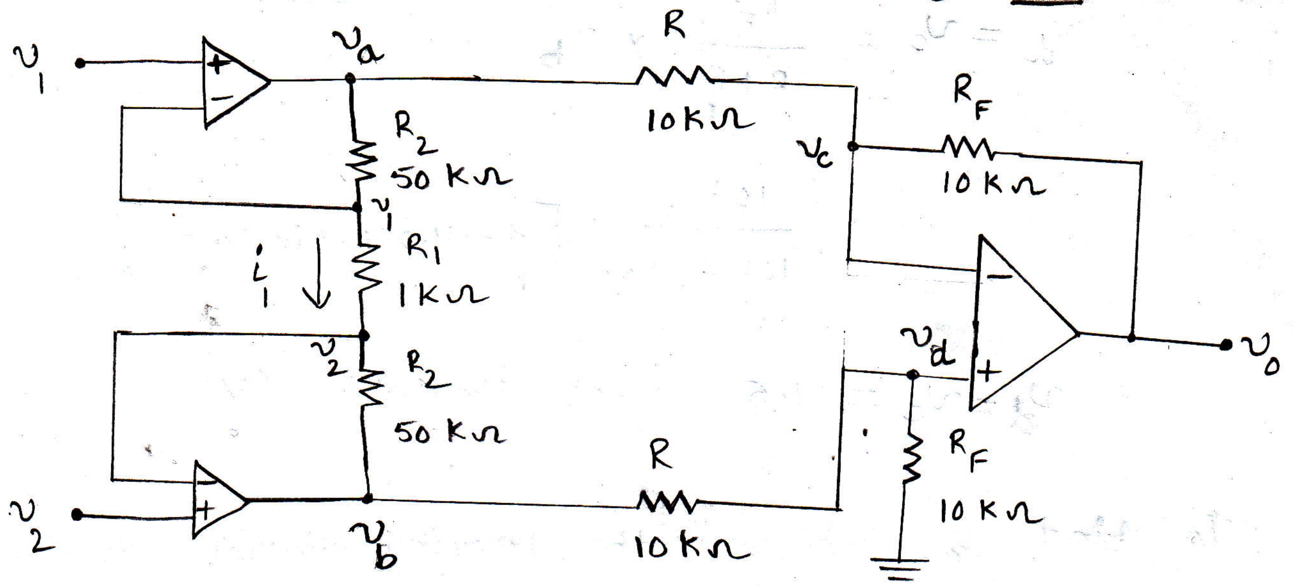



**Fig.5**




$$v_1 = 3 + 0.04 \sin(\omega t) \quad (V)$$

$$v_2 = 3 - 0.04 \sin(\omega t) \quad (V)$$

from the figure,

$$i_1 = \frac{v_1 - v_2}{R_1} = \frac{3 + 0.04 \sin(\omega t) - 3 + 0.04 \sin(\omega t)}{1K}$$

$$= 0.08 \sin(\omega t) \text{ mA.}$$

Then,

$$v_a = v_1 + i_1 R_2 = 3 + 0.04 \sin(\omega t) + [0.08 \sin(\omega t) \times 10^{-3} \times 50 \times 10^{3}]$$

$$= 3 + 0.04 \sin(\omega t) + 4 \sin(\omega t)$$

$$= 3 + 4.04 \sin(\omega t) \quad (V)$$

$$v_b = v_2 - i_1 R_2 = 3 - 0.04 \sin(\omega t) - [0.08 \times 10^{-3} \sin(\omega t) \times 50 \times 10^{3}]$$

$$= 3 - 0.04 \sin(\omega t) - 4 \sin(\omega t)$$

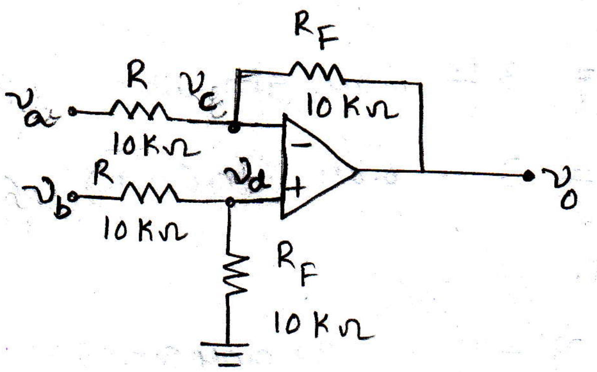
$$= 3 - 4.04 \sin(\omega t) \quad (V)$$

$$v_d = v_c = \frac{R_F}{R+R_F} \times v_b$$

$$= \frac{10\,K}{10K+10K}\left[3-4.04\ \sin(\omega t)\right]$$

$$\Rightarrow v_d = v_c = 1.5 - 2.02\ \sin(\omega t)\quad (V).$$

To find $v_o''$, we use the following deduced circuit.




$$V_o = V_a\left(-\frac{R_F}{R}\right) + V_b \times \frac{R_F}{R_F+R}\left(1+\frac{R_F}{R}\right)$$

$$= \frac{R_F}{R}\left(V_b - V_a\right)$$

For $R_F = R = 10\,K\Omega$; $\quad V_o = V_b - V_a$

$$= 3-4.04\ \sin(\omega t) - 3 - 4.04\ \sin(\omega t)$$

$$\Rightarrow v_o = -8.08\ \sin(\omega t)\quad (V)$$

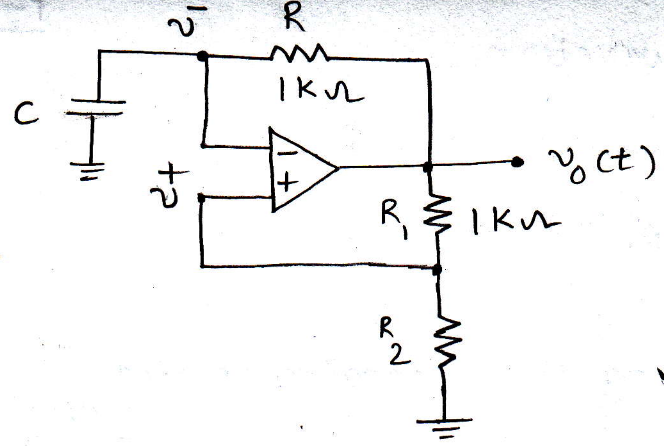
Now,

$$\text{voltage gain, } A_{dm} = \frac{v_o}{v_2 - v_1} = \frac{-8.08\ \sin(\omega t)}{3-0.04\ \sin(\omega t) - 3 - 0.04\ \sin(\omega t)}$$

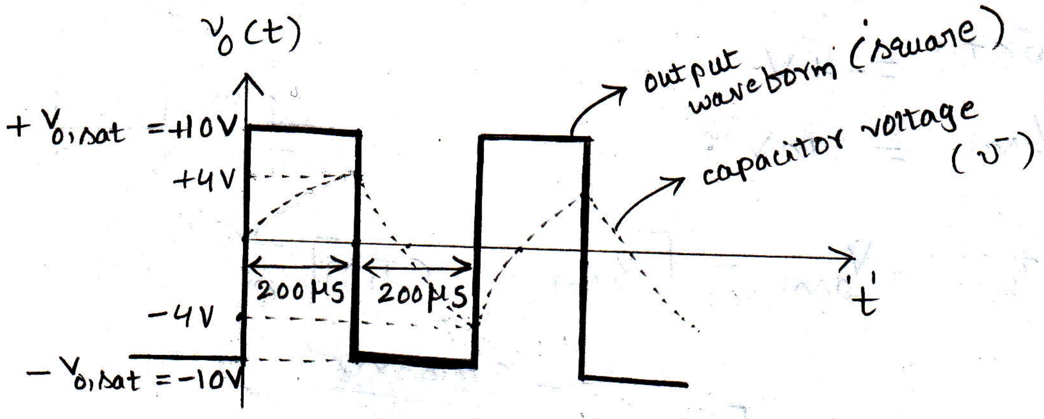
$$= \frac{-8.08}{-0.08} = 101$$

$\therefore$

$$\left.\begin{aligned} v_a &= 3 + 4.04\ \sin(\omega t)\quad (V) \\ v_b &= 3 - 4.04\ \sin(\omega t)\quad (V) \\ v_c = v_d &= 1.5 - 2.02\ \sin(\omega t)\quad (V) \\ \text{Voltage gain, } A_{dm} &= 101 \end{aligned}\right\} \rightarrow \text{Ans.}$$




$V_{osat} = 10V$




when $v_o = +10\,V = (V_{osat})$

$$v^+ = \frac{R_2}{R_1+R_2} \times v_o = \frac{10R_2}{R_2+1000}$$

Capacitor will charge till $v^-$ gets equal to $v^+$.

From the waveform given above, we have

$v^- = v^+ = 4\,V$ when $V_o = +V_{sat} = +10V$

$$\Rightarrow 4 = \frac{10R_2}{R_2+1000}$$

$$\Rightarrow 4R_2 + 4000 = 10R_2$$

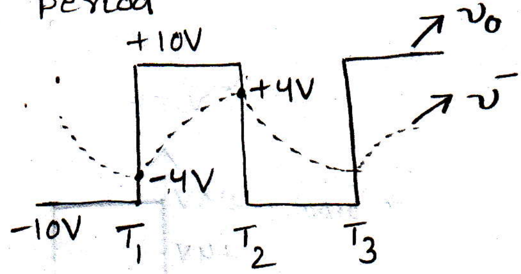
$$\Rightarrow 6R_2 = 4000$$

$$\Rightarrow R_2 = \frac{4000}{6} = \frac{2}{3}\,k\Omega$$

And also brom the waveborm,

capacitor changes bor the period of 200 μs and discharges bor the period of 200 μs

let's consider during the changing period




$v^-(T_1) = -4\,V$

$V_{osat} = 10\,V$

then

$$v^-(T_2) = +V_{osat} - \left[V_{osat} - v^-(T_1)\right] e^{-\left(\frac{T_2 - T_1}{RC}\right)}$$

$$= 10 - [10 - (-4)]\, e^{-\left(\frac{200\times10^{-6}}{RC}\right)}$$

$$= 10 - 14\, e^{-(200\times10^{-6})/RC}$$

brom the above bigure $v^-(T_2) = +4\,V$

$$\Rightarrow 4 = 10 - 14\, e^{-\frac{200\times10^{-6}}{RC}}$$

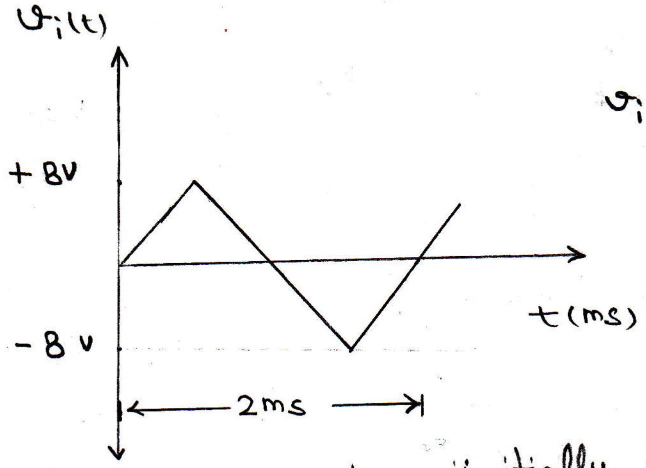
$$\Rightarrow 14\, e^{-\frac{200\times10^{-6}}{1000\times C}} = 10 - 4 = 6$$

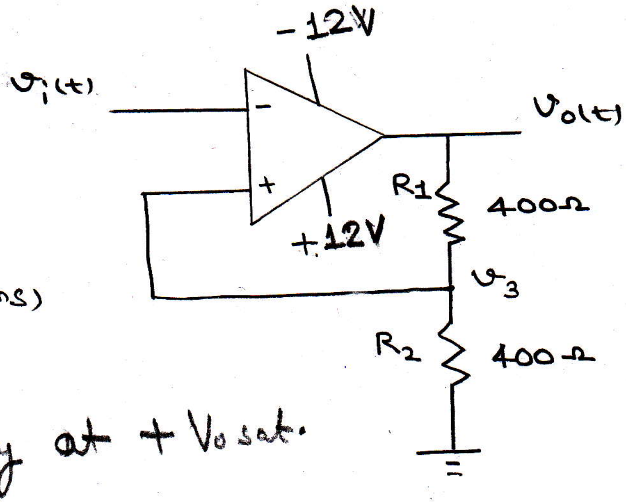
$$\Rightarrow e^{-\frac{2\times10^{-7}}{C}} = \frac{6}{14} \Rightarrow \frac{-2\times10^{-7}}{C} = \ln\frac{6}{14} = -0.8473$$

$$\Rightarrow C = \frac{-2\times10^{-7}}{-0.8473}\,F = 0.236\times10^{-6}\,F = 0.236\,\mu F$$

$$\therefore \boxed{\begin{aligned} \frac{R}{2} &= \frac{2}{3}\,k\Omega \\ C &= 0.236\,\mu F \end{aligned}}$$

SOLN. 3 P-5




Considering op-amp is initially at + Vo sat.

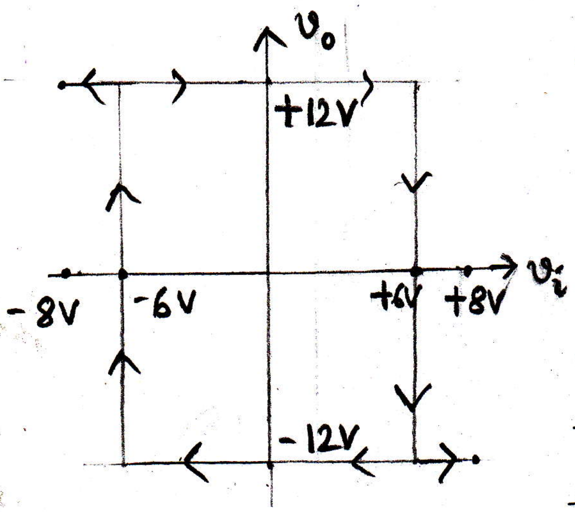
$V_{osat} = +12$ V

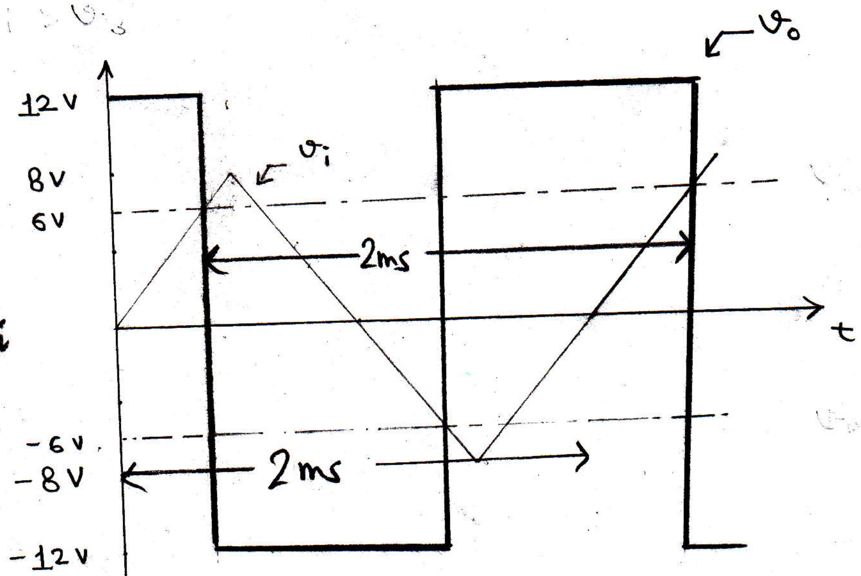
So $V_3 = 12 \times \frac{400}{400+400} = 6$ V.

Now if $v_i$ goes more than 6V, op-amp will switch to $-V_{osat}$ (= −12V)

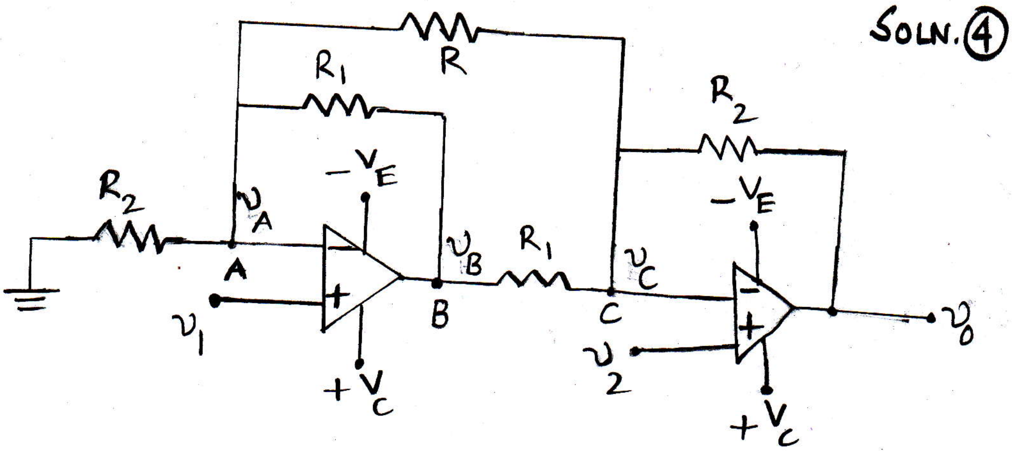
$$v_3 = -12 \times \frac{400}{400+400} = -6V$$

Further, if $v_i$ falls below −6V, op-amp will again switch to $+V_{osat}$ (= +12V)



SOLN. 4 




Given all the op-amps are ideal. So $v_A = v_1$ and $v_C = v_2$

Apply 'KCL' at node "A",

$$\frac{v_1}{R_2} + \frac{v_1 - v_B}{R_1} + \frac{v_1 - v_2}{R} = 0$$

$$\Rightarrow \frac{v_B}{R_1} = -\frac{v_2}{R} + v_1\left(\frac{1}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right) \quad \text{— ①}$$

Apply 'KCL' at node "C",

$$\frac{v_2 - v_B}{R_1} + \frac{v_2 - v_1}{R} + \frac{v_2 - v_0}{R_2} = 0$$

$$\Rightarrow \frac{v_0}{R_2} = v_2\left(\frac{1}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{v_1}{R} - \frac{v_B}{R_1}$$

$$= v_2\left(\frac{1}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{v_1}{R} + \frac{v_2}{R} - v_1\left(\frac{1}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right)$$

[∵ From ①]

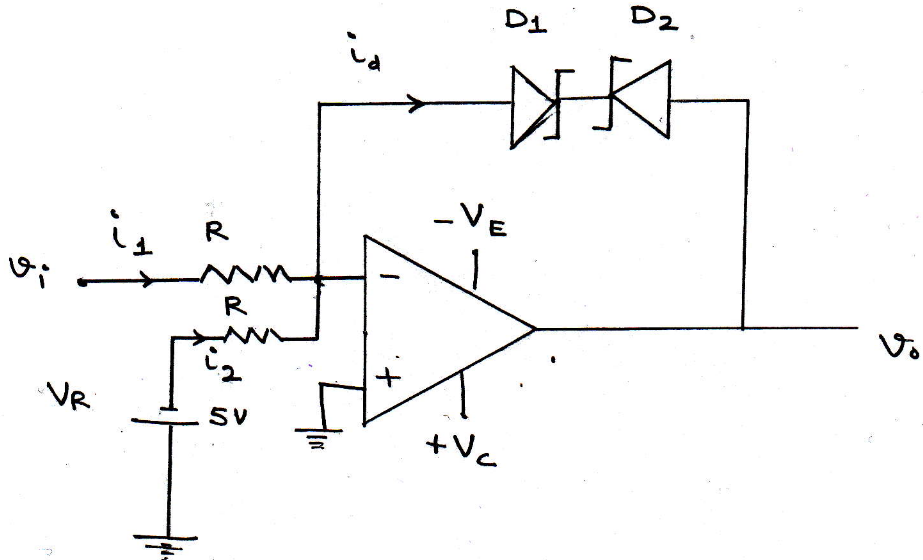
$$\Rightarrow \frac{v_0}{R_2} = v_2\left(\frac{2}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right) - v_1\left(\frac{2}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\Rightarrow v_0 = R_2\left(\frac{2}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right)(v_2 - v_1)$$

$$= K(v_2 - v_1)$$

$$\boxed{\therefore K = R_2\left(\frac{2}{R} + \frac{1}{R_1} + \frac{1}{R_2}\right)}$$

SOLN. 5 




$\Rightarrow \because \; i_d = i_1 + i_2$

$\Rightarrow i_d = \frac{v_i}{R} + \frac{V_R}{R} \quad \Rightarrow i_d = \frac{(v_i - 5)}{R} \quad \left(\because i_1 = \frac{v_i}{R} \text{ and } v_R = -5V. \;\; \therefore i_2 = -\frac{5}{R}\right).$

$\Rightarrow$ $i_d$ will be positive for $v_i > 5V$.

Otherwise $i_d$ will remain negative.

$\Rightarrow$ if $v_i > 5V$; $v_o = -(6 + 0.7) = -6.7V$.
($D_1$ is forward biased & $D_2$ is reverse biased) $v_o = -(V_Z + V_\gamma)$

$v_i < 5V$; $v_o = 6 + 0.7 = 6.7V$
($D_2$ is forward biased & $D_1$ is reverse biased)
$v_o = (v_Z + v_\gamma)$