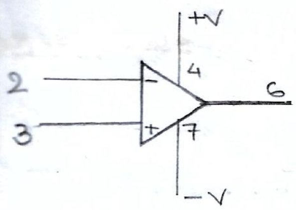
Operational Amplifier

Symbol:



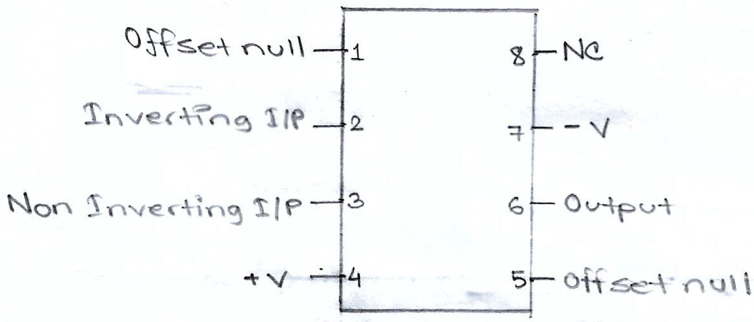
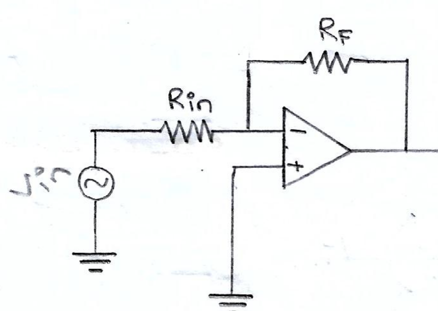


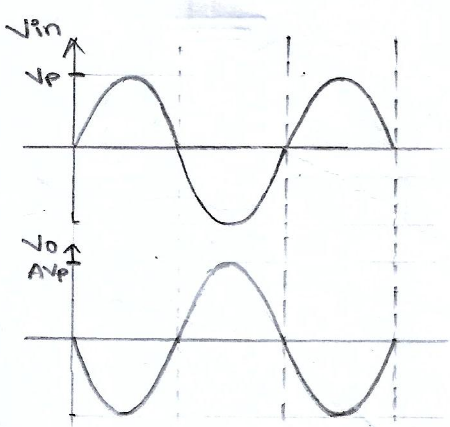
Fig : Pin configuration

Inverting Operation of OP-Amp:

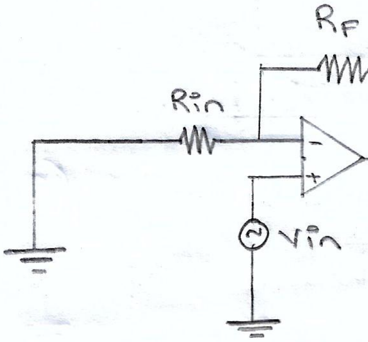


$$V_{out} = -\frac{R_F}{R_{in}} V_{in}$$

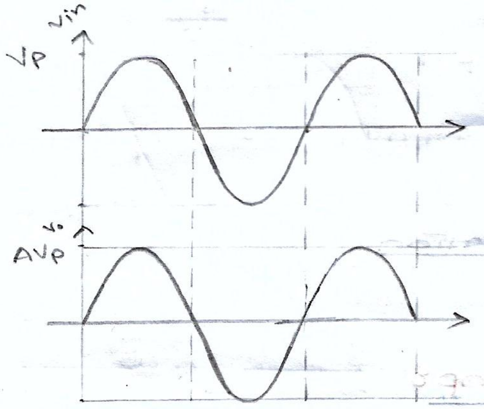
$$= -A\, V_{in}$$



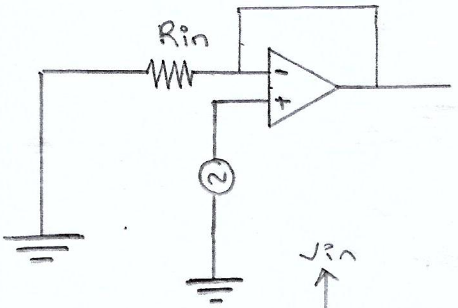
Non-Inverting Operation of Op-Amp:



$$V_{out} = \left(1 + \frac{R_F}{R_{in}}\right) V_{in}.$$



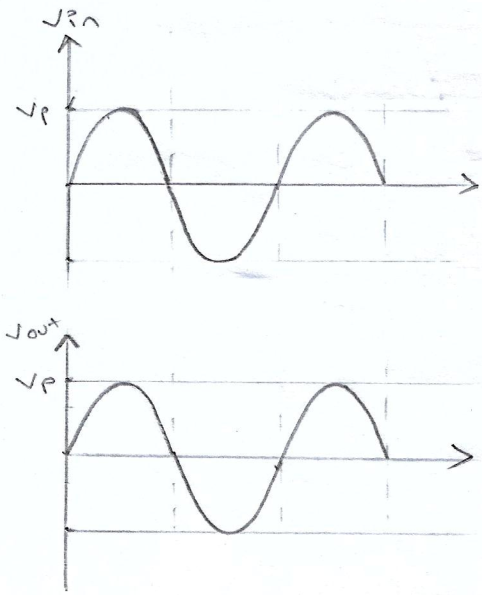
Voltage follower Circuit:



$$V_{out} = \left(1 + \frac{R_F}{R_{in}}\right) V_{in}$$

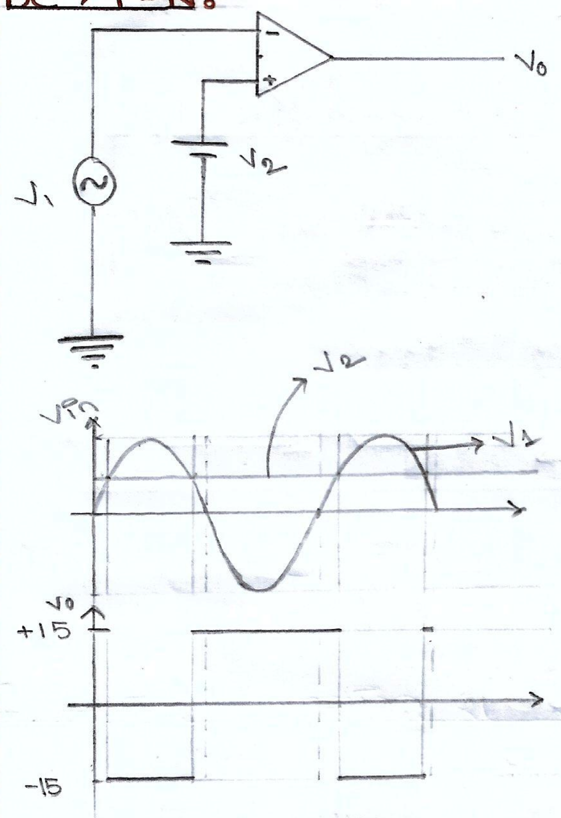
$$V_{out} = \left(1 + \frac{0}{R_{in}}\right) V_{in}$$

$$V_{out} = V_{in}$$

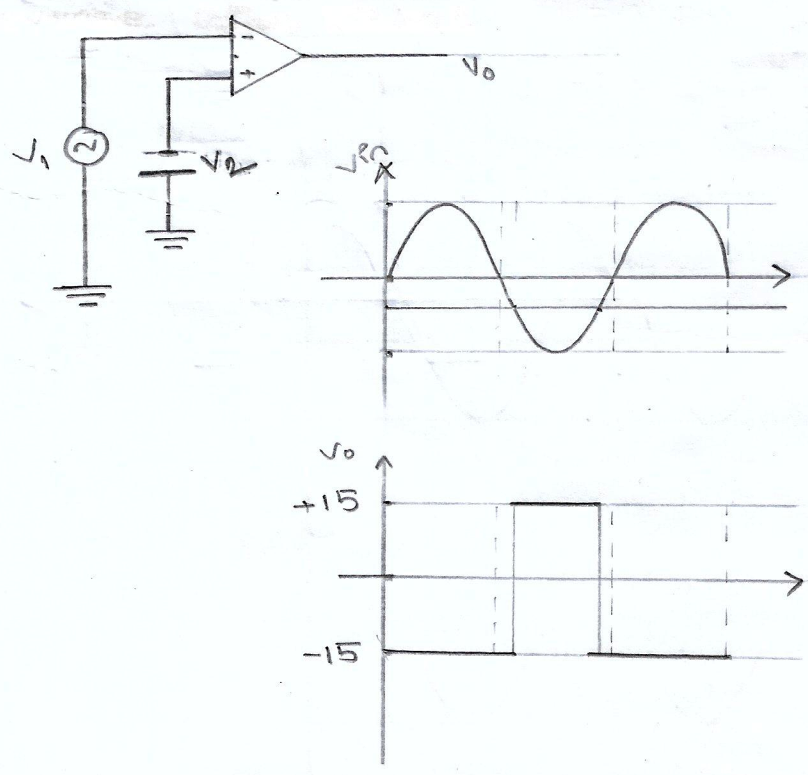


Comparator Circuit:

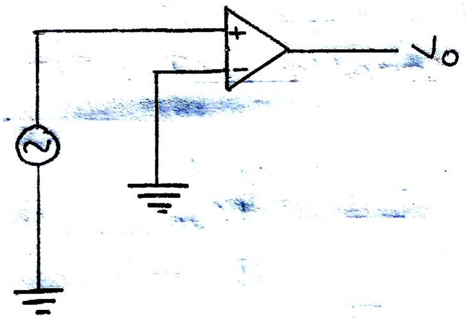
DC → P-N:

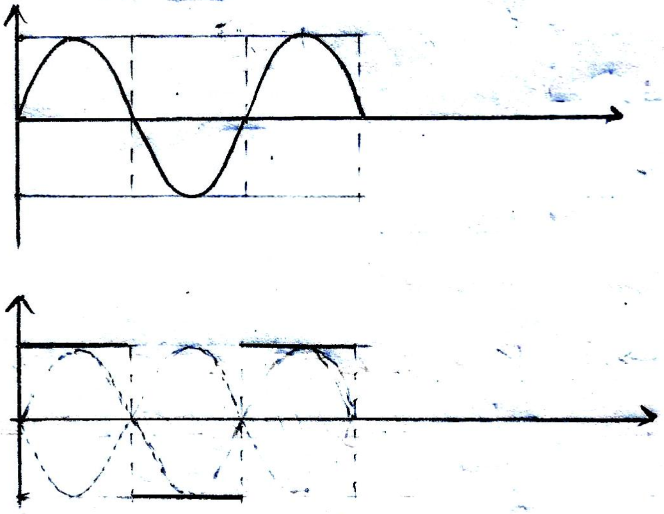


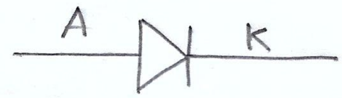
DC → N-P:



Zero - Crossing Detector :



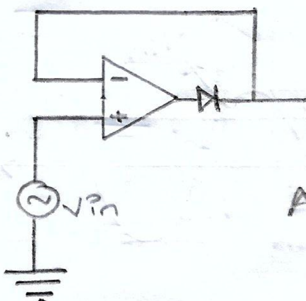




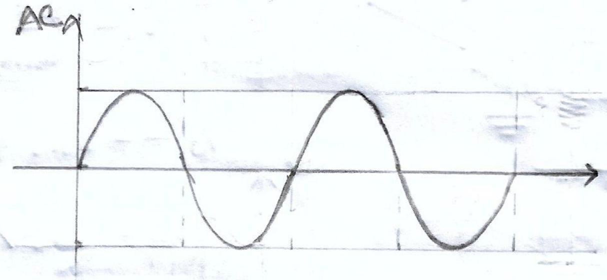
Positive:

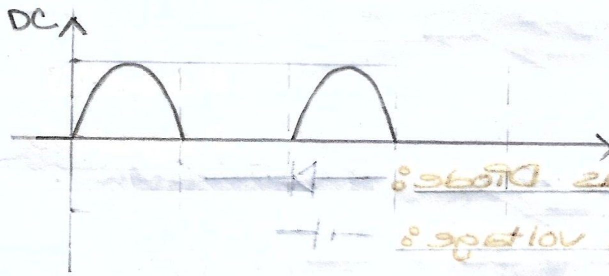
Half wave Rectifier:

Forward Bias Diode:



$$V_o = \left(1 + \frac{R_f \to 0}{R_{in}}\right) V_{in} \Rightarrow V_{out} = V_{in}$$

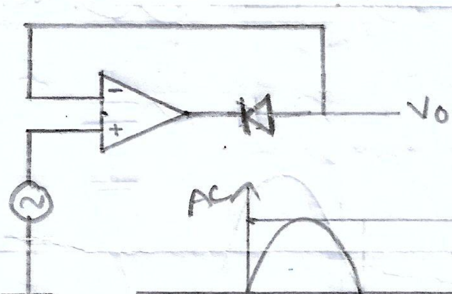


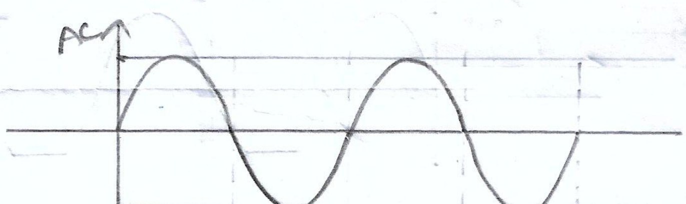


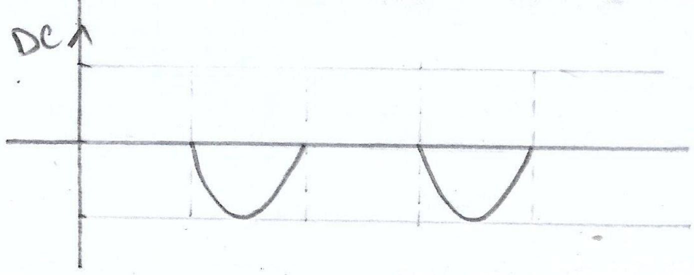
Negative:

Halfwave Rectifier:

Reverse Bias Diode:

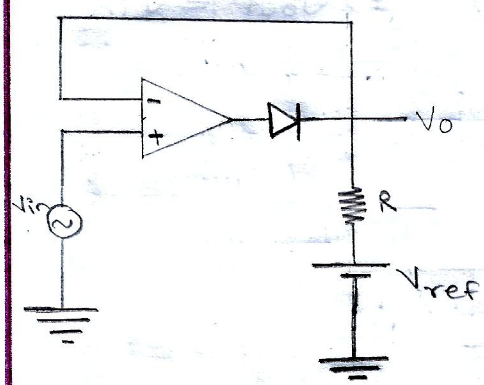


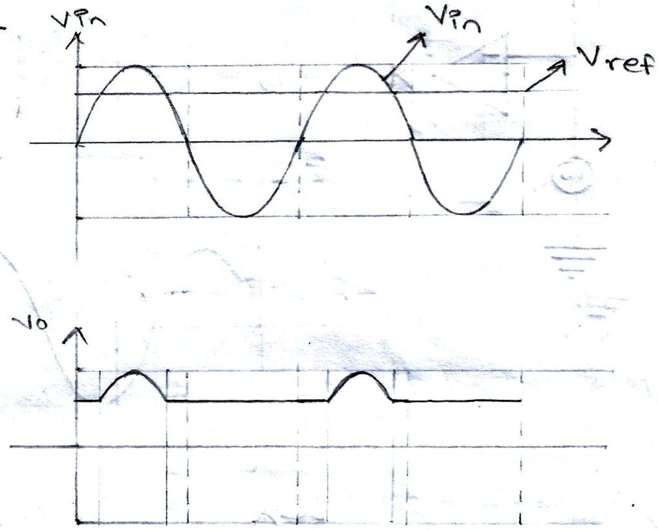




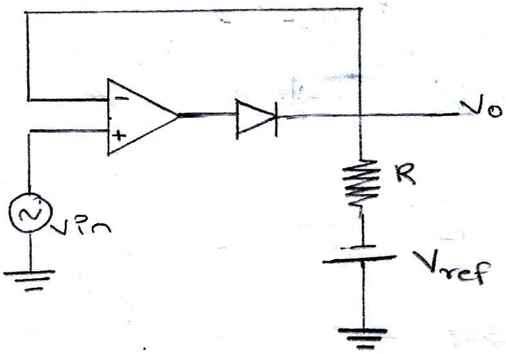
Clipper's Circuit:

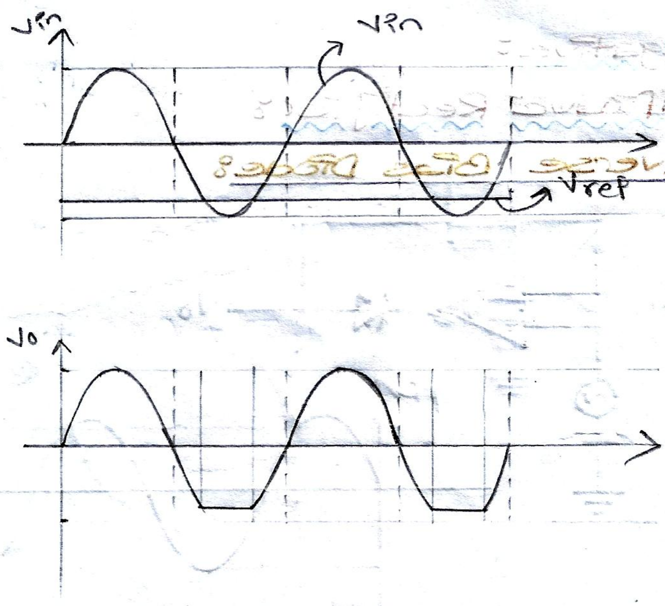
Forward Bias Diode:
Positive DC voltage:





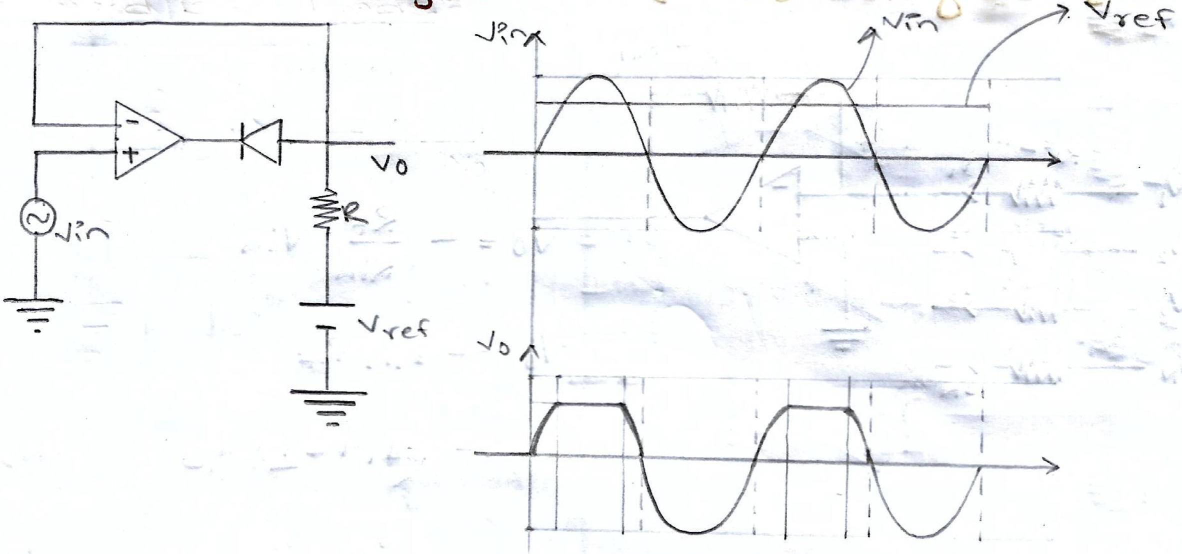
Forward Bias Diode:
Negative DC voltage:





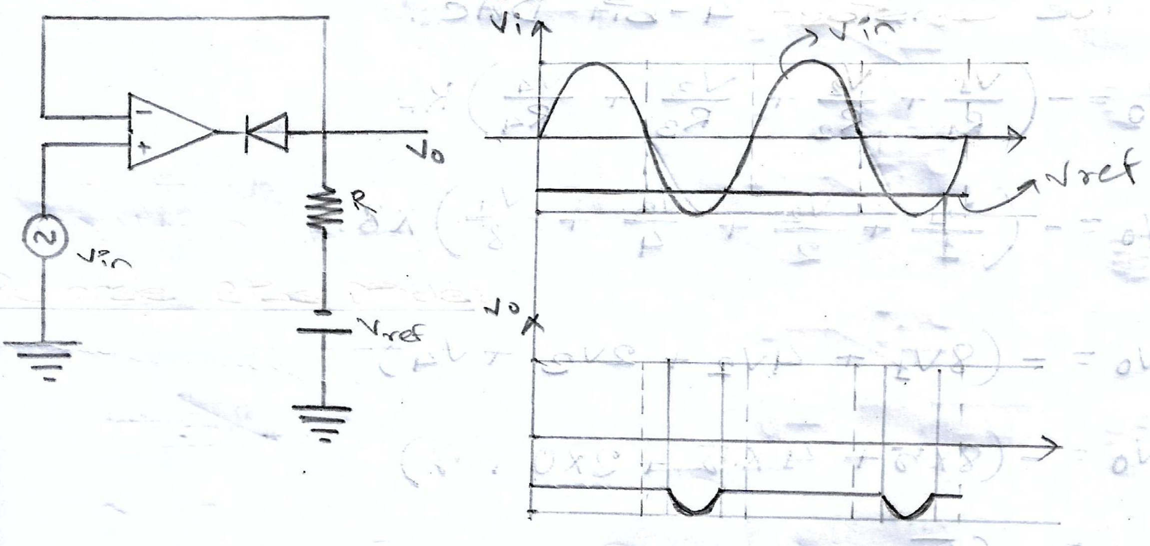
Reverse Bias Diode:

Positive DC voltage:



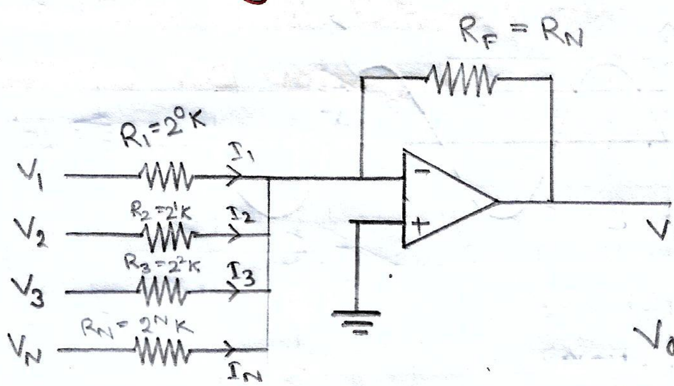
Reverse Bias Diode:

Negative DC voltage:



Digital to Analog Converter (DAC)

Binary Weighted (DAC)



$$V_0 = -\frac{R_F}{R_{in}} V_{in}$$

$$V_0 = -I_{in} R_F$$

$$= -(I_1 + I_2 + I_3 + \dots + I_N) R_F$$

$$= -\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \dots + \frac{V_N}{R_N}\right) R_F$$

If we consider 4-bit DAC.

$$V_0 = -\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \frac{V_4}{R_4}\right) R_F$$

$$V_0 = -\left(\frac{V_1}{1} + \frac{V_2}{2} + \frac{V_3}{4} + \frac{V_4}{8}\right) \times 8.$$

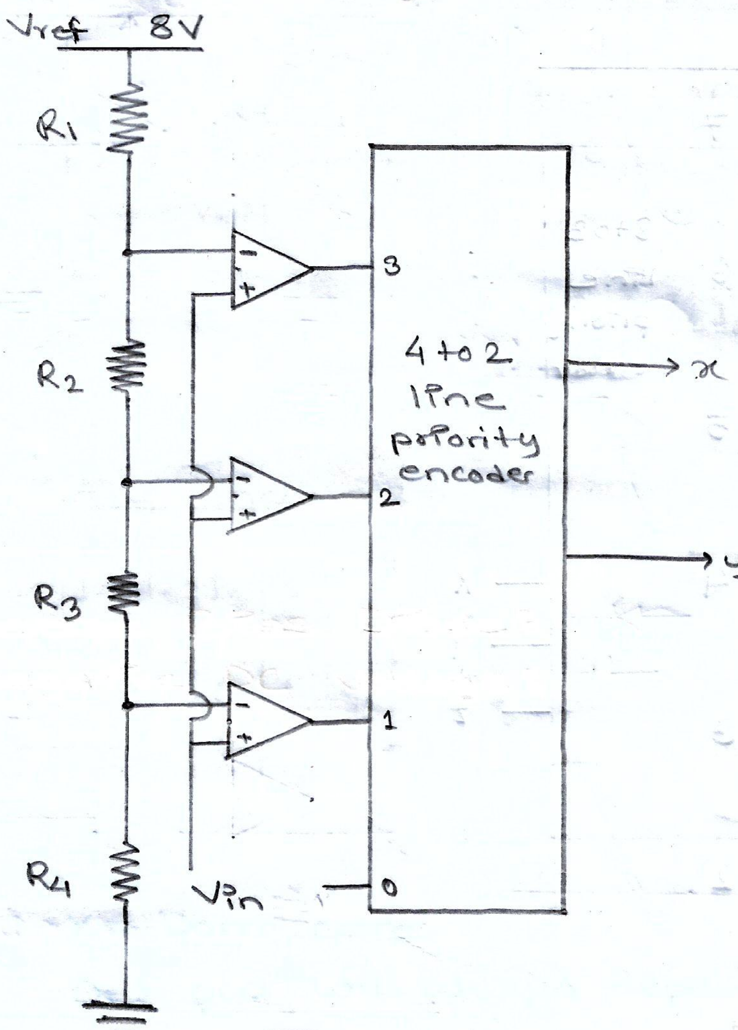
$$V_0 = -(8V_1 + 4V_2 + 2V_3 + V_4)$$

$$V_0 = -(8\times5 + 4\times5 + 2\times0 + 5)$$

$$= -65.$$

ADC:

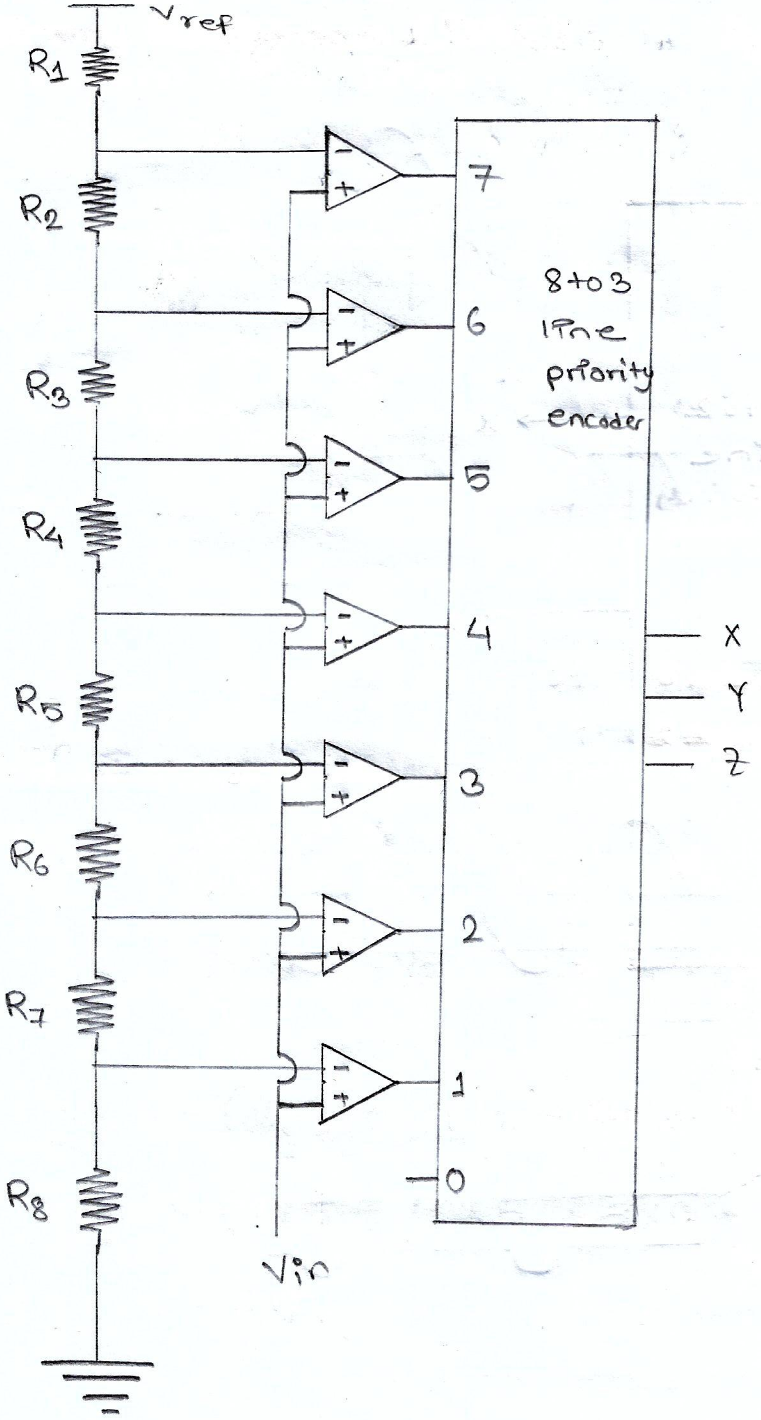
2 bit ADC:



$OP = 2^2 - 1$
$= 3$

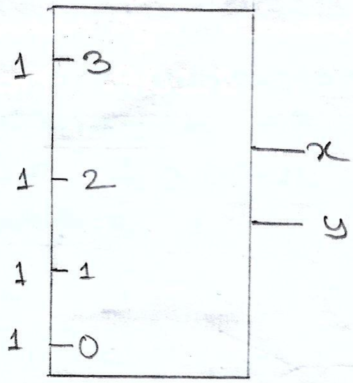
$R = 2^2 = 4.$

3-bit ADC:



$OP = 2^3 - 1 = 7.$

$R = 2^3 = 8.$



I_0	I_1	I_2	I_3	x	y
1	0	0	0	0	0
0	1	0	0	0	1
0	0	1	0	1	0
0	0	0	1	1	1

$$x = \bar{I}_0 \bar{I}_1 I_2 \bar{I}_3 + \bar{I}_0 \bar{I}_1 \bar{I}_2 I_3$$

Priority encoder:

I_0	I_1	I_2	I_3	x	y
X	X	X	1	1	1
X	X	1	0	1	0
X	1	0	0	0	1
1	0	0	0	0	0

I_3 High priority.
I_2
I_1
I_0 Low priority

Note:
X = Dont care
Out put will always depend on the priority List.

Successive Approximation ADC

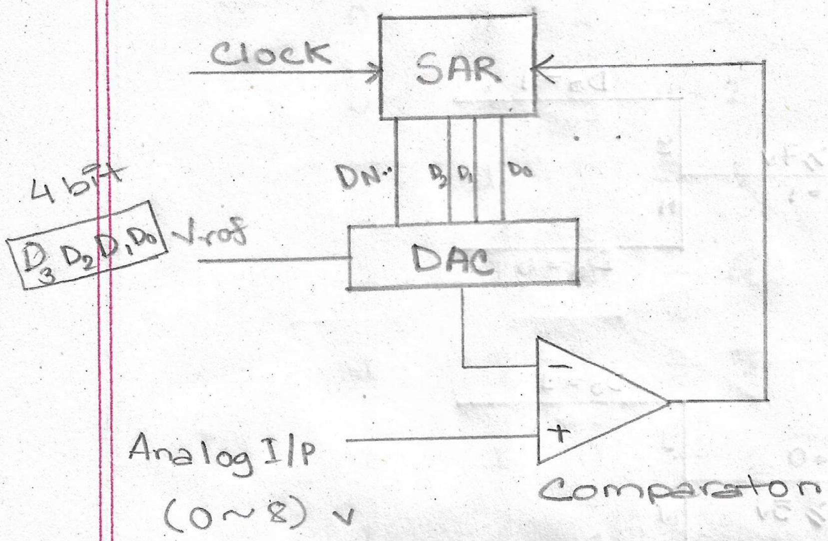
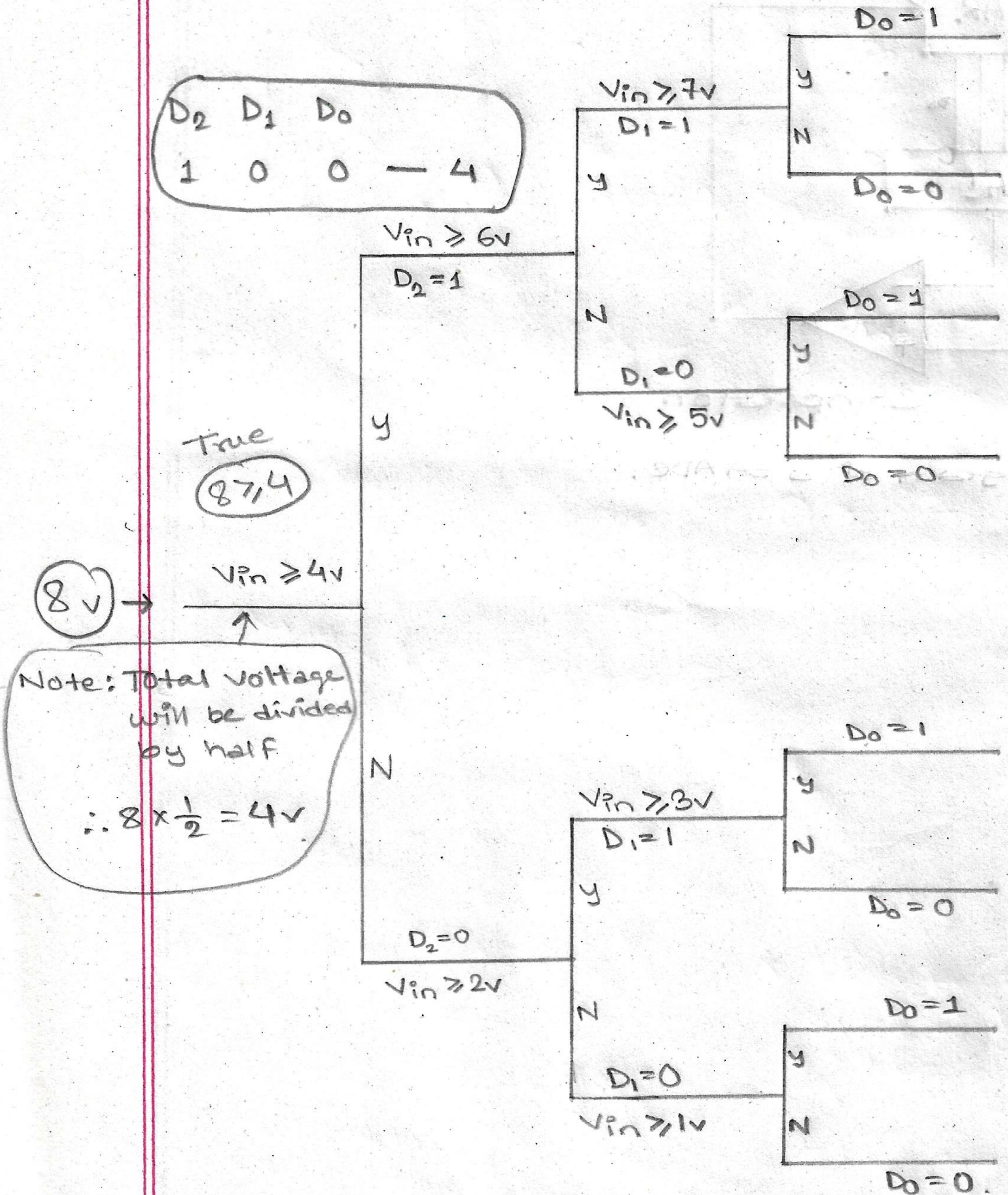


Fig: Block diagram of a SA ADC.

* 2 - 3v = 2 bit (4) v * 15 - 16v = 4 bit (16) v

* 4 - 5v = 3 bit (8) v * 30 - 32v = 8 bit (32) v



Tree diagram of SA ADC

Note:

D_2	D_1	D_0	
0	0	0	— 0
0	0	1	— 1
0	1	0	— 2
0	1	1	— 3
1	0	0	— 4
1	0	1	— 5
1	1	0	— 6
1	1	1	— 7.

⊞ we can convert voltage into bit.

⊞ If $V_{in} = 4.75V = 1\ 0\ 0.$

Q. Find out Binary bit for an input voltage of 3.9v using SA ADC.

555 Timer:

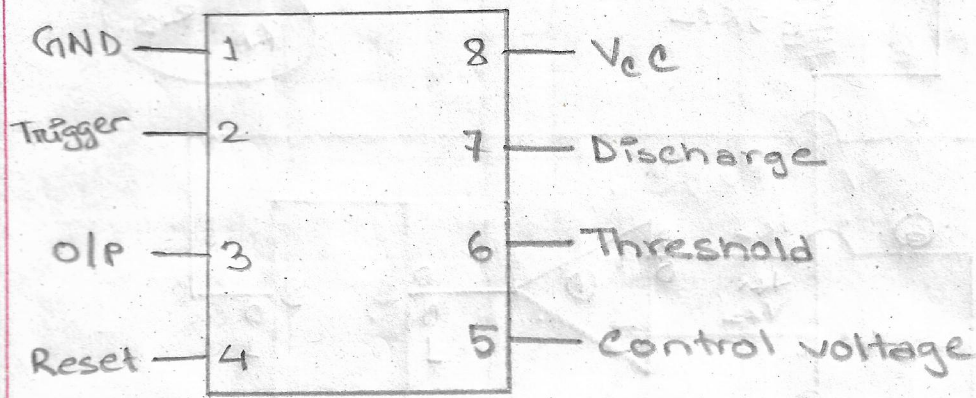
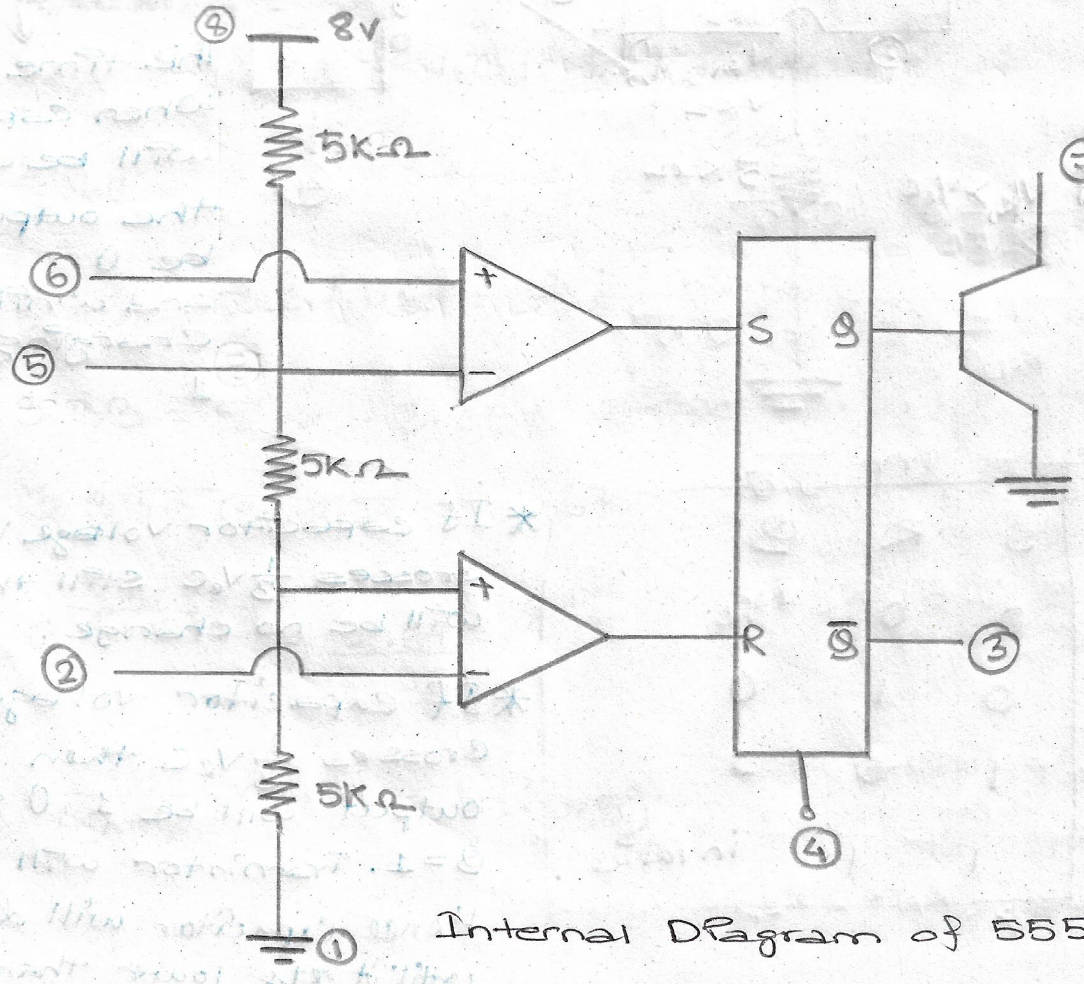
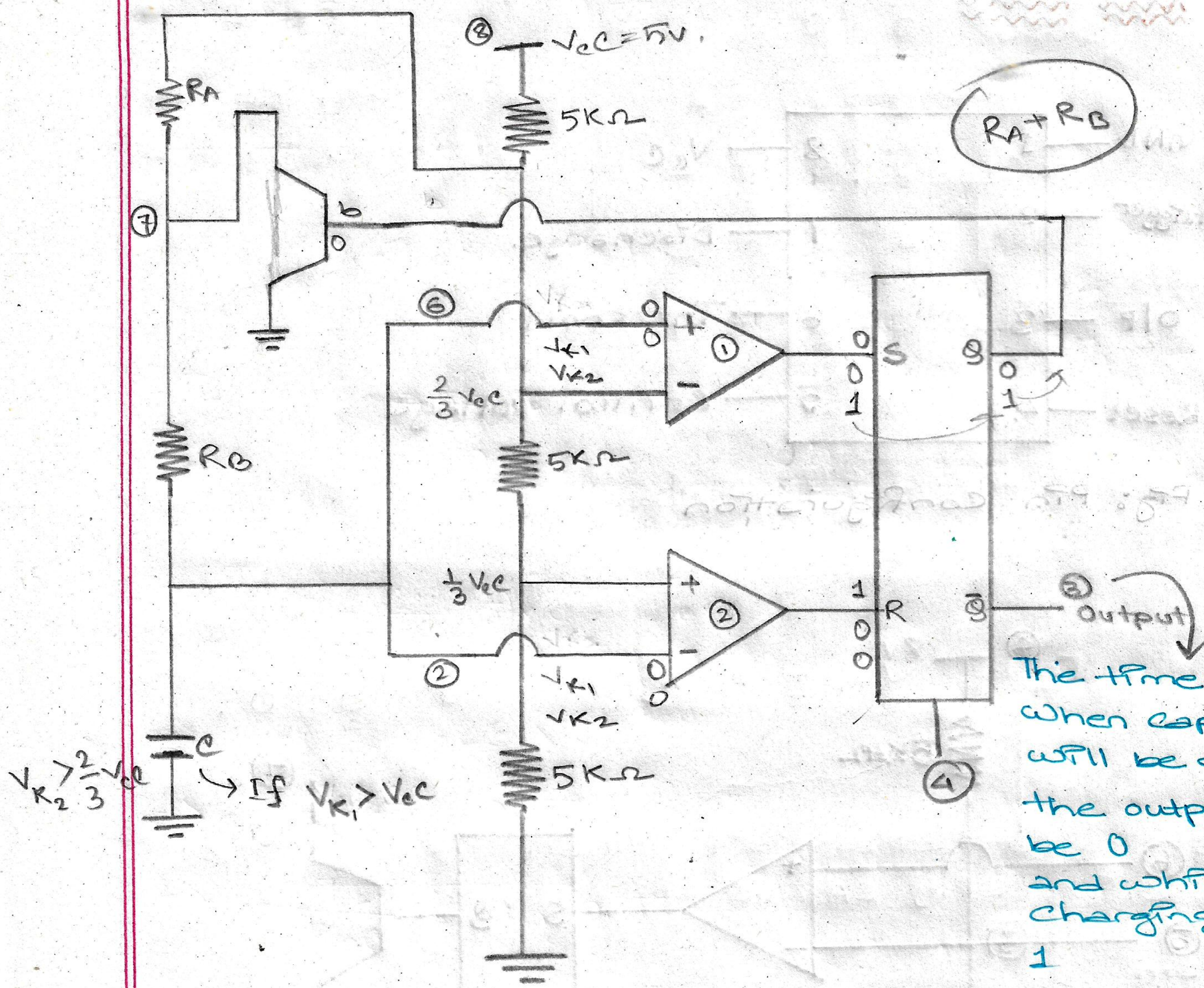


Fig: Pin configuration



Internal Diagram of 555 Timer.

Astable Operation of 555 Timer:

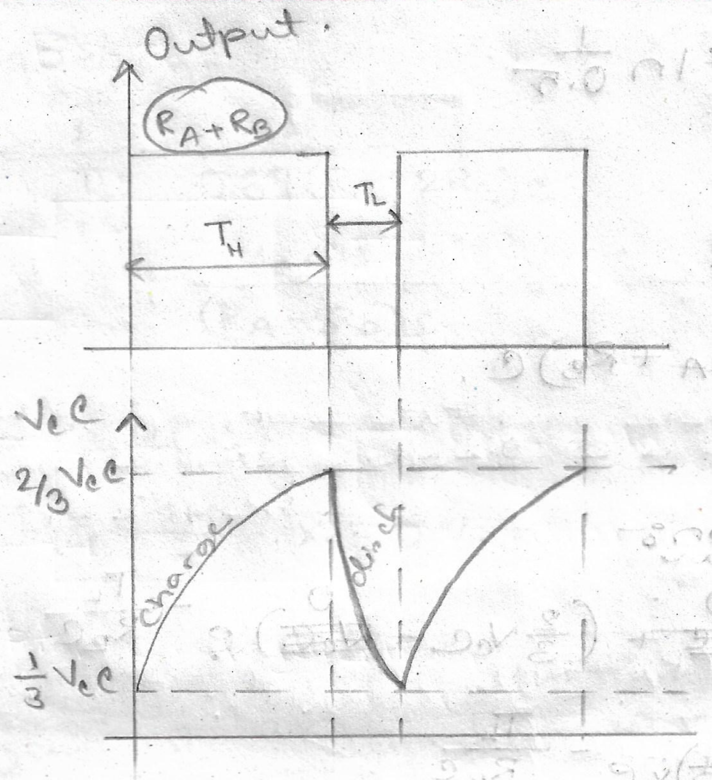


The time period when capacitor will be discharged the output will be 0 and while charging output 1

<u>Note:</u>

S	R	Q
0	0	N/C
0	1	0
1	0	1
1	1	invalid

* If capacitor voltage V_{K_1} crosses $\frac{1}{3}V_cC$ still there will be no change.
* If capacitor voltage V_{K_2} crosses $\frac{2}{3}V_cC$ then output will be 1, 0 so Q = 1. Transistor will short. Hence capacitor will discharge until it gets lower than $\frac{1}{3}V_cC$



T_H Calculation:

$$V_{out} = V_{CC} + \left(\frac{1}{3}V_{CC} - V_{CC}\right)e^{-\frac{T_H}{(R_A+R_B)C}}$$

$$\frac{2}{3}V_{CC} = 5 + \left(\frac{1}{3}\times 5 - 5\right)e^{-\frac{T_H}{(R_A+R_B)C}}$$

$$\frac{2}{3}\times 5 = 5 + (1.67 - 5)\,e^{-\frac{T_H}{(R_A+R_B)C}}$$

$$3.33 = 5 \cancel{+} - 3.33e^{-\frac{T_H}{(R_A+R_B)C}}$$

$$3.33e^{-\frac{T_h}{(R_A+R_B)C}} = 1.67$$

$$e^{-\frac{T_H}{(R_A+R_B)C}} = \frac{1.67}{3.33}.$$

$$-\frac{T_H}{(R_A+R_B)C}\times \ln e = \ln(0.5)$$

$$\cancel{-}\frac{T_H}{(R_A+R_B)C} = \cancel{-}\ln\frac{1}{0.5}$$

$$\frac{T_H}{(R_A+R_B)C} = 0.69$$

$$T_H = 0.69\,(R_A+R_B)C.$$

T_L calculation:

$$\frac{1}{3}V_{cc} = \overset{0}{\cancel{V_{cc}}} + \left(\frac{2}{3}V_{cc} - \overset{0}{\cancel{V_{cc}}}\right)e^{-\frac{T_L}{R_BC}}$$

$$\Rightarrow \frac{1}{3}\times 5 = \left(\frac{2}{3}\times 5\right)\times e^{-\frac{T_L}{R_BC}}$$

$$\Rightarrow 1.67 = 3.33\times e^{-\frac{T_L}{R_BC}}$$

$$\Rightarrow e^{-\frac{T_L}{R_BC}} = 0.5$$

$$\Rightarrow -\frac{T_L}{R_BC} = \ln 0.5$$

$$\Rightarrow \frac{T_L}{R_BC} = \ln\frac{1}{0.5}$$

$$\Rightarrow T_L = 0.69\,R_BC.$$

Time period,

$$T = T_H + T_L$$

$$= 0.69\,(R_A+2R_B)C.$$

Frequency,

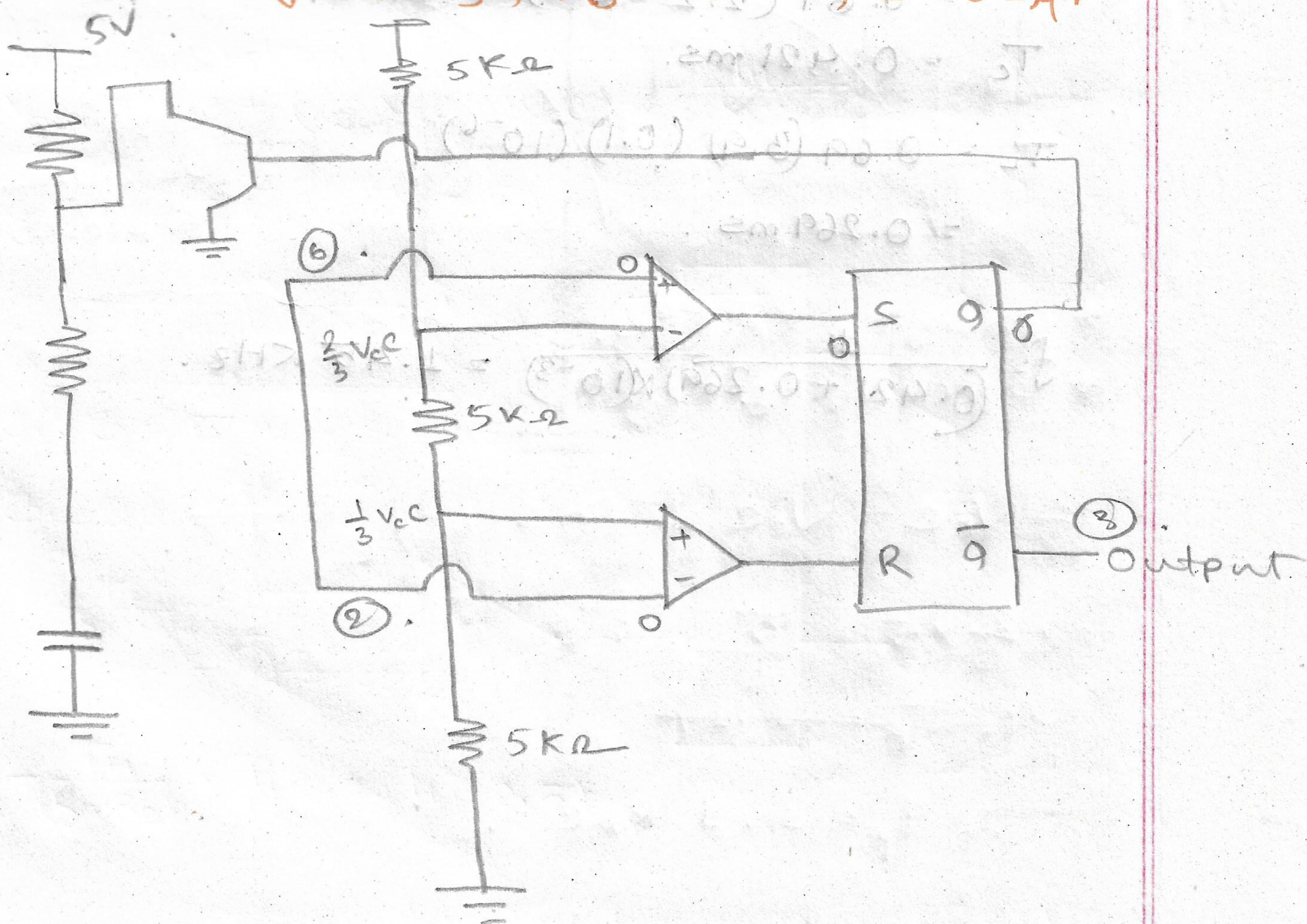
$$f = \frac{1}{T} = \frac{1}{0.69(R_A + 2R_B)C}$$

$$= \frac{1.45}{(R_A + 2R_B)C}$$

Duty cycle,

$$D = \frac{T_H}{T} \times 100\%$$

Q Design a astable Multivibrator circuit whose $f = 2KHz$, $R_B = 10K\Omega$, $C = 0.1\mu F$



$$T_H = (R_A + R_B)\, C \times 0.69.$$

$$\frac{1}{f} = T_H + T_L.$$

$$\Rightarrow \frac{1}{2\times10^{3}} = T_H \times (0.69 \times 10 \times 10^{3} \times 0.1 \times 10^{-6}).$$

8. In the astable multivibrator, $R_A = 2.2\,K\Omega$, $R_B = 3.9\,K\Omega$ and $C = 0.1\,\mu F$. Determine the positive pulse width t_c, negative pulse width t_d and free-running frequency.

$$T_H = 0.69 (R_A + R_B) C$$

$$= 0.69\,(2.2 + 3.9) \times (0.1)(10^{-6}).$$

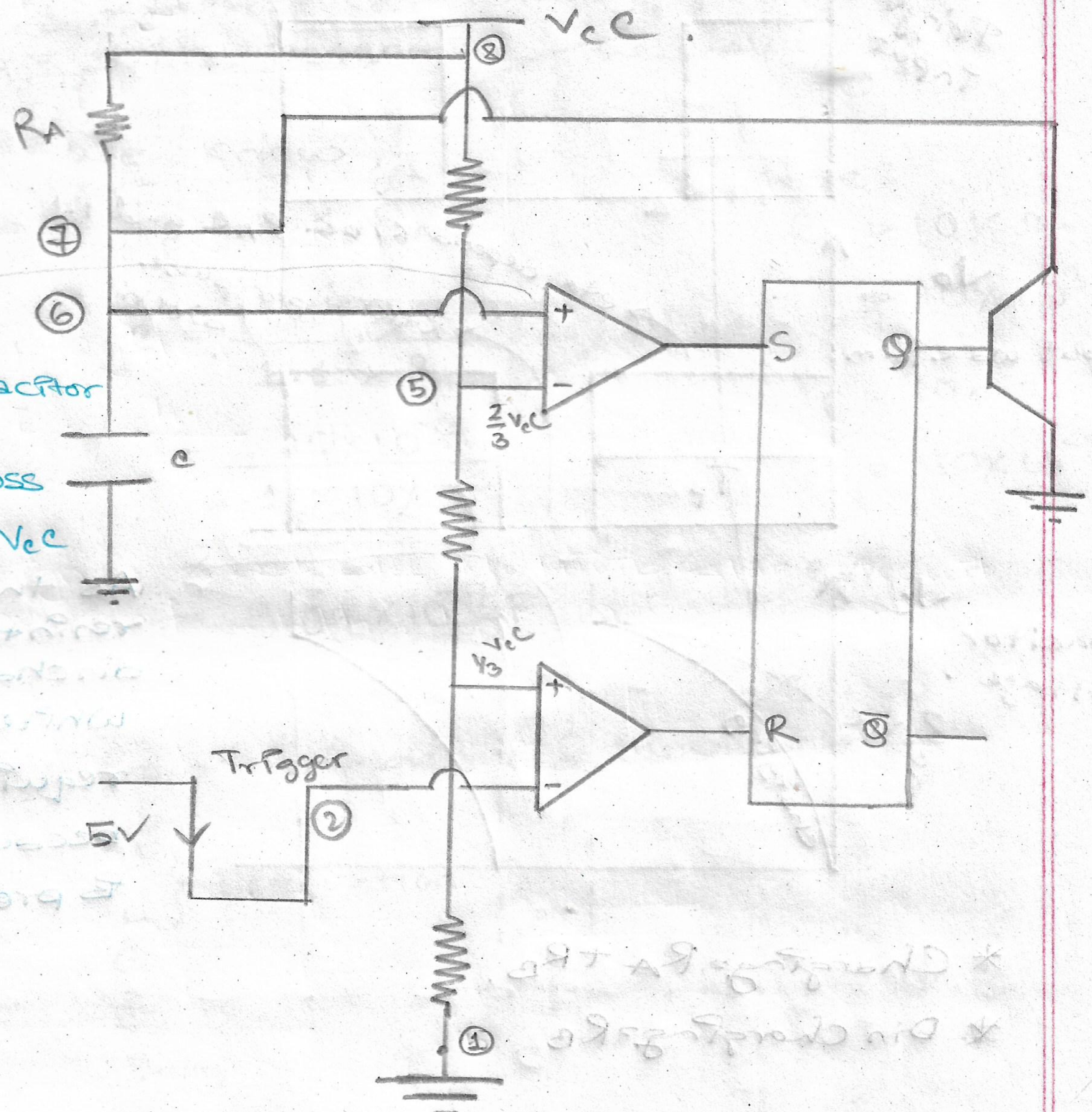
$$T_c = 0.421 \text{ ms.}$$

$$T_L = 0.69\,(3.9)\,(0.1)\,(10^{-6}).$$

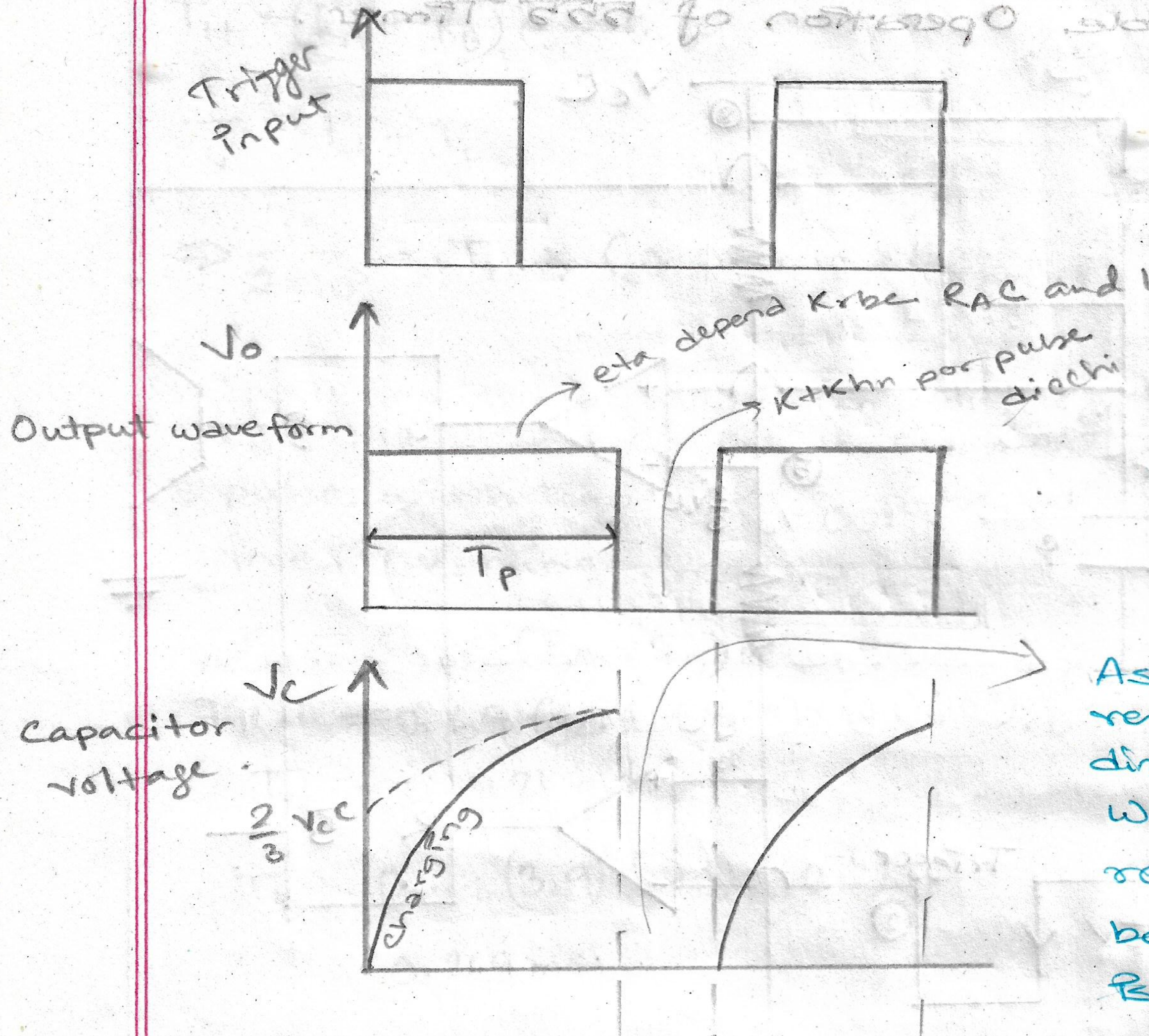
$$= 0.269 \text{ ms.}$$

$$f = \frac{1}{(0.421 + 0.269) \times (10^{-3})} = 1.45 \text{ KHz.}$$

Monostable Operation of 555 Timer.



As the capacitor charges the voltage accross the positive Vcc increases



As there is no resistor so discharges quickly while charging requires time because R_A is present there.

* Charging = $R_A + R_B$.

* Discharging = R_B

$$\frac{2}{3}V_cC = V_cC + (0 - V_cC)\, e^{-\frac{T_p}{R_AC}}.$$

$$\Rightarrow \frac{2}{3} \times 5 = 5 - 5e^{-\frac{T_P}{R_AC}}$$

~~$\therefore T_p = 1.1A$~~

$$\therefore T_p = 1.1\, R_AC.$$

8. For a monostable operation of 555 Timer, ~~Their~~ $R_a = 10K\Omega$, the pulse width $t_p = 10\,ms$. Determine the value of C.

We know,

$$T_p = 1.1\, R_A C.$$

$$C = \frac{T_p}{1.1 \times R_A}$$

$$= \frac{10 \times 10^{-3}}{1.1 \times 10 \times 10^{3}}$$

$$= 9.09 \times 10^{-7}\, F$$

Here

$R_A = 10K\Omega$

$= 10 \times 10^{3}\,\Omega$

$T_p = 10\,ms$

$= 10 \times 10^{-3}\,s.$

$C = ?$

Imp: from astable and monostable

T_H, T_L } Derivation.

C

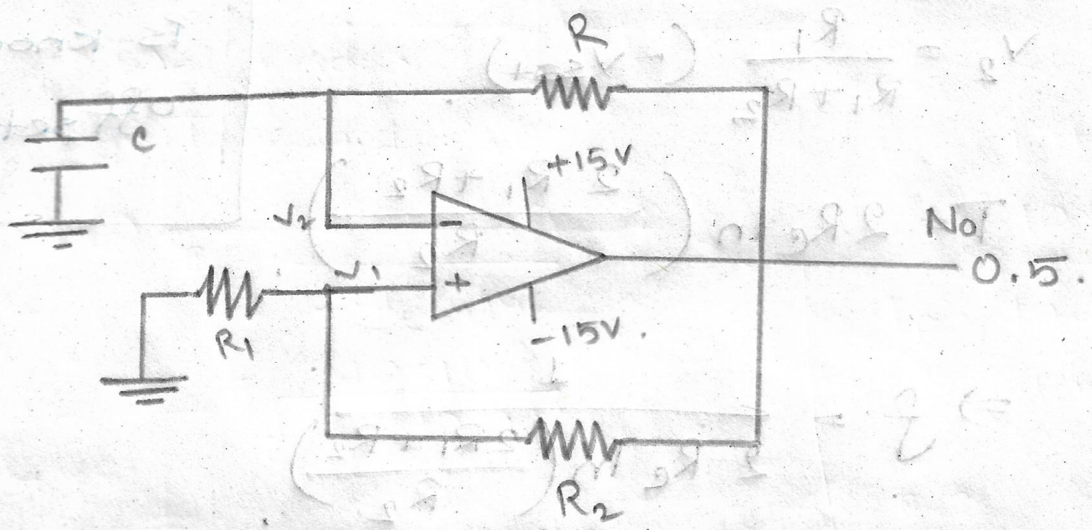
f

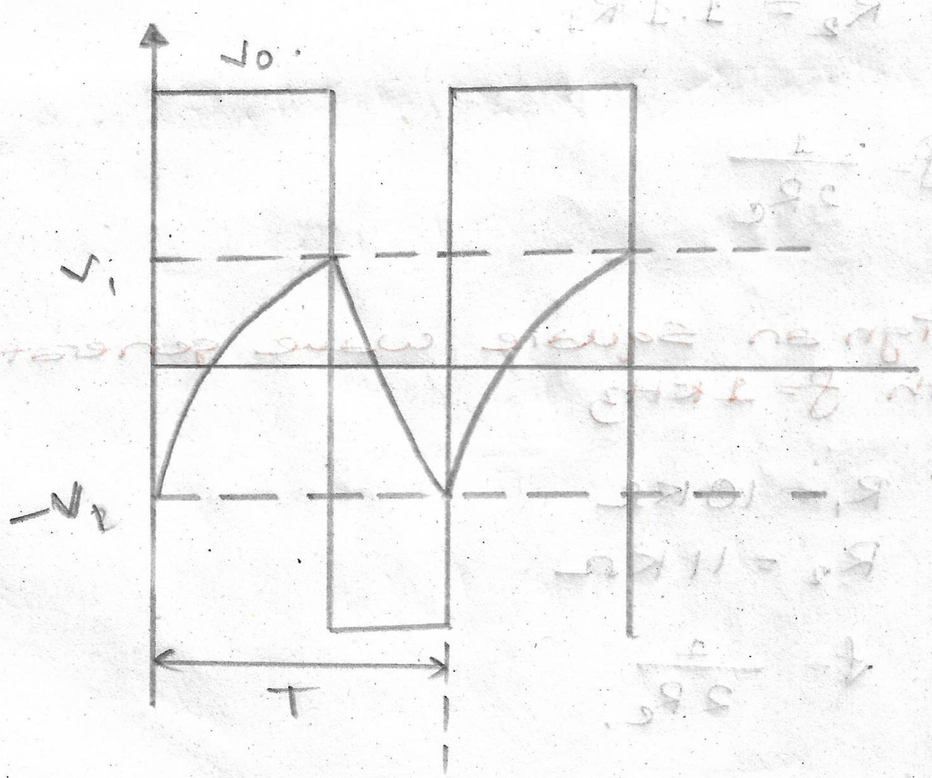
Duty

$T_p \rightarrow$ Derivation.

Graphical representation.

Square wave generator using Op-Amp:





$$V_1 = \frac{R_1}{R_1 + R_2}(+V_{sat}).$$

OR,

$$V_2 = \frac{R_1}{R_1+R_2}(-V_{sat}).$$

Note:
When we get lowest voltage is known as offset voltage.

$$T = 2R_C \ln\left(\frac{2R_1+R_2}{R_2}\right).$$

$$\Rightarrow f = \frac{1}{2R_C \ln\left(\frac{2R_1+R_2}{R_2}\right)}.$$

if, $R_2 = 1.1 R_1$.

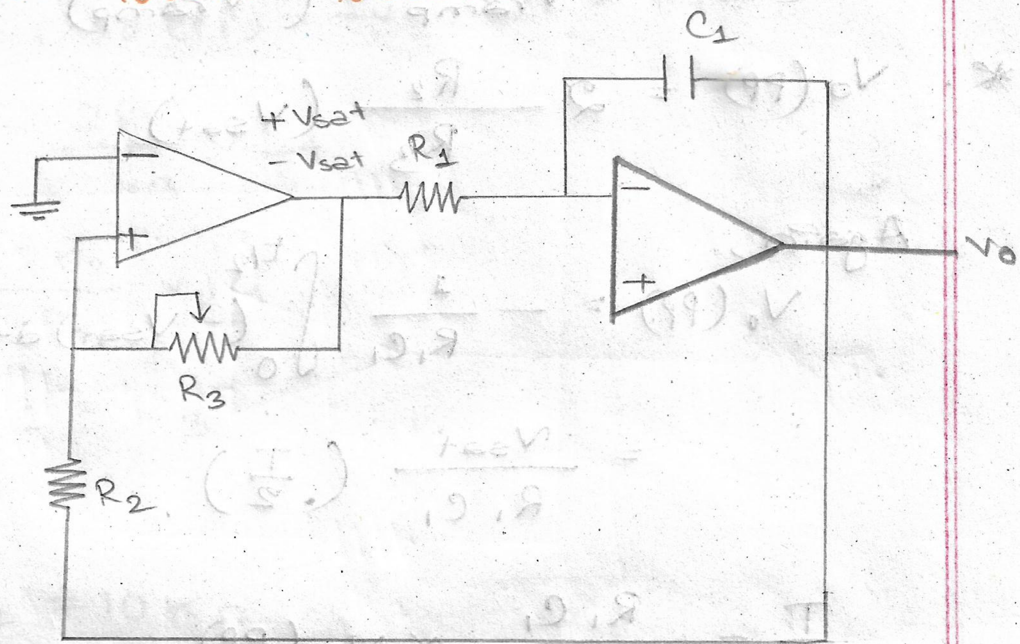
$$f = \frac{1}{2R_C}$$

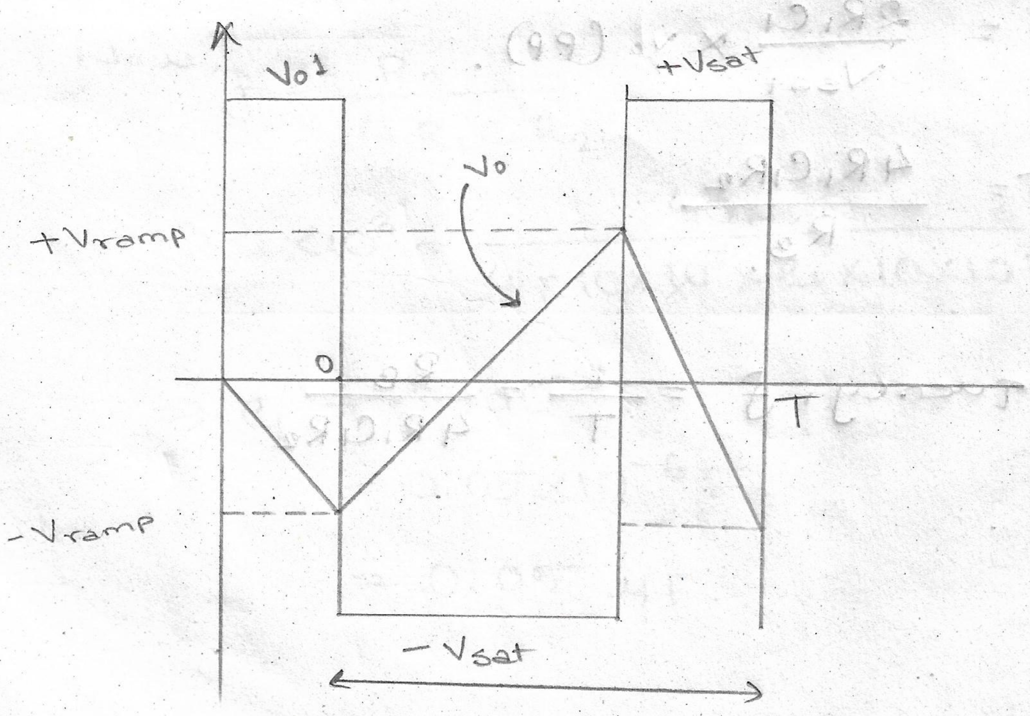
8. Design an square wave generator with $f = 1\,KHz$

let $R_1 = 10\,K\Omega$
$R_2 = 11\,K\Omega$

$$f = \frac{1}{2R_C}.$$

Triangular wave generator:





$$+V_{ramp} = -\frac{R_2}{R_3}(-V_{sat})$$

$$-V_{ramp} = -\frac{R_2}{R_3}(+V_{sat}).$$

$$V_o(PP) = +V_{ramp} - (-V_{ramp})$$

* $$V_o(PP) = 2\frac{R_2}{R_3}(V_{sat}).$$

Again,

$$V_o(PP) = -\frac{1}{R_1C_1}\int_0^{t/2}(-V_{sat})\,dt.$$

$$= \frac{V_{sat}}{R_1C_1}\left(\frac{T}{2}\right).$$

$$\frac{T}{2} = \frac{R_1C_1}{V_{sat}} \times V_o(PP).$$

$$T = \frac{2R_1C_1}{V_{sat}} \times V_o(PP).$$

$$T = \frac{4R_1C_1R_2}{R_3}.$$

$$\text{frequency, } f = \frac{1}{T} = \frac{R_3}{4R_1C_1R_2}$$

8. Design a triangular wave generator of $f = 2\,KHz$, $V_o(PP) = 7V$ $V_{sat} = 14V$.

$$V_o(PP) = \frac{2R_2}{R_3} V_{sat}.$$

$$\Rightarrow 7 = \frac{2R_2}{R_3} \times 14.$$

$$\Rightarrow 4R_2 = R_3.$$

let,

$$R_2 = 10\,K\Omega$$

$$R_3 = 40\,K\Omega$$

Now,

$$f = \frac{R_3}{4R_1C_1R_2}$$

$$\Rightarrow 2\times10^3 = \frac{40\times\cancel{10^3}}{4\times10\times\cancel{10^3}\times C_1\times10\times10^3}$$

$$\Rightarrow C_1 = 5\times10^{-8}\,F.$$

$$= 0.05\times10^{-6}\,F.$$

$$= 0.05\,\mu F.$$