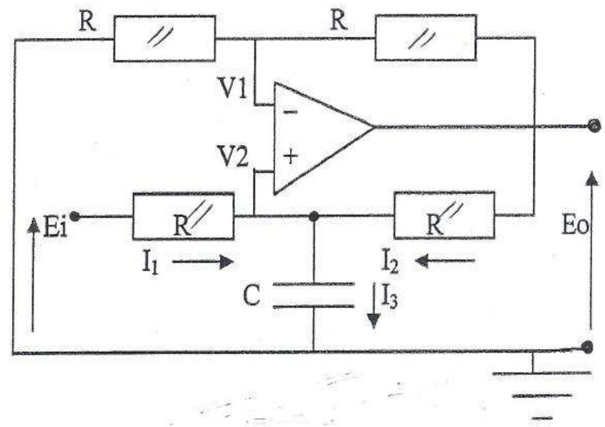
EX: The circuit shown in Figure bellow: - show that the output $E_O$ is given as

$$E_O = \frac{2}{Rc}\int Ei\,dt$$




Sol: -

$V_1 = V_2$ (1)

$$V_1 = \left[\frac{R}{R+R}\right]E_O = \frac{1}{2}E_O \quad (2)$$

$$I_1 + I_2 = I_3 \quad (3)$$

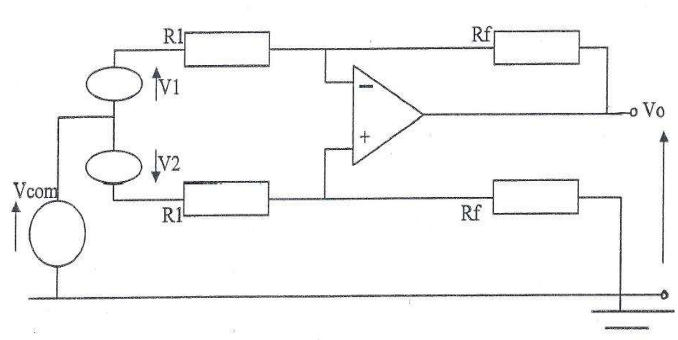
$$\frac{E_i - V_1}{R} + \frac{E_O - V_1}{R} = C\frac{dV_1}{dt} \quad (4)$$

$$\frac{E_i - (\frac{1}{2})E_O}{R} + \frac{E_O - (\frac{1}{2})E_O}{R} = C\frac{d(\frac{1}{2})E_O}{dt}$$

$$E_O = \frac{2}{RC}\int Eidt$$

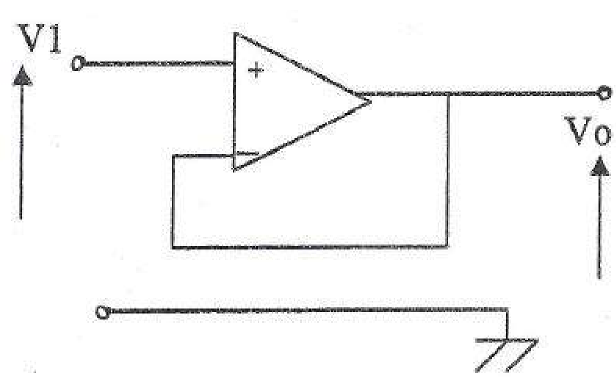
# 4.9The differential OP-amp

$$V_o = [V_2 - V_1]\frac{Rf}{R1}$$



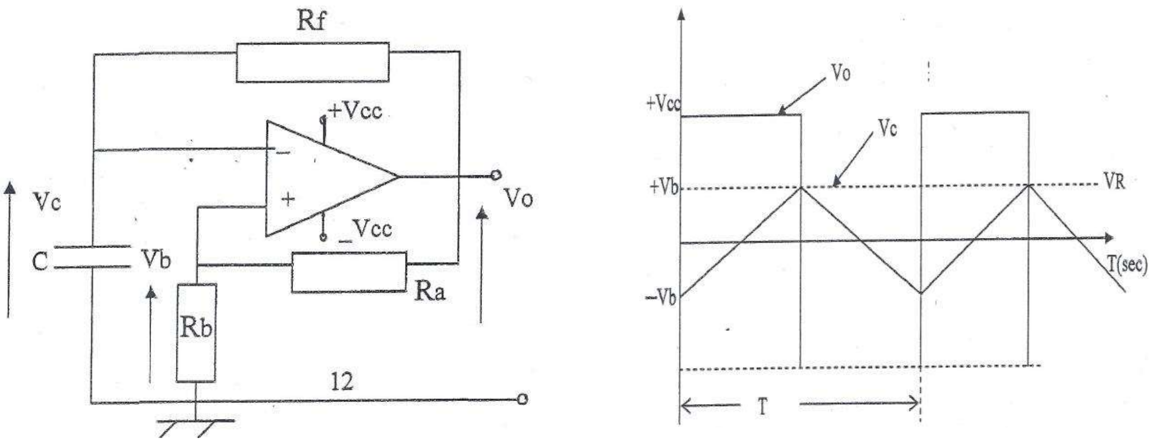

# 4.10 Op-amp voltage follower

$$V_o = V_1$$



# 4.11Op-amp Signal Generator

OP-AMP Signal Generator:- It has negative and positive feedback circuits (a) Rf = negative feedback resistance and (b) K= positive feedback coefficient, $K = \frac{R_b}{R_A+R_b}$ see figure bellow.




$V_b$= non-linear input of the op-amp (v)

$V_b = kV_o = \pm kV_{cc}$ (1)

T = the periodic time of the output/input signals (sec)

$T = 2R_F C \ln\frac{1+k}{1-k}$ (2)

F = Frequency of the generated signals (Hz)

$F = \frac{1}{T}$ (3)

EX :- Op-amp signal generator, if Ra=Rb, Rf =10KΩ, C= 0.1μF, and $V_{cc}$=±18V;Find(1) $V_b$ and (2) Frequency F

Sol.

(1) $V_b = kV_o = \pm kV_{cc}$

K= $\frac{R_b}{R_a+R_b} = 0.5$

$V_b = \pm 0.5 \times 18 = \pm 9$

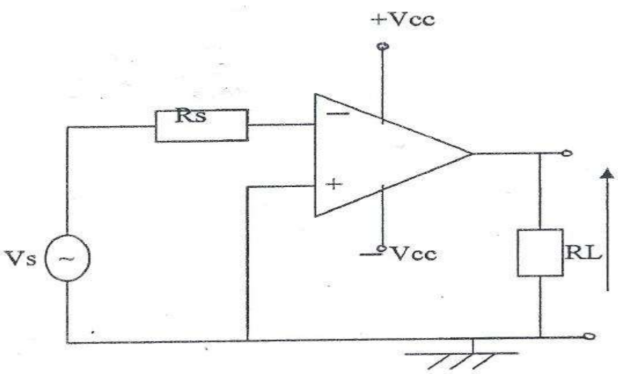
(2) T= $2R_f C \ln\frac{1+k}{1-k}$

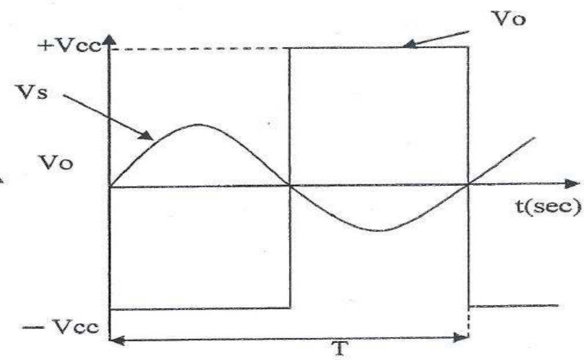
T= $2\times 10 \times 10^4 \times 0.1 \times 10^{-6} \ln\frac{1+0.5}{1-0.5} = 2.197\times 10^{-3}$

F= $\frac{1}{T} = \frac{1}{2.197\times10^{-3}} = 455Hz$

# 4.12Op-amp Zero Crossing Detector

OP-AMP Zero Crossing Detector: -This is one of the open loop applications of op-amp, also called sinewave to square wave converter.




$V_O = \pm V_{cc}$ and $F_o = F_i = 1/T = \omega/2\pi$

EX:- Op-amp, Zero crossing detector has $V_{cc}=\pm 15v$, $V_s = 5sin337t$ (a) Draw the power circuit diagram,(b) Sketch the input-output waveforms (c) Calculate $F_O$

Sol: -

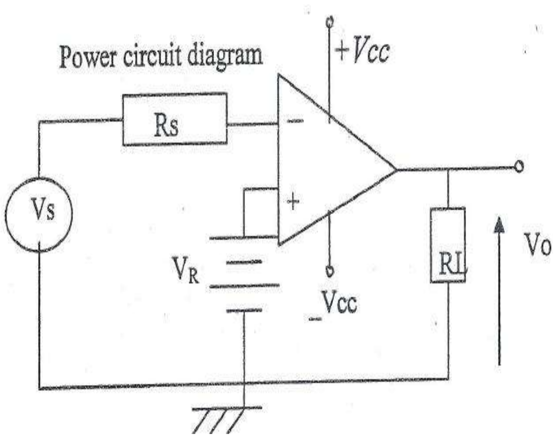
(a) And (b) as shown in Figure above (previous slide)

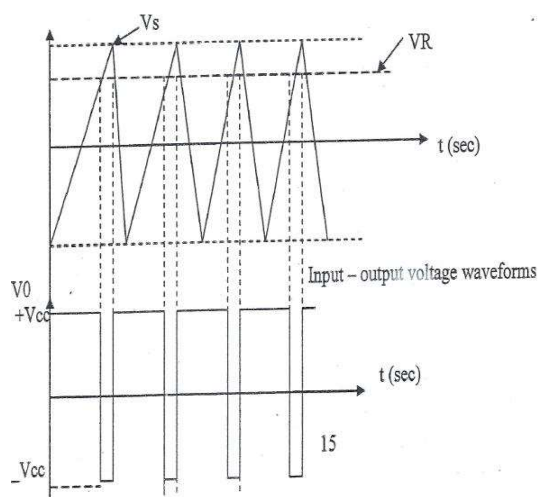
(c) $F_o = F_i = 1/T = \omega/2\pi$ , ω= 377

$F_o$= 377/(2× 3.14) = 60Hz

# 4.13The Comparator

The Comparator: - This is also one of the open loop applications of op-amp, it is used to compare two voltages one of it's a dc voltage called reference voltage $[V_R]$



# 4.14 Exercises and Problems

**Q1**/: For OP-AMP Signal Generation, fill the blank in the following in the table

| No. | Resistances | $V_{cc}$ | $R_f$ | C | K | $V_b$ | Frequency (F) |
|---|---|---|---|---|---|---|---|
| 1. | $R_a = R_b$ | $\pm 18$ | $10K\Omega$ | 0.1µF | $K_1$= | $V_{b1}$ = | $F_1$= |
| 2. | $R_a = 2R_b$ | $\pm 18$ | $10K\Omega$ | 0.1µF | $K_2$= | $V_{b2}$ = | $F_2$= |
| 3. | $R_a = 3R_b$ | $\pm 18$ | $10K\Omega$ | 0.1µF | $K_3$= | $V_{b3}$ = | $F_3$= |

Ans:

$K_1 = \frac{R_b}{R_a+R_b}$ , $R_a = R_b$ , $K_1 = \frac{R_a}{R_a+R_a} = \frac{1}{2}$ , $V_{b1} = \pm K\, V_{cc} = \pm\frac{1}{2} \times 18 = \pm 9v$

$K_2 = \frac{R_b}{R_a+R_b}$ , $R_a = 2R_b$ , $K_1 = \frac{R_b}{2R_b+R_b} = \frac{1}{3}$ , $V_{b2} = \pm K\, V_{cc} = \pm\frac{1}{3} \times 18 = \pm 6v$

$K_3 = \frac{R_b}{R_a+R_b}$ , $R_a = 3R_b$ , $K_1 = \frac{R_b}{3R_b+R_b} = \frac{1}{4}$ , $V_{b3} = \pm K\, V_{cc} = \pm\frac{1}{4} \times 18 = \pm\frac{9}{2}v$

$F_1 = \frac{1}{T_1}$, $T_1 = 2R_f C \ln\frac{1+k_1}{1-k_1}$ , $T_1 = 2 \times 10 \times 10^3 \times 0.1 \times 10^{-6} \ln\frac{1+1/2}{1-1/2}$,
$F_1$=455.1Hz

$F_2 = \frac{1}{T_2}$, $T_2 = 2R_f C \ln\frac{1+k_2}{1-k_2}$ , $T_2 = 2 \times 10 \times 10^3 \times 0.1 \times 10^{-6} \ln\frac{1+1/3}{1-1/3}$,
$F_2$=721.3Hz

$F_3 = \frac{1}{T_3}$, $T_3 = 2R_f C \ln\frac{1+k_3}{1-k_3}$ , $T_3 = 2 \times 10 \times 10^3 \times 0.1 \times 10^{-6} \ln\frac{1+1/4}{1-1/4}$,
$F_2$=978.8Hz

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**Q2**/: Design Summing op-amp circuit to solve the following equations

1. Vo= 4V1-2V2+0.5V3+V4

Consider the feedback resistance is equal to 10KΩ

Ans

Vo= 4V1-2V2+0.5V3+V4

Vo=$-\frac{Rf}{R1}\text{V1} - \frac{Rf}{R2}\text{V2} - \frac{Rf}{R3}\text{V3} - \frac{Rf}{R4}\text{V4}$

$$4 = \frac{Rf}{R1} \to 4 = \frac{10}{R1} \to R1 = 2.5K\Omega$$

$$2 = \frac{Rf}{R2} \to 2 = \frac{10}{R2} \to R2 = 5K\Omega$$

$$0.5 = \frac{Rf}{R3} \to 0.5 = \frac{10}{R3} \to R3 = 20K\Omega$$

$$1 = \frac{Rf}{R1} \to 1 = \frac{10}{R1} \to R4 = 10K\Omega$$