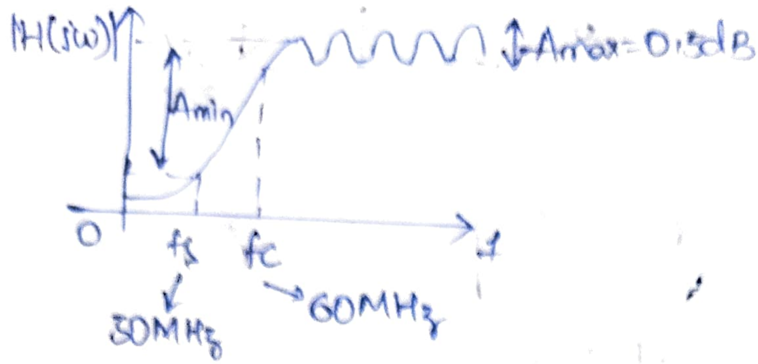
Q. A chebyshev HPF has,

$f_c = 60MHz$, $A_{min} = 40dB$, $f_s = 30MHz$, $A_{max} = 0.5dB$

find order of filter.



norm HPF ⇒

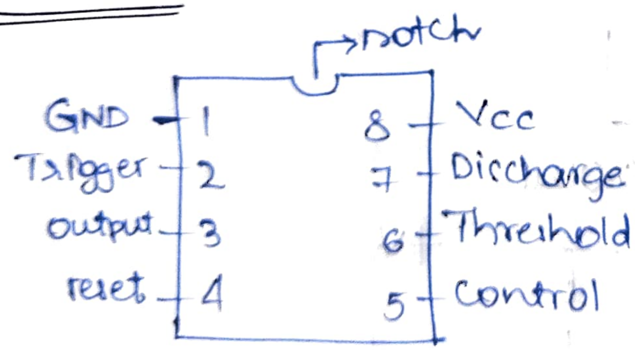
$$n = \frac{\cosh^{-1}\left(\left(10^{\frac{A_{min}}{10}} - 1\right) / \left(10^{\frac{A_{max}}{10}} - 1\right) \right)^{1/2}}{\cosh^{-1}\left(\frac{\omega_s}{\omega_c}\right)}$$

n → ?

poles → ?

T.F → ?

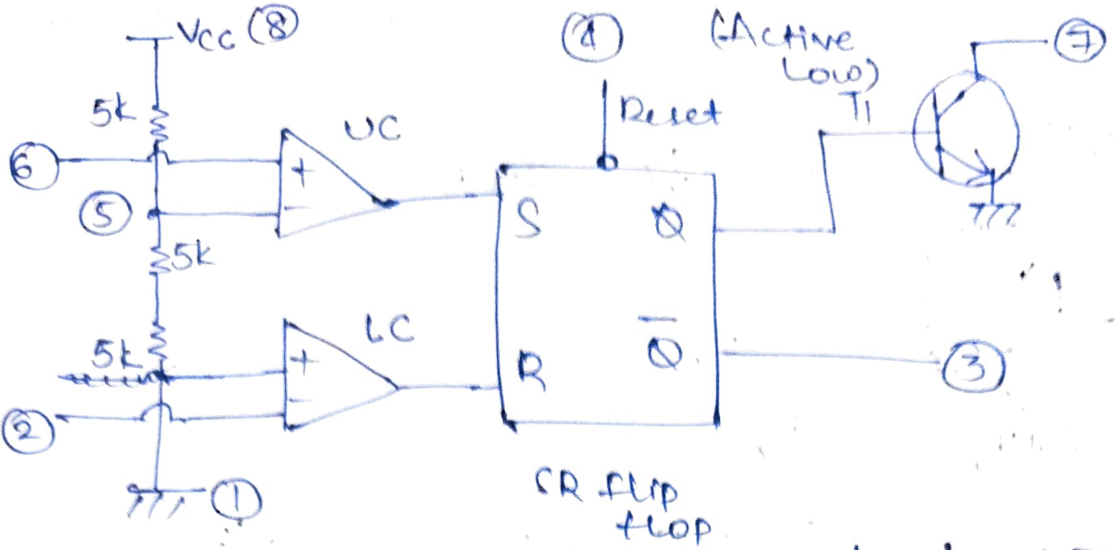
IC555:



pin diagram

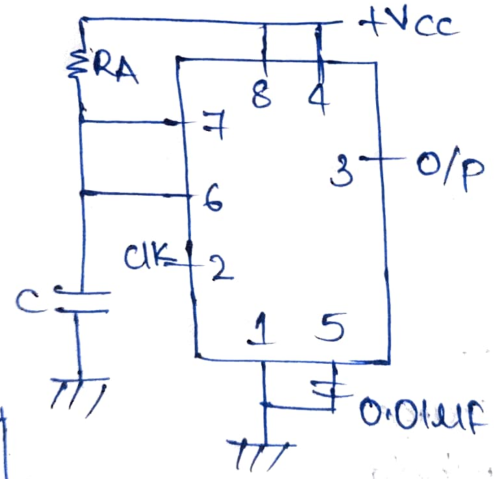
UC - upper comparator
LC - lower comparator

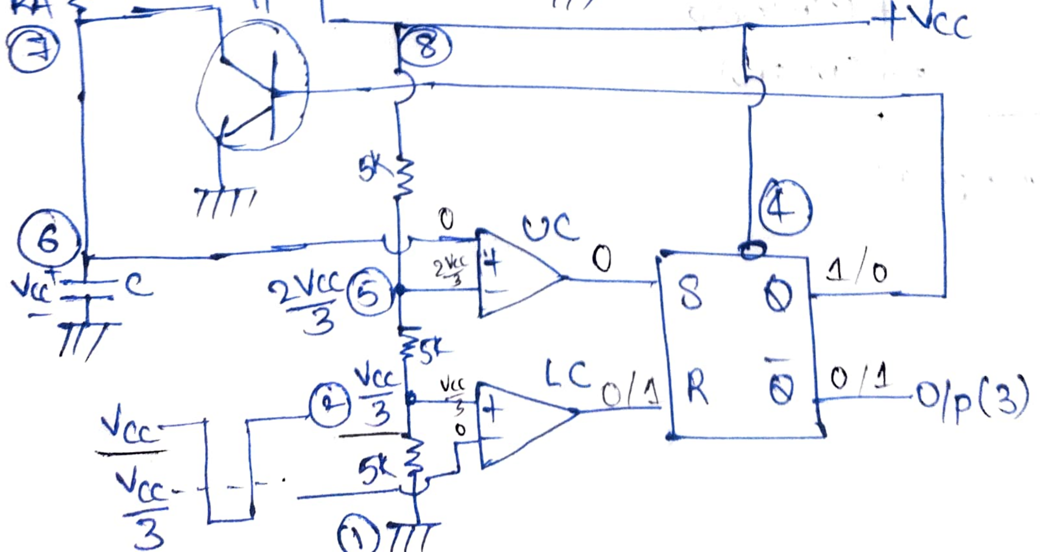
functional diagram

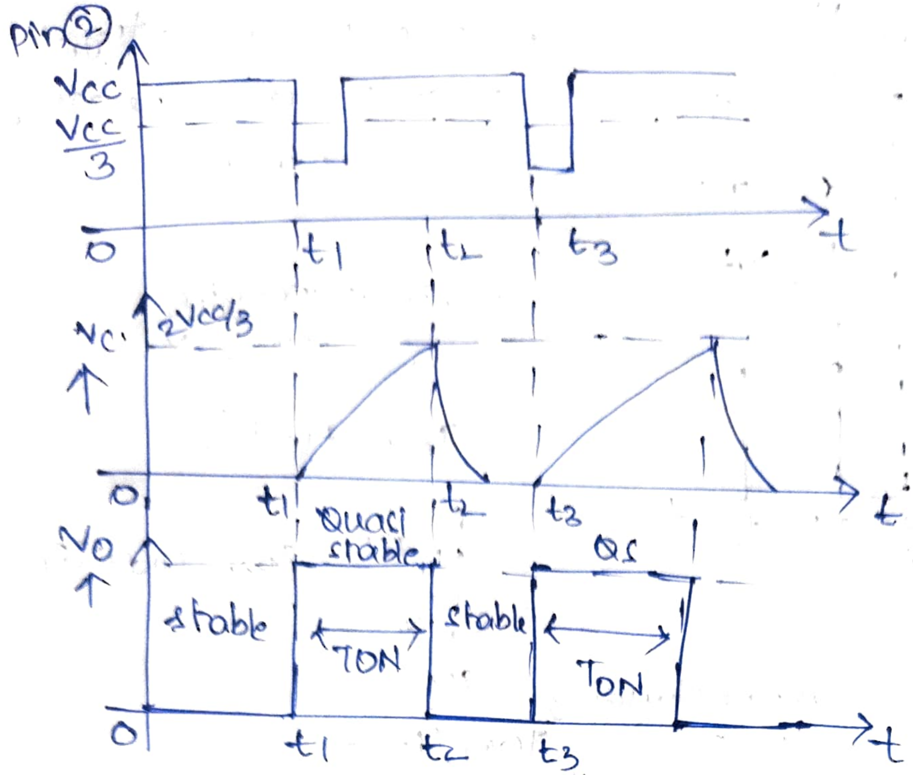


S	R	Q	$\bar{Q}$	
1	0	1	0	(set state)
0	0	1	0	(No change)
0	1	0	1	(reset)
0	0	0	1	
1	1	Invalid		

IC555 as Monostable Multivibrator.







Time duration (TON)

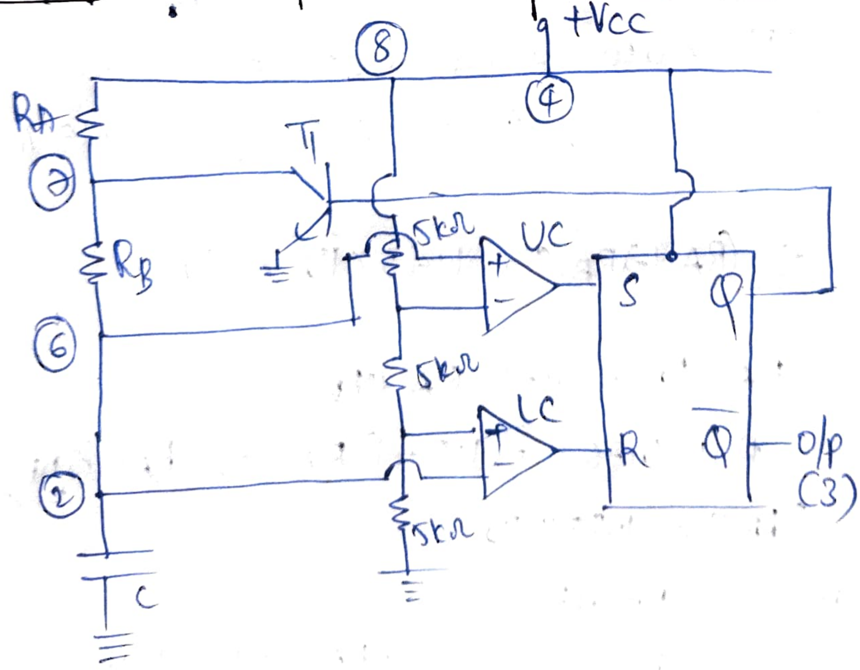
$$V_C = V_{CC}\left(1 - e^{-t/R_A C}\right)$$

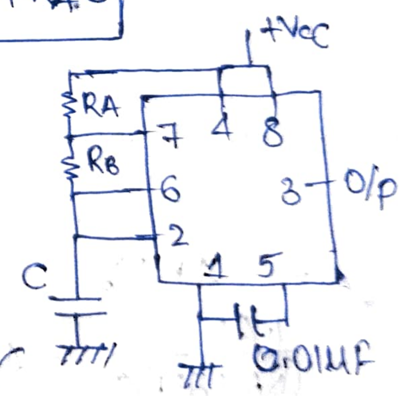
At $t = T_{ON}$, $V_C = \frac{2V_{CC}}{3}$

$$\frac{2V_{CC}}{3} = V_{CC}\left(1 - e^{-T_{ON}/R_A C}\right)$$

$$\Rightarrow \boxed{T_{ON} = 1.1\, R_A C}$$

IC55 Astable operation using IC555 timer

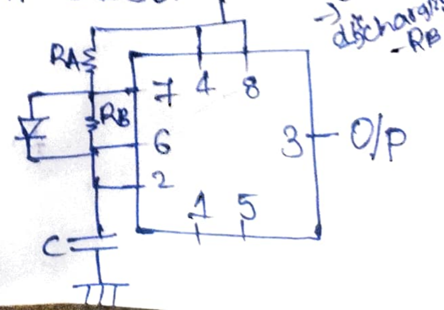


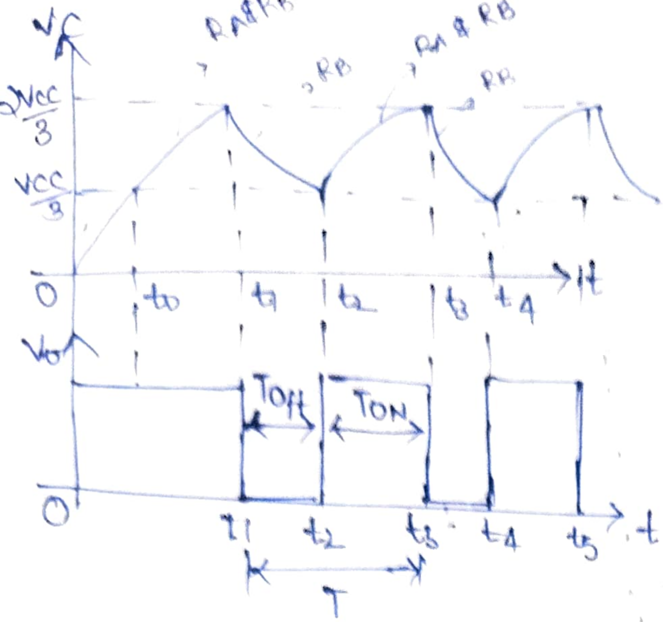


* $\boxed{D > 50\%}$

if $D < 50\%$,

charging - RA
→ discharging - RB

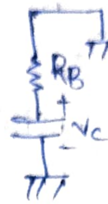




- without getting a trigger pulse we are generating a square wave

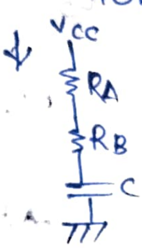
while discharging
$\left(\frac{2V_{cc}}{3} \to \frac{V_{cc}}{3}\right)$

$T_{OFF}\ (t_1 - t_2)$



$T_{off} = 0.693(R_B)C$

while charging.
$T_{ON}\ (t_2 - t_3)$



$T_{ON} = 0.693(R_A + R_B)C$

- Timeperiod(T)

$T = T_{OFF} + T_{ON}$

$= 0.693(R_A + 2R_B)C$

$f = \frac{1}{T} = \frac{1}{0.693(R_A+2R_B)C} = \frac{1.45}{(R_A+2R_B)C}$

- Duty cycle 'D' $= \frac{T_{ON}}{T}$

$D' = \frac{0.693(R_A + R_B)C}{0.693(R_A+2R_B)C} \Rightarrow \boxed{D = \frac{R_A + R_B}{R_A + 2R_B}}$

Q Design a Astable multivibrator using IC555 timer which generates a signal with frequency 1KHz & Dutycycle 75%.

$f = 1\,KHz$

$\frac{1.45}{(R_A+2R_B)C} = 1k \Rightarrow (R_A+2R_B)C = 1.45\times10^{-3}$ — ①

$D = \frac{R_A + R_B}{R_A + 2R_B} = 0.75 \Rightarrow R_A + R_B = 0.75(R_A + 2R_B)$

$R(1-0.75) = (1.5-1)R_B \Rightarrow R_A = 2R_B$ — ②

$\Rightarrow 4R_BC = 1.45\times10^{-3}$

Assume $C = 0.1\mu F$

$\Rightarrow R_B = 3625\,\Omega$, $R_A = 7.25\,k\Omega$

note: when Duty cycle (D) < 50%

$$T_{ON} = 0.693 (R_A) C$$

$$T_{OFF} = 0.693 (R_B) C$$

$$T = 0.693 (R_A + R_B) C \Rightarrow f = \frac{1}{0.693 (R_A + R_B) C}$$

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

$$D = \frac{T_{ON}}{T} = \frac{R_A}{R_A + R_B}$$

Q. Design a astable multivibrator using IC555 timer which generates a signal with frequency 1K Hz & duty cycle 25%.

$$\frac{R_A}{R_A + R_B} = \frac{25}{100} \Rightarrow 3R_A = R_B \quad — ①$$

$$\frac{1.45}{(R_A + R_B) C} = 1 \times 10^3 \quad — ②$$

Assume $C = 0.1 \mu F$.

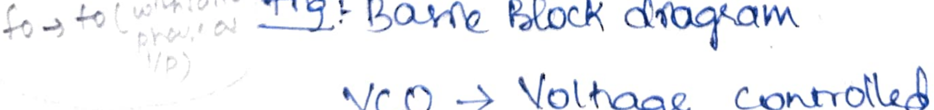
① & ② ⇒ $R_A = 3.6 k\Omega$

$R_B = 10.8 k\Omega$

PHASE LOCKED LOOP: (PLL)

Ve - error voltage
Vc - low dc vol. signal
fo - default freq.

Vin = f1
fo → f1



Vin = fo (phase change)
fo → fo (without any previous I/P)

fig: Basic Block diagram

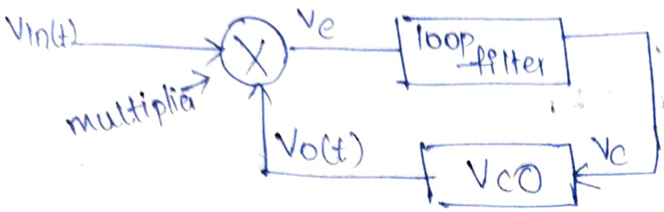
VCO → Voltage controlled Oscillator

Modes of operation:

1. free running state (Vin = 0) (fo)
2. Capture state (when Vin is non zero)
3. Lock state (Vco frequency has change to f_1 from fo)

1. capture range - range of frequencies to attain lock

2. lock range - range of frequencies over which PLL can maintain the lock state (after attaing the lock, when again freq. of Vin is changed.)



$e(t) \longrightarrow \boxed{VCO} \longrightarrow B\cos(\omega_c t + \theta_o(t))$

$$VCO \text{ o/p} \rightarrow V_o = B\cos(\omega_c t + \theta_o(t))$$

Instantaneous angular freq. of VCO o/p $= \omega_c + \dot{\theta}_o(t)$

where, $\dot{\theta}_o(t) = c\,e(t)$

when $e(t) = 0 \rightarrow \dot{\theta}_o(t) = 0$

So, Instantaneous angular freq, of VCO o/p is $\omega_c = 2\pi f_c$

where $f_c \rightarrow$ free running frequency of VCO

Let $V_{in}(t) = A\sin(\omega_i t + \psi_o) = A\sin(\omega_c t + \theta_i(t))$

$$V_{in}(t) = A\sin(\omega_c t + (\omega_i - \omega_c)t + \psi_o)$$

$$\theta_i(t) = (\omega_i - \omega_c)t + \psi_o$$

$$\theta_i(s) = \frac{(\omega_o - \omega_c)}{s^2} + \frac{\psi_o}{s}$$

$V_o(t) = B\cos(\omega_c t + \theta_o(t))$

$V_e(t) = AB\sin(\omega_c t + \theta_i(t))\cos(\omega_c t + \theta_o(t))$

$V_e(t) = \frac{1}{2}AB\left[\sin(\theta_i(t) - \theta_o(t))\right] + \sin(2\omega_c t + \theta_i(t) + \theta_o(t))]$

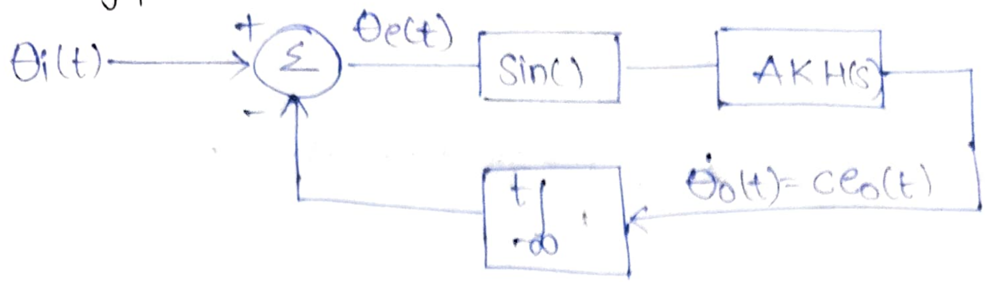
Since loop filter is LPF

$V_c = \frac{1}{2}AB\left[\sin(\theta_i(t) - \theta_o(t))\right] = \frac{1}{2}AB\sin(\theta_e(t))$

$[\theta_e(t) = \theta_i(t) - \theta_o(t)]$

let $H(s)$ be transfer function of loop filter

Interms of phase



$\dot{\theta}_0(t) = ce_0(t)$ | $K = \frac{1}{2}CB$

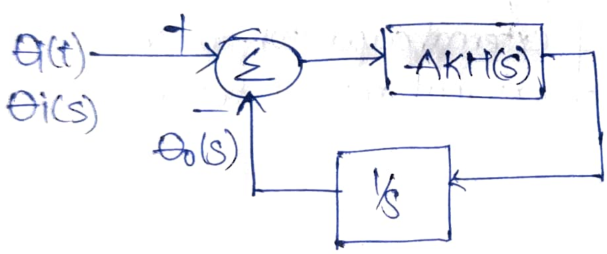
$e_0(t) = h(t) * \frac{1}{2} AB\sin(\theta_i(t) - \theta_0(t))$

$ce(t) = ch(t) * \frac{1}{2} AB\sin(\theta_i(t) - \theta_0(t))$

$\dot{\theta}_0(t) = ce_0(t) = \frac{CAB}{2} \int_{-\infty}^{t} h(t-x)\sin(\theta_i(x) - \theta_0(x))\,dx$

$\dot{\theta}_0(t) = AK \int_{-\infty}^{t} h(t-x)\sin(\theta_e(t))\,dx$

If $\sin(\theta_e(t)) \approx \theta_e(t)$, then entire circuit becomes linear & we can apply Convolution. Assume $\theta_e(t) << \pi/2$, then $\boxed{\sin(\theta_e) \simeq \theta_e}$



$\theta_0(s) = [\theta_i(s) - \theta_0(s)] \frac{AKH(s)}{s}$

$\theta_0(s)\left[1 + \frac{AKH(s)}{s}\right] = \frac{\theta_i(s)AKH(s)}{s}$

$\frac{\theta_0(s)}{\theta_i(s)} = \frac{AKH(s)}{s + AKH(s)}$

$\theta_e(s) = \theta_i(s) - \theta_0(s)$

$\theta_e(s) = \frac{s\theta_i(s)}{s + AKH(s)}$

$\theta_i(t) = (\omega_i - \omega_c)t + \varphi_0$

$\theta_i(s) = \frac{\omega_0 - \omega_c}{s^2} + \frac{\varphi_0}{s}$

$\theta_e(s) = \frac{s}{s + AKH(s)}\left[\frac{\omega_i - \omega_c}{s^2} + \frac{\varphi_0}{s}\right]$

let $H(s) = 1$ (1st order LPF)

$\theta_e(s) = \frac{s}{s + AK}\left[\frac{\omega_i - \omega_c}{s^2} + \frac{\varphi_0}{s}\right]$

$\theta_e(s) = \frac{\omega_i - \omega_c}{s(s + AK)} + \frac{\varphi_0}{(s + AK)}$

$\theta_e(s) = \frac{(\omega_i - \omega_c)/AK}{s} - \frac{(\omega_i - \omega_c)/AK}{s + AK} + \frac{\varphi_0}{s + AK}$

$$\theta_e(t) = \frac{\omega_i - \omega_c}{AK} - \frac{(\omega_i - \omega_c)}{AK} e^{-AKt} + \varphi_0 e^{-AKt}$$

let, $\boxed{\lim_{t \to \infty} \theta_e(t) = \left(\frac{\omega_i - \omega_c}{AK}\right)}$ → steady state response

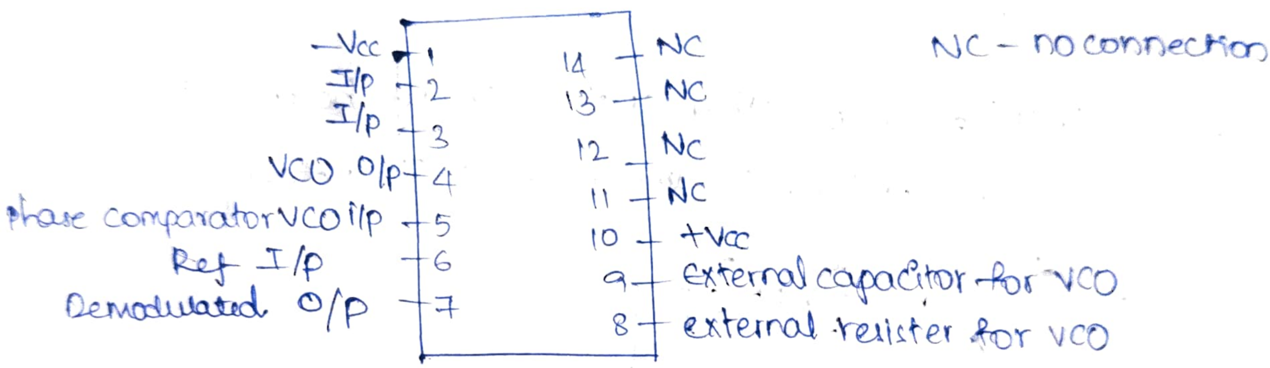
$$H(s) = \frac{s+a}{s}, \quad \theta_e(s) = \frac{s}{s + AK\left(\frac{s+a}{s}\right)} \left[\frac{\omega_i - \omega_c}{s^2} + \frac{\varphi_0}{s}\right]$$

From final value theorem,

$$\theta_e(t=\infty) = \lim_{s \to 0} s\theta_e(s) \rightarrow \underline{\theta_e(t=\infty) = 0}$$

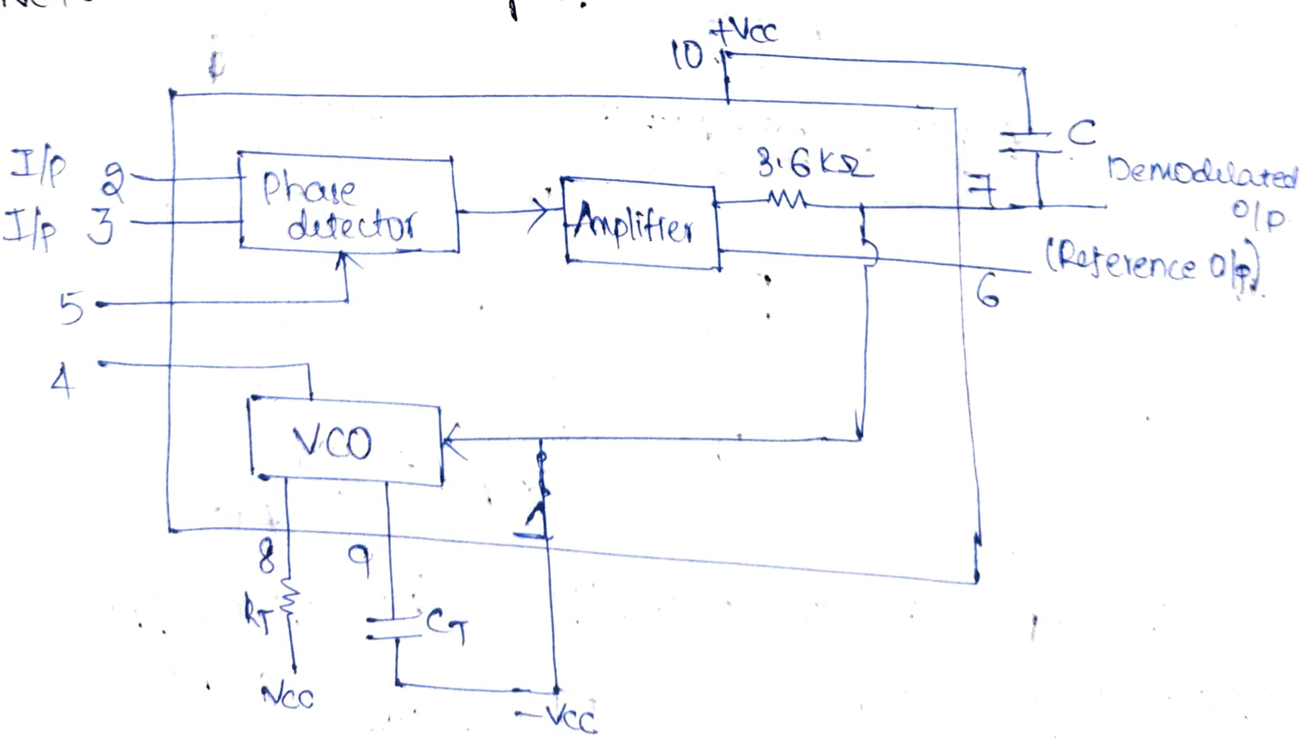
There is a exact phase difference of $\pi/2$ between I/p & O/p

IC PLL 565



Pin diagram

NE/SE 565 PLL Block diagram.



Important electrical parameters of 565 PLL

- operating frequency range = 0.001 Hz to 500 kHz
- operating voltage range = ±6V to ±12V
- Input level: 10 mV rms (min) to 3V(p-p) max
- o/p sink current = 1 mA (typical)
- I/p impedence = 10 kΩ

Lock in range (IC565 PLL)

$$\Delta f_L = \pm \frac{7.8 f_o}{V} \quad ; \quad V = +V_{cc} - (-V_{cc})$$

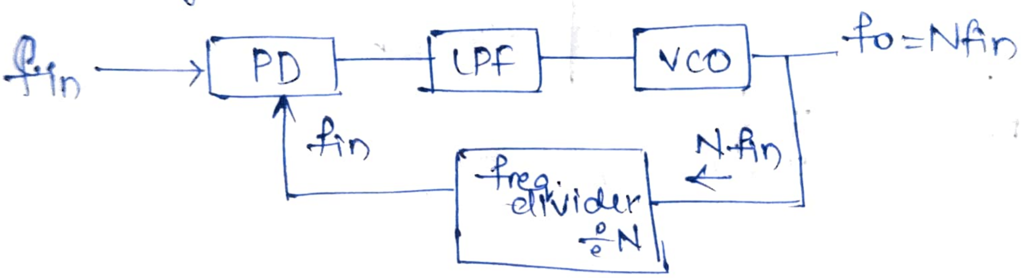
Capture range:

$$\Delta f_c = \pm \left[\frac{\Delta f_L}{(2\pi)(3.6)10^3 C} \right]^{1/2}$$

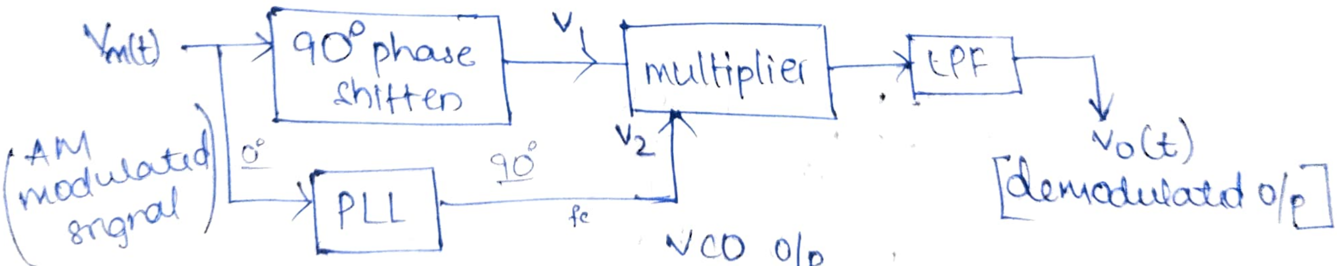
$$\Rightarrow f_o = \frac{0.25}{R_T C_T} \text{ Hz}$$ → free running freq.

Applications of PLL:

① Frequency multiplier

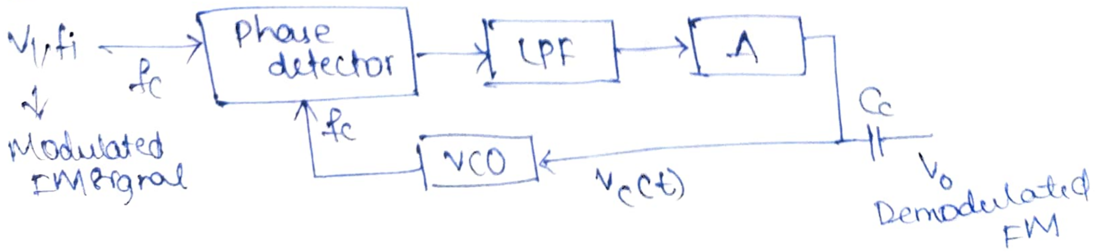


② AM detection



f_c = carrier frequency.

③ FM detection



Important electrical parameters of 565 PLL

- operating frequency range = 0.001 Hz to 500 kHz
- operating voltage range = ±6 V to ±12 V
- Input level: 10 mV rms (min) to 3 V (p-p) max
- o/p sink current = 1 mA (typical)
- I/p impedence = 10 kΩ

Lockin range. (IC565 PLL)

$$\Delta f_L = \pm \frac{7.8 f_o}{V} \quad ; \quad V = +V_{cc} - (-V_{cc})$$

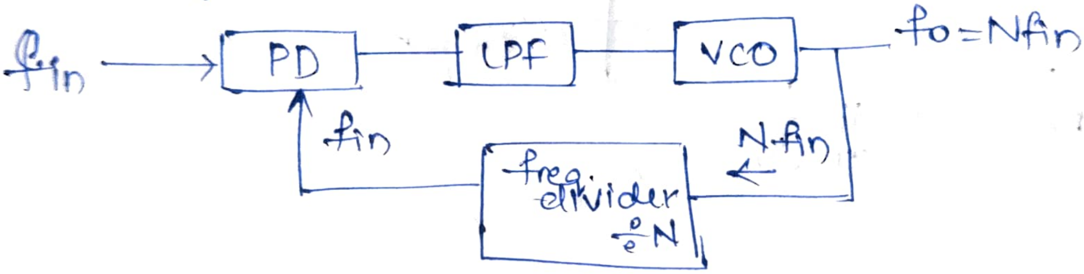
Capture range:

$$\Delta f_c = \pm \left[\frac{\Delta f_L}{(2\pi)(3.6)10^3 C} \right]^{1/2} , \quad \Rightarrow f_o = \frac{0.25}{R_T C_T}\ \text{Hz}$$

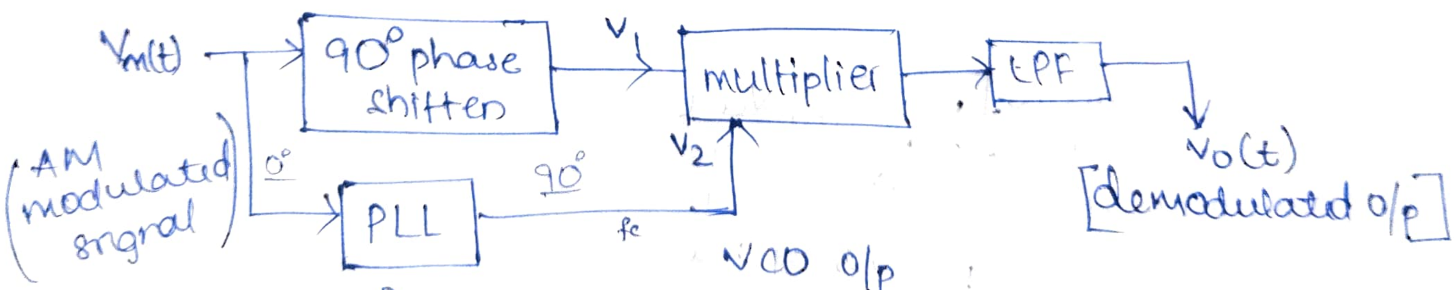
→ free running freq.

Applications of PLL:

① Frequency multiplier

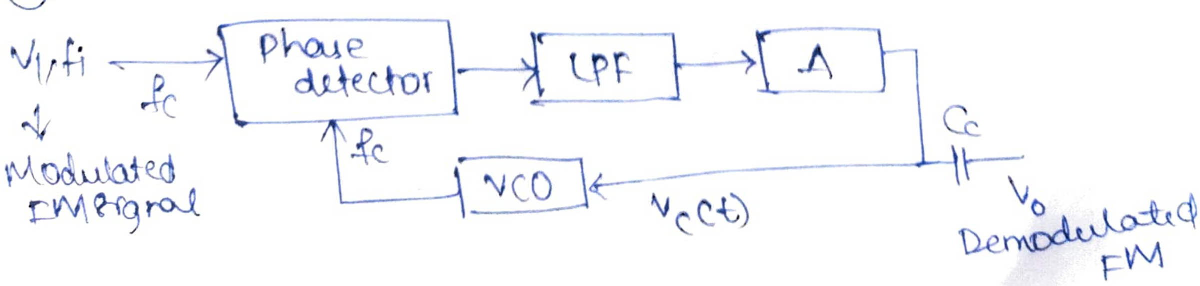


② AM detection



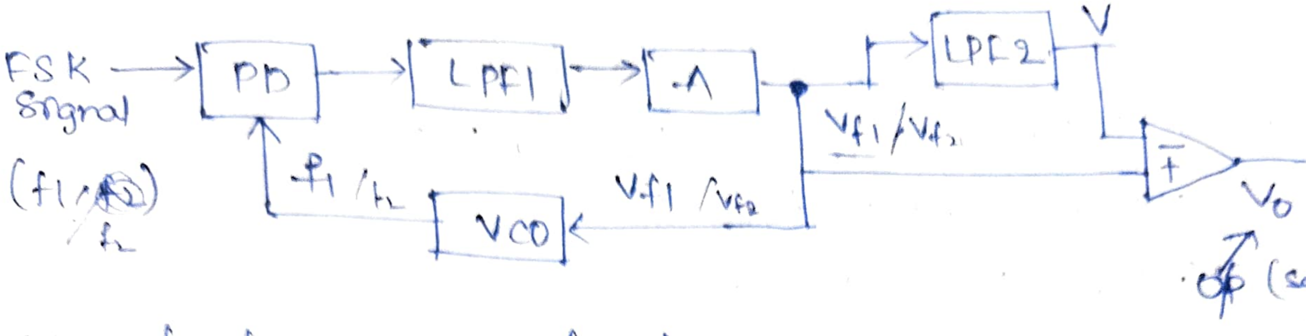
fc = carrier frequency.

③ FM detection.

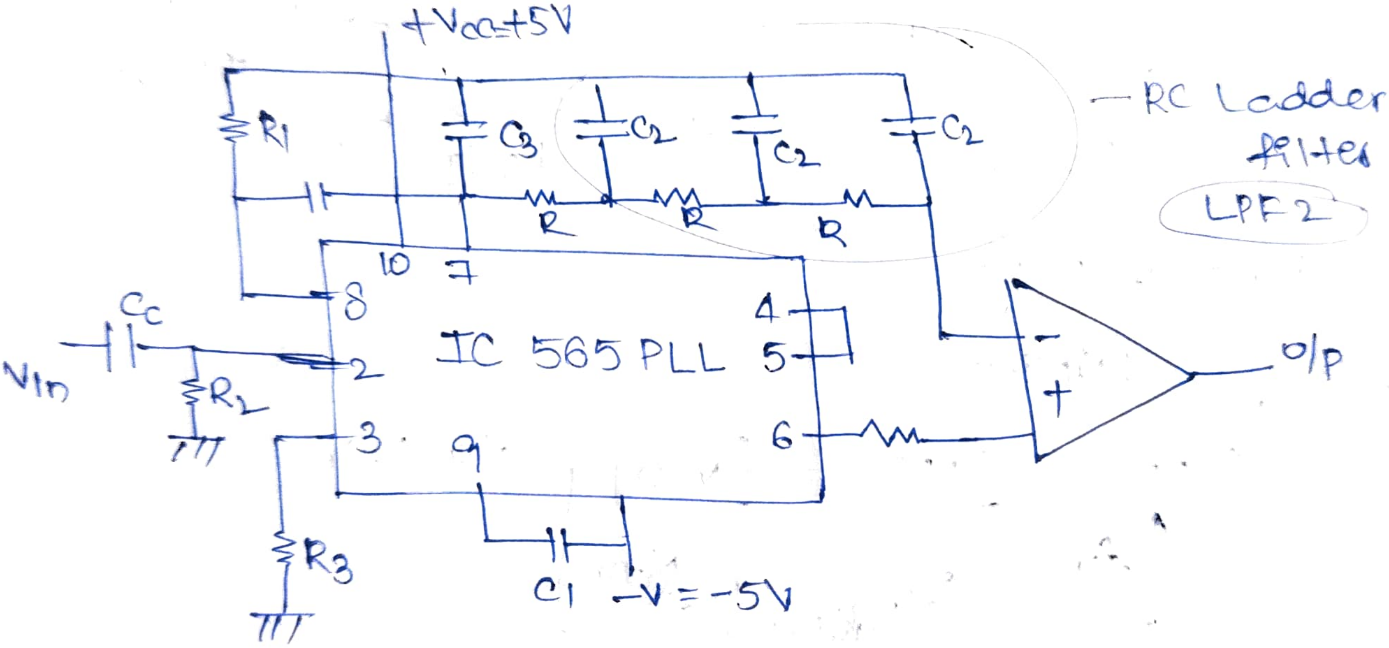


A - Amplifier.

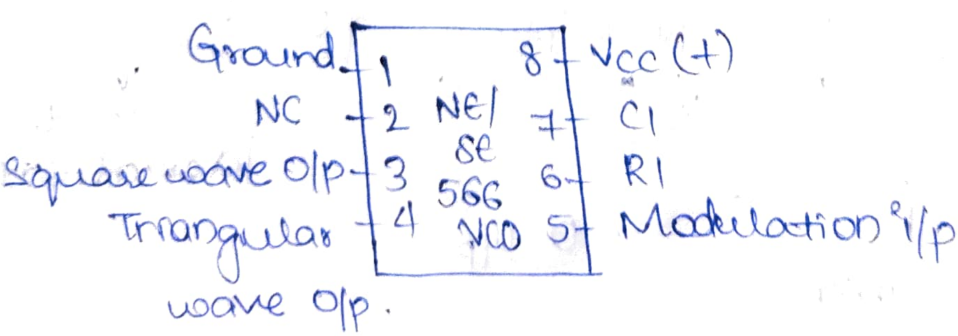
FSK Demodulation:

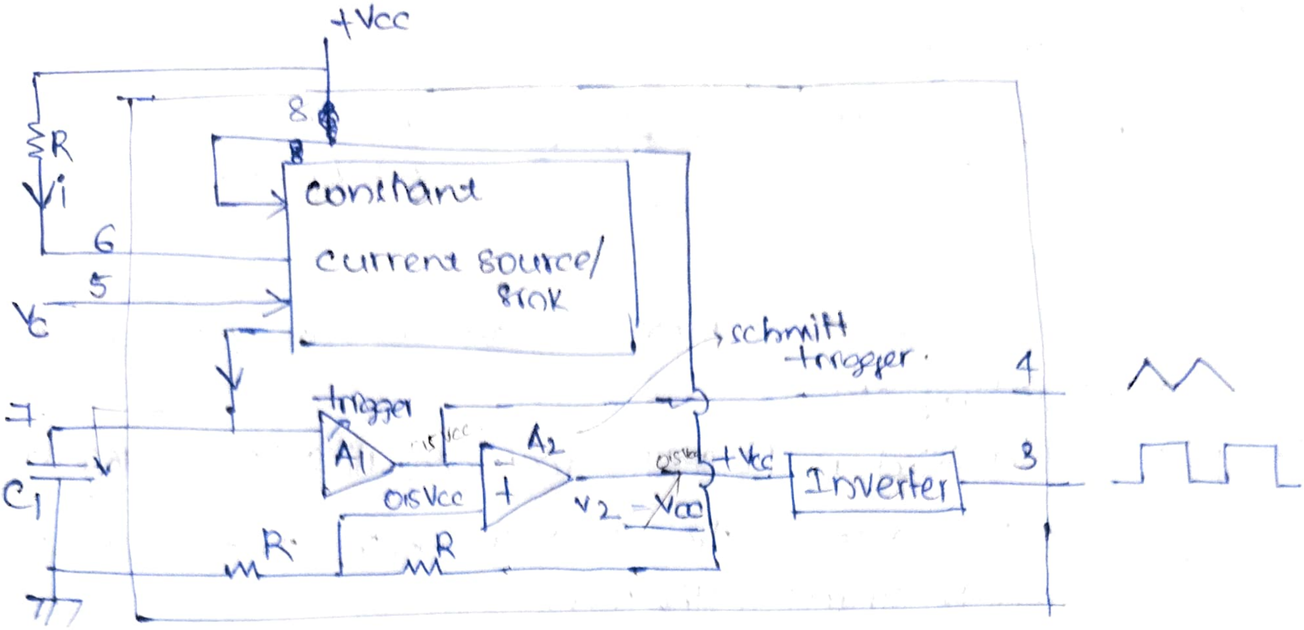


$$V_{f1} = \frac{f_1 - f_o}{K_o} \; ; \; V_{f2} = \frac{f_2 - f_o}{K_o} \qquad \Delta V_f = \frac{f_2 - f_1}{K_o}$$



IC VOLTAGE CONTROLLED OSCILLATOR NE/SE 566 (VCO)





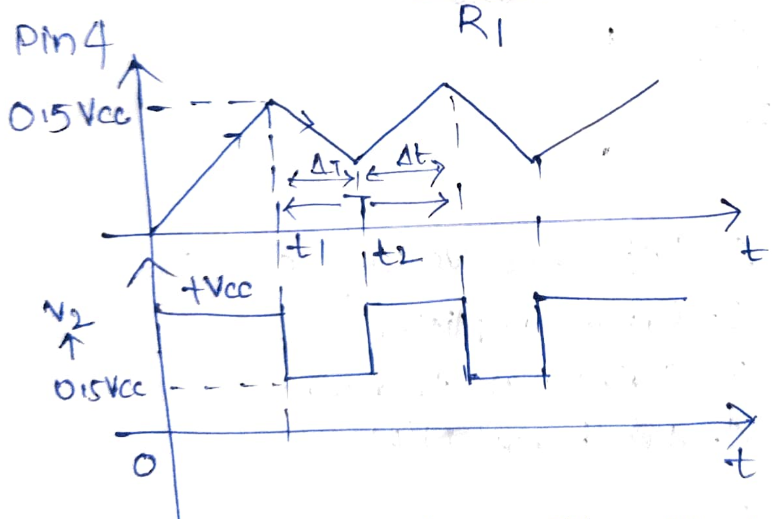
Vc - modulating input voltage.

V_2 = o/p of OPAMP A_2 = $+V_{sat} = +V_{cc}$

$-V_{sat} = 0.5\,V_{cc}$

when $V_2 = +V_{cc}$, Block behaves as Constant current source.

$$i = \frac{V_{cc} - V_c}{R_1}$$



c/p charging and discharging with same current we get triangular wave.

when $V_2 = 0.5V_{cc}$, block behaves as constant current sink.

$Q = CV$

$i = C \cdot \frac{dv}{dt}$

$$i = C_1 \cdot \frac{\Delta V}{\Delta t} = \frac{C_1(0.25\,V_{cc})}{\Delta t} \Rightarrow \boxed{\Delta t = \frac{C_1(0.25\,V_{cc})}{i}}$$

$$i = \frac{V_{cc} - V_c}{R_1}$$

$$\Delta t = \frac{C_1(0.25 V_{cc})R_1}{V_{cc} - V_c}$$

$$T = 2\Delta t = \frac{0.5 V_{cc} C_1 R_1}{V_{cc} - V_c} \quad ; \quad f_o = \frac{1}{T} = \frac{V_{cc} - V_c}{0.5 V_{cc} R_1 C_1}$$

VOLTAGE REGULATOR:

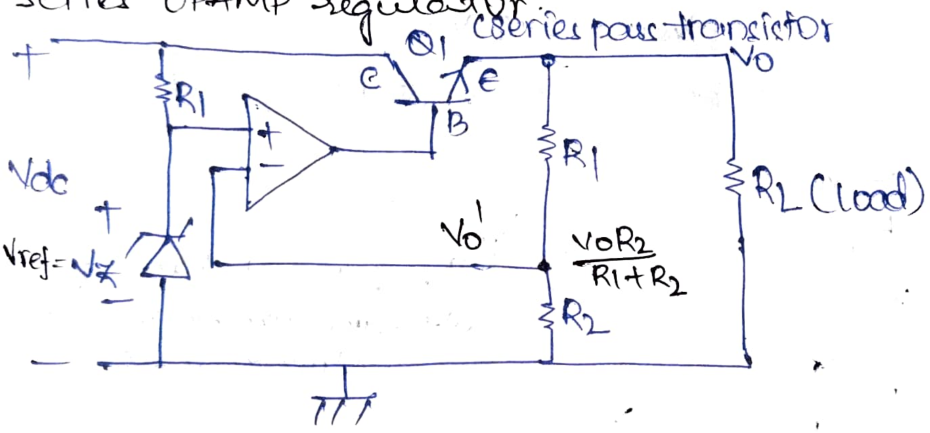
→ It is a electronic circuit that provides a voltage independent of load current, temp etc.

→ They can be classified as (i) series regulator (ii) switching regulator.

Series regulators use a power transistor connected in series b/w the unregulated DC input & the load.

Switching regulators operate the power transistor as a high frequency analog switch so that power transistor doesnot conduct current continously.

Series OPAMP regulator:



Circuit consists of 4 parts:
1. Reference voltage circuit
2. Error amplifier
3. Series pass transistor
4. feedback N/W

$$V_o' = A(V_Z - \beta V_o) \; ; \; \beta = \frac{R_2}{R_1 + R_2}$$

$$V_o' = V_o = A[V_Z - \beta V_o] \implies V_o = \frac{AV_Z}{1 + A\beta}$$

IC Voltage Regulators.

Fixed voltage series regulator:

78XX series are 3 terminal, positive voltage fixed regulators

In 78XX, the last 2 numbers (XX) indicate the o/p voltage. There are seven o/p voltage options available such as 5, 6, 8, 12, 15, 18 & 24 V.

→ 79XX series → generates –ve DC voltage.

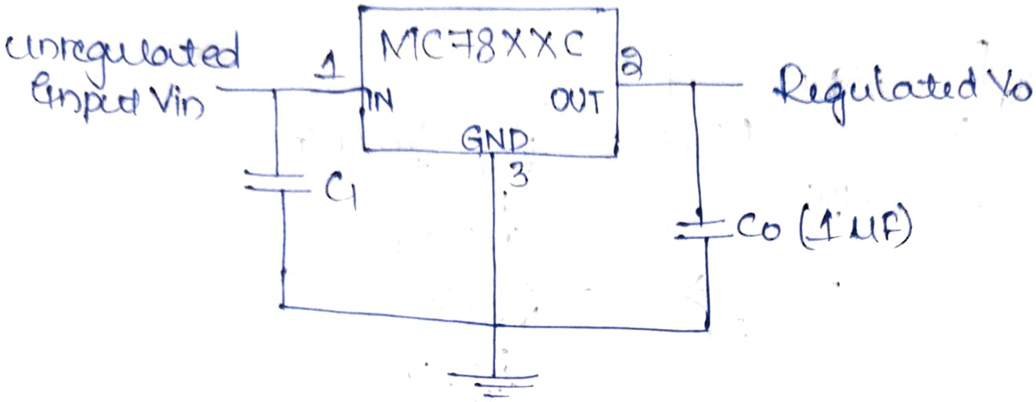


fig. standard representation of a three terminal positive regulator

Characteristics:

① Vo: The regulated o/p voltage is fixed value specified by manufacturer.

② $|V_{in}| \geq |V_o| + 2$ Volts.

The unregulated input voltage must be atleast 2V more than regulated o/p voltage

③ $I_{o(max)}$: The load current may vary from '0' to rated maximum output current.

④ Thermal shutdown: The IC has temperature sensor, which turns off the IC when it becomes hot (125°C–150°C)

Line/Input regulation:

It is defined as percentage change in o/p voltage for a change in input voltage.

load regulation:

It is defined as the change in o/p voltage for change in load current.

Ripple regulation:

The IC regulator not only keeps the o/p voltage constant but also reduces the amount of ripple.

current source

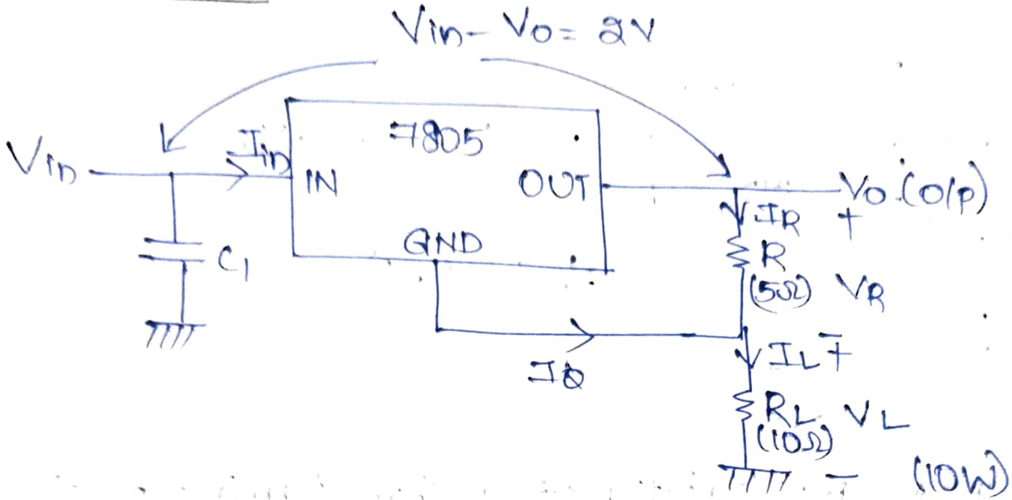


fig: IC 7805 as a current source.

The circuit is wired to supply a current of 1 Ampere to a 10Ω, 10Watt load

$$I_L = I_R + I_Q$$

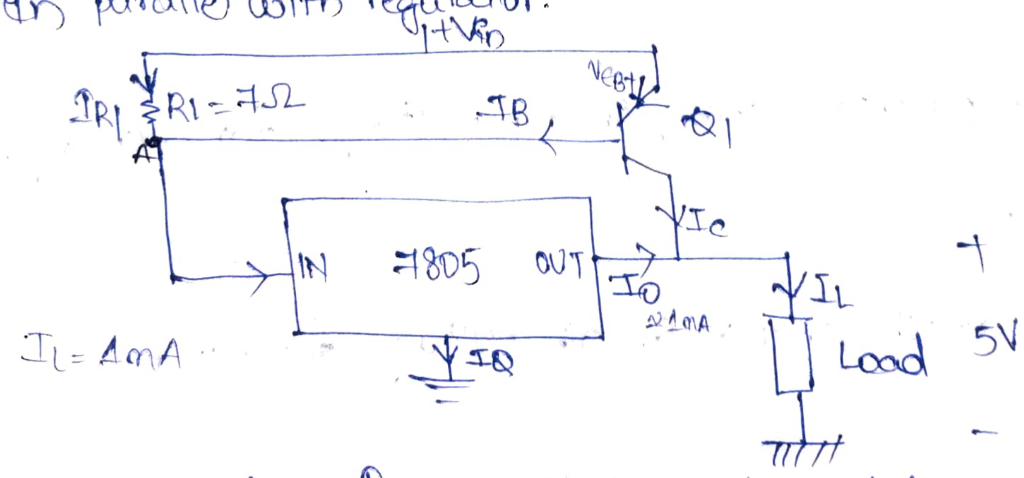
where I_Q is quiescent current & is about 4.2mA for 7805.

$$I_L = \frac{V_R}{R} + I_Q$$

Since, $I_L = 1A$, $\frac{V_R}{R} \simeq 1A$ (neglecting I_Q)

Boosting IC Regulator o/p current.

It is possible to boost the o/p current of 3 terminal regulator simply by connecting an external pass transistor in parallel with regulator.



$I_O = I_Q + I_{IN}$

very small

$\Rightarrow I_O = I_{IN}$

fig(6) Boosting a 3 terminal regulator

A) For low load currents, the voltage drop accross (R) is insufficient (<0.7V) to turn on transistor Q_1 & regulator itself is able to supply the load current. If I_L increases, V_{R1} increases when $V_{R1} = 0.7V$, transistor is turned 'on'

If $I_L = 100mA$, $V_{EB} = V_{R1} = 0.7V$

If $I_1 \geq 100mA$, the transistor Q is turned 'ON' & it supplies extra current.

when Q_1 is ON, $V_{EB(ON)}$ remains fairly constant, & excess current comes from Q_1.

$$I_L = I_C + I_o \quad \& \quad I_C = \beta I_B$$

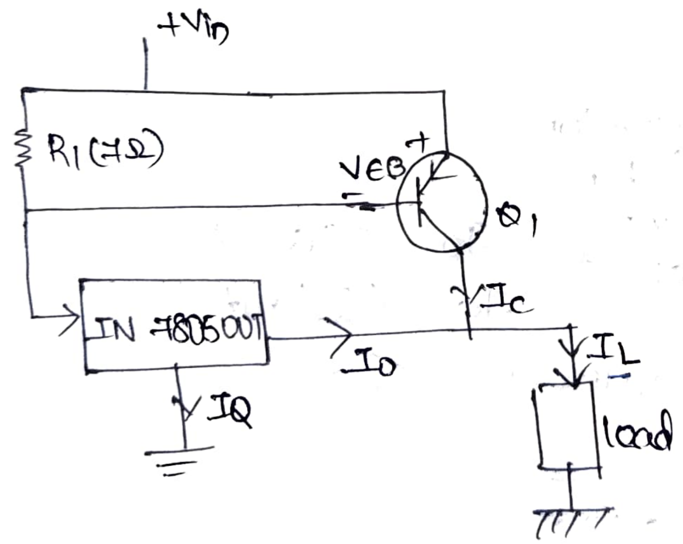
for regulator $\rightarrow I_o = I_i - I_Q$, $I_o \approx I_1$

(KCL at A) $I_B = I_i - I_{R1} = I_o - I_{R1}$

$$I_B \cong I_o - \frac{V_{EB(ON)}}{R_1}$$

$$I_L = (\beta+1) I_o - \frac{\beta V_{EB(ON)}}{R_1}$$

Q)



Let $V_{EB(ON)} = 1V$ & $\beta = 15$. Calculate the o/p current coming from 7805 & Ic coming from transistor Q_1 for loads 100Ω, 5Ω, 1Ω.

Ans: for load 100Ω: for 7805, the o/p voltage across load will be 5V.

$$I_L = \frac{5V}{100} = 50mA.$$

let Q_1 be off, then, $V_{EB} = 50mA \times 7\Omega \Rightarrow V_{EB} = 350mV$

so, Q_1 is OFF,

$I_C = 0$; $I_L = I_O = 50mA$ $\nearrow I_C + I_O/\beta = I_O$, $I_C = I_O$

for load 5Ω: for 7805, the o/p voltage across load will be 5V

$$I_L = \frac{5}{5} = 1A \Rightarrow Q_1 \text{ is ON.}$$

$$I_L = (\beta+1) I_O - \frac{\beta V_{EB(ON)}}{R_1}$$

$$1 = (16) I_O - \frac{15 \times 1}{7} \Rightarrow \underline{I_O = 196mA.}$$

$I_O + I_C = I_L$

$196mA + I_C = 1A$

$\Rightarrow \underline{I_C = 804mA}$

for load 1Ω:

Assume Q_1 is OFF ($I_C = 0$) $\rightarrow I_L = \frac{5}{1} = 5A$

$V_{EB} = 5 \times 7 = 35V$

so, Q_1 is (ON)

$$I_L = (\beta+1) I_O - \frac{\beta V_{EB(ON)}}{R_1}$$

$$35 = 16 I_O - \frac{15 \times 1}{7} \Rightarrow I_O = 446mA$$

$I_C = 454mA$

Fixed Regulator used as Adjustable Regulator:

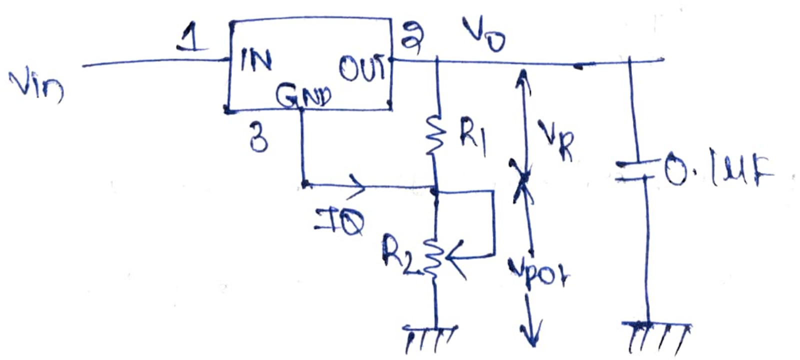


fig 1.

$V_O = V_R + V_{POT} = V_R + (I_Q + I_{R1}) R_2 \Rightarrow V_O = V_R + I_Q R_2 + \frac{V_R}{R_1} R_2$

I_Q is neglected

$$\boxed{V_O \simeq V_R \left(1 + R_2/R_1\right)}$$

→ choose a small value R_2, so the effect of $I_Q R_2$ is not effected

ex: Specify suitable component value to get $V_O = 7.5\,V$ in the circuit of fig 1 using a 7805 using a 7805 regulator.

Sol from the data sheet of 7805,

$I_Q = 4.2\,mA$

we choose $I_{R1} = 25\,mA$,

As $V_R = 5V$, for 7805, $R_1 = \frac{5\,V}{25\,mA} = 200\,\Omega$; $V_{R2} = 2.5\,V$

$$R_2 = \frac{V_{R2}}{I_{R1} + I_Q} \Rightarrow R_2 = 856\,\Omega$$