As the gain of integrator ↓, with freq ↑, the integrator ckt will not have frequency as differentiator

ii) At low frequency, gain becomes ∞,

J.S.
19/07/11

~~20/7/11~~
27/7/11

V-I Converter (Trans Conductance Amplifier)

(i) floating load.

(ii) Grounded load.

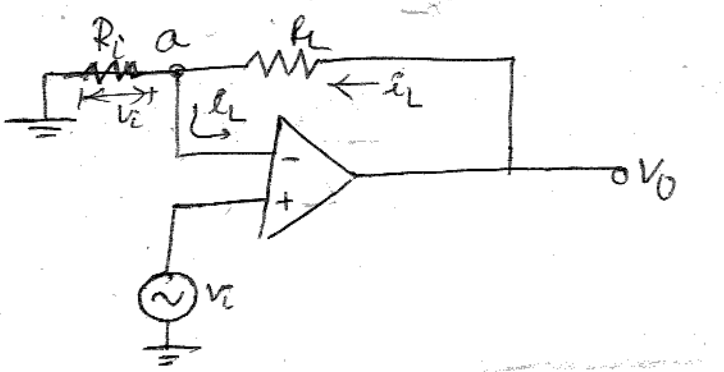
$V_i \rightarrow i/p$

$I_o \rightarrow o/p$

$$I = \frac{V}{R} = \left(\frac{1}{R}\right) V$$

↑ Conductance.

Floating load :-

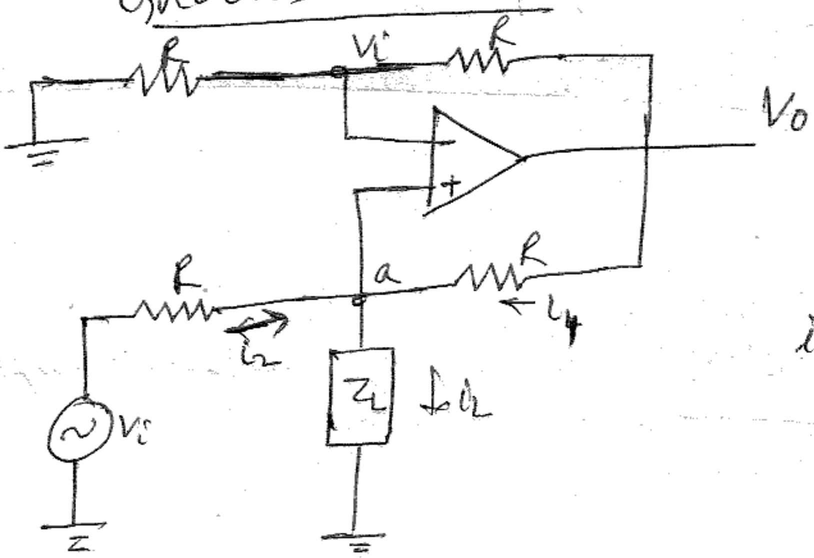


Since op-amp is said to be ideal,

$$V_i = R_i \, i_L$$

$$\boxed{i_L = \frac{V_i}{R_i}}$$

GROUNDED LOAD



$i_L = i_1 + i_2$

$V_i \rightarrow i_L$
↳ load Current

Apply KCL, at node 'a',

$$i_1 = i_2 + i_L$$

$$\frac{V_o - V_a}{R} = \frac{V_i}{R} + \frac{V_a}{Z_L}$$

$$\Rightarrow \frac{V_o}{\cancel{R}} = \left[\frac{V_i}{R} + \frac{V_a}{Z_L} + \frac{V_a}{R}\right] R$$

$$V_o = \left[V_i + \frac{V_a R}{Z_L} + V_a\right]$$

Gain of Non inverting terminal

$$= 1 + \frac{R_f}{R_a} = 1 + \frac{R}{R}$$

$$= 2.$$

$$V_o = \text{gain}\,(V_i)$$

$$\Rightarrow V_i + V_a + \frac{V_a(R)}{Z_L} = 2[V_i]$$

Apply KCL at node a.

$$i_1 + i_2 = i_L \,;$$

$$i_L = \frac{V_o - V_a}{R} + \frac{V_i - V_a}{R}$$

$$i_L R = V_o - V_a + V_i - V_a$$

$$= V_o + V_i - 2V_a$$

$$\Rightarrow \boxed{2V_a = V_o + V_i - i_L R}.$$

Gain of Non- Inverting terminal

$$= 1 + \frac{R_f}{R} = 1 + R/R = 2$$

$$V_o = \text{gain}\,(\text{i/p voltage})$$

$$= 2V_a.$$

$$V_o = V_o + V_i - i_L R$$

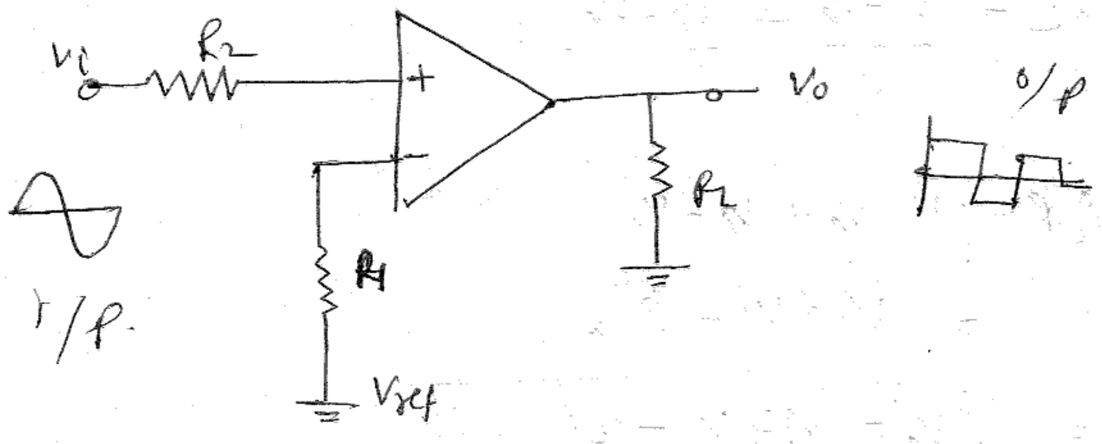
$$\Rightarrow \quad V_i = i_L R \quad \Rightarrow \boxed{i_L = \frac{V_i}{R}}$$

As I/P impedance of non-inverting amplifier is very high, this ckt has the advantage of drawing a very little current from the source.

Applications :-

(i) LED,
(ii) ZENER DIODE TESTER

COMPORATOR :-

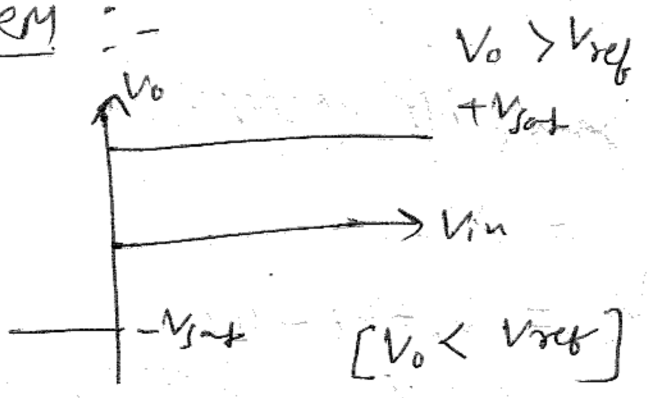


$V_i \rightarrow$ Varying w.r to time &

V_{ref} = Constant voltage

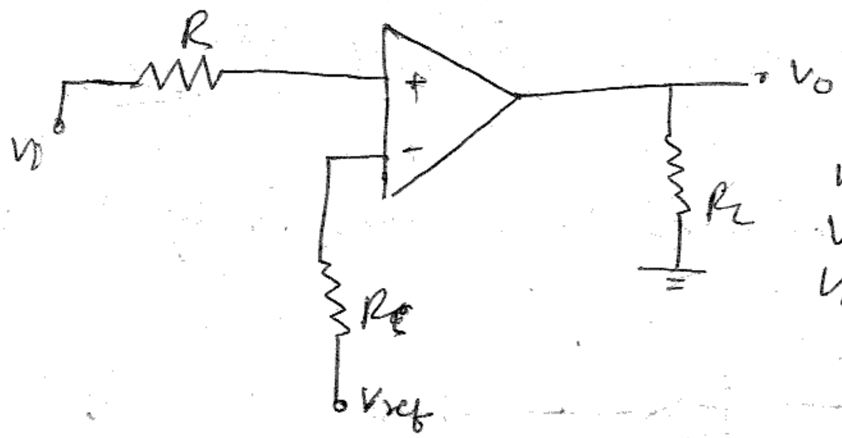
WAVEFORM :-

always
I/P is Sinewave }
O/P is Square wave }

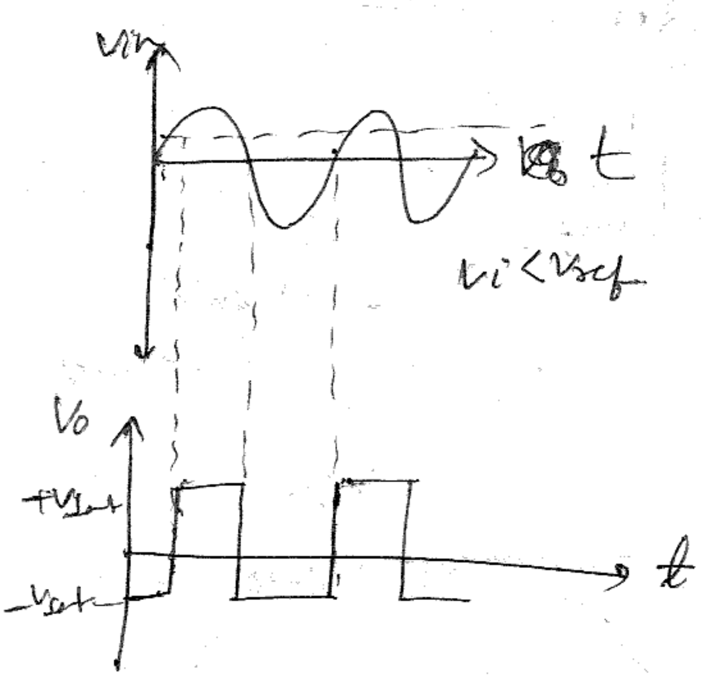


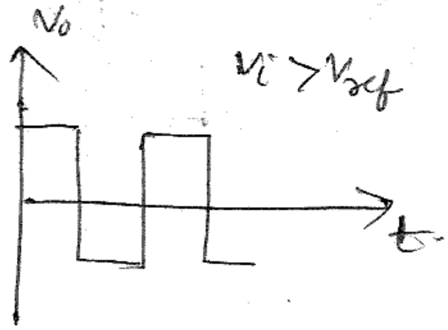
ideal Comparator

Non-Inverting

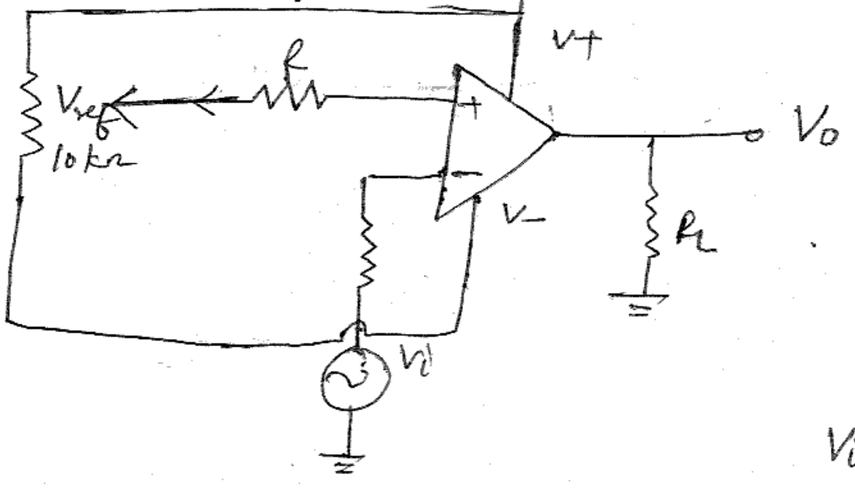


o/p
when
Vi < Vref
$V_0 = -V_{sat}$.





Inverting Comparator



$V_i < V_{ref}$

$V_0 = +V_{sat}$

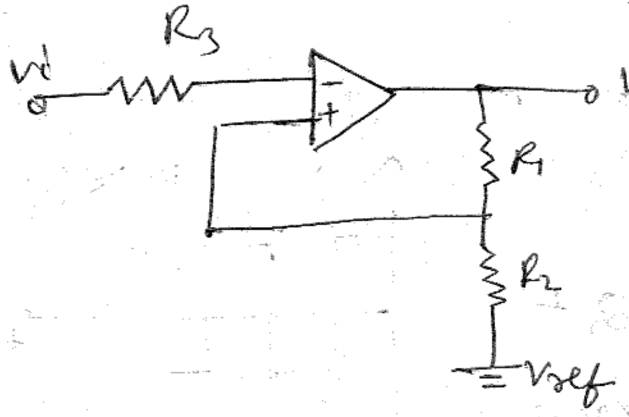
$V_i > V_{ref}$

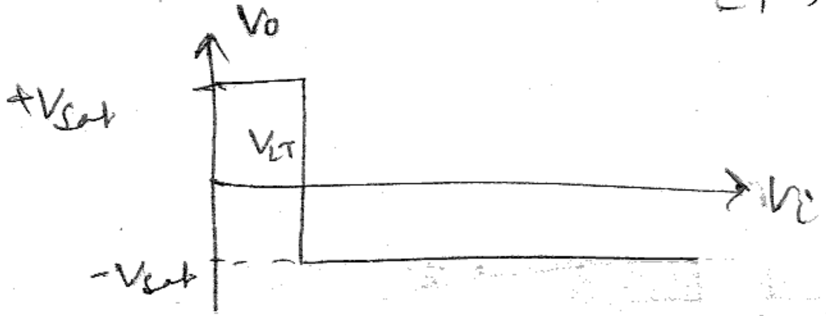
$V_0 = -V_{sat}$

Regenerative Comparator :-

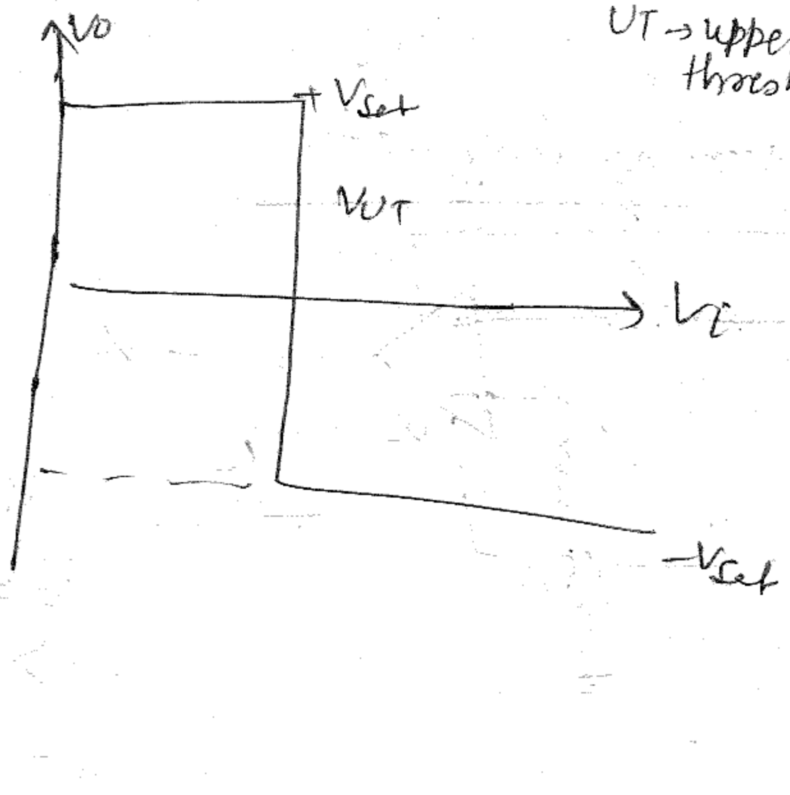
→ also known as Schmitt Trigger

→ Converts sine wave to square wave



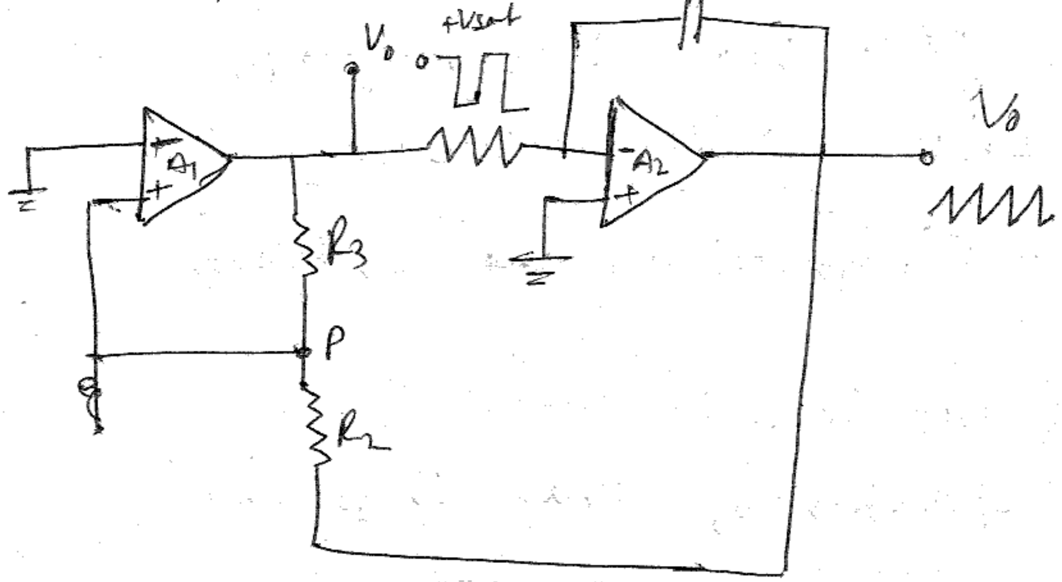


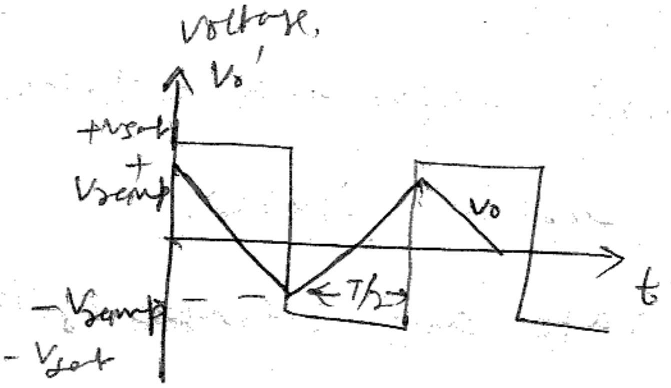
LT → Lower Threshold.



UT → upper threshold

Triangular wave generation





3/8/14 Important Q

→ ① R-C phase shift oscillator
→ ~~Wein Bridge oscillator~~
→ ② Differentiator and Integrator

③ Wilson current source.

④ operation of ~~Phase shift~~ basic differential amplifier.

⑤ Frequency Componsation techniques.

⑥ Wibler Current source.

⑦ slew rate and methods of improving slew rate.

⑧ Voltage to Current Convertor.
④ Triangular wave generator.

⑨. schmitt Trigger., and Comparator.

4/8/11

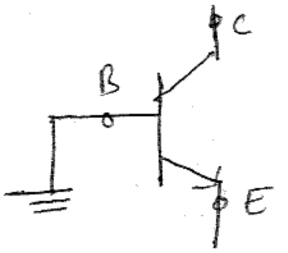
Precission Diode Rectifier (PDR)

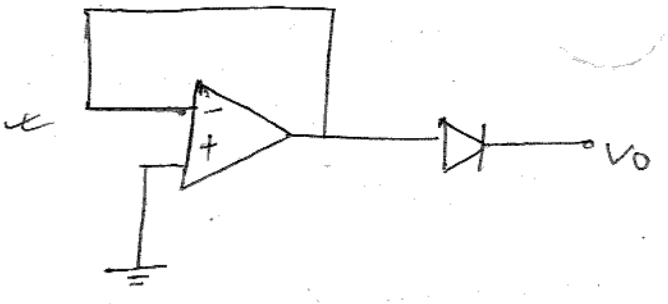
Diode (Cut in volt) ≃ 0.6 volt

Ideal voltage operates only above the cut in voltage.

⇒ ~~RRP~~ PDR Can operate below 0.6 V.

⇒ Process to make transistor as a diode.



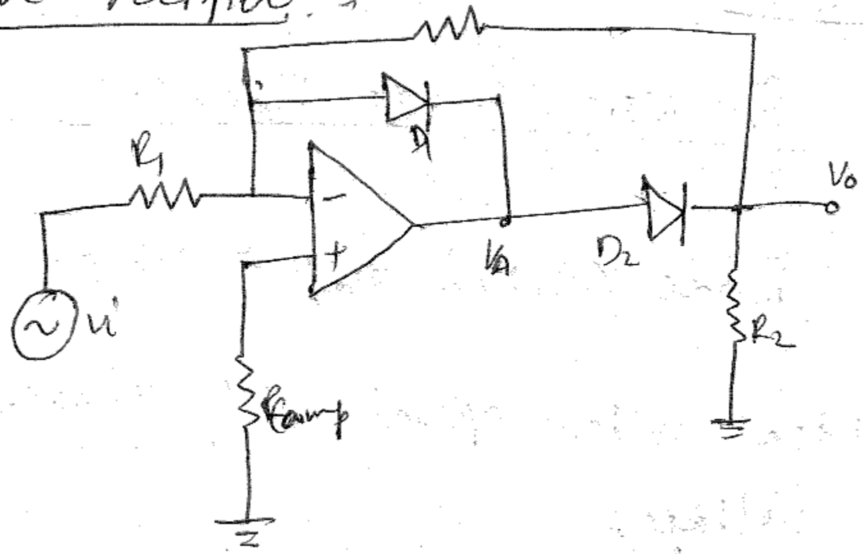


This ckt is also called Precission diode by Connecting a diode in the feedback path of an op-amp. This ckt is capable of rectifying I/P Signal of millivolts.

Types of Rectifier

(i) Half wave
(ii) full wave

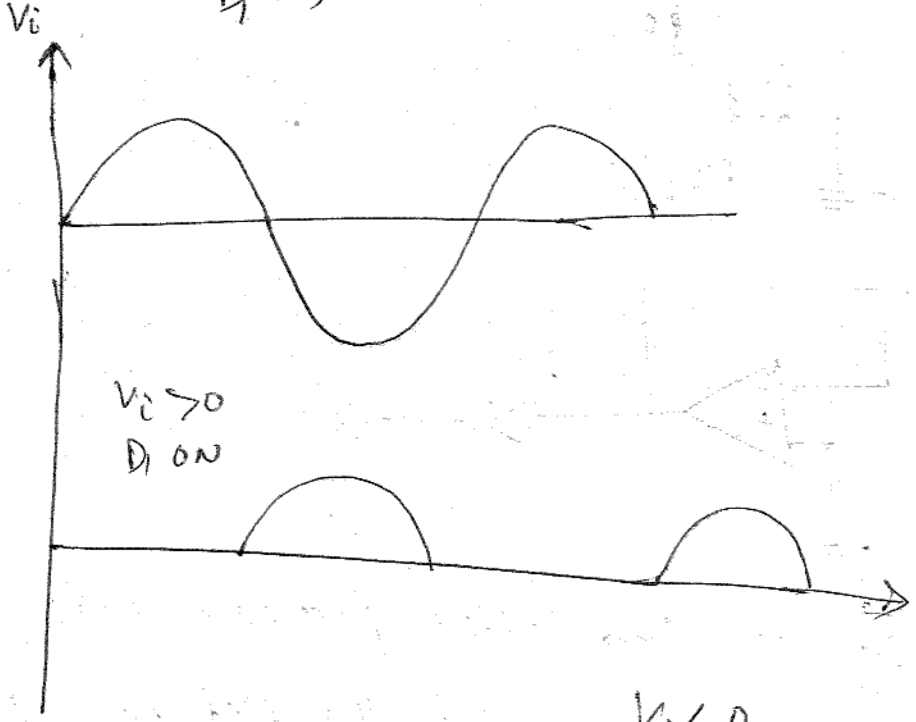
Half wave rectifier :-



Analysis :- $V_i > 0V$

L +ve

$D_1 \rightarrow$ Conduct



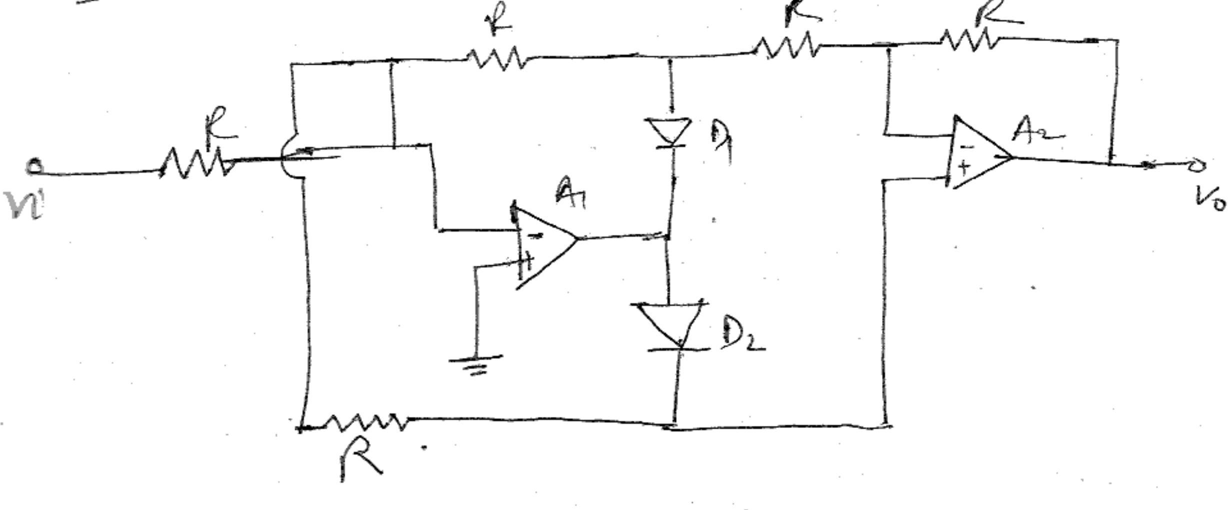
$V_i < 0$

$D_1 \rightarrow$ OFF

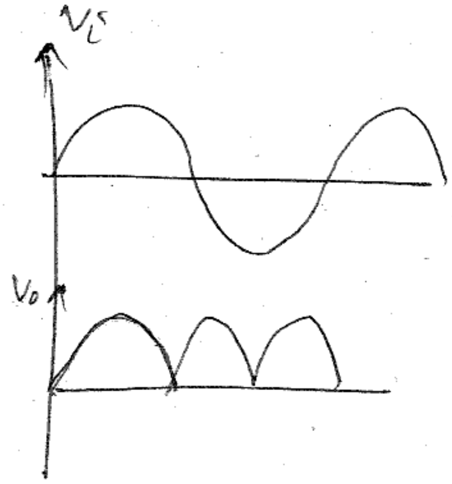
$D_2 \rightarrow$ ON

$V_0 \rightarrow$ ON

Full wave Rectifier



Both the op-amps act as inverter and O/P voltage V_o = I/p voltage v_i.



opon :-

$V_i > 0$

$D_1 \rightarrow ON$

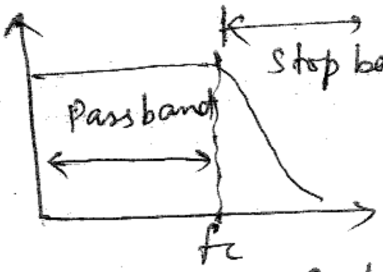
$D_2 \rightarrow OFF$

10/8/12.

FILTERS

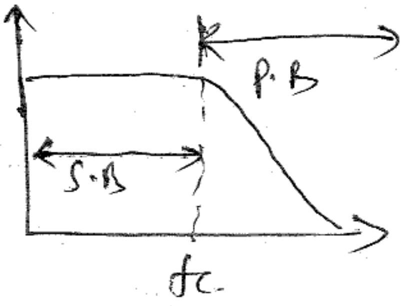
types:- LPF
HPF
BPF

A filter is a circuit that process the signals based on frequency dependency characteristics, the manner in which the behaviour of the filter varies frequency, is known as frequency response.

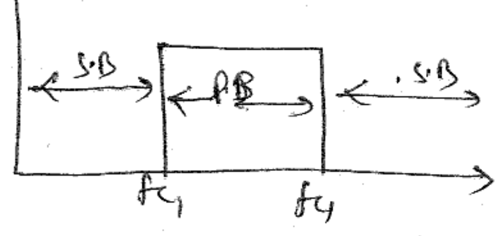


LPF: it allows only lower freq. which is lower than cutoff freq

HPF:-

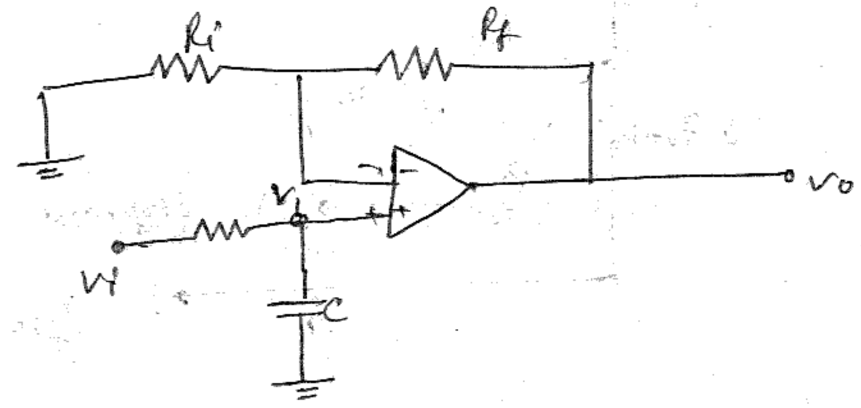


BPF:-



BPF:- It allows only particular range of frequency.

First order LPF



First order filter :- Consist of single RC n/wk, Connected to non-inverting terminal. Ri & Rf determines the gain of the filter in pass band.

Voltage at C

voltage across capacitor, $V_1(s) = \frac{1/sC}{R+\frac{1}{sC}} V_i(s)$

$$\Rightarrow \boxed{\frac{V_1(s)}{V_i(s)} = \frac{1}{1+sCR}}$$

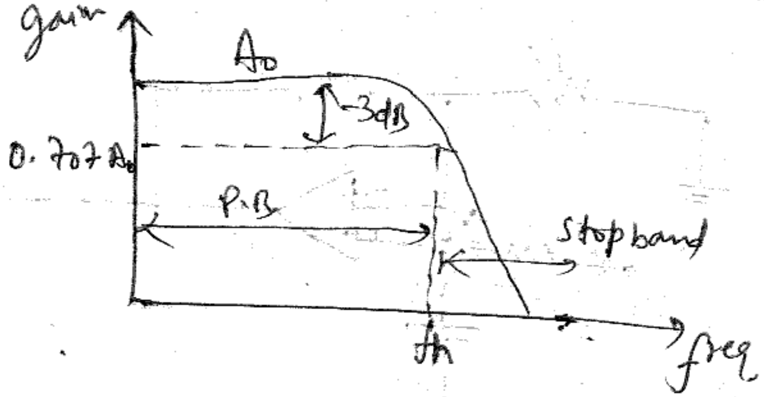
Gain of op-amp :- $\boxed{\frac{V_o}{V_1} = 1+\frac{R_f}{R_i}}$

Now,

$$\frac{V_o}{V_i} = \frac{V_o}{V_1} \times \frac{V_1}{V_i} = \left(1+\frac{R_f}{R_i}\right)\left(\frac{1}{1+sCR}\right)$$

$$\Rightarrow \boxed{\frac{V_o}{V_i} = \left(A_{OL} \cdot \frac{1}{1+sCR}\right)} \quad \because A_{OL} = 1+\frac{R_f}{R_i}$$

Frequency Response :-



$$\because \frac{V_0(s)}{V_i(s)} = \frac{A_0}{1+sCR} \Rightarrow H(s) = \frac{A_0}{1+sCR}$$

$\because$ Put $s = j\omega$

$$\Rightarrow H(j\omega) = \frac{A_0}{1+j\omega CR}$$

Put $\frac{1}{RC} = \omega_0$

Substitute $\frac{1}{RC} = \omega_h$

$$\Rightarrow H(j\omega) = \frac{A_0}{1+j\omega/\omega_h}$$

$$\boxed{H(j\omega) = \frac{A_0}{1+(f/f_h)}}$$

f_h → Cut off frequency.

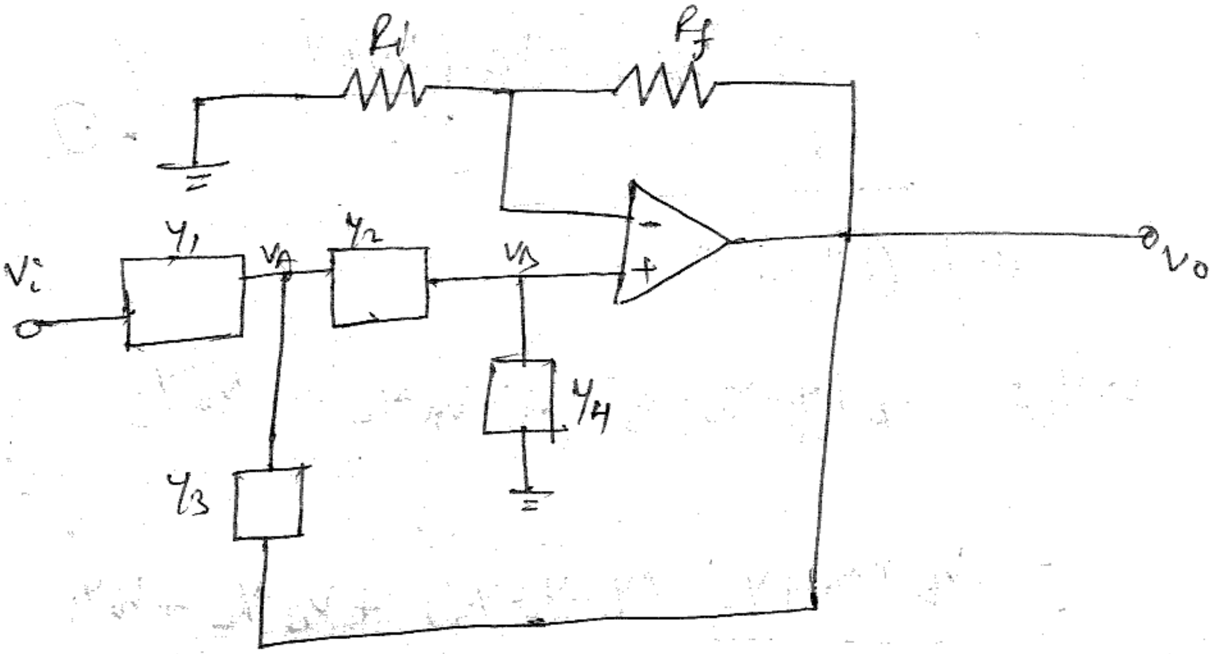
If $f < f_h$ → Pass Band

$f = f_h \Rightarrow$ gain $= 0.707 A_0$

$$v_i Y_r = V_A Y_1 - V_A Y_2 + V_B Y_2 - V_A Y_3 + V_0 Y_3$$

$$\Rightarrow V_i Y_1 = V_A(Y_1 - Y_2 - Y_3) + V_B Y_2$$

Second order LPF (Sallen Key filter)



An improved version filter responds can be obtained by using 2nd order active filter. It consist of 2 Rc pairs, and has a slope of -40dB

$$\text{Gain} \quad \boxed{A = \frac{V_0}{V_B} = 1 + \frac{R_f}{R_i}}$$

Apply KCL at node 'A',

$$(V_i - V_A)Y_1 + (V_A - V_B)Y_2 + (V_A - V_0)Y_3 = 0$$

$$\Rightarrow \cancel{V_i Y_1 = V_A(Y_1 + Y_2 + Y_2) + V_0 Y_3} \quad \text{—①}$$

$$V_i Y_1 = V_A Y_1 - V_A Y_2 - V_A Y_3 + V_B Y_2 + V_0 Y_3$$

$$V_i Y_1 = V_A(Y_1 - Y_2 - Y_3) + V_B Y_2 + V_0 Y_3$$

Apply KCL at 'B',

$$V_B(Y_4) + (V_B - V_A)Y_2 = 0$$

$$V_B(Y_4 + Y_2) = V_A Y_2$$

$$\boxed{V_A = \frac{V_B(Y_4+Y_2)}{Y_2}} \quad \text{②}$$

Sub ② in ①,

$$V_i Y_1 = V_A(Y_1 - Y_2 - Y_3) + V_B Y_2 + V_o Y_3$$

$$= \frac{V_B(Y_4+Y_2)}{Y_2}(Y_1 - Y_2 - Y_3) + V_B Y_2 + V_o Y_3$$

$$= V_B\left[\frac{(Y_4+Y_2)(Y_1-Y_2-Y_3)}{Y_2} + Y_2\right] + V_o Y_3$$

$$= V_B\left\{\frac{Y_1Y_4 - Y_2Y_4 - Y_3Y_4 + Y_1Y_2 - \cancel{Y_2^2} - Y_2Y_3 + \cancel{Y_2^2}}{Y_2}\right\} + V_o Y_3$$

$$= V_B\left\{\frac{Y_1Y_4 - Y_2Y_4 - Y_3Y_4 + Y_1Y_2 - Y_2Y_3}{Y_2}\right\} + V_o Y_3$$

~~Apply kcl at node A~~

~~$(V_A - V_i)Y_1 + (V_B - V_A)Y_2 + (V_0 - V_A)Y_3 = 0$~~

Sub ② in ①,

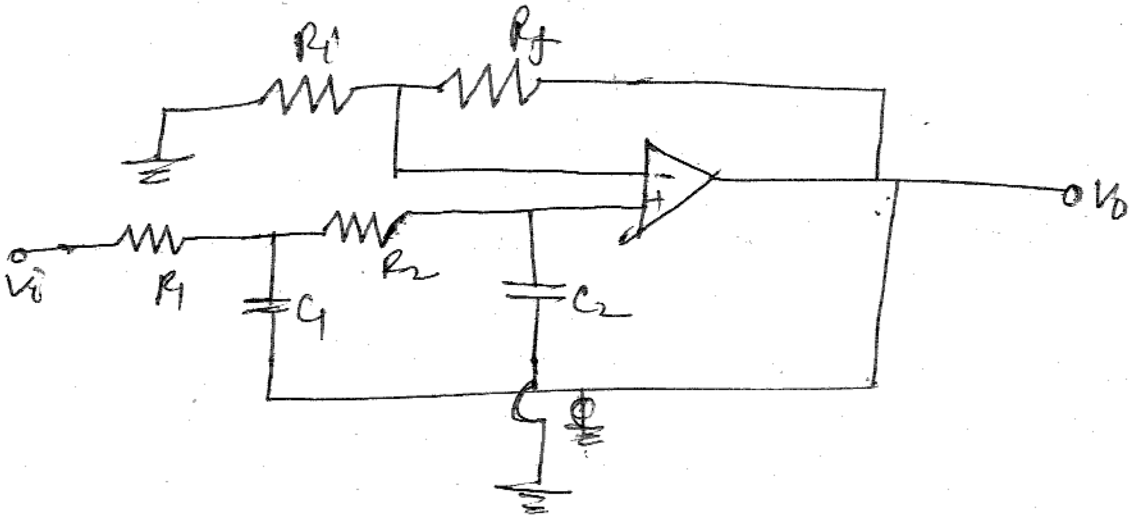
$$V_i Y_1 = \frac{V_B}{Y_2}(y_2 + y_4)(y_1 + y_2 + y_3) - V_0 Y_3 - V_0 y_2$$

we set $\frac{V_0}{V_B} = A$

$$\Rightarrow \boxed{V_0 = A V_B}$$

$$\boxed{\frac{V_0}{V_i} = \frac{A Y_1 Y_2}{Y_1 Y_2 + Y_4 (y_1 + y_2 + y_3) + Y_3 y_3 (1 - A)}}$$

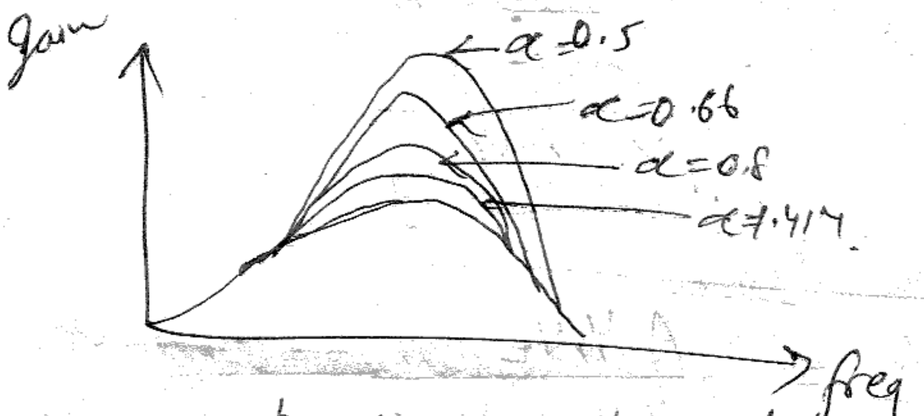
To make it a 2nd order filter, as low pass filter choose $y_1 = y_2 = \frac{1}{R}$ and $Y_3 = Y_4 = Sc$



$$\frac{V_0(s)}{V_i(s)} = \frac{A}{1+s^2C^2R^2+sCR(3-A)}$$

$$H(s) = \frac{A}{1+s^2C^2R^2+sCR(3-A)}$$

$$\boxed{\text{damping coefficient } \alpha = 3-A}$$



The flatest Pass band occurs for damping Coefficient of $\alpha = 1.414$, this is called Butter worth filter, audio filters are usually Butter worth filter.

11/8/11

Band pass filter

$\longrightarrow$ NBPF $(Q > 10)$

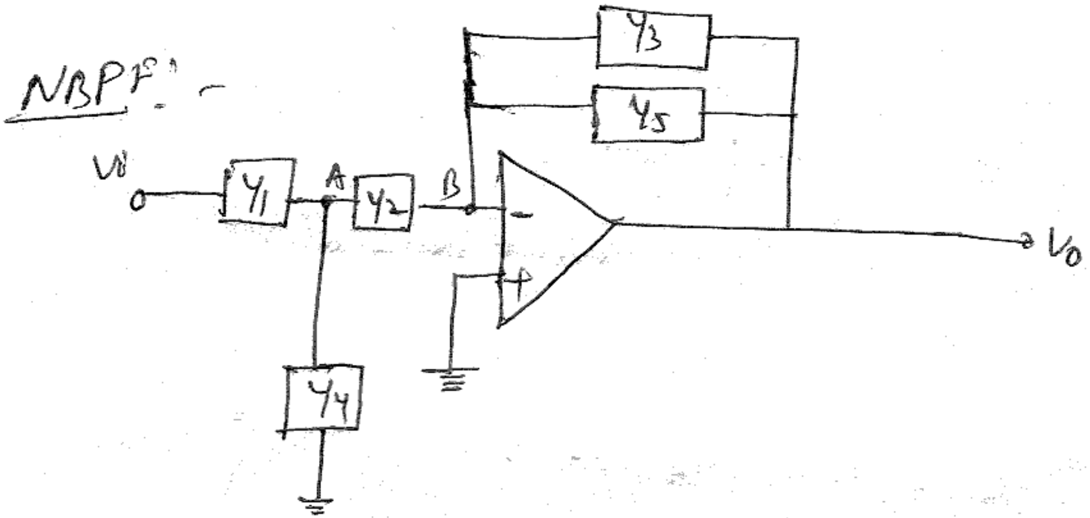
$\longrightarrow$ WBPF $(Q < 10)$

Narrow BPF → Path Narrow

wideband BPF → wide.

Quality Filter :- $\boxed{Q = \frac{f_0}{BW}}$

NBPF :-



Apply KCL at node A,

$$V_i Y_1 = (V_A - V_B) Y_2 + V_A Y_4$$

$$V_i Y_1 = V_A (Y_2 + Y_4)$$

$\because V_B = 0$

$\because V_B$ is at ground potential;

apply ~~KCL~~ at node B,

$$(V_A - V_B) Y_2 = (V_B - V_o) Y_5 + (V_B - V_o) Y_3$$

$[V_B = 0]$,

$$V_A Y_2 = \cancel{V_B} Y_5 - V_o Y_5 + V_B Y_3 - V_o Y_3$$

$$V_o(y_5+y_3) = V_B(y_5+y_3) - V_A y_2$$

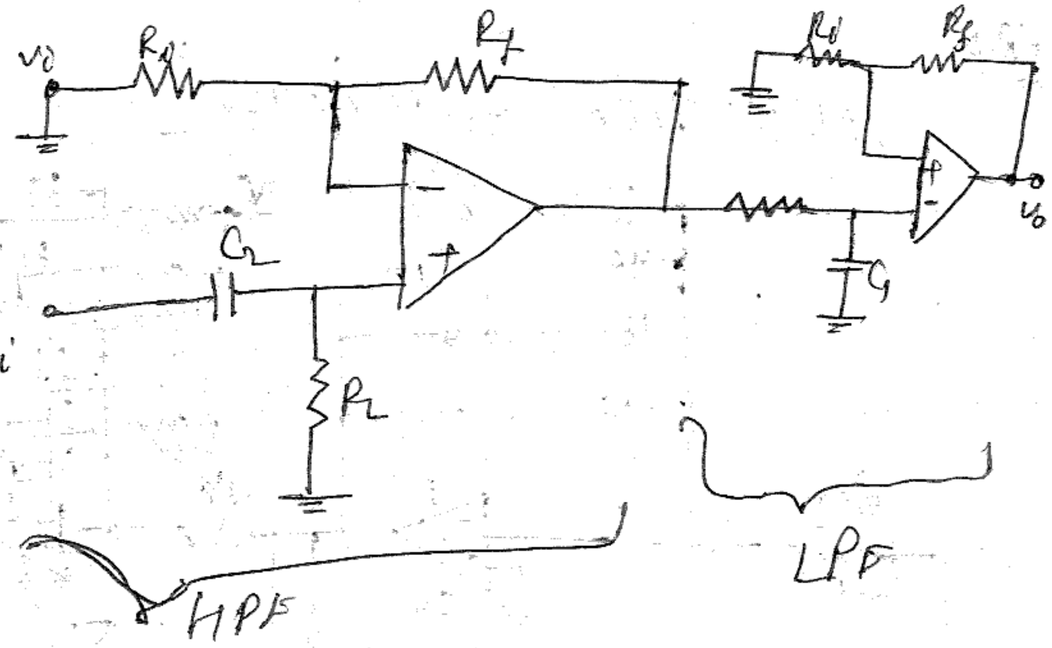
$$\boxed{V_o = -V_A y_2 / y_5 + y_3} \quad ②$$

$$\boxed{\frac{V_o}{V_i} = \frac{-y_1 y_2}{(y_3+y_5)(y_2+y_4)}}$$

for,

to be band pass filter (narrow), put $y_1 = G_1$, $y_2 = SC_2$, $y_3 = SC_3$, $y_4 = G_4$, $y_5 = G_5$.

wide band pass filter :- It is formed by cascading high pass filter with low pass filter



11/8/11

~~Band Pass filter~~

- ~~→ NBPF~~
- ~~→~~

~~Ⓖ~~

~~$= \frac{1}{3}(f_L+f_3) - \frac{V_4}{2}$~~

~~Narrow BPF →~~

~~wideband~~

~~Quality~~

$$\boxed{A_0 = A_{01} \times A_{02}}$$

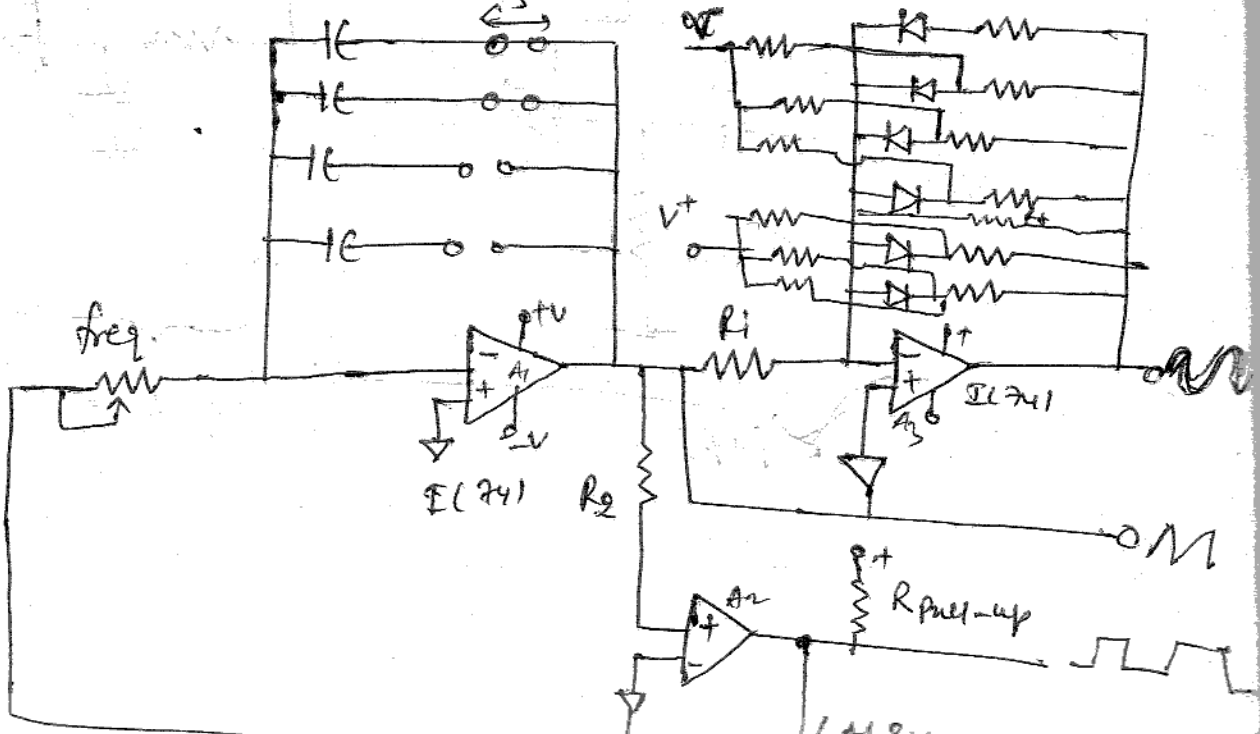
voltage gain

~~ta~~ of band pass ... the product of gain of low pass filter and high pass filter

$$\boxed{\left|\frac{V_0}{V_i}\right| = \left|\frac{A_0 (f/f_L)}{R_f \sqrt{1+(f/f_H)^2}\sqrt{1+(f/f_L)^2}}\right|}$$

11/8/11.

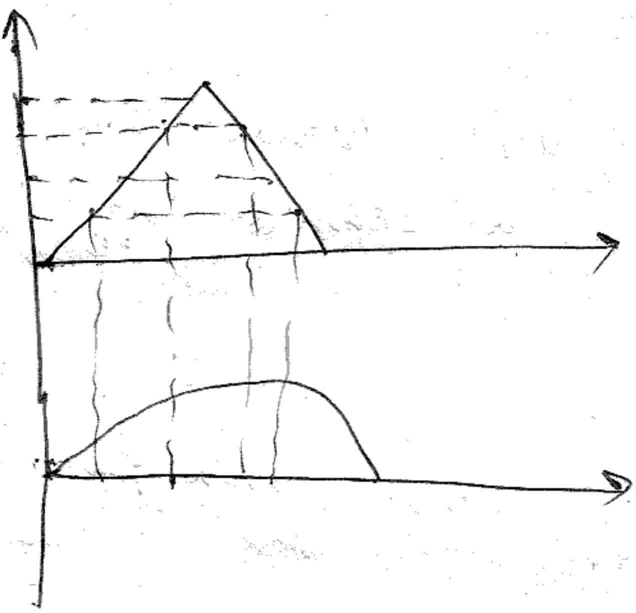
FUNCTION GENERATOR

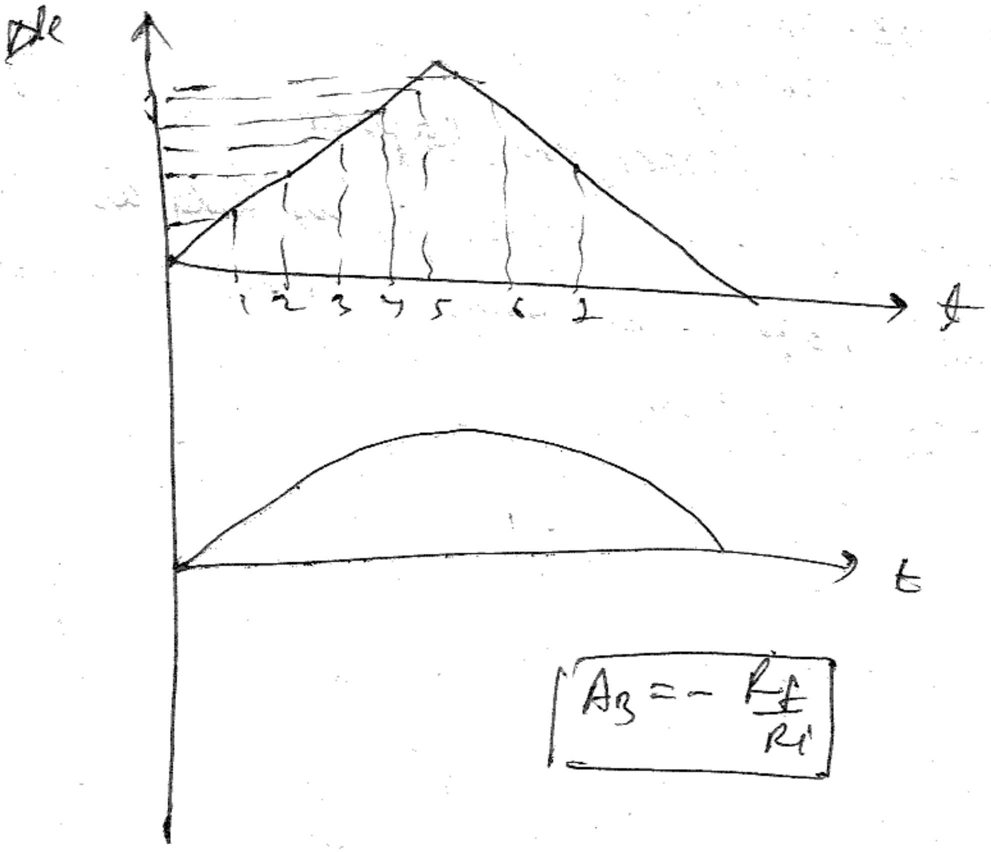


LM311 represents Comparator

A_1 acts as integrator

A_3 act as sine wave shaper.





$$\boxed{A_3 = -\frac{R_f}{R_1}}$$

Function generator produces three types of waveforms, it is possible to achieve the frequency from very low value (0.01 Hz to 10 MHz) without significant distortion.

⇒ op-amp A_2 produces square waveform as it is used as a schmitt trigger, or Comparator

⇒ LM311 represents a high speed Comparator to produce square wave with fast rise & fall time.

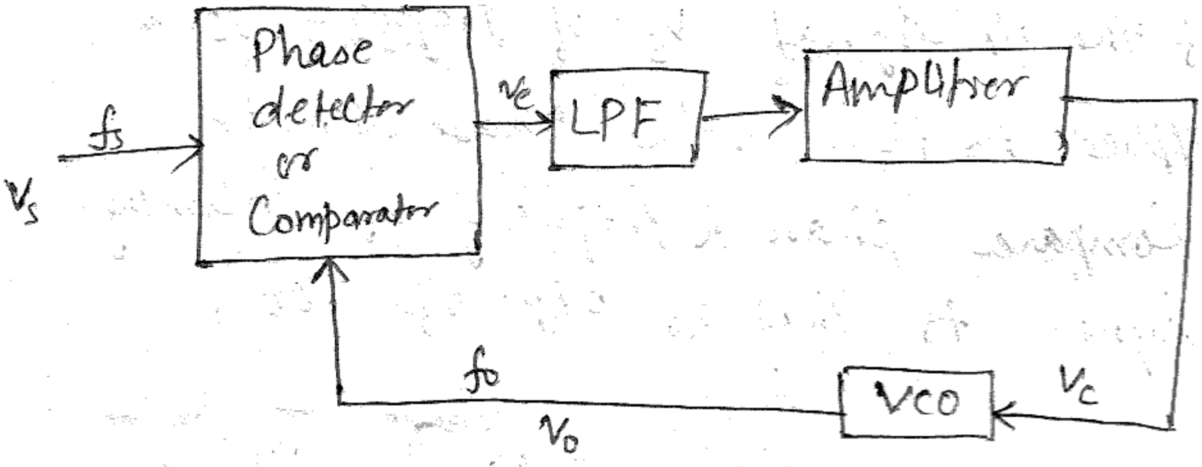
⇒ The op-amp A_1 is used as integrator to produce triangular waveform.

⇒ Switch S selects the capacitor & operating frequency. . A_3 (op-amp) is used as sine shaper it shapes triangular wave into sine waveform

17/8/14.

UNIT 3

Phase Locked Loop



(1) Phase detector or Comparator

O/P → (f_s+f_o) or (f_s-f_o)

LPF → It filters the high freq & allow the low freq (f_s-f_o)

V_c → dc voltage

$$\boxed{V_o \propto V_c}$$

Lock in range :- when $f_s=f_o$, then PLL is said to be locked.

Capture range :- range of freq $f_o=f_s$.

⇒ VCO (Voltage Controlled oscillator), is a free running multivibrator & operates at a set frequency f_o called free running frequency.

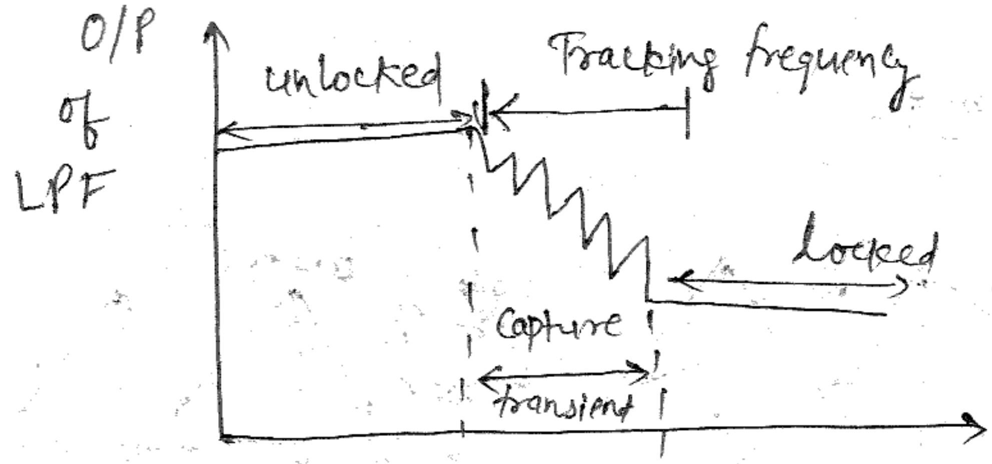
The frequency deviation is directly proportional to V_c Controlled voltage & hence it is Called VCO.

If the I/P signal V_s of frequency f_s is applied to PLL, the phase detector Compares phase & frequency of incoming Signal, to that of O/P of VCO.

Locked in Range:- Once the PLL is locked it Can track the frequency in the incoming Signal, the range of frequency over which the PLL Can maintain is known as Lock in range.

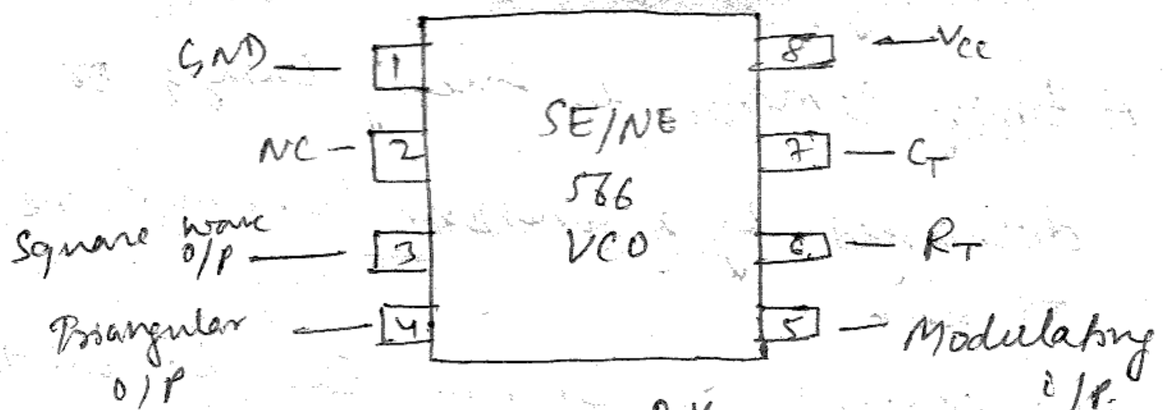
Captured Range:- The range of frequencies over which the PLL Can acquire Lock Called as Capture range.

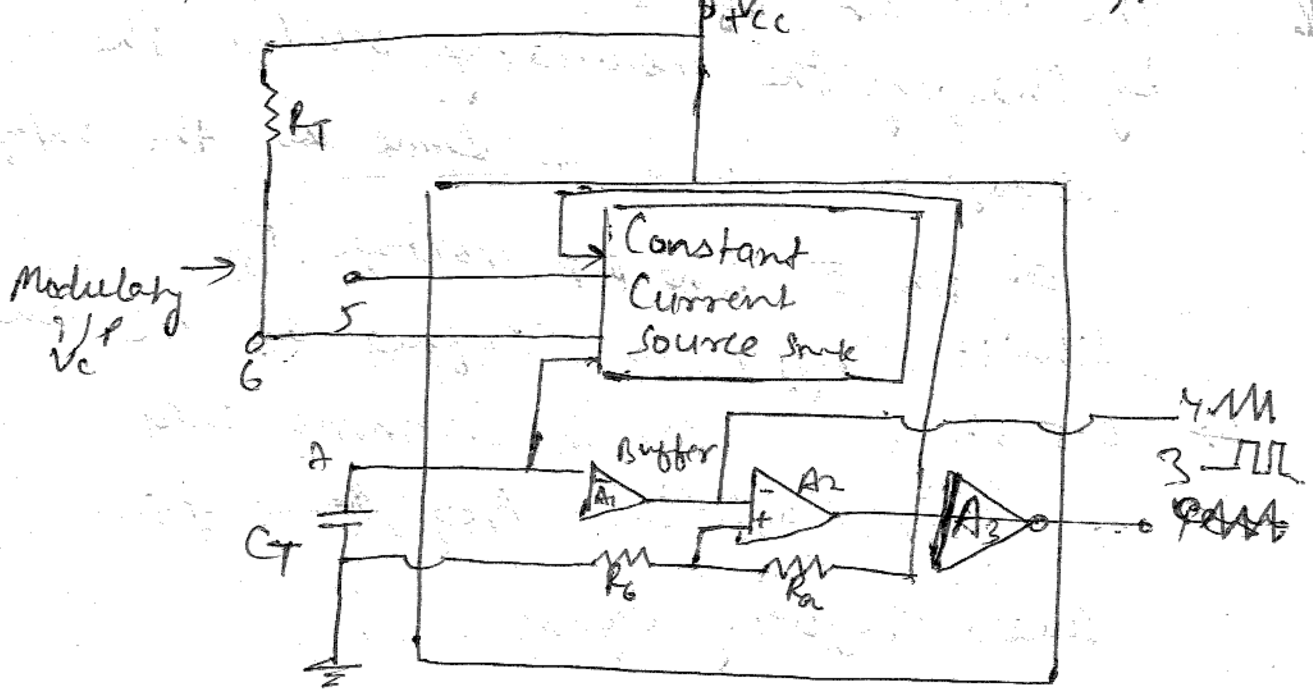
Pull-in time:- The total time taken by the PLL to Stablish lock



Capture transient.

Voltage Controlled Oscillator





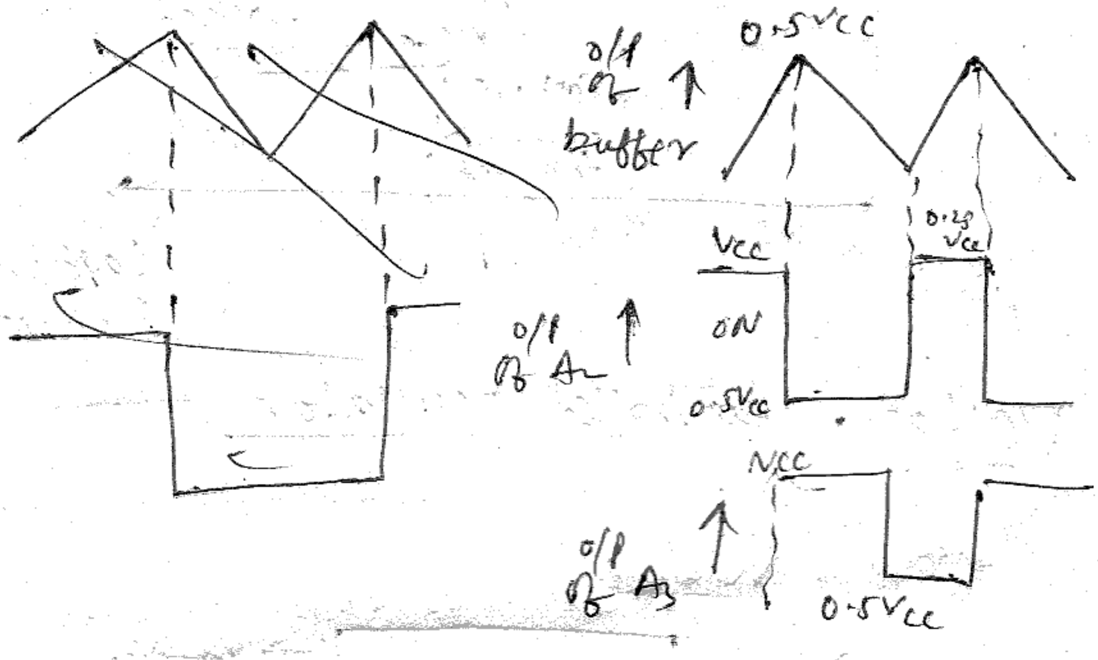
Block Diagram of VCO

A_2 → Schmitt Trigger

A_3 → inverter

R_T, C_T → ext timing. R & C.

Waveform :-



A timing capacitor is linearly charged or discharged by a constant current source or sink

The amount of current can be controlled by changing the modulating voltage. The voltage at pin 6 is same as the voltage at pin 5. The o/p voltage of Schmitt Trigger is designed as Vcc and ~~po~~ 0.5 Vcc. VCO is commonly used in converting low freq signal to audio frequency signal.

O/P freq of VCO :-

f_o (c)

$$\frac{\Delta V}{\Delta t} = i/C_T, \quad \boxed{\Delta V = 0.25 V_{cc}}$$

The o/p freqn is calculated by change in voltage w.r.t time.

ΔV varies from $0.25 V_{cc}$ to $0.5 V_{cc}$.

$$\Delta t = \frac{0.25 V_{cc} C_T}{i}$$

Time period of Δ wave, $T = 2\Delta T$

$$\boxed{T = \frac{0.5 V_{cc} C_T}{i}}$$

also, $$\boxed{\frac{i}{C_T} = \frac{0.25 V_{cc}}{\Delta t}}$$

$$\cancel{f_o = \frac{1}{t}} \quad \boxed{f_o = \frac{i}{0.5 V_{cc} C_T}}$$

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

$$\boxed{f_o = \frac{V_{cc} - V_c}{0.5 V_{cc} R_T C_T}}$$

The o/p frequency of ~~Vco~~ Vco can be changed either by R_T, C_T or modulating i/p V_c

Modulating i/p, $\boxed{V_c = \frac{7}{8} V_{cc}}$.

$$f_0 = \frac{V_{cc} - \frac{7}{8} V_{cc}}{0.5\, V_{cc} R_T C_T}$$

$$= \frac{V_{cc}}{4\, V_{cc} R_T C_T}$$

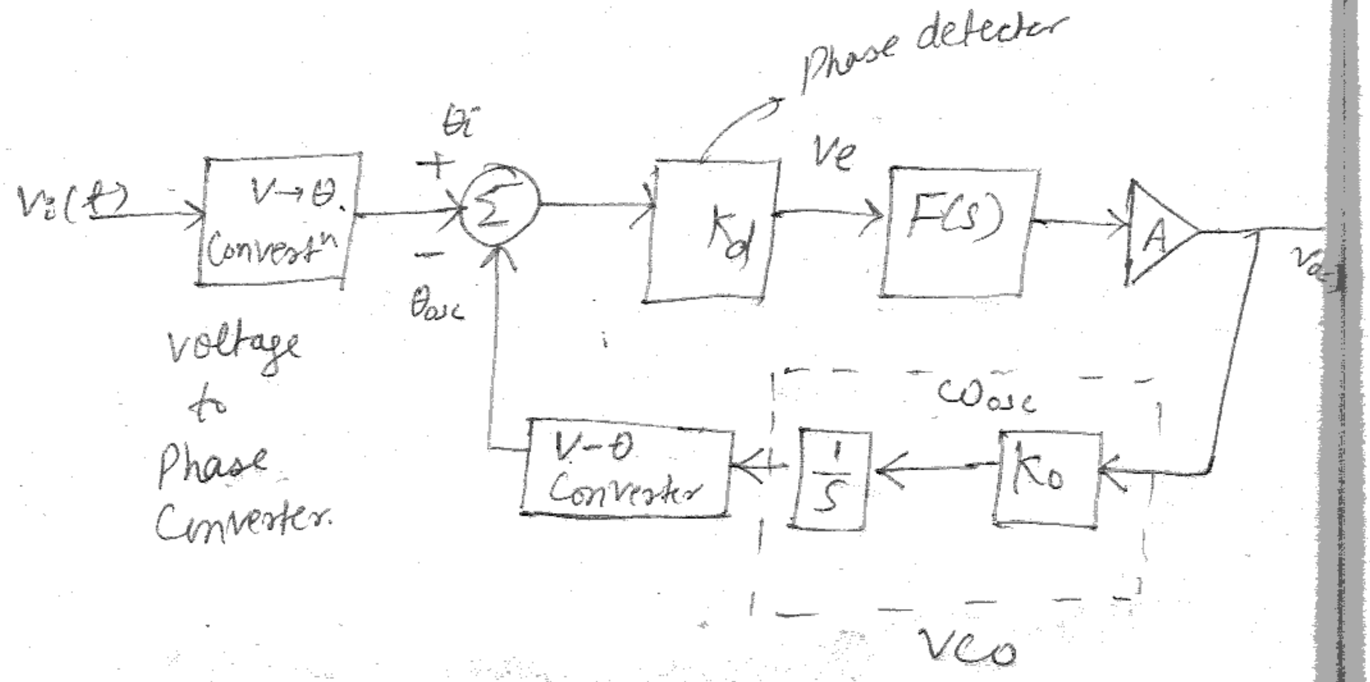
$$\boxed{f_0 = \frac{1}{4 R_T C_T}}.$$

Important parameter of VCO is Voltage to frequency conversion factor. It is represented by (k_v)

$$\boxed{K_V = \frac{\Delta f_0}{\Delta V_c}}$$

18/8/14

Closed Loop Analysis of PLL



$$\frac{V_o(t)}{\theta_{os}(t)} = \frac{G(s)}{1+G(s)\cdot H(s)} \quad \text{— eq}^n \text{ ①}$$

$$V_e = K_d(\theta_i - \theta_{osc})$$

$$\boxed{V_i(t) = \sin(\omega t + \theta_i)}$$

$$\omega_{osc} \leftrightarrow \theta_{osc}$$

$$\omega_{osc} = \frac{d\theta_{osc}}{dt}$$

$$\theta_{osc} = \int_0^t \omega_{osc}(t)\,dt$$

In s-domain eq^n ① becomes

$$\frac{V_o(s)}{\theta_{o_s}(s)} = \frac{K_d\,A\,f(s)}{1+K_d\,A\,f(s)\cdot\frac{K_o}{s}}$$

Consider $F(s)=1$

$$\frac{V_o(s)}{\theta_{os}(s)} = \frac{A\,K_d}{1+K_d\,A\,K_o/s}$$

$$\boxed{\frac{V_o(s)}{\theta_{os}(s)} = \frac{s\,A\,K_d}{s+K_d\,A\,K_o}}$$

This is the response w.r.t. VCO ~~freq.~~ O/P. Considering phase of o/p signal.

$$\frac{V_o(s)}{\theta_{os}(s)} = \frac{s\,A\,K_d}{s+K_d\,A\,K_o}$$

$$\boxed{\frac{V_o(s)}{\omega_{osc}(s)} = \frac{A\,K_d}{s+K_d\,A\,K_o}}$$

$K_v = K_d\,A\,K_o$

$$\boxed{\frac{V_o(s)}{\omega_{osc}(s)} = \frac{A\,K_v}{s+K_v}\cdot\frac{1}{K_o}}$$

K_v is known as loop Bandwidth

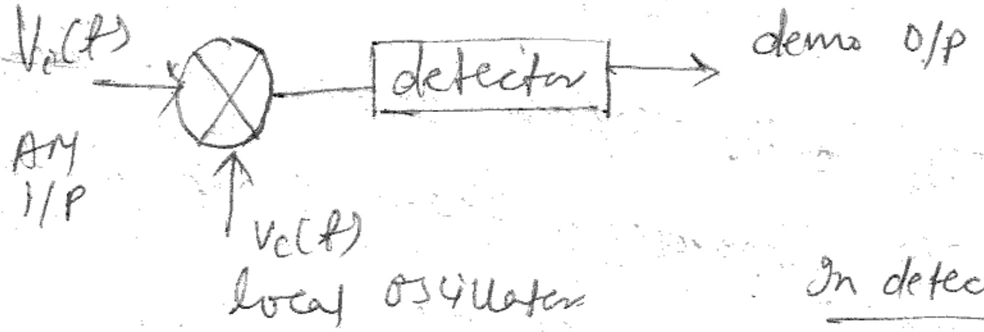
It is the effective bandwidth at which the capture range ~~one~~ are dependent upon K_v. As $K_v \downarrow$, capture time $\uparrow$, and capture range $\downarrow$

Therefore interference rejection improves

Applications of PLL :-

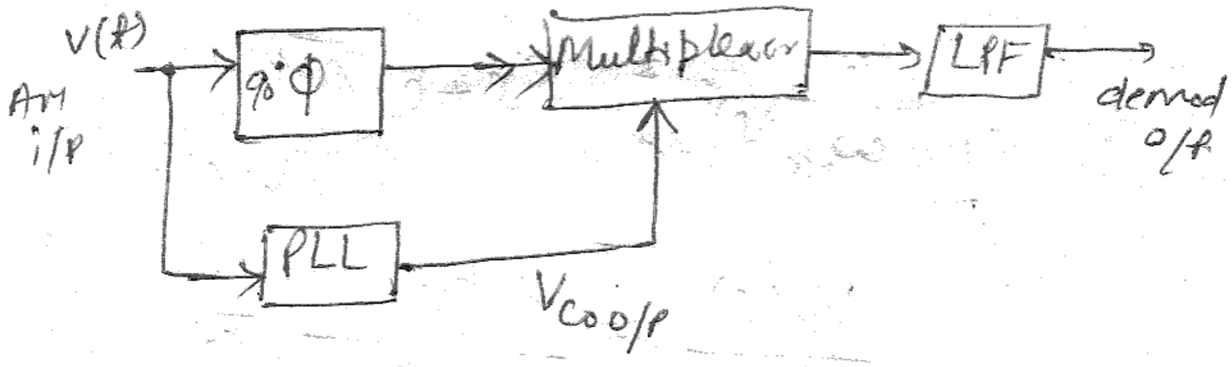
(i) AM detection.
(ii) FM detection
(iii) FSK detection
(iv) frequency synthesizing.

AM detection :-



In detecter we have LPF + demodⁿ

AM detection using PLL



→ ~~If~~ When PLL is locked O/P freq from VCO is 90° phase shifted w.r.t i/p frequency.

$$V(t) = A\sin(\omega_c t + \theta)$$
$$= A\sin(\omega_c t - \theta)$$

Carrier freq :- V_{co} O/P $= V_c \sin(\omega_c - \theta)$

⇒ PLL is locked to carrier freq. which has the same value as carrier

but ~~the~~ unmodulated is applied as one i/p to the multiplier

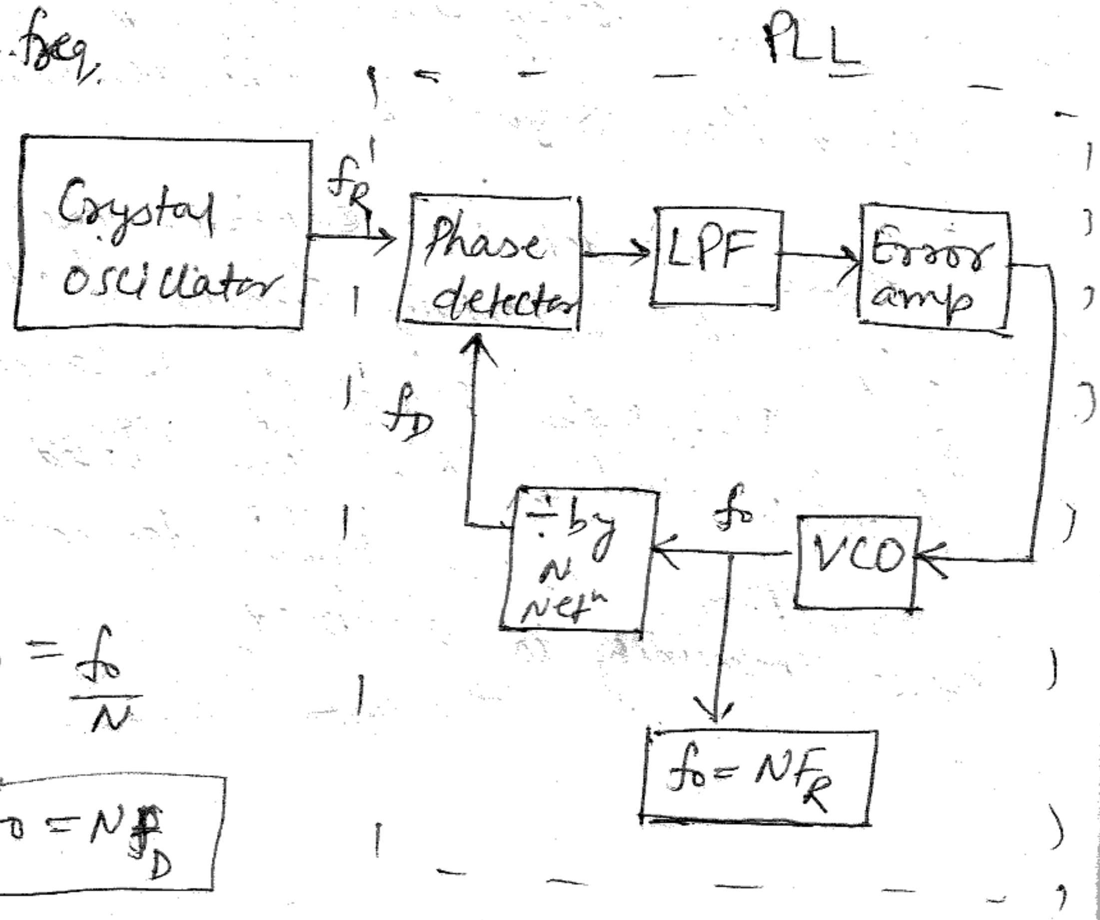
90° phase shift & multiplier o/p will be ~~off~~ of high frequency signal. LPF allows only lower frequency signal and this signal is the demodulated o/p.

This AM detector exhibits the high degree of selectivity due to that PLL responds selectively to carrier frequency, which are very closed to VCO o/p. Therefore higher degree of noise immunity is achieved

19/8/11

FREQUENCY SYNTHESIZER

f_R → Ref. freq.



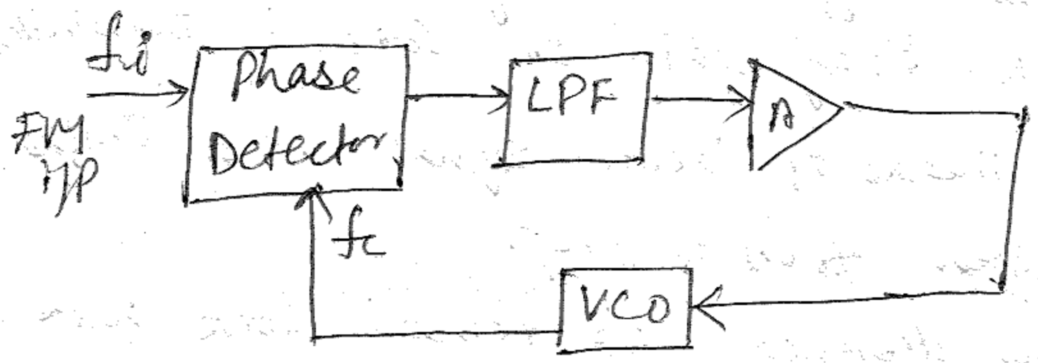
$f_D = \frac{f_o}{N}$

$\boxed{f_o = N f_D}$

When I/P freq = VCO freq. PLL is said to be locked.

~~Using~~
→ PLL can be used as the base is for freq. synthesizer that can produce pre-size freq. from a ~~single~~ a crystal oscillator, under locked condition O/P freq of VCO is n times of Refrance frequenly, therefore it is possible to obtained multiples of reference freq.

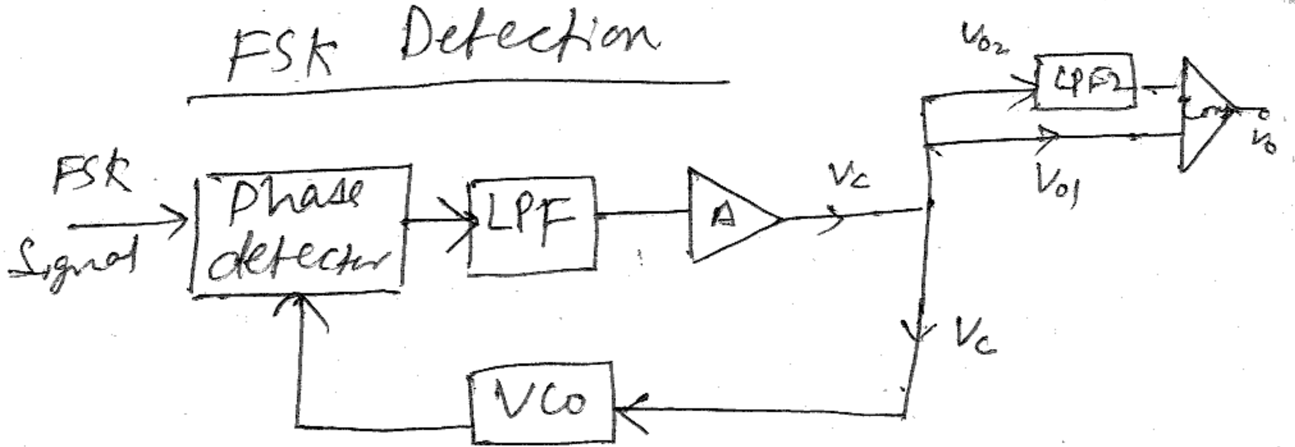
(1) FM detection.



PLL is locked with input FM Signal then VCO freq. will be equal to instantaneous freq of FM Signal -

O/P → inst value of FM Signal
The Controlled voltage of VCO is a linear function of freq deviation., of instantaneous Signal. Hence FM signal is demodulated without any distortion.

FSK Detection



I/P → binary 0's & 1's.
Carrier → 
FSK O/P →

Binary data is varied according to the carrier signal

FSK is a type of frequency modulation in which binary data or code is transmitted by means of carrier signal i.e is shifted between to set of freq.

PLL is designed to remain lock with FSK signal for both freq. The comparator is used to compare this two set of frequencies & produces the o/p which is the demodulated FSK.