Clippers and Clampers:

Waveshaping circuits are commonly used in digital computers and communication such as TV and FM receiver. Waveshaping technique include clipping and clamping. In op-amp clipper circuits a rectifier diode may be used to clip off a certain portion of the input signal to obtain a desired o/p waveform. The diode works as an ideal diode (switch) because when on -> the voltage drop across the diode is divided by the open loop gain of the op-amp. When off(reverse biased) -> the diode is an open circuit.

In an op-amp clamper circuits, however a predetermined dc level is deliberately inserted in the o/p volt. For this reason, the clamper is sometimes called a dc inverter.

Positive and Negative Clipper:

Positive Clipper:

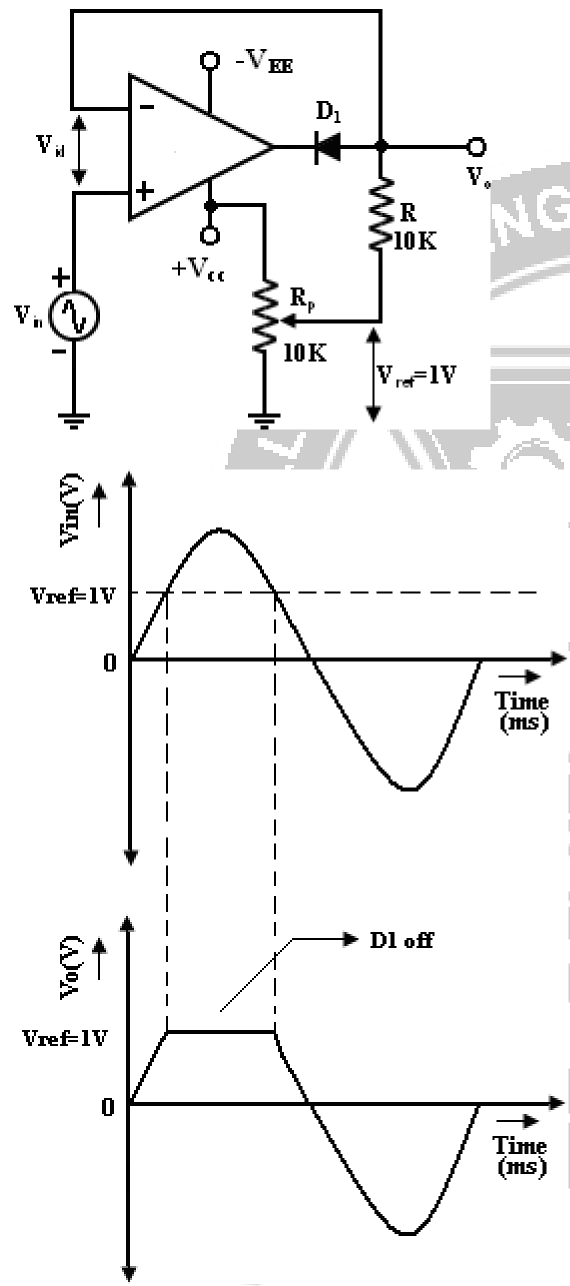
A Circuit that removes positive parts of the input signal can be formed by using an op-amp with a rectifier diode. The clipping level is determined by the reference voltage Vref, which should less than the i/p range of the op-amp (Vref < Vin). The Output voltage has the portions of the positive half cycles above Vref clipped off.

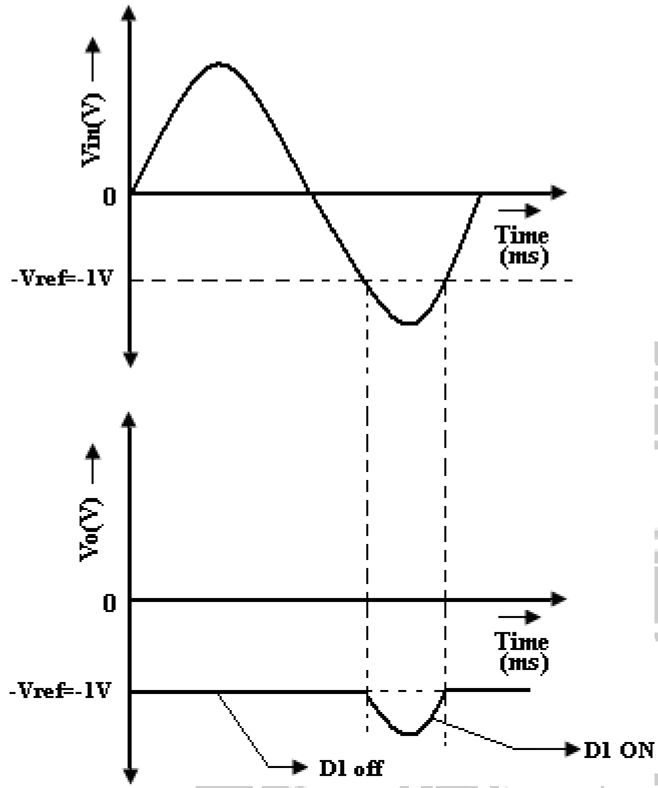
The circuit works as follows:

During the positive half cycle of the input, the diode D_1 conducts only until Vin = Vref. This happens because when Vin <Vref, the output volts V_0 _ of the op-amp becomes negative to device D_1 into conduction when D_1 coonducts it closes feedback loop and op-amp operates as a voltage follower. (i.e) Output V_0 follows input until Vin = Vref.

When Vin > Vref => the V'_0 becomes +ve to derive D_1 into off. It open the feedback loop and op-amp operates open loop. When Vin drops below Vref (Vin<Vref) the o/p of the op-amp V'_0 again becomes –ve to device D_1 into conduction. It closed the f/b. (o/p follows the i/p). Thus diode D_1 is

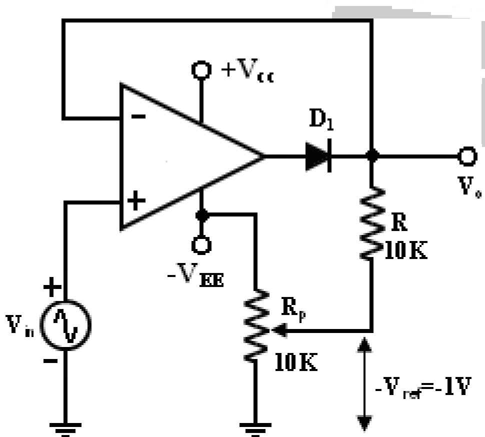
on for vin<Vref (o/p follows the i/p) and D_1 is off for Vin>Vref. The op-amp alternates between open loop (off) and closed loop operation as the D_1 is turned off and on respectively. For this reason the op-amp used must be high speed and preferably compensated for unity gain.

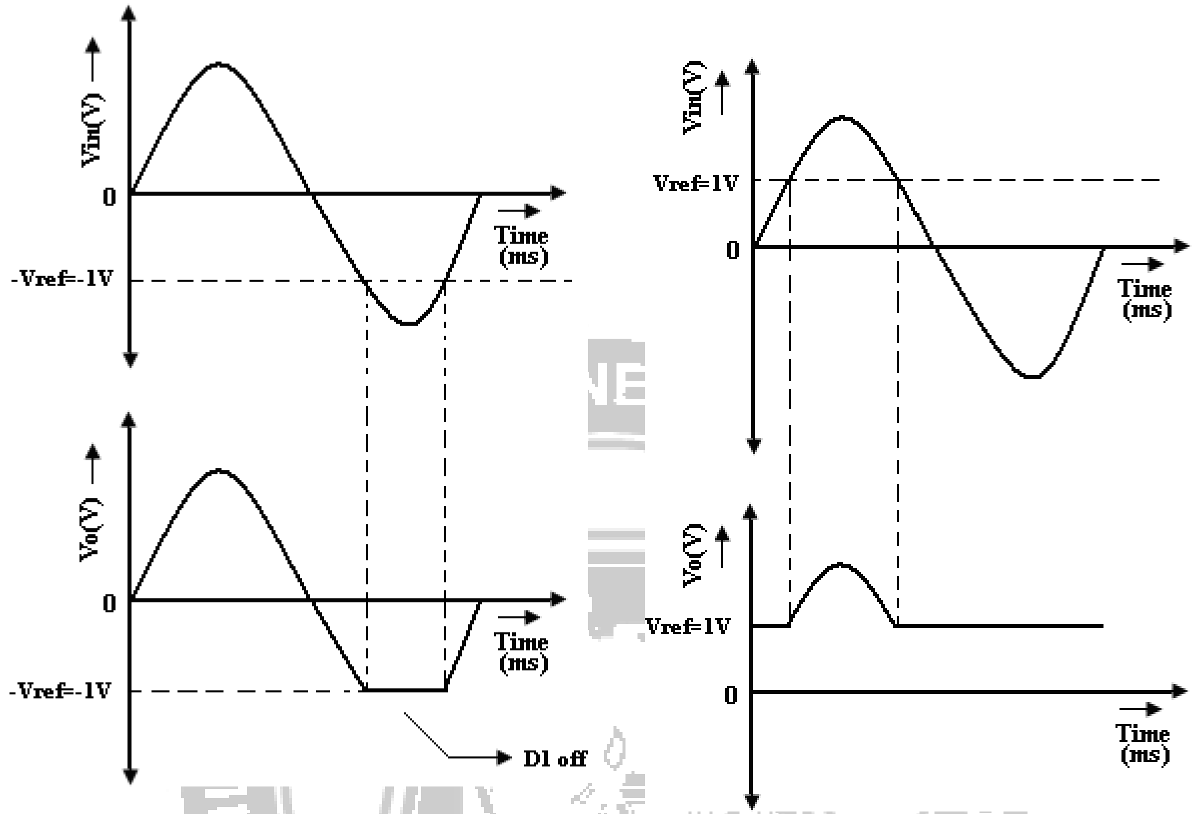




Ex: for high speed op-amp HA 2500, LM310, µA 318. In addition the difference input voltage (Vid=high) is high during the time when the feedback loop is open (D_1 is off) hence an op-amp with a high difference input voltage is necessary to prevent input breakdown. If R_p (pot) is connected to $-V_{EE}$ instead of +Vcc, the ref voltage Vref will be negative (Vref = - ve). This will cause the entire o/p waveform above –Vref to be clipped off.

Negative Clipper:





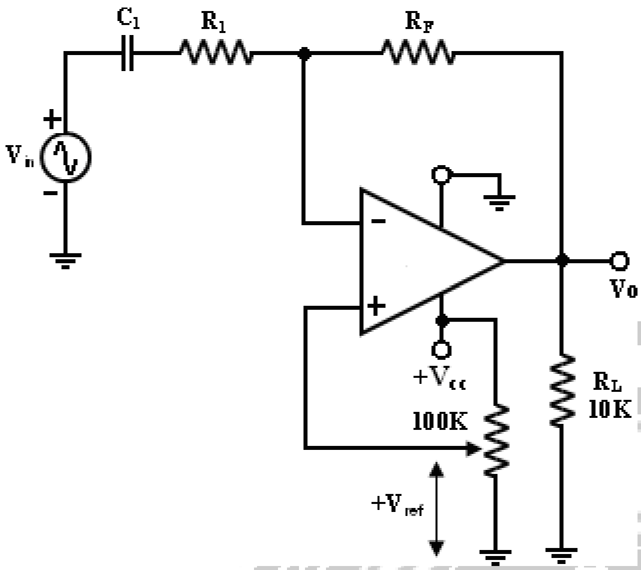
The positive clipper is converted into a –ve clipper by simply reversing diode D_1 and changing the polarity of Vref voltage. The negative clipper -> clips off the –ve parts of the input signal belo w the reference voltage. Diode D_1 conducts -> when Vin > -Vref and therefore during this period o/p volt V_0 follows the i/p volt Vin. The –Ve portion of the output volt below –Vref is clipped off because (D_1 is off) Vin<-Vref. If –Vref is changed to –Vref by connecting the potentiometer R_p to the +Vcc, the V_0 below +Vref will be clipped off. The diode D_1 must be on for Vin > Vref and off for Vin.

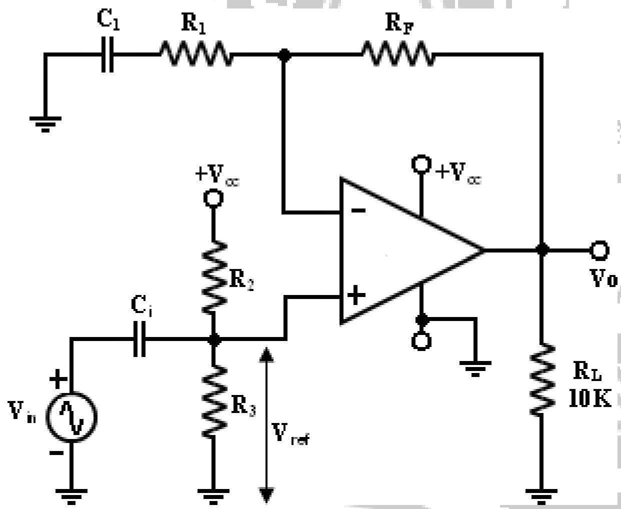
Positive and Negative Clampers:

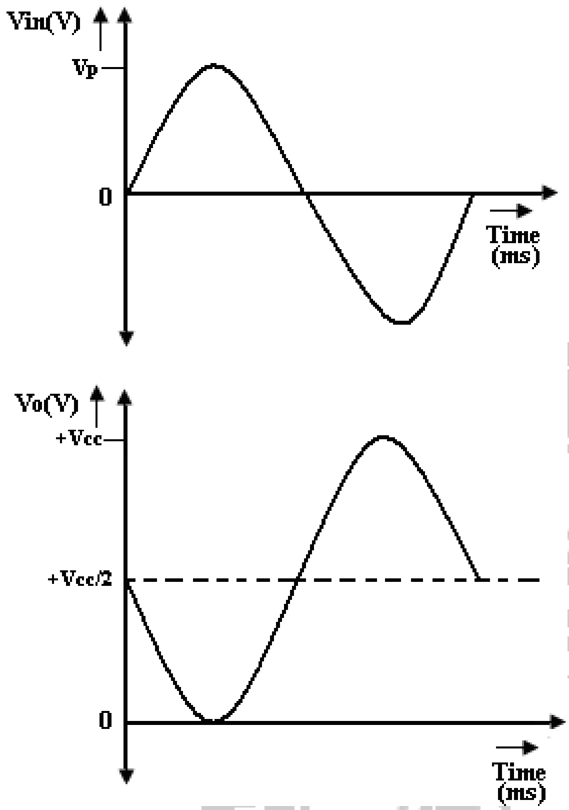
In clamper circuits a predetermined dc level is added to the output voltage. (or) The output is clamped to a desired dc level.

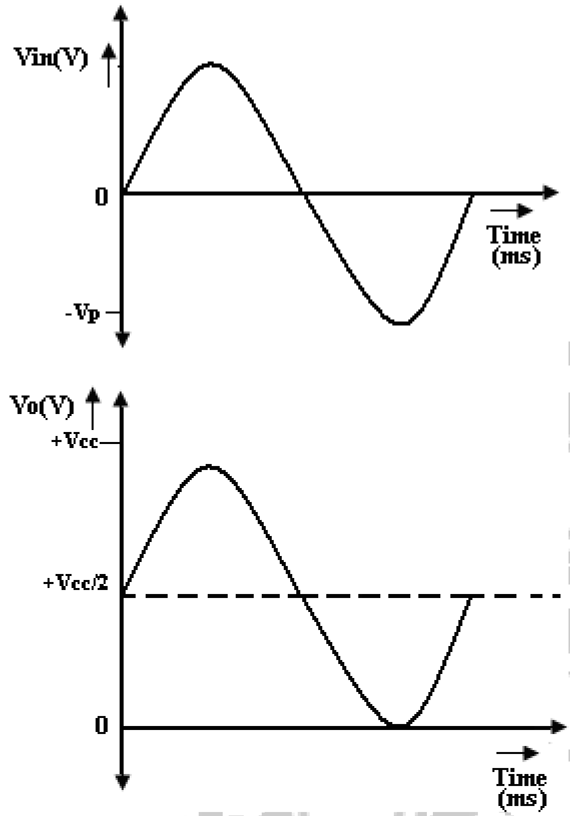
1. If the clamped dc level is +ve, the clamper is positive clamper
2. If the clamped dc level is –ve, the clamper is negative clamper.

Other equivalent terms used for clamper are dc inserter or restorer. Inverting and Non-Inverting that use this technique.


C1
R1
RF
Vin
+Vcc
100K
+Vref
RL
10K
Vo


C1
R1
RF
+Vcc
+Vcc
R2
Ci
R3
Vin
Vref
RL
10K
Vo


Vin(V)
Vp
0
Time
(ms)
Vo(V)
+Vcc
+Vcc/2
0
Time
(ms)



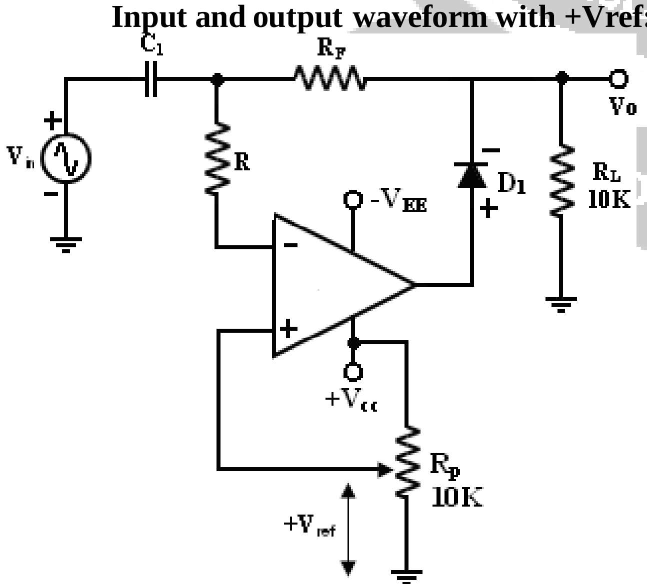
Capacitor:

The Value of the capacitors in these circuits depends on different input rates and pulse widths.

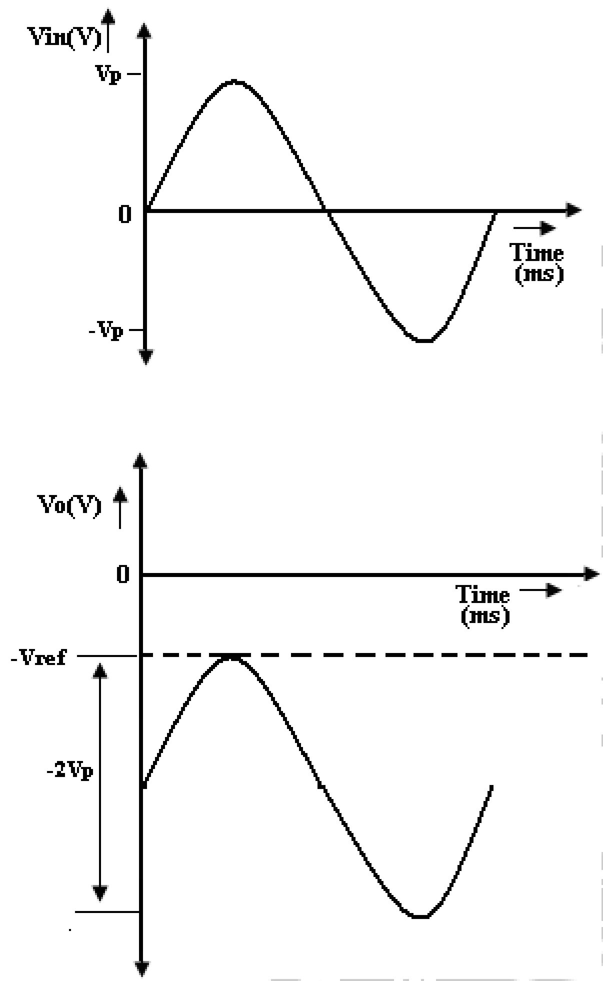
1. In both circuits the dc level added to the o/p voltage is approximately equal to Vcc/2.
2. This +ve fixed dc level is needed to obtain a maximum undistored symmetrical sine wave.

Peak clamper circuit:

Input and output waveform with +Vref:



Input and Output Waveform with –Vref:



In this circuit, the input waveform peak is clamped at Vref. For this reason, the circuit is called the peak clamper.

First consider the input voltage Vref at the (+) input: since this volt is +ve, V'_0 is also +ve which forward biases D_1 . This closed the feedback loop.

Voltage Vin at the (-) input: During its –ve half cycle, diode D_1 conducts, charging c; to the –ve peak value of V_p . During the +ve half cycle, diode D_1 in reverse biased. Since this voltage V_p is in series with the +ve peak volt V_p the o/p volt $V_0 = 2\ V_p$. Thus the nett o/p is Vref plus 2 V_p. so the –ve peak of 2 V_p is at Vref. For precision clamping, $C_iR_d << T/2$

Where R_d = resistance of diode D_1 when it is forward biased.

T = time period of the input waveform.

Resistor r => is used to protect the op-amp against excessive discharge currents from capacitor C_i especially when the dc supply voltages are switched off. A +ve peak c lamping is accomplished by reversing D_1 and using –ve reference voltage (-Vref).

Note:

Inv and Non-Inv clamper – Fixed dc level

Peak clamper – Variable dc level

Active filters:

Another important field of application using op-amp.

Filters and Oscillators:

An electric filter is often a frequency selective circuit that passes a specified band of frequencies and blocks or alternates signal and frequencies outside this band.

Filters may be classified as

1. Analog or digital.
2. Active or passive
3. Audio (AF) or Radio Frequency (RF)

1. Analog or digital filters:

Analog filters are designed to process analog signals, while digital filters process analog signals using digital technique.

2. Active or Passive:

Depending on the type of elements used in their construction, filter may be classified as passive or Active elements used in passive filters are Resistors, capacitors, inductors. Elements used in active filters are transistor, or op-amp.

Active filters offers the following advantages over a passive filters:

1. Gain and Frequency adjustment flexibility:

Since the op-amp is capable of providing a gain, the i/p signal is not attenuated as it is in a passive filter. [Active filter is easier to tune or adjust].

2. No loading problem:

Because of the high input resistance and low o/p resistance of the op-amp, the active filter does not cause loading of the source or load.

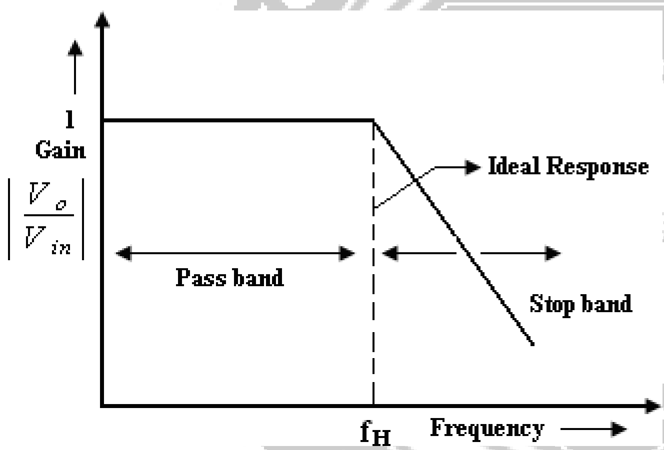
3. Cost:

Active filters are more economical than passive filter. This is because of the variety of cheaper op-amps and the absence of inductors.

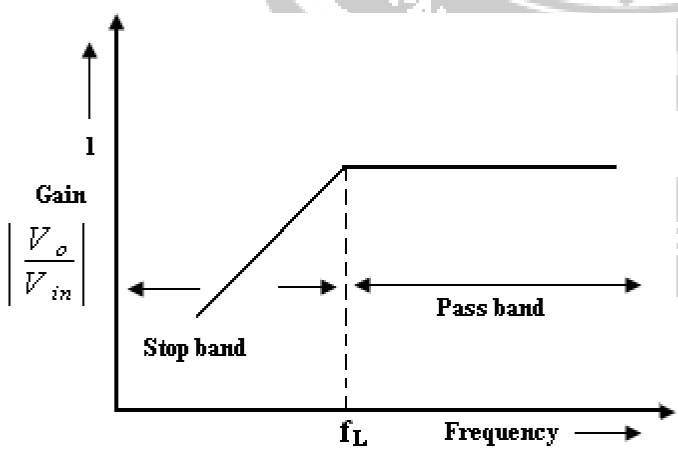
The most commonly used filters are these:

1. Low pass Filters
2. High pass Filters
3. Band pass filters
4. Band –reject filters
5. All pass filters.

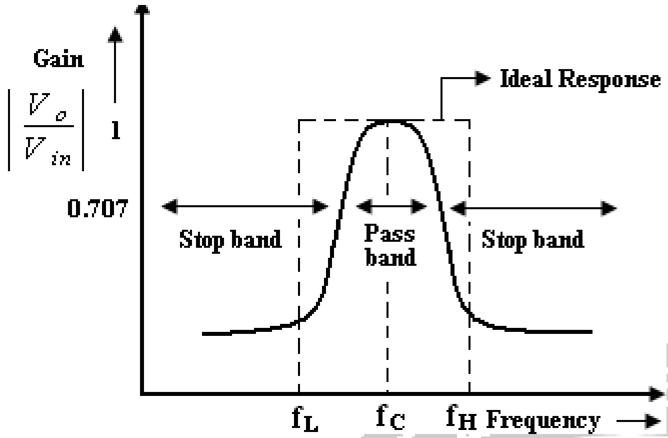
Frequency response of the active filters:



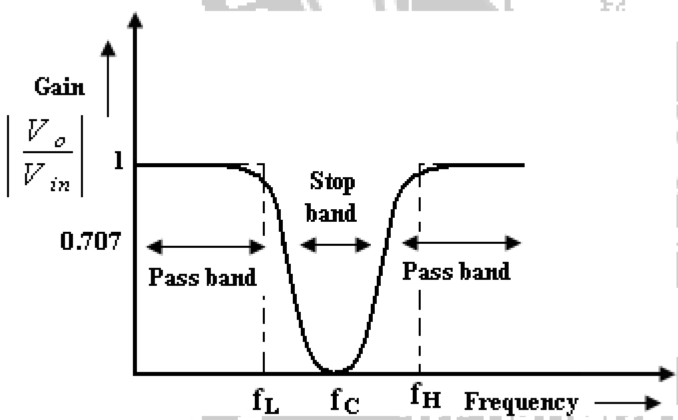
Low pass Filter



High pass Filter



Band Pass Filters



Band Reject

Low pass filters:

1. It has a constant gain from 0 Hz to a high cutoff frequency f_1.
2. At f_H the gain in down by 3db.

3. The frequency between 0hz and f_H are known as the passband frequencies. Where as the range of frequencies those beyond $f_{H,}$ that are attenuated includes the stopband frequencies.
4. Butterworth, clebyshev and cauer filter are some of the most commonly used practical filters.
5. The key characteristics of the butter worth filter is that it has a flat pass band as well as stop band. For this reason, it is sometimes called a flat-flat filters.
6. Chebyshev filter -> has a ripple pass band & flat stop band.
7. Causer Filter -> has a ripple pass band & ripple stopband. It gives best stopband response among the three.

High pass filter:

High pass filter with a stop band $0<f< f_L$ and a pass band $f> f_L$

f_L -> low cut off frequency

f -> operating frequency.

Band pass filter:

It has a pass band between 2 cut off frequencies f_H and f_L where $f_H > f_L$ and two, stop bands : $0<f< f_L$ and $f > f_H$ between the band pass filter (equal to f_H - f_L .

Band –reject filter: (Band stop or Band elimination)

It performs exactly opposite to the band pass. It has a band stop between 2 cut-off frequency f_L and f_H and 2 passbands: $0<f< f_L$ and $f> f_H$

f_C -> center frequency.

Note:

The actual response curves of the filters in the stopband either R or S or both with R in frequencies.

The rate at which the gain of the filter changes in the stopband is determined by the order of the filter.

Ex: 1^{st} order low pass filter the gain rolls off at the rate of 20dB/decade in the stopband. (i.e) for $f > f_H$.

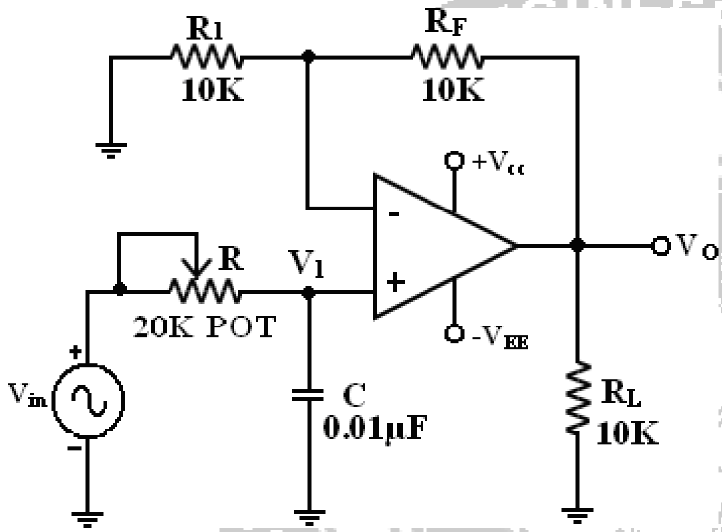
2^{nd} order LPF -> the gain roll off rate is 40dB/decade.

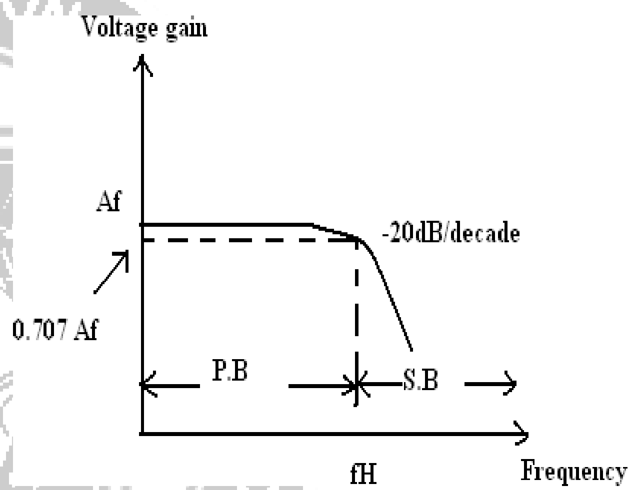
1^{st} order HPF -> the gain Rs at the rate of 20dB (i.e) until f:f_L

2^{nd} order HPF -> the gain Rs at the rate of 40dB/decade

First order LPF Butterworth filter:

First order LPF that uses an RC for filtering op-amp is used in the non inverting configuration. Resistor R1 & R_f determine the gain of the filter. According to the voltage –divider rule, the voltage at the non-inverting terminal (across capacitor) C is,

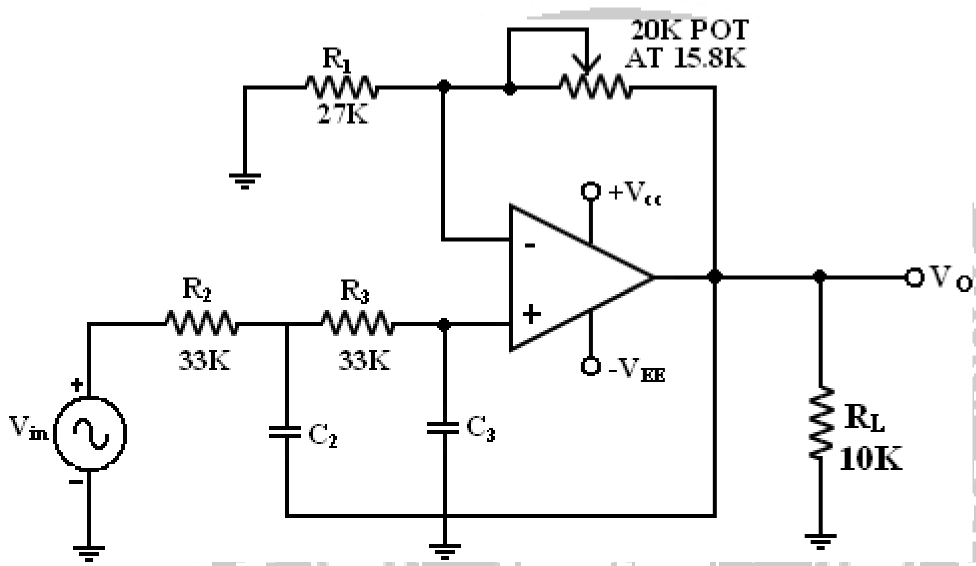


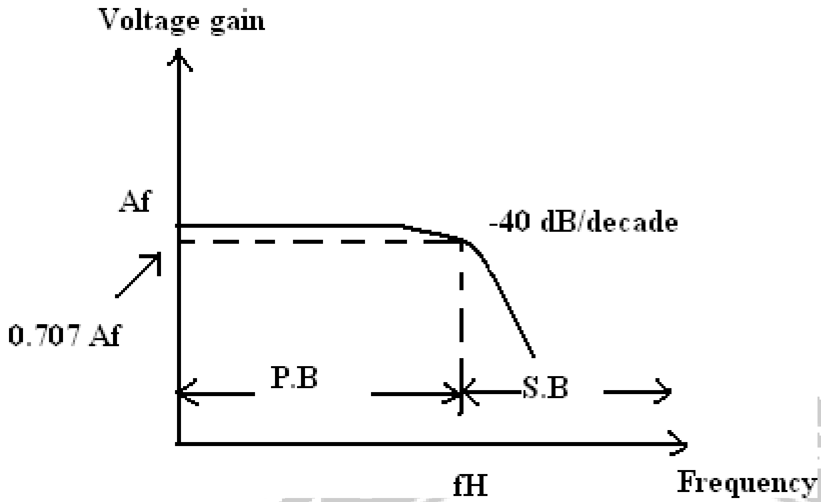


Second order LP Butterworth filter:

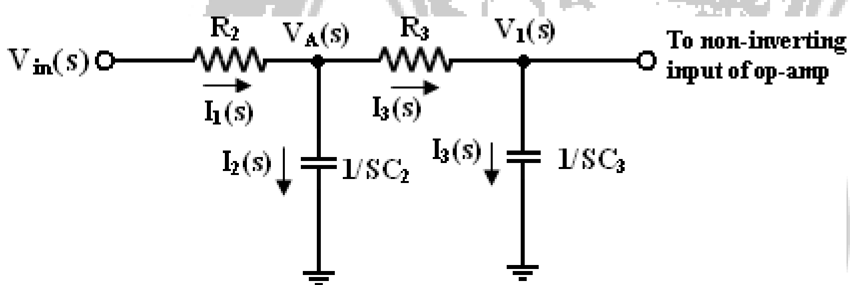
A second order LPF having a gain 40dB/decade in stop band. A First order LPF can be converted into a II order type simply by using an additional RC network.

The gain of the II order filter is set by R1 and R_F, while the high cut off frequency f_H is determined by R2,C2,R3 and C3.





This above fig transferred into S domain.



In this circuit all the components and the circuit parameters are expressed in the S-domain where S = j .

Writing Kirchoff‛s current law at node V_A (S) .

$I_1 = I_2 + I_3$

and solving forV_1, we get,

The denominator quadratic in the gain (V_0/Vin) eqn must have two real and equal roots. This means that

Filter Design:

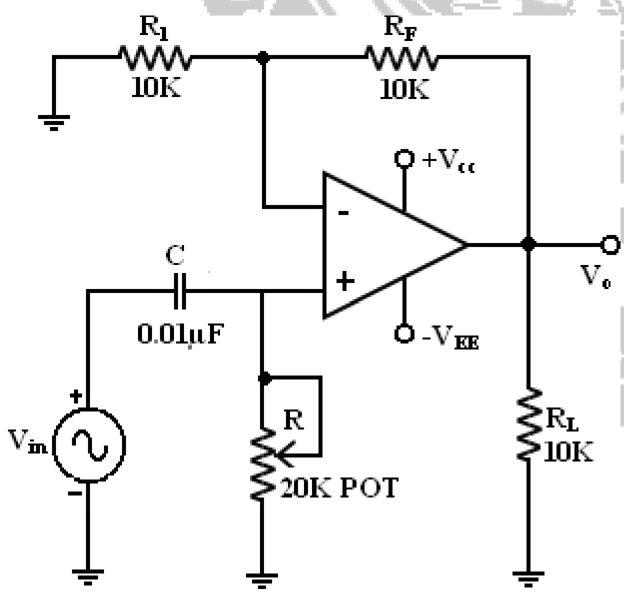
1. Choose a value for a high cut off freq (f_H).
2. To simplify the design calculations, set $R_2 = R_3 = R$ and $C_2 = C_3 = C$ then choose a value of c<=1μf.

4. Finally, because of the equal resistor ($R_2 = R_3$) and capacitor ($C_2 = C_3$) values, the pass band volt gain $A_F = 1 + R_F / R_1$ of the second order had to be = to 1.586. $R_F = 0.586\ R_1$. Hence choose a value of R_1 <=100kΩ and
5. Calculate the value of R_F.

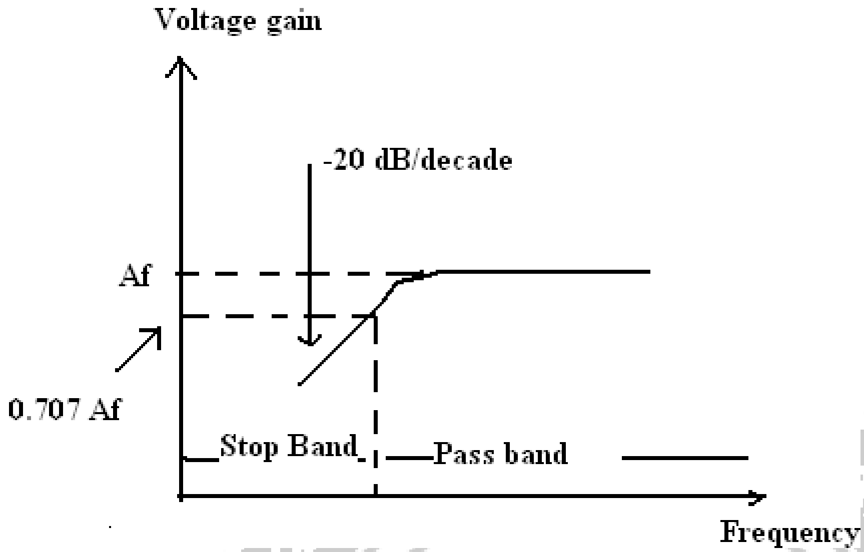
First order HP Butterworth filter:

High pass filters are often formed simply by interchanging frequency-determining resistors and capacitors in low-pass filters.

(i.e) I order HPF is formed from a I order LPF by interchanging components R & C. Similarly II order HPF is formed from a II order LPF by interchanging R & C.



I order HPF

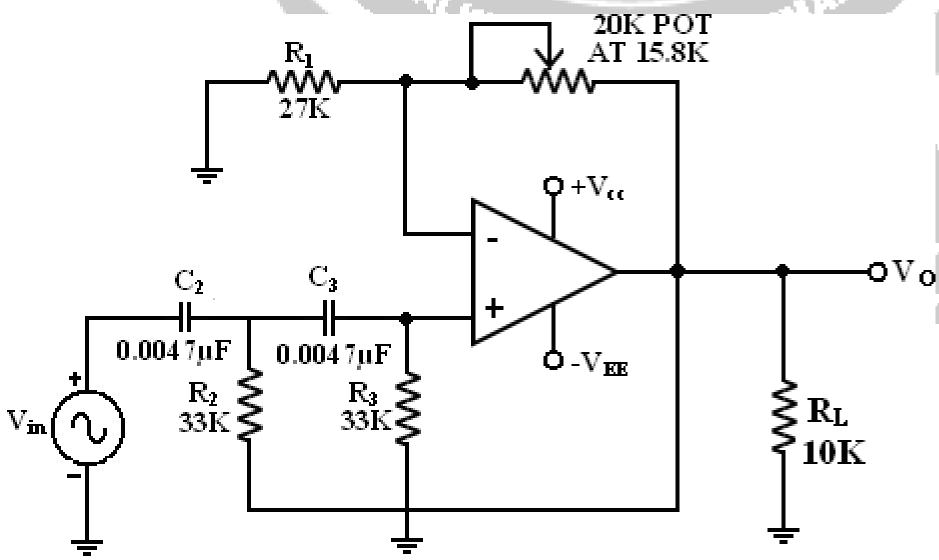


Here I order HPF with a low cut off frequency of f_L. This is the frequency at which the magnitude of the gain is 0.707 times its passband value.

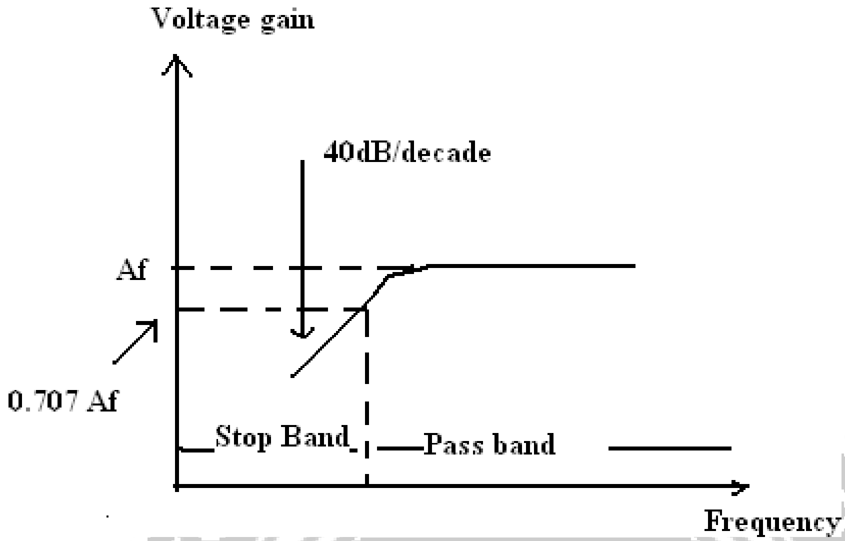
Here all the frequencies higher than f_L are passband frequencies.

Second – order High Pass Butterworth Filter:

I order Filter, II order HPF can be formed from a II order LPF by interchanging the frequency – determine resistors and capacitors.



II order HPF


Voltage gain
40dB/decade
Af
0.707 Af
Stop Band
Pass band
Frequency