Electronic Circuits

Operational Amplifier

Lecture 5

Dr. Roaa Mubarak

Op-Amp Applications

Linear Applications

1- The Inverting Amplifier

2-The Noninverting Amplifier

3- Summing Amplifier

4- Subtractor

5- Voltage Follower

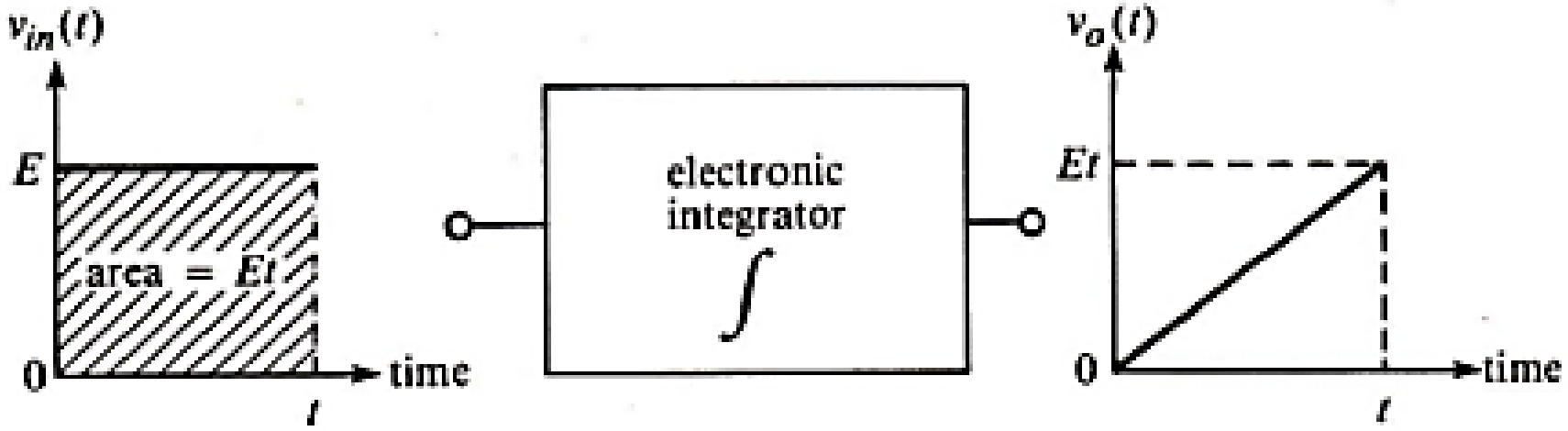
6- Controlled Sources

7- Integrator

8- Differentiator

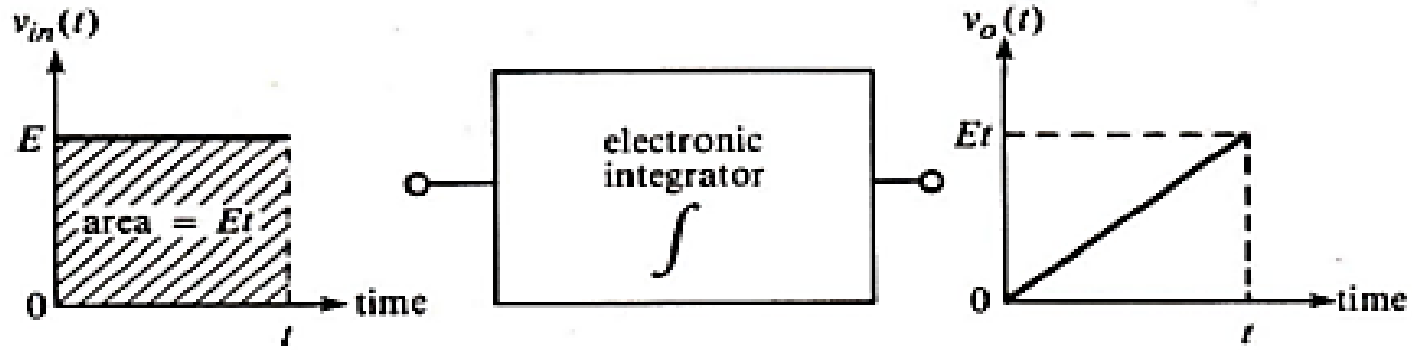
7- Integrator (Active Low Pass Filter)

- An electronic integrator is a device that produces an output waveform whose value at any instant of time equals **the total area under the input waveform** up to that point in time. A mathematical integration, the process produces the time varying function $\int_0^t v_{in}\, dt$.



7- Integrator (Active Low Pass Filter)

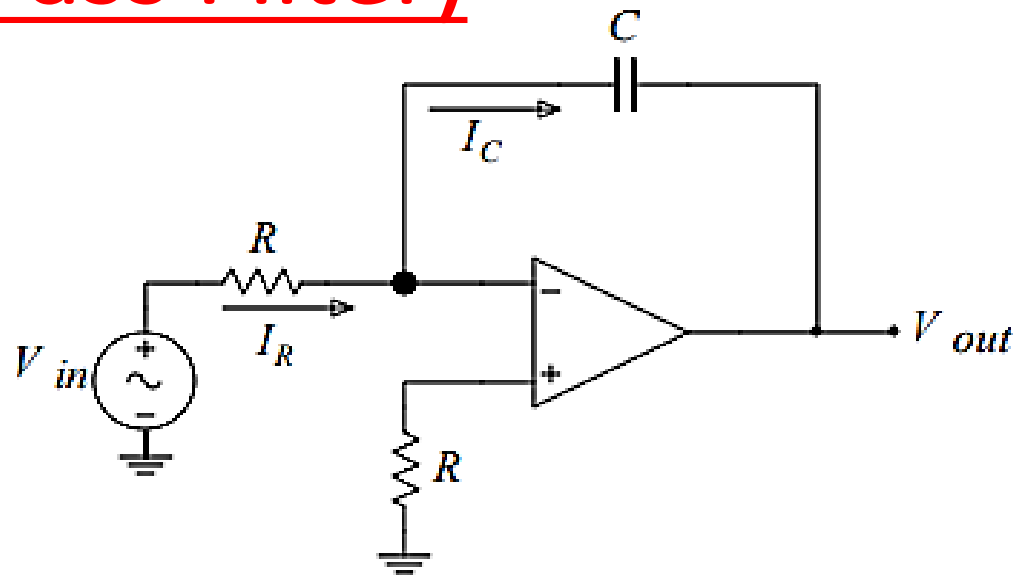
- Suppose the input to an electronic integrator is the dc level E volts, which is first connected to integrator at an instant of time we will call t = 0.
- The plot of the dc "waveform" versus time is simply a horizontal line at level E volts, since the dc voltage is constant. The more time that we allow to pass, the greater the area that accumulates under the dc waveform.
- At any time-point t, the total area under the input waveform between time 0 and time t is (height) × (width) = Et volts.
- For example, if E = 5 V dc, then the output will be 5 V at t = 1 s, 10 V at t = 2 s, 15 V at t = 3 s, and so forth. We see that the output is the ramp voltage v(t) = Et.



7- Integrator (Active Low Pass Filter)

$$I_R = I_C$$

$$\frac{V_{in}}{R} = -C\frac{dV_{out}}{dt}$$



Rearranging the Equation and integrating from 0 to t, we obtain

$$\int dV_{out} = -\int \frac{V_{in}(\tau)}{RC} d\tau \quad \Rightarrow \quad V_{out}(t) = -\frac{1}{RC}\int_0^t V_{in}(t)\, dt$$

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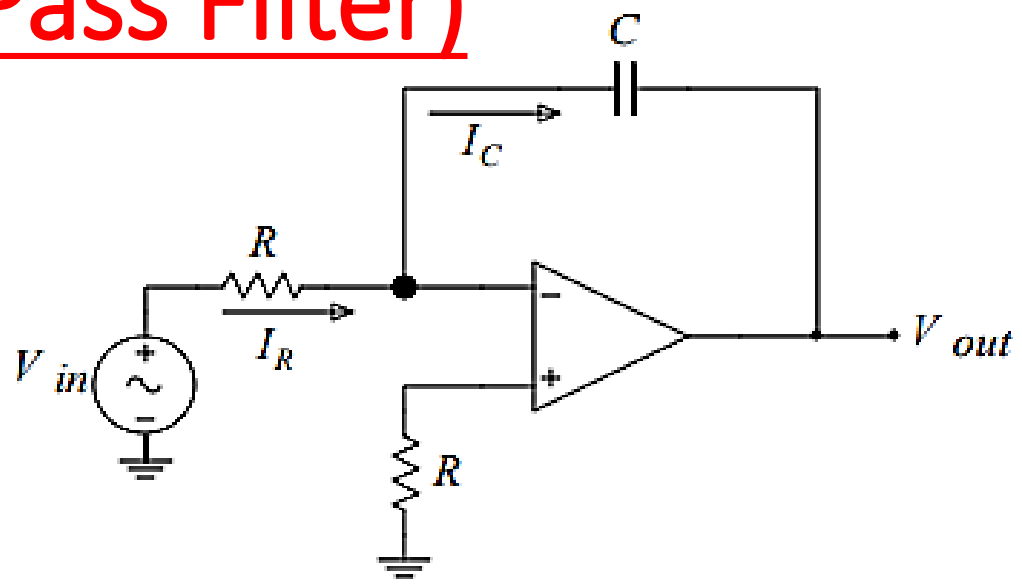
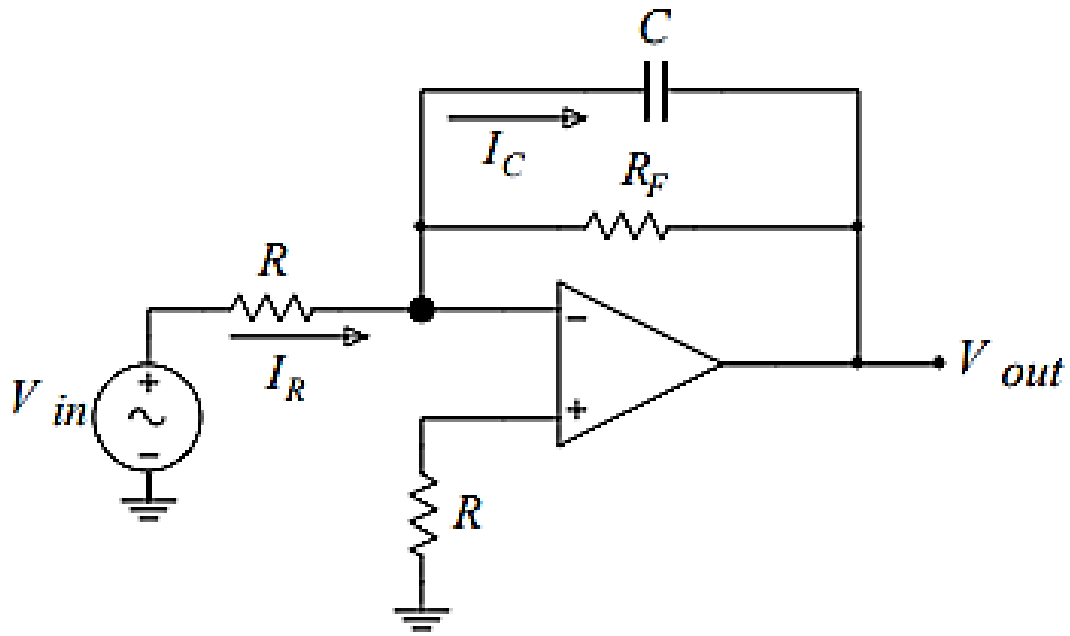
7- Integrator (Active Low Pass Filter)



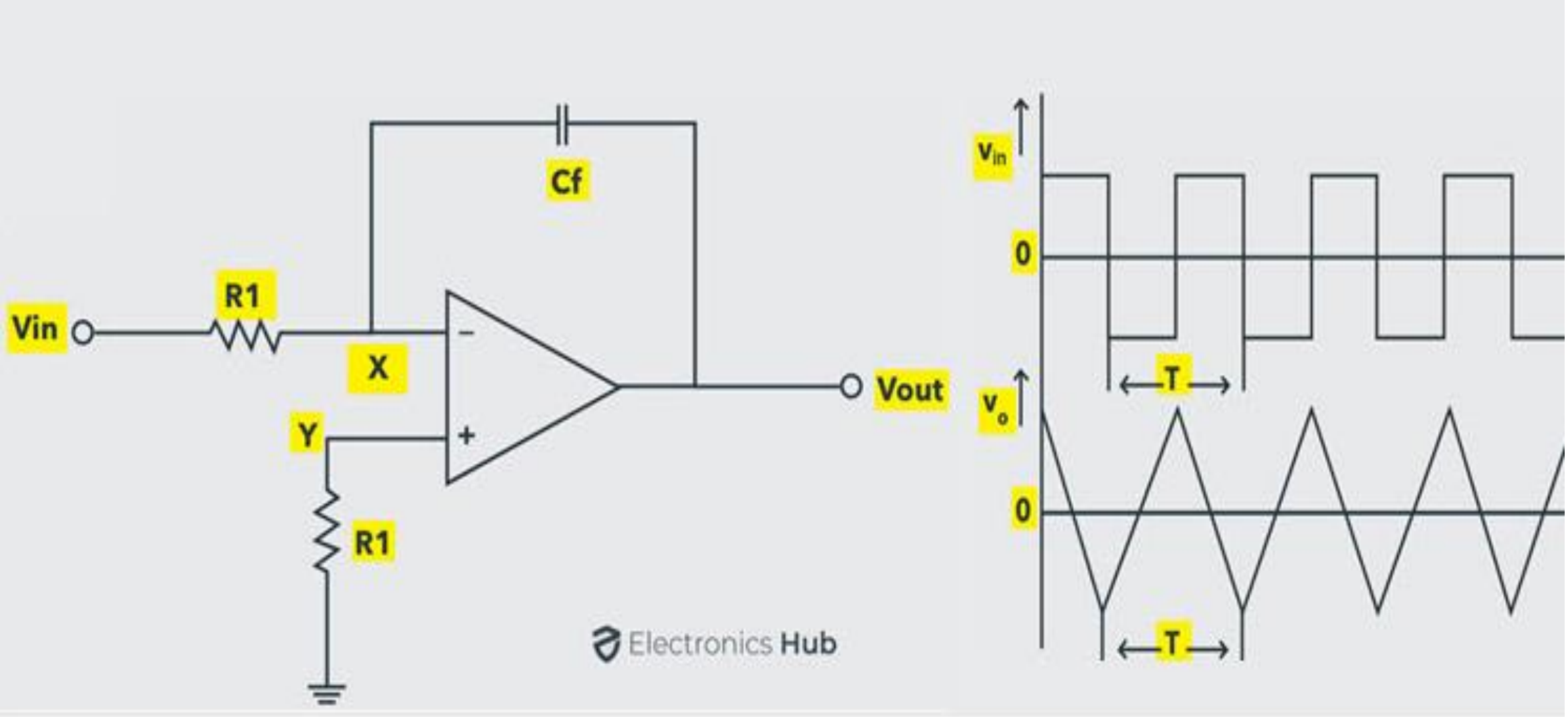
- The feedback element is a capacitor, and the capacitor behaves as an open circuit at DC, so there is no negative feedback !!!. This will cause a problem for this integrator as any tiny dc component in the input signal will theoretically produce an infinite output.
- Of course, no infinite output voltage results in practice; rather, the output of the amplifier saturates at a voltage close to the op-amp positive or negative power supply depending on the polarity of the input dc signal.

7- Integrator (Active Low Pass Filter)



- To eliminate this problem in practical integrators using general purpose amplifiers, a resistor is connected in parallel with the feedback capacitor.
- Since the capacitor is an open circuit as dc is concerned, the dc closed loop gain of the integrator is –Rf/R. At high frequencies, XC is much smaller than Rf , so the parallel combination of C and Rf is essentially the same as C alone, and signals are integrated as usual.

7- Integrator (Active Low Pass Filter)



Filters

- The word ‘filter’, it means it will remove the unwanted things. The best example of a filter is a water filter. Why it is used? It is used to remove impurities from the water. The electric filter also works the same as a water filter.
- The electric filter contains resistors, inductors, capacitors, and amplifiers. The electric filter is used to pass the signal with a certain level of frequency and it will attenuate the signal with lower or higher than a certain frequency.
- The frequency at which filter operates, that frequency is known as **cut-off frequency**. The cut-off frequency is set while designing the filter.
- **Types of Filter:**

-Low pass filter.

-High pass filter.

-Bandpass filter.

Low Pass Filter

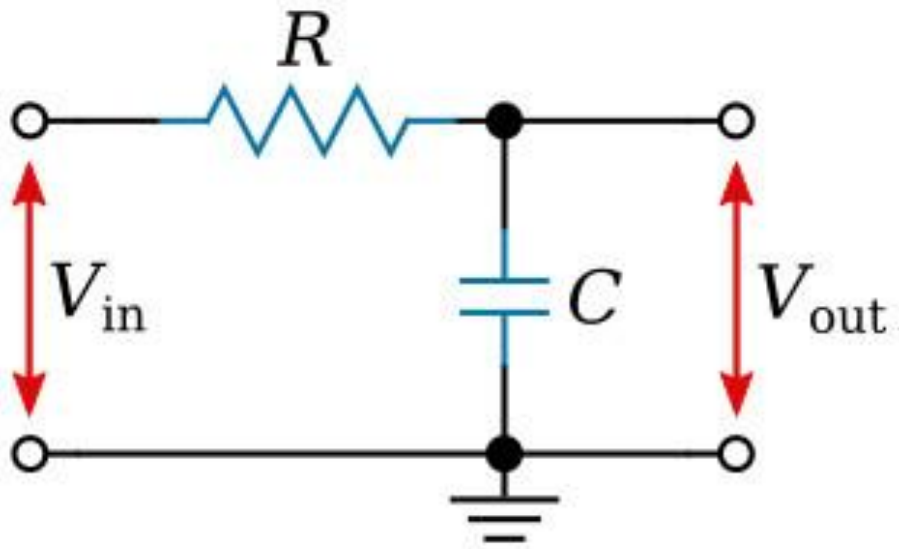
- A low-pass filter is a filter that passes signals with a frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency.
- Electronic low-pass filters are used on inputs to subwoofers and other types of loudspeakers, to block high pitches that they cannot efficiently reproduce. Radio transmitters use low-pass filters to block harmonic emissions that might interfere with other communications. The tone knob on many electric guitars is a low-pass filter used to reduce the amount of treble in the sound.
- **Types of Low pass filter:**

❑Passive low pass filter

❑Active low pass filter

Passive Low Pass Filter

- A **low-pass** filter passes frequencies below a certain cutoff frequency and attenuates those beyond that frequency.
- In a passive circuit, the output signal amplitude is smaller than the input signal amplitude.

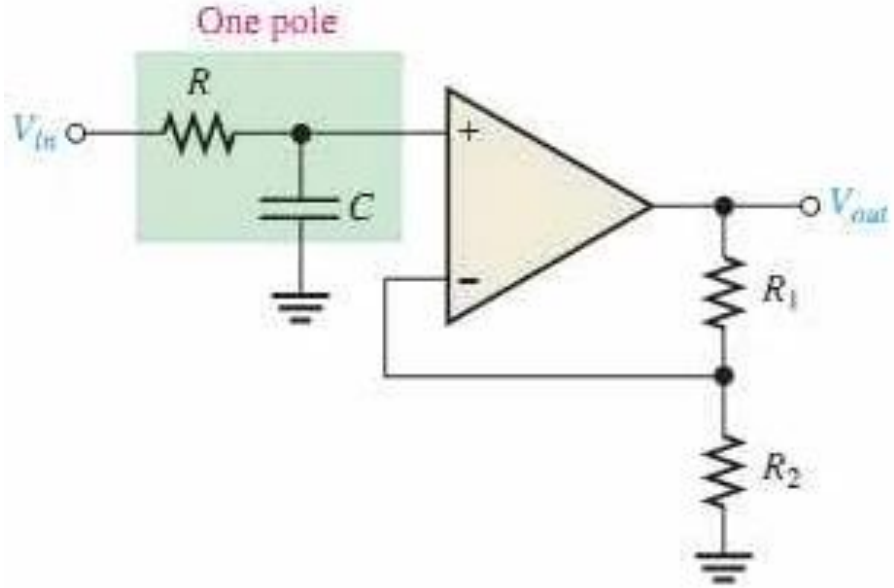


Active Low Pass Filter

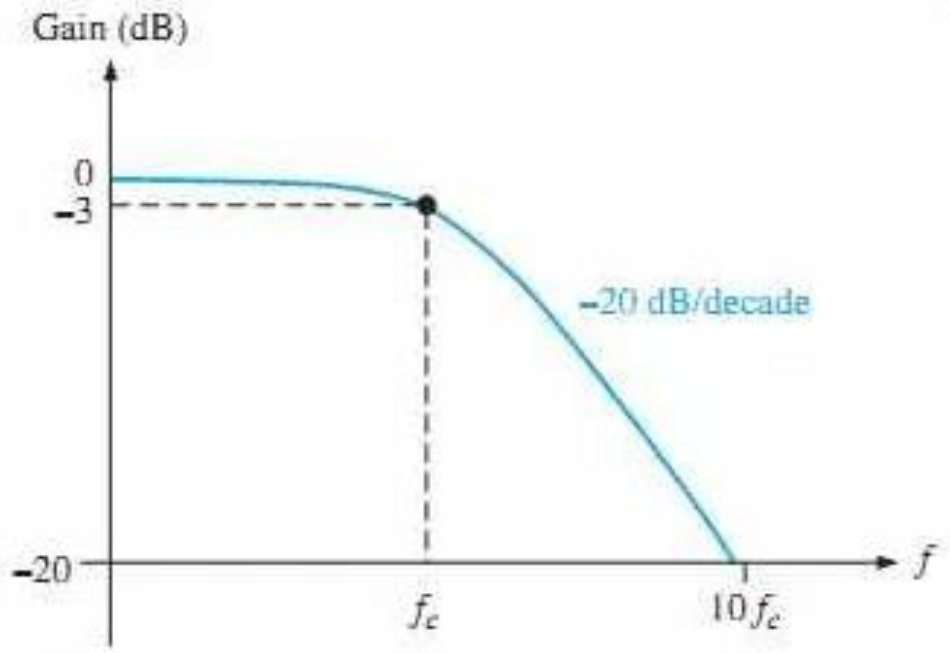
- An **active filter** is a type of filter that includes one or more active circuit components such as a transistor or an operational amplifier (Op-Amp). They derive their energy from an external source of energy and use it to increase or amplify the signal output.
- Operational amplifiers can also be used to form or change the circuit frequency response by making the filter's output bandwidth narrower or even wider by generating a more selective output reaction.
- An Op-Amp has a high input impedance, a low output impedance and a voltage gain within its feedback loop arising from the mixture of the resistor. Active filters, when used with careful circuit design, generate excellent performance features, very good precision with a steep roll-off and low noise.

Active Low Pass Filter

- When a passive low pass filter is connected to an Op-Amp either in inverting or non-inverting condition, it gives an active low pass filter design.
- An integrator is another time constant low-pass filter.



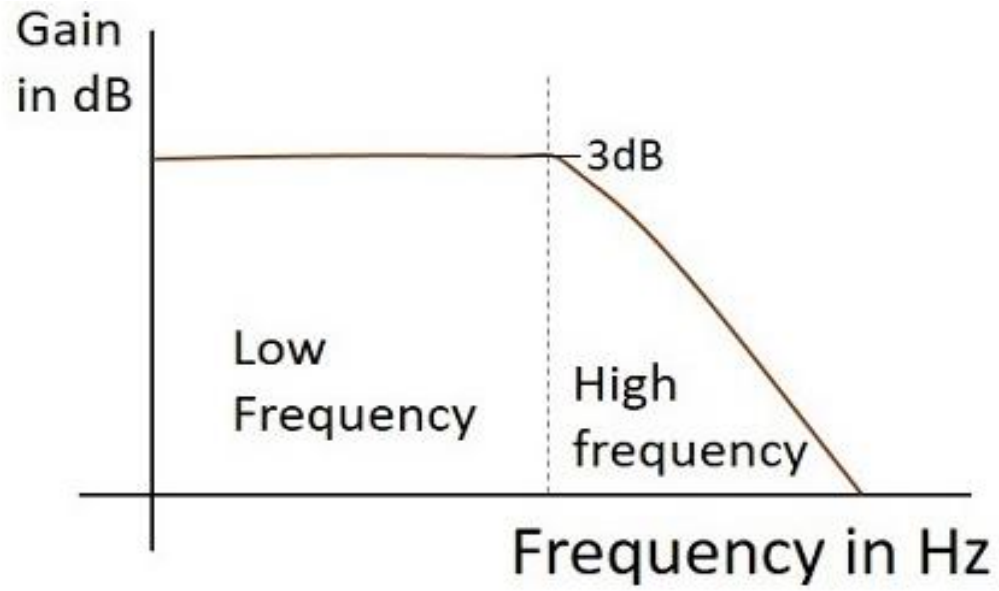
(a)



(b)

Low Pass Filter as Integrator

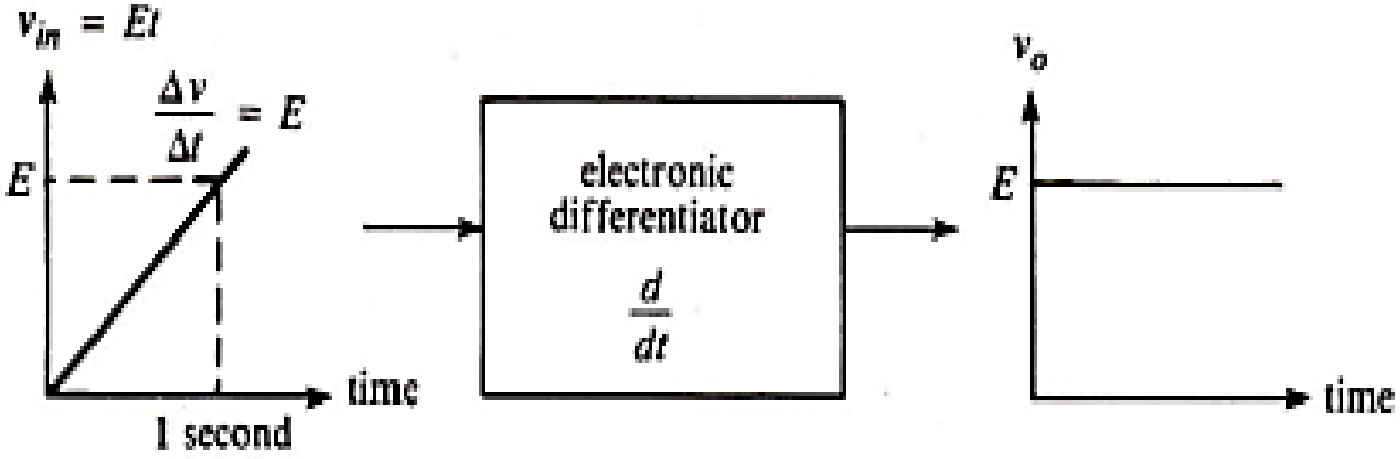
- At low frequencies, the capacitive reactance tends to become infinite and at high frequencies the reactance becomes zero. Hence at low frequencies, the LPF has finite output and at high frequencies the output is nil, which is same for an integrator circuit. Hence low pass filter can be said to be worked as an **integrator**.
- For the LPF to behave as an integrator



8- Differentiator (Active High pass Filter)

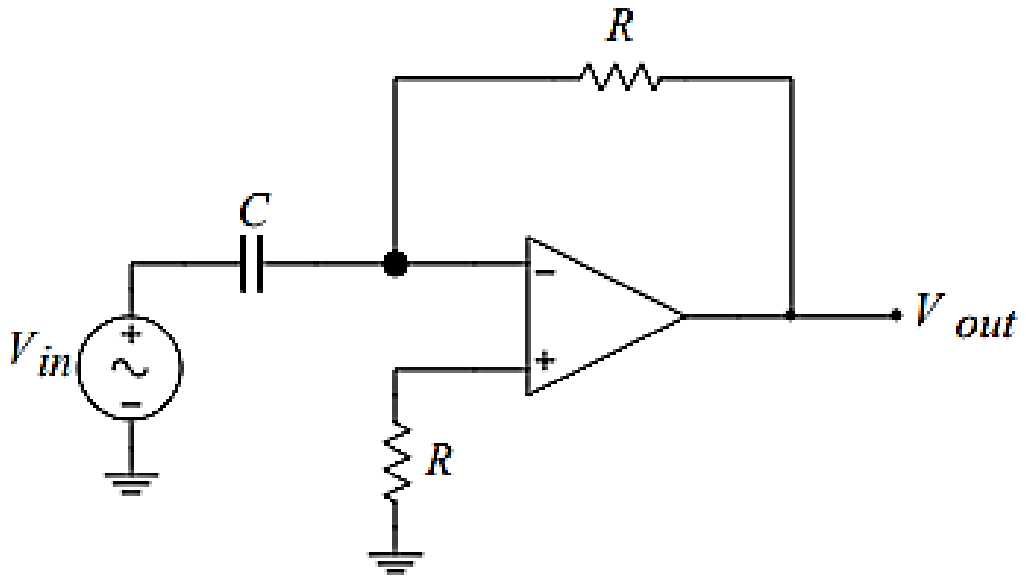
- An electronic differentiator produces an output waveform whose value at any instant of time is equal to **the rate of change of the input at that point in time**. The input is the ramp voltage vin = Et. The rate of change, or slope, of this ramp is a constant E volts/second. Since the rate of change of the input is constant, we see that the output of the differentiator is the constant dc level E volts.

$$\frac{dv_{in}}{dt} = \frac{d(Et)}{dt} = E$$



8- Differentiator (Active High pass Filter)

- A differentiator circuit may be obtained by replacing the capacitor with an inductor in Integrator circuit. In practice this is rarely done since inductors are expensive, bulky and inefficient devices.
- A fundamental differentiator circuit constructed with a capacitor and a resistor.



8- Differentiator (Active High pass Filter)

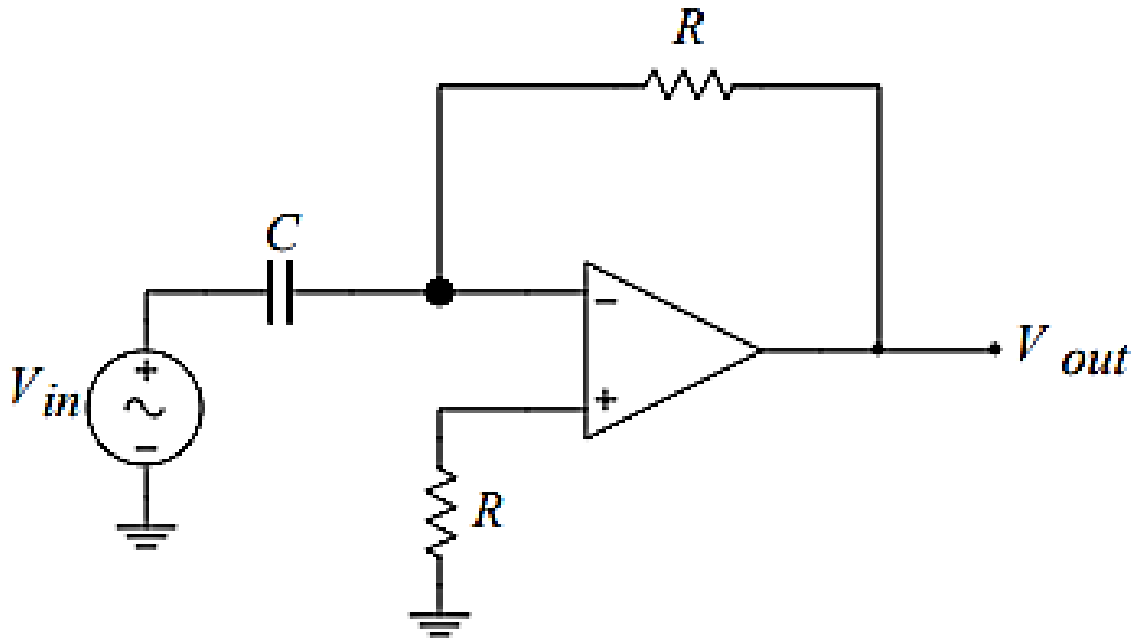
- For an ideal op-amp, the current flowing through the capacitor,

$$i_c = C\frac{dV_{in}}{dt}$$

$$i_R = \frac{-V_{out}}{R}$$

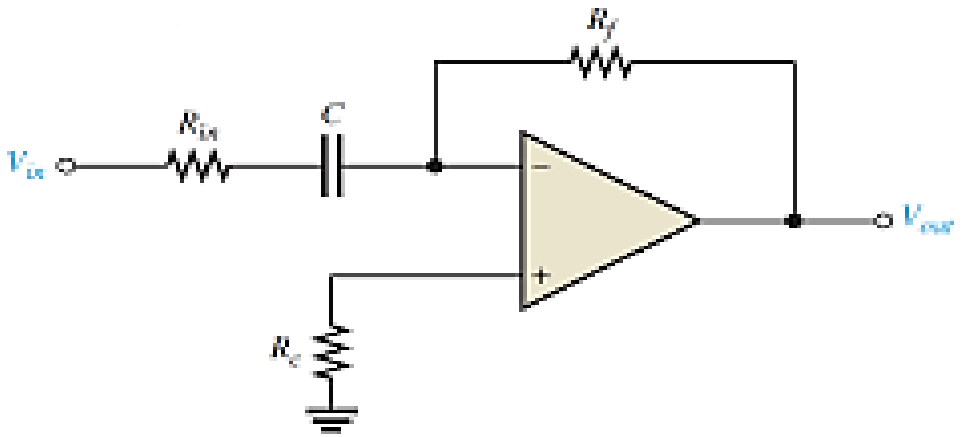
$$i_c = i_R$$

$$V_{out} = -RC\frac{dV_{in}}{dt}$$

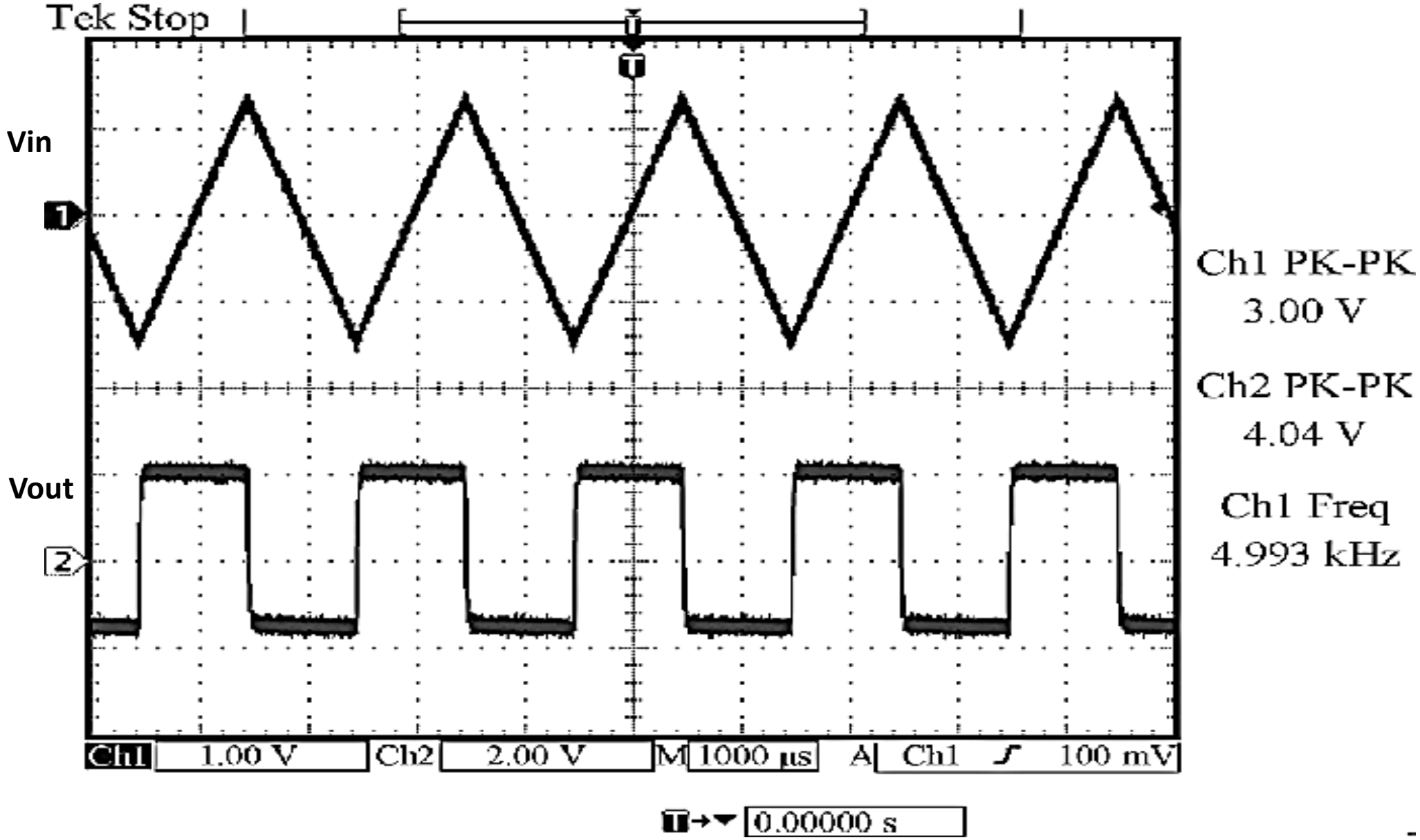


8- Differentiator (Active High pass Filter)

- As the integrator is sensitive to DC drifts, the differentiator is sensitive to high frequency noise. The differentiator thus is a great way to search for transients, but will add noise. The integrator will decrease noise. Both of these arguments assume the common situation of the noise being at higher frequency than the signal.
- The very low reactance of C at high frequencies means an ideal differentiator circuit has very high gain for high-frequency noise. To compensate for this, a small series resistor is often added to the input. This practical differentiator has reduced high frequency gain and is less prone to noise.



8- Differentiator (Active High pass Filter)



High Pass Filter

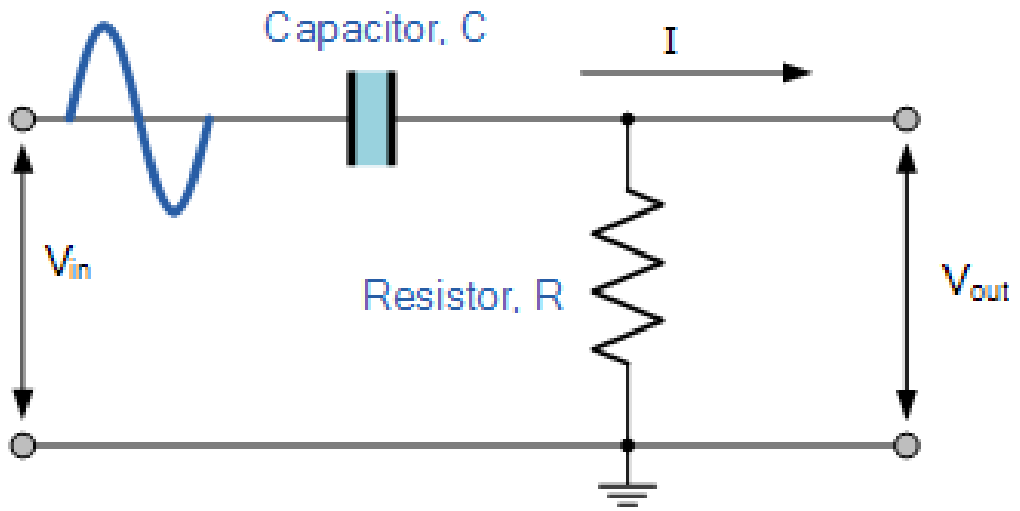
- A **high-pass filter** (**HPF**) is an electronic filter that passes signals with a frequency higher than a certain cutoff frequency and attenuates signals with frequencies lower than the cutoff frequency. The amount of attenuation for each frequency depends on the filter design.
- High-pass filters have many uses, such as blocking DC from circuitry sensitive to non-zero average voltages or radio frequency devices. They can also be used in conjunction with a low-pass filter to produce a bandpass filter.
- For sharpening the image, high pass filters are used in image processing. It is used in various control systems.
- **Types of High pass filter:**

❑Passive high pass filter

❑Active high pass filter

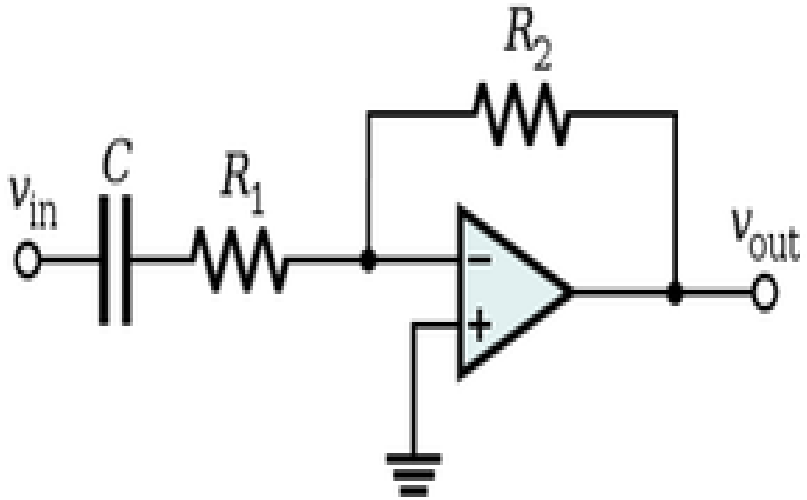
Passive High Pass Filter

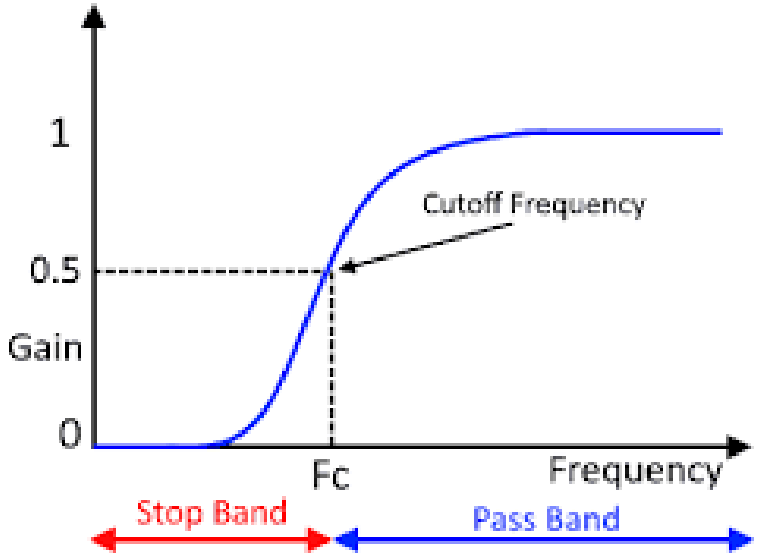
- A High Pass Filter is the exact opposite to the low pass filter circuit as the two components have been interchanged with the filters output signal now being taken from across the resistor
- Where as the low pass filter only allowed signals to pass below its cut-off frequency point, ƒc, the passive high pass filter circuit as its name implies, only passes signals above the selected cut-off point, ƒc eliminating any low frequency signals from the waveform.



Active High Pass Filter

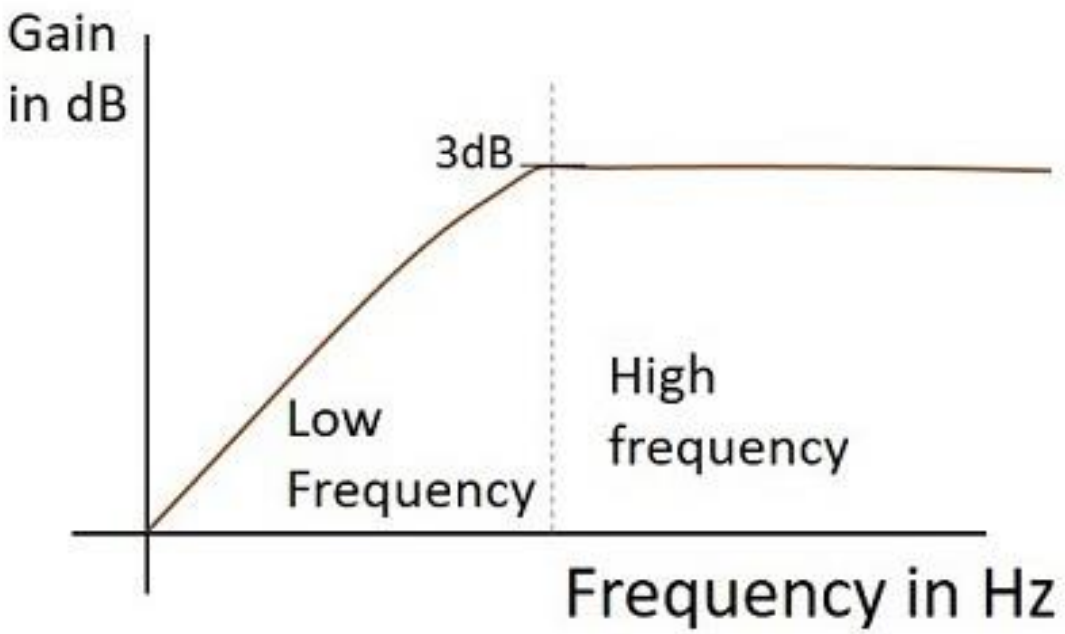
- The Active filter is a combination of a passive filter with an operational amplifier (OP-AMP) or it includes an amplifier with gain control.
- It is made by connecting an inverting or non-inverting component of OP-AMP with a passive filter.





High Pass Filter as Differentiator

- At low frequencies, the output of a differentiator is zero whereas at high frequencies, its output is of some finite value. This is same as for a differentiator. Hence the high pass filter is said to be behaved as a differentiator.



Difference between Low pass filter and High pass filter:

Low pass filter	High pass filter
It is used for smoothing the image.	It is used for sharpening the image.
It attenuates the high frequency.	It attenuates the low frequency.
Low frequency is preserved in it.	High frequency is preserved in it.
It allows the frequencies below cut off frequency to pass through it.	It allows the frequencies above cut off frequency to pass through it.
It consists of resistor that is followed by capacitor.	It consists of capacitor that is followed by a resistor.
It helps in removal of aliasing effect.	It helps in removal of noise.