

Active Filters

Theory

An electric filter is a frequency-selecting circuit designed to pass a specified band of frequencies while attenuating signals of frequencies outside this band. Filters may be either active or passive depending on the type of elements used in their circuitry. Passive filters contain only resistors, capacitors, and inductors. Active filters employ transistors or op-amps in addition to resistors and capacitors. Active filters offer several advantages over passive filters. Since the op-amp is capable of providing a gain, the input signal is not attenuated as it is in a passive filter. Because of the high input and low output resistance of the op-amp, the active filter does not cause loading of the source or load. There are four types of filters: low-pass, high-pass, band-pass, and band-reject filters. A low-pass filter has a constant gain ($=V_{out}/V_{in}$) from 0 Hz to a high cut off frequency f_H . This cut off frequency is defined as the frequency where the voltage gain is reduced to 0.707, that is at f_H the gain is down by 3 dB; after that ($f > f_H$) it decreases as f increases. The frequencies between 0 Hz and f_H are called pass band frequencies, whereas the frequencies beyond f_H are the so-called stop band frequencies. A common use of a low-pass filter is to remove noise or other unwanted high-frequency components in a signal for which you are only interested in the dc or low frequency components. Low-pass filters are also used to avoid aliasing in analog-digital conversion correspondingly, a high-pass filter has a stop band for $0 < f < f_L$ and where f_L is the low cut off frequency. A common use for a high-pass filter is to remove the dc component of a signal for which you are only interested in the ac components (such as an audio signal). A band pass filter has a pass band between two cut off frequencies f_H and f_L , ($f_H > f_L$), and two stop bands $0 < f < f_L$ and $f > f_H$. The bandwidth of a band pass filter is equal to $f_H - f_L$. The actual response curves of the filters in the stop band either steadily decrease or increase with increase of frequency. The roll-off rate, measured at [dB/decade] or [dB/octave] is defined as rate change of power at 10 times (decade) or 2 times (octave) change of frequency in the stop band. The “First-order” filters attenuate voltages in the stop band 20 dB/decade (for example, a first-order low pass filter would attenuate a signal at a frequency 100 times (2 decades) higher than f_H by 40 dB. The second-order filters attenuate by about 40 dB/decade.

Lab 10

Low Pass Filter

Objectives:

To study the Active Low pass filter and to evaluate:

- High cutoff frequency of Low pass filter.
- Pass band gain of Low pass filter.
- Plot the frequency response of Low pass filter.

Equipment:

1. DC power supplies +15V, -15V from external source
2. Function generator
3. Oscilloscope
4. Digital Multimeter

Components:

1. Resistance 10kΩ
2. Resistance 22kΩ
3. Capacitor 0.01μF
4. LM 741

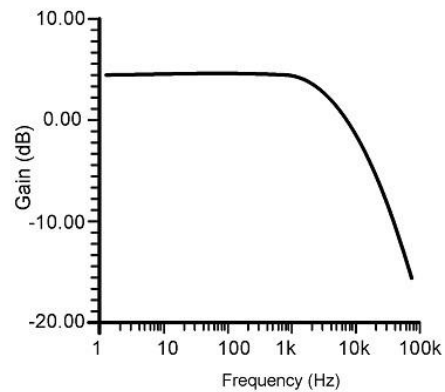
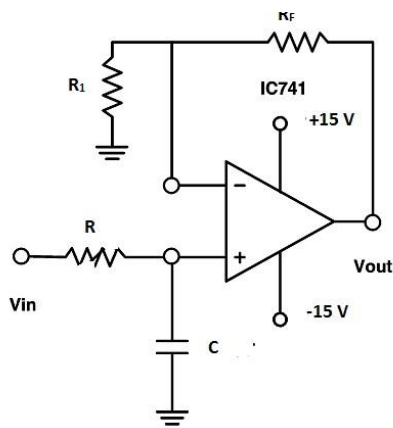


Figure 1

Equation of low pass filter

$$\frac{V_{out}}{V_{in}} = \frac{A_F}{1+j(f/f_h)} \quad 1$$

$$\frac{V_{out}}{V_{in}} = \frac{A_F}{\sqrt{1 + \left(\frac{f}{f_h}\right)^2}} \quad 2$$

V_{in} = Input signal Voltage

V_{out} = Output signal Voltage

$|V_{out}/V_{in}|$ = Gain of filter as a function of frequency

$A_F = 1 + R_F/R_1$ = pass band gain of filter

f = frequency of input signal

$f_H = 1/2\pi RC$ = high cut off frequency, 3-dB frequency, corner frequency

Operation of low pass filter using equation 2

- a. At low frequencies $f < f_H$; $\left| \frac{V_{out}}{V_{in}} \right| = A_F$
- b. At $f = f_H$ $\left| \frac{V_{out}}{V_{in}} \right| = 0.707 * A_{F(Approx)}$
- c. At $f > f_H$ $\left| \frac{V_{out}}{V_{in}} \right| < A_F$

The ideal low pass filter has a constant gain A_F from 0 to high cut off frequency (f_H) at f_H the gain is $0.707 * A_F$, and after f_H it decreases at a constant rate with an increase in frequency i.e., when input frequency is increased tenfold (one decade), the voltage gain is divided by 10. Gain (dB) = $20 \log |V_{out} / V_{in}|$ i.e., Gain Roll off rate is $-20\text{dB} / \text{decade}$.

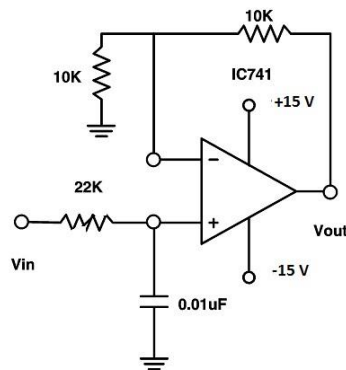


Figure 2

Procedure:

1. Connect the circuit as shown in Figure 2.
2. Switch ON the power supply
3. Connect a sinusoidal signal of amplitude 1V (p-p) of frequency 1KHz to V_{in} of Low pass filter from function generator
4. Connect Ch-1 of oscilloscope to the signal source
5. Observe output on Ch-2 of oscilloscope
6. Increase the frequency of input signal step by step and observe the effect on output V_{out} on oscilloscope
7. Tabulate values of V_{out} , gain, gain (dB) at different values of input frequency shown in observation Table 2.
8. Plot the frequency response of low pass filter using the data obtained at different input frequencies.

Theoretical Calculations:

Calculate all the following values

1. Pass band gain of Low pass filter $A_F = 1 + R_F / R_I$
2. Pass band gain (dB) = $20 \log |V_{out} / V_{in}|$
3. 3 dB frequency $f_H = 1/2\pi RC$
4. Gain at 3 dB frequency $f_H = 0.707 * A_F$
5. Roll off rate = -20db/decade

Results:

	Theoretical	Practical
Pass band gain(A_f)		
Pass band gain(A_f) in db		
3db frequency f_H		
Gain at 3db frequency (f_H) in db		

Table 1

Sr. No.	Input Frequency (Hz)	V_{out}	$ V_{out}/V_{in} = \text{Gain}$	Gain (dB) = $20 \log V_{out} / V_{in} $
1	300			
2	500			
3	700			
4	1k			
5	5k			
6	10k			
7	15k			

Table 2