ActiveLowPassFilter -- Overview

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OBJECTIVES:

At the end of performing this experiment, learners would be able to:
• Describe the concept of active Low Pass Butterworth Filter
• Obtain the roll-off factor and cutoff frequency of the filter designed
• Compare the designed cut-off frequency with the desired cut-off frequency
• Understand the working of μA741 IC (Op Amp)

EQUIPMENT:

• IC μA741
• Signal generator
• Resistors
• Capacitor
• +/- 15V DC Power Supply
• Digital Storage Oscilloscope & probes
• Connecting wires & Bread Board

DESIGN:

• Obtain the internal impedance RS of the signal source
• Given cut-off frequency f Hz, assume suitable R, (greater than RS),
• Calculate C using equation (5)
• Assume R1 and compute R2 using equation (6)

THEORY:

• Op - Amp is a DC-coupled high-gain electronic voltage amplifier with a differential input and a output.

• The μA741 device is a general-purpose operational amplifier featuring offset-voltage null capability

• The n poles of an n th order Butterworth filter lie on the left half of the s-plane, on a circle of radius unity (the poles have an angular separation of π/n radians). The second order Butterworth filter has two poles p1 and p2 located on the left half of the s-plane as shown in the figure 1. Hence the transfer function of the filter with cut-off frequency Wc = 1 radians/second is given by

$$H(s) = \frac{1}{(s - p1)(s - p2)} \qquad (1)$$

Where, $p1 = (-0.707 + j0.707)$ and $p2 = (-0.707 - j0.707)$

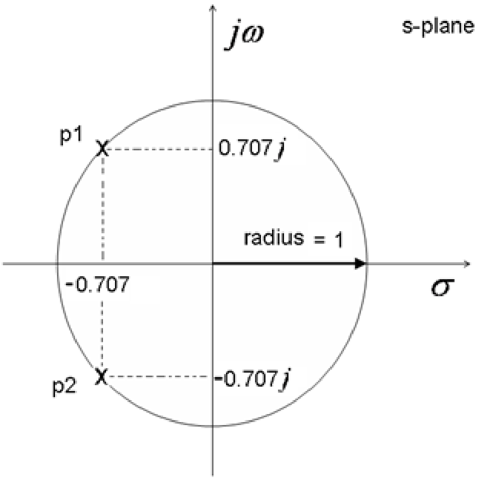


Figure 1: The two poles of the second order Butterworth low pass filter

Which is equivalent to

$$H(s) = \frac{1}{(s^2 + 1.414s + 1)} \qquad (2)$$

To obtain the transfer function of a filter with cut-off Wc radians/second, we replace s by s/Wc, and we have,

$$H(s) = \frac{1}{((s/\omega_c)^2 + 1.414(s/\omega_c) + 1)} \qquad (3)$$

The practical realization of the equation (3) is given by figure 2, has the transfer function

$$H_f(s) = \frac{(1/RC)}{(s^2 + ((3 - A_F)/RC)s + (1/RC)^2)} \qquad (4)$$

Comparing equations (3) and (4), we have the cut-off frequency as Wc = 1/RC radians/second

or $$f_c = \frac{1}{2\pi RC} Hz \qquad (5)$$

with feedback gain A_F $$A_F = \left(1 + \frac{R_2}{R_1}\right) = 1.586 \qquad (6)$$

Reference Reading:

1) Theory and application of Digital SIgnal Processing, by Lawrence R Rabine and Bernard Gold, Prentice Hall, Easter Economy Edition
2) Integrated Electronics, by Millman and Halkias, Tata McGraw-Hill

Acknowledgement

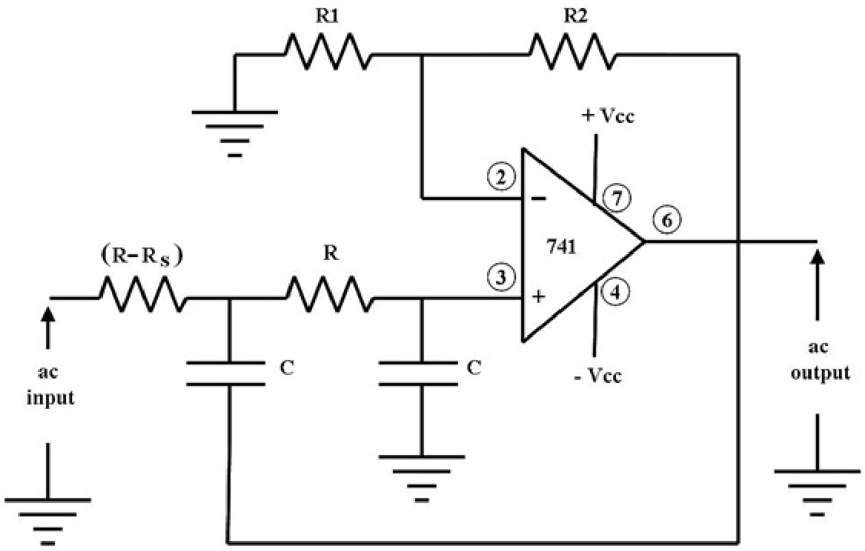
Mr. Shreenivas B for converting laboratory experiment to Tektronix courseware format

ActiveLowPassFilter -- Procedures

Step 1

Circuit setup:

Build the following circuit with given designed values



Second order low-pass active Butterworth filter

Step 2

• Use a signal generator to generate analog input . The analog input will be set to 1 Vpp Sine wave
• Turn on the supply of the circuit and enable signal generator that is feeding signal to the circuit.

Step 3

• Connect the DSO probe – CH1 at analog input (Sine wave), CH2 at output (pin # 6 of μA741 IC)
• Perform Autoset on DSO and capture the output signal.

Step 4

• Configure PEAK-to-PEAK measurement on the input and output signal.
• Observe and record the signal – input and output.

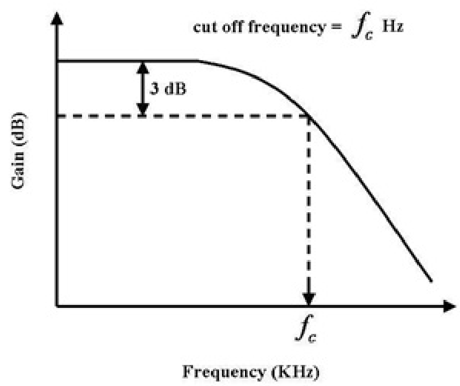
Step 5

Record the input and output peak-to-peak voltage for various input frequencies, and complete the table below

Frequency (Hz)	Vin(v)	Vout (v)	Gain (dB) = 20 log (Vout / Vin)
100 Hz			
200 Hz			
......			
1KHz			
2KHz			
......			
10KHz			
20KHz			
......			
100KHz			
200KHz			
......			
1MHz			

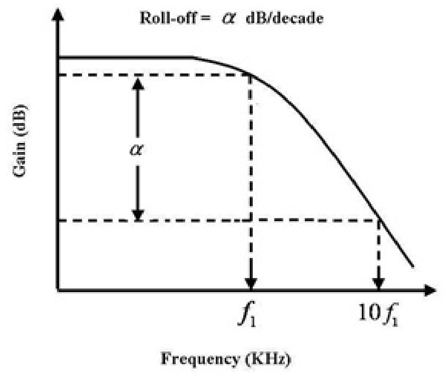
Step 6

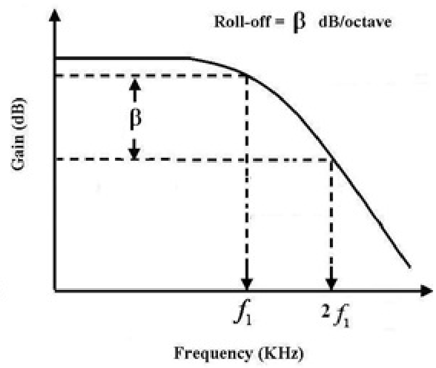
Plot the frequency response of the designed filter (Plot of Frequency Vs. Gain on a semi-log sheet), and hence obtain the cut-off frequency



Step 7

Compute the Roll-off factor of the designed filter (The ideal value of roll-off factor is - 40dB/decade or -12dB/octave)





Step 8

Observations:

i) The designed filter has a cut-off frequency ………….Hz
ii) The designed filter has a roll-off factor ……….. dB/decade

Step 9

Open-ended Question / Can you answer this?

What will be the result if:
1) We repeat the frequency response readings for Passive Low Pass Filter. How does it compare Active Low Pass Filter
2) We sketch the frequency response of the passive and active second order LPF on the same graph sheet. What is the observation?
3) We give a square wave equal to the designed cut-off frequency and record the output. Give reason if the output waveform is a sine wave.