Experiment
2

Active Filters

Objectives

To design Second-Order Active Filter by using OP-Amp as an active device, and resistance and capacitance as passive devices.

Overview

1. Transfer function of Second-Order active filter (二階濾波轉移函數)：

   The general form of the transfer function of second-order active filter is shown as follow.

$$T(S) = \frac{A_2 S^2 + A_1 S + A_0}{S^2 + (\omega_0 / Q) S + \omega_0^2}$$

   If $A_1 = A_2 = 0$, $T(S)$ represents the transfer function of a low-pass filter.
   If $A_0 = A_1 = 0$, $T(S)$ represents the transfer function of a high-pass filter.
   If $A_0 = A_2 = 0$, $T(S)$ represents the transfer function of a band-pass filter.

2. Two-Integrator-Loop filter, TIL filter:

   In Fig. 1, if we assume all the applied OP-Amps are ideal, we could show that, for the input signal V_i, V_{hp}/V_i, V_{bp}/V_i, $V_{\ell p}/V_i$ represent the transfer function of high pass, band pass and low pass filer, respectively. If V_{hp}, V_{bp}, $V_{\ell p}$ are appropriately combined all together, we could, therefore, have any kind of second order transfer function of biquadratic filter.

   Additionally, cascading the circuits shown in Fig. 1 is able to make transfer function to be any order. However, because of the restriction of the circuit components (the tolerance from R and C, or the limited bandwidth of OP-Amps), the circuit is usually designed for the filter type less than 4 order. Readers can refer to the relationships of f_{3dB}, Q, ω_0, R and C in chapter 11 of the text book.

3. Single-amplifier biquadratic active filter, SAB active filter:

   TIL filter is a multi-function and high-performance filter. However, it needs more chips of OP-Amps, which means the power consumption of TIL filter is higher. In another word, it is not able to reach the low requirement of power waste.

On the other hand, SAB active filters shown in Fig. 2 and Fig.3 need only one OP-Amp, and they can be designed as second-order filters, which mean the power consumption of SAB active filters are low. However, the different value of *R* and *C* makes the sensitivity of the circuit higher.

4. Conclusion:

TIL filter:

(1) Advantage: Multi-functional, better performance,

(2) Disadvantage: High power consumption

SAB active filter:

(1) Advantage: Low power consumption,

(2) Disadvantage: High sensitivity. (resulted by the different value of *R* and *C*.)

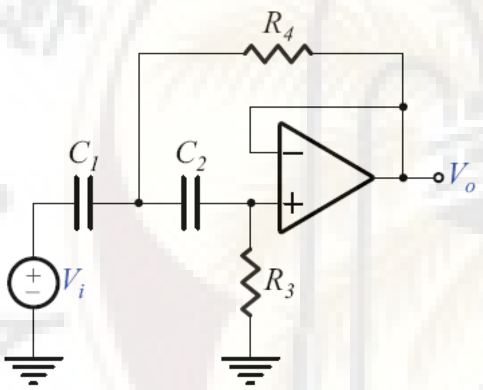


Fig. 2 SAB Active HPF

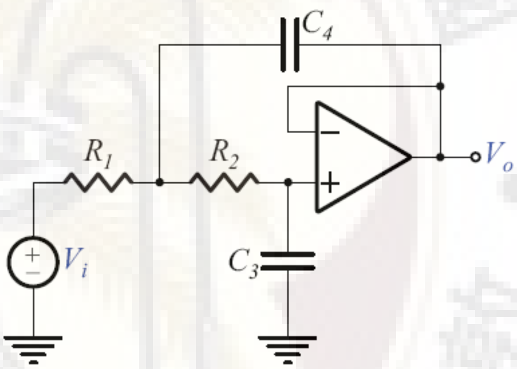


Fig. 3 SAB Active LPF

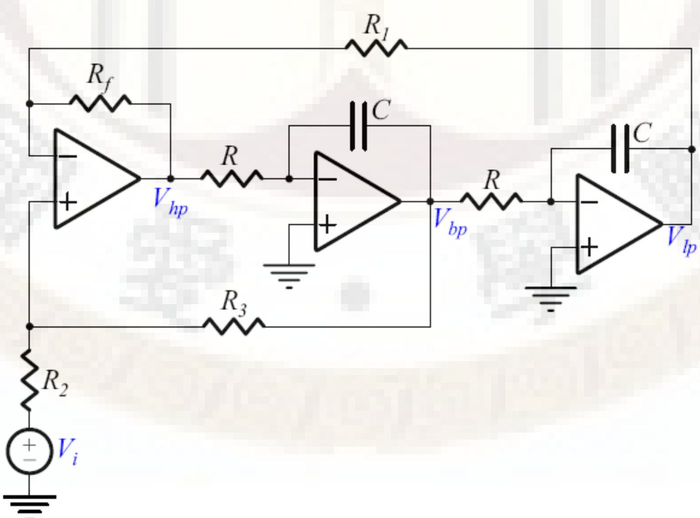


Fig. 1 Two-Integral-Loop Active Filter

Components and Instrumentation

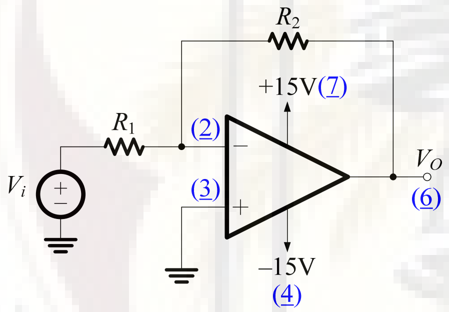
Instrument	Quantity	Components	Quantity
Oscilloscope	1	μA 741	3
Multi-meter	1	Resistance	Designed value
Power supplier	1	Capacitance	Designed value
Function Gen.	1		

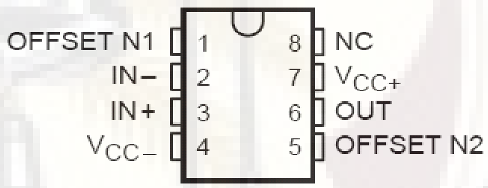
Instrument confirmation

Before you proceed to any part of the experiment, please remember to do the **Instrument Examinations** to the instruments before performing any experiment. The examining procedures are shown in experiment 1.

Components confirmation

μA741 — PINOUT & Functional confirmation





µA741M . . . U PACKAGE
(TOP VIEW)

$$Check\ 1.\ A_V = \frac{V_o}{V_i} \overset{?}{=} -\left(\frac{R_2}{R_1}\right)$$

$$Check\ 2.\ f_{3dB} \overset{?}{=} 100kHz \sim 500kHz$$

Note: Recall the expression of gain — bandwidth product: $A_V \times f_{3dB}$=constant, that is, f_{3dB} will reduce as A_V increases. If the results of confirmation appear the same as those shown in check 1 and 2, the μA741 chip of OP amp is workable.

Lab Work

1. SAB active filter − HPF

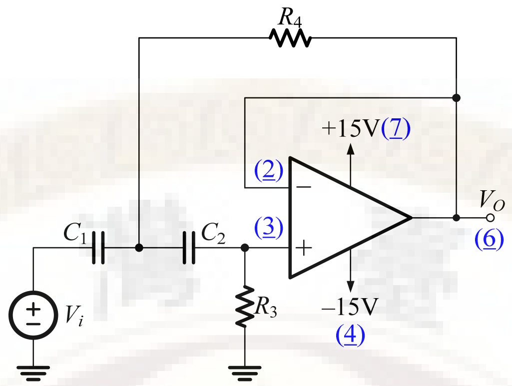


Fig. 2 SAB Active HPF

(1) Employ the designed value of C_1, C_2, R_3, R_4 to the circuit in Fig. 2.

(2) Apply the input small signal V_i to the breadboard by using function generator to generate $v_i = v_{ac} \times \sin(2\pi ft)$, $2v_{ac} = 1V_{(p\text{-}p)}$.

(3) Make sure that the v_i is measured from the breadboard by using the probe from **CH1** in oscilloscope.

(4) Keep the previous adjustment of V_i constantly, and do not adjust the amplitude tuner in function generator any further.

(5) Oscilloscope ► **YT mode.**

(6) Oscilloscope ► Observe $V_{i(p\text{-}p)}$ in **CH1** and $V_{o(p\text{-}p)}$ in **CH2**.

(7) Record the voltage gain A_M = ________ V/V ($V_o/V_i \sim 1$) as $f > f_{H3dB}$.

(8) Record the frequency f_{H3dB} = ________ Hz.

(9) Change the frequency of input voltage source, and record the input and output voltage shown in oscilloscope to the following table.

f (Hz)	$V_{i(p\text{-}p)}$	$V_{O(p\text{-}p)}$	A_V	f (Hz)	$V_{i(p\text{-}p)}$	$V_{O(p\text{-}p)}$	A_V
20				10K			
50				20K			
100				50K			
200				100K			
500				200K			
1K				500K			
2K				1M			
5K				2M			

※ *Homework* #1: Apply the measured data from the above table to the editing software such as EXCEL and MATLAB, and illustrate the frequency-response diagram with marking f_{3dB} and the corresponding voltage.

2. SAB Active LPF

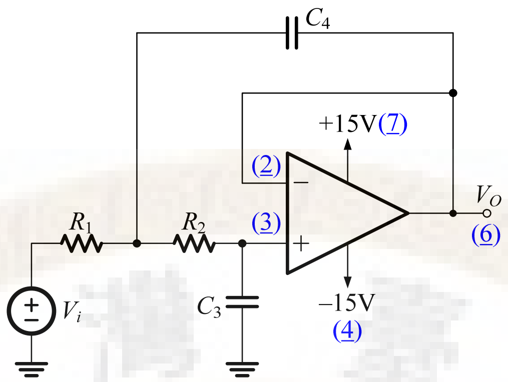


Fig. 3 SAB Active LPF

(1) Repeat step (2) ~ (9) shown in step 1.

(2) Record the voltage gain A_M = ________ V/V (V_o/V_i~1) as $f < f_{L3dB}$.

(3) Record the frequency f_{L3dB} = ____________ Hz.

(4) Change the frequency of input voltage source, and record the input and output voltage shown in oscilloscope to the following table.

f (Hz)	$V_{i(p\text{-}p)}$	$V_{O(p\text{-}p)}$	A_V	f (Hz)	$V_{i(p\text{-}p)}$	$V_{O(p\text{-}p)}$	A_V
20				10K			
50				20K			
100				50K			
200				100K			
500				200K			
1K				500K			
2K				1M			
5K				2M			

※ *Homework* #2: Apply the measured data from the above table to the editing software such as EXCEL and MATLAB, and illustrate the frequency-response diagram with marking f_{3dB} and the corresponding voltage.

3. Two-integrator-loop filter (TIL filter)

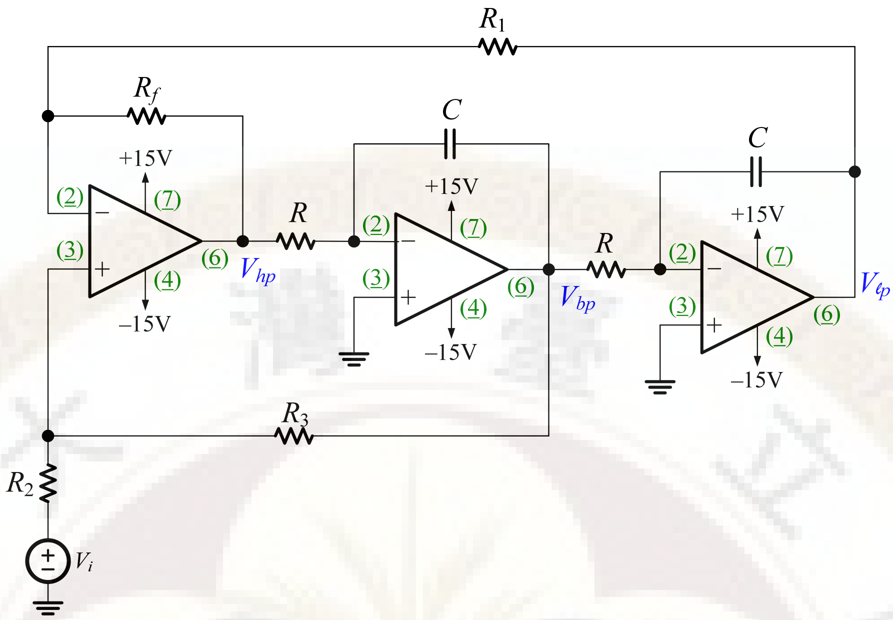


Fig. 1 Two-Integral-Loop Active Filter

(1) Employ the designed value from problem 1(a) in PR for C_1, C_2, R_3, R_f to the circuit in Fig. 1.

(2) Apply the input small signal V_i to the breadboard by using function generator to generate $v_i = v_{ac}\times\sin(2\pi ft)$, $2v_{ac} = 1\mathrm{V}_{(\text{p-p})}$.

(3) Make sure that the v_i is measured from the breadboard by using the probe from **CH1** in oscilloscope.

(4) Keep the previous adjustment of V_i constantly, and do not adjust the amplitude tuner in function generator any further.

(5) Oscilloscope ► **YT mode.**

(6) Oscilloscope ► Observe $V_{i(\text{p-p})}$ in **CH1** and $V_{o(\text{p-p})}$ in **CH2**.

(7) Record the voltage gain A_0 = ________V/V (V_{bp}/V_i~10~15) and $f = f_0$ represents central frequency of the band-pass filter)

(8) Record the frequency f_{L3dB}=________Hz, f_{H3dB} =________Hz, f_0=________Hz.

(9) Change the frequency of input voltage source, and record the input and output voltage shown in oscilloscope to the following table.

f (Hz)	$V_{bp(\text{p-p})}$	f (Hz)	$V_{bp(\text{p-p})}$
10		10K	
20		20K	
50		50K	
100		100K	
1K		200K	
2K		500K	
5K			

(10) Employ the designed value from problem 1(b) in PR for C_1, C_2, R_3, R_f to the circuit in Fig. 1.

(11) Keep the previous adjustment of V_i constantly, and do not adjust the amplitude tuner in function generator any further.

(12) Record the voltage gain A_M = ________ V/V ($V_{lp}/V_i \sim 1$) as $f < f_{L3dB}$.

(13) Record the frequency f_{L3dB}=______ Hz,

(14) Change the frequency of input voltage source, and record the input and output voltage shown in oscilloscope to the following table.

f (Hz)	$V_{lp(p\text{-}p)}$	f (Hz)	$V_{lp(p\text{-}p)}$
10		10K	
20		20K	
50		50K	
100		100K	
1K		200K	
2K		500K	
5K			

※ *Homework* #3: Apply the measured data from the above table to the editing software such as EXCEL and MATLAB, and illustrate the frequency-response diagram with marking f_{3dB} and the corresponding voltage.

Reference

1. A.S. Sedra and K.C. Smith, *Microelectronic Circuits*, 6th ed., Oxford University Press publishing, New York, 2011.
2. A.S. Sedra and K.C. Smith, *Laboratory Manual for Microelectronic Circuits*, 3rd ed., Oxford University Press publishing, New York, 1997.
3. Paul Horowitz, Winfield Hill, *The art of electronics*, 2nd ed., Cambridge University Press, New York, 1989.