Experiment

5

Multi-Pole Feedback Network OP-Amp Circuit

Objectives

1. To analyze the theory of *feedback network* in the multi-pole OP-Amp circuit.
2. To discuss the issue of *stability* for the feedback amplifier.
3. To understand the physical meaning of *sinusoidal vibration*.

Overview

The shunt-shunt feedback circuit to be explored is shown in Fig. 1.

Here the underlying assumption is that the poles associated with each follower are very high in frequency, and that those associated with the single inverter (without C_1) are high enough to be ignored. With this assumption, the circuit has three controllable poles for which the associated time constants are RC_1, RC_2 and RC_3. The total (open loop) gain at low frequencies is $-R/r$. Resistors R_1 and R_2 establish a nominal closed-loop minimum gain of -1. Potentiometer R_P allows the closed-loop gain to be adjusted from -1 to $-R/r$ continuously. Accordingly, reference will likewise be broad, covering Sections 8.1, 8.6~8.10 of the text [Reference 1].

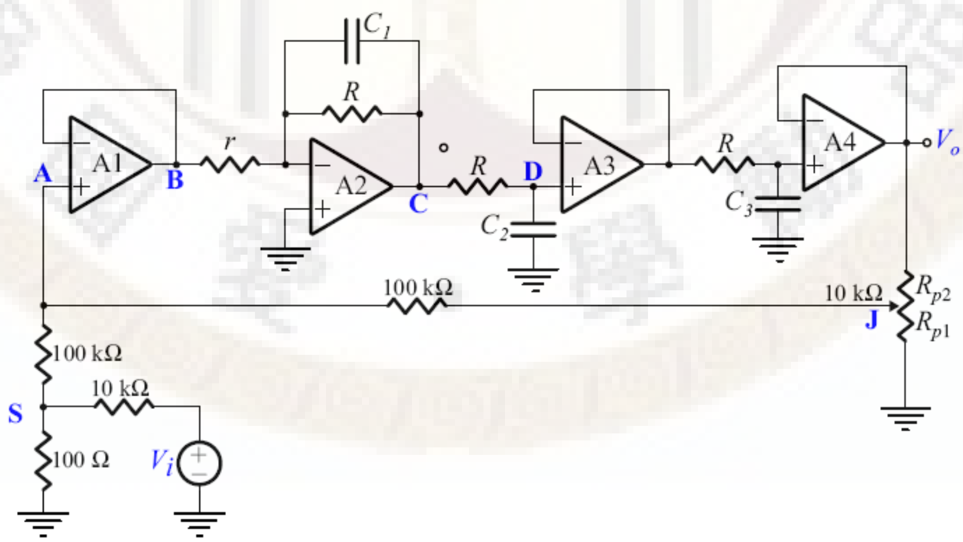


Fig. 1 Multi-pole feedback network OP-Amp circuit

Components and Instrumentation

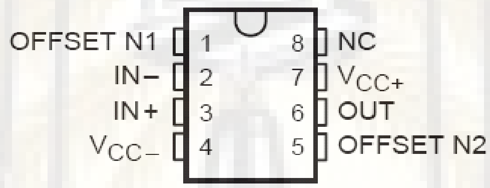
Instrument	Quantity	Component	Quantity
Oscilloscope	1	μA 741	4
Multi-meter	1	VR (10 kΩ)	1
Power supplier	1	100 Ω	2
Function Gen.	1	10 kΩ	4
0.1 μF	3	100 kΩ	2

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.

Lab Work

1. μA741—PINOUT & Functional confirmation



µA741M . . . U PACKAGE
(TOP VIEW)

2. DC Functional Confirmation of A_1

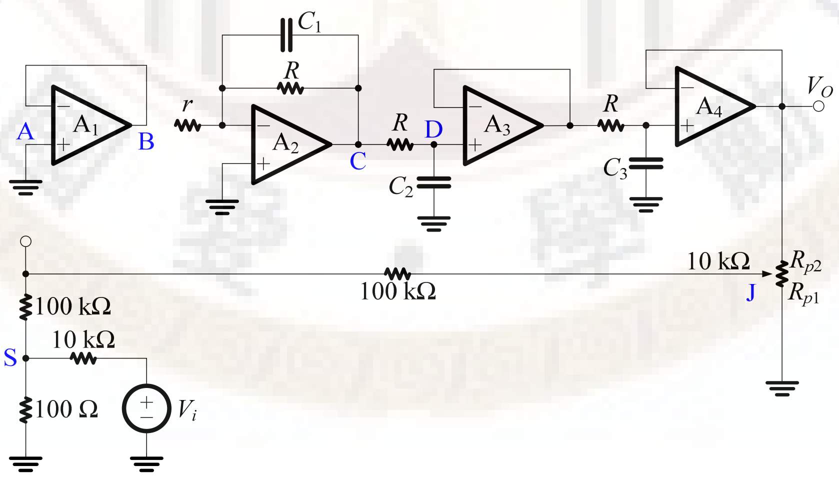


Fig. 2 DC Functional Confirmation of A_1

(1) Reference pin voltage for A_1,

(2) $V_{pin7} \fallingdotseq +15V$, $V_{pin4} \fallingdotseq -15V$, $V_{pin2}=V_{pin3}=V_{pin6} \fallingdotseq 0V$.

(3) Record the measured pin voltage for A_1, V_{pin7} =_____V, V_{pin4} =_____V, V_{pin2} = _______V, V_{pin3} =_____V, V_{pin6} =_____V.

3. DC Functional Confirmation of A_2

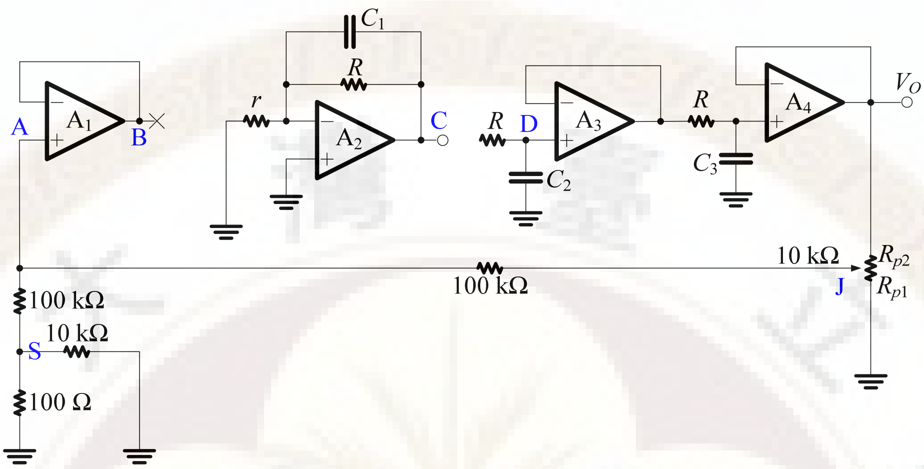


Fig. 3 DC Functional Confirmation of A_2

(4) Use R = 10 kΩ, r = 100 Ω, C_1 = 0.1 μF (104) for A_2 (Single-time-constant Low-pass Filter, STC LPF) in Fig. 3.

(5) Supply voltage source V_{CC} = +15V, and $-V_{CC}$ = −15V to the circuit.

(6) Reference pin voltage for A_2,

(7) $V_{pin7} \doteqdot +15V$, $V_{pin4} \doteqdot -15V$, $V_{pin2}=V_{pin3}=V_{pin6} \doteqdot 0V$.

(8) Record the measured pin voltage for A_2, V_{pin7} =_____V, V_{pin4} =_____V, V_{pin2} = _____V, V_{pin3} =_____V, V_{pin6} =_____V.

Note: If the measured values are far different from those shown in the reference pin voltage, try to change a chip of μA741 and repeat step 2 until they are correct.

4. Small signal analysis

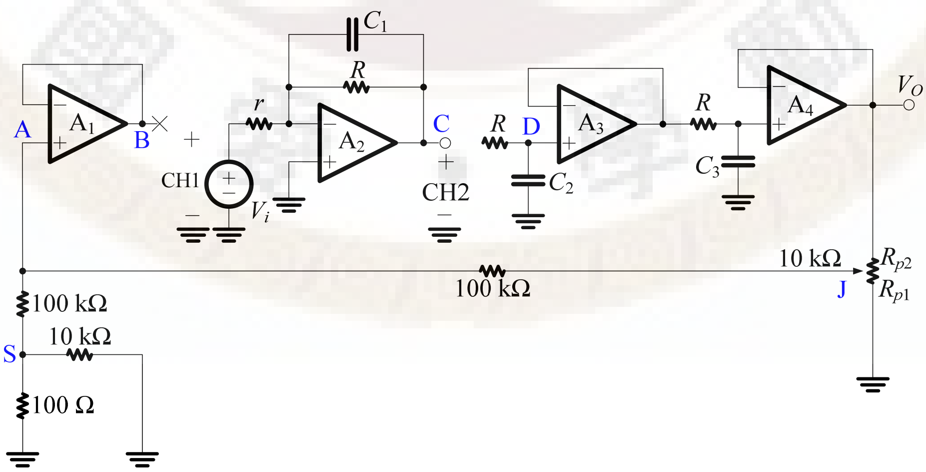


Fig. 4 Small signal analysis of A_2

(1) Use $R = 10$ kΩ, $r = 100$ Ω, $C_1 = 0.1$ μF(104) for A_2 in Fig. 4.

(2) Supply voltage source $V_{CC} = +15$V, and $-V_{CC} = -15$V to the circuit.

(3) Apply the input small signal V_i to the breadboard by using function generator to generate $v_i = v_{ac} \times \sin(2\pi ft)$, $2v_{ac} = 100\text{mV}_{(p\text{-}p)}$, $f = 100$ Hz.

$$T(j\omega) = \frac{V_C(j\omega)}{V_B(j\omega)} = -\frac{R}{r} \cdot \frac{1}{1 + j\omega \cdot (RC_1)} = \frac{-A_M}{1 + \dfrac{j\omega}{1/(RC_1)}}$$

$$where: \omega_{3dB} = \frac{1}{RC_1}, A_M = \frac{R}{r} = \frac{10k\Omega}{0.1k\Omega} = 100$$

$$\left|T(j\omega_{3dB})\right|_{\omega=\omega_{3dB}} = \frac{-A_M}{\sqrt{2}} = -0.707 \times A_M = -70.7$$

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

(5) Oscilloscope ▶ Press the **CH1** and **CH2 MENU** ▶ **Coupling** ▶ **AC**.

(6) Observe $V_{i(p\text{-}p)}$ and $V_{o(p\text{-}p)}$ in CH1 and CH2, respectively.

(7) Keep the previous adjustment of V_i constantly.

(8) Record the voltage gain A_M = ____________ V/V in the oscilloscope.

(9) Function generator ▶ Adjust Frequency and observe the voltage gain A_V in oscilloscope until $A_V = 0.707 \times A_M$.

(10) Record the frequency f_{3dB} = ____________ Hz. (Reference value f_{3dB} = 160Hz.)

5. DC Functional Confirmation of A_3

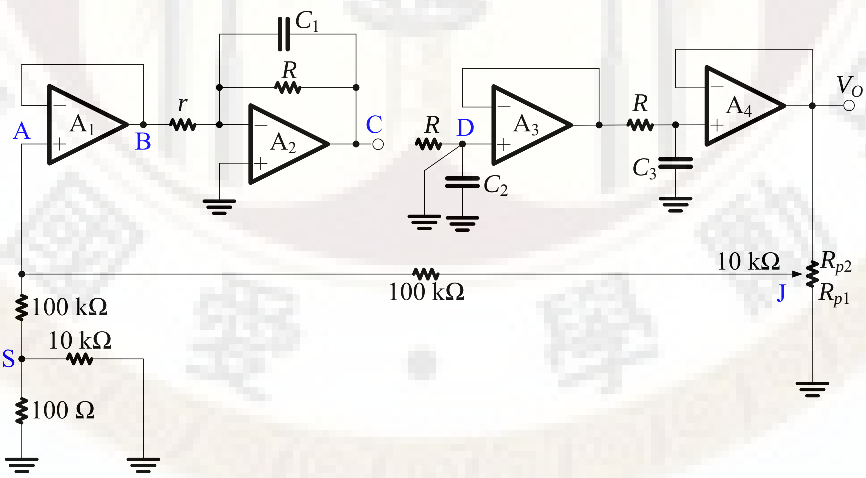


Fig. 5 DC Functional Confirmation of A_3

(1) In the Fig. 5, short terminal **D** to the ground.

(2) Reference pin voltage for A_3, $V_{pin7} \fallingdotseq +15$V, $V_{pin4} \fallingdotseq -15$V, $V_{pin2} = V_{pin3} = V_{pin6} \fallingdotseq 0$V.

(3) Record the measured pin voltage for A_3, V_{pin7} =_____V, V_{pin4} =_____V,

V_{pin2} = ______V, V_{pin3} =_____V, V_{pin6} =_____V.

6. DC Functional Confirmation of A_4

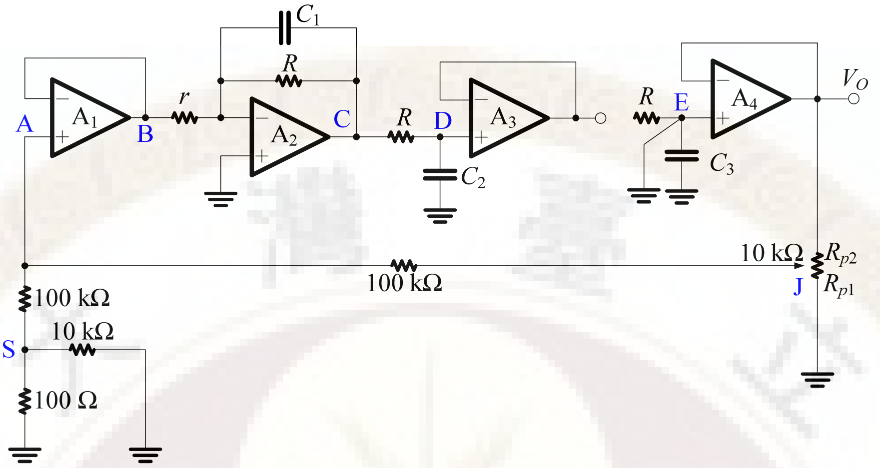


Fig. 6 DC Functional Confirmation of A_4

(4) In the Fig. 6, short terminal **E** to the ground.

(5) Reference pin voltage for A_4,

(6) $V_{pin7} \fallingdotseq +15V$, $V_{pin4} \fallingdotseq -15V$, $V_{pin2} = V_{pin3} = V_{pin6} \fallingdotseq 0V$.

(7) Record the measured pin voltage for A_4, V_{pin7} =_____V, V_{pin4} =_____V, V_{pin2} = ______V, V_{pin3} =_____V, V_{pin6} =_____V.

7. Initial state of the feedback network circuit

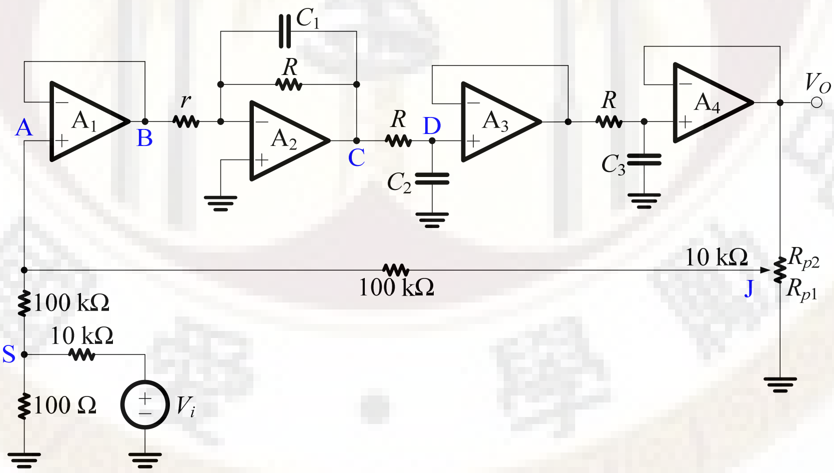


Fig. 7 Multi-pole feedback network OP-Amp circuit

(1) In Fig. 7, use R = 10 kΩ, r = 100 Ω, $C_1 = C_2 = C_3$ =0.1 μF(104), VR=10 kΩ for R_{p1}(R_{p2}).

(2) Adjust VR to have R_{p1} =0 Ω, R_{p2} = 10 kΩ.

(3) Apply the input signal V_i to the breadboard by using function generator

to generate $v_i = v_{ac} \times \text{square}(2\pi f t)$, $2v_{ac} = 5\text{V}_{(\text{p-p})}$, $f = 0\sim10$ Hz. (即 0~10Hz 之方波)。

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

(5) Oscilloscope ► Press the **CH1** and **CH2 MENU** ► **Coupling** ► DC.

(6) Observe whether the waveform shown in CH1 and CH2 distort (Y/N)? ________

Homework #1: Why should we use *DC Coupling* to observe both the waveforms in oscilloscope? Try to explain it in the conclusive report by electronic or mathematical expression.

8. Vibration observation of the circuit

(1) Keep the previous adjustment in step 7 constantly.

(2) Observe the waveform of $V_{o(\text{p-p})}$ in CH2 when slowly increasing the value of R_{p1} (decrease R_{p2}) until the sinusoidal vibration occur.

(3) As the sinusoidal vibration occur, record $V_{S(\text{p-p})}$ =_____V, $V_{J(\text{p-p})}$ =_____V, $V_{o(\text{p-p})}$ =_____V, f_o =_____Hz from the oscilloscope, R_{p1} =______ kΩ, R_{p2} =______ kΩ.

(4) During the adjustment of appearing sin-vibration, observe whether the waveform of $V_{o(\text{p-p})}$ occur damping phenomenon (Y/N). ____

(5) ※ Observe the waveform of $V_{o(\text{p-p})}$ in CH2, what if Disconnect the input signal V_i to the breadboard? Does it disappear? Why?

Homework #2: Try to explain it in the conclusive report by electronic or mathematical expression.

Reference

1. A.S. Sedra and K.C. Smith, *Microelectronic Circuits*, 6th ed., Oxford University Press publishing, New York, August 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.