EXPERIMENT 5

FEEDBACK (SERIES-SHUNT) AMPLIFIER USING OP-AMP

I. OBJECTIVES

- To familiarize the student with the basic feedback topology and technical terms.
- To explore the influence of the negative feedback on the gain, the bandwidth and the terminal resistances of an Op_Amp based system.

II. INTRODUCTION AND THEORY

Feedback can be classified into two categories, a negative feedback and a positive feedback. The first category is the most widely used in all stable systems. Other systems that operate under unstable operating condition mainly use positive feedback. For example, Oscillator uses a positive feedback under certain conditions. The feedback process starts at the output terminals of the circuit or the system to be controlled. A small portion of the output (current or voltage) is taken, then inverted (changing its sign) and added to the input signal. Figure 1 shows the general block diagram of the negative feedback system.

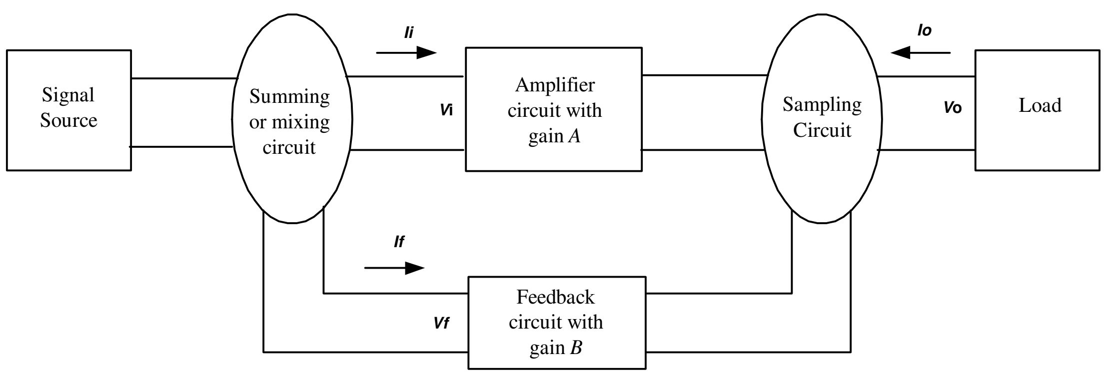


Figure **1** Basic structure of amplifier with feedback network

Applying the concept of the general feedback to the amplifier circuit, the sample of the output signal will be current or voltage with phase shift of 180 degrees compared to the input signal. The negative feedback is found to improve the amplifier stability (under some circumstances), improve the circuit's noise immunity, extend the bandwidth of the amplifier and control the input and output resistance of the amplifier by selecting the appropriate feedback topology. The feedback topology often refers to the interface between the input-feedback-output circuits. For example, Series- Shunt topology means that the interface between the input-feedback circuits is done in a series connection and the interface between the output-feedback circuits is done in a shunt connection. Also the feedback topology may refer to how the signals are mixed (summed) at the input or sampled at the output circuits. Usually voltage is mixed at the input circuit through a series connection with the input circuit. Similarly, the current is mixed at the input circuit through a shunt connection with the input circuit. At the output side, the voltages and currents are sampled through a shunt and series connections with the output circuits, respectively. In practice, the possible feedback topologies are:

- Voltage sampled - series mixed (voltage) at the input ⇔ **Series-Shunt** feedback topology.
- Current sampled - series mixed (voltage) at the input ⇔ **Series-Series** feedback topology.
- Current sampled - shunt mixed (current) at the input ⇔ **Shunt-Series** feedback topology.
- Voltage sampled - shunt mixed (current) at the input ⇔ **Shunt-Shunt** feedback topology.

Figure 2 below shows the basic feedback topologies using an Op_Amp. Notice the difference in connection between the sampling point at the output and the mixing point at the input.

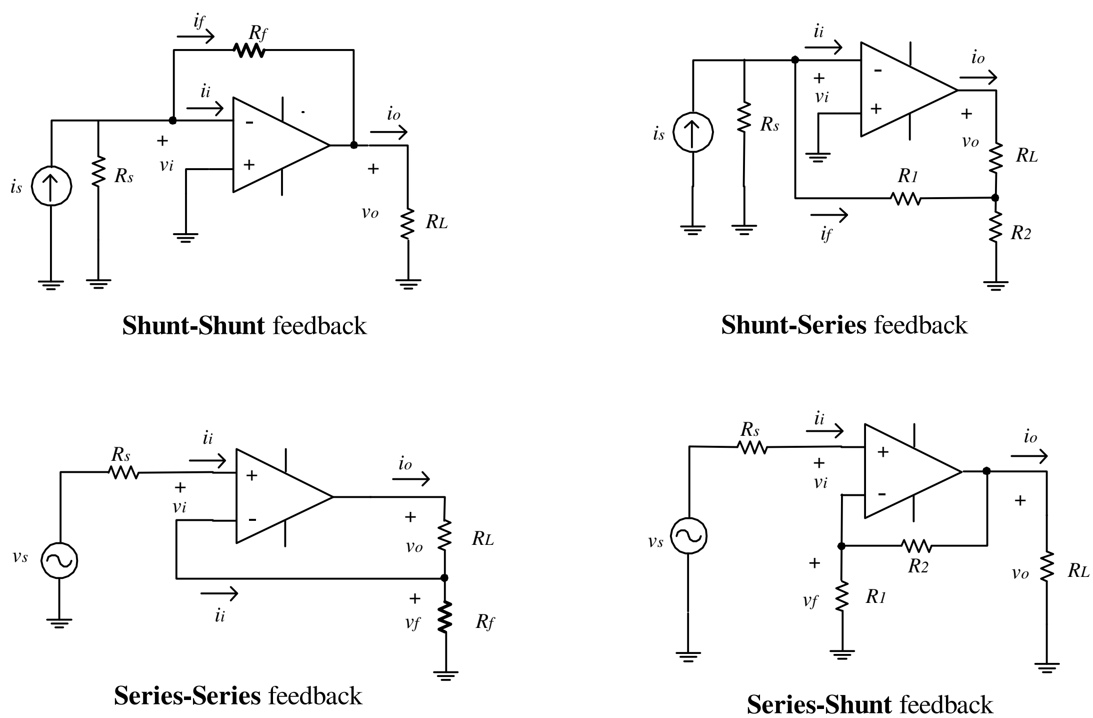
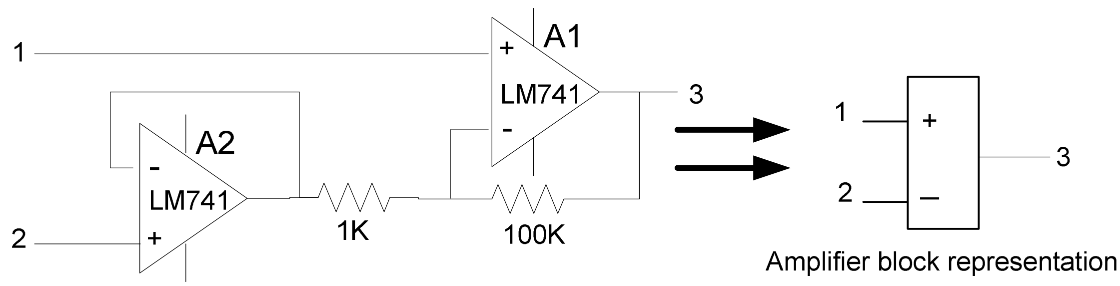


Figure **2** Basic feedback topologies using operational amplifiers

Series-Shunt feedback amplifier

One benefit of using feedback is to control the characteristics of the amplifier under test. To find A, A_f, B, R_{if}, and R_{of} through analysis the following steps are carried out:

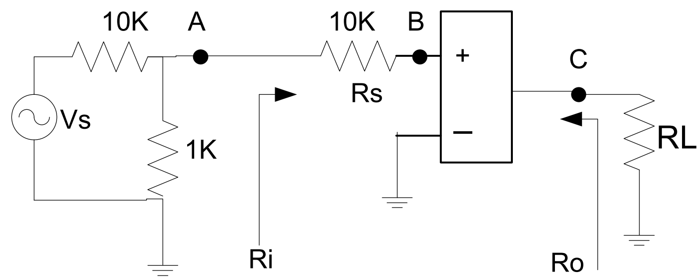
1- Identify the feedback topology and the feedback gain B. This refers to Fig. 1.
2- Draw the basic amplifier without the feedback circuit, and then replace the active device by the proper equivalent circuit.
3- Determine the loading element values and construct the loaded amplifier circuits.
4- Determine the amplifier gain A, R_i and R_o of the loaded amplifier as shown in series-shunt example in the textbook
5- Determine the feedback parameter B as described in the textbook.
6- Use your textbook to determine the expressions for R_{if} and R_{of}.



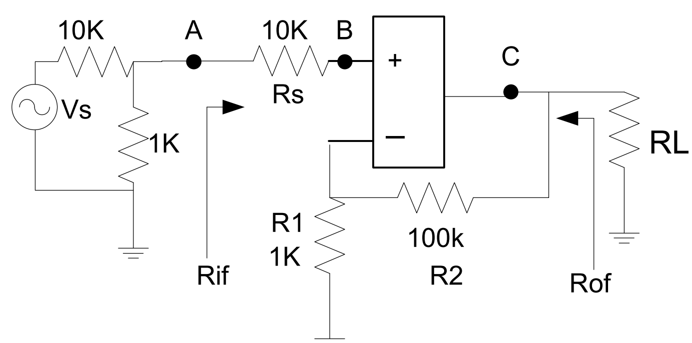
Basic amplifier block with gain 100

Figure **3** Basic amplifier block with open loop gain 100

In this experiment, two operational amplifiers will be used to construct the basic amplifier block with limited open loop gain $A = 100$ as shown in figure 3. The basic amplifier block consists of one amplifier stage A1 with gain 100 and a unity gain stage A2 (buffer). The input resistance R_i is essentially infinite as a result of using buffer at the input. Also the output resistance is almost zero.



4(a) Open loop measurement



4(b) Closed loop measurement

Fig. 4- Basic amplifier and Series-Shunt feedback amplifier

PROCEDURE

Assemble the basic amplifier block shown in figure 3, using power supply $\pm 15\,\text{V}$ (make sure that the power supply is connected to both 741 operational amplifiers). Attach a voltage divider at the input terminal of the basic amplifier as shown in Figure 4(a), and then conduct the following measurements using the oscilloscope. Note that in the following measurements, you would be using two different values of load resistance RL, ∞ and $10\text{k}\,\Omega$.

Open Loop Measurements

1- With RL= ∞ (open circuit at C), apply a sinusoidal waveform input signal with frequency 100Hz and suitable amplitude to get undistorted output waveform. (**Troubleshooting**- If you see no output at point C, then look for the signal at point A. Usually there should be a signal there unless the breadboard has a bad contact. Subsequently, measure the signal at the non-inverting input of op-amp A1 (see Fig.3) which is the same point as B in Fig. 4(a). In case you don't see any signal, A2 of Fig 3 is likely bad. Otherwise measure the signal at inverting input of A1. Here, you should have the same signal as B of Fig 4(a). If you don't see any signal, A1 is likely bad. A1 and A2 are referred to in Fig.3.

2- Measure the peak-to-peak voltage at nodes A, B and C. Record these values for later use.

3- Increase the frequency of the input signal until the voltage at node C drops to 0.707 of its value at 100Hz. Record the upper 3dB frequency of the amplifier.

4- Attach a 10kΩ load (at node C) to the output of the amplifier block and repeat step 2.

5- Tabulate your records for both values of the load resistance (∞ and 10kΩ).

6- Use the above record of the measurements to compute the gain A and the output resistance R_o (use equation 2 given in Expt.#4). What is the upper 3dB point in each case? Comment on the results. (Please Note that the input resistance is very hard to measure (about 10MΩ) because of the presence of the buffer amplifier at the input of the basic amplifier block).

Closed Loop Measurements (Amplifier with feedback)

7- Assemble the Series-Shunt feedback amplifier as shown in figure 4(b) using the previous amplifier block you have just built.

8- Apply input signal as described in step1 with the load resistance R_L initially disconnected (RL=∞).

9- Measure the peak-to-peak voltage at nodes A, B and C. Record these values for later use.

10- Increase the frequency of the input signal until the voltage at node C drops to 0.707 of its value at 100Hz. Record the upper 3dB frequency of the amplifier.

11- Attach the load resistance of 10KΩ back and repeat step 9.

12- Tabulate your records for both values of the load resistance (∞ and 10KΩ).

13- Use the above record of the measurements to compute the gain A_f between nodes A, C, the input resistance R_{if} and the output resistance R_{of}. What is the upper 3dB frequency of the amplifier? Comment on the results.

14- Comment on the results and discuss the influence of the feedback on the amplifier gain, the upper 3dB frequency, the input and the output resistances.

III. QUESTIONS

1- For the circuit shown in figure 4(b) find A and β using theoretical considerations.
2- Compare the gain-bandwidth product for all of the above cases.
3- For the circuit in Fig. 4(a), use theoretical analysis to obtain gain (V_C/V_A).