EE100B
Experiment 3

Feedback Principles Using an Op-Amp Building Block

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Objective

To familiarize with a sampling of the basic properties of feedback circuits. Various properties of op-amp feedback circuits (gain, bandwidth, input and output resistance) will be measured.

Equipment

2 operational amplifiers (741), resistors (1kΩ, 10kΩ, 100kΩ), capacitors (1000pF, 0.1μF, 100μF), function generator, oscilloscope, digital multimeter, DC power supply, breadboard

Note: The primary component to be used will be a 741 op-amp, provided in an 8-pin dual-in-line package (DIP) as shown in Figure L3.1.

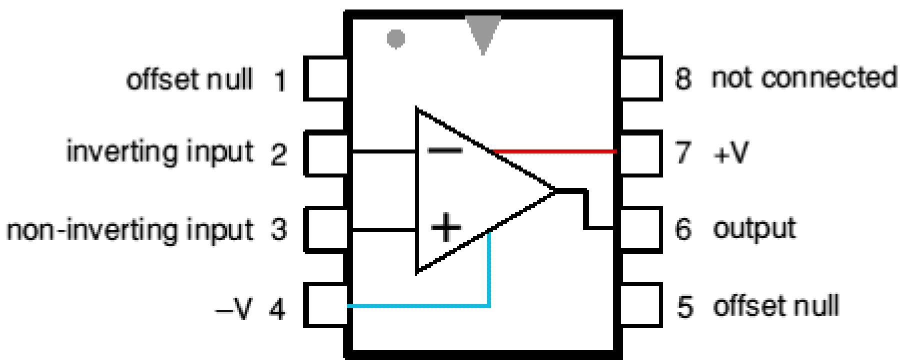

Figure L3.1 741 Op-Amp Pin Connection

Prelab

Read the sections of your textbook relevant to this laboratory session.

Open-loop Circuit
A basic gain block with gain μ=100 (with C_B considered as open circuit at frequency f<<1.59 kHz), shown in Figure L3.2, is used as a unit in this experiment. For the circuit in Figure L3.3 with v_i = 1 V_{pp} at 100 Hz, estimate the output voltage v_c.

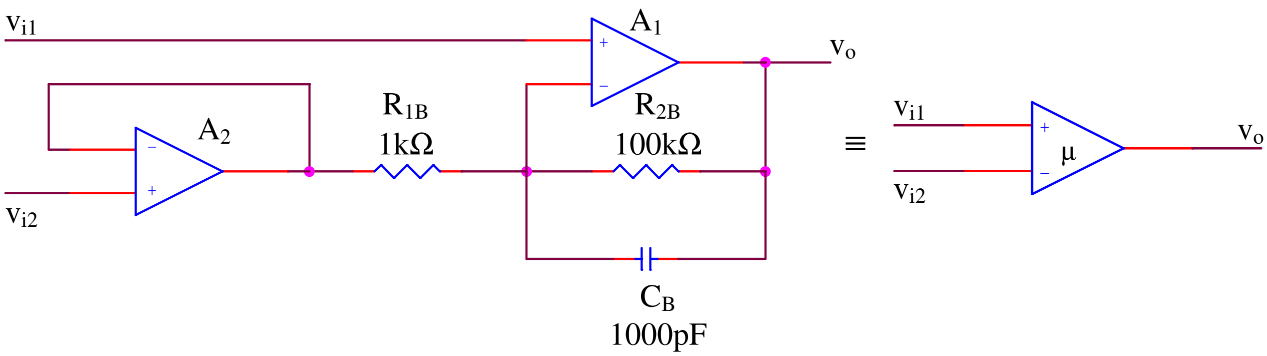

Figure L3.2 A Basic Gain Block

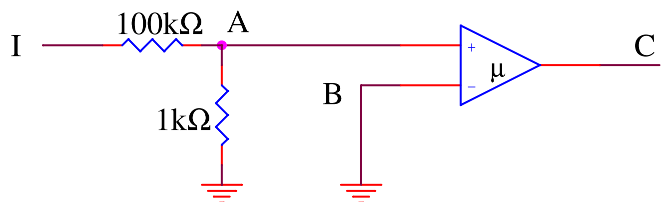

Figure L3.3 An Open-loop Circuit

<u>The Effects of Feedback</u>

1. Finite Gain
   For the circuit as shown in Figure L3.4 with μ=100, estimate the gain v_c/v_i for R_1 = 1kΩ and R_2 = 100 kΩ. What is the gain v_c/v_i for R_1 = 10kΩ and R_2 = 100kΩ?

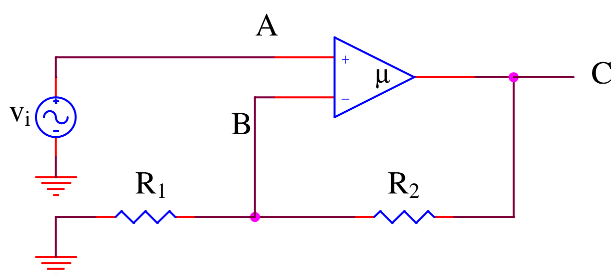

Figure L3.4 A Feedback Circuit

2. Output Resistance
   For the closed-loop shown in Figure L3.5, for which μ=100, estimate the output resistance (looking left at node D).

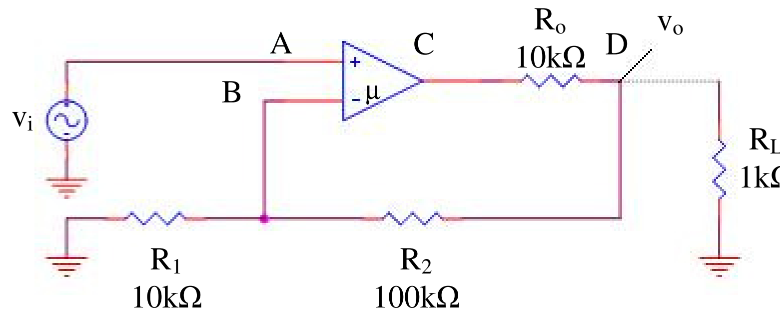

Figure L3.5 Measuring the Effects of Open-loop Output Resistance

3. Input Resistance
   For the closed-loop shown in Figure L3.6 with μ=100, find an expression for R_{in} in terms of R. What is R_{in} for R = 10 kΩ?

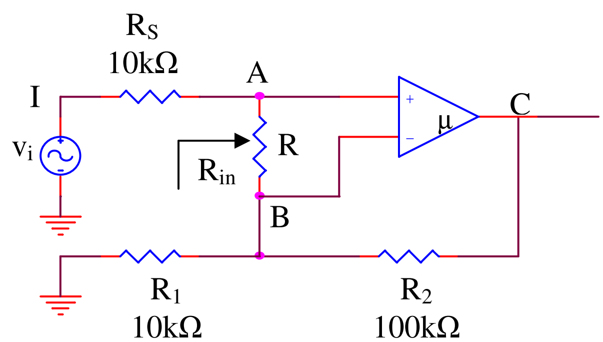

Figure L3.6 Measuring the Effects of Low Input Resistance

Laboratory Procedure

The Basic Building Block

1. A basic gain block
   The basic gain block shown in Figure L3.2 is to be employed in many parts of this experiment. The right-hand side of Figure L3.2 shows the simplifying symbol for which it will be frequently used. Here A_1 provides the basic voltage gain μ, controlled by resistors R_{1B} and R_{2B}, the overall gain $|\mu|=R_{2B}/R_{1B}$ (=100 V/V, for the values shown with C_B open circuit), and the output resistance is essentially zero. The capacitor C_B shapes the frequency response largely independently of the characteristics of the op amp itself. It provides the basic block with a bandwidth extending from dc to $f_{3dB} = \dfrac{1}{2\pi R_{2B} C_B}$,
   (=1.59 kHz for the values shown).
   Assemble the basic gain block as shown in Figure L3.2 using the pin assignments suggested with ±15V supplies. Be sure to include power-supply bypass capacitors, e.g. two 0.1μF and two 100μF (to be explained in the lab).

2. Open-loop circuit
   Assemble the circuit as shown in Figure L3.3. Apply a sinusoidal signal with 1 V_{pp} at 100 Hz to node I. Measure the peak-to-peak voltages at nodes I, A, and C with the oscilloscope.

With I and C displayed, and compared, apply a 100Ω load at node C, noting the change in voltage. With no load, raise the frequency until the voltage at node C drops to 0.707 of its lower-frequency value. Record the frequency as f_{H1}.

Consider the ideality of this circuit. What are its gain, output resistance, and cutoff frequency? Note that its input resistance is very high, but is difficult to measure.

The Effects of Feedback

1. Finite Gain

   Assemble the series-shunt feedback circuit as shown in Figure L3.4 with R_1 = 1kΩ and R_2 = 100kΩ. Apply a sinusoidal signal with 0.2 V_{pp} at 100 Hz to node A. Measure the voltages at nodes C and B with the oscilloscope. What are the feedback signal, the error signal, and the closed-loop gain?

   Change R_2 to a 10kΩ resistor and repeat the process described in the previous step.

   Short R_2 and repeat the process again.

   With R_1 = 1kΩ and R_2 = 100kΩ initially, shunt R_1 with a 1kΩ resistor and repeat the process for the last time.

2. Finite Bandwidth

   Assemble the circuit as shown in Figure L3.4. With R_1 = 1kΩ and R_2 = 10kΩ, and a 1V_{pp} sinusoidal signal at 100 Hz applied at node A, measure nodes A and C while raising the frequency slowly. Find the frequency, f_{H2}, when the gain reduces by 3dB.

   To find f_{H3}, repeat the process described above, but with R_2 = 0Ω.

3. Output Resistance

   Assemble the circuit as shown in Figure L3.5. With R_L initially disconnected, apply a sinusoidal signal of 0.2 V_{pp} at 100 Hz to node A. Measure the voltages at nodes A, B, C, and D. With nodes A and D displayed, and the gain and offset on the "node A" channel adjusted for displayed waveform superposition, connect the 1kΩ load intermittently. Observe the drop in output peak-to-peak voltage level, and use it to estimate the output resistance of the closed-loop amplifier.

4. Input Resistance

   Assemble the circuit as shown in Figure L3.6. With R = 10kΩ initially, apply a sinusoidal signal of 0.2 V_{pp} at 100 Hz to node I. Measure the relative voltages at nodes I, A and B (very carefully), and the voltage at node C. Estimate the input resistance, R_{in}, of the closed-loop amplifier as seen looking right from R_S (into node A). Consider the value of R_{in} in relationship to the values of R and the amount of feedback.