ESC201 Introduction to Electronics Lab 7 Handout for Lab Experiments
Applications of Op-Amp in Negative Feedback

Aim: The aim of this lab is to study the application of operational amplifier (op-amp) in negative feedback.
Introduction: The op-amp as shown in Fig. A (a schematic), Fig. B (the actual chip denoted by the number 741), and Fig. C (a schematic of the chip with pin numbers), is among the most basic linear integrated circuits frequently employed in diverse low frequency applications.

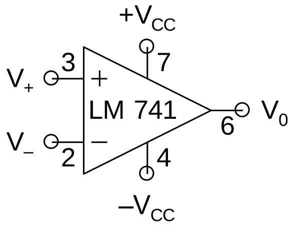

Figure A

Figure B

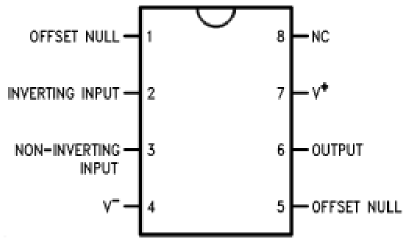

Figure C

The actual chip has four pins on each side, (fully shown in Fig. C only, and partly shown in Fig. B). Referring to Figs. A and C, the op-amp has two inputs, viz., inverting (V^-: pin no. 2) and non-inverting (V^+: pin no. 3), and one output (V_O: pin no. 6). Pin numbers 7 and 4 are used for the power supplies, $+V_{CC}$ and $-V_{CC}$ respectively. Pin numbers 1 and 5 will not be used in this experiment (*keep them open*).

Note: Use the FG from the DSO. The ground of the DC power supply, the FG and the DSO must be the same.

Experiment 1: Voltage Amplification using Op-Amp (*5 × 2 = 10 marks*)

A. Inverting Amplifier

Wire the circuit of Fig. E1a. Choose $R_2 = 51$ kΩ. Adjust the FG output to produce $V_i = 0.1 \sin(\omega t)$ V of 1 kHz frequency. Observe, measure and plot the V_i and V_0 waveforms. Measure the voltage gain $A_v \equiv V_0/V_i$. What is its sign? Compare the experimental value with the theoretically calculated one.

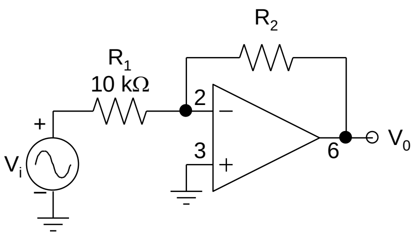

Figure E1a: Inverting Amplifier

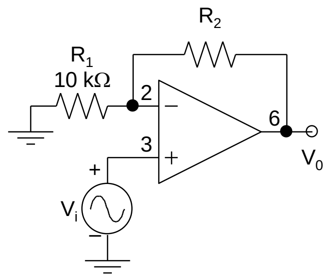

Figure E1b: Non-inverting Amplifier

B. Non-Inverting Amplifier

Wire the circuit of Fig. E1b. Choose $R_2 = 51$ kΩ. Adjust the FG output to produce $V_i = 0.1 \sin(\omega t)$ V of 1 kHz frequency. Observe, measure and plot the V_i and V_0 waveforms. Measure the voltage gain. $A_v \equiv V_0/V_i$. What is its sign? Compare the experimental value with the theoretically calculated one.

Experiment 2: Difference Amplifier (DA) using Op-Amp (*7 × 2 = 14 marks*)

The aim of this part of the experiment is to study the performance of a DA by measuring its common-mode (CM) and differential-mode (DM) gains. In an ideal DA, the differential-mode gain A_d is infinite and the common-mode gain A_c is zero, thus giving an infinite common-mode rejection ratio (CMRR $\equiv |A_d/A_c|$). However, in a practical op-amp circuit, since A_d is finite and A_c is not exactly zero (but quite small), the CMRR might be of the order of 10^4. The circuit of Fig. E2a and E2b will work as a DA when $R_2/R_1 = R_4'/R_3$ (where $R_4' = R_4$ + part of the 10 kΩ potentiometer R), giving a voltage gain of R_2/R_1.

A. Measurement of the Common-Mode Gain A_c

Wire the circuit of Fig. E2a, i.e., apply V_i to one end of R_1 as well as R_3. Adjust the FG output to produce a $V_i = 10 \sin(\omega t)$ V of 1 kHz frequency. Observe, measure and plot the output voltage V_0 and minimize its amplitude by adjusting the 10 kΩ potentiometer. Calculate the common-mode gain $A_c \equiv (V_o/V_i)_{cm}$.

Perform this step as best as you can. As V_o decreases with the potentiometer adjustment, increase the sensitivity of the DSO channel by changing the amplification ratio and obtain the very minimum possible V_o. Keep this setting of the potentiometer unchanged for the next part of the experiment.

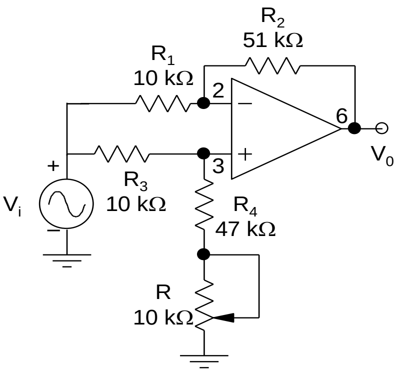

Figure E2a: Common Mode Circuit

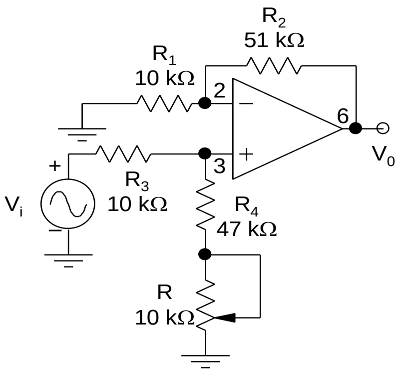

Figure E2b: Differential Mode Circuit

B. Measurement of the Differential-Mode Gain A_d

Wire the circuit of Fig. E2b, i.e., connect one end of R_1 to ground and apply the input V_i to one end of R_3. Adjust the FG output to give $V_i = 0.5 \sin(\omega t)$ V of 1 kHz frequency. Observe, measure and plot the output voltage V_o. Calculate the differential-mode gain $A_d \equiv (V_o/V_i)_{dm}$ and compare it with the theoretical value.

Experiment 3: Differentiator and Integrator OR High-Pass and Low-Pass Filters

These circuits use op-amps (see Fig. E3a and Fig. E3b) to improve upon the less-than ideal behavior of the earlier attempted integrators and differentiators using only RC and RL circuits.

A. Differentiator/High-Pass Filter (*4 × 2 = 8 marks*)

i. Wire the circuit of Fig. E3a with R = 1 kΩ, C = 0.1 µF. Apply input of 4 V p-p 1 kHz triangular wave. Observe, measure and plot both the input and output waveforms, and verify if the circuit is working as desired.

ii. Now, measure and plot the frequency response (both the magnitude and phase Bode plots) of the circuit for frequency range of 100 Hz to 500 kHz. Use input voltage of 4 V pp and take 100 data points for measurement.

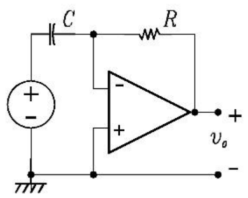

Figure E3a: Differentiator/High-Pass Filter

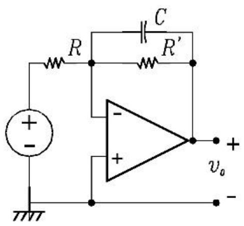

Figure E3b: Integrator/Low-Pass Filter

B. Integrator/Low-Pass Filter (*4 × 2 = 8 marks*)

i. Wire the circuit of Fig. E3b with R = 10 kΩ, R′ = 100 kΩ, C = 0.01 µF. Apply input of 4 V p-p 25 kHz square wave. Observe, measure and plot both the input and output waveforms, and verify if the circuit is working as desired. What is the role of the resistor R′?

ii. Now, measure and plot the frequency response (both the magnitude and phase Bode plots) of the circuit for frequency range of 100 Hz to 500 kHz. Use input voltage of 4 V pp and take 100 data points for measurement.