Experiment 7
Operational Amplifier

Introduction

The operational amplifier (abbreviated as op-amp) denoted by the number 741 as shown in Fig.1 (schematic), Fig. 2 (actual chip), and Fig. 3 (pin numbers), is among the most basic linear integrated circuits frequently employed in diverse low frequency applications. The actual chip has four pins on each side, with a dot (or an indent) just above pin no.1 (Fig.2).

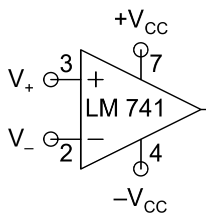

Fig. 1

Fig. 2

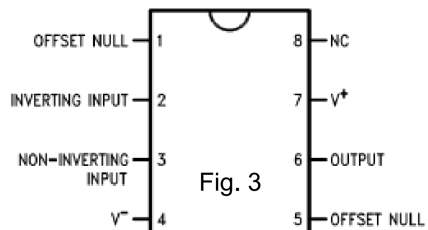

Fig. 3

Referring to Figs. 1 and 3, the op-amp has two inputs, viz., inverting (V^-: pin no. 2) and non-inverting (V^+: pin no. 3), and one output (V_0: 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***). The input-output relationship of an op-amp is given by $V_o = A(V^+ - V^-)$, where the differentia1 voltage gain A is very large. For an ideal opamp: (i) A is infinite, (ii) the input impedance is infinite, and (iii) the output impedance is zero, making it practically an ideal controlled voltage source. However, in a practical op-amp, A is typically in the range of 10^4 to 10^6 over the frequency range of interest and for different IC types.

CARE

- Connect the op-amp such that its pin 1 is on your left side, as shown in Fig. 2.
- Be doubly sure that the +12 V (pin 7) and –12 V (pin 4) supplies are connected properly to the op-amp. If you interchange these connections or connect them to some other pins, the op-amp will get damaged instantly. This is the most common reason for op-amp damage.
- Make sure to turn the power supply on after all the connections are made, and turn it off after the measurements are done.
- It is a good practice to keep the DSO and FG in ON condition. Connect the FG output to the left side of the breadboard and use a jumper to connect it to your circuit as required. ***Note that the FG signal should appear at the op-amp circuit input only after the opamp receives DC power.***

1. Inverting Amplifier

(i) Wire the circuit of Fig. 4. Choose R_2 = 51 kΩ. Adjust the FG output to produce $V_i = 0.1 \sin(\omega t)$ (f = 1 kHz).

(ii) Observe and sketch the V_i and V_0 waveforms.

(iii) Measure the voltage gain $A_v \equiv V_0/V_i$. What is its sign?

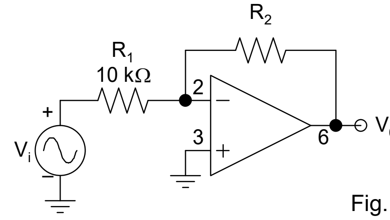

Fig. 4

2. Non-Inverting Amplifier

(i) Wire the circuit of Fig. 5. Choose R_2 = 51 kΩ. Adjust the FG output to produce $V_i = 0.1 \sin(\omega t)$ (f = 1 kHz).

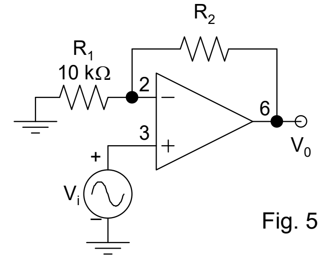

Fig. 5

(ii) Observe and sketch V_i and V_0 waveforms.
(iii) Measure the voltage gain.

3. Difference Amplifier (DA)

The aim of this part of the experiment is to study the performance of a DA by measuring its ***common-mode*** and ***differential-mode*** 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. 6 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) that is not shunted), giving a voltage gain of R_2/R_1.

A. Measurement of the Common-Mode Gain A_c

(i) Wire the circuit of Fig. 6, but instead of grounding one end of R_1, apply V_i to both R_1 and R_3. Adjust the FG output to produce $V_i = 10\sin(\omega t)$ (f = 1 kHz).
(ii) Observe the output voltage V_0 on the CRO and minimize its amplitude by adjusting the 10 kΩ potentiometer. ***(Perform this step as best as you can. As V_o decreases with the potentiometer adjustment, increase the sensitivity of the CRO channel and obtain the very minimum possible V_o). Keep this setting of the potentiometer unchanged for the next part of the experiment.***
(iii) Calculate $A_c \equiv (V_o/V_i)_{\text{common-mode}}$

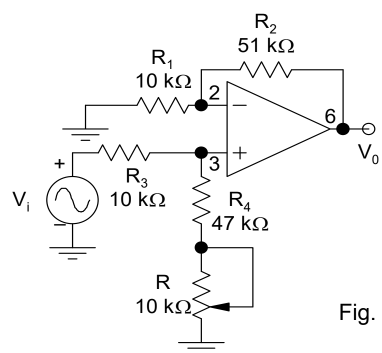

Fig. 6

B. Measurement of the Differential-Mode Gain A_d

(i) Remove the input V_i from one end of R_1 and connect that end to ground, i.e., the connection of the circuit now should look exactly as given in Fig. 6. Adjust the FG output to give $V_i = 0.5\sin(\omega t)$ (f = 1 kHz). Observe the output voltage V_o on the CRO.
(ii) Calculate $A_d \equiv (V_o/V_i)_{\text{differential-mode}}$
(iii) Calculate CMRR $\equiv |A_d/A_c|$.

4. Schmitt Trigger (Regenerative Comparator)

Schmitt trigger circuits are also used extensively in wave shaping. The positive feedback in the circuit ensures that the output will be either at $+V_{sat}$ or at $-V_{sat}$. This is especially useful when the input signal is slowly rising or falling. The hysteresis seen in its transfer characteristics (Fig. 7) finds use in many practical applications.

(i) Wire the circuit of Fig. 8. Adjust the FG output to produce $V_i = 8\sin(\omega t)$ (f = 1 kHz). Connect V_i to CH-1 (X) and V_O to CH-2 (Y) of the DSO, and observe the V_O versus V_i characteristics in the XY mode.
(ii) Vary the 10 kΩ potentiometer from one extreme to the other and observe the changes in the response.
(iii) For the two extreme positions of the potentiometer, observe

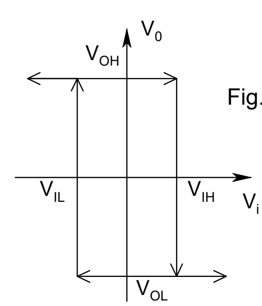

Fig. 7

and sketch the V_o versus V_i characteristics. (DSO in X-Y mode)

(iv) From these characteristics, determine V_{OH}, V_{OL}, V_{IH}, and V_{IL} for the two cases.

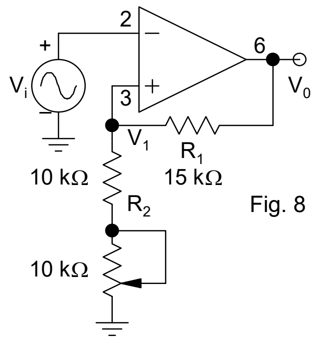

Fig. 8