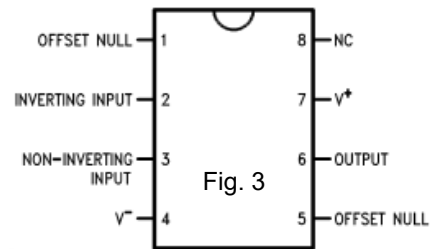
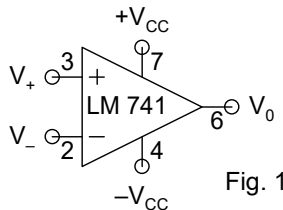


Experiment 7 Operational Amplifier

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).



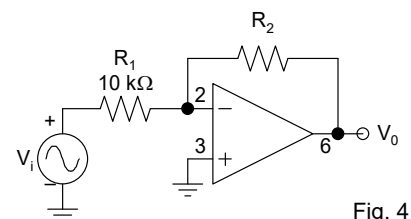
Referring to Figs. 1 and 3, the op-amp has two inputs, viz., **inverting (V^- : pin no. 2)** and **non-inverting (V^+ : pin no. 3)**, and one output (V_o : pin no. 6). Pin numbers 7 and 4 are used for the **power supplies ($+V_{CC}$ and $-V_{CC}$ respectively)**. Pin numbers 1 and 5 will not be used in this experiment (**keep them open**). The input-output relationship of an op-amp is given by $V_o = A(V^+ - V^-)$, where the differential 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.**

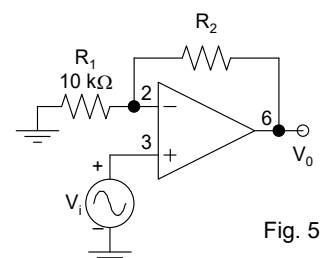
1. Inverting Amplifier

- Wire the circuit of Fig. 4. Choose $R_2 = 51 \text{ k}\Omega$. Adjust the FG output to produce $V_i = 0.1 \sin(\omega t)$ ($f = 1 \text{ kHz}$).
- Observe and sketch the V_i and V_o waveforms.
- Measure the voltage gain $A_v \equiv V_o/V_i$. What is its sign?



2. Non-Inverting Amplifier

- Wire the circuit of Fig. 5. Choose $R_2 = 51 \text{ k}\Omega$. Adjust the FG output to produce $V_i = 0.1 \sin(\omega t)$ ($f = 1 \text{ kHz}$).



- (ii) Observe and sketch V_i and V_o 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 $R'_4 = R_4 + \text{part of the } 10 \text{ k}\Omega \text{ potentiometer (R) that is not shunted}$), 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 $V_i = 10 \sin(\omega t)$ ($f = 1 \text{ kHz}$).
- (ii) Observe the output voltage V_o on the CRO and minimize its amplitude by adjusting the $10 \text{ k}\Omega$ 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 $A_c \equiv (V_o/V_i)_{\text{common-mode}}$

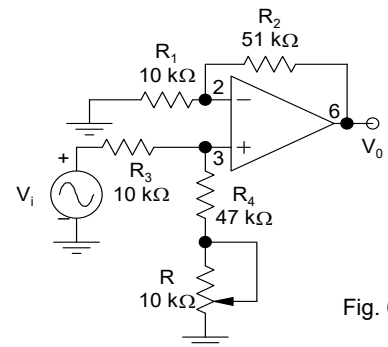


Fig. 6

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 $V_i = 0.5 \sin(\omega t)$ ($f = 1 \text{ kHz}$). 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 $+V_{\text{sat}}$ or at $-V_{\text{sat}}$. 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 $V_i = 8 \sin(\omega t)$ ($f = 1 \text{ kHz}$). 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 $10 \text{ k}\Omega$ potentiometer from one extreme to the other and observe the changes in the response.
- (iii) For the two extreme positions of the potentiometer, observe

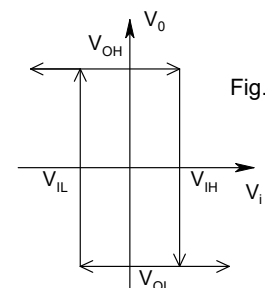


Fig. 7

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.

