ESC201 Introduction to Electronics Lab 8 Handout for Lab Experiments
Applications of Op-Amp in Open Loop and Positive 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.

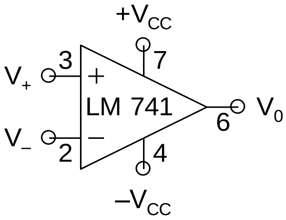

Figure A

Figure B

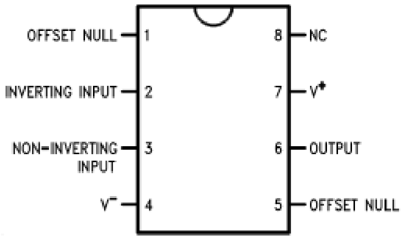

Figure C

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: High DC Open Loop Gain of Op-Amp (*5 marks*)
The input-output relationship of an ideal op-amp in the linear region is given by $V_o = A(V^+ - V^-)$, where the open loop differential voltage gain A is very large. For an ideal op-amp, we assume that, (i) the open loop differential gain A is infinite, (ii) the input impedance is infinite, and (iii) the output impedance is zero, making it practically an ideal voltage-controlled voltage source. However, in a practical op-amp, the gain A is typically in the range of 10^4 to 10^6 over the frequency range of interest considering different IC types.

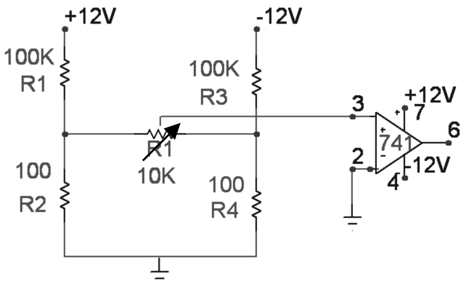

Figure E1: Open Loop Gain

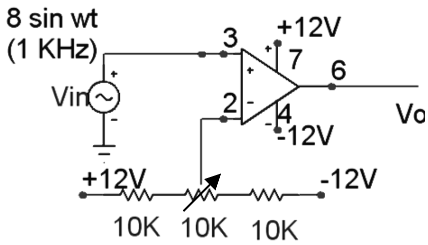

Figure E2: Comparator

The aim of this experiment is to verify that the op-amp has very high DC gain. Very small voltages are applied to its input to see abrupt changes in the output as the input voltages is varied around 0 V. Wire the circuit of Fig. E1. Connect the pin 3 and 6 of the Op-Amp to CH-1 and CH-2 of the DSO, respectively, and set the DSO in the XY mode. Vary the 10K potentiometer slowly from one extreme to the other. Verify that the op-amp output is jumping abruptly from one saturation level to the other over a very small voltage region.
Find out the saturation voltages $\pm V_{sat}$ for the op-amp. For power supply voltages of ±12 V to the op-amp, the saturation voltages are approximately ±11 V, a little less in magnitude than 12 V.

Experiment 2: Op-Amp Based Comparator (*5 × 3 = 15 marks*)

Op-Amp based comparators are frequency used in wave-shaping applications. Wire the circuit of Fig. E2 taking care to make the right connections. Connect V_{in} from the FG to CH-1 and V_O to CH-2 of the DSO. Connect the 10K potentiometer between the +12 V and –12 V supplies with the resistors in series as indicated and to the pin 2 of the op-amp. Switch on the ±12 V power supply and adjust FG output to give 8 sin(ωt) V of 1 kHz frequency input signal to the circuit as indicated. Vary the 10K potentiometer from one extreme to the other and observe the changes in the V_O waveform and note it down.

Vary the potentiometer to obtain approximately the following voltage V_2 at pin 2 of the op-amp, one by one: (i) +4 V, (ii) 0 V, and (iii) –4 V. (Measure the voltage at pin 2 of the op-amp using one channel of the DSO.) For each of these voltages at pin 2 of the op-amp mentioned above: observe, measure and plot the V_{in} and Vo waveform using both channels of the DSO.

Experiment 3: Op-Amp Based Schmitt Trigger (Regenerative Comparator) (*5 × 2 = 10 marks*)

Schmitt trigger circuits are also used extensively in wave-shaping application. 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. E3) finds use in many practical applications. Wire the circuit of Fig. E3. Adjust the FG output to produce V_i = 8 sin(ωt) V of 1 kHz frequency. Connect V_i to CH-1 and V_O to CH-2 of the DSO, and observe and measure the V_O versus V_{in} characteristics in the XY mode. Vary the 10 kΩ potentiometer from one extreme to the other and observe the changes in the V_O versus V_{in} characteristics, and note it down. Observe, measure and sketch the V_o versus V_{in} characteristics for the two extreme positions of the potentiometer knob, i.e., for (i) R_{pot} = 0 Ω, and (ii) R_{pot} = 10 kΩ.

From these characteristics, determine V_{OH}, V_{OL}, V_{IH}, and V_{IL} for each of the two cases mentioned above, i.e., for two extreme positions of the potentiometer. Compare these values with the theoretically calculated ones.

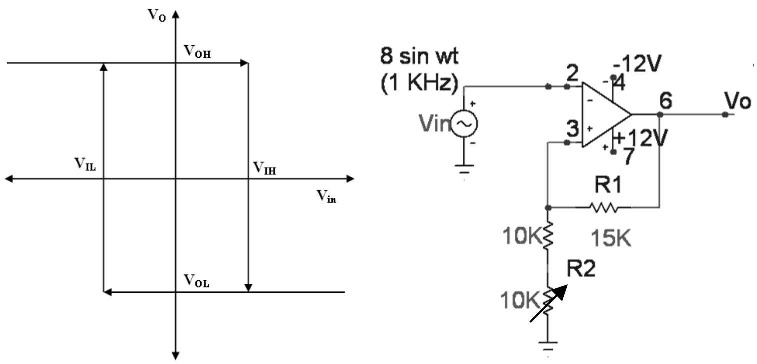

Figure E3: Schmitt Trigger (Regenerative Comparator)

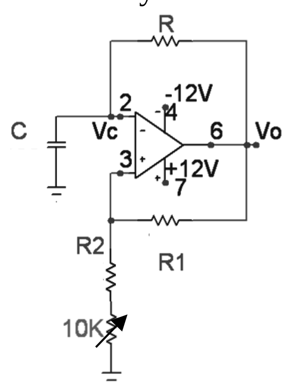

Figure E4: Astable Multivibrator

Experiment 4: Op-amp Based Astable Multivibrator (*5 × 2 = 10 marks*)

An astable multivibrator is a circuit that repeatedly moves between two states as long as it is powered up. Wire the circuit of Fig. E4 with the following specifications: R_1 = 10 kΩ; R_2 = 4.7 kΩ in series with a 10 kΩ pot, and choose C = 1 μF. Do the following experiment for two cases: (i) R = 10 kΩ, (ii) R = 100 kΩ, one by one.

For each value of R, observe the changes in the capacitor voltage V_C and the op-amp output voltage V_O under manipulation of k, defined as $k \equiv R_1/(R_1+R_2)$, by varying R_2 using the potentiometer knob. For two extreme positions of the potentiometer, observe, measure and plot the capacitor voltage V_C and the op-amp output V_O. Observe the V_C vs V_O in the XY mode, measure and plot the result. From this, find V_{OH}, V_{OL}, V_{IH}, and V_{IL}. Indicate V_{OH}, V_{OL}, V_{IH}, and V_{IL} on the V_C and V_O waveforms plotted with time. Measure the T_H and T_L time periods corresponding to the pulse HIGH and pulse LOW periods, respectively, and compare these with the theoretical values. The theoretical formulas for T_H and T_L are given by $T_H = RC \ln [(V_{OH} – V_{IL}) / (V_{OH} – V_{IH})]$, and $T_L = RC \ln [(V_{IH} – V_{OL}) / (V_{IL} – V_{OL})]$. Also, find the frequency of the output waveform V_O.