EXPERIMENT 4

CHARACTERIZATION OF OP-AMP

OBJECTIVES

1. To sketch and briefly explain an operational amplifier circuit symbol and identify all terminals.

2. To list the amplifier stages in a typical op-amp and briefly discs each stage.

3. To explain the negative feedback control in op-amp circuits.

4. To discuss the op-amp modes and most important op-amp parameters.

5. To measure the input bias current, input offset current, input offset voltage, input and output voltage ranges, the slew rate and bandwidth of op amp.

INTRODUCTION AND THEORY

An op-amp is a high gain, direct coupled differential linear amplifier choose response characteristics are externally controlled by negative feedback from the output to input, op-amp has very high input impedance, typically a few mega ohms and low output impedance, less than 100Ω. Op-amps can perform mathematical operations like summation, integration, differentiation, logarithm, anti-logarithm, etc., and hence the name operational amplifier. Op-amps are also used as video and audio amplifiers, in oscillators, in communication electronics, in instrumentation and control mechanism, in medical electronics, etc.

The circuit schematic of an op-amp is a triangle as shown below in Fig. 1. It has two input terminal. The minus input, marked (-) is the inverting input. A signal applied to the minus terminal will be shifted in phase 180^o at the output. The plus input, marked (+) is the non-inverting input. A signal applied to the plus terminal will appear in the same phase at the output as at the input. +VCC denotes the positive and negative power supplies. Most op-amps operate with a wide range of supply voltages. A dual power supply of +15V is quite common in practical op-amp circuits. The use of the positive and negative supply voltages allows the output of the op-amp to swing in both positive and negative directions.

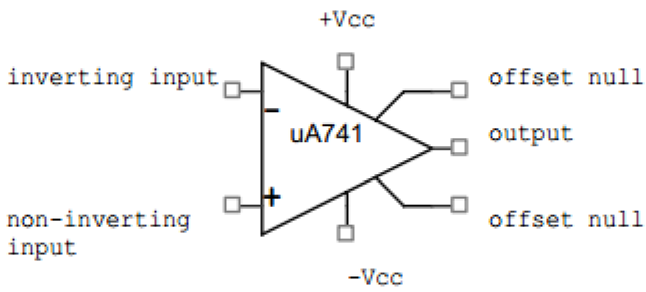

***Fig 1** op-amp circuit symbol*

Op-amp characteristics

An ideal op-amp draws no current from the source and its response is also independent of temperature. However, a real op-amp does not work this way. Current is taken from the source into op-amp inputs. Also the two inputs respond differently to current and voltage due to mismatch in transistors. A real op-amp also shifts its operation with temperature. These non-ideal characteristics are:

1. Input bias current
2. Input offset current
3. Input offset voltage
4. Thermal drift
5. Slew rate

Input bias current

The op-amp's input is a differential amplifier, which may be made of. BJT or FET. In either case the input transistors must be biased into this linear region by supplying currents into the bases. In an ideal op-amp, no current is drawn from the input terminals. However, practically, input terminals conduct a small value of dc current to bias the input transistors when base currents flow through external resistances, they produce a small differential input voltage or unbalance; this represents a false input signal. When amplified, this small input unbalance produces an offset in the output voltage. The input bias current shown on data sheets is the average value of base currents entering into the terminals of an op-amp.

$$I_B = \frac{(I_B^{+} + I_B^{-})}{2}$$

For 741, the bias current is 500nA or less. The smaller the input bias current, the smaller the offset at the output voltage.

Input offset current

The input offset current is the difference between the two input currents driven from a common source

$$|I_{OS}| = I_B^{+} + I_B^{-}$$

It tells you how much larger one current is than the other. Bias current compensation will work if both bias currents I_B^{+} and I_B^{-} are equal. So, the smaller the input offset current the better the OP amp. The 741 op-amps have input offset current of 20nA.

Input offset voltage

Ideally, the output voltage should be zero when the voltage between the inverting and non-inverting inputs is zero. In reality, the output voltage may not be zero with zero input voltage. This is due to un-avoidable imbalances, mismatches, tolerances, and so on inside the op-amp. In order to make the output voltage zero, we have to apply a small voltage at the input terminals to make output voltage zero. This voltage is called *input offset voltage* .i.e., input offset voltage is the voltage required to be applied at the input for making output voltage to zero volts. The 741 op-amp has input offset voltage of 5mV under no signal conditions. Therefore, we may have to apply a differential input of 5mV, to produce an output voltage of exactly zero.

Thermal drift

Bias current, offset current and offset voltage change with temperature. A circuit carefully mulled at 25°C may not remain so when the temperature rises to 35°C. This is called drift often, offset current drift is expressed in n A/°C and offset voltage drift in mV/°C. These indicate the change is offset for each degree celsius change in temperature. There are very few techniques that can be used to minimize the effect of drift.

Slew rate

Among all specifications affecting the ac operation of the op-amp, slew rate is the most important because it places a severe limit on a large signals operation. ***Slew rate*** *is defined as the maximum rate at which the output voltage can change.* The 741 op-amp has a typical slew rate of 0.5 volts per microsecond (V/µs). This is the ultimate speed of a typical 741; its output voltage can change no faster than 0.5V/µs. If we drive a 741 with large step input, it takes 20µs (0.5 V/µsX10V) for the output voltage to change from 0 to 10V.

Band width

Slew rate distortion of a sine wave starts at a point where the initial slope of the sine wave equals the slew rate of the op-amp. The maximum frequency at which the op-amp can be operated without distortion is

$$f_{max} = \frac{SR}{(2\pi V_P)}$$

where SR=slew rate of op-amp, V_P= peak voltage of output sine wave.

PROCEDURE

Use op-amp dc power supply voltages ±15V wherever not specified

1. Input bias current and input offset current

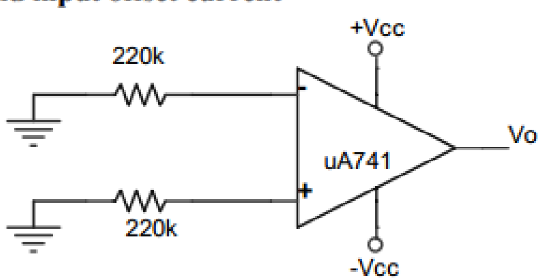

Fig 2 *Input bias and input offset current*

DC voltage at the non-inverting terminal V^+	**DC voltage at the inverting terminal V^-**	$I_B^+ = \frac{V^+}{220K}$	$I_B^- = \frac{V^-}{220K}$	**Input bias current** $I_B = \frac{(I_B^+ + I_B^-)}{2}$	**Input offset current** $I_{OS} = \lvert I_B^+ - I_B^- \rvert$

1. Connect the circuit of Fig. 2.
2. Measure the DC voltages at both terminals and record the values in the Table.
3. By Ohm's law, calculate the input currents I_B^+ and I_B^-. Average these values to find out the input Bias current. Also, find the difference between these two currents to know the input offset current. Record these values in Table.

2. Input offset voltage

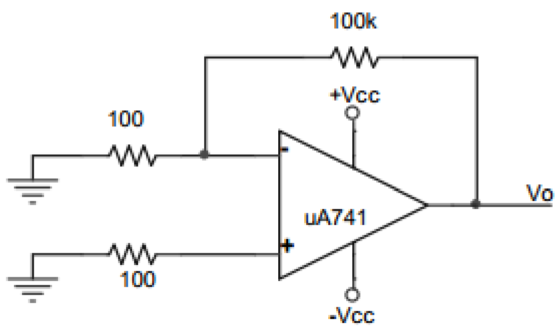

Fig 3 *Input offset voltage*

V_{out}	$V_{in} = V_{ou}t/1000$

1. Connect the circuit of Fig. 3.
2. Measure the DC output voltage at pin 6 using multimeter and record the result in Table.
3. Calculate the input offset voltage using the formula:

Vin = Vout / 1000

and record the value in the Table.

3. Slew rate and bandwidth

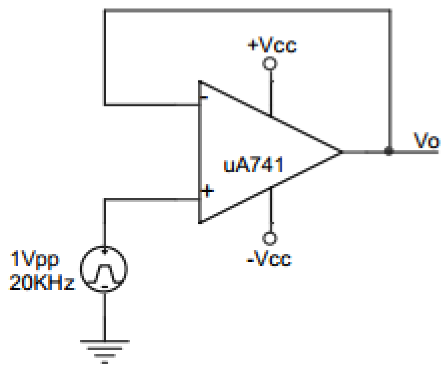

Fig 4 Slew rate and bandwidth

ΔV	ΔT	SR = ΔV/ΔT

1. Connect the circuit of Fig. 4.
2. Provide a 1V peak to peak square wave with a frequency of 25 KHz.
3. With an oscilloscope, observe the output of OPAMP. Adjust the oscilloscope timing to get a couple of cycles.
4. Measure the voltage change ΔV and time change ΔT of the output waveform. (From the output waveform, determine ΔV for a ΔT time change using the rising edge) Record the results in Table.
5. Calculate the slew rate using SR = ΔV / ΔT.

4. Input and output voltage ranges

Assemble the voltage follower circuit as shown in Figure 5 with R1 = R2 = 100 kΩ. Use op-amp dc power supply voltages of ±9 V.

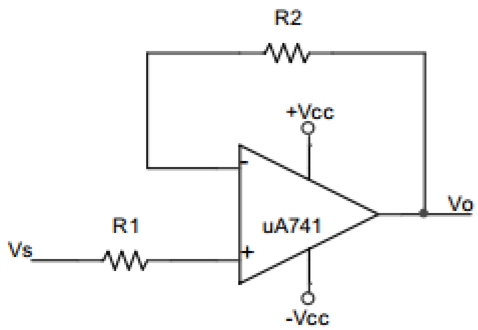

***Fig* 5** *Circuit to find the input voltage range*

Apply ±5 V, 100 Hz sinusoidal input, Vs. Observe the voltages at the non-inverting input and output pins simultaneously. Increase the signal amplitude until distortion is observed at the peak value of the output. Measure the positive and negative input voltage peak values. This gives the op-amp input voltage range.

Change the circuit of Figure 5 to an inverting amplifier. Connect R1 between the source and inverting input. Ground the non-inverting input. Choose R1 = 10 kΩ, R2 = 100 kΩ. Repeat observations of the steps discussed above, starting with ±0.5 V, 100 Hz sinusoidal input. Measure the positive and negative output voltage peak values. This gives the op-amp output voltage range.