Experiment No. 7

Non- Ideal characteristics of Op Amp Circuits

Objectives:

Measurement of Offset Voltage, Bias Currents, Slew rate and Open-loop Gain of Op-Amps

Equipment/Components Required:

1. Op-Amp µA 741
2. Resistors – 100 Ω
3. Regulated Power Supply
4. Variable Power Supply
5. Multimeter
6. Digital Storage Oscilloscope
7. Arbitrary Function Generator

Steps:

Part A: Input offset voltage

1. Wire up the circuit as shown in Figure 1. Let R1=R2=10kΩ.

2. Measure the values of the resistors using multimeter.

3. Measure the output Voltage, V_o.

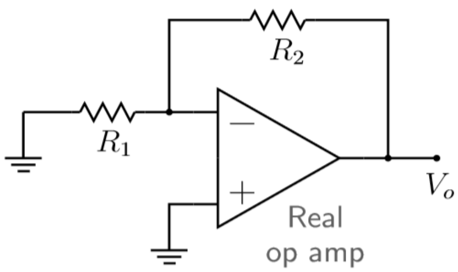

Figure 1: Offset voltage measurement

4. The Offset voltage, V_{OS} is calculated as:

$$V_{OS} = \frac{V_0}{A_v}$$

Part B: Offset current measurement

1. First wire up the circuit as shown in Figure 2 (a).

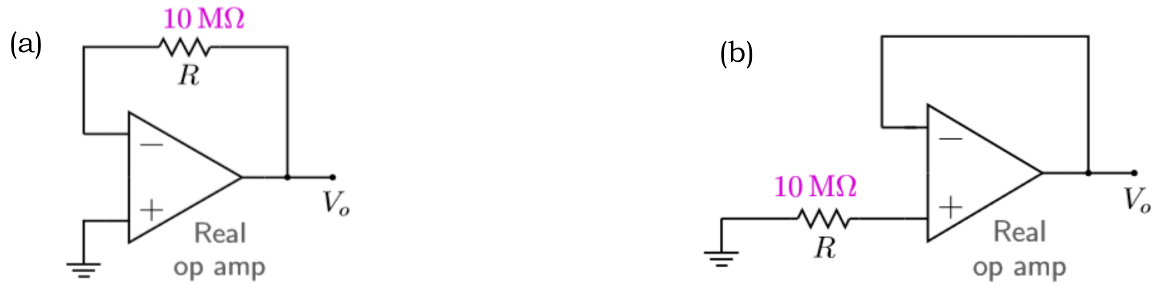

Figure 2: Circuits for Offset current measurement (a) I_{B^-} (b) I_{B^+}

2. Measure the output voltage, V_0.

3. Now connect the circuit as shown in Figure 2(b) and measure the output voltage.

4. Fill-in your observations and calculate the input bias current, I_B and offset current, I_{OS} using the formulae given in the table

Vo (V)	$I_{B^-} = \frac{Vo}{R}$	$I_{B^+} = \frac{Vo}{R}$	$I_B = (I_{B^-} + I_{B^+})$	$I_{OS} = \lvert I_{B^+} - I_{B^-} \rvert$

Part C: Slew rate and Bandwidth measurement

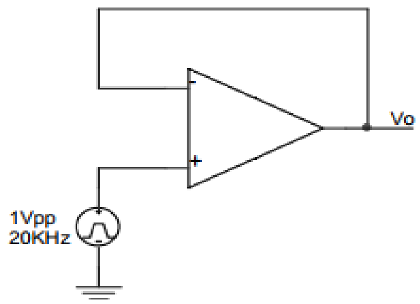

Figure 3: Circuit for Slew rate measurement

1. Connect the circuit of Figure 3.
2. Using a function generator, provide a 1V peak-to-peak square wave with a frequency of 25 KHz.
3. With an oscilloscope, observe the output of Op-Amp. Adjust the oscilloscope timing the get a couple of cycles.

4. Measure the voltage change during rising edge and the falling edge of the output voltage, ΔV.
5. Note the change in time change, ΔT for which ΔV occurs in the output waveform.
6. Calculate the slew rate using the formula SR = ΔV / ΔT.

Sl. No	Frequency	ΔV	ΔT	SR = ΔV/ΔT

Part D: Bandwidth measurement

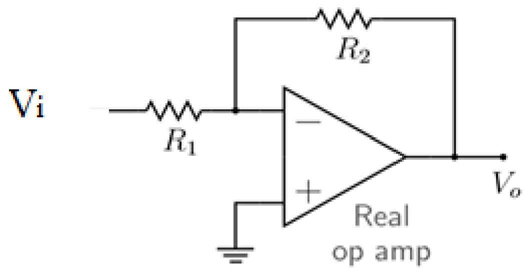

Figure 4: Bandwidth measurement

1. Connect the circuit of Figure 4.
2. Using a function generator, provide a 1V peak-to-peak sine wave.
3. Vary the frequency from 1 kHz to 500 k Hz and note down the corresponding gain.
4. Measure the bandwidth when gain falls below 3dB.

V_i= 1V_{p-p}, R1=R_2 = 10 kΩ

Sl. No.	Frequency	Gain

Bandwidth =_______________________________

Part E: Measurement of DC open-loop gain

One of the most important features of an op amp is a high open-loop gain AOL that is typically in the range 10^5 to 10^6. Measurement of A_{OL} with a simple scheme shown in Figure 5 does not work for the following reasons:

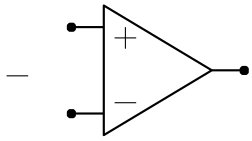

Figure 5: An op amp operated in the open-loop configuration.

(a) With a large gain of 10^5 or more, the op amp is likely to be driven to saturation because of the input offset voltage V_{OS} which is typically in the range −5mV to +5mV for Op Amp 741.

(b) Even if we had a magical op amp with V_{OS} =0V (or we compensated for the effect of V_{OS} by some means), measurement of A_{OL} is still a challenge. Suppose $A_{OL} = 2\times10^5$, and we want an output voltage of 1V, for example. This would require $V_i = 1V/2\times10^5 = 5\mu V$, a very small voltage to apply or measure in the lab.

Given the above difficulties, how do we reliably measure V_{OL}? The trick is to use the op amp in a "servo loop" which ensures that its input voltage remains small enough to keep it in the linear region. The op amp for which we want to measure A_{OL} is marked in the figure 6 as the Device under Test (DUT). The circuit has a high overall gain, but because of the negative feedback provided by R3, it is stable. The capacitor C prevents the circuit from oscillating. We can measure the open-loop gain A_{OL} of the DUT using the following steps.

1. Using the 10k pot, first nullify the effect of the offset voltage of the DUT to the extent possible, i.e., adjust the pot, with the switch in position 1 (or simply open), to make V_o as small as possible. Let us use $V^A{}_o$ and $V^A{}_{o1}$ to denote the values of Vo and V_{o1}, respectively.

2. Now change the switch to position 2. With $V_{(2)-} \approx V_{(2)+}$ = 0V and with the capacitor behaving like an open circuit in the DC condition, we have $i_1 = i_2$, and

$$V_{o1} = V_-^{(2)} - i_2 R_4 = 0 - \frac{V'}{R_5} R_4 = -V'.$$

let V_0 be denoted by $V^B{}_o$ and V_{o1} by $V^B{}_{o1}$. We can attribute the difference ($V^B{}_o$ – $V^A{}_0$) to the change in V_{o1}, i.e., $\Delta V_{o1} = V^B{}_{o1} - V^A{}_{o1} = -V' = -V'$.

For the DUT, its output Vo1 has undergone a change of –V', and it is a result of a change in ($V^{(1)}{}_+ - V^{(1)}{}_-$) which is equal to

$$\frac{R_2}{R_2 + R_3} (V_o^B - V_o^A) \times A_{OL} = -V'$$

Which can be used to obtain A_{OL} for the DUT.

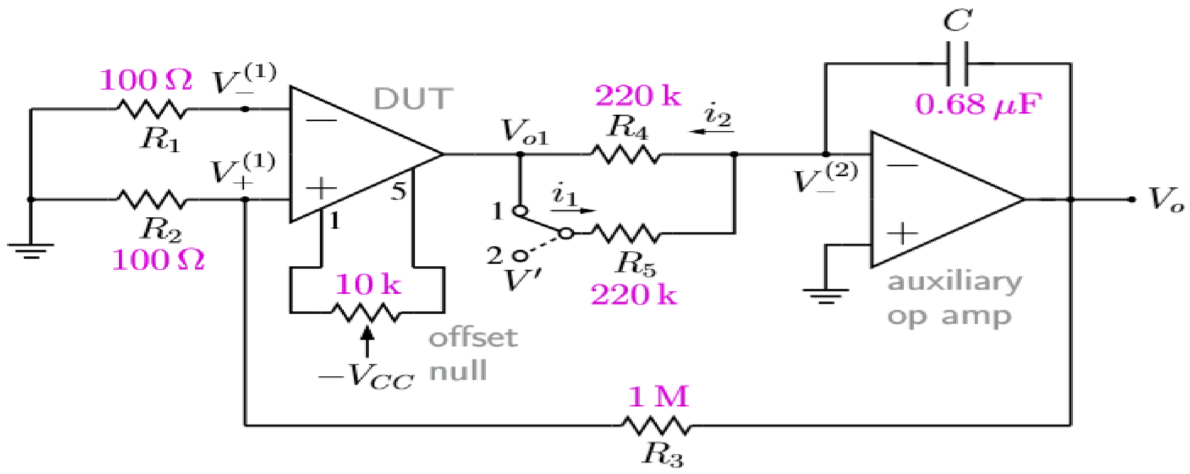

Figure 6: Open loop gain measurement

Vo	**Vo^A**	**Vo^B**	**A_{OL}**