EE 230 Experiment - 9

Measurement of Opamp DC Parameters

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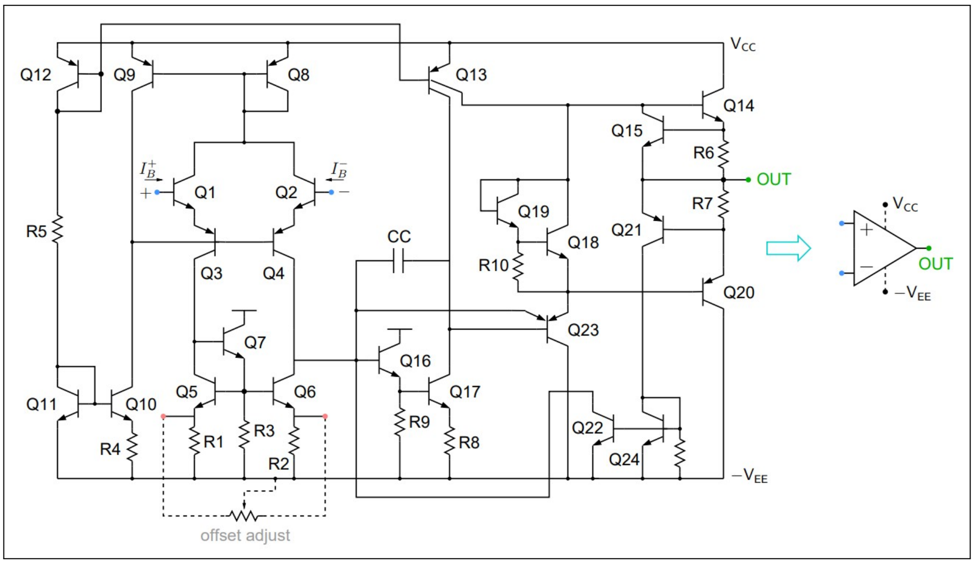
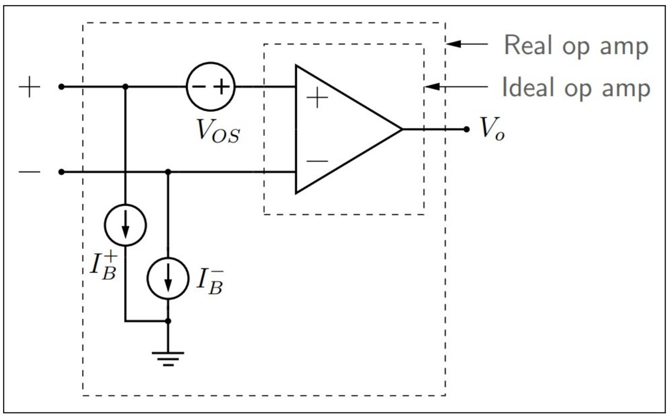
Vinamra Baghel 190010070

1 Input Offset Voltage

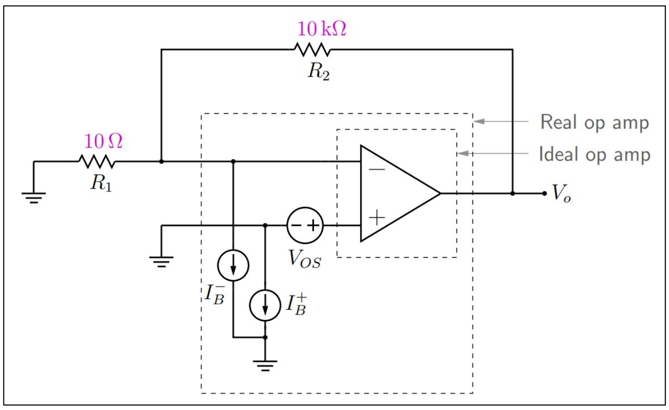


A UA741 OpAmp

In practical scenarios, the input transistors of an OpAmp have small differences between them, for instance: different β values. This difference causes the V_o vs V_i graph to shift along the V_i axis.



(a) Representation of OpAmp Non-idealities



(b) Measurement of Input Offset Voltage

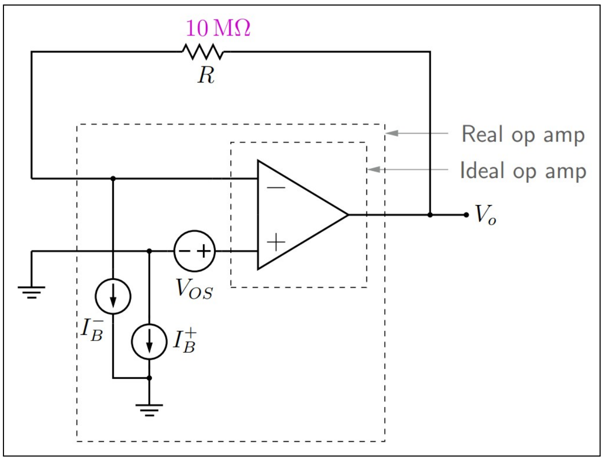
Measurement:

When we carry out a measurement, both - offset voltage and bias currents play roles. Hence, we design circuits where the contribution of one of these parameters is enhanced while that of others is suppressed.
In the figure above, we can apply superposition to obtain:

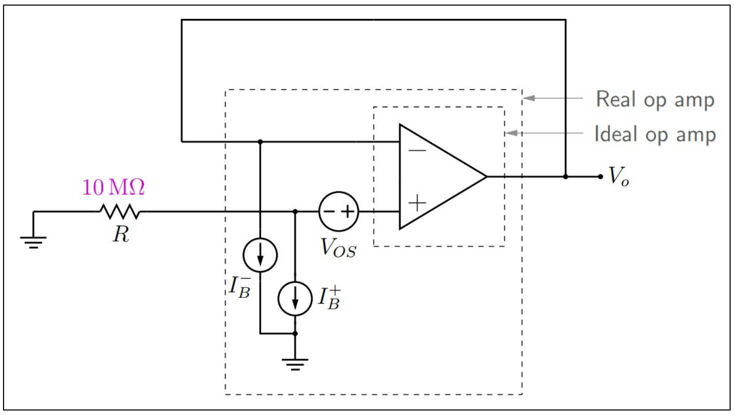
$$V_o = V_{OS}\left(1 + \frac{R_2}{R_1}\right) + R_2 I_B^-$$

The 2nd term has negligible effect and hence can be ignored.

2 Input Bias Currents



(a) Measurement of Bias Current I_B^-



(b) Measurement of Bias Current I_B^+

In the first circuit below, we obtain the relation:

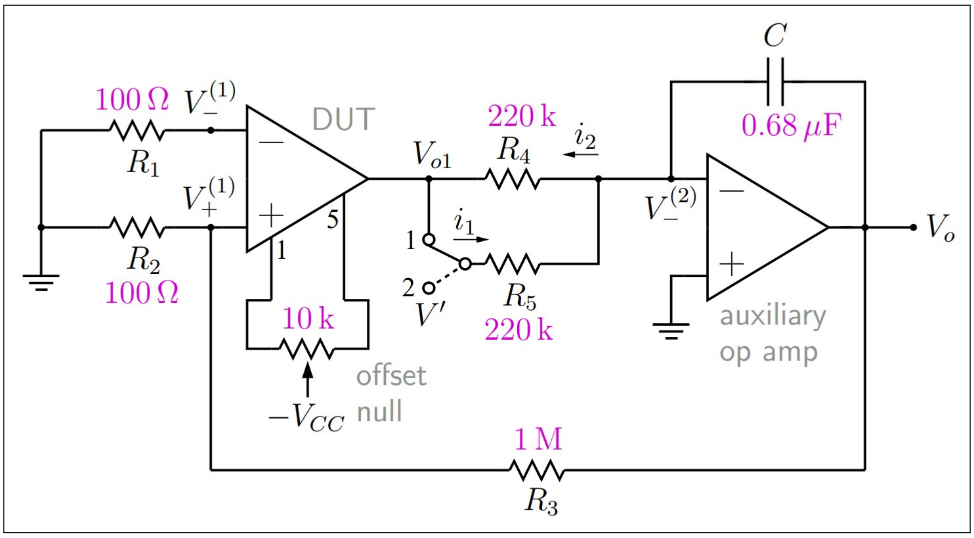
$$V_o = V_- + I_B^- R = V_{OS} + I_B^- R$$

In the second circuit, we obtain the relation:

$$V_o = V_- = V_+ = V_{OS} + I_B^+ R$$

In both cases, the second term is much more significant.

3 Measurement of DC Open-Loop Gain



Measurement of DC Open-Loop Gain

The open loop gain, A_{OL} is generally high, typically in the range 10^5 to 10^6. This is what makes it difficult to measure it for two primary reasons:

- The OpAmp might get driven to saturation by the offset voltage, which is typically in the range -5 mV to 5 mV, itself.
- It is impossibly difficult to obtain a test voltage small enough to not drive the OpAmp to saturation.

The trick to now effectively measure open loop gain is to use the OpAmp in a ***Servo Loop***. In the figure above, the device to be tested is marked **'DUT'**. The gain is controlled and stabilised by the negative feedback provided by R_3. Capacitor C prevents the circuit from oscillating.

Steps to measure the open-loop gain:

1. Using the 10k pot, we first nullify the effect of offset voltage, initialising V_{o1} to 0 V. The switch is at position 1.
2. We now turn the switch to position 2. With $V_-^2 \approx V_+^2 = 0V$, we have $i_1 = i_2$, and $V_{o1} = -V'$.
   Now, $V_+^1 - V_-^1 = \frac{R_2}{R_2+R_3}.(V_o^{new} - V_o^{initial})$. Or,

$$\frac{R_2}{R_2 + R_3}.(V_o^{new} - V_o^{initial}).A_{OL} = -V'$$

4 Offset Voltage and Current and Gain Values

OpAmp Model	UA741	TL084	LM324
Input Offset Voltage, V_{OS}	1 mV	3 mV	3 mV
Input Bias Current, I_B^-	80 nA	20 pA	20 nA
Input Bias Current, I_B^+	20 nA	5 pA	2 nA
Open Loop Gain, A_{OL}	200 V/mV	200 V/mV	100 m/mV

Learnings: OpAmp non-idealities.