EXPERIMENT NO. 2

DATE: : -- / -- /----

MEASUREMENT OF OPERATIONAL AMPLIFIER PARAMETERS

AIM

To measure the following op-amp parameters for uA741

1 Input offset Voltage
2. Input offset current
3. Slew Rate
4. CMRR

THEORY

An ideal op-amp has the following parameter values:

- Open loop voltage gain, $A_{OL} = \infty$
- i/p impedance, $R_i = \infty$
- o/p impedance, $R_o = 0$
- Bandwidth=∞
- Zero offset. i.e., $v_o = 0 \, when \, v_1 = v_2 = 0$
- Ideal op amp draws no current at its i/p terminals, $i_P = i_N = 0$
- o/p voltage is independent of the current drawn from the circuit
- CMRR =∞
- Slew Rate=∞

A practical op-amp has neither infinite gain and bandwidth nor zero output resistance. It may have a non-zero input offset voltage and a finite slew rate. These non-ideal parameters may have a significant impact on the circuit performance.

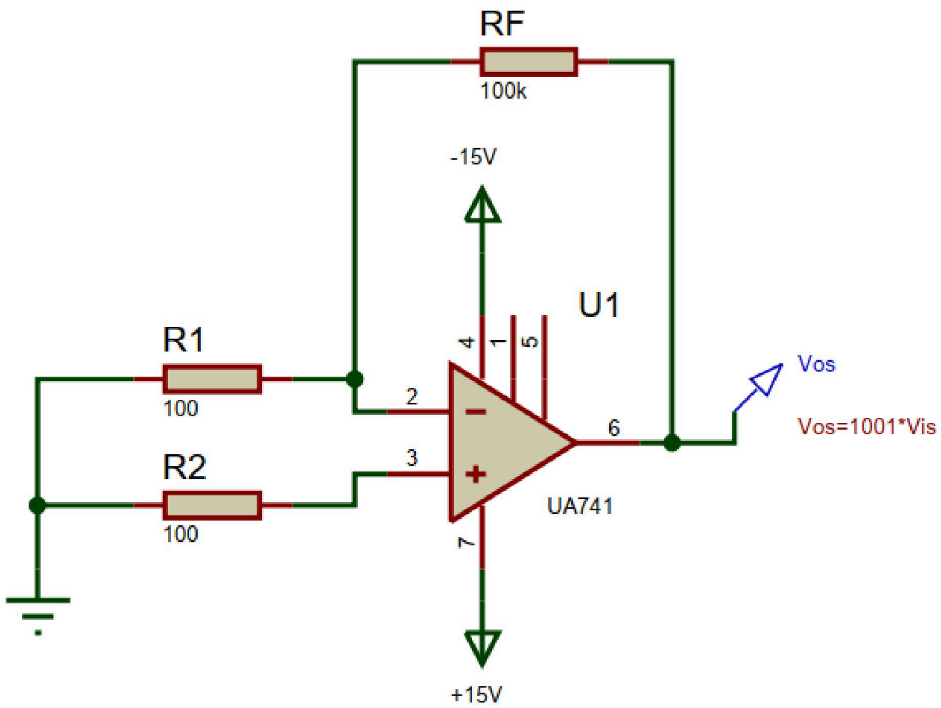
Input Offset Voltage

The ideal op-amp produces zero volts out for zero volts in. In a practical op-amp, how ever, a small dc voltage, appears at the output even when no differential input voltage is applied. Its primary cause is a slight mismatch of the base-emitter voltages of the differential input stage of an op-amp.

Input Offset Voltage is defined as the voltage that must be applied between the two input terminals of an op amp to nullify the output.

Maximum value of $V_{io} = 6mV$ for 741

The following circuit may be used to measure the input offset voltage of an op-amp



Input Bias Current

The input terminals of a bipolar differential amplifier are the transistor bases and, therefore, the input currents are the base currents. i.e., The input bias current I_B is the average of the current entering the input terminals. It is used for biasing the input transistors

$$I_B = \frac{I_{B1} + I_{B2}}{2}$$

I_B =500nA for 741C

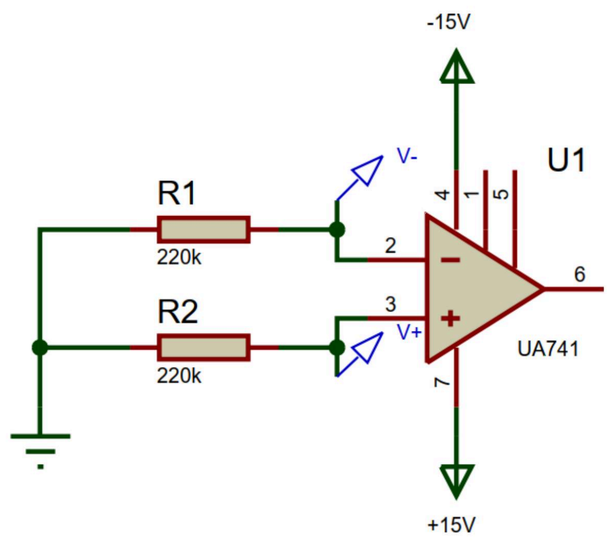
Input Offset Current

Ideally, the two input bias currents are equal, and thus their difference is zero. In a practical op-amp, however, the bias currents are not exactly equal. The input offset current I_{io} is the difference between the currents into inverting and non-inverting terminals of a balanced amplifier

$$I_{io} = |I_{B1} - I_{B2}|$$

Maximum $I_{io} = 200nA$ for 741C

Circuit diagram for measuring the input offset and bias currents is given below:



Slew Rate

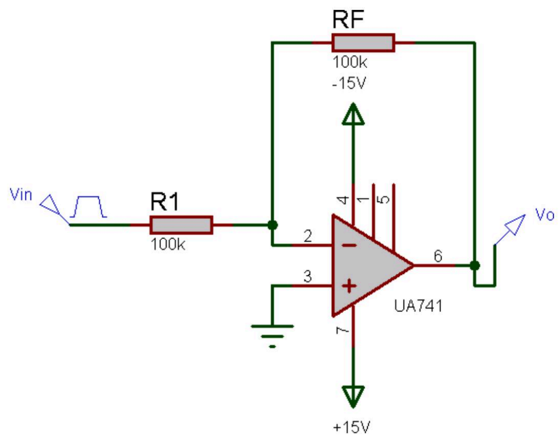
Slew rate is defined as the maximum rate of change of output voltage per unit of time under large signal conditions. Slew rate indicates how rapidly the output of an op amp can change in response to changes in the input frequency. It is expressed in V/μs

$$SR = \frac{dV_o}{dt}|_{\max}$$

The slew rate changes with change in voltage gain and is normally specified at unity gain

Its low slew rate (0.5V/μs) is a drawback for 741C

Circuit diagram for measuring the slew rate is given below:



CMRR(Common mode Rejection Ratio) (Simulation Only)

CMRR is the ratio of the differential voltage gain A_d to the common mode voltage gain A_{CM}

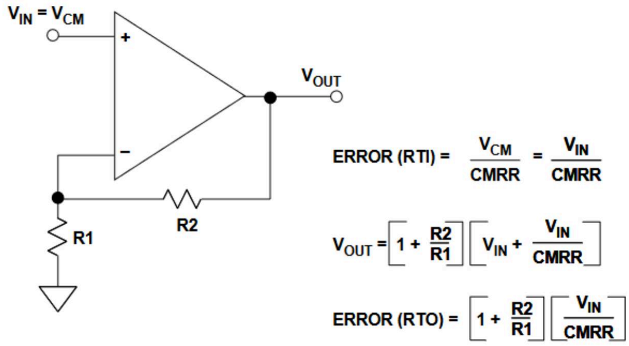
An ideal opamp has infinite CMRR

Typical value of CMRR=90dB for 741C

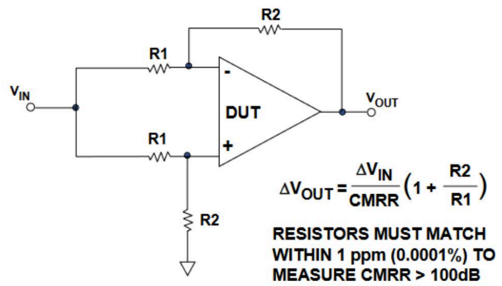
The higher the value of CMRR, the better is the matching between two input terminals & the smaller is the output common mode voltage

CMRR produces a corresponding output offset voltage error in op amps configured in the non-inverting mode as shown below. Note that inverting mode operating op amps will have less CMRR error. Since both inputs are held at a ground (or virtual ground), there is no CM dynamic voltage.

The sensitivity to v_{CM} can be modeled with an input-offset-voltage term of value $v_{CM}/CMRR$



To measure the CMRR of an opamp the difference amplifer configuration shown below may be used.



Here $v_P = v_{IN} \times \frac{R_2}{R_1+R_2} = v_{CM}$

Also $v_N = v_P$ due to virtual short

$$v_{OUT} = (v_P + \frac{v_{CM}}{CMRR})\left(1+\frac{R_2}{R_1}\right) - v_{IN}\left(\frac{R_2}{R_1}\right)$$

$$= v_{IN} \times \frac{R_2}{R_1+R_2}\left(1+\frac{R_2}{R_1}\right) + \frac{v_{IN}}{CMRR} \times \frac{R_2}{R_1+R_2}\left(1+\frac{R_2}{R_1}\right) - v_{IN}\left(\frac{R_2}{R_1}\right)$$

$$= \frac{v_{IN}}{CMRR} \times \frac{R_2}{R_1 + R_2}\left(1 + \frac{R_2}{R_1}\right)$$

Thus $\Delta v_{OUT} = \frac{\Delta v_{IN}}{CMRR} \times \frac{R_2}{R_1+R_2}\left(1 + \frac{R_2}{R_1}\right)$

$$=> CMRR = \frac{\Delta v_{IN}}{\Delta v_{OUT}} \times \frac{R_2}{R_1 + R_2}\left(1 + \frac{R_2}{R_1}\right)$$

**The above circuit requires precision resistors*

DESIGN

Input Offset Voltage

Choose $R_F = 100k\Omega$ and $R_1 = 100\Omega$ so that the gain of the non-inverting amplifier=$1 + \frac{R_F}{R_1} = 1001$

Thus $V_{is} = \frac{Vos}{1001}$

Input Bias current & Input Offset Current

Choose $R_1 = R_2 = 220k\Omega$

$I_{B_-} = \frac{V_-}{220k}$ and $I_{B_+} = \frac{V_+}{220k}$

Thus, input Bias current, $I_B = \frac{I_{B_-}+I_{B_+}}{2}$ and

Input Offset Current, $I_{io} = |I_{B_-} - I_{B_+}|$

Slew Rate

Choose $R_F = 100k\Omega$ and $R_1 = 100k\Omega$

Ideally, $V_o = V_{in}$

PROCEDURE

Input Offset Voltage

- Set up the circuit as per the given circuit diagram and give supply voltages to the op-amp
- Measure the dc output voltage, V_{os}
- Divide this value with the gain of the amplifier(1001) to obtain the input offset voltage $V_{is} = \frac{V_{os}}{1001}$

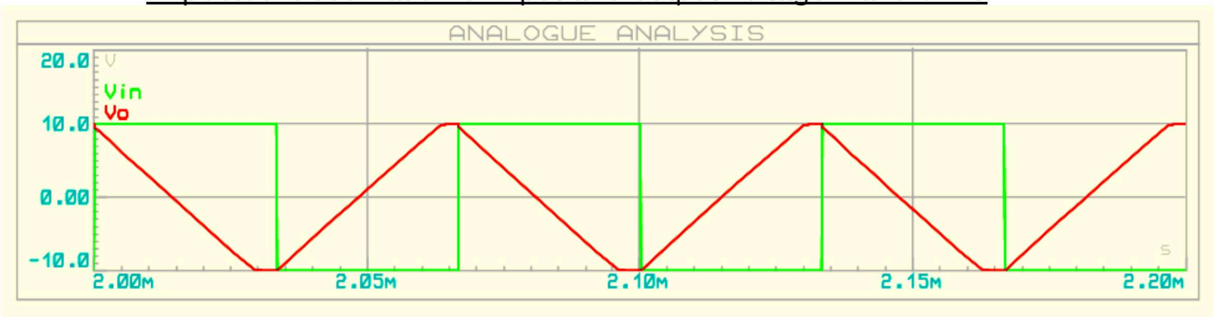
Input Bias current & Input Offset Current

- Set up the circuit as per the given circuit diagram and give supply voltages to the op-amp
- Measure the voltages V_- and V_+ at the inverting and non-inverting input terminals of the op-amp respectively
- Compute the base currents using $I_{B_-} = \frac{V_-}{220k}$ and $I_{B_+} = \frac{V_+}{220k}$
- Compute input Bias current, $I_B = \frac{I_{B_-}+I_{B_+}}{2}$
- Compute the input Offset Current, $I_{io} = |I_{B_-} - I_{B_+}|$

SLEW RATE

- Set up the circuit as per the given circuit diagram and give supply voltages to the op-amp
- Apply a square wave of 20Vpp amplitude and 1kHz frequncy at inverting terminal of op-amp and observe the output waveform on the CRO
- Increase the frequency of the square wave until the output becomes triangular (with 20Vpp amplitude)
- Compute the rising edge slope of the triangle-wave at the output. This value is taken as the slew rate of the op-amp.

Expected Observation of input and output voltage waveforms



CMRR

- Set up the circuit as per the given circuit diagram and give supply voltages to the op-amp
- Give $V_{IN} = 1V$ dc and measure V_{OUT}
- Give $V_{IN} = 2V$ dc and measure V_{OUT}
- Compute ΔV_{OUT} and substitute in the expression below expression to obtain the CMRR value

$$CMRR = \frac{\Delta v_{IN}}{\Delta v_{OUT}} \times \frac{R_2}{R_1+R_2}\left(1+\frac{R_2}{R_1}\right)$$

Observations:

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Results:

The following parameters were measured for opamp IC uA741

1. Input offset Voltage = ___ ___
2. Input offset current= ___
3. Slew Rate= ___
4. CMRR= ___