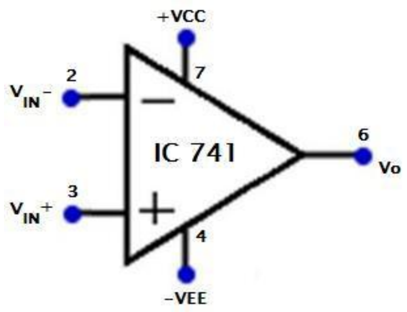
EXPERIMENT #2 OP-AMP IMPERFECTIONS

I OBJECTIVES

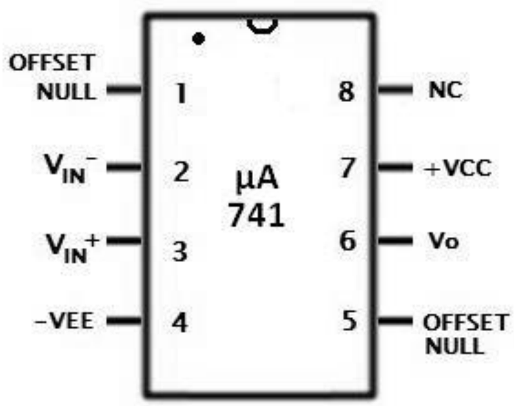
The objective of this experiment is to familiarize the student with the non-ideal features of an operational amplifier. You will use a simple approach to finding bias current, offset current and offset voltage by indirect measurement using a Bench multimeter.

II COMPONENTS AND INSTRUMENTATION

The focus is on the 741-type op amp whose schematic connection diagram is shown in Fig. 2.1. You need two power supplies, ±15 V, a variety of resistors and capacitors. Note that it is important to bypass the two power supplies directly on your prototyping board, using, for each supply, a parallel combination of a 100µF tantalum or electrolytic capacitors, and or 0.1 µF low inductance ceramic capacitor. For measurement, you will need a bench multimeter, a two channel oscilloscope with probes and a waveform generator.



µA 741 Symbol



Pin diagram

Fig. 2.1 Circuit symbol of op-Amp and the pin diagram

III PREPARATION

Input offset voltage: In Fig. 2.2, the non-ideal feature of input offset voltage is modelled using an ideal, offset-free op amp along the input offset voltage brought out external to the op-amp. Thus the modelled circuit functions as an ideal non-inverting amplifier with input offset voltage as the input signal. Hence the output $v_o = E_o$, where

$$v_o = \left(1 + \frac{R_2}{R_1}\right) v_{os}$$

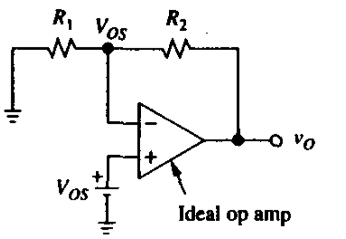


Fig. 2.2

Input bias and offset currents:

Because of unavoidable mismatches between the two halves of the input stage, particularly between the βs of input stage transistors, I_P and I_N will themselves be mismatched. The average of the two currents is called the input bias current.

$$I_B = \frac{I_P + I_N}{2}$$

and their difference is called the input offset current, $I_{os} = I_p \sim I_N$

Slew rate Limiting SR:

The slew rate limiting is a non-linear effect that arises from the internal circuitry of the op-amp to respond to large and sudden changes at the input (i.e., to charge or discharge the internal capacitance). The SR is expressed as the maximum change in output voltage per second (in V/µs). The data sheets of µA 741 op-amp can be referred to for more information.

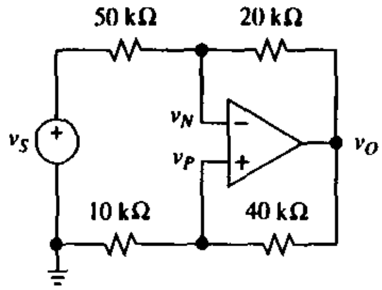


Fig. Q1

Q1. What is the significance of the output short circuit current?

Q2. Can a 741 op-amp (successfully) drive an 8Ω speaker directly? Justify your answer.

Q3. What is the effect of 'slew rate limiting' if the input voltage is a square wave of 10 kHz? Sketch V_{in} and V_{out} in the limiting case.

Q4. Investigate the effect of I_B and I_{os} on the output voltage of the circuit in Fig. Q_1 if I_B=100nA and I_{os} = 10 nA. Find Vo due to I_B and I_{os} .

Q5. A type 9914A hybrid operational amplifier has a slew rate of 1000 V/µs. Find the maximum frequency at which this amplifier can supply a 10-V peak-to-peak sine wave.

IV EXPERIMENTATION

4.1– *Input offset voltage*

4.1.1 –**Draw the circuit diagram** of the closed loop op-amp with R_1=10Ω and R_2=100Ω including the power supply. Indicate both input pins being shorted to ground.

Assemble the circuit. Ground the input terminal and connect a dc voltmeter at the output. Record the output voltage V_{oio} and calculate the input offset voltage ($V_{io}= V_{oio} (R_1/R_1+R_2)$)

V_{io}=

Compare this to the specified input offset voltage for a 741. **Comment:**

4.2 Input bias and offset currents

Connect a 741 voltage follower circuit as in Fig. 2.3 with a nulling potentiometer. Ground the voltage follower input and connect a digital dc voltmeter at the output. Adjust the nulling potentiometer to give zero output voltage. If the output offset cannot be completely nulled, note the level of V_o.

V_o =

Switch off the power supply and insert a 1 MΩ resistor in series with the non-inverting input terminal. Sketch the circuit showing this detail.

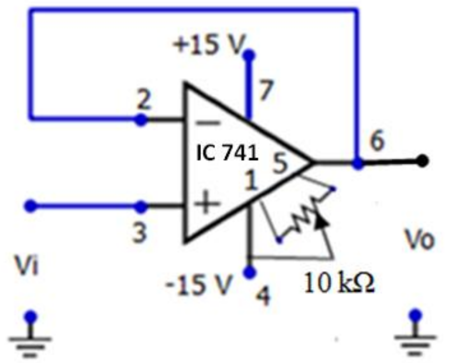


Fig. 2.3 Circuit for offset nulling

Switch the supply on again and note the change in output voltage (from the V_0 nulled level). Calculate the input bias current at the op-amp non-inverting input ($I_+ = \Delta V_0/$ 1 MΩ).

$I_+ =$

Switch off the supply, and reconnect the same 1 MΩ resistor in series with the inverting input terminal (between input and output terminals). Directly ground the non-inverting input once again. Sketch the circuit showing this detail.

Switch the supply on again, and note the new change in V_0 (from the nulled level). Calculate the input bias current as the op-amp inverting input. ($I- = \Delta V_0 / 1\ M\Omega$). Calculate the input offset current, ($I_{offset} = I_+ - I-$).

$V_0 =$

$I_+ =$

$I_- =$

$I_{os} = I_+ \sim I- =$

$$I_B = \frac{I_+ + I_-}{2} =$$

Compare the input bias and offset currents to the specified quantities for the 741. **Comment:**

5.2 Slew rate Limiting

To explore rate limiting behaviour of an op-amp output for large output for large signals. Assemble the circuit shown in Fig.2.4. Give a sinusoidal input voltage of 1 V (pp) at 1 kHz.
Switch on the dual power supply.

Vary the input frequency and observe the output.

Note down the value of the input frequency at which the output waveform just starts to get distorted. Determine the slew rate from the given formula
Slew rate SR= $(2\pi f V_{om} / 10^6)$ in V/s

Hence V_{om}= ; (peak output voltage)

SR=

Repeat the above procedure by giving a square wave input.

Increase the frequency till the output just becomes a triangular wave.

At this instant, find the slew rate from the given formula.
SR = $\Delta V_o / \Delta t$

SR =

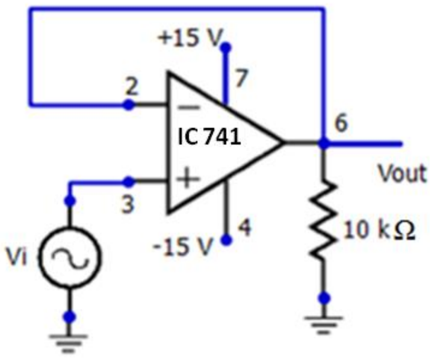


Fig. 2.5 A Circuit for Evaluating Slew Rate

VI. INFERENCE/CONCLUSIONS