OPERATIONAL AMPLIFIER (OP AMP):

Some Experiments based on OP AMPs.

LAB 330
Electronics Part
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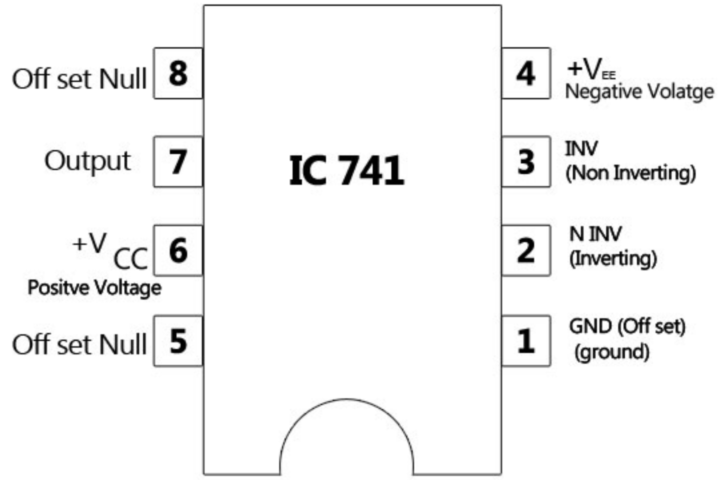
1 Introduction

The Operational Amplifier (OP AMP) is a high gain direct coupled amplifier which can be used to implement a wide variety of linear and non-linear operations by merely changing a few external elements such as resistors, capacitors, diodes etc.Originally OP AMPs were used to perform various mathematical operations like summation, sign changing, integration, differentiation etc.in analog computers, that's why it is so named.Now-a-days they are widely used in analog computers, amplifiers, oscillators, digital circuits etc.



741.jpg

Figure 1: A typical OP AMP IC, normally used in performing experiments.**Note the notch on the IC, it is the identification mark for counting pins.**

2 Circuit Diagram :

The OP AMP circuit diagram with pin numbers is given below...

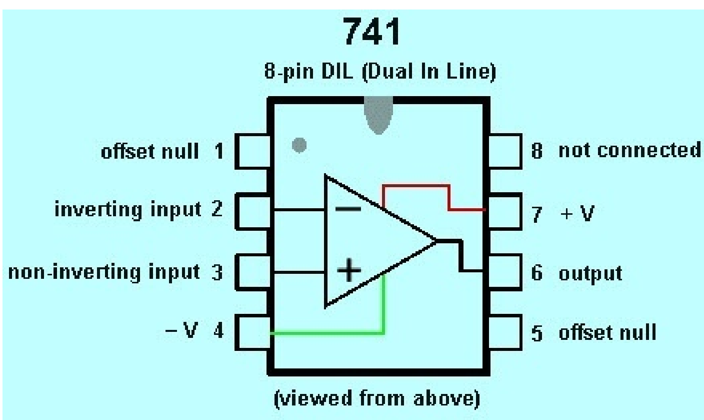


Figure 2: The Circuit Diagram of OP AMP within IC 741

3 OffSet :

OP AMP's inputs are made of coupled Transistors(BJTs). For the OP AMP to be ideal, these BJTs should be symmetric, so that there should be 0 output when no inputs are given. But as we know, experimentally nothing is ideal, so these BJTs are not exactly symmetric, for this reason, there is a very small output even when we have practically no inputs. Now to get rid of this problem, we use the Off Set Null arrangement. The circuit is shown below. two plugs of a potentiometer is connected between pin 1 and 5, and pin 4 is floating between the terminals to get 0 output, while both the inputs are grounded. The off set condition is maintained throughout the experiment.

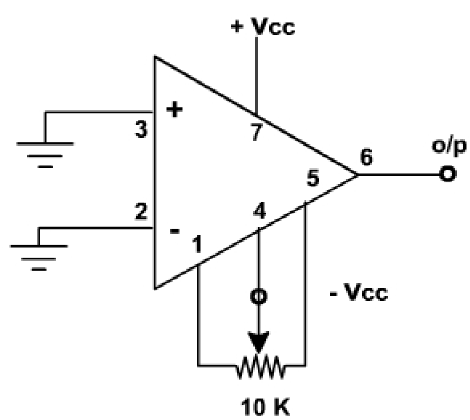


Figure 3: The Circuit Diagram of OP AMP off set null adjustment.

4 OP AMP Characteristics:

An ideal OP AMP has the following characteristics...
1. Input Impedance, $R1 = \infty$
2. Output Impedence, $Ro = 0$
3. Open loop (i.e. without feedback arrangement) voltage gain (A_v) is infinite.
4. Typical band width is infinite.
5. Taking care of offset, we get perfect balance;i.e.$v_o = 0$ when $v_1 = v_2$
6. Characteristic do not drift with temperature.

5 OP AMP as Inverting Amplifier:

The simplified circuit of an Inverting Amplifier is given below.**Please note that the offset condition and supply are not shown in this diagram, but you need to do it when you will make the circuit.** The closed loop gain of this amplifier is

$$A_v = \frac{V_o}{V_i} = -\frac{R_f}{R_i}$$

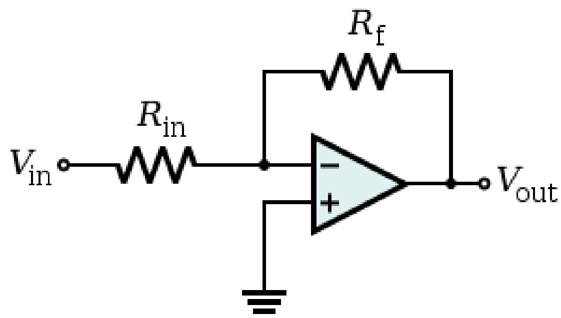


Figure 4: The Circuit Diagram of Inverting Amplifier using OP AMP

6 Apparatus:

1. An IC OP AMP.
2. A bread board.
3. A stabilized DC power supply.
4. DMM. and wires.
5. A variable DC source and a 10k potentiometer for the offset null arrangement.

7 What to do:

1. Check the offset null properly.
2. Choose R_i and R_f such that the gain is 10.
3. Vary the input voltage with the fixed gain and note down output.Show that it is Inverting Amplifier.

4. Plot Input vs Output curve. From the slope of that curve, calculate the gain and verify it with the resistance ratio.
5. Do the same with a different gain.

8 OP AMP as Non-Inverting Amplifier:

The simplified circuit of a Non-Inverting Amplifier is given below.**Please note that the offset condition and supply are not shown in this diagram, but you need to do it when you will make the circuit.** The closed loop gain of this amplifier is

$$A_v = \frac{V_o}{V_i} = 1 + \frac{R_f}{R_g}$$

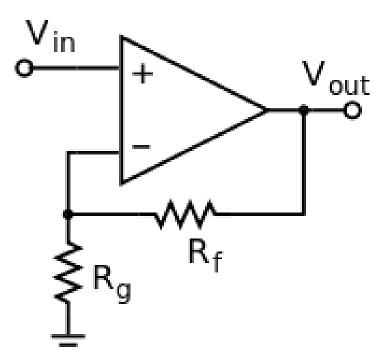


Figure 5: The Circuit Diagram of Non-Inverting Amplifier using OP AMP

9 Apparatus:

Same as before.

10 What to Do:

Same as before, just replace R_i by R_g and put a 'Non' in front of the Inverting.

11 Example Table:

Resistors		No of Obs	Input Voltage(V)	Output Voltage(V)	Experimental Gain from the Graph	Theoretical Gain.
R_i	R_f					

12 Note:

Make such two tables for two different experiments. Create a column named 'Set No.' and also divide the 'Experimental Gain' column in 3 parts mentioning the 'the variations in input voltage', 'variations in output voltage' and 'the slope' , which is the gain precisely. You need not have to make any separate table for the offset null adjustment, just check with the teacher after doing the offset.

13 OP AMP as Integrator:

The ideal and practical circuit of OP AMP integrator is given below,

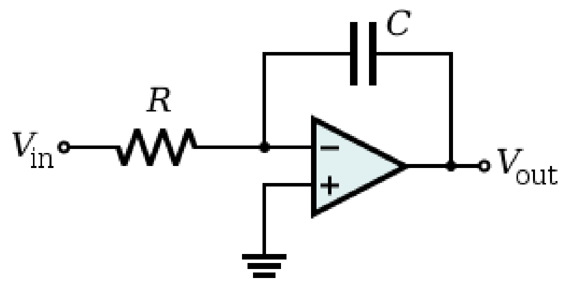


Figure 6: The Circuit Diagram of ideal Integrator using OP AMP

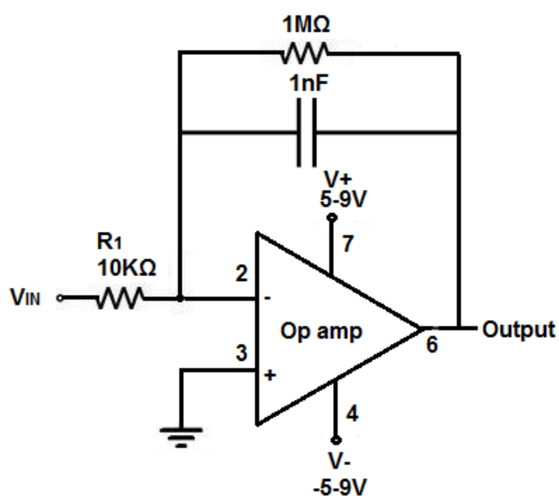


Figure 7: The Circuit Diagram of practical Integrator using OP AMP, the resistor values are just casually given, do not be so serious about them.

The output voltage of an integrator is found to proportional to the input voltage, and it is as follows,

$$v_o = -\frac{1}{R_1 C}\int_0^t v_i dt$$

where R_1 is the resistance connected to the input. For the input $v_i = V_0 sin\omega t$, the output will be,

$$v_o = -\frac{V_0}{R_1 C\omega} cos\omega t$$

$$\left|\frac{v_i}{v_o}\right| = R_1 C\omega = 2\pi R_1 C f$$

It shows that the closed loop gain $\left|\frac{v_i}{v_o}\right|$ decreases with frequency.

14 Cut Off Frequency:

For proper performance of the Integrator, we must choose $R_2 \geq 10R_1$,
R_2 is the resistance parallel to capacitor. and the frequency of the signal must be larger than gain limiting frequency

$$f_0 = \frac{1}{2\pi C R_2}$$

15 Note:

All these practical circuit and cut off frequency is necessary for the DC stability of the entire circuit. For what is the origin of this cut off frequency, you need to think about that..

16 Apparatus:

1. An IC OP AMP.

2. A bread board, Capacitor,resistors.
3. A stabilized DC power supply.
4. DMM. and wires.
5. A variable DC source and a 10k potentiometer for the offset null arrangement.
6. AC signal generator, Digital Oscilloscope.

17 Procedure:

1. Construct the practical circuit.
2. Find f_0 by choosing $R_1 = 10k$ and $C = 0.01\mu F$
3. Check for Offset null
4. Connect the AC signal generator in Sine mode, keep the voltage $1V$, adjust the freq to $10f_0$ and find $\left|\frac{v_i}{v_o}\right|$
5. Plot $\left|\frac{v_i}{v_o}\right|$ vs f and from the slope of the curve find the value of the Capacitor, considering R_1 to be known.
6. Verify with the actual value you have taken.
7. Do for at least another set of resistors and Capacitors.

18 Instructions for making Table:

Follow the instructions and make a table of your own by creating these columns,

1. No of obs

2. Freq
3. rms input(V)
4. rms output(V)
5. $\left|\frac{v_i}{v_o}\right|$

19 Differentiator using OP AMP:

The basic circuit of OP AMP differentiator is given below,

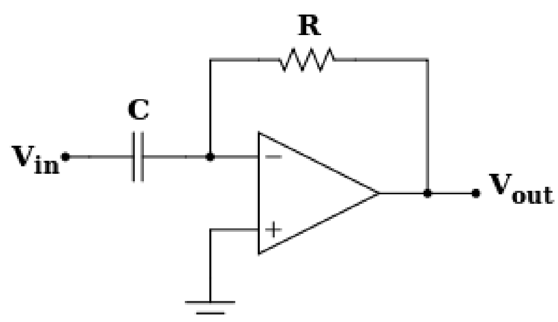


Figure 8: The Circuit Diagram of ideal Differentiator using OP AMP

The practical circuit is following...

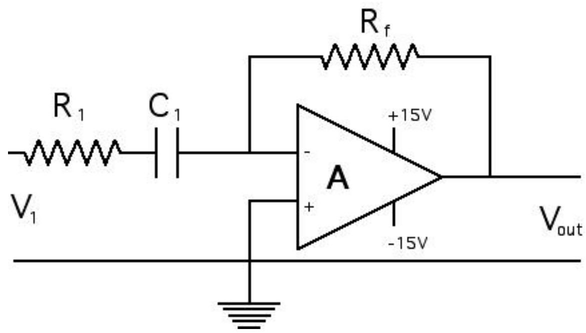


Figure 9: The Circuit Diagram of practical Integrator using OP AMP

The output of this circuit can be written as,

$$v_0 = -R_2 C \frac{dv_i}{dt}$$

Here R_1 is the resistor beside the capacitor and R_2 is connected from the Capacitor and the output of the practical Ckt. For a sinusoidal input,

$$v_i = V_0 sin\omega t$$

$$v_o = -V_0 R_2 cos\omega t$$

or,

$$\left|\frac{v_o}{v_i}\right| = 2\pi R_2 C f$$

20 The Cut Off Frequency:

Similar to the Integrator, it also has a cut off frequency above which the entire circuit is unstable.So, for proper calculation, the signal frequency should be much less than this cut off frequency,

$$f_0 = \frac{1}{2\pi C R_2}$$

21 Note:

Again just like before, you by yourself need to find why this practical circuit is necessary and using this idea you should find the origin of this cut off.

22 Apparatus:

Same as before.

23 Procedure:

1. If you want to operate the circuit from few Hz to 1kHz, then choose $C = 0.1\mu F$, then find R_2, mostly it will be 1.5K.
2. Construct the practical circuit.
3. Choose $R_1 = \frac{R_2}{20}$...In generally a typical value of R_1 is between $\frac{R_2}{10}$ to $\frac{R_2}{20}$
4. Check for Offset null.
5. Connect the AC signal generator in Sine mode, keep the voltage $1V$, adjust the freq much lower thanf_0 and vary upto the cut off and find $\left|\frac{v_o}{v_i}\right|$.
6. Plot $\left|\frac{v_o}{v_i}\right|$ vs f and from the slope of the curve find the value of the R_2, considering C to be known.
7. Verify with the actual value you have taken.
8. Do for at least another set of resistors and Capacitors.

24 Instructions for making Table:

Same as before, just replace $\left|\frac{v_i}{v_o}\right|$. by $\left|\frac{v_o}{v_i}\right|$.

25 Error Analysis:

Do possible error analysis.

26 Precautions:

Write what precautions you need to take care.

27 Discussion:

Write what you have learned from the experiment.

You are always welcomed to try new ideas on these experiments, try to explain the results of your ideas by means of scientific justifications.

D.B.