Experiment 11

Analyzing Non-Ideal Characteristics of Operational Amplifier (Op-Amp)

1.6 Measuring Input and Output Impedances of Inverting Amplifiers

1.7 Measuring Frequency Band of Inverting Amplifiers

1.8 Analyzing Frequency-Gain Relation of Inverting Amplifier

EXPERIMENT MODULE : Y-0014 / 01

OUTPUT OFFSET VOLTAGE OF OPERATIONAL AMPLIFIERS

When no signal is applied to the inputs of the operational amplifier, the voltage between the input pins must be zero. But practically, due to the difference in the characteristics of the transistors connected to the input pins, there may be a small voltage difference. That difference is multiplied by the gain of the operational amplifier and transferred to the output. That unbalanced situation is undesired in most of the applications. That undesired voltage at the output is called output offset voltage (**Voo**). The output offset voltage is generally prevented by connecting an adjustable resistor between the negative supply voltage and the offset pins of the operational amplifier (generally the middle pins).

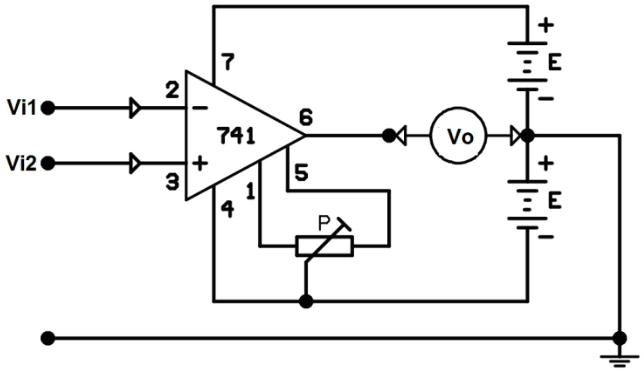


Figure 2.1

The circuit used to adjust the offset voltage is given in figure 2.1. The potentiometer P is adjusted until zero voltage is obtained at the output while there is not any signal at the input.

The output offset voltage is formed by three parameters.

1- Input bias current (**IB**)
2- Input offset current (**IOC**)
3- Input offset voltage (**ViO)**

Operational amplifiers are fabricated by using transistor technology. So, the input offset voltage is increased by the increasing temperature and the operation of the circuit. That increase is approximately 5μVolt for $1\,^{0}$C increase in the temperature.

THE INPUT BIAS CURRENT OF OPERATIONAL AMPLIFIERS

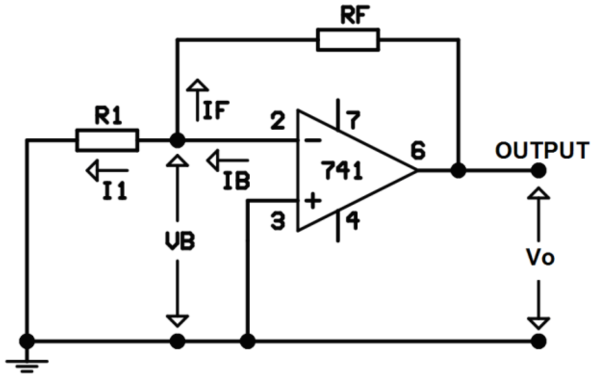


Figure 3.1

The input currents of the operational amplifier are seen in figure 3.1. The input bias current is the average of the input currents. As we know, input bias current is one of the reasons for output offset voltage (VoO).

Input Bias Current is IB= I1+IF.

I1= $\frac{VB}{R1}$ **IF=** $\frac{VB-Vo}{RF}$ **IB=** $\frac{VB}{R1}+\frac{VB-Vo}{RF}$.

The current I1 is assumed to be zero since the voltage VB is too small. Then the effect of the input bias current to the output offset voltage is calculated by VoO=IB.RF. The methods given in figure 3.2 and 3.3 are used to minimize the effect of the input bias current to the output offset voltage.

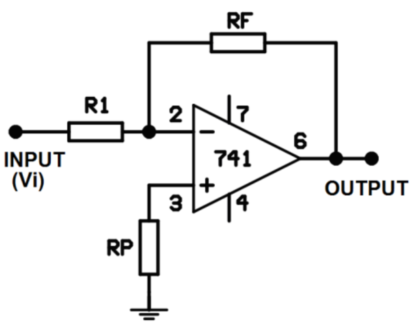


Figure 3.2

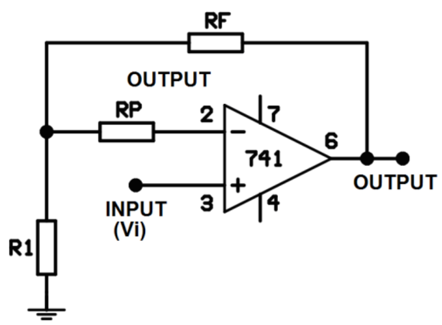


Figure 3.3

The resistance R1 is the input resistance and the resistance RF is the feedback resistance in the figure. RP is the resistance used to minimize the effect of the input bias current to the output offset voltage.

The value of the resistance RP is;

$$\textbf{RP=}\frac{R1.RF}{R1+RF}$$

INPUT OFFSET VOLTAGE OF OPERATIONAL AMPLIFIERS

The input offset current is the difference between the currents when the inputs are grounded and the output offset voltage is set to zero.

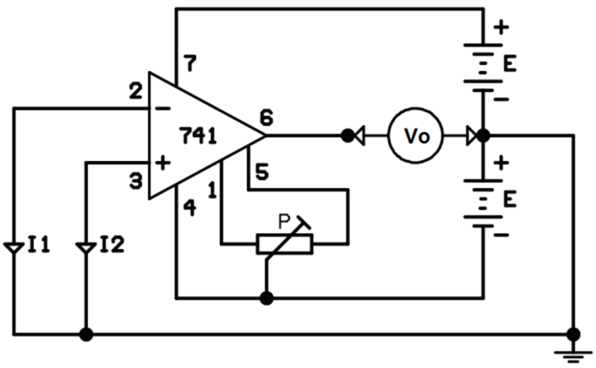


Figure 4.1

Input offset current is:

IiO= I1-I2 or IiO= I2-I1.

The input offset current causes the output offset voltage to increase VoO=RF.IiO times when a signal is applied to the inputs of the operational amplifier.

As we know, input offset voltage is the voltage between the inputs when no signal is applied to the inputs.

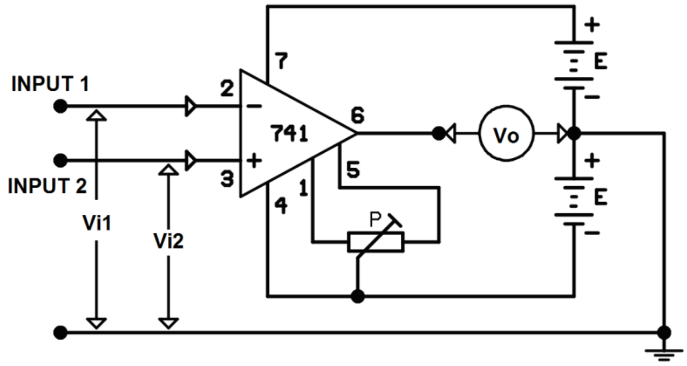


Figure 4.2

Input offset voltage is;

ViO= Vi1-Vi2 or ViO= Vi2-Vi1

Input offset voltage causes the output offset voltage to increase VoO=ViO.A times. **(A)** is the gain of the operational amplifier.

INPUT AND OUTPUT IMPEDANCES OF AMPLIFIERS

The operation frequency used while analyzing the AC parameters of electronic circuits is 1 KHz all over the world.

A-Input Impedance (Zi): It is the resistance seen by the signal source when the output is open circuit, the non-inverting input is grounded and 1 KHz sine wave is applied to the inverting input of the operational amplifier.

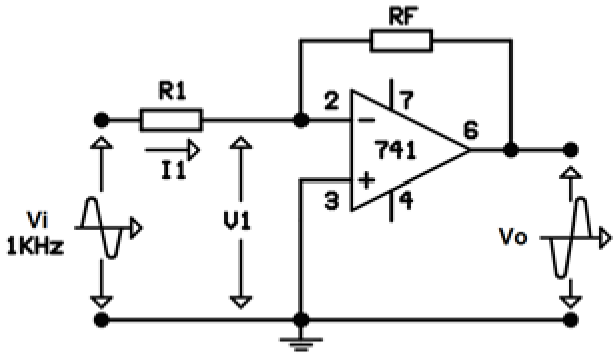


Figure 6.1

The input current in the figure 6.1 is;

$$I1 = \frac{Vi - V1}{R1}.$$

The input impedance of the circuit is;

$$Zi = \frac{Vi - V1}{I1} = \frac{Vi - V1}{\frac{Vi - V1}{R1}} = (Vi - V1).\left(\frac{R1}{Vi - V1}\right)$$

$$Zi = \frac{(Vi - V1)}{(Vi - V1)}.R1 = 1.R1 = R1.$$

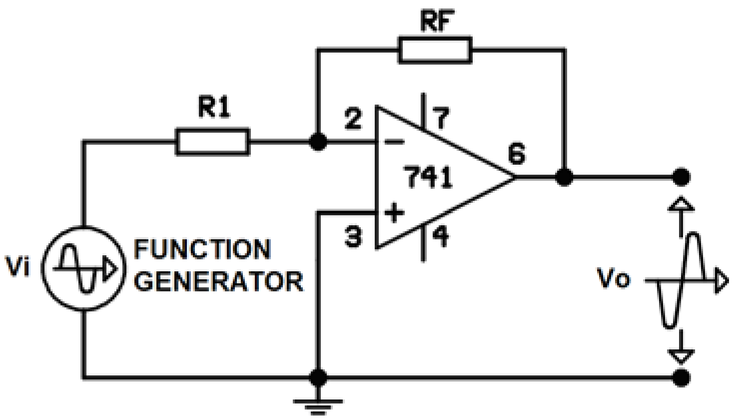
The voltage measured at the input where the signal is applied is close to zero. That means, the voltage drops on the resistance R1. So, the input impedance equals to the resistance R1 and this value is small for electronic circuits. The signal source may be affected by that small resistance. That situation is always undesired.

B.Output Impedance (Zo): The minimum resistance can be driven by the 1 KHz sine wave obtained at the output when the output is floating. The amplitude of the output signal **(Vo)** is measured while the output is open circuit. Without making any change, a variable resistor is connected to the output. Voltage at the output is adjusted to Vo/2 by using the variable resistor. The variable resistor is disconnected and the value of the resistor is measured. That value is the output impedance. In other words, output impedance is the resistance value at which the output signal corrupted.

The ouput impedance of the inverting amplifier is small. That means, inverting amplifier can drive all types of loads. That is always an advantage for electronic circuits.

FREQUENCY BAND OF AMPLIFIERS

It is desired for the operational amplifiers to have the same gain while it is operating with DC or with a high frequency signal. But it is difficult to satisfy that condition.



We know that the gain is very high at operations with DC signals and with signals close to DC **(up to 10Hz)**. If the frequency of the input signal is increased, the gain decreases.

Let us apply a sinusoidal AC signal with amplitude 1Vpp and frequency 1 KHz to the circuit given in figure 7.1 and let us assume that we obtain a signal with amplitude 9Vpp at the output. If we increase the frequency slowly, we observe the decrease in the amplitude of the output signal. The upper limit of the frequency band is -3dB decreasing gain when the amplitude becomes $1/\sqrt{2}$ of the initial amplitude

That means, the operational amplifier operates efficiently from DC up to that frequency. That frequency interval is called the band width.

FREQUENCY-GAIN RELATION OF AMPLIFIER

Since the gain of the operational amplifiers is very high at operations with DC signals and with signals close to DC, their gain decreases with increasing frequency. That means, their gain should be kept small, if they are used at high frequencies. As we know, the gain is;

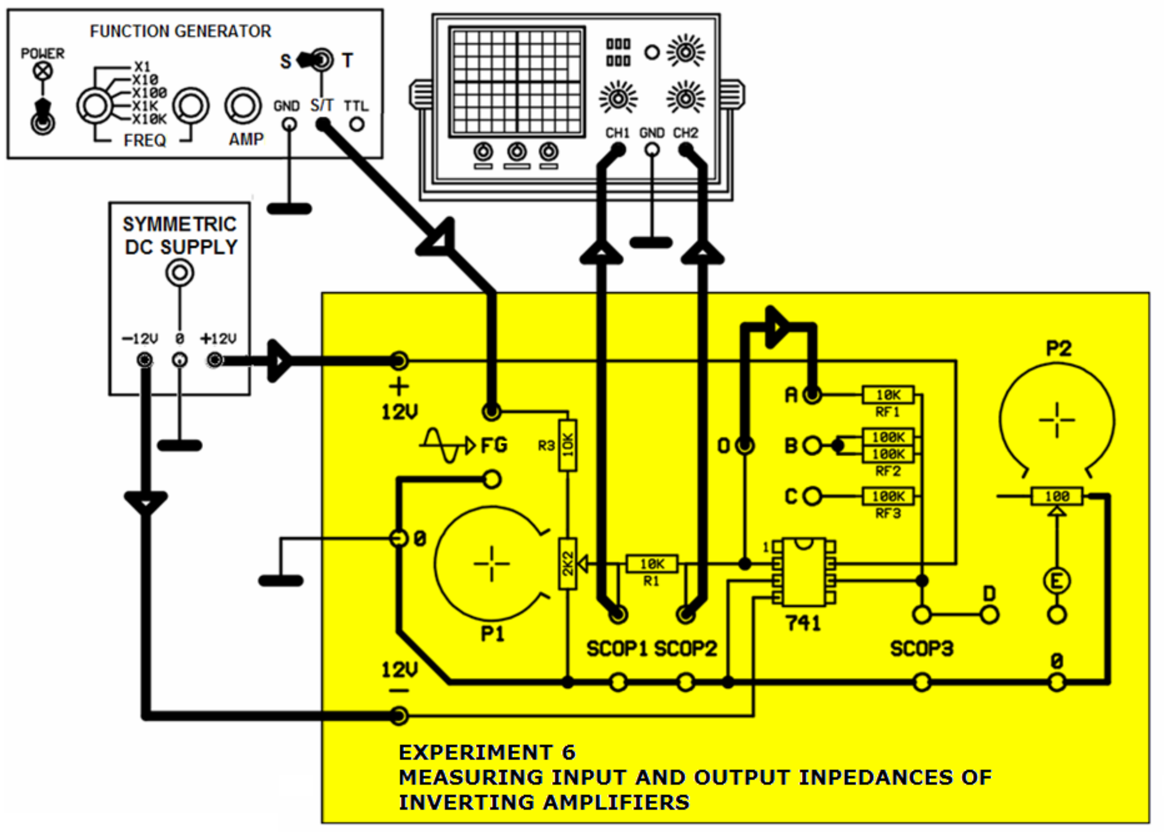
$$A = \frac{RF}{R1}$$

If that ratio is kept small while selecting the resistors, stable operation is satisfied at high frequencies.

EXPERIMENT: 1.6

MEASURING INPUT AND OUTPUT IMPEDANCES OF INVERTING AMPLIFIERS

Connect the circuit as shown in the figure.



1- Apply power to the circuit. Set the output of the function generator to sinusoidal wave with frequency 1 KHz and amplitude 1V peak to peak by using scope1.

2- Measure the amplitude of the signal at Scope2.

3- Calculate the current passing through the resistance R1.

4- Calculate the input impedance of the inverting amplifier.

5- What is the relation between the input impedance and the resistance R1?

6- Change the resistance RF **(short OB or OC).** Is there any change in Scope2?

7- What is the effect of the resistance RF on the input impedance?

8- Take Scope2 to terminals of Scope3. Again short the points O-A. Measure the output voltage.

9- Short the points D-E. Adjust the potentiometer P2. Set the output voltage half of its value. Open the points D-E and measure the resistance between the points O-E.

10- What does this resistance value correspond to?

11- Open the short circuit between the points O-A. Short the points O-B. Measure the output voltage.

12- Short the points D-E. Adjust the potentiometer P2. Set the output voltage half of its value. Open short circuit between the points D-E and measure the resistance between the points O-E.

13- Does the resistance RF affect the output impedance?

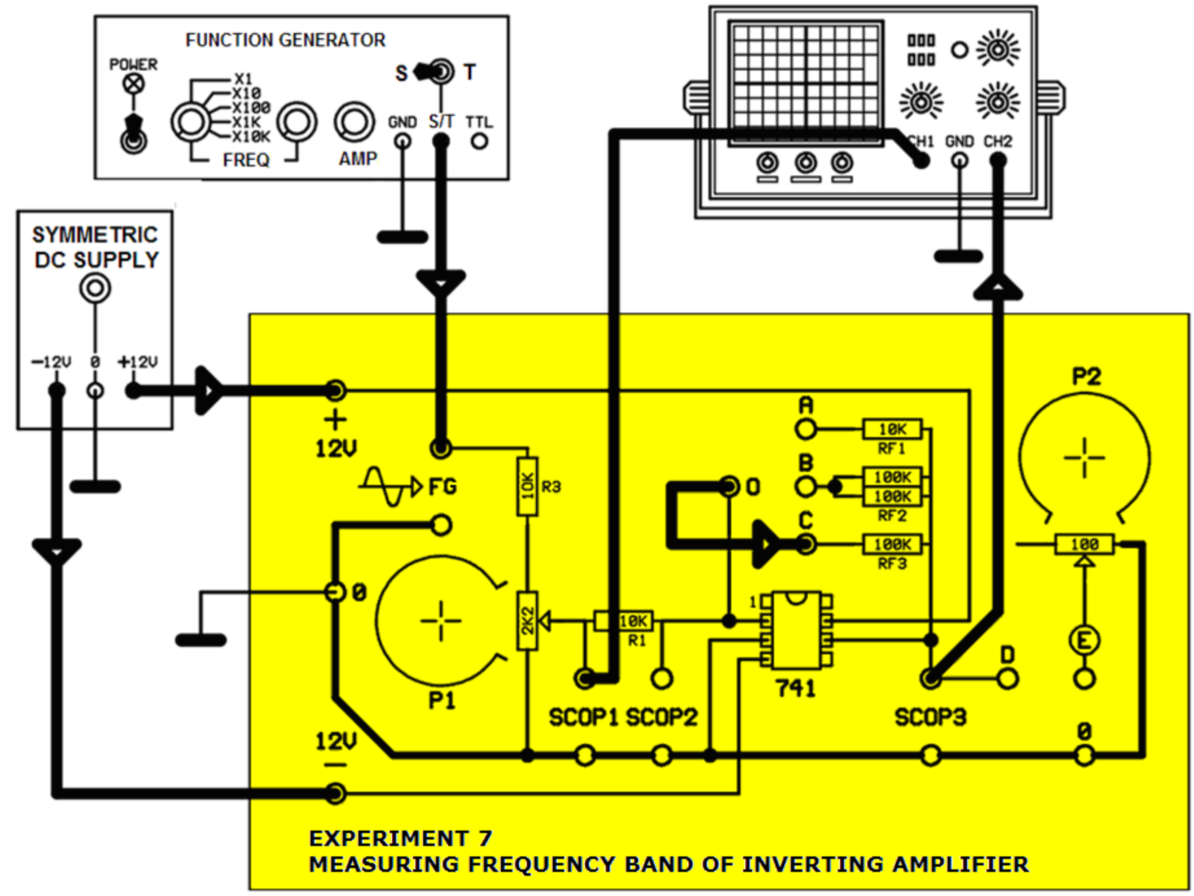
14- Short the output pins **(terminals of Scope3)** via an ampermeter (1mA). Read the current value.

15- Short the output terminals. Does the system operate normally? What does this mean?

EXPERIMENT 1.7:

MEASURING FREQUENCY BAND OF INVERTING AMPLIFIERS

Connect the circuit as shown in the figure



1- Apply power to the circuit. Set the output of the function generator to sinusoidal wave with frequency 1 KHz and amplitude 1V peak to peak by using scope1.

2- Measure the amplitude of the output signal at Scope3.

3- Adjust the frequency of the function generator until the amplitude of the output signal becomes $1/\sqrt{2}$ of it.

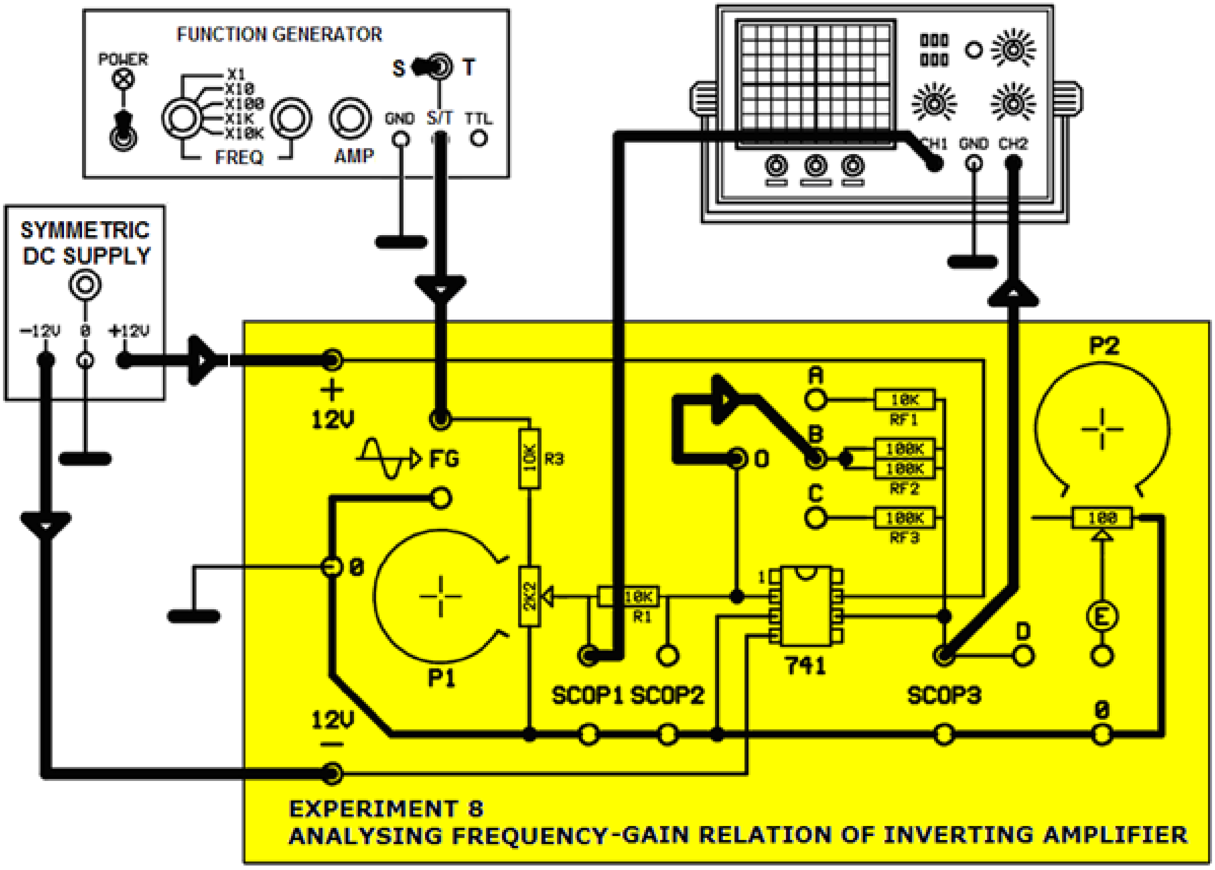
Measure the frequency at that instant.

4- What does this frequency value correspond to?

EXPERIMENT 1.8:

ANALYZING FREQUENCY-GAIN RELATION OF INVERTING AMPLIFIER

Connect the circuit as shown in the figure



1- Apply power to the circuit. Set the output of the function generator to sinusoidal wave with frequency 1 KHz and amplitude 1V peak to peak by using scope1.

2- Measure the amplitude of the output signal at Scope3.

3- Adjust the frequency of the function generator until the amplitude of the output signal becomes $1/\sqrt{2}$ of it.
Measure the frequency at that instant.

4- What does this frequency correspond to?

5- How do we explain the relationship between the gain and the frequency bandwidth if we compare the results of this experiment with the results of the experiment 1.7 ?