EEEN 202 ELECTRICAL AND ELECTRONIC CIRCUITS II

EXPERIMENT 1: DC/AC OPERATION OF AMPLIFIERS

OPERATIONAL AMPLIFIERS

Operational Amplifiers are the multiple staged, directly coupled, high gain differential amplifiers which are used to amplify AC and DC signals. To obtain a stable controllable gain, a feedback network should be constructed by peripheral elements. If negative feedback is used, we obtain higher gains. Operational amplifiers are linear amplifiers. It is possible to perform addition, subtraction, integration and differentiation if they are used with appropriate circuit elements. Today, operational amplifiers are widely used in power supplies, all types of signal generators, telecommunication equipments, computers, test and measurement devices and industrial control systems. There are eight important properties of operational amplifier circuits.

These are;

1. Their AC and DC gains are very high. (**AA=200000**).
2. Their input impedances are very high. So, they do not load the signal generator at the input. (**Zi=∞)**.
3. Their output impedance is very low. So they can easily drive the output circuit. (Zo=0).
4. The time delay between the input signal and the output signal is very low.
5. There is no signal at the output if there is no signal at the input. It amplifies without distortion.
6. If they are used witout feedback, the difference at the input is amplified to a voltage close to the supply voltage.
7. Their frequency band is wide (**1MHz**).
8. Their characteristic does not change with the temperature.

CONNECTING OPERATIONAL AMPLIFIERS TO THE CIRCUIT

Inner structures of operational amplifiers are too complex. The most widely used type of operational amplifiers, 741, is composed of almost 20 transistors depending on the manufacturer. The important thing that one must know in the applications is the pins of the operational amplifier and their function. Connecting operational amplifiers to the circuit is very simple. Generally 5 of the pins are used. The most widely used symbol and its pin numbers are given in Figure 1.1.

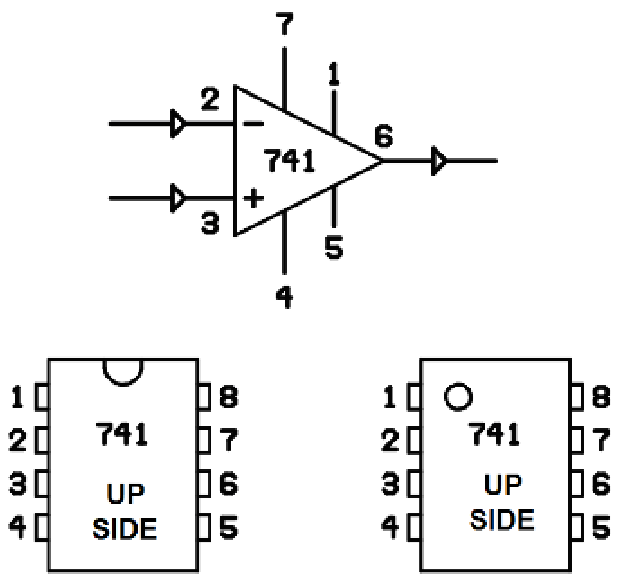


Figure 1.1

Input Pins: There are two input pins ((+) and (-)) in operational amplifiers. In 741 IC operational amplifier; 2^{nd} pin is the (-) input. This pin is also called inverting input. If the input is applied to that pin, there apears a 180 degree phase difference between the input and output signals. 3^{rd} pin is the (+) input. This pin is also called non-inverting input. If the input is applied to that pin, the output signal becomes in phase with the input signals. If the input voltages are equal to each other, the output becomes zero. In operational amplifiers the resistance between the inputs and the resistance between the inputs and the ground is very high. So they do not load the signal source.

Output Pin: There is a single output pin for operational amplifiers. For 741 IC the output pin is the 6^{th} pin. The load resistor RL is connected between the output pin and the ground. The amplitude of the output voltage is limited by the supply voltages. The maximum output voltage has amplitude approximately 1V less than the supply voltage. That 1V drops on the transistors at the output stage. The resistance between the output terminal and the ground is very low. So, sufficient current is supplied to the resistive load at the output.

Supply Pins: There are two supply pins ((+) and (-)) of operational amplifiers. In 741 IC operational amplifier; the 4^{th} pin is the (-) supply pin. The 7^{th} pin is the (+) supply pin. In applications symmetric supplies are used in order to obtain stable operation. Operational amplifiers may be supplied with ±5Volt and ±18Volt. The supply for operational amplifiers is given in Figure 1.2.

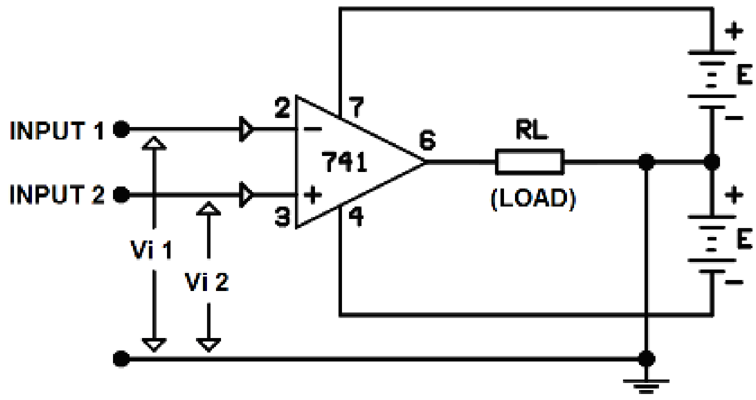


Figure 1.2

In the DC applications of operational amplifiers, symmetric power supplies must be used. In AC applications, single supply may be used if necessary. Then the other input should be connected to ground via a capacitor. The AC operation of the operational amplifier with single supply is seen in Figure 1.3.

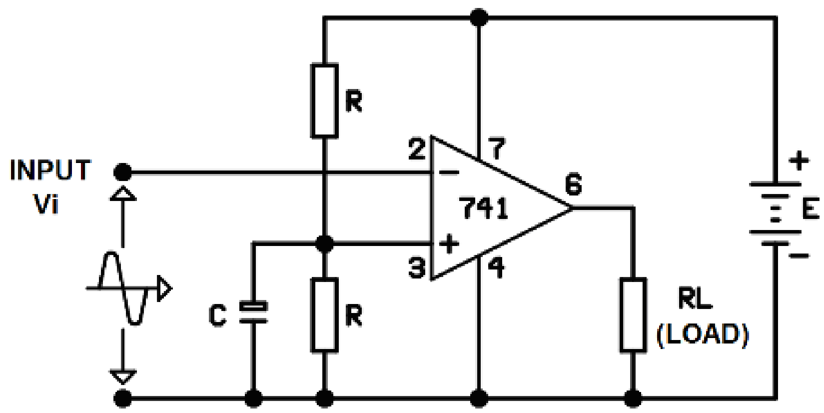


Figure 1.3

The resistances should be equal. The supply is generally not shown in operational amplifier circuits. In that case, the supply pins should be found in the datasheet of the operational amplifier and then they should be used in the application.

Offset Pins: We know that, when the same signal is applied to both of the inputs of the operational amplifiers, or no signal is applied to the inputs, or the inputs are short circuited; the output may be different than zero. That undesired signal may be unfavorable in sensitive applications. In order to avoid that problem, two pins taken from the offset stage are used. In 741 IC 1^{st} and the 5^{th} pins are the offset pins. The undesired signal is eliminated by connecting some circuit elements to those pins. This operation is called offset adjustment.

EXPERIMENT 1.1 ANALYZING DC OPERATION OF INVERTING AMPLIFIERS

Inverting operation of operational amplifier is given in Figure 1.4.

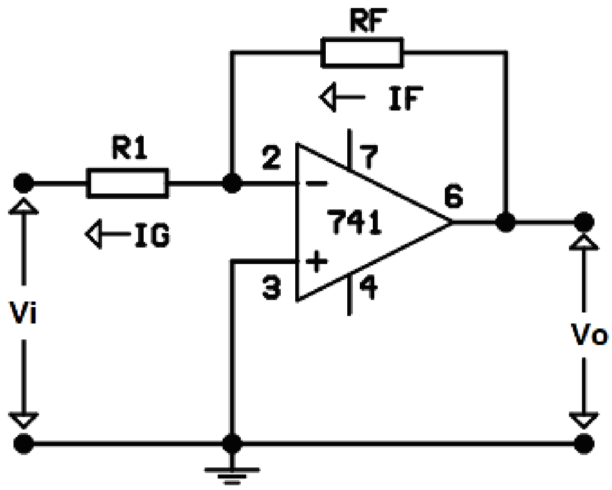


Figure 1.4

Operational amplifiers are good at DC amplification. Input is applied to the negative pin of the inverting amplifier. There is a 180 degree phase difference between the input and the output. If positive signal is applied to the input, a negative signal is taken from the output with amplitude as much as the gain. Similarly, if negative signal is applied to the input, a positive signal is taken from the output with amplitude as much as the gain. The resistance R1 is the input resistance and the resistance RF is the feedback resistance in the circuit. The voltage between the negative input (2^{nd} pin) of the operational amplifier and the chassis is zero volts. For that case;

$$V_i = -I_G \cdot R_I$$

For the output $I_G = I_F$ so, $V_i = I_F \cdot R_F = I_G \cdot R_F$. In electronic circuits, the gain always equals to the ratio of the output to the input.

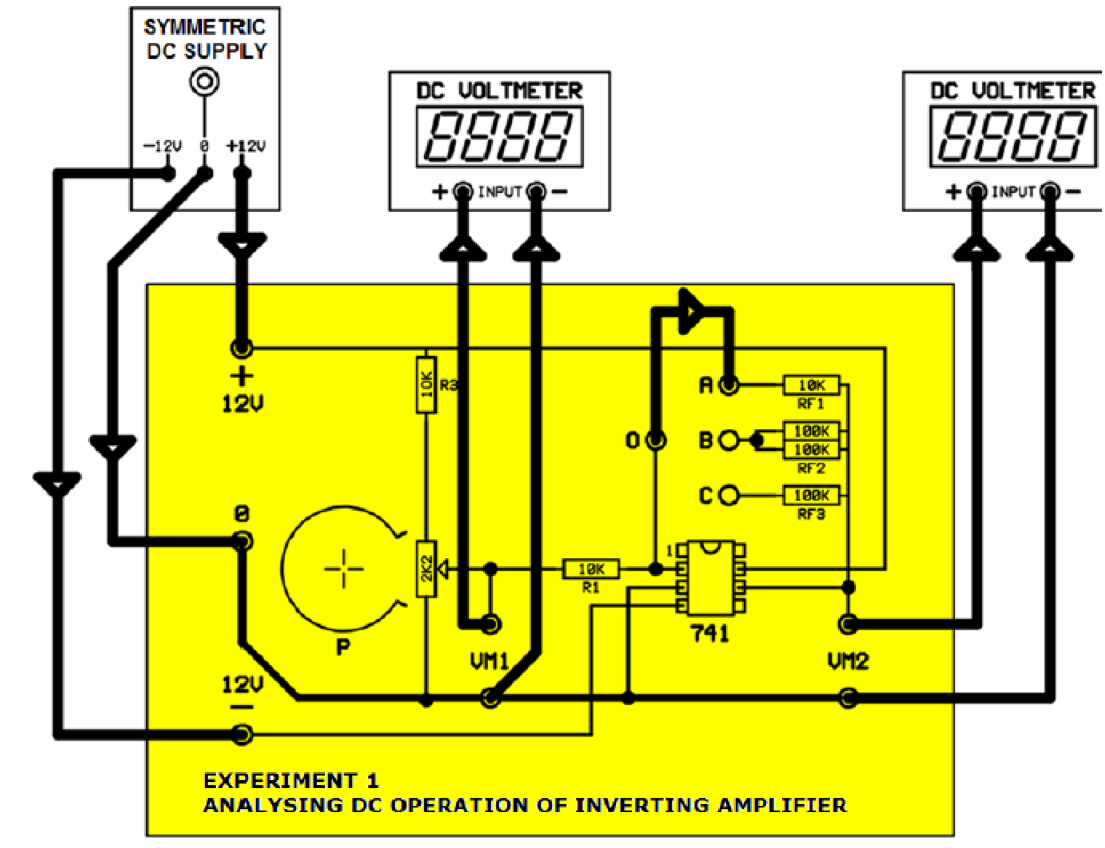
$$A = \frac{V_0}{V_i} = \frac{I_G \cdot R_F}{-I_G \cdot R_I} = -\frac{R_F}{R_I}$$

It must always be remembered that there is a 180 degree phase difference between the inputs and the outputs of the inverting amplifier. Operational amplifiers operate with both negative input signal and positive input signal. So they are used for AC amplification. If the input and the output signals are visualized by using an oscilloscope with two channels, phase relation is easily observed.

In our experiment set, in the operational amplifier experiments, we have chosen 10K, 50K, and 100K for resistance RF for simplicity in calculations. 50K resistance is obtained by parallel combination of two 100K resistances since 50K is not a standard value.

EXPERIMENTAL PROCEDURE:

Connect the circuit as shown in the following figure.



1. Apply power to the circuit.
2. Adjust the input voltage to values (VM1) given in Table 1 by using potentiometer P. Take note of the output voltage (VM2) in each step.

VM1 (Volt)	VM2 (Volt)
0.2	
0.4	
0.6	

3. What is the sign of the output voltage? Why?

4. What is the voltage gain of the circuit?

5. What dose the gain of the inverting amplifier depend on?

6. Calculate the gain of the circuit for each case in the above table.

7. Open the short circuit O-A and short circuit O-B. Take note of the output voltages for the inputs given in the 2nd step.

VM1 (Volt)	VM2 (Volt)
0.2	
0.4	
0.6	

8. Does the equation $|A| = \frac{R_{F2}}{R_I}$ satisfy the gain?

9. Does the operational amplifier operate as DC amplifier? Why/Why not?

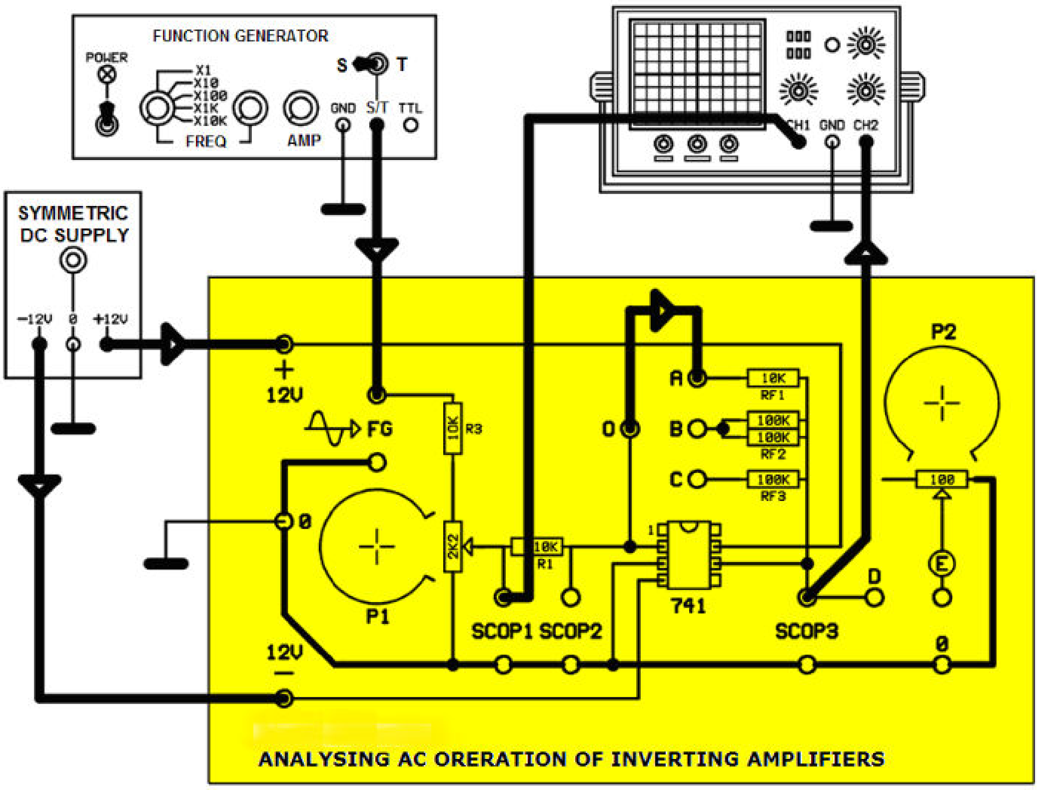
10. How should the supply be when the operational amplifier is operating as a DC amplifier?

EXPERIMENT 1.2 ANALYZING AC OPERATION OF INVERTING AMPLIFIERS

The preliminary information has been given in Experiment 1.1.

EXPERIMENTAL PROCEDURE:

Connect the circuit as shown in the following 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. Observe the input and the output signals on the oscilloscope screen. Write your observation.

3. Measure the amplitudes of the input and the output signals.

4. What is the phase difference between the input and the output signals?

5. Open the short circuit O-A. Short circuit the points O-B. Measure the gain of the circuit.

6. Open the short circuit O-B. Short circuit the points O-C. Measure the gain of the circuit.

EXPERIMENT 1.3 ANALYZING DC OPERATION OF NON-INVERTING AMPLIFIERS

The non-inverting operation of operational amplifier is shown in Figure 1.5.

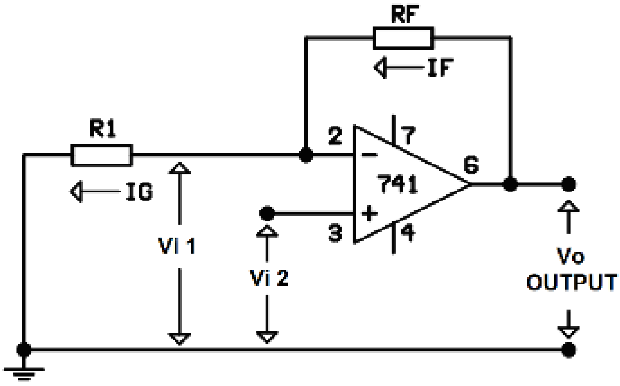


Figure 1.5

The input signal is applied to the positive input in non-inverting amplifiers. The input and the output signals are in phase. The input signal is amplified as much as the gain and it is transferred to the output with the same sign. In the circuit, R1 is the input resistance and RF is the feedback resistance. For an ideal op-amp, the voltages at the inputs with respect to the chassis are equal.

$$V_{i1} = V_{i2}$$

For the output; $I_G = I_F$, that is

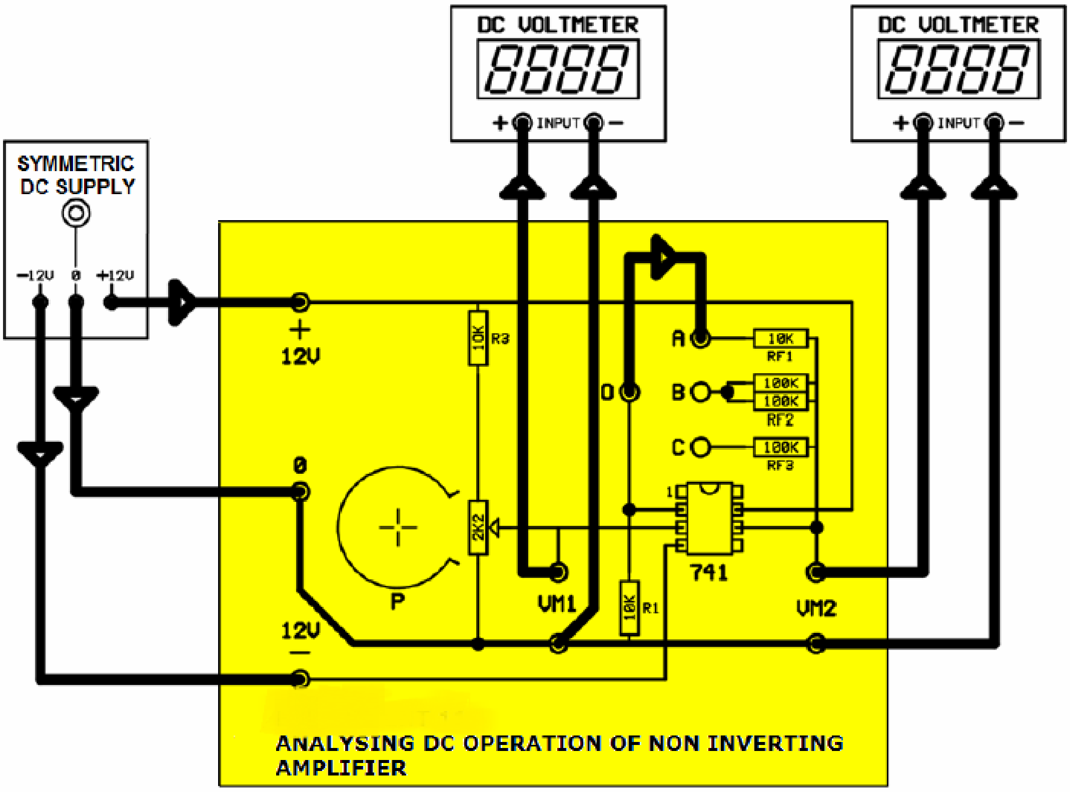
$$I_G = \frac{V_{i2}}{R_1} = I_F = \frac{V_0 - V_{i2}}{R_F}$$

$$\Rightarrow \left(R_F + R_1\right)V_{i2} = R_1 V_0 \Rightarrow \frac{V_0}{V_{i2}} \triangleq A = \frac{R_F + R_1}{R_1} = 1 + \frac{R_F}{R_1}$$

The gain of the non-inverting amplifier is always 1 more than the gain of the inverting amplifier as it is seen from the equations. Non-inverting amplifiers operate with both negative and positive input signals. That means they are used in AC amplification.

EXPERIMENTAL PROCEDURE:

Connect the circuit as shown in the following figure.



1. Apply power to the circuit.
2. Adjust the input voltage to values (VM1) given in Table 1 by using potentiometer P. Take note of the output voltage (VM2) in each step.

VM1 (Volt)	VM2 (Volt)
0.2	
0.4	
0.6	

3. Is there any phase difference between the input and the output signals?

4. Calculate the gain of the circuit?

5. Does the ratio $1+\frac{R_F}{R_1}$ verify the gain? Calculate.

6. Open the short circuit O-A and short circuit O-B. Take note of the output voltages for the inputs given in the 2nd step.

VM1 (Volt)	VM2 (Volt)
0.2	
0.4	
0.6	

7. Calculate the gain of the circuit for the 2nd step.

8. Does the operational amplifier operate as a DC amplifier?

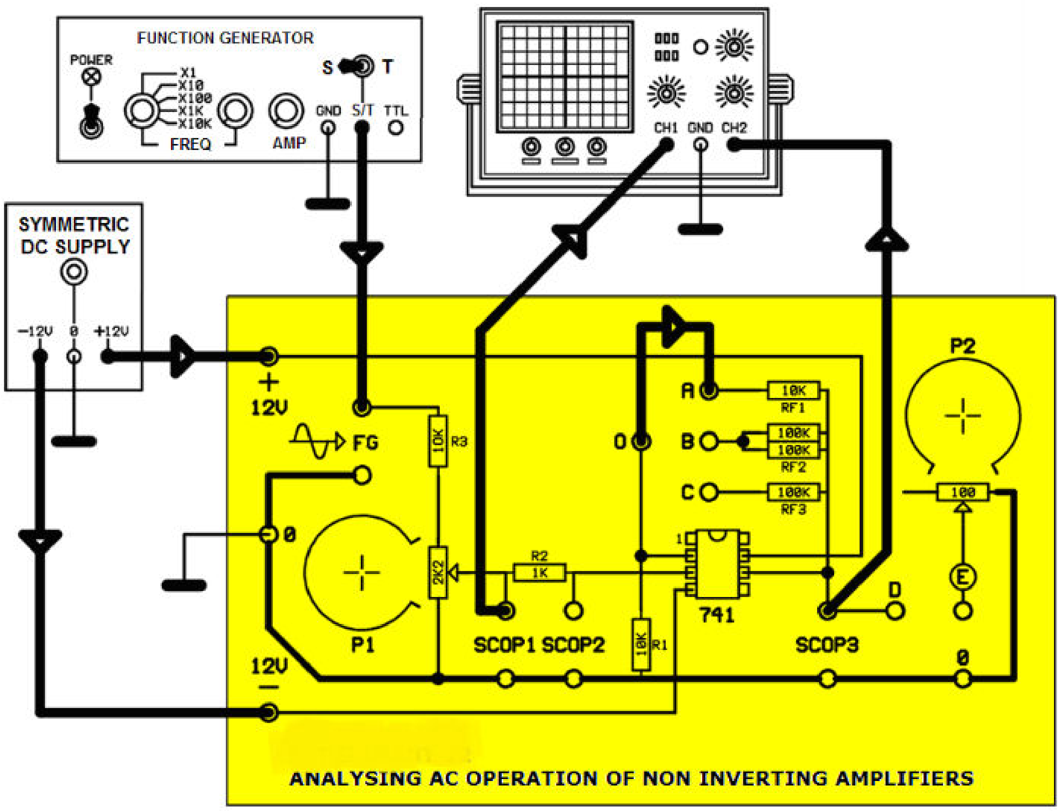
9. How should the supply be when the operational amplifier is operating as an DC amplifier? Why/Why not?

EXPERIMENT 1.4 ANALYZING AC OPERATION OF NON-INVERTING AMPLIFIERS

The preliminary information has been given in Experiment 1.3.

EXPERIMENTAL PROCEDURE:

Connect the circuit as shown in the following 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. Observe the input and the output signals on the oscilloscope screen. Write your observation.

3. Measure the amplitudes of the input and the output signals.

4. What is the phase difference between the input and the output signals?

5. Open the short circuit O-A. Short circuit the points O-B. Measure the gain of the circuit.

6. Open the short circuit O-B. Short circuit the points O-C. Measure the gain of the circuit.