OPERATIONAL AMPLIFIERS AND APPLICATIONS

PREPARATORY WORKS

1. Give information about the features and structure of operational amplifiers 741
2. Determine the equations for inverting amplifier, derivative receiver, integral receiver, adder and comparator circuits realized with operational amplifiers.
3. Set up the circuits given in Experiment1, Experiment2, Experiment3, Experiment4 and Experiment5 in the Multisim program and observe the output signals in response to the given input values.
4. Breadbord özelliklerini inceleyiniz ve bir breadboard üzerinde elektrik devresinin nasıl kurulacağı hakkında bilgi edininiz.

NOTE: Come to the experiments by preparing the preparatory work as a report (with the report cover). Those without a preparation report will not be admitted to the experiments

1. EXPLANATIONS

An operational amplifier is an amplifier with very high gain, very high input impedance (typically several MΩ) and low output impedance (less than 100Ω). The basic circuit consists of a difference amplifier with two inputs (V+, V-), two supplies (+Vcc, -Vcc) and at least one output (V-output). A basic operational amplifier circuit is shown in Figure 1.

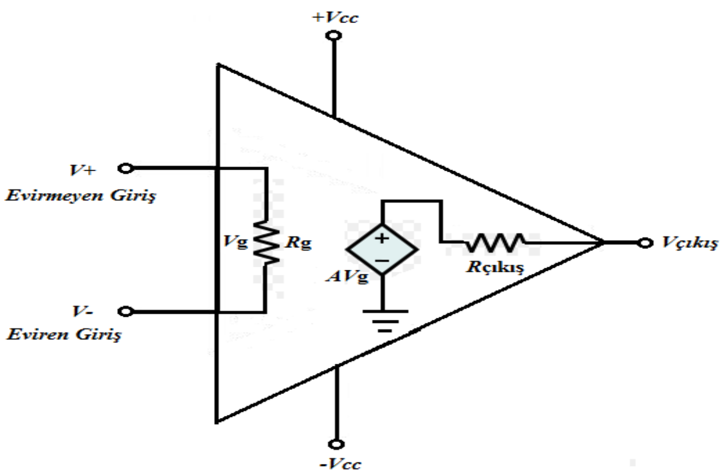

Figure 1. Basic operational amplifier circuit

In the circuit shown in Figure 1, the signal applied from the non-inverting input (*V+*) produces an amplified signal at the output of the amplifier (V-output) in phase with itself, while a 180° phase difference occurs between the signal applied from the inverting input and the output signal. The gain of operational amplifiers is very high (10^3- 10^{15}) and varies according to the type of operational amplifier. The operating frequencies of operational amplifiers start from DC and go up to THz levels. It should be well known that the maximum value of the output voltage (*Vo*) of an operational amplifier is equal to the supply voltages *(+Vcc, -Vcc)* of this amplifier. So first the calculation is done and if If the output value obtained as a result of the calculation is higher than the supply voltages, the output is limited to (*+Vcc*, *-Vcc*). Operational amplifiers can perform mathematical operations such as multiplication, division, addition, subtraction, differentiation and integration and are widely used in many measurement and control systems, such as regulators, oscillators, logarithmic amplifiers, peak detectors, and voltage comparators.

There are two basic rules used to analyze ideal operational amplifiers;

- Ideal operational amplifiers have zero input current.
- Ideal operational amplifiers have zero voltage drop across the input terminals.

The leg connections of the LM741 operational amplifier to be used in the experiment are given in Figure 2.

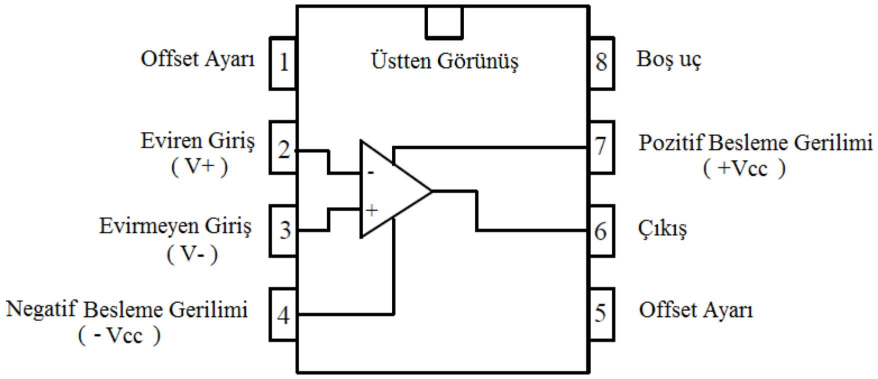

Figure 2. LM741 operational amplifier leg connections

1. 1. Inverting Amplifier

The basic inverting amplifier circuit is given in Figure 3. *Ro* is the feedback resistor.

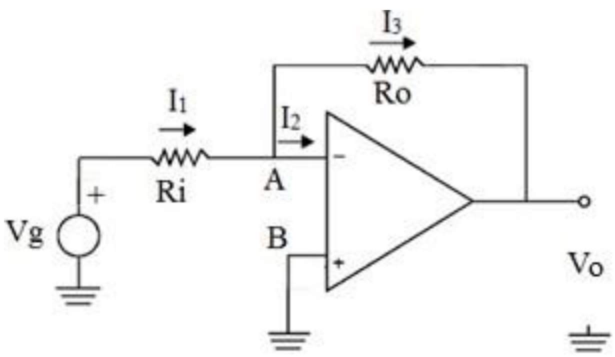

Figure 3. Inverting Amplifier

In the circuit shown in Figure 3, the voltage *Vo* is calculated based on two basic rules used in operational amplifiers. In this case, as a first rule, I_2 current is taken as zero and I_1 current is equal to I_3 current, as a second rule, since there will be no voltage drop between the input terminals.

The voltage at point A and the voltage at point B are equal. Based on these statements The voltage Vo is calculated as follows.

$$I_2=0A; \tag{1}$$

$$I_1=I_3; \tag{2}$$

$$V_A=V_B = 0V; \tag{3}$$

Using equations (1), (2) and (3), the output voltage is expressed in terms of the input voltage;

$$Vg=I_1*Ri \tag{4}$$

$$I_1=\frac{Vg}{Ri} \tag{5}$$

$$Vo= -I_3*Ro = -I_1*Ro \tag{6}$$

If the I1 value found in equation (5) is substituted in equation (6), the output voltage;

$$Vo= -\frac{Ro}{Ri}Vg \tag{7}$$

is calculated as.

1. 2. Derivative Reciever

The general structure of the derivative receiver circuit is given in Figure 4. The difference of this circuit from the inverting amplifier is the use of capacitor C instead of resistor Ri. The capacitor connected to the input signal will pass AC signals but not DC signals and so, just as the derivative of a fixed number is zero, a DC signal applied to the derivative receiver circuit will result in an output voltage of 0 Volts.

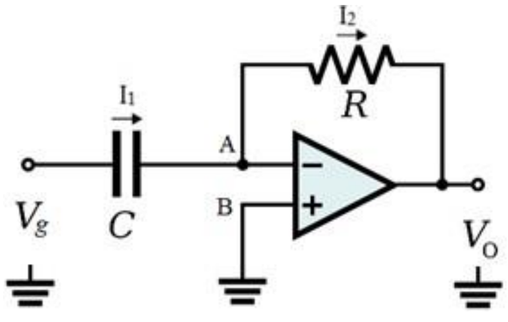

Figure 4. Derivative Receiver circuit

To calculate the output signal Vo in terms of the input signal Vg, we perform the same operations as in the inverting amplifier circuit, as follows;

Since the voltages of point A and point B are equal to each other and 0 Volt, they are first written as in equations (8) and (9).

$$Vg = \frac{1}{C}\int I_1\, dt \tag{8}$$

$$I_1 = C\frac{dVg}{dt} \tag{9}$$

For output voltage;

$$V_o = -I_2 * R \tag{10}$$

$I1$ and $I2$ currents are equal to each other, so if $I1$ in equation (9) is substituted for $I2$ in equation (10);

$$V_o = -RC\frac{dVg}{dt} \tag{11}$$

It can be seen from equation (11) that the output signal is the derivative of the input signal.

1.3. Integral Receiver

The circuit that integrates the signal applied to its input is given in Figure 5. In this circuit, the integration process is performed with the help of capacitor C on the feedback path..

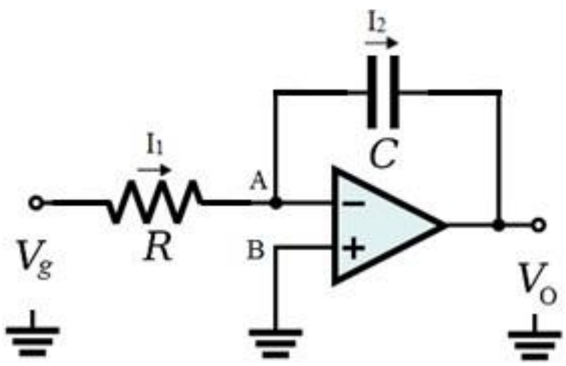

Figure 5. Integral Receiver

The expression of the output voltage (Vo) in terms of the input voltage (Vg) is given by the following equations.

$$Vg = I_1 * R \tag{12}$$

$$V_0 = -\frac{1}{C}\int I_2 dt \tag{13}$$

$I1$ and $I2$ currents are equal to each other, therefore $I1$ can be obtained from equation (12). If we substitute the expression $I2$ in equation (13), the output voltage;

$$V_0 = -\frac{1}{RC}\int V_g dt \tag{14}$$

It can be seen from equation (14) that the output signal is the integral of the input signal.

1.4. Adder Amplifier

Perhaps the most widely used circuit of operational amplifier circuits in practice is the summing amplifier. The adder circuit built with an operational amplifier to sum two input signals is shown in Figure 6.

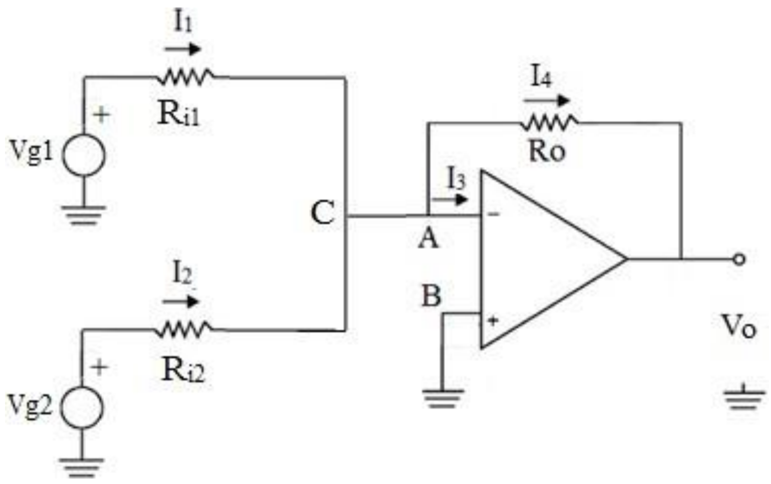

Figure 6. Adder circuit

Since the voltages of point A and B are equal to each other and 0 Volt, equations (15) and (16) are written first;

$$Vg1 = I_1 * R_{i1}\ ,\ I_1 = \frac{Vg1}{R_{i1}} \tag{15}$$

$$Vg2 = I_2 * R_{i2}\ ,\ I_2 = \frac{Vg2}{R_{i2}} \tag{16}$$

$I1$ and $I2$ currents are summed at point C and since $I3$ current is zero, $I4$ current is $I1$ and $I2$ is equal to the sum of their currents, i.e. $I4 = I1 + I2$. If the output voltage is $V0$;

$$V_0 = -\, I_4 * Ro \tag{17}$$

If $I4$ current is substituted for $I1$ and $I2$, the output voltage can be written as in equation;

$$V_0 = -Ro\left(\frac{Vg1}{R_{i1}} + \frac{Vg2}{R_{i2}}\right) \tag{18}$$

As can be seen from equation (18), the output signal is the sum of the input signals.

1.5. Comparator

A comparator is a circuit that compares a reference voltage with an input voltage. The output voltage is equal to one of the positive and negative supply voltages (+Vcc, -Vcc) depending on whether the input signal is above or below the reference signal. A basic comparator is shown in Figure 7.

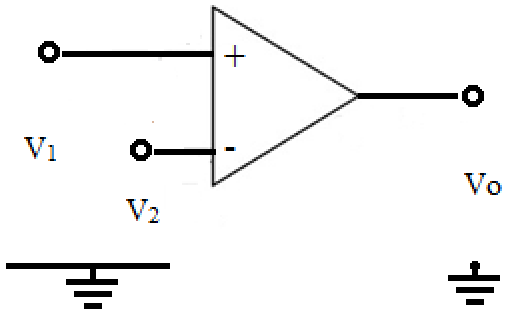

Figure 7. Comparator circuit with operational amplifier

In the circuit shown in Figure 7, if the amplitude of the signal applied to the non-inverting input (V1) is greater than the amplitude of the voltage applied to the inverting input (V2), the output voltage (Vo) is equal to the positive supply voltage (+Vcc). However, in the opposite case, the output voltage (Vo) is equal to the negative supply voltage (-Vcc). The related equations are given below;

$$V_1 > V_2 => \ Vo = +Vcc \tag{19}$$

$$V_2 > V_1 \ => \ Vo = -Vcc \tag{20}$$

When operational amplifiers are operated as comparators, the active region operating state is ignored.

Experimental Procedure:

Materials Used in the Experiment

- 11kΩ, 10kΩ resistor and 10nF, 0.1µF capacitor
- 741 Operational amplifier
- Signal generator
- Oscilloscope
- Connection cables

Experiment 1. Inverting Amplifier Experiment

Build the circuit given in Figure 3 using Ri=1kΩ and Ro=10kΩ resistors and apply a sinusoidal signal with a maximum value between 1Volt and 2Volt to the input of the circuit and draw the voltage change at the output of the circuit on the relevant graphs in the experiment report.

Experiment 2. Derivative Receiver Experiment

Build the circuit given in Figure 4 using C=10nF and Ro=10kΩ, apply a triangle wave signal with a peak-to-peak amplitude of 0.5 Volt and a frequency of 2kHz to the input of the circuit. Plot the changes of the input voltage and output voltage on the graphs in the experiment report.

Build the circuit given in Figure 5 using C=0.1µF and Ri=4.7kΩ, apply a square wave signal with a maximum amplitude of 1Volt and a frequency of 2kHz to the input of the circuit.

Experiment 4. Adder Experiment

Build the circuit given in Figure 6 with Ri1, Ri2 and Ro resistance values of 1 kΩ. Apply a square wave and a triangle wave with a maximum value of 1Volt and a frequency of 2kHz to the input of the circuit. Plot the input and output signals on the graphs in the experiment report.

Experiment 5. Comparator Experiment

In the circuit shown in Figure 7, apply a sinusoidal signal with DC 2 volts to input V1 and a maximum voltage of 4 volts to input V2. Plot the input signals and the output signal on the relevant graphs in the experiment report.

Note: The experiments must be performed properly and the theoretical part of the methods must be well known.