National Aviation University

Department of Electronics, Robotics, Monitoring and IoT Technologies

Course: “Analog and Digital Instrumentation”

Experiment 2

“Non-inverting and Inverting Operational Amplifier Circuits”

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OBJECTIVES

1. To study the ac characteristics of the non-inverting op-amp configuration.
2. To study the ac characteristics of the inverting op-amp configuration.
3. To simulate the non-inverting and inverting op-amp circuits using MULTISIM software.

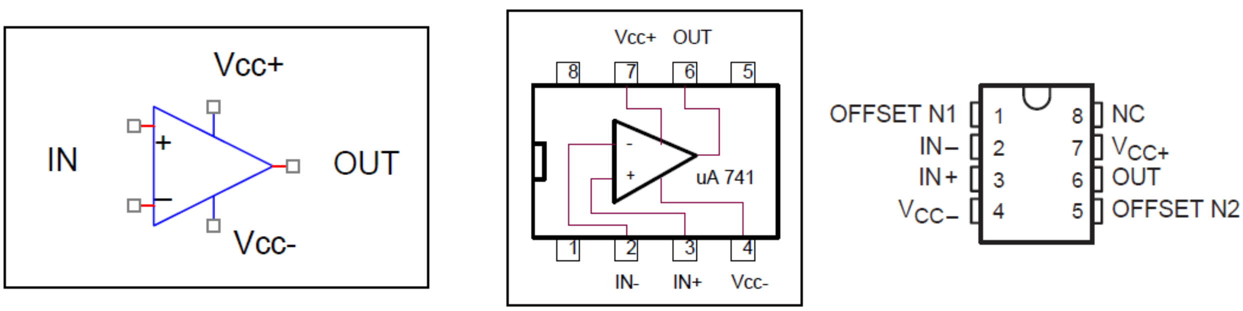
INFORMATION

Note: Actual lab procedure follows this information section.

The integrated circuit operational amplifier (op-amp) is an extremely versatile electronic device, which is encountered in a wide variety of applications ranging from consumer electronics (stereos, VCR's) to complex commercial applications and industrial controls. This versatility stems from the very high voltage gain (100,000 and higher for the 741) together with high input resistance (typically 1 MΩ) and low output resistance (typically 50Ω). These characteristics allow use of large amounts of feedback from output to input with the result that the desired output signal is dependent only on the external components.

Op-amps are direct coupled devices such that the input signal may be either AC or DC, or a combination of the two. The industrial standard op-amp, the 741, requires two power supplies, one positive and one negative. For most applications the magnitude of these two voltages is the same. All op-amps have two inputs connected in a differential mode, so that output voltage is $\mathbf{V_o = A(V_+ - V_-)}$ where $\mathbf{V_+}$ is the voltage at the non-inverting input and $\mathbf{V_-}$ is the voltage at the inverting input. **A** is the open loop gain of the op-amp.

The circuit symbol for an op-amp is shown in Fig. 1(a). The pin connections for the 8 pin DIP package μA741 op-amp are given in Fig. 1(b).



(a) (b)

Figure 1: Symbol for a basic op-amp (a), the μA741 op-amp package (b)

Ideally, an op-amp will have infinite open loop voltage gain **A**, infinite input resistance $\mathbf{R_{in}}$ and zero output resistance $\mathbf{R_o}$. The input currents in the two differential inputs and the voltage difference between the two inputs will be vanishingly small. In practice these quantities are finite and in most applications can be ignored.

1. Basic non-inverting amplifier

The basic non-inverting op-amp configuration is shown in Fig. 2.

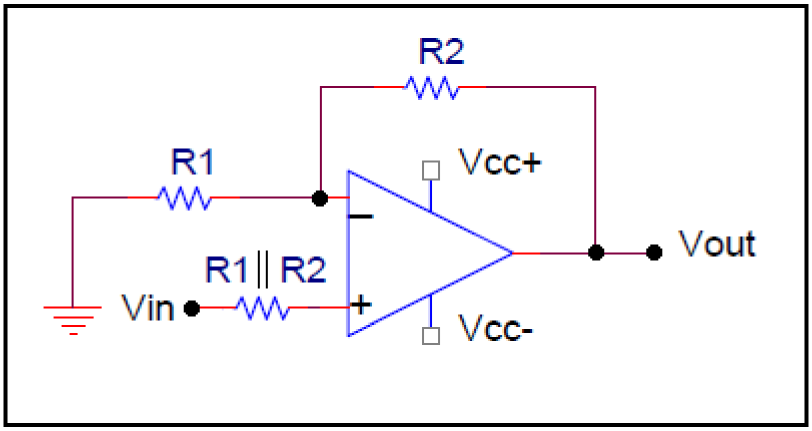


Figure 2 Basic non-inverting amplifier

A particular value of the closed-loop gain A_v of the non-inverting amplifier can be achieved by choosing the R1 and R2 values. The theoretical ideal characteristics are determined largely by the external biasing resistors, and are given by the following equations:

$$R_{in} \to \infty \Omega$$

$$R_o \to 0\Omega$$

$$A_V = \frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$

2. Basic inverting amplifier

The basic inverting op-amp configuration is shown in Fig. 3. You can achieve a particular value of the closed-loop gain Av of the inverting amplifier by choosing the R1 and R2 values.

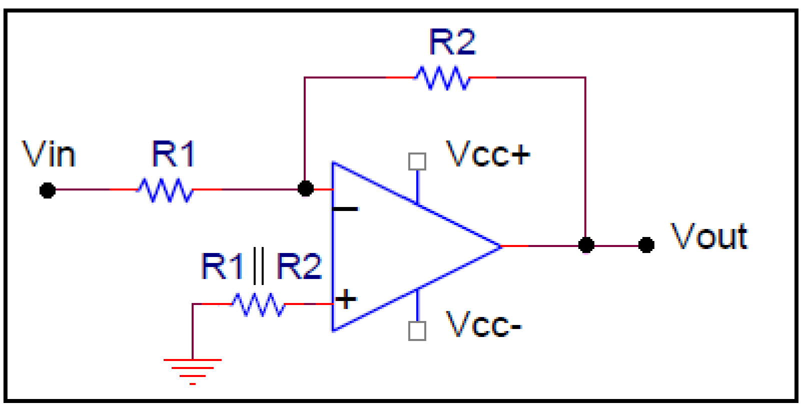


Figure 3 Basic inverting amplifier

The theoretical ideal characteristics are determined largely by the external biasing resistors, and are given by the following equations:

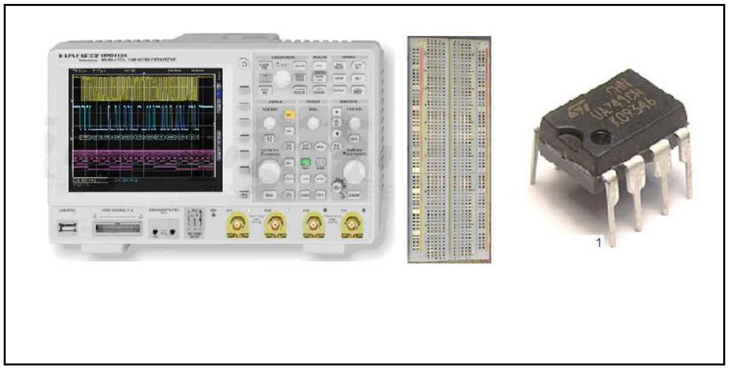
$$R_{in} = R_1$$

$$R_o \to 0\Omega$$

$$A_V = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}$$

EQUIPMENT

1. Digital multimeter UT33B
2. Solderless breadboard BB830T
3. Oscilloscope HAMEG HMO1024
4. Sinusoidal generator
5. Power Supply +12V, 0, -12V
6. Resistors: 10 kΩ, 2×1.8 kΩ, 1 kΩ
7. Capacitors 2x100nF
8. UA741 (УД708) op-amp



PROCEDURE

The pin connections for the 8 pin DIP package uA741 (УД708) op-amp are given in Fig. 1. Throughout this experiment use the external DC Power Supply Unit with **+12V**, **0**, **-12V** jacks. The initial location of the uA741 chip and connections to +12V, 0, -12V terminals of the power supply are shown in Fig. 4.

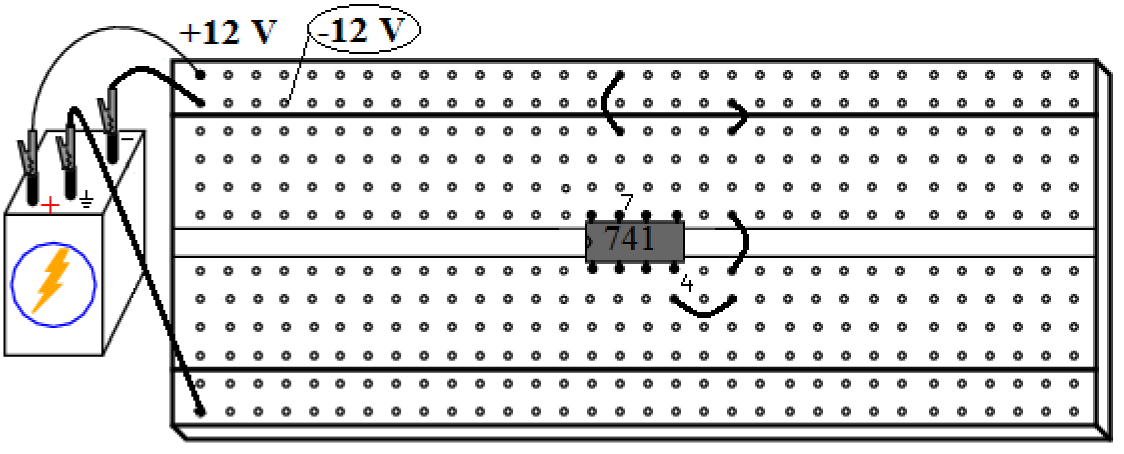


Figure 4: Initial location of uA741 chip on the solderless breadboard

Use the dual trace oscilloscope to observe the shape and to measure the amplitude of the input and output waveforms.

To use the Power Supply Unit:

• Turn the Power Supply ON. This will set both positive and negative power sources respectively to **+12V** and **–12V**. Measure these voltages with digital multemeter.

• Turn the Power Supply OFF before connecting to the circuits.

• Connect the **+12V** terminal of the Power Supply to the V_{CC}^{+} of your circuit as shown in Fig. 4. Connect the **-12V** terminal of the Power Supply to the V_{CC}^{-} of your circuit as shown in

Fig. 4. Connect the **COM** terminal of the Power Supply to the ground of your circuit as shown in Fig. 4.

1. Non-inverting amplifier measurements

1.1. Build the circuit of Figure 5 using an 8-pin uA741 (УД708) op-amp with R1 = 1.8kΩ and R2 = 10 kΩ. To achieve better circuit stability, connect 100nF capacitors between pins #4 and #7 of the uA741 and the Ground, as shown in Figure 5.

1.2. Apply a 1kHz sinusoidal voltage signal from the **Signal Generator** to the input and use the dual trace oscilloscope to observe both input and output waveforms. Adjust the magnitude of the input signal until clipping occurs on either the positive or negative peak of the output voltage. Determine the **maximum possible ac voltage swing**, i.e. maximum peak to peak voltage that can be obtained at the output of the circuit without clipping. Compare this to the DC power supply voltages. Put this information in section 1 of the Lab Measurements Sheet.

1.3. For $V_{in_{p\text{-}p}}$=1 V at F=1kHz measure the amplitude of the output signal V_{out} and calculate voltage gain of this circuit. Record data and compare the measured value of the voltage gain as ratio of V_{out}/V_{in} with the theoretical value of voltage gain represented by equation $1+R_2/R_1$.

1.4. Draw (photograph) the input and output waveforms.

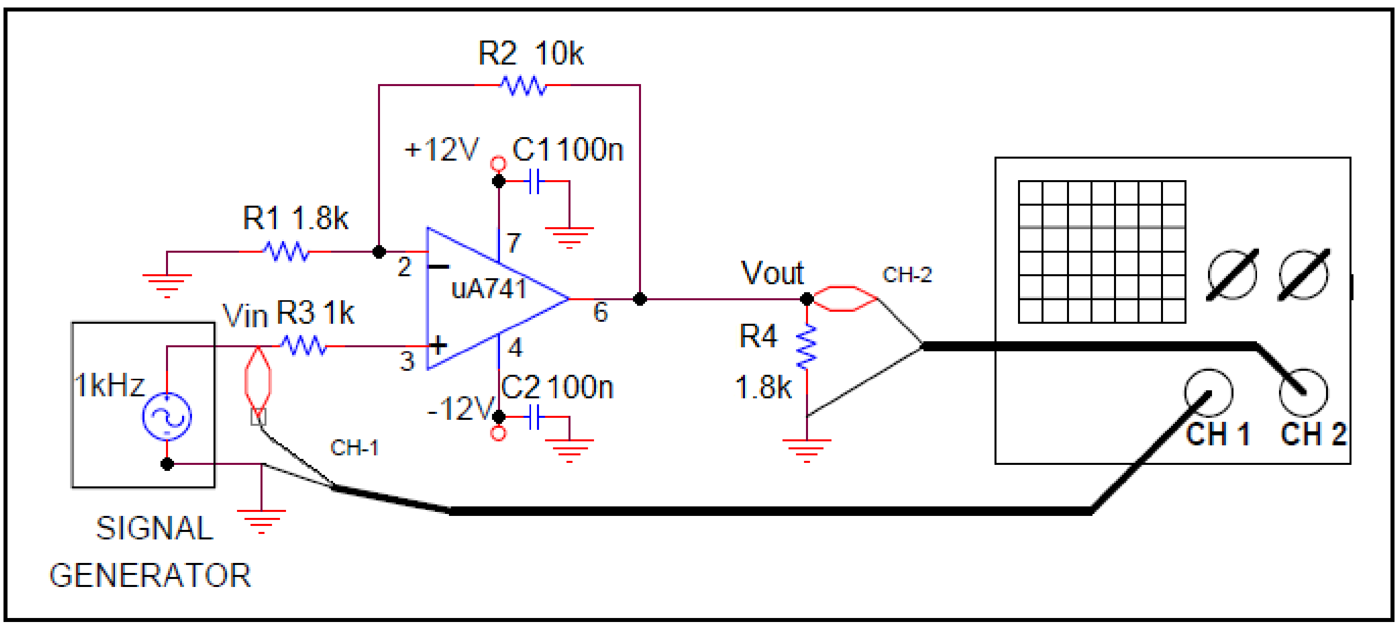


Figure 5 Measurement circuit for non-inverting amplifier

2. Inverting amplifier measurements

2.1. Build the circuit of Figure 6 using an 8-pin uA741 op-amp with R1 = 1.8kΩ, R2 = 10 kΩ. To achieve better circuit stability, connect 100nF capacitors between the pins #4 and #7 of the uA741 and the Ground, as shown in Figure 6.

2.2. Apply a 1kHz sinusoidal voltage signal from the **Signal Generator** to the input and use the dual trace oscilloscope to observe both input and output waveforms. Adjust the magnitude of the input signal until clipping occurs on either the positive or negative peak of the output voltage. Determine the **maximum possible ac voltage swing**, i.e. maximum peak to peak voltage that can be obtained at the output of the circuit without clipping. Compare this to the DC power supply voltages. Put this information in section 1 of the Lab Measurements Sheet.

2.3. For $V_{in_{p\text{-}p}}$=1V at F=1kHz measure the amplitude of the output signal V_{out} and calculate voltage gain of this circuit. Record data and compare the measured value of the voltage gain as ratio of V_{out}/V_{in} with the theoretical value of voltage gain represented by equation $-R_2/R_1$.

2.4. Draw (photograph) the input and output waveforms.

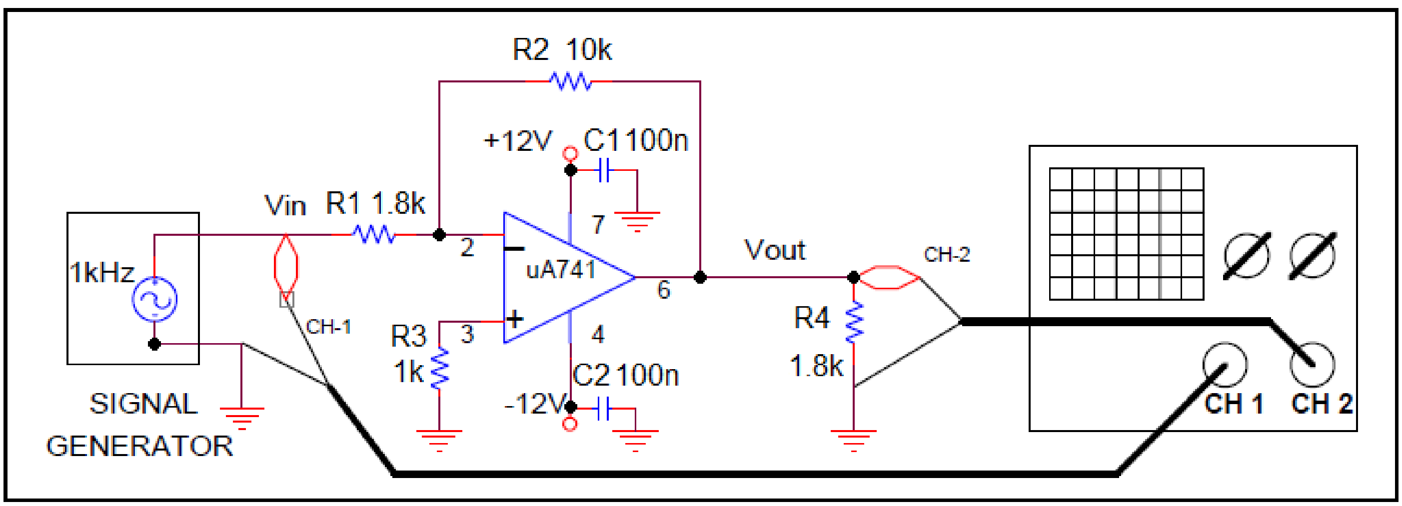


Figure 6 Measurement circuit for inverting amplifier

REFERENCE

1. A.S. Sedra and K.S. Smith, “Microelectronic circuits”, 5th ed., New York: Oxford University Press, 2004, 1283 p.

APPENDIX

Pin diagram of uA 741 OPA (УД708)