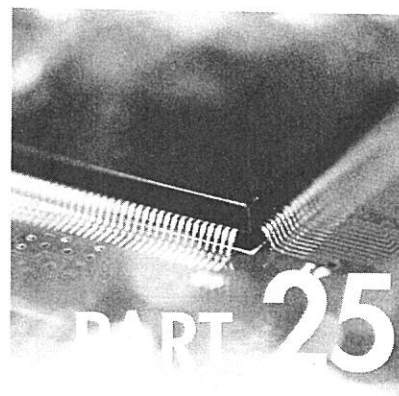


OPERATIONAL AMPLIFIERS

Forum Instructions:

You should take a screen shot of each amplifier circuit showing the input/output relationships, the max & min signal voltages labelled, and your name/initials on the screen shot. Post one screen shot from your inverting amp and one from your non-inverting amp. For the Comparator Circuit (Schmitt-Trigger), post two screen shots. One showing the V_{in} vs. V_{out} with respect to time. One showing V_{in} vs. V_{out} (hysteresis curve).



Objectives

You will connect basic inverting and noninverting op-amp circuits, and then you will compare their input and output signal levels and phases. You will also study the operation of a Schmitt-trigger circuit built with op-amp circuitry.

In completing these projects, you will connect circuits, observe waveforms with an oscilloscope, draw conclusions, and answer questions about the following items related to op-amp circuits:

- Explain how the location of input and feedback resistors determines whether the circuit operates as an inverting or noninverting amplifier
- Explain how the ratio of feedback to input resistance affects the voltage gain of op-amp circuits
- Describe the operation of a simple op-amp Schmitt-trigger circuit

Project/Topic Correlation Information

PROJECT	TEXT CHAPTER	SECTION	RELATED TEXT TOPIC(S)
76 Inverting Op-Amp Circuit	28	28-2	An Inverting Amplifier
77 Noninverting Op-Amp Circuit	28	28-3	A Noninverting Amplifier
78 Op-Amp Schmitt-Trigger Circuit	28	28-5	An Op-Amp Schmitt-Trigger Circuit

Operational Amplifiers

Inverting Op-Amp Circuit

PROJECT 76

Name: _____ Date: _____

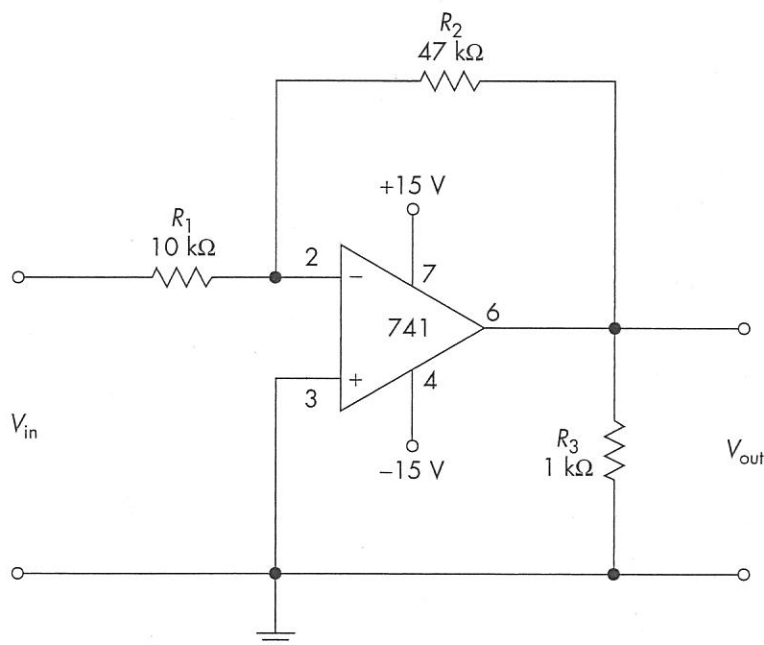


FIGURE 76-1

PROJECT PURPOSE This project demonstrates the operation of a basic inverting op-amp.

PARTS NEEDED

- | | |
|---|---|
| <input type="checkbox"/> DMM | <input type="checkbox"/> CIS |
| <input type="checkbox"/> Dual-trace oscilloscope | <input type="checkbox"/> Operational amplifier: 741 |
| <input type="checkbox"/> ± 15 V DC power supply | <input type="checkbox"/> Resistors |
| <input type="checkbox"/> Function generator or audio oscillator | 1 kΩ 47 kΩ |
| | 10 kΩ 100 kΩ |

SPECIAL NOTE:

You will need the following formula to complete the work:

$$A_V = -(R_2/R_1)$$

where:

A_V is the voltage gain

R_2 is the value of the feedback resistor

R_1 is the value of the input resistor

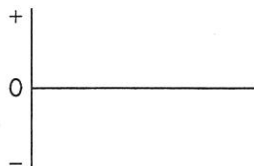
PROCEDURE

1. Connect the circuit exactly as shown in Figure 76-1. Make sure the positive terminal of the $\pm 15\text{-Vdc}$ supply is connected to pin 7 of the 741 IC, the negative terminal is connected to pin 4, and the common terminal is connected to the common line as shown in the figure. Be sure you take all meter and oscilloscope readings with respect to the common line of the circuit (and not the -15-V connection of the power source). Measure and record the dc voltages requested in the "Observation" section.

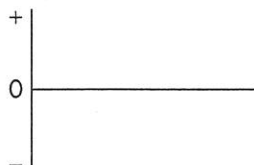
▲ OBSERVATION DC voltage from pin 7 to common = _____ V.
 DC voltage from pin 4 to common = _____ V.

2. Connect the function generator (sine-wave mode) or audio oscillator to V_{in} . Connect one channel of the oscilloscope to V_{in} , and connect the second channel of the oscilloscope to V_{out} . Adjust the signal source for an input signal of 1 kHz at 1 V_{p-p} . Sketch the waveforms and determine the readings specified in the Observation section.

▲ OBSERVATION Peak-to-peak voltage from V_{in} to common = _____ V.
 Peak-to-peak voltage from V_{out} to common = _____ V.



V_{in} Waveform:



V_{out} Waveform:

▲ CONCLUSION What is the calculated voltage gain of the circuit shown in Figure 76-1? _____.
 What is the actual voltage gain of the circuit as determined by the measured values of V_{in} and V_{out} ? _____. The output waveform is shifted (0° , 90° , 180°) _____ relative to the input waveform.

3. Increase the level of V_{in} to 2 V_{p-p} ; measure and record the values of V_{in} and V_{out} .

▲ OBSERVATION Peak-to-peak voltage from V_{in} to common = _____ V.
 Peak-to-peak voltage from V_{out} to common = _____ V.

▲ CONCLUSION What is the actual voltage gain of the circuit as determined by the measured values of V_{in} and V_{out} in Procedure step 3? _____. Does increasing the value of V_{in} have any significant effect upon the value of V_{out} ? _____. Does increasing the value of V_{in} have any significant effect upon the voltage gain of the circuit? _____.

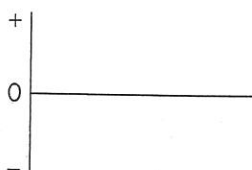
4. Replace R_2 with a resistor having a value of $100\text{ k}\Omega$.
5. Adjust the signal source for $1\text{ V}_{\text{P-P}}$. Sketch the waveforms and determine the readings specified in the "Observation" section.

▲ OBSERVATION

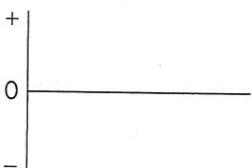
Peak-to-peak voltage from V_{in} to common = _____ V.

Peak-to-peak voltage from V_{out} to common = _____ V.

V_{in} Waveform:



V_{out} Waveform:

**▲ CONCLUSION**

What is the calculated voltage gain of the circuit when $R_2 = 100\text{ k}\Omega$? _____.

What is the actual voltage gain of the circuit as determined by the measured values of V_{in} and V_{out} ? _____. Does increasing the value of R_2 have any significant effect upon the voltage gain of the circuit? _____.

Operational Amplifiers

Noninverting Op-Amp Circuit

PROJECT 77

Name: _____ Date: _____

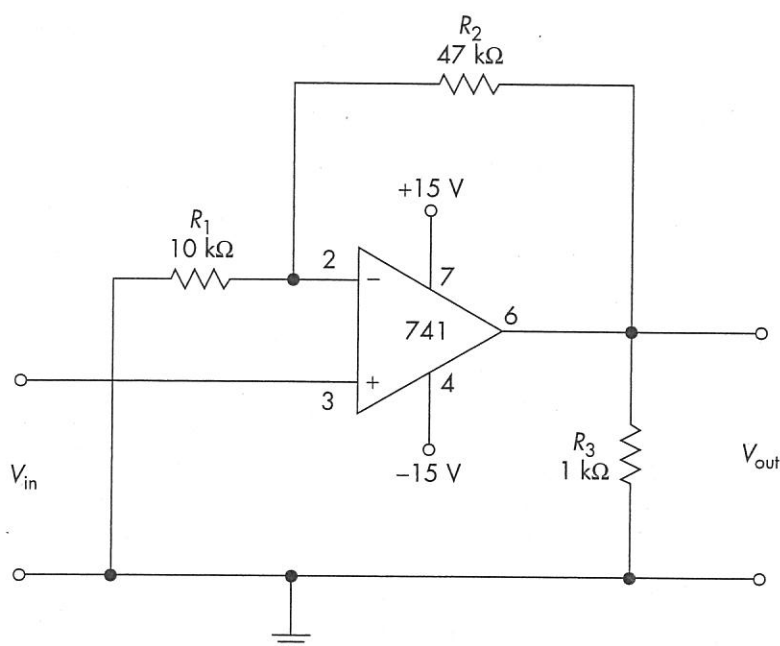


FIGURE 77-1

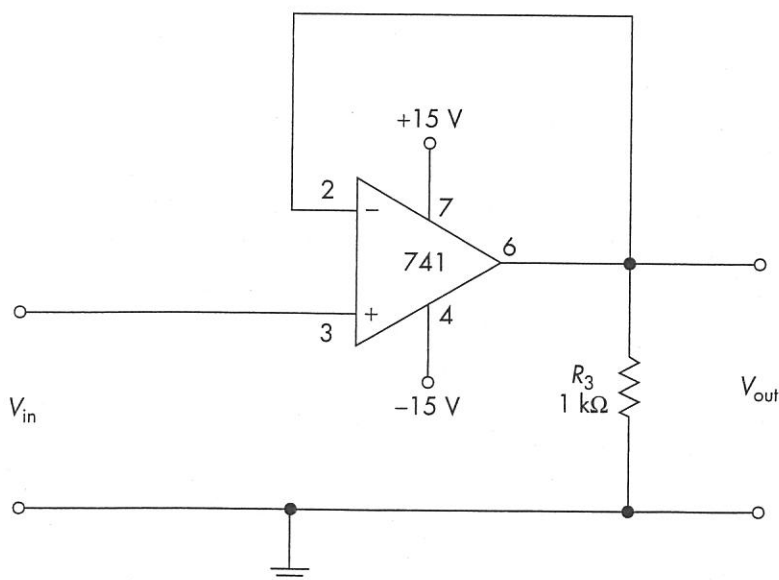


FIGURE 77-2

PROJECT PURPOSE In this project you will observe the operation of a noninverting op-amp circuit, including a voltage-follower version. You will also see the effects of overdriving an op-amp circuit that has excessive voltage gain.

PARTS NEEDED	<input type="checkbox"/> DMM	<input type="checkbox"/> Operational amplifier: 741
	<input type="checkbox"/> Dual-trace oscilloscope	<input type="checkbox"/> Resistors
	<input type="checkbox"/> ± 15 -Vdc power supply	1 k Ω 100 k Ω
	<input type="checkbox"/> Function generator or audio oscillator	10 k Ω 1 M Ω
	<input type="checkbox"/> CIS	47 k Ω

SPECIAL NOTE:

The following formula can be helpful:

$$A_V = (R_2/R_1) + 1$$

where:

A_V is the voltage gain of a noninverting op-amp

R_2 is the value of the feedback resistor

R_1 is the value of the input resistor

PROCEDURE

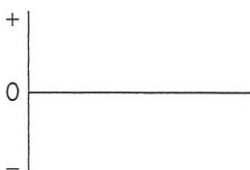
1. Connect the circuit exactly as shown in Figure 77-1. Make sure the positive terminal of the ± 15 -Vdc supply is connected to pin 7 of the 741 IC, the negative terminal is connected to pin 4, and the common terminal is connected to the common line as shown in the figure. Be sure you take all meter and oscilloscope readings with respect to the common line of the circuit (and not the -15 -V connection of the power source). Measure and record the dc voltages requested in the "Observation" section.

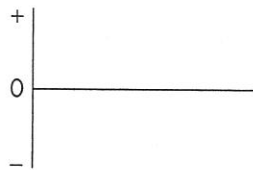
▲ OBSERVATION DC voltage from pin 7 to common = _____ V.
DC voltage from pin 4 to common = _____ V.

2. Connect the function generator (sine-wave mode) or audio oscillator to V_{in} . Connect one channel of the oscilloscope to V_{in} , and connect the second channel of the oscilloscope to V_{out} . Adjust the signal source for an input signal of 1 kHz at 1 V_{p-p}. Sketch the waveforms and determine the readings specified in the "Observation" section.

▲ OBSERVATION Peak-to-peak voltage from V_{in} to common = _____ V.
Peak-to-peak voltage from V_{out} to common = _____ V.

V_{in} Waveform:



V_{out} Waveform:**CONCLUSION**

What is the calculated voltage gain of the circuit shown in Figure 77-1? _____.

What is the actual voltage gain of the circuit as determined by the measured values of V_{in} and V_{out} ? _____. The output waveform is shifted (0° , 90° , 180°) _____ relative to the input waveform.

- Replace R_2 with a resistor having a value of $10\text{ k}\Omega$.
- Leave the signal source at $1\text{ V}_{p.p.}$. Measure and record the data specified in the "Observation" section.

OBSERVATION

Peak-to-peak voltage from V_{in} to common = _____ V.

Peak-to-peak voltage from V_{out} to common = _____ V.

CONCLUSION

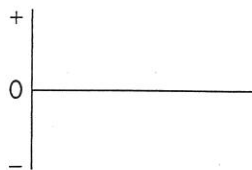
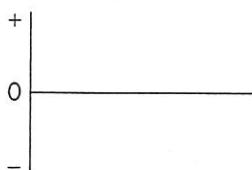
What is the calculated voltage gain of the circuit when $R_2 = 10\text{ k}\Omega$? _____. What is the actual voltage gain of the circuit as determined by the measured values of V_{in} and V_{out} ? _____. Explain why this particular circuit might be called a voltage follower. _____

- Replace R_2 with a resistor having a value of $1\text{ M}\Omega$.
- Leave the signal source at $1\text{ V}_{p.p.}$. Sketch the waveforms and determine the readings specified in the "Observation" section.

OBSERVATION

Peak-to-peak voltage from V_{in} to common = _____ V.

Peak-to-peak voltage from V_{out} to common = _____ V.

 V_{in} Waveform: V_{out} Waveform:

▲ CONCLUSION

What is the calculated voltage gain of the circuit when $R_2 = 1\text{ M}\Omega$? _____.

Explain why the output waveform is distorted. _____

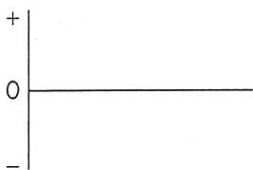
_____.

7. Connect the circuit exactly as shown in Figure 77-2.

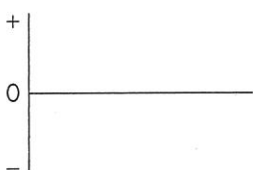
8. Connect the function generator to V_{in} . Set the function generator to 1 V_{p-p} and 1-kHz sine wave. Connect scope channel 1 to V_{in} and scope channel 2 to V_{out} . Sketch the V_{in} and V_{out} waveforms.

▲ OBSERVATION

V_{in} Waveform:



V_{out} Waveform:

**▲ CONCLUSION**

What is the calculated voltage gain of the circuit? _____. What is the actual voltage gain of the circuit as determined by the measured values of V_{in} and V_{out} ?

_____. Explain why this circuit might be called a unity gain analog buffer. _____

_____.

Operational Amplifiers

Op-Amp Schmitt-Trigger Circuit

PROJECT

78

Name: _____ Date: _____

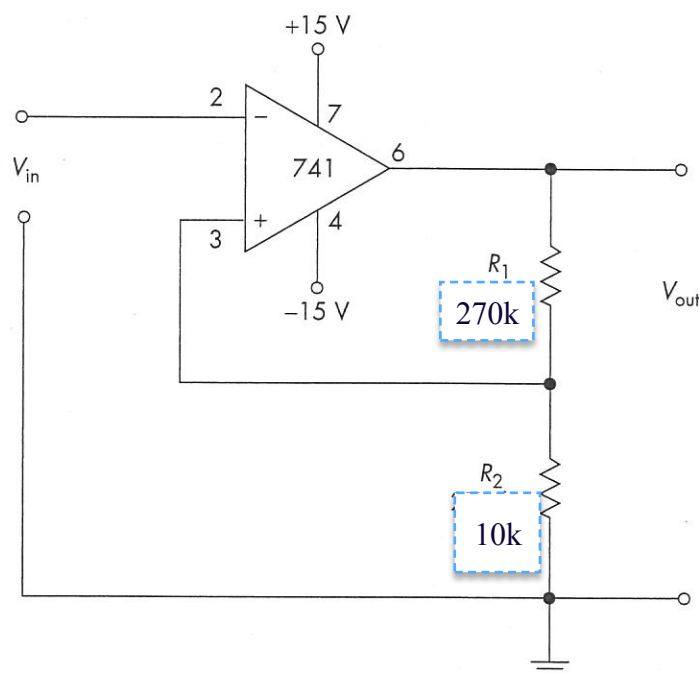


FIGURE 78-1

PROJECT PURPOSE In this project you will observe the application of an op-amp as a Schmitt-trigger circuit.

PARTS NEEDED

- | | |
|---|---|
| <input type="checkbox"/> DMM | <input type="checkbox"/> CIS |
| <input type="checkbox"/> Dual-trace oscilloscope | <input type="checkbox"/> Operational amplifier: 741 |
| <input type="checkbox"/> ± 15 -Vdc power supply | <input type="checkbox"/> Resistors |
| <input type="checkbox"/> Function generator or audio oscillator | 10 k Ω |
| | 270 k Ω |

PROCEDURE

1. Connect the circuit exactly as shown in Figure 78-1. Make sure the positive terminal of the ± 15 -Vdc supply is connected to pin 7 of the 741 IC, the negative terminal is connected to pin 4, and the common terminal is connected to the common line as shown in the figure. (Be sure you take all meter and oscilloscope readings with respect to the common line of the circuit.)

2. Measure and record the dc voltages requested in the "Observation" section.

▲ OBSERVATION DC voltage from pin 7 to common = _____ V.
DC voltage from pin 4 to common = _____ V.

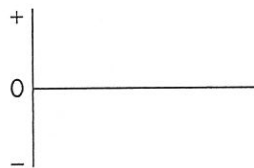
▲ CONCLUSION Explain why having an ac input waveform makes it necessary to have both positive and negative supply voltages for an op-amp circuit. _____

_____.

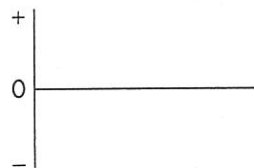
3. Connect the function generator (sine-wave mode) or audio oscillator to V_{in} . Connect one channel of the oscilloscope to V_{in} and connect the second channel of the oscilloscope to V_{out} . Adjust the signal source for an input signal of 1 kHz at 1 V_{P-P}.

4. Sketch the waveforms and determine the readings specified in the "Observation" section.

▲ OBSERVATION Peak-to-peak voltage from V_{in} to common = _____ V.
Peak-to-peak voltage from V_{out} to common = _____ V.
 V_{in} Waveform:



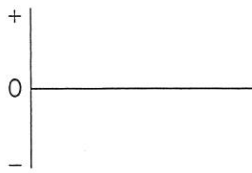
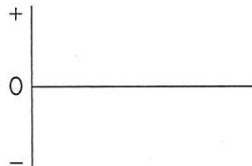
V_{out} Waveform:



▲ CONCLUSION Calculate the following values for the Schmitt-trigger circuit in Figure 78-1. UTP (calculated) = _____ V. LTP (calculated) = _____ V. Hysteresis = _____ V. If you superimpose oscilloscope waveforms for V_{in} and V_{out} , you should be able to determine the actual values of: UTP (measured) = _____ V. LTP (measured) = _____ V. Hysteresis = _____ V. The polarity of the output waveform is shifted (0° , 90° , 180°) _____ relative to the input waveform. This is an example of a nonlinear amplifier circuit. (True, False) _____.

5. Adjust the signal source for an input signal 0.1 V_{P-P}. Sketch the waveforms and determine the readings specified in the "Observation" section.

▲ OBSERVATION Peak-to-peak voltage from V_{in} to common = _____ V.
Peak-to-peak voltage from V_{out} to common = _____ V.

V_{in} Waveform: V_{out} Waveform:**▲ CONCLUSION**

Describe how the waveforms are different from those in Procedure step 4. _____

How do you account for the differences? _____

Summary

Operational Amplifiers

Name: _____ Date: _____

Complete the following review questions, indicating the appropriate response by placing a check in the box next to the correct answer.

1. For an inverting op-amp
 - ☐ the input and feedback resistors are both connected to the noninverting input
 - ☐ the input resistor is connected to the inverting input and the feedback resistor is connected to the noninverting input
 - ☐ the input resistor is connected to the noninverting input and the feedback resistor is connected to the inverting input
 - ☐ the input and feedback resistors are both connected to the inverting input
2. The voltage gain of an inverting op amp is determined by
 - ☐ dividing the amount of feedback resistance by the amount of input resistance
 - ☐ dividing the amount of input resistance by the amount of feedback resistance
 - ☐ dividing the amount of input voltage by the value of the input resistance
 - ☐ multiplying the amount of input voltage by the amount of output voltage
3. An inverting op-amp circuit can never be used as a voltage follower because
 - ☐ the output voltage is always larger than the input voltage
 - ☐ the output waveform is always out of phase with the input waveform
 - ☐ the output is nonlinear
4. What is the voltage gain of an inverting op-amp circuit when the input resistance equals the feedback resistance?
 - ☐ 0
 - ☐ +1
 - ☐ -1
 - ☐ Cannot be determined without knowing the resistor values
5. For a noninverting op amp
 - ☐ the input is applied to the noninverting input and the feedback resistor is connected to the noninverting input
 - ☐ the input is applied to the inverting input and the feedback resistor is connected to the noninverting input
 - ☐ the input is applied to the noninverting input and the feedback resistor is connected to the inverting input
 - ☐ the input is applied to the inverting input and the feedback resistor is connected to the inverting input

6. The voltage gain of a noninverting op amp
- ☐ can be determined by dividing the amount of feedback resistance by the amount of input resistance
 - ☐ can be determined by dividing the amount of output voltage by the amount of input voltage
 - ☐ can be determined by dividing the amount of input voltage by the value of the feedback resistance
 - ☐ is always 1
7. What is the voltage gain of a noninverting amplifier when the feedback resistance is zero ohms?
- ☐ 0
 - ☐ 1
 - ☐ 2
 - ☐ Cannot be determined
8. As long as the output of an op-amp remains undistorted, the amount of input voltage has little to do with the amount of voltage gain for the circuit.
- ☐ True
 - ☐ False
9. One of the main purposes of a Schmitt-trigger circuit is to transform a sine waveform into a rectangular waveform.
- ☐ True
 - ☐ False
10. The fact that the input signal for an op-amp Schmitt-trigger circuit goes to the inverting input accounts for
- ☐ the flattening of the output waveform
 - ☐ the very high voltage gain of the circuit
 - ☐ the 180° phase shift of the waveform
 - ☐ none of these