

INTRODUCTION TO OPERATIONAL AMPLIFIERS

Purpose:

To become familiar with common operational amplifier packages, and pin-out configuration. A circuit using an operational amplifier as an inverting amplifier will be constructed.

Introduction:

An operational amplifier is a very high gain amplifier, which commonly comes in three packages. The 8-lead mini-DIP (dual in-line package, pin arrangement shown below) is the one using in our laboratory. Note that pins 4 and 7 must be connected to a power source. This connection is usually not shown in circuit schematics.

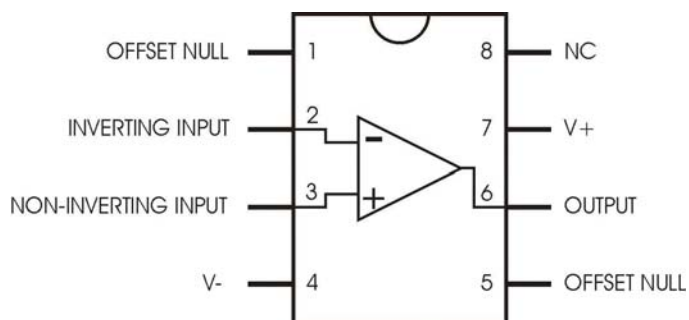


Figure 1 8-pin form used in the lab. (NC - not connected)

Absolute Maximum Ratings of the 741 amplifiers			
	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	-55°C to +125°C	-55°C to +125°C	0°C to +70°C
Storage Temperature Range	-65°C to +150°C	-65°C to +150°C	-65°C to +150°C
Junction Temperature	150°C	150°C	100°C

Equipment and materials:

Resistors

Operational amplifier, 8-lead mini-DIP BNC connector and a BNC splitter.

Capacitors, two $0.1 \mu\text{F}$

Bread board

Jumper wires (all the above in a tackle box)

Oscilloscope, dual trace, two sets of oscilloscope leads, additional coaxial cable with BNC connector and a BNC splitter.

Sine wave signal generator (in some cases part of the oscilloscope)

Operational amplifier, 8-lead mini-DIP

Digital multimeter (DMM)

Power supply, $\pm 15 \text{ V}$

Procedure:

1. Set up the circuit as shown in Figure 2:

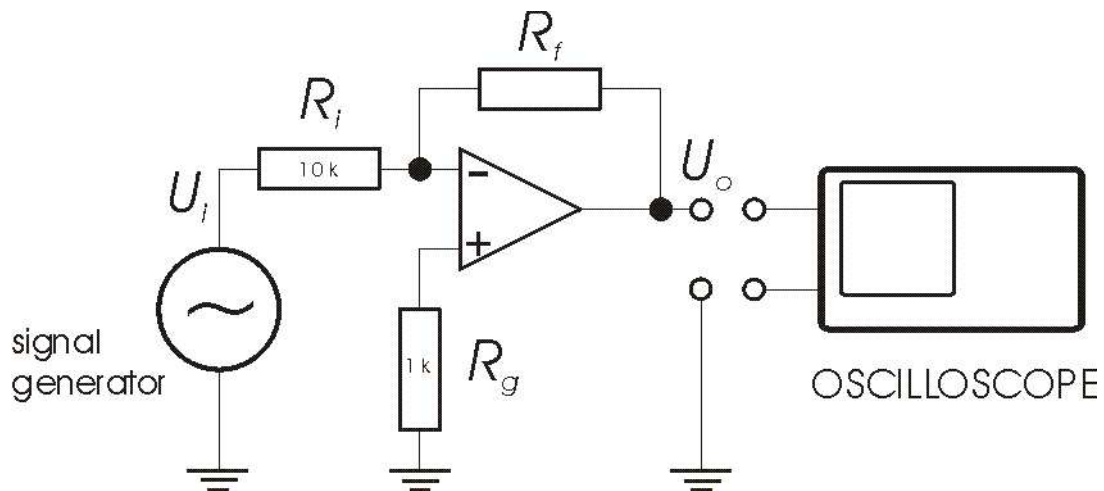


Figure 2 Diagram of the circuit to be constructed

Bypass the supply potential pins directly on the board to the ground with $0.1 \mu\text{F}$ capacitors. Carefully sketch the circuit diagram for the circuit including $\pm 15 \text{ V}$ source in your notebook. In this diagram show the meaning of pin numbers. Pin 4 is $V_{\text{CC-}}$ and pin 7 is $V_{\text{CC+}}$. For R_g use a resistor no more than $1 \text{ k}\Omega$, or replace with a jumper. Use a multimeter to verify the actual resistance of the resistors.

2. Test for open circuits or short circuits within the operational amplifier. This can be done by measuring the current supplied to the operational amplifier by the positive lead of the power supply. It should be $1 \text{ mA} < I_{\text{input}} < 5 \text{ mA}$. Lack of current usually means improper connection or problem with a power source. The power source is overload-protected and if it was accidentally shorted, it needs to be turned off and back on to reset.

3. Feedback resistance. Choose R_f (the feedback resistance) so that the amplification (A_f) is about 20. Show your calculations and record your results. Be certain to show the value of R_f on your circuit diagram. The choice of the resistance should not result in amplification that would require over 10 V on the output.

4. Amplification (A_f) and phase (Φ). Adjust the signal generator for $<0.4 V_{pp}$ ($pp = \text{peak-to-peak}$) sine wave of about 1 kHz. Measure the frequency using the time base of the oscilloscope. Recall that frequency is the reciprocal value of a sine wave period. By using the dual trace capability of the oscilloscope, observe the U_i and U_o simultaneously. Carefully sketch the waveform. From your sketch, determine:

- i) Amplification (A_f),
- ii) calculate the gain in dB ($\text{Gain} = 20 \log U_o/U_i$),
- iii) phase shift of U_o with respect to U_i .

Note on the oscilloscope use: Make sure that you set the variable inputs and time base knobs to the locked, calibrated position, before taking any numerical readings.

5. Frequency effects. Measure the U_o , U_i and phase shift at various frequencies going to the highest frequency the signal generator can provide. Record your data in a table. Plot graphs of amplification, gain and phase shift vs. log frequency. The recommended frequencies are 200 Hz, 500 Hz, 1 kHz, 2 kHz, 5 kHz, 10 kHz, 20 kHz, 50 kHz, 100 kHz, 200 kHz, 500 kHz and 1 MHz as long as the signal generator allows.

Record your results in a table similar to this one:

set value	measured values			calculated values	
Frequency [Hz]	U_i [V]	U_o [V]	phase shift [degrees]	Amplification [1]	Gain [dB]

Answer the following questions in your report:

1. What is the purpose of the 0.1 μF capacitors?
2. From your results in part 5, determine the bandwidth and rise time of your amplifier.
3. Calculate the gain-bandwidth product of your operational amplifier.

Additional plentiful information about operational amplifiers can be found on Wikipedia http://en.wikipedia.org/wiki/741_operational_amplifier (working as of 3 April 2007 and still available 14 January 2009).

Note on making prototypes using the breadboard (From Global Specialties material)

Before using your proto-board there are a few points of information worth noting.

BINDING POSTS

The binding posts facilitate power, and ground connections to and from external sources on the proto-board. These posts can accept banana plugs, pin jacks, and spade lugs. They can also accept alligator clips, solid and stranded wire.

BUSES

Horizontal and vertical buses are provided on each proto-board. Depending on the proto-board model, both the number of buses and the number of contacts on each bus will vary. Typical Tie-point matrix schemes are shown in Figure 3. If in doubt, a quick check with an ohmmeter will clarify the bus scheme for you.

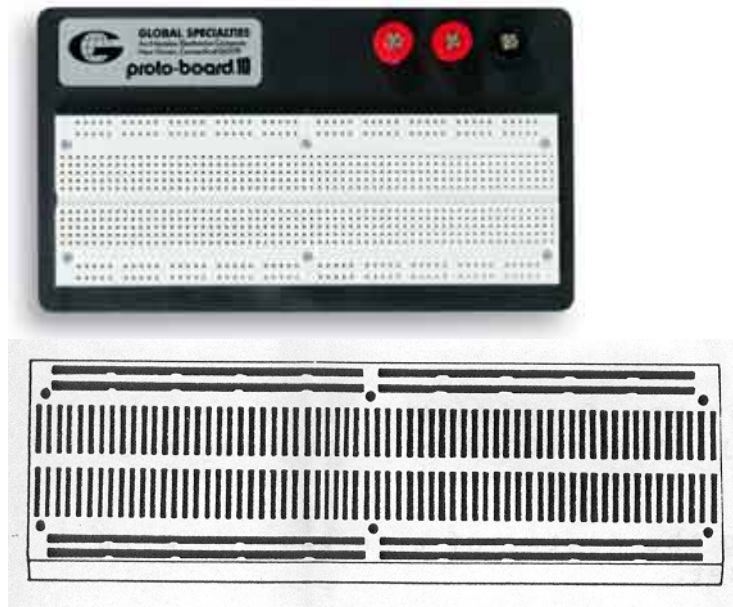


Figure 3 Typical tie-point matrix

COMPONENT INSERTION

IC's are mounted by lining up the leads with the contact holes on each side of the center of a socket, then pressing gently at the center of the IC until it clicks into position..

Withdrawing the IC can be tricky. You should use a thin-bladed screwdriver or similar object. Slide the end of the screwdriver blade under one end of the IC and lift gently. Repeat on the other side. Then remove the IC from the socket. By following this procedure, you will not bend the leads of the IC. Pre-forming the leads so they resemble a DIP pack can accommodate TO-5 case IC's. This is easily done with a pair of long nose pliers.

Transistors can be inserted bridging the center of a socket, or with leads-in-line on one side -of the socket.

Diodes, resistors, and capacitors may be inserted in the same manner as jumper wires.

Special components such as switches, potentiometers, etc. can be used with sockets by simply soldering short lengths of #20-24 gauge solid wire to their terminals and then inserting them into a socket or bus strip.

JUMPER WIRE

The jumper wires should be #20-24 gauge solid hook-up wires. We suggest that the insulation on the

jumper wires be stripped 1/4" to 3/16" from each end to insure easy insertion into the sockets and bus strips.

After you have built up a few circuits, you will have a good collection of pre-stripped jumper wires. Save them. By reusing these wires, you can save even more time and effort in assembling future circuits. For your convenience, Global Specialties provides a kit of 350 pre-cut, pre-stripped, #22 gauge wires in 13 different lengths. The manufacturer of the board also supplies pre-cut wires in a WK-1 Wire kit.

RECOMMENDED PROCEDURES FOR BREADBOARDING

The following steps and procedures should be followed when breadboarding circuits. However, you must make a judgment call between how much time you spend on neatness, and how much time you spend getting the circuit functioning correctly. Recommendation: lay out components neatly, then connect with jumper wires as quickly as possible. When circuit works, go back and route jumper wires, shortening and rerouting where necessary, using the balance of your time to improve neatness.

1. Remove any components or wires left from previous projects.
2. Place components on the breadboard in a visually pleasing manner, as closely as possible to the layout on the schematic. This makes troubleshooting easier for you and for the judges.
3. Trim leads of components so that components rest on or near the surface of the board. Use jumpers to connect components to other components rather than using leaded components (resistor, capacitors, diodes, transistors) as jumpers. This eliminates possible short circuits between bare leads.
4. Leaded components (resistor, capacitors, diodes) should be mounted either vertically or horizontally (not diagonally), and oriented in a consistent direction (i.e., with the first band of the color code, anode, or cathode at the top or on the left). Transistors should each be mounted into three consecutive rows (or every other row) with the collector at the top, base in the center, and emitter at the bottom.
5. Component leads should be bent in a rounded 90° turn (see comment on bending jumper leads) and be inserted straight down into the board, not angled out or in.
6. IC's should be aligned in a row where possible, with pin one on each chip at the upper left position.
7. Strip approximately 1/4" of insulation from jumper wires (never more than 5/16" nor less than 3/16") so as to allow as little bare wire to show between the insulation of the wire and the breadboard socket as possible, in no case should more than 1/8" of bare wire be exposed out of the breadboard socket. If prestripped wires are used, use the shortest wire which will make the connection. Neatly bend the excess out of the way or cut the wire and strip to an exact fit.
8. Jumper wires should be placed as flat and as close to the breadboard as possible, running parallel to each other and not crossing any more than necessary.
9. Jumper wires should be run neatly beside and between components, as straight and as short as possible. Do not use excessively long wires when short ones will do. Excessive wire causes electrical problems and makes troubleshooting more difficult.
10. Bends in jumper wires should be slightly rounded, to avoid stressing wire or insulation, but as tight as possible. Technically, minimum bend radius should be 1.5 times the wire diameter (National Electrical Code, 1996, National Fire Protection Association).
11. NEVER cross components with jumper wires. Routing wires around components simplifies measuring voltages at component leads and removing components for testing or replacement.