

Continental Specialties solderless socket accepts 8-16-pin IC's and other components that can be "plugged in."

# Getting Started with Op Amps

*A solderless socket, a handful of parts, and you are ready to experiment with these versatile devices.*

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**M**ANY hobbyists have avoided experimenting with op amps because they haven't had an easy means of breadboarding circuits with the multi-pin IC packages. Fortunately, a new concept that overcomes the breadboarding obstacle has been developed—the multi-receptacle solderless socket.

The socket is available in a number of different sizes, ranging from a one-IC block to a large block that can accommodate a half dozen IC's and their associated components with room to

spare. All solderless sockets, regardless of size, are made in the same manner. Each consists of two sets of five series-connected receptacles in each row, with block size determining the number of rows in a given socket. The smallest socket has eight rows and can accommodate IC's with up to 16 pins. The receptacles are housed in a tough molded plastic block. Access to the receptacles is provided through a hole "matrix" in the block.

Running the length of the block, midway between the pairs of contacts,

is a shallow groove. The IC must be inserted so that it straddles the groove, leaving four receptacle holes unoccupied for component hookups to each IC pin. Interconnections are made with lengths of #20 or #22 solid hookup wire and components with lead diameters averaging the same size as those found on 1/4-watt resistors and disc capacitors. (You can use 1/2-watt resistors, but the larger diameter of their leads will require additional insertion force.)

One or more of the solderless sock-

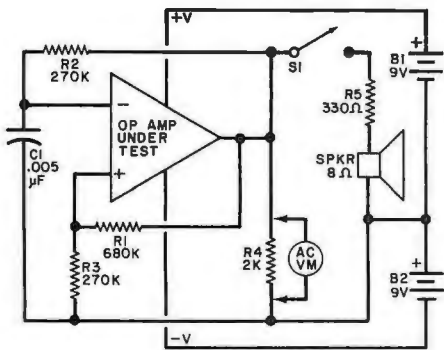


Fig. 1. Simple op amp tester has meter and audio outputs.

ets can be mounted on a sheet of perforated board. Connections to external devices—such as power supply, input and output connectors, meters, etc.—can be made via spring clips or binding posts that can be “plugged” into the holes in the perf board. Mount a rubber foot at each corner of the board, and you’re in business.

Once you have an appropriate breadboarding system, experimenting with op amps becomes a simple matter. The op amps we selected for the following experiments are the types 709 and 741, both of which are low cost and widely available. These IC’s are available in a number of different packages. The box shows the package configurations and pin designations.

**Op-Amp Testing.** The first experiment to try with your op amp is shown schematically in Fig. 1. This is an op-amp test circuit, a multivibrator arrangement where the IC acts as a free-running oscillator that produces a square-wave output.

The “quality” of the op amp is quickly determined by monitoring the output voltage, preferably peak-to-peak with a high-impedance voltmeter, or at a correspondingly lower average ac level with a 5000-ohms/volt

VOM. The output voltage across the 2000-ohm load should be at least two-thirds of the  $\pm 9$ -volt supply (at least 12 volts peak-to-peak).

When S1 is closed, an audible tone should be heard from the speaker, and the measured potential should drop to about 6 volts p-p. Bear in mind that the average meter indication with a VOM will be about half the peak-to-peak value. The oscillator frequency is determined by the R2-C1 time constant. If you change the value of either (or both) component, the frequency will change accordingly.

This test circuit can handle many different types of op amps. In addition to the internally compensated op amps, of which the 741 is an example, the tester will also work with externally compensated op amps without circuit changes because the use of a compensating capacitor is not necessary in this setup. The LM107, 741, MC1556, CA3100S, and HEP-6052P are examples of internally compensated op amps, while the LM101A, NE531, 709, 748, and HEP6053P are examples of externally compensated op amps.

Because the dual in-line package (DIP) IC’s have two parallel rows of leads, they are easy to insert into the solderless socket. If you have round metal-can op amps, you can form the leads into the correct in-line configuration with the aid of long-nose pliers; work carefully. Fig. 2 illustrates how the circuit is breadboarded.

**LED Experiment.** The light-emitting diode, or LED, is a natural companion for the op amp. The LED requires only about 1.6 volts at 20 mA for proper operation, which is well within the output capabilities of the op amp.

The circuit shown in Fig. 3 uses an op amp to pulse a LED at a visible rate. This circuit can also be used as a clocking oscillator for digital circuits so that countdown action can easily be followed.

The basic circuit in Fig. 3 is similar

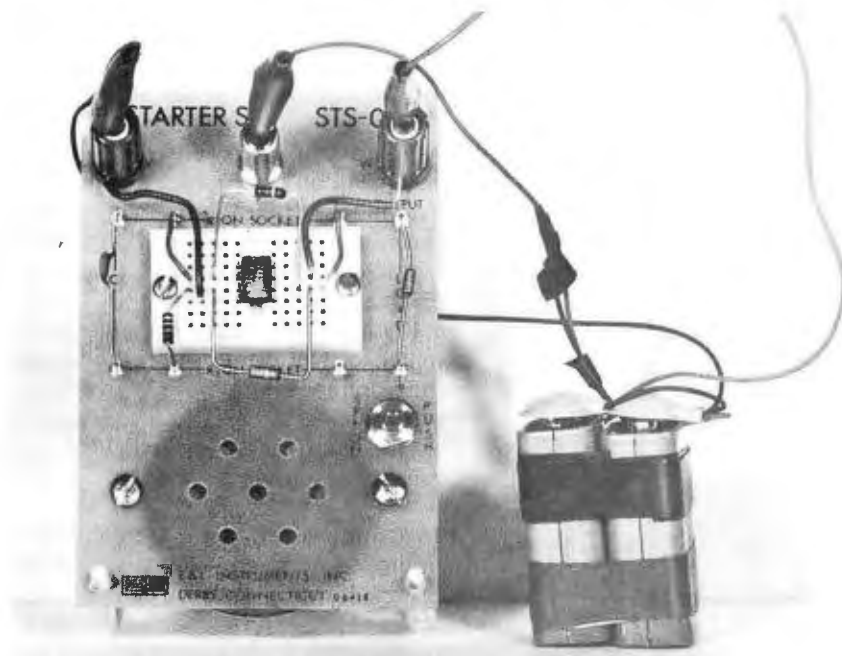
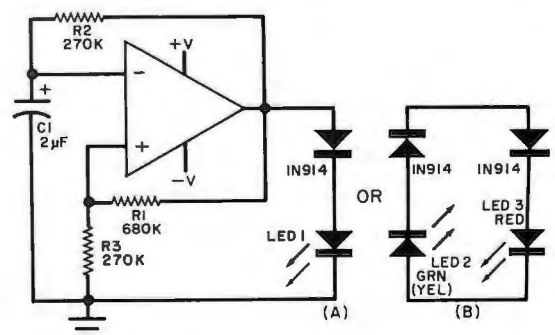


Fig. 2. Commercially available “starter kit” from E&L Instruments illustrates breadboarding of the test circuit in Fig. 1.

Fig. 3. A 1-Hz op amp oscillator can drive either a single LED on the positive-going cycles, or a pair of LED’s alternately.





to that shown in Fig. 1, except that the value of C1 has been greatly increased to slow down the repetition rate to about 1 Hz (1 pps). Display circuit A shows the addition of a conventional silicon diode and a LED (any color) that will pulse on with each positive-going portion of the oscillation pulse. The variation shown in circuit B employs two differently colored LED's. Arranged with silicon diodes, the LED's pulse on and off in step with the op amp's oscillator signal. (Note: some of the older type green and yellow LED's require more drive current than do red LED's, which means that they might not glow as brightly. If you use the newer GaP green or yellow LED's, you will encounter no difficulty in glow light level.) The two-color circuit can also serve as a polarity indicator for other circuits, if you assume the red LED to be on for one polarity and the green LED on for the other polarity.

**Microphone Amplifier.** The basic simplicity of op-amp amplification is shown in Fig. 4. The two modes—low- and high-input impedance—correspond to the two differential op-amp input connections. In using a single-ended input for a microphone, you

have a choice of using either the inverting (-) or non-inverting (+) input. In either case, the closed-loop gain is substantially the same and is determined by the ratio of R1 to R2.

The choice of input is determined by the greatly differing input impedances for each connection. In circuit A, the input impedance is approximately the same as the value selected for R1. Hence, for this mode, you can make the input impedance any reasonably low value (by selecting the proper value for R1) and determine the required gain by selecting the appropriate value for R2. In circuit A, the gain is  $R2/R1 = 240,000/1200 = 200$  or 46 dB.

If you need a high-impedance input, in the range of hundreds of megohms, feed the input signal to the non-inverting (+) input as shown in circuit B. If you wish to use a crystal or ceramic microphone in this mode, you must shunt it by about 1 megohm to provide a dc path for the bias on the + input. The load in both circuits is a 2000-ohm earphone because of the limited ability of the op amp to supply substantial output current.

At these high gains, the 741 op amp will cover only the speech frequencies. For extended bandwidth, you will

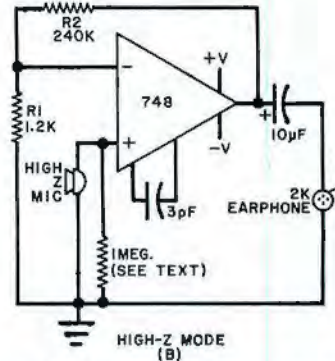
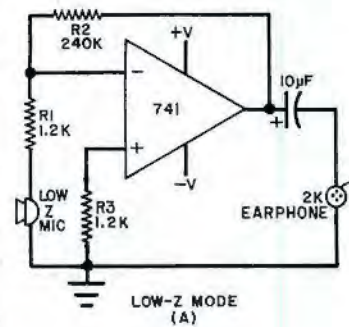


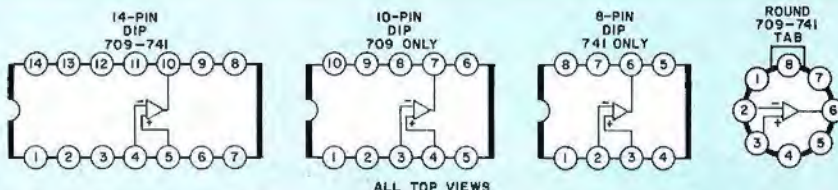
Fig. 4. Low-impedance microphone can be used with circuit (A) and a high-impedance unit with (B). Since 741 is frequency-limited, a 748 (externally compensated) can be used to extend the range.

have to use an externally compensated 748 op amp in place of the 741. For loudspeaker operation, replace the earphone with an equivalent value fixed resistor and use this signal to drive an audio amplifier.

If you want to make a simple audio mixer for two or more signal sources (microphones, turntables, tape recorders, receivers, etc.), use a separate R1 for each source in the Fig. 4A circuit in a summing mode.

**In Conclusion.** There are an almost unlimited number of relatively simple op-amp experiments you can perform, many of which have been published in these pages in the past. Most such experiments can be assembled and tested for educational purposes or modified as the experiment progresses. They can be taken apart and reassembled in only a few seconds using the solderless-socket breadboard approach.

While in this article we have stressed the use of the solderless socket as a breadboarding system for linear (op-amp) circuits, this does not preclude their use in digital IC experiments and projects. Using one of the largest sockets, you can breadboard a complete logic system in only minutes.



#### PIN ARRANGEMENTS

Following is a table of pin designations and the various package configurations for the popular 709 and 741 op amp IC's shown above.

Pin No.	14-Pin DIP		10-Pin DIP	8-Pin DIP	Round Package	
	709	741	709	741	709	741
1	NC	NC	NC	Offset Null	Input Comp	Offset Null
2	NC	NC	Input Comp	-Input	-Input	-Input
3	Input Comp	Offset Null	-Input	+Input	+Input	+Input
4	-Input	-Input	+Input	-V	-V	-V
5	+Input	+Input	-V	Offset Null	Output Comp	Offset Null
6	-V	-V	Output Comp	Output	Output	Output
7	NC	NC	Output	+V	+V	+V
8	NC	NC	+V	NC	Input Comp	NC
9	Output Comp	Offset Null	Input Comp			
10	Output	Output	NC			
11	+V	+V				
12	Input Comp	NC				
13	NC	NC				
14	NC	NC				

Note: NC = No Connection

The 10-pin configuration is a flat pack that cannot be used with solderless sockets. It is shown only to illustrate all packages used with IC op amps.