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PHONE-LINE SIMULATOR

A LOW-COST, EASY-TO-BUILD TELEPHONE-loop simulator will permit you to test telephone answering machines, fax machines, modems, electronic telephones, automatic dialers, and other telephone-related equipment. It includes a talk battery, ringing voltage, and simulated dial tone that are necessary for this testing.

Phone Helper, the telephone-loop simulator described here, makes the testing of telephone equipment as simple as plugging in RJ-11 plugs. It simulates a common-carrier telephone line, and permits you to test equipment without tying up several working telephone lines—and possibly damaging one of them if there is a fault in the equipment-under-test. It also permits you to perform tests without an assistant.

Build this low-cost telephone-line simulator that tests phone-based equipment without tying up two phone lines and perhaps an assistant's time.

Figure 1 is the schematic, and Table 1 gives the unit's specifications. One switch is toggled on and off to obtain a simulated dial tone, and the other can be jogged to provide a simulated ring signal.

Commercial telephone-loop

simulators capable of performing the same tests as Phone Helper are priced at a several hundred dollars or more. Phone Helper costs a lot less: just the parts cost less than \$50, and you can purchase a completely assembled and tested unit with an AC-line adapter from the source given in the Parts List for less than \$70.

FCC Requirements

Before discussing the loop simulator further, it will be useful to review the related telephone-ringing variables. The Federal Communications Commission's (FCC) Rule Section 68.312 defines the permissible AC voltages, frequencies, and impedances for ringing circuits. These are required guidelines for both domestic and foreign telephone equipment

LED's (for example, LED1 will light for Line 1, LED2 for line 2, etc.) will stay illuminated until the jumper on relay RY17 is removed.

After removing the jumper from RY17, ring selector should reset and LED1 (or LED2, LED3, LED4, depending on which relay is under test) will extinguish. If the switching circuit being tested shuts off while this test is being performed, it indicates a fault, probably with the connections from RY17. Recheck the wiring, and make any necessary changes before proceeding with further testing of the unit.

4. Repeat test 2 to verify the proper operation of the disable relay functions. Immediately after shorting relay RY13, momentarily ground pin 5 of RY5. When pin 5 of these relays is grounded, the switching circuit should shut off immediately. Then test relay RY14 with RY6 grounded, RY15 with RY7 grounded, and RY16 with RY8 grounded.

5. Connect the leads of a continuity checker to positions 3 and 4 on terminal strip TS1 that terminate the red (ring) wire and the green (tip) wire, respectively. There should be no continuity. If there is, recheck the wiring and correct the fault before proceeding with any further testing.

6. With the continuity checker still attached to the terminal strip as in step 5, trigger relays RY13, RY14, RY15 and RY16 (as described in step 2). As relays RY13 to RY16 are actuated, observe or listen to the continuity checker to be sure there are no shorts. If there is a short, recheck the wiring, looking for an error, and correct that error before proceeding.

7. With the continuity checker still attached as in step 6, connect a jumper across the terminals for line 1 (positions 5 and 6) on terminal strip TS1 to short them together. Actuate RY13 and observe or listen to the continuity checker. There should be an indication of a short to indicate that line 1 is wired properly. Repeat this test on the other lines, being sure to

PARTS LIST

All resistors are 1/4-watt, 10%, unless otherwise specified.

R1-R12, R17-R24—1000 ohms
 R13-R16—470,000 ohms
 R25-R28—47,000 ohms
 R29-R32—2,200 ohms
 R33-R36—560 ohms

Capacitors
 C1-C4—22 μ F, 16 volts, aluminum electrolytic

Semiconductors
 Q1-Q20—2N2222 NPN switching transistor
 SCR1-SCR4—silicon-controlled rectifier, 1.5 ampere, Motorola MCR22-2 or equivalent
 IC1, IC2—556 dual timer, Motorola MC3456 or equivalent
 D1-D20—1N914 silicon switching diode
 LED1-LED4—yellow light-emitting diode, T-1 3/4 package
 LED5—red light-emitting diode, T-1 3/4 package
 LED6—green light-emitting diode, T-1 3/4 package

Relays
 RY1, RY2, RY3, RY4—4PDT Relay, 5-volt DC coil, Magnecraft W78PCX-1 or equivalent.
 RY5, RY6, RY7, RY8—SPDT Relay, 5-volt DC coil, Magnecraft W178RE1-5DC or equivalent
 RY9, RY10, RY11, RY12, RY13, RY14, RY15, RY16—SPST Reed

Relay, 5-volt DC coil Magnecraft W117SIP-1 or equivalent.
 RY17—Line-sense relay, Teltone Corp. No. M-949-01. (see text)

Other components
 J1—RJ-11 telephone jack
 J2—RJ-45 telephone jack
 TS1—12-position, PCB terminal strip with screw connections

Miscellaneous: Two 0.10-inch perforated phenolic circuit boards with copper pads (see text), two 14-pin IC sockets, aluminum two-part case (see text), AC-to-DC adapter with 6-volt, 200 mA DC output, six snap-in sockets for T-1 $\frac{3}{4}$ LED's, two plastic cable clamps, No. 18 AWG insulated hookup wire, screws, nuts, spacers, solder, plastic adhesive.

Note: The following parts are available from Christopher Zguris, 521 West 26th Street, New York, NY 10001

- Complete kit of components including perforated boards, relays, IC's, transistors, resistors, diodes, LED's, phone jacks and terminal strip.—\$58.00
- Line sense relay—\$5.00

Add \$4.00 for shipping and handling. New York State residents add appropriate sales tax for county of residence.

move the shorting wire to each line you are testing. After completing this test, remove the jumper.

8. After completing the tests, remove the continuity checker and wire both telephone jacks J1 and J2 to the terminal strip. After this is completed, plug a telephone into J1, then connect a telephone line to line 1 on the terminal strip (positions 5 and 6).

If the switching circuit for line 1 engages, disconnect the telephone line and reverse the wires to the terminal strip (positions 5 and 6) to correct the polarity. Repeat the test for line 1. The switching circuit should not engage.

With the telephone line attached, ask another person to dial the telephone number for the line attached to Ring Selector. When the phone rings, the switching circuit should en-

gage immediately. Take the handset off the cradle of the telephone plugged into J1; LED6 should light and the circuit should remain functional. Speak into the handset to be sure that the circuit is working properly. Hang up the telephone plugged into J1, and the switching circuit should disconnect after a few seconds. Repeat this test for all of the other telephone lines.

9. The ring selector should now be completely tested and fully operational.

Reassemble the circuit boards on the four screws. Then close the cover and fasten it. If the "immediate engage" problem discussed in step 8 should recur, it is possible that the telephone cord has reversed wires that cause the problem. If this happens, all you have to do is reverse the connection as discussed in step 8.

manufacturers.

The FCC requires that manufacturers submit prototype equipment for testing by an approved laboratory, which runs many different tests on it. The test lab assigns a unitless ringer equivalency number (REN) that states the power required to actuate the ringing circuitry of the equipment. The manufacturer must stamp or print that number on all approved interconnect products sold.

The telephone operating companies require that no interconnect device shall have a REN greater than 5. In addition, the sum of all REN's on a particular loop must not exceed 5. A standard mechanical bell-type telephone typically has a REN of 1.0A. The "A" indicates that the device will respond to a ringing frequency between 17 and 33 Hz). Similarly a "B" indicates that the unit will respond to a ringing frequency between 15.3 Hz and 68 Hz.

A long list of REN suffixes from A to Z has been prepared to cover all combinations and permutations of ringing arrangements. Nevertheless, A and B type devices predominate, but today most answering machines, modems, fax machines, and electronic telephones are type B.

That equipment typically includes a bridge rectifier installed across the telephone line for receiving a large AC voltage

which is rectified to obtain the signal for tripping the ring-detect circuitry. As a result, most of this equipment can be tested with a simulator that is based on a 60-Hz ringing-voltage source capable of operating only Class B ringers.

Versatile 20-Hz generator

The test unit in this article includes a true 20-Hz ringing generator rather than a 60-Hz ringing voltage source, so it can actuate both class B and class A ringers. (See the box in this article for a 60-Hz alternative tester.) The 20-Hz ringing generator provides about 85 volts at 20 Hz with enough power to drive up to five 1.0A or 1.0B REN numbered devices simultaneously. It is packaged as a potted module that can be directly mounted on a circuit board.

The module contains a 20-Hz multivibrator and amplifiers to obtain the power needed to actuate the ringers. It is available from the source given in the Parts List.

Telephone dial tone

Now it will be useful to review the basics of telephone dial tones. The telephone equipment industry has specified that the dial tone be composed of an equal mixture of 350-Hz and 440-Hz frequencies that leave the central office at a level of -13 dBm0 (measured at the zero transmission level point).

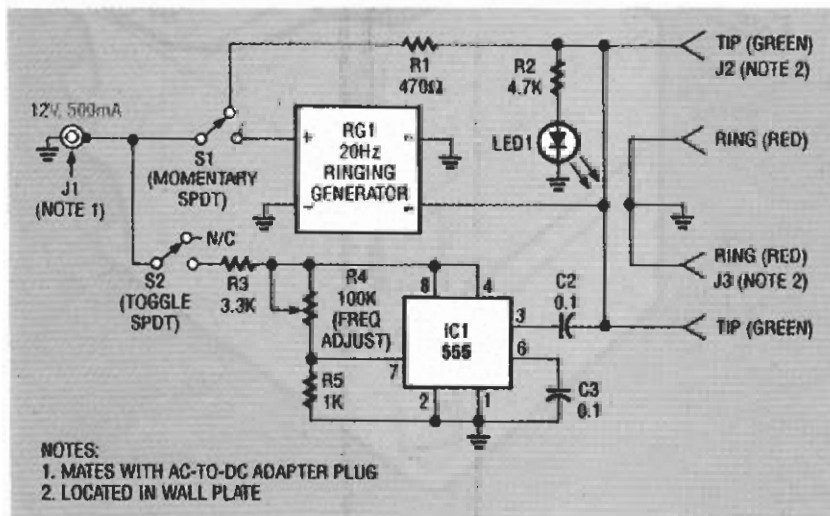


FIG. 1—SCHEMATIC FOR PHONE HELPER 1. The ringing generator is a proprietary device available from the source in the Parts List.

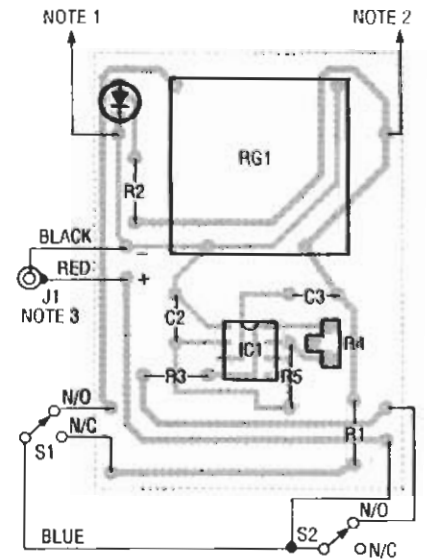


FIG. 2—PARTS PLACEMENT DIAGRAM for Phone Helper 1 circuit board.

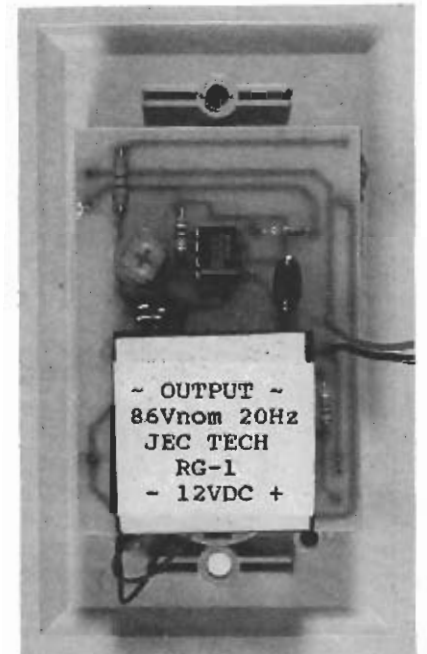


FIG. 3—PHOTOGRAPH OF PHONE Helper circuit board showing external connections.

The signal could have dropped as much as 10 dBm0 lower (-23 dBm0) when it reaches the subscriber. However, tests have shown that most telephone interconnect devices will respond if they receive a steady tone that is close to either 350 Hz or 440 Hz.

For example, if a single-fre-

quency tone of about 500 Hz is presented to them, most telephone-related devices will respond as if they received a true dial-tone signal. This fact permits the design and construction of lower cost, less complicated telephone-loop simulators.

A note of caution here: some telephone-related products are designed to respond only to a "precision" dial tone; they won't be fooled by a single tone. They require both 350-Hz and 440-Hz signals to respond—and then only if the tones don't deviate too far from their true frequencies. Fortunately, these products are in the minority.

The single-tone generator in the simulator is included be-

cause some equipment, such as modems and fax machines, are designed to respond to a dial tone before they will dial out.

If a product does not "hear" a dial tone (when directed to dial out), it triggers the dreaded NO DIAL TONE message that can show up on your personal computer's display or your fax machine. In that case, a brief tone burst from a single-tone oscillator triggers the unit, causing it to dial the number.

Building Phone Helper

The construction of Phone Helper is simple because it obtains its power from a wall-mounted AC-to-DC adapter rather than directly from the 120-volt line. A circuit board foil

pattern has been included here for those who want to make the circuit board. Alternatively, you can purchase a completed board from the source given in the Parts List, or use a perforated phenolic board cut to the same size and wire the circuit components point-to-point.

A design objective for Phone Helper was to package it in the smallest possible case without making it difficult to build. A basic requirement for the project was the availability of two RJ11/14 phone jacks, and this was met by a standard dual-jack wall plate, which also serves as the case cover. The nominal 2¾ × 4½-inch plate permits the use of a standard 3½ × 2½-inch × 2⅛-inch deep (inside di-

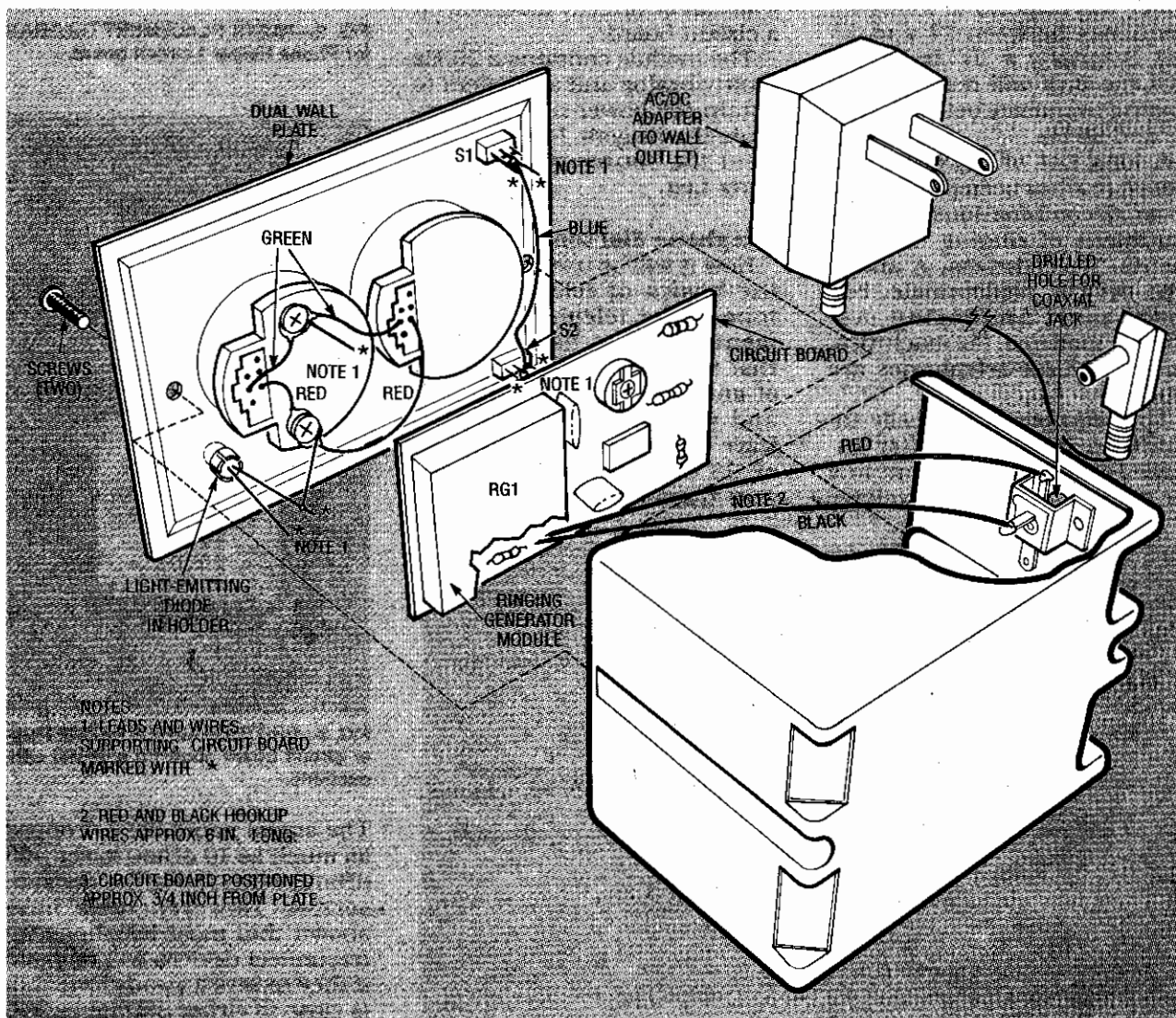


FIG. 4—EXPLODED VIEW OF PHONE HELPER 1 showing showing method of assembly and off-board wiring.

How about an economy model?

If you do not require the performance offered by DC-powered Phone Helper with its 20-Hz ringing generator, you can build a lower-cost version. Phone Helper 2 can test only Class B ringers (Phone Helper 1 will test both Class A and B). It is powered directly from the 120-volt AC line, and a transformer replaces the ring generator.

Figure 6 is the schematic for the Phone Helper 2. Notice that the output side is identical to that of Phone Helper 1 (see Fig. 1), but the input includes a transformer, and a packaged full bridge rectifier. There is also a zener diode, and there are some differences in the values of the resistors and capacitors. However, Phone Helper 2 will fit in the same plastic case that was specified for the DC-powered unit, and the cover is the same dual RJ-11 wall plate. Table 2 summarizes the specifications for Phone Helper 2.

Building Phone Helper 2

The principal circuitry of Phone Helper 2 can be built on a 3 × 2-inch piece of 0.10-inch pitch perforated phenolic circuit board, or it can be built on a circuit board. In both alternatives, notches or holes must be formed at the ends of the board to permit the passage of the screws from the wall plate to the case. The foil pattern of the circuit board is provided here for those who want to

make their own, but a complete circuit board is available from the source given in the Parts List.

Transformer T1 has a dual 120-volt AC primary and a dual secondary. The transformer in the prototype was made by Microtran, Valley Stream, NY. It has a 12 VA rating with dual 17-volt outputs. (Digi-Key offers the MT1127-ND that meets this requirement.) However, any transformer that provides up to 20 volts DC after rectification and filtering will work here.

One of the primaries is powered by 120 volts AC and the second primary provides the ringing voltage. The dual secondaries are wired in parallel to increase current, and the output is rectified and filtered to produce the talk voltage and a power source for the dial-tone simulator circuit.

Figure 7 is the parts placement diagram for the AC-powered simulator. Figure 7-a shows the components on the "component" side and Fig. 7-b shows the components mounted on the foil side. There are three jumpers on the foil side. The longest is made from insulated No. 18 AWG hookup wire and the other two are made from scraps of bare wire.

The location of the components on the circuit board was dictated by the size of the case and not by any critical placement considerations. It is recommended that all of the small components be in-

serted and soldered before mounting the transformer.

The transformer was clamped to the PC board by bending the end tabs of the frame around the edges of the board and compressing them with pliers. A thin strip of plastic was placed between the transformer and the board as insulation.

After completing the component assembly and wiring on both sides of the board, refer again to Fig. 7-b and complete the off-board wiring. Install the switches in the drilled holes in the wall plate and install the socket for LED1. Then install LED1. Solder bare copper wires to the two terminals on switch S1 and one on switch S2. Solder a third 1/4-inch bare wire to the lug on the ring (red) terminal.

Solder a bare jumper to the center terminals of both switches. Solder resistor R2 to the tip (green) lug; solder its other end to the anode of LED1, and its cathode to ground. Drill a hole in the case large enough to admit a line-cord locking grommet and line cord. Strip the ends of the line cord 1/4 inch, and solder the wires to the board.

Using Fig. 4 as a guide, mount the loaded board on the wall plate with the foil side toward the plate. Position the three bare wires in the appropriate board holes and solder them in position. (Note that the positions of the momentary and toggle switches have been reversed.)

dimensions) plastic outlet box as the case.

While referring to schematic Fig. 1 and parts placement diagram Fig. 2, begin construction by mounting all of the electronics components on the circuit board (or perforated board). There is nothing critical about the placement of components on the circuit board and the parts layout diagram shows a simple layout. Insert and solder all of the resistors, capacitors, trimmer potentiometer and timer IC1 before mounting the 20-Hz ringing generator module RG1.

Regardless of the construction option you select, follow accepted workmanship practice in soldering all component leads. Check carefully to be sure that all solder joints are shiny and clean, and that there are no unwanted solder "bridges" or cold-soldered joints, which are dull gray and lumpy. Figure 3 is a photograph of the completed circuit board

showing some of its off-board wiring.

After completing the circuit board assembly, proceed with the mechanical construction. Prepare the wall outlet case by removing any small plastic tabs. Drill the 1/4-inch hole in the case to admit the DC power jack in the location shown in exploded view Fig. 4. Then drill either one or two smaller holes adjacent to that hole for fastening the jack to the case with rivets or screws.

Prepare the wall plate by removing all but two of the screws that secure the associated wiring and clipping off the black and yellow wires. The red and green wires are for *line 1*, the pair found on all standard telephone-connected devices. Drill the three holes in the wall plate with the diameters necessary for mounting switches S1 and S2, and the panel-mounting clip for LED1 using the drilling template provided here as a guide.

Mount switches S1 and S2 on

the back of the wall plate with their washers and locknuts. Then insert the snap-in-holder for the T-1 3/4 LED in the wall plate and insert LED1 in the holder. Solder two bare, solid hookup wires approximately one inch long to two of the terminals on switches S1 and S2 as shown in Fig. 4. Solder another short length of wire to the lug at the end of the red ring wire on the back of the wall plate. Then solder a short length of insulated hookup wire between the center terminals of switches S1 and S2. (It is shown as a blue wire in Fig. 4).

Cut two six-inch lengths of red and black insulated hookup wire, trim their ends, and solder them to coaxial jack J1 as shown in Fig. 4. Insert the other two ends in the circuit board from the component side as shown in Figs. 2 and 4, and solder them in position.

The circuit board assembly is light enough to permit it to be supported by the seven leads

Testing the simulator

Before plugging the completed unit into the 120-volt, 60 Hz outlet, be sure the line is properly protected with a fuse or circuit breaker. The LED should light up as soon as the cord is plugged in. **Caution:** Do not plug any equipment into the RJ-11 jacks J1 and J2. With a suitable voltmeter, measure the voltage across the tip (green) and ring (red) connections on the back of the wall plate.

If transformer T1 has dual 10- to 20-volt secondaries, the voltage should read between 15 and 45 volts AC rms. If the voltage is near zero, the secondaries were probably wired out-of-phase. Correct any errors before proceeding. If the voltage is significantly more than 50 volts DC, replace the transformer with one that meets the stated requirements.

Telephone operating companies can place from 40 to 130 volts DC across their lines when all phone are on-hook. Typically the on-hook voltage for telephone operating companies in the U.S. is about 48 volts DC.

Plug a telephone into one of the two RJ-11 jacks (J1 or J2) and remove the handset. The brightness of LED1 should decrease, indicating that the voltage has dropped. Measure across the tip and ring again. The reading should now be between 4 and 12 volts DC. If it is outside those limits, check the wiring again and

make any corrections before proceeding. If the off-hook voltage is too low, reduce the value of resistor R1 to put the output within the acceptable range.

Toggle DIAL switch S2 and listen for the single dial-tone simulation. Trimmer potentiometer R4 might have to be adjusted to obtain an audible tone. If you have access to a telephone system transmission test set, set it for an output frequency of 500 Hz.

However, if that equipment is not available, you can approximate a 500-Hz note by striking the middle C key on a piano, which provides a 440-Hz tone. Hold the sustain pedal in to prolong the note, and adjust trimmer potentiometer R4 so that the tone you hear is slightly higher than the piano's middle C.

Now hang up the handset and jog the RING toggle switch S1. The brightness of LED1 should increase, indicating that the simulator is working correctly.

PARTS LIST

All resistors are 1/4-watt, 10%, unless otherwise specified.

- R1—1000 ohms, 1 watt (see text)
- R2—10,000 ohms
- R3—2,200 ohms

R4—100,000 ohms, trimmer potentiometer

R5—1000 ohms

Capacitors

C1—1000 μ F, 50 volt, aluminum electrolytic

C1, C2—0.1 μ F

Semiconductors

IC1—555 Timer IC

BR1—Bridge rectifier, 1.5 ampere

D1—1N4742A, 12-volt, 1 watt Zener

LED1—red light-emitting diode, T-1 $\frac{1}{4}$ package

Other components

S1—SPDT momentary toggle switch, panel mount, miniature

S2—SPDT toggle switch, panel mount, miniature

T1—two 120-volt input and two 17-volt output (see text)

Miscellaneous: circuit board, PC or perforated board (see text), dual RJ-11 wall plate, plastic outlet box (see text), snap-in holder for a T-1 $\frac{1}{4}$ LED, insulated No. 18 AWG stranded hookup wire, solid bare hookup wire, six foot length of AC line cord terminated by a polarized plug, solder.

from switches S1 and S2, the green tip wire lug, and the leads of LED1. Insert those leads in the foil side of the circuit board assembly as shown in Figs. 2 and 4, and adjust the spacing of the loaded board so that it is parallel with the back of the wall

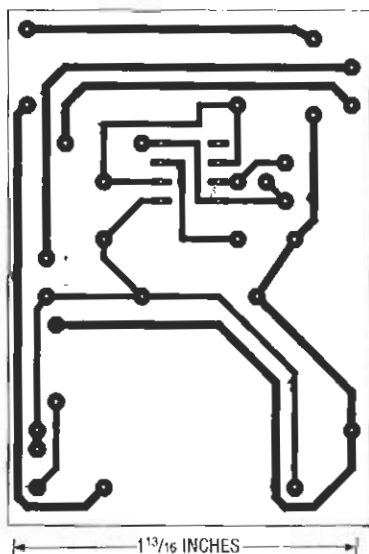
plate and spaced about 7/8-inch away from it. Then solder the seven wires on the foil side of the board, and solder the jumper and the red ring terminal lug to the cathode of LED1.

Testing Phone Helper

When Phone Helper construction is complete, and before fastening the cover in position with two screws, verify that the DC power supply sec-

tion is working properly. Plug the AC-to-DC adapter into a 120-volt AC outlet, and plug its power cord into the coaxial jack in the case. The LED should light normally during this test.

Plug a telephone known to be in proper working condition into RJ-11 jack J2 or J3 and make voltage measurement with a suitable voltmeter. Place the negative probe on the ring (red) terminal and the positive



FOIL PATTERN FOR PHONE HELPER
1 circuit board.

TABLE 1
SPECIFICATIONS FOR PHONE HELPER

Ring Signal (1)	85 V, 20 Hz, 5 REN
Dialtone (2)	-20 dBm0 (min), 500Hz + 20%
Power Requirements	12 V DC, 500 mA.

Notes: 1. Momentary switch S1 jogged on and off
2. Switch S2 on or off

TABLE 2
SPECIFICATIONS PHONE HELPER 2

Ring Signal (1)	90 Vrms, 60 Hz, 4 REN
Dialtone (2)	-20 dBm0 (min), 500 Hz + 20%
Power Requirements	12 V DC, 500 mA.

Notes: 1. Momentary switch S1 jogged on and off
2. Switch S2 on or off

PARTS LIST

All resistors are ¼-watt, 10%, unless otherwise specified.

R1—470 ohms, ½ watt

R2—4.700 ohms

R3—3.300 ohms

R4—100,000 ohms trimmer potentiometer

R5—1000 ohms

Capacitors

C1, C2—0.1µF

Semiconductors

IC1—555 Timer IC

LED1—red light-emitting diode, T-1¾ package

Other components

S1—SPDT momentary toggle switch, panel mount, miniature

S2—SPDT toggle switch, panel mount, miniature

RG1—20-Hz ringing generator, (see text)

Miscellaneous: dual RJ-11 wall plate, plastic outlet box (see text), AC-to-DC adapter with 12-V, 500-mA output, coaxial power connector to mate with plug of 12-volt adapter, snap-in holder for a T-1¾ LED, insulated No. 18 AWG stranded hookup wire—(red, black, and blue), solid bare hookup wire, solder.

Note: Parts as well as an assembled and tested Phone Helper are available from JEC TECH, 13962 Olde Post Road, Pickerington, OH 43147.

- Assembled and tested Phone Helper 1 with a 12-volt AC-to-DC adapter—\$69.50

- Complete Phone Helper 1 kit with a 12-volt AC-to-DC adapter—\$59.50

- Ringing generator module (RG1) and a complete circuit board—\$44.00

- Assembled and tested Phone Helper 2—\$44.50

- Partial Phone Helper 2 kit with transformer and a complete circuit board—\$34.50

Add \$4.00 shipping and handling. Ohio residents add appropriate sales tax.

probe on the tip (green) terminal. With the attached telephone's handset on-hook, the reading should be 15 ± 2 volts DC; with it off-hook the reading should be 4 to 12 volts DC.

Testing with Phone Helper

To test a telephone-answering machine with Phone Helper, plug it into one of the RJ-11 jacks



FIG. 5—SETUP FOR TESTING AN ANSWERING MACHINE with phone helper.

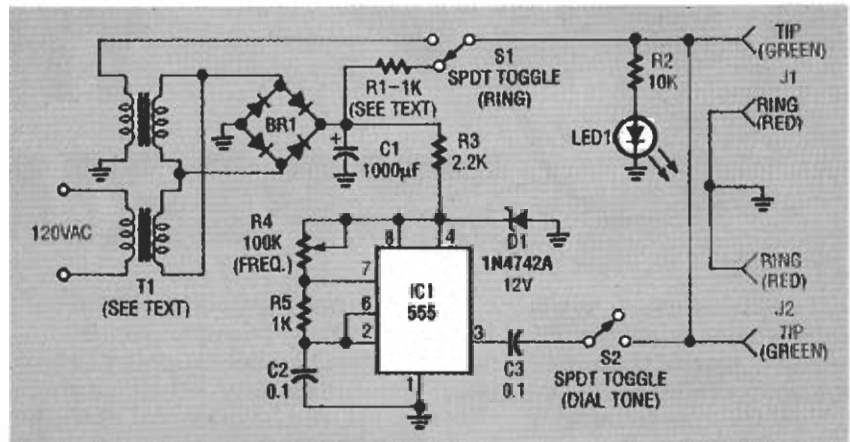
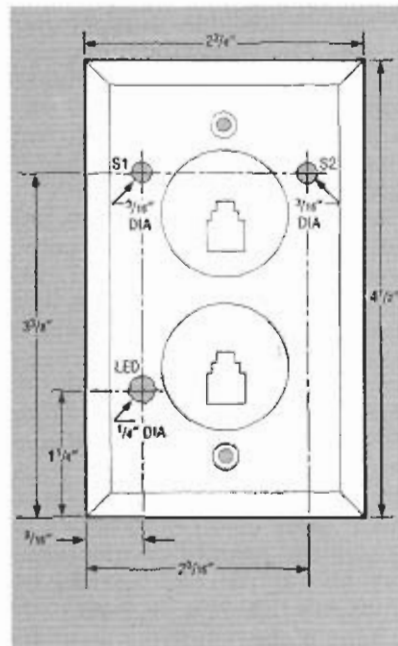


FIG. 6—SCHEMATIC FOR PHONE HELPER 2. A transformer replaces the 20Hz ringing generator of Phone Helper 1.



TEMPLATE FOR DRILLING HOLES.

on Phone Helper and plug a telephone into the other jack, as shown in Fig. 5. Set the answering machine to receive calls, and jog the RING toggle switch S1 often enough to simulate a ring that makes the answering machine answer. When the answering machine answers, pick up the telephone handset and you will hear the outgoing message.

A plugged-in telephone, whose handset can be taken off-hook is necessary to make this test because most answering machines will reset if the telephone is on-hook—indicating that the calling party has hung up. You can then leave a message or retrieve stored messages, just as you would if you were calling in from the outside.

To test a facsimile machine,

Continued on page 84

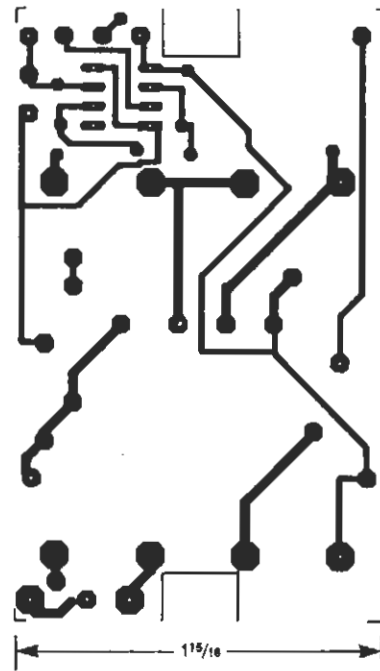
PHONE HELPER

continued from page 63

plug the unit-under-test into one of the jacks of Phone helper, and then plug a jack from a known good fax machine (or fax card) into the other jack. The receive capabilities of the fax machine under test can be determined by placing a call on the known good unit with the simulated dial-tone function if needed.

Once the fax machine known to be in good working condition has dialed out, jog the momentary RING toggle switch S1 often enough to signal the unit-under-test. It should answer, establishing a connection with the known good unit, which will then send your test fax.

If you have a fax card in your computer and a stand-alone fax

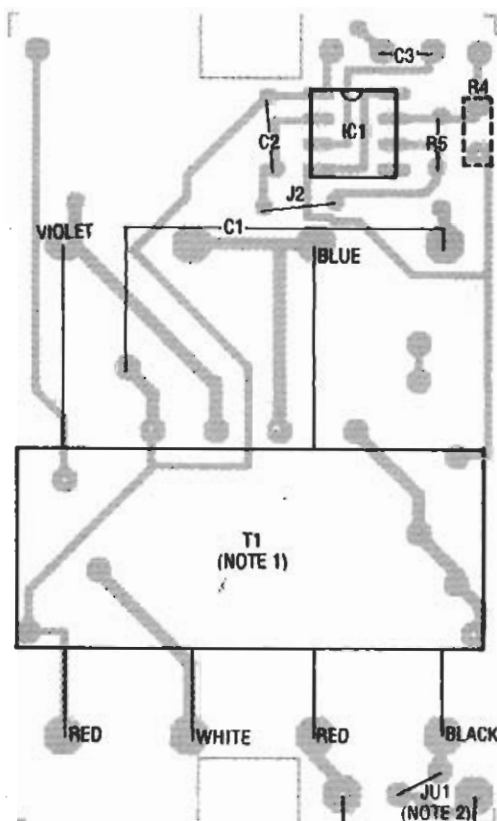


FOIL PATTERN FOR PHONE HELPER 2.

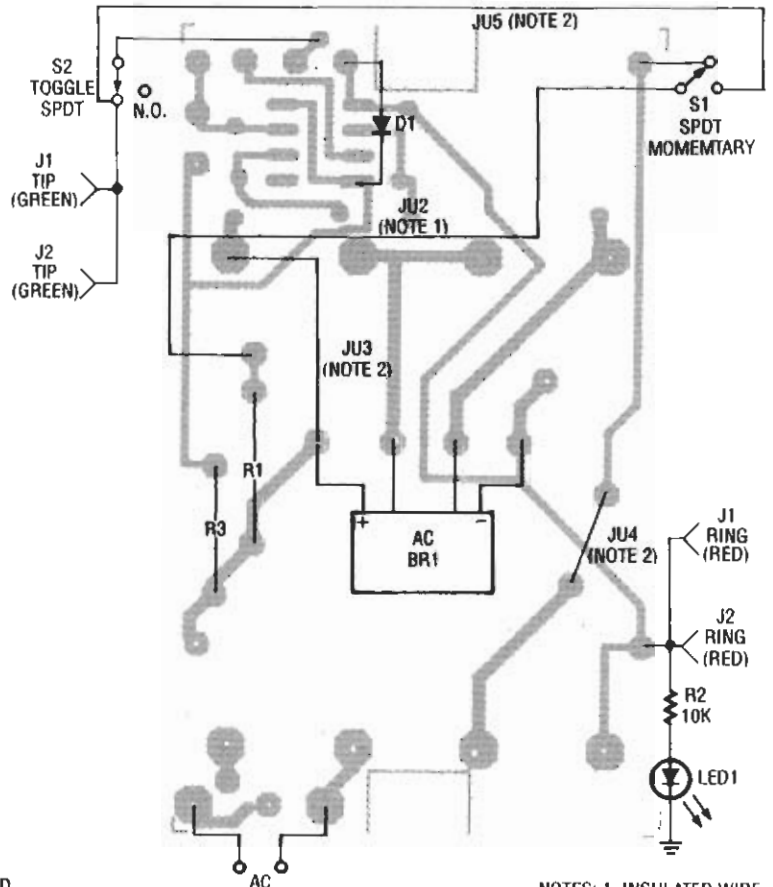
machine, Phone Helper will permit you to convert your fax machine into a full-page scanner. Insert a page of images and text that you want to enter into your computer into your stand-alone fax machine. Then "call" your fax card (any number will do) and send it the text or images. You can now modify your computer files with a graphics editor or run the text through an optical character recognition program to convert the scanned-in text into an ASCII file.

Modems can be tested in exactly the same way. The only difference will be in the frequencies of the tones that are used to communicate between them.

Several accessories will come in handy for making equipment tests with Phone Helper. An inexpensive electronic telephone and a duplex adapter will permit you to monitor while testing. ☺



NOTES: 1. TRANSFORMER CLAMPED TO BOARD BY BENDING TABS
2. BARE WIRE



NOTES: 1. INSULATED WIRE
2. BARE WIRE

Electronics Now, August 1993

FIG. 7—PARTS PLACEMENT DIAGRAM for Phone Helper 2. Timer IC1, transformer T1, and all capacitors are placed on the "component" side of the board (a), and the low-profile components are on the "foil" side (b).