

# Bus-Line Tracer

*Novel instrument speeds circuit troubleshooting by audibly indicating defective components along a bus line without disconnecting them*

By David Miga, CET

**P**icture a scenario where you're working on a defective TV receiver that has only 6 volts on its 30-volt supply line and the supply is okay. Since the line reads only 8 ohms to ground when the set is turned off, some part is obviously partially shorted. No problem, you might think—until you realize that the line runs to more than 60 components!

There are a lot of ways to approach this troubleshooting problem. Most methods are very time consuming. Using a special instrument, the Bus-Line Tracer described here, however, allows you to locate the defect with amazing speed while the power is turned off. It does not require unsoldering a single device or even looking at a meter's indication. Instead, it beeps in increasingly higher sound pitches as you move a test probe to each successive component on the line. When the defective component is reached, whether it's the second one or the thirty-second one, the pitch suddenly increases, indicating that you've found the culprit.

The foregoing represents an actual experience I had while using the Tracer. The 32nd component turned out to be a leaky 47-microfarad capacitor. Double-checking by moving the probe to the next device, the beep was lower, while moving it back to the 47- $\mu$ F capacitor caused the Tracer to beep at a significantly higher pitch. To verify that the capacitor was defective, I sprayed the com-



ponent with a freeze spray while the Tracer beeped away. The pitch changed drastically and I knew that I had found the leaky "8-ohm" device—in about five minutes.

Think of the Tracer as an ohmmeter with a 15-ohm maximum scale, but with a resolution of just 5 milliohms, and a beeper instead of a meter scale and you'll understand what we've got here: a substitute for a very costly 5½ digit micro-ohmmeter. Whether the problem is caused by a shorted or leaky component or a solder bridge on a pc board's copper trace, the Tracer will pinpoint it for you.

Its parts, including case and test

leads, all on a pc board measuring only 2½ × 3 inches, at a total cost of less than \$80 plus your assembling efforts, is a welcome alternative to buying an instrument for a few thousand dollars or unsoldering components one by one along the bus line.

## About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the Bus Line Tracer, including its ac-operated power supply. In the power-supply circuit, the 117-volt ac line potential is transformed to 30 volts ac by power transformer *TI*. This lower voltage is converted to pulsating dc by bridge rectifier *RECT1*, after which it is

smoothed to pure dc by filter capacitors *C1* and *C2*, respectively. Regulators *IC1*, *IC2* and *IC3* then convert the unregulated dc to +8, -8, and +5 volts (all referenced to the grounded center tap of *T1*) for distribution to the remainder of the circuitry as needed. Capacitors *C3*, *C4* and *C5* add stability to the regulator outputs.

Integrated circuit *IC4* is a dual operational amplifier in a single package. The first op amp in *IC4* is wired as a unity-gain precision adjustable voltage reference that supplies the negative input of the second on-chip op amp at pin 6 of *IC4*. This second op amp is wired to provide a voltage gain of 4,700 with the values specified for resistors *R1* and *R2*.

In operation, a precise +5 volts is delivered from *IC3* through *R3* to the red test probe and, hence, to the component under test. Depending on the resistance of the component under test, a potential of between 0 and +5 volts is placed across *R3*. This voltage is monitored by the second op amp in *IC4* through *R4*. A test potential of +5 volts was decided upon because it is great enough to force a stubborn solid-state junction into conduction and drive intermittent components but is still low enough to permit testing in digital equipment without inflicting damage.

The output from the second op amp in *IC4*, at pin 7, can be anywhere between -8 and +8 volts. This output voltage is passed through stabilizing resistor *R5* to the delta-voltage input at pin 5 of 555 timer *IC5*. The timer is configured as an astable multivibrator. The pin 5 output from *IC5* is also applied to the circuit made up of *D1*, *R6*, *Q1*, *R7* and *R8*. This circuit holds reset pin 4 of *IC5* low when the red test probe is not touching a cir-

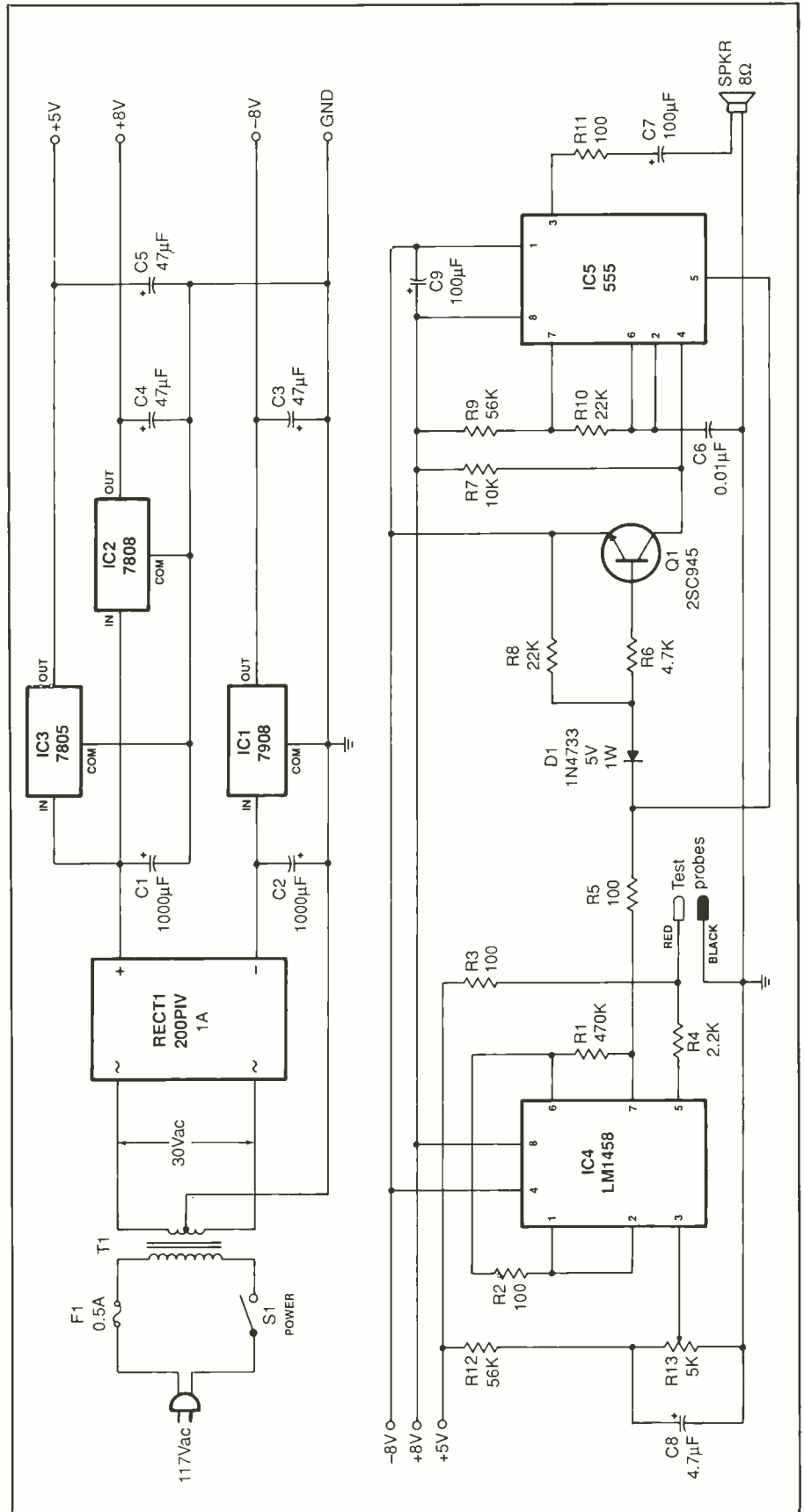


Fig. 1. Complete schematic diagram of the Bus Line Tracer, including its ac-operated power supply.

cuit or component under test. Hence, it serves as a muting system that prevents the project from sounding between measurements.

Oscillating frequency range of *IC5* depends on the values used for *C6*, *R9* and *R10*. With the values specified for these components, the project outputs a tone that is in the audible range between 1 kHz and 5 kHz. The specific frequency of the audio tone depends on the voltage applied to pin 5 of *IC5*. This audio tone, which is passed through limiting resistor *R11* and dc isolation capacitor *C7* to the speaker, is the only "indicator" this project uses.

### Construction

Since only low frequencies are used in this project, component layout is not overly critical, though use of a printed-circuit board on which to wire the circuit is highly recommended. What is important is the length and thickness of the wire used for the 5-volt run to *R3* and the red test probe. Wiring in this portion of the circuit should be selected to provide the least amount of resistance to assure maximum instrument accuracy.

If you wish, you can fabricate your own printed-circuit board, using the actual-size etching-and-drilling guide shown in Fig. 2. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

As shown in the Fig. 3 wiring diagram, all components except POWER switch *S1*, power transformer *T1*, fuse *F1*, potentiometer *R13* and miniature 8-ohm speaker *SPKR* mount directly on the pc board. As you wire the board, make certain that you properly orient the electrolytic capacitors, diodes, transistor and ICs before soldering any leads or pins to the copper pads on the bottom of the board.

After all on-board components have been mounted, install the two wire jumpers in the indicated loca-

### Semiconductors

D1—1N4733 or similar 5-volt, 1-watt zener diode  
 IC1—7908 - 8-volt, 1-ampere voltage regulator  
 IC2—7808 + 8-volt, 1-ampere voltage regulator  
 IC3—7805 + 5-volt, 1-ampere voltage regulator  
 IC4—LM1458 or RC4558 dual operational amplifier  
 IC5—NE555N timer  
 Q1—2SC945 or ECG123A npn silicon transistor  
 RECT1—Philips ECG5304 or Mouser No. 33SC020 200-PIV, 1-ampere bridge rectifier

### Capacitors

C1,C2—1,000- $\mu$ F, 25-volt electrolytic  
 C3,C4,C5—47- $\mu$ F, 16-volt electrolytic  
 C6—0.01- $\mu$ F, 50-volt Mylar  
 C7,C9—100- $\mu$ F, 25-volt electrolytic  
 C8—4.7- $\mu$ F, 50-volt electrolytic

### Resistors (1/4-watt, 5% tolerance)

R1—470,000 ohms  
 R2,R5,R11—100 ohms  
 R4—2,200 ohms  
 R6—4,700 ohms  
 R7—10,000 ohms  
 R8,R10—22,000 ohms  
 R9,R12—56,000 ohms

### PARTS LIST

R3—100 ohms, 3-watt metal-film  
 R13—5,000-ohm, linear-taper, panel-mount potentiometer

### Miscellaneous

F1—500-milliamperere pigtail fuse  
 S1—Spst slide or toggle switch  
 SPKR—8-ohm, 0.1-watt, 1.5" diameter speaker (Panasonic No. 4P15SA or similar)  
 T1—30-volt, center-tapped, 1-ampere power transformer  
 Printed-circuit board; 3-lug terminal strip; suitable enclosure (Radio Shack Cat. No. 270-252A or similar; see text); ac line cord with plug; red and black-coded test leads (Vanco TL-1 or similar; see text); large pointer-type control knob for R13; machine hardware; hookup wire; solder; etc.

**Note:** The following items are available from Electronic Design Specialists, Inc., 951 SW 82 Ave., N. Lauderdale, FL 33068: Kit of all components, test leads and pc board but not including enclosure and rubber grommets, No. EDS-68KIT, \$59; No. EDS-68PCB single-sided printed-circuit board with layout, \$15; No. 256861 30-volt, center-tapped power transformer, \$12; Vanco TL-1 modified test-lead set, \$5. Add \$6 postage & insurance for kit, \$4 for any individual component. Florida residents, please include 6% sales tax.

tions. You can use bare solid hookup wire or cut-off resistor or capacitor leads for these jumpers. Now strip 1/4 inch of insulation from both ends of five 4-inch lengths of hookup wire. If you use stranded hookup wire, tightly twist together the fine conductors at all wire ends and sparingly tin with solder. Then plug one end of these wires into the holes for POT, POT WIPER, +SPKR and two to GND. The other ends of these wires will be connected later, after the circuit-board assembly has been mounted inside its enclosure.

Extensive testing, using many kinds of test leads, has led this author to conclude that the best type to use has thick probes, like those on

the Vanco TLB-1 test-lead set. The probes on these *must* have the tip filed flat for maximum surface contact area. The most important thing to remember for this project is that the lower the resistance of the test leads and probes, the more accurate will be your test results. Therefore, cut the test-lead cables to as short a length as you can manage, but do not leave them longer than 18 inches or so.

Snip off as much test lead length from the banana-plug ends of the cables. (Use of the usual banana plug/jack arrangement is *not* recommended in this project because the small amount of resistance they normally introduce in the test lines will result in large inaccuracies in test re-



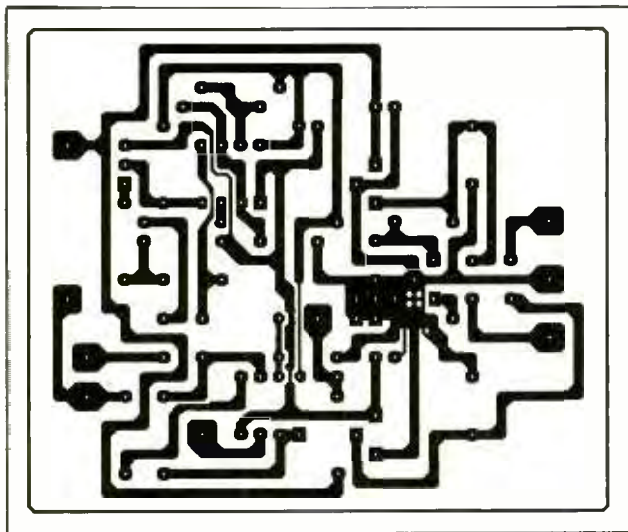


Fig. 2. Actual-size etching-and-drilling guide to use when fabricating your own printed-circuit board.

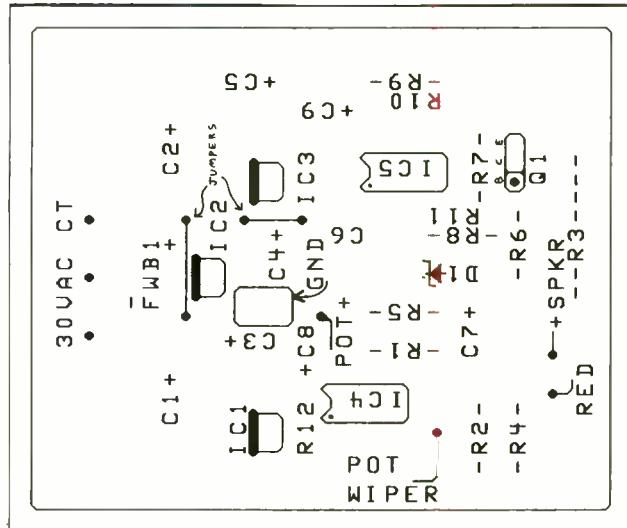


Fig. 3. Wiring diagram for printed-circuit board. Note the two wire jumpers that must be installed.

sults.) After removing the banana plugs, strip  $\frac{1}{4}$  inch of insulation from both test-lead cable ends, tightly twist together the fine conductors and tin with solder. Do the same for the raw end of the line-cord cable.

You can house the project in any type of enclosure that will comfortably accommodate the circuit-board assembly and all off-the-board components and has adequate front-panel space for mounting the switch and potentiometer and rear-panel space for mounting a three-lug terminal strip (no lugs grounded) on it where they will not physically or electrically interfere with the rest of the circuitry.

Use of the Radio Shack project box specified in the Parts List will minimize your machining task because it comes with adequate slots in it to permit the sound from the speaker to escape. If you use a different enclosure, cut slots or drill extra holes for the speaker's sound to escape, in addition to drilling the mounting holes for the circuit-board assembly, off-the-board components and terminal strip, and to permit the test leads and ac line cord to enter it.

After machining is done, deburr all holes and line the ones through which the line cord and test lead cables are to pass with small rubber grommets. Tie a strain-relieving knot in the line cord and test-lead cable pair about 4 inches from the prepared ends inside the enclosure.

Plug the secondary wires of *T1* into the holes labeled 30VAC and CT and solder into place. Also, solder the free end of the red test lead into the hole labeled RED and the free end of the black test lead into one of the holes labeled GND. Then use  $\frac{1}{4}$ -inch spacers and 4-40  $\times$   $\frac{1}{4}$ -inch machine screws, nuts and lockwashers to mount the circuit-board assembly into place inside the enclosure. Then mount the power transformer, switch, fuse block, potentiometer and speaker in their respective locations.

Locate the wire coming from the hole labeled R13 WIPER and crimp and solder its free end to the center lug on the potentiometer. Then crimp and solder the free end of one GND wire to the right lug, viewed from the rear, of the pot and the R13 wire to the left lug. Next, crimp and solder the ends of the wires coming

from the +SPKR and GND holes to the appropriate lugs on the speaker.

Wire the primary side of the power transformer as follows. First, bend the leads of the pigtail fuse as needed and crimp them to the end lugs on the terminal strip. Crimp one line-cord lead to the nearer-end lug and solder the double connection. Crimp one transformer primary lead to the other end lug and solder the double connection. Next, cut a length of stranded hookup wire to as long as needed to bridge from the center lug on the terminal strip and the other lug on the switch. Strip  $\frac{1}{4}$  inch of insulation from both ends of this wire, tightly twist together the fine wires and tin with solder. Crimp and solder one end of this wire to the unoccupied switch lug and the other end of this wire and the remaining power transformer primary lead to the center lug of the terminal strip.

### Calibration & Use

When the project is fully assembled, slide onto the potentiometer's shaft a large pointer-type control knob. Plug its line cord into an ac receptacle. Set the POWER switch to on and

the potentiometer to mid-rotation. Firmly press the black and red test probes against a pc-board's copper trace with about 1 inch of separation between the two probe points and hold for about 5 seconds. Remove the probes from the copper trace and use a finger to touch each of the regulators in turn and note if any is operating hot. If any is, this is a sign that something is wrong with your wiring.

None of the voltage regulators in this project is heat-sinked for the simple reason that the circuit draws very little current until the test probes are applied to a component under test. Even then, current flow through the test probes into the circuit under test is limited to 50 milliamperes. So if any regulator operates hot, power down the project and carefully check it over for incorrectly installed components, poor soldering or an inadvertent solder bridge between copper pads and traces on the pc board. Re-

flow the solder on any suspicious connection and use solder wick or a vacuum-type solder sucker to remove shorting bridges. Do not use the Bus Line Tracer until you have corrected any problem. When the project is ready to use, assemble its enclosure.

To calibrate the potentiometer with legends that indicate resistance on a leaky bus, you need resistors in 1-ohm increments starting with 1 ohm and ending with 10 ohms. With power applied to the project, simply measure each resistor with the test probes and make a mark on the front panel at the position for each at which you hear a "beep" in the middle of the project's audio-frequency range.

When you are finished measuring resistances, power down the project and remove the knob from the potentiometer's shaft. Use a dry-transfer lettering kit to label each marked location with the resistance value measured. Seal the potentiometer's shaft and the switch with masking tape. Then spray two or three *light* coats of clear acrylic over the lettering to protect it from scratching when you use the project. Allow each coat to dry before spraying on the next.

When the acrylic spray has completely dried, remove the masking tape from the pot's shaft and switch. Then replace the knob on the potentiometer's shaft.

To use the Bus Line Tracer to make actual measurements, connect the black test probe firmly to the main circuit ground of the equipment under test. The best way to do this is to actually solder the probe tip to circuit ground to assure a perfect ground connection. (This will also allow you to free one hand to adjust the potentiometer on the project.)

Firmly press the red probe tip to any copper trace on the printed-circuit board to which any component under suspicion is soldered. Then adjust the potentiometer's setting for an audio-tone pitch midway in the

project's audio-frequency range to calibrate the project to whatever reference bus-line resistance to ground.

Instead of being limited to finding only full short circuits, the Bus Line Tracer can be adjusted to any resistance in the range from 0 to 15 ohms. By doing this, the only difference between readings can only be the copper trace on the pc board under test. The resistance of a 1/8-inch-wide copper trace being about 10 milliohms per inch, the Bus Line Tracer can find a leaky component that is only 1/2 inch away from a good component soldered to the same trace bus run. If a copper trace is much narrower than 1/8 inch, as is the case with many computer pc assemblies, accuracy of the project is increased because the trace has more resistance per unit of length.


The range of reference potentiometer *R13* in Fig. 1 is limited to 15 ohms by the 47,000-ohm value chosen for *R12*. You can change the value of *R12* if you prefer a different range. For example, a 56,000-ohm value limits the range to only 10 ohms. Be advised that the circuit becomes increasingly more sensitive and, thus, more difficult to adjust as the resistance of the component under test increases as it heats up. Actually, though, this heat-up effect can be used to advantage. If the red test probe is soldered to the bus line and the reference is adjusted accordingly, a can of freeze spray can be used to cool each suspected component. The one that causes a dramatic change in the pitch of the Tracer's audio tone is the defective one in this case.

The Bus Line Tracer is not the kind of test instrument you reach for as often as you would your DMM. However, when you do need it, you will discover that no other instrument will suffice. With this project, you can zip through dozens of component tests along a bus line in a small fraction of the time it would take you to accomplish the same with traditional test equipment. **ME**

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