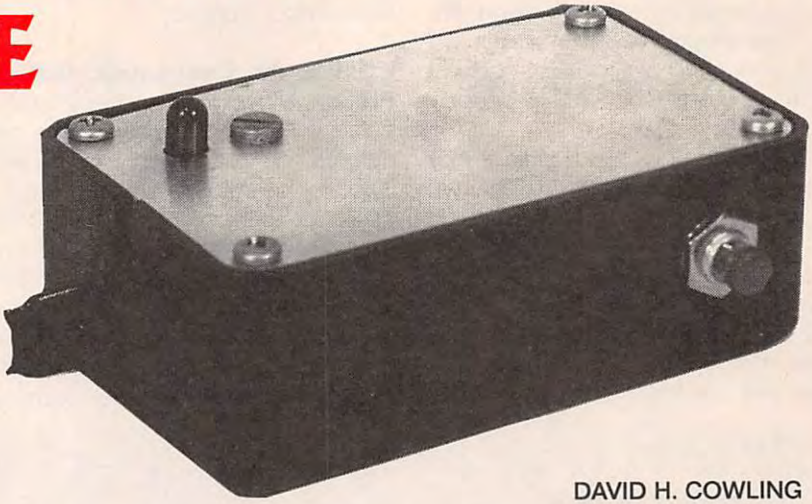
Check For Live AC Wires With This ELECTROSTATIC VOLTAGE PROBE



Determine if terminals, sockets, or extension cords are hot without connecting a voltmeter.

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How many times have you wanted to know if a wall socket, lamp, or some other electrical device that you are getting ready to repair is still electrically "hot"? You may have pulled the circuit breaker, but unless you actually check the socket or lamp with a voltmeter, you don't know for sure.

The Electrostatic Voltage Probe presented here will give you a warning if voltage is present. What's more, it doesn't need to be connected to the circuit. You only need to hold the test probe next to the terminal or wire under question and a warning will be given if the circuit is energized.

How It Works. The Electrostatic Voltage Probe makes use of the phenomenon knows as *stray capacitance*. That occurs when any two conductors come close to each other without actually touching. In effect, a capacitor is formed with the two conductors becoming the plates, and whatever separates them serving as the dielectric.

One feature of capacitors is their ability to "conduct" alternating current while blocking any DC voltage. That feature is taken advantage of by the Electrostatic Voltage Probe to sense the presence of AC current in a wire. The small AC signal that is coupled to the Electrostatic Voltage Probe is amplified, triggering an alarm buzzer as well as an LED. The effect is to give both a visual and an audible warning. The circuit is sensitive enough to spot the "hot" terminals in a junction box. It can also tell when an extension cord is connected to a live wall socket. In that case, it is only necessary to hold the probe alongside the cord. Additionally, by plugging a wire into a wall socket, the Electrostatic Voltage Probe can tell the difference between the hot and neutral wires.

Circuit Description. Refer to the schematic diagram shown in Fig. 1 during the following description. The probe plate is connected to Q2, a very high-impedance amplifier, through C1. Although C1 is not needed for proper operation of the circuit, it is a necessary part from a safety standpoint. Should any lethal voltages accidentally be connected to the probe, they will be blocked by C1.

Once the input signal is amplified by Q2, it passes through a negative-voltage clamp formed by C2 and D1. The clamp output is rectified by D2 so that only negative voltages will affect Q2. That transistor is normally turned on by R4, but when the clamp is active, Q2 turns off.

When Q2 turns off, pin 4 (the reset line) of IC1 is released. A positive voltage is applied by R5, allowing IC1 to begin oscillating. The output of IC1 (pin 3) drives both a piezoelectric buzzer and an LED. The current through LED1 is limited by R8. The frequency that IC1 oscillates at is set by R6, R7, and C5.

Part Substitutions. One nice feature of the Electrostatic Voltage Probe's design is that all of the parts are easy to find—possibly being no farther than your "junk" box. If that will be your main source of components, here are some points to keep in mind concerning substitutions:

The field-effect transistor used for Q2 is listed as a 2N3819 type. However, any good N-channel JFET, such as a 2N5458 or 2N5459, will work equally well. Likewise, there are lots of acceptable substitutes for Q1. For example, while a 2N2222 is recommended, any good NPN-type audio or switching transistor such as a 2N3904 will work fine.

The piezoelectric buzzer is also non-critical. Note however that some devices have their own built-in drive electronics. Those units will not work well with the Electrostatic Voltage Probe since IC1 is already driving the buzzer.

The value of C1 is not critical. Any value from 100 pF to 0.01 μF will work well. The only requirement for C1 is that its working voltage should be a minimum of 500 volts. That is for protection in case the probe head comes in direct contact with a bare wire that is carrying high voltage. The rest of the components are generic; values that are close to the listed ones will work fine.

The author's prototype used a molded plastic case with an aluminum lid. Any type of case will do, although cases made only of metal should be avoided for safety reasons. The size of the case should be as small as possible yet still have room for the PC board, a battery, a switch, and a buzzer.

Building the Electrostatic Voltage Probe. Although the Electrostatic Voltage Probe is a very simple circuit, do not try to build it on a perfboard. Potentially lethal voltages could be present at the probe tip should something go wrong such as touching the probe tip to a bare wire that is carrying house current. A foil pattern has been included here—it is a single-sided design that does not need any jumper wires. As an added feature, the surface plate for the probe is a part of the pattern.

Traditionally, construction of any electronic project starts with soldering the components to the PC board. Although that approach can be taken with the Electrostatic Voltage Probe, it is a better idea to start by preparing the case first. That way, you will be sure that the PC board will fit in the case without having to cut or file any excess material from the board after the components have been soldered in place.

The layout of the author's prototype is shown in Fig. 2. Assuming you want to follow that, begin by cutting a slot in one side of the case. It should be the width of the PC board—the probe will slide into it. Test-fit the blank PC board in the case. If needed, trim the PC board to fit. Once the PC board fits in the case with the lid closed, set the PC board aside.

Drill a hole for an angle bracket that will hold the back end of the PC board in place. A small hole (or a series of small holes) should also be drilled where BZ1 will be mounted; they will act like a speaker grille. A hole for S1 should be drilled near BZ1.

Suitable holes for LED1 should be drilled in the case lid. If you wish, you can use a panel-mount clip for LED1. An alternative method that was used in the author's prototype is to use a short length of terminal strip. The LED is soldered to the terminals, and insulated wires are used to connect LED1 to the PC board. You can vary the positioning of the various parts depending on personal taste and size of the selected case. An important consideration for placement of S1 and LED1 is that of safety. Although it might feel more comfortable, do not place S1 near the probe. That will keep your hands as far away from any wires under test as possible. You should also be able to easily see LED1 while holding the unit.

Glue BZ1 in place inside the case, making sure that it is centered over the hole that was drilled for it. If you are using the buzzer suggested in the Parts List, it will have three wires—red, black, and blue. The blue wire is meant for feedback in a single-transistor oscillator, and is not

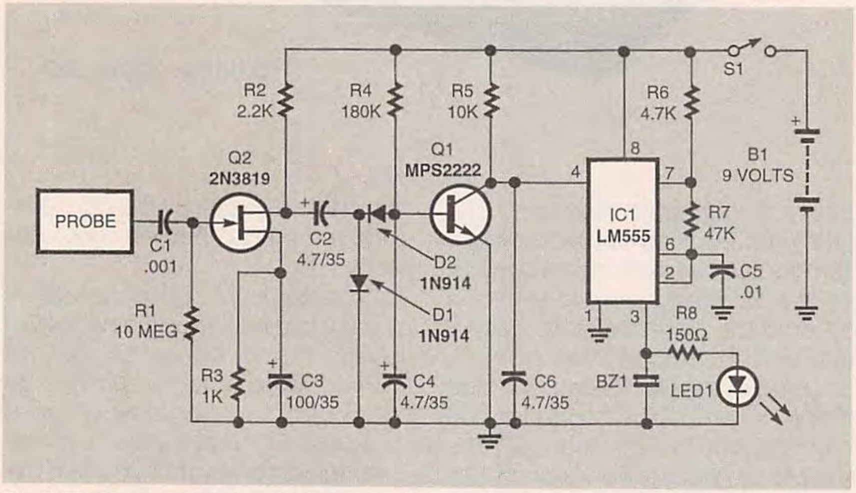


Fig. 1. The Electrostatic Voltage Probe is a simple circuit that is designed to detect AC signals through the phenomenon of stray capacitance. The probe plate forms one side of a capacitor. AC signals are amplified, rectified, and used to trigger a 555 timer that drives a buzzer and an LED.

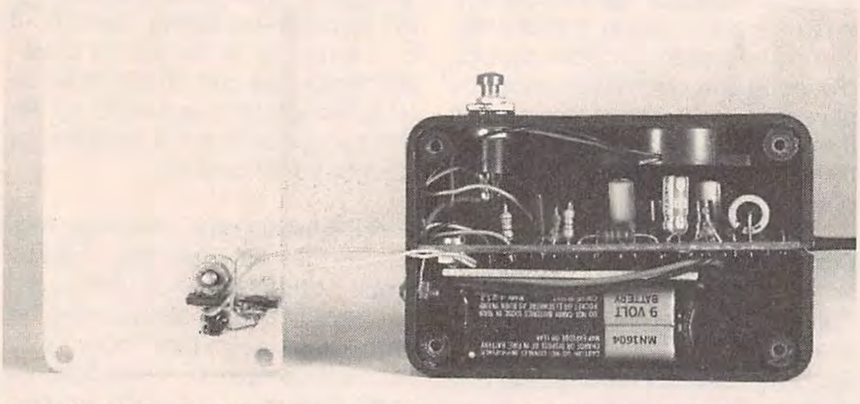


Fig. 2. Here is the author's prototype unit with the cover removed. Note how the PC board is mounted in the case along with the additional components. A piece of scrap plastic is wedged between the battery and the PC board so that the battery's metal case won't short out the circuit. A piece of heat-shrink tubing over the probe will help prevent accidental shocks if the probe touches a bare live wire.

needed here; cut it off at the body of BZ1. Mount LED1 to the case lid by whatever method you've selected. If you are going to use a terminal strip, be sure to solder the cathode of LED1 to the terminal that goes to the case lid. Solder three-inch lengths of insulated wire to the LED connections.

Solder the red lead from a 9-volt battery connector to one terminal of S1; a two-inch length of wire goes to the other terminal. Mount S1 in the case. The case is now ready for the PC board; set it aside.

The PC board is assembled according to the parts-placement diagram shown in Fig. 3. Keep the leads fairly short and mount the component bodies as close to the board as possible. Before soldering any polarized components such as the semiconductors, C2, C3, and C4, double-check their orientation. Resistors R6, R7, and R8 are mounted vertically in order to fit the available space. When mounting the transistors, shape the leads to fit the hole pattern in the board before soldering them. Any stress on the leads could cause the component to crack and fail when heated during the soldering process. To help position IC1 correctly, there is a "dot" in the foil pattern next to pin 1.

With the PC board completed, check your workmanship for any bad solder joints, wrong values, or reversed polarities.

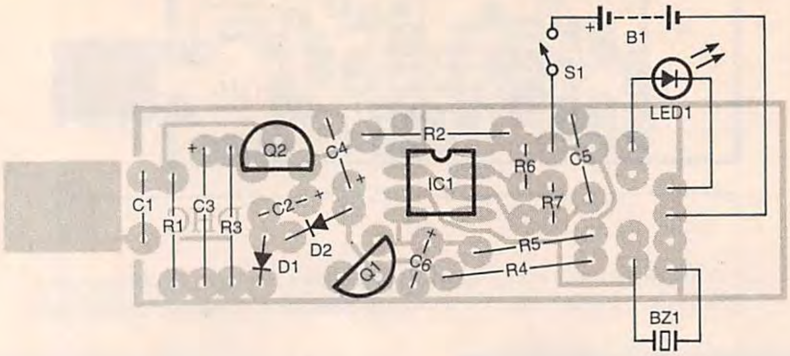


Fig. 3. All of the components for the Electrostatic Voltage Probe fit neatly on a small single-sided PC board. Several resistors are mounted vertically to save space. Note the large foil pad next to C1. That pad is the probe—neatly designed into the board layout!

PARTS LIST FOR THE ELECTROSTATIC VOLTAGE PROBE

SEMICONDUCTORS

IC1—LM555 timer, integrated circuit
Q1—MPS2222 NPN silicon transistor
Q2—2N3819 N-channel junction-type field-effect transistor
D1, D2—1N914 silicon diode
LED1—Light-emitting diode, red

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1—10-megohm
R2—2200-ohm
R3—1000-ohm
R4—180,000-ohm
R5—10,000-ohm
R6—4700-ohm
R7—47,000-ohm
R8—150-ohm

CAPACITORS

C1—0.001-µF, 500-WVDC, ceramic disc
C2, C4, C6—4.7-µF, 35-WVDC, electrolytic
C3—100-µF, 35-WVDC, electrolytic
C5—0.01-µF, ceramic-disc

ADDITIONAL PARTS AND MATERIALS

B1—9-volt battery
BZ1—Piezo-electric buzzer
S1—Single-pole, single-throw, momentary-contact switch, normally-open
Case, 9-volt battery connector, heatshrink tubing, wire, hardware, etc.

Final Assembly and Testing. Test-fit the PC board in the case to check that the components do not get in the way of BZ1, S1, LED1, or B1. Connect the wires from those components to the PC board using Fig. 3 as a guide. When connecting BZ1, the black lead goes to the common ground along with the negative terminal of B1 and the cathode of LED1.

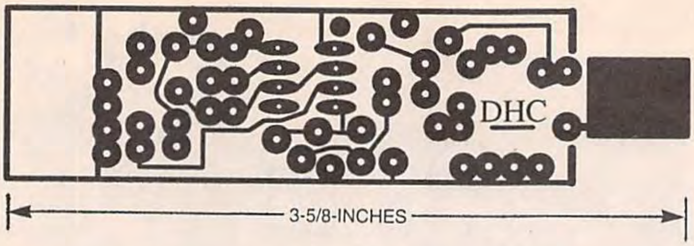
Connect a 9-volt battery to the Electrostatic Voltage Probe. When S1 is pressed, LED1 should flash briefly while BZ1 sounds as C4 charges up. If that happens, the circuit is probably working correctly. The final test is to bring an extension cord that is plugged into a wall socket near the probe while S1 is being held closed. The cord should be placed against the flat side of the probe; pointing the probe tip at a wire will do nothing. See Fig. 4 for the proper way to hold and use the Electrostatic Voltage Probe. The LED should light and the buzzer should beep steadily. Remove the extension cord; both LED1 and BZ1 should go out.

If the Electrostatic Voltage Probe passes that test, it is working properly. Mount the PC board in the case, route the wires from B1, S1, and LED1 around the end of the PC board between the board and the case. Bolt the PC to a right-angle bracket to hold the board in position. A scrap piece of plastic, cardboard, or blank PC board without any copper on it should be inserted between B1 and the PC board. Close up the case and put a piece of heatshrink tubing over the probe where it comes out of the case. Cut the tubing slightly longer than the probe itself so that there will be no bare PC board metal exposed.

A good test is to walk around the house and check some extension cords. Note that you will be able to detect which side of a parallel-conductor lamp cord is the hot side. If the cord is of twisted-pair construction, then the voltage probe will beep intermittently as you slide the probe down the cord.

Troubleshooting. It is hoped that your Electrostatic Voltage Probe worked perfectly the first time you tried using it; if so, you can skip this section. In case things haven't gone as planned, refer to the schematic diagram in Fig. 1 and the parts-placement diagram in Fig. 3 as we look at some spots that might cause problems.

Difficulties with the Electrostatic Voltage Probe will probably fit into one of two categories. The first category is when LED1 and BZ1 are on continuously whether there is an AC



Here's the foil pattern for the Electrostatic Voltage Probe. Not only is the design an easy-to-fabricate single-sided layout, it is also compact and doesn't require any jumper wires!

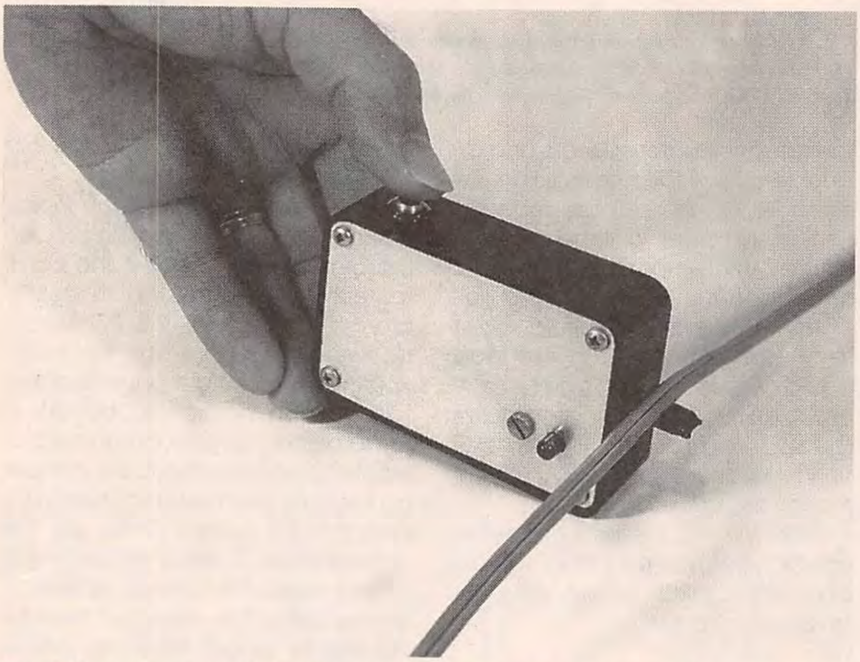


Fig. 4. Here is how to use the Electrostatic Voltage Probe when checking an AC line cord. If the cord is hot, then the Electrostatic Voltage Probe will emit a warning tone and the red LED will glow. The unit is sensitive enough to let you find which side of the line cord is the "hot" side.

power cord nearby or not. If that occurs, make sure that a fluorescent desk lamp that might be near (perhaps lighting your bench) is not causing the problem. If that doesn't clear the problem, then the problem will be caused by Q1 not saturating and pulling the reset pin (pin 4) of IC1 low. Using a voltmeter, check that the base of Q1 is at least 0.7 volts above ground. The collector of Q1 should be almost at ground potential. If both the base and collector are high, replace Q1. If the base is high and collector is low, look for a bad solder joint at pin 4 of IC1. If the base is low (less than 0.7 volts to ground), C4 might be either bad or installed backwards. If it was installed backwards, it might already be ruined.

Capacitor C6 is needed to prevent any noise that might be induced onto the 9-volt bus from retriggering IC1. If an oscilloscope shows noise being picked up that is greater than about one volt in amplitude on pin 4 of IC1, replace C6.

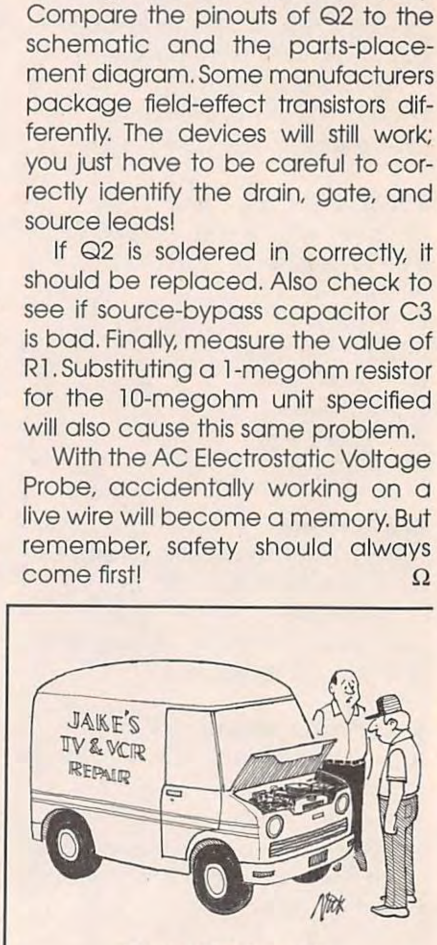
The second category is the exact opposite: LED1 won't light and BZ1 will not beep when the probe is exposed to a 120-volt AC field. There are several causes for that condition, including:

- IC1 is defective
- Q1 is shorted between collector-emitter or collector-base
- D1 or D2 are either bad or installed backwards
- C2 is either bad or installed backwards
- Q2 is either bad or installed incorrectly
- C3 is either open or installed backwards

We'll start with IC1. First, we'll check that the voltages are as they should be. With the probe lying close to a live extension cord, pin 4 should be above 8 volts. If it is, check all of the connections and solder joints near IC1; replace IC1 if needed. If the voltage on pin 4 is low, check Q1. The base of Q1 should be near ground potential. If it is being exposed to a very strong AC field, it might even be at a negative voltage with respect to ground. If the base is less than 0.5 volts and pin 4 of IC1 is still low, replace Q1. If Q1 has 0.7 volts or higher on its base, then check D1 and D2. They might be either bad (open or shorted) or be installed backwards. The same effect can be caused by C2 either being open or installed backwards. If the circuit checks good all the way back to Q2, check to make sure that Q2 is biased correctly. The DC voltage on the source of Q2 should be at about 3.2 volts, and the drain should be at about 6.8 volts. If those values (within 0.5 volts) are off, Q2 might be installed incorrectly. Compare the pinouts of Q2 to the schematic and the parts-placement diagram. Some manufacturers package field-effect transistors differently. The devices will still work; you just have to be careful to correctly identify the drain, gate, and source leads!

If Q2 is soldered in correctly, it should be replaced. Also check to see if source-bypass capacitor C3 is bad. Finally, measure the value of R1. Substituting a 1-megohm resistor for the 10-megohm unit specified will also cause this same problem.

With the AC Electrostatic Voltage Probe, accidentally working on a live wire will become a memory. But remember, safety should always come first! Ω



"It won't fast-forward."