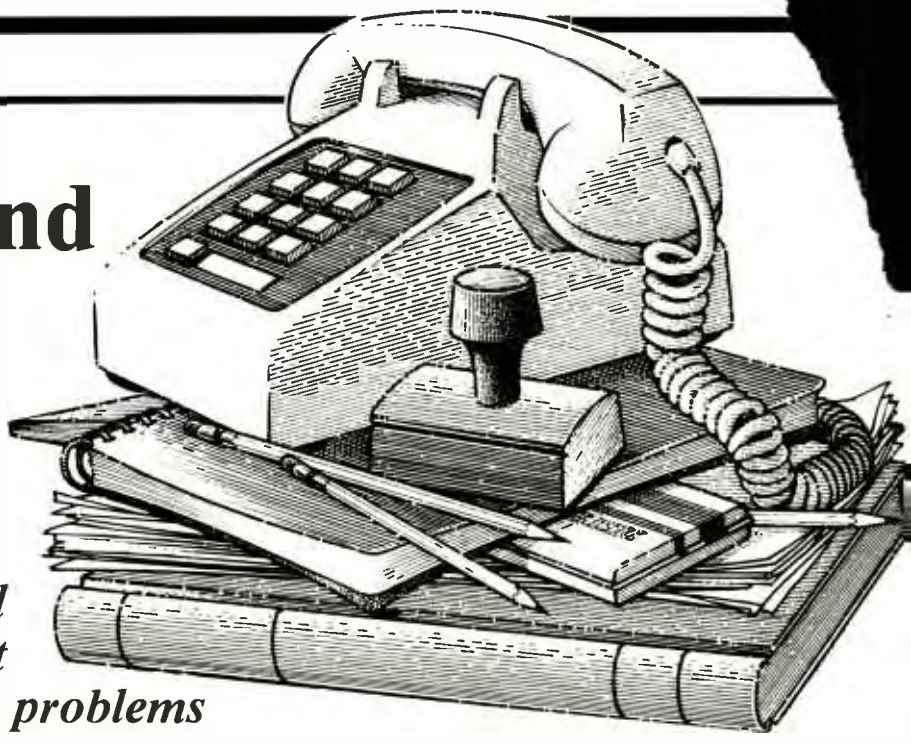
Telephones and Their Repair

Part 1



How telephones work and how you can troubleshoot and correct most common problems

By TJ Byers

With the words, "Mr. Watson, come here, I want you," Alexander Graham Bell established forever a revolutionary way of communicating.

For most of us, the telephone has become such an indispensible part of daily living that when something goes wrong with it, we view it as a crisis situation. Fortunately, telephones and telephone systems aren't difficult to repair. Armed with an understanding of basic electricity and a few details about the telephone system and how it works will help you get an ailing phone or line back into working condition in almost no time at all.

Basic Telephone Technology

Since its introduction, the basic design of the telephone hasn't changed much. In fact, today's telephones work pretty much the same as did Bell's invention 100 years ago.

Basically, the telephone consists of a carbon microphone in series with a battery and a remote speaker (Fig. 1). The mike works by varying the resistance of a loosely-packed carbon granules. A thin diaphragm across the carbon granules alternately compresses and expands the granules, varying the resistance according to the frequencies and amplitudes of the sounds intercepted. As the resistance varies, there's a proportional change in the current flowing through the circuit to the speaker. This current, in turn, is translated into mechanical motion (cone movement) to reproduce the original sounds in the speaker.

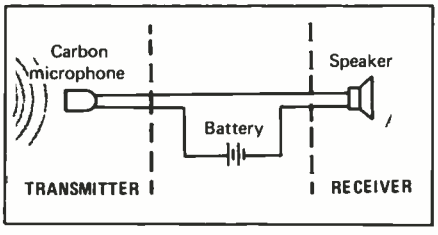


Fig. 1. The telephone is basically a carbon microphone in series with a battery and a remote speaker. Sound pressure on the carbon element varies its resistance and, thus, the current flowing through the circuit. The speaker translates these currents back into sound.

In actuality, the microphone/speaker combination is no longer in use. In modern systems, the circuit has been rearranged (Fig. 2). Now, the battery is in a central location called an *exchange*, from which the phone company runs two wires to each subscriber and selectively switches between them to complete the loop when a call is placed.

At the subscriber's end of the line is a pair of wires with a voltage across them. The telephone company calls these the "tip" and "ring" wires. (These names have deep-rooted meaning in telephone history but have little significance today.) The open-circuit voltage across this line is approximately 48 volts, but this can range from 42.75 to 52.50 volts.

In the most elementary terms, when you place a call, all you're really doing is connecting a microphone across your particular tip-and-ring wire pair. All else is accomplished at the phone company.

In reality, things are a bit more complicated than that. For instance, the phone company must be able to detect when you wish to go on-line. It does this with a current-sensing relay at the exchange.

Since the telephone is essentially a current-operated device, when you go on-line, current flows through your instrument, into the central exchange, and through your intended party's instrument, to create the loop required for communications. Limited at the exchange, the current is

nominally 30 mA but can vary from 20 to 80 mA.

When you lift your phone's handset, a switch inside the instrument closes a circuit that causes current to flow. A relay at the central exchange detects the current and puts you on-line. A load of 600 ohms (which just happens to be the impedance of the telephone handset's carbon mike) or less is needed to assure that sufficient current flows to trip the relay.

Once the circuit is made, the central exchange acknowledges the off-hook condition by emitting a dial-tone. The dialtone consists of 350- and 440-Hz signals. It remains in effect for approximately 10 seconds as long as there's no activity. At the end of the 10 seconds, if no activity occurs, the phone company issues an off-hook warning signal made up 1400-, 2060-, 2450-, and 2600-Hz tones that are pulsed at a rate of five times per second.

If a call is placed before the off-hook warning, the central exchange rings your party with a high-voltage ac signal. The ringer signal is a 20-Hz voltage superimposed across the ring and tip lines and is nominally 86 volts but can vary in amplitude from 65 to 130 volts ac. The ring voltage is also normally pulsed by an *interrupter* that provides a short burst of ringing with a pause between burst sequences. Although the ringing sequence varies from company to company, it is generally 2 seconds on followed by 4 seconds off. When the answering party lifts the receiver, the second leg of the current loop is completed and the ringer voltage is discontinued. The exchange then connects the two parties together.

Should the called phone already be on-line when a call is placed to it, a busy signal consisting of 440- and 620-Hz tones is fed back to the caller. The busy signal is pulsed at a 50-percent duty cycle, with 0.5-second on and off times.

As you can see, the telephone system is no more complicated than a simple dc circuit with a little ac superimposed on it from time to time. The system is so simple, in fact, that it takes little more than a multimeter and some common sense to fix most telephone problems. This being the case, let's take a look at the more common ailments.

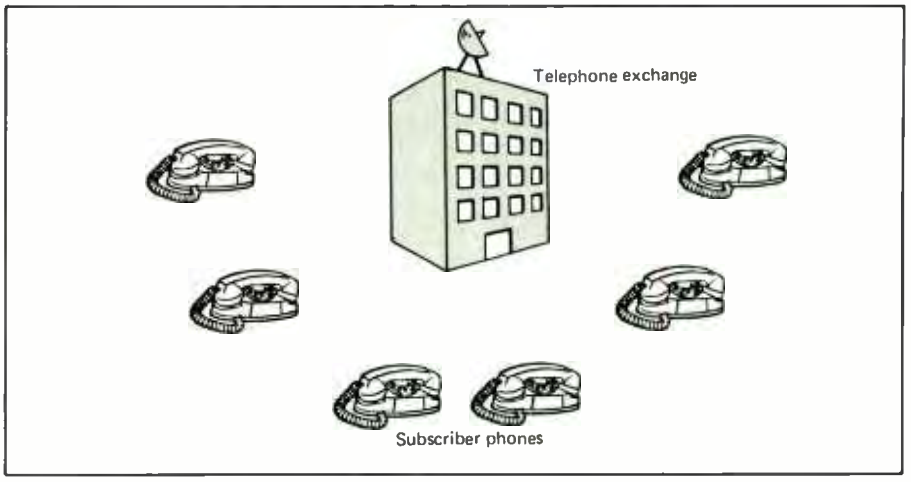


Fig. 2. A central telephone exchange is used to connect together subscriber phones. Inside the exchange is a bank of batteries and the switching circuits needed to connect together the phones.

No Dialtone

The most common complaint, absence of a dialtone, can be created by a number of conditions. These include deliberate discontinuation of service by the phone company for any of a number of reasons or interruption of service as a result of a storm or other circumstance. Bear in mind that the phone company reserves the right to discontinue service at any time if you connect equipment that interferes with its system. So make sure you have service *before* jumping to conclusions.

If you have no dialtone, suspect the telephone instrument first. More often than not, it's the source of the problem. Your best service tool in this situation is an auxiliary telephone. A "cheapie" phone like those selling for $10 or so is an adequate piece of test equipment in this case. While the tonal quality of these instruments leaves much to be desired, they do serve the purpose and sure beat the $25 or so most companies charge for a service call.

You begin troubleshooting by removing the suspected telephone and replacing it with your test phone. If the system you're servicing isn't equipped with a standard RJ-11 or RJ-14 modulator outlet, now is a good time to install one. (See the "Installing Modular Jacks" box.) If you hear a dialtone in the test phone, you've narrowed the problem to the original telephone or its cord.

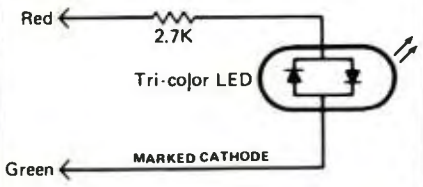
Should the test phone also be dead,

Installing Modular Jacks

If your system doesn't presently have modular outlets, you should convert to them. The conversion involves a simple installation procedure. (Modular outlets can be purchased from any number of places, including your local telephone center or Radio Shack. A good jack will run you about $2.00.)

To install the modular jack, remove and discard the plastic cover of the block where your telephone wires go into the wall. Remove the telephone wires from the block. Do *not* remove the incoming system wires. Now connect the wires from the modular jack to the screw terminals of the wall block, carefully matching the colors. Finally, mount the modular cover in place of the original block cover.

An Inexpensive Line Tester



A simple line tester can be made using a single resistor and a tricolor LED (the LED actually contains a red LED and a green LED wired in reverse parallel). Depending on the nature of the voltage applied, the LED will glow one of three colors—red, green or yellow.

If line polarity and voltage are correct, the LED tester glows green. Reverse polarity causes the LED to glow red. An ac signal, such as a ring voltage, causes both LEDs to light on alternate half-cycles, producing a yellow glow.

you'll have to go into the system itself for further troubleshooting. Begin by removing the outlet cover to gain access to the phone company's wires. Residential lines have red, green, yellow, and black wires, while commercial lines have these plus an additional two wires (six altogether) for a second line.

The red and green wires are identified as ring and tip, respectively. In some systems, the yellow wire is ring ground return. To avoid confusion, simply short the yellow and green wires together.

With the telephone disconnected from the circuit, measure the voltage across the red and green lines; it should be approximately 50 volts. (Not all systems adhere to the green/red color code. So check all possible combinations for the source voltage.) If you don't obtain a 50-volt reading, the problem is further up the line. In installations with more than one outlet, check the voltage at each outlet. The problem could be a broken line between extensions.

Trace the problem as far as you can, all the way up to the terminal junction box (where the phone line enters your house), if necessary. If the problem appears to be beyond the junction box, responsibility for repair lies with the phone company, at no charge to you. If there's no voltage coming into the terminal box, call the phone company's repair service.

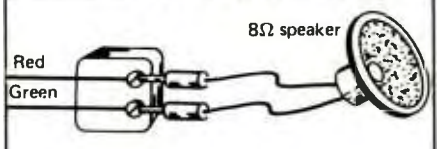
If you have voltage at the outlet but still no dialtone, the problem can be two-fold. It might be that the polarity of the line (green and red wires) is reversed or that not enough load is being placed across the line to activate the off-hook relay.

A quick way to test for dialtone is to clip a small 8-ohm speaker across the phone line and listen for a tone. The speaker's low impedance will allow maximum current to flow to activate the system. Additionally, the speaker isn't polarity sensitive.

If you hear a tone through the speaker, reverse the green and red wires and try your test phone again. Still no dialtone means that the problem is somewhere in the relay located at the central exchange or in the lines leading to it, like that caused by a high-resistance splice. It's best to perform this test at the terminal box —not an outlet—as the problem may lie in the wiring between the terminal junction and your outlet. If you really want to get technical, use the ammeter function of a multimeter to test your line; you should obtain a reading of 18 mA minimum. This is the triggering current that activates the off-hook relay.

Static on the line can also be attributed to bad connections. They're a little more difficult to detect, but the ammeter method works well when the noise is severe. It can tell you if the problem is before or after the terminal junction in most cases. A fluctuating line current normally indicates a bad connection that can lead to static. But don't be fooled by periodic signal changes, such as those created by an off-hook warning.

Tips & Tricks



A quick way to test for presence of a dialtone without elaborate equipment is with a small 8-ohm speaker. Simply connect the speaker across the incoming line. The speaker's low impedance represents a virtual short circuit, which guarantees to engage the off-hook relay. Besides, the speaker isn't polarity-sensitive.

No Ring

Remember that the ring function is activated by a high-voltage ac signal put on the line over the dc voltage. It's never less than 65 volts and can be as high as 150 volts. There are two ways to test for a ring signal, both requiring the assistance of a second party, either the operator or a friend. First gain access to the wiring and have another person call you.

In the first method, you simply substitute the test phone for the original instrument. If it fails to ring, chances are there's a problem in the system, since the ringer isn't polarity sensitive. If you do obtain a ring with the test phone, you've pinpointed the problem to the original telephone. Not all telephones respond equally to ringer voltage, however; so it could be that the ringer voltage may activate one phone but not another.

To test this theory, a second, more sophisticated test must be used, shown schematically in Fig. 3. Measure the voltage across the incoming line with the phone disconnected. Each time a ring signal is received, the voltmeter will indicate a voltage somewhere in the range between 60 and 200 volts.

If it appears that the ring voltage is too high or too low, contact your local phone company representative and ask what the voltage should be. An out-of-spec ring voltage should be reported to your telephone repair service facility after you've thoroughly tested the system. Because different voltmeters measure ac voltage differently, tread lightly

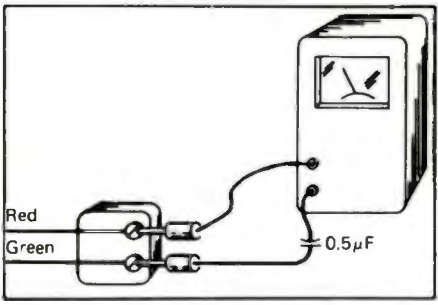
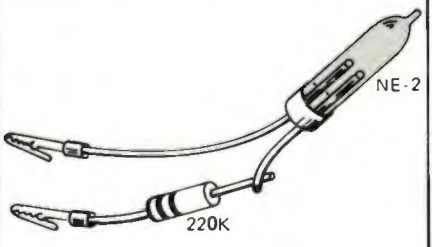


Fig. 3. Use a multimeter and capacitor to measure ring voltage.

here—a misdiagnosed problem could cost you a service call. The best meter for the job is a cheap multimeter with an rms scale.

Also be aware that extension phones can create ring problems. Ring current is limited. In most cases, the phone company guarantees to service only five extensions—and balk at that. If you have several extensions with ringers, begin eliminating them one by one until the problem is resolved. If necessary, you can permanently disconnect the bell without affecting performance of the telephone.

Tips & Tricks



A neon lamp in series with a limiting resistor makes a simple ring detector. Neon lamps like the NE-2 have a threshold potential of approximately 65 volts and, therefore, respond to only the higher ringing voltages.

Coming Next Month

This ends Part 1 of this article. In next month's conclusion, we'll zero in on what to do if the problem is isolated to the telephone instrument. ME