All About Telephones and How to Repair Them

A look at telephone repair

By TJ Byers

Last month, in Part 1 of this article we examined the telephone system as it exists today and the ways to troubleshoot it. This month, our focus is in how to correct problems that develop within the telephone instrument itself. Before we do this, however, you should know the basic elements that make up the typical telephone.

The modern-day telephone consists essentially of five parts. These are the ringer, the dialer, the hook-switch, the handset and the network. The most frequent failures occur in the ringer and dialing sections. Let's begin our discussion with the ringer section.

Ringer Problems

The basic ringer detects the nominal 86-volt, 20-Hz ac signal the phone company delivers to a subscriber's line when a call is coming in. It does so in a uniquely simple way. A bell-type telephone ringer consists of a coil of wire to which is attached a pivoting metal bar with a clapper at its end. One or two bells are mounted near the clapper. When the low-frequency ac current flows through the coil, the metal bar is attracted by the electromagnetic field, causing the clapper to strike the bell(s) 20 times each second.

A 0.5-microfarad capacitor wired in series with the coil (Fig. 4) isolates the bell coil from the dc portion of the circuit. This capacitor blocks dc but passes the ac that energizes the ringer
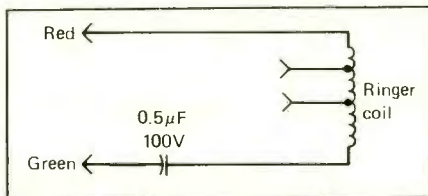

Fig. 4. A 0.5-μF capacitor in series with the coil isolates bell from dc portion of the circuit.

when a ring signal is present. It's this capacitor that's the most frequent cause of ringer failure, usually by becoming an open circuit. When this occurs, the only remedy is to replace the capacitor. Because the capacitor is an integral part of the terminal board and is not normally accessible the only effective "repair" can be made by jumpering an external capacitor across the proper terminal connections (see Fig. 5). Use a metal-film capacitor rated at 100 or more working volts.

A capacitor rarely shorts, and the coil just as rarely fails. However, if you suspect either condition, remove the coil wires from the terminal board and measure the components with an ohmmeter. Replacement is the only cure if your suspicions are borne out.

Electronic Ringer

Solid-state technology is rapidly making the electromechanical bell ringer a thing of the past. Replacing the bells is the electronic tone ringer (a beeper, a chirper or whatever). Electronic tone ringers can take many forms, but the most common is a piezoelectric transducer driven by an electronic oscillator.
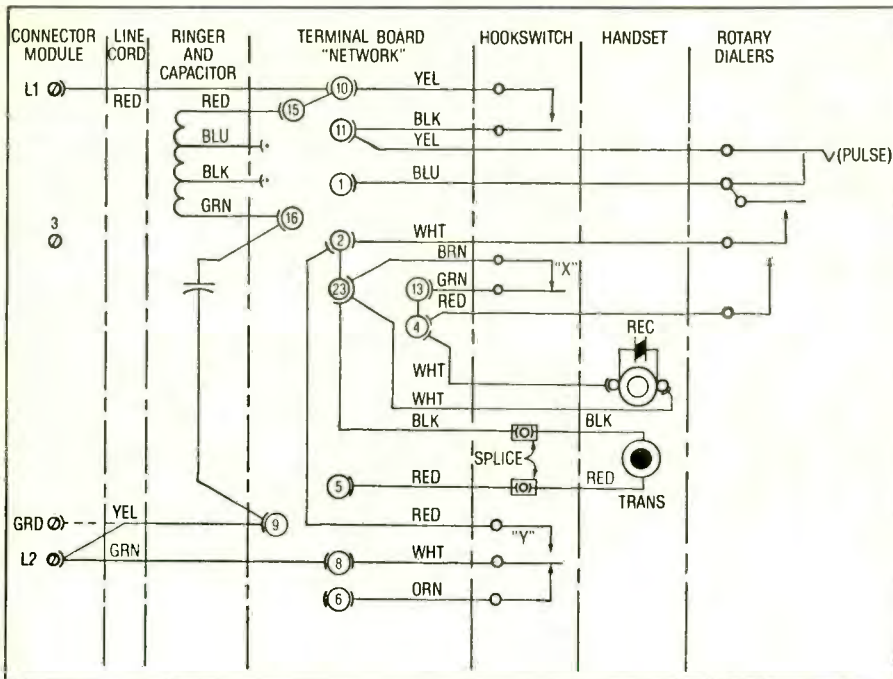
Fig. 5. This is the schematic diagram of a traditional telephone instrument. Included is the terminal board nomenclature.

Integrated circuits are normally used with electronic ringers to detect the ring voltage and drive the piezo-electric element. The Motorola MC34017 is typical of electronic tone ringer chips. As Fig. 6 shows, the MC34017 is a complete ring detector circuit and oscillator in a single 8-pin DIP package. Power for the chip is taken from the telephone line by rectifying the ac ring signal using an internal full-wave rectifier and zener-diode voltage regulator.

To isolate the tone ringer from the voice part of the circuit, the chip uses a series capacitor/resistor combination that connects to the line. The ring tone is set by C2 and R2, while C3 and R3 form a filtering circuit that rejects false triggers.

In normal operation, C1 blocks dc from entering the IC, but when ac exceeding 36 volts appears on the line, current passes through it and into the chip's power supply. Application of power to the internal relaxation oscillator then produces a tone that's buffer fed to the piezoelectric device.

Failure of an electronic tone ringer can often be traced to the transducer or the chip itself. The circuit can be tested by securing the hookswitch in the off position (on-hook) and applying a 60-Hz signal from a Variac, adjusted to 60 volts across the input line. The Variac provides a steady input signal that allows you to take voltage measurements and monitor circuit conditions. Oscillator output can be monitored with a signal trace or substitute transducer. Make sure all tests are performed with the phone removed from service.

Rotary Dialers

Most prevalent of telephone problems are those that occur in the dialer, especially in the case of the mechanical rotary dialer. An amazing achievement of mechanical engineering, the rotary dial is an intricate assembly that rapidly opens and closes a set of contacts connected across the phone line to produce a string of pulses that the phone company interprets as calling numbers.

As you turn the dial, a spring winds and an auxiliary set of shunt spring contacts are activated. The shunt springs short the handset to prevent the pulsing from being heard in the earphones. When the dial is released, a ratchet engages a cam that actuates pulser contacts. Dial speed is maintained at a constant 10 pulses per second by a mechanical governor.

The ratio of time that the pulser contacts are open to being closed is critical for proper dialer operation. This ratio is 61 percent, or 0.61-sec-
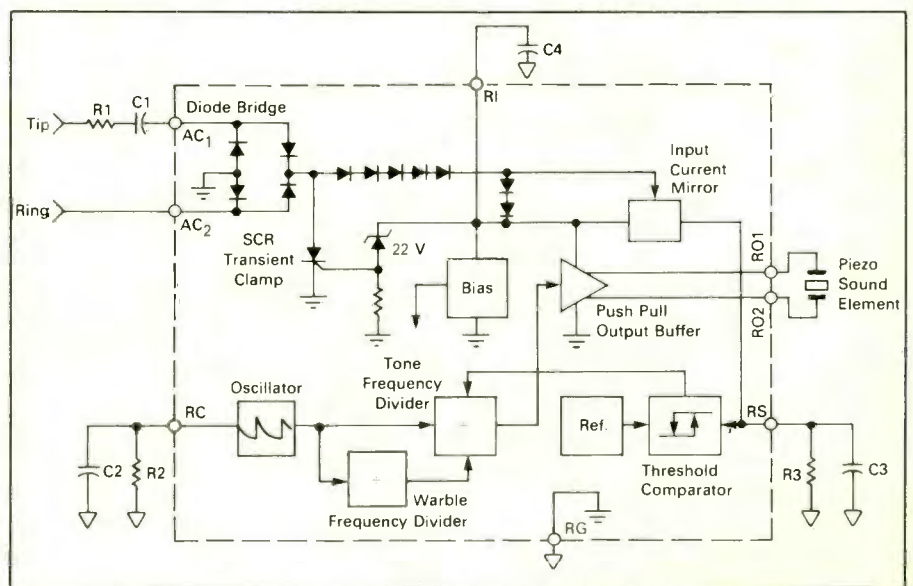

Fig. 6. The MC34017, a complete ring detector circuit and tone generator in a single 8-pin DIP package, replaces the bulky electromenchanical bell.

ond open and 0.039-second closed. Each 100-millisecond (0.100-second) period represents a dial pulse, and each pulse represents a part of a number. The number of pulses in a continuous train is the same as the number of the digit dialed. For example six pulses are generated when the 6 key on the keypad is pressed, and 10 pulses are generated when the 0 (Operator) key is pressed.

Most residential telephones in the U.S. still use mechanical pulse dialers. Since mechanical elements are much less reliable than are all-electronic devices, this explains why dialing problems are the most frequently encountered.

Repairing a rotary dialer is no easy task. Pulse rate and dwell time are determined by spring tension and mechanical spacing inside the dialer. In the case of the pulse rate, the mechanical governor uses spring tension to control "fly-away" weights used to slow down the return of the dial. Too little spring tension on these counterweights, and the dialer pulses too slowly; too much, and it returns too quickly.

Dwell time is determined by the gap between the pulser contact points in relationship to the cam angle. It's set by a procedure very similar to the setting of points in a car and is just as tricky to perform.

Dwell time can also be altered by both contact resistance and contact tension, in addition to the point gap, so check all possibilities. Pulse rate is less critical, and may vary by as much as 100 percent (up to 21 pulses per second) in many exchanges.

Electronic Pulse Dialers

VLSI (Very Large Scale Integration) IC circuits and pushbutton keypads have made the pulse dialer more reliable. In place of the rotating cam and pulser contacts, the new ICs place digital pulses directly on the telephone line electronically.

There are many different types of pushbutton pulse dialers, but all function the same. A representative
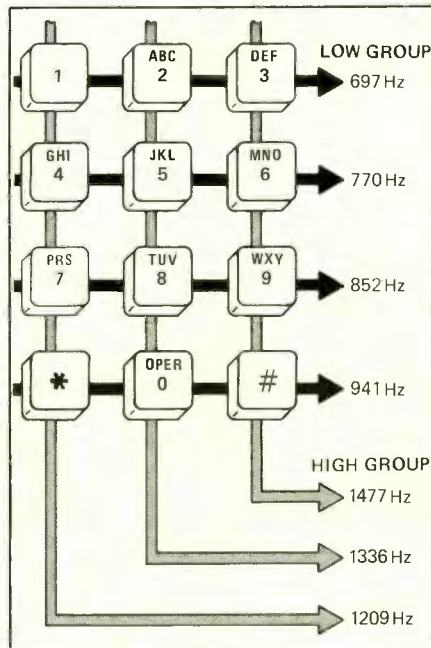

Fig. 7. A block diagram of a typical electronic pulse dialer.

block diagram is shown in Fig. 7. The keypad logic changes a 3-by-4 pushbutton matrix input into a series of output pulses that corresponds to the numeral key pressed. The pulse train is timed exactly the same as the rotary dial, with 61 and 39 milliseconds of off and on times, respectively. At least 750 milliseconds of delay is inserted between pulse streams (numbers) to avoid run-on.

Most of us can punch buttons faster than the dialer can output pulses, though, so the chip contains a memory feature. When a number is entered, it's stored in a memory register inside the chip. As the pulses are outputted, the chip recalls these numbers from memory in the same sequence in which they were entered. This is what makes possible the automatic-redial function found in many modern telephones. Since the telephone number last dialed remains in memory, a single keystroke can recall it. Because of this, most electronically pulsed phones have this feature.

Very little can go wrong with an electronic pulse dialer, other than failure of the chip. Almost all functions are contained within the chip itself—with the possible exception of the power supply.

Digital dialers derive power from the 50-volt telephone line. In most cases, the diodes needed to steer the source voltage aren't inside the chip. They're found as discrete components on the printed-circuit board, usually within easy reach of the hookswitch.

Should one of the diodes fail, strange things can—and do—occur. There are four diodes, usually of the 1N4000 series, arranged as a full-wave bridge rectifier. This configuration doesn't change ac into dc; rather, it steers the positive and negative lines so that the telephone isn't polarity sensitive. So if your automatic pluse dialer isn't working, the first thing to check are the diodes.

Touch Tone Dialing

Touch Tone is a signaling system that's rapidly replacing the rotary dial and holds the promise of expanded services for the future. Technically defined as Dual-Tone Multi-Frequency (DTMF) communications, Touch Tone offers increased speed and the ability to communicate data.

Instead of sending groups of pulses to the central office, Touch Tone transmits pairs of tones to the central exchange, where they're deciphered by special receiving equipment. Because the DTMF tones are in the audio range, two tones are used to distinguish between actual signaling and voice. Tone signaling is based on an internationally accepted standard of frequencies that includes four tones of a lower register and three of a higher frequency. All digits are derived by combining one low group frequency and one high group frequency, as illustrated in Fig. 8. DTMF tones are sent with a minimum duration of 50 milliseconds and interdigit time of 45 milliseconds.

The tone frequencies must be accurate to within 1.5 percent of their stipulated value under all conditions of temperature and voltage through-
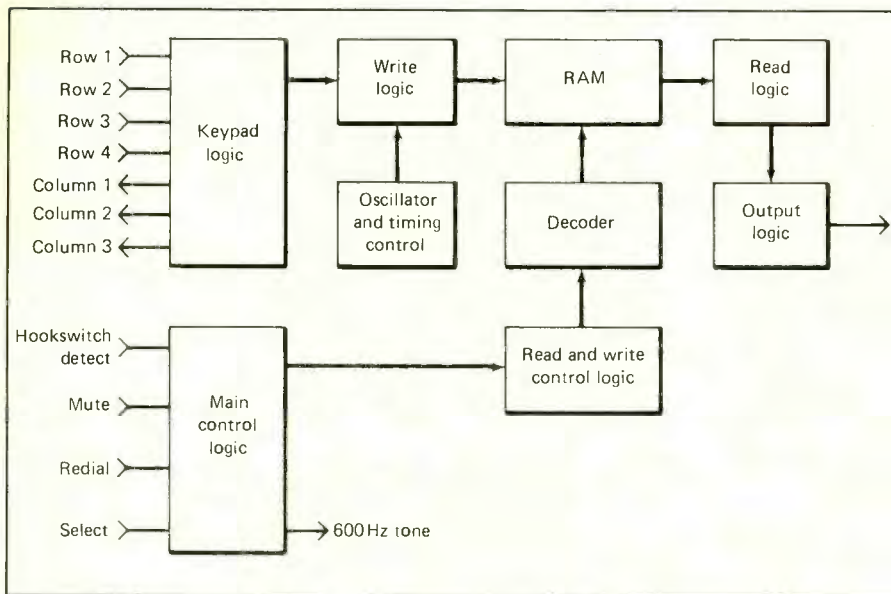
Fig. 8. Touch Tone dialing uses tones instead of pulses for transmitting numbers and data. All 10 digits and two special-purpose keys are represented by combining one low group and one high group frequencies to form a DTMF tone.

out the life of the telephone. Touch Tone dialers manufactured by Western Electric (a subsidiary still retained by AT&T) uses a single trasistor LC oscillator to achieve the stability necessary for DTMF. The inductors used for the oscillator are multitapped for different impedance values.

Touch Tone pushbuttons are mechanically connected to 11 sets of gold-plated contacts. Pressing any one button actuates seven of the 11 contacts, causing a different inductance to be inserted into the oscillator circuit, and a different pair of tones to be generated. Five contacts are sealed in a clear plastic dust cover and seldom, if ever, need servicing. The remaining six are located around the upper perimeter of the Touch Tone keypad, occasionally giving trouble. The trouble usually appears as a single tone instead of the normal two. Repair is simple: clean the contacts, using only nonabrasive chemical cleaners—*never* sandpaper.
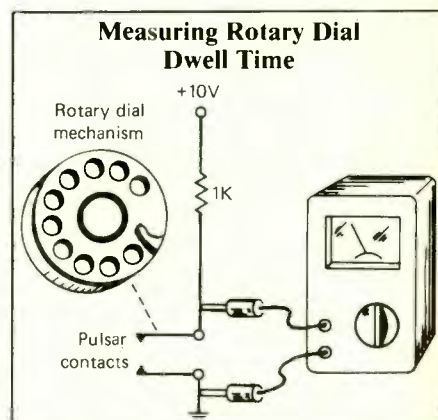
The inductors are slug tuned, using a triangular alignment tool. One inductor tunes the high range, the other the low range. Always use a frequency counter when adjusting these coils.

Recently, telephones have been introduced that include all the electronics necessary for a reliable DTMF system on a single chip. Like pulse dialer ICs, the DTMF circuits decode a keyboard input and translate it into dual-frequency tones. Failure of this design can almost always be attributed to power supply, DTMF chip, or keypad, in that order. Use the techniques outlined above for troubleshooting.

Voice Processing Networks

There are three parts to the voice circuit. They are the hookswitch, the handset and the network. The hookswitch is that part of the circuit that determines if the phone is on-hook (out of service) or off-hook (in use) and is the device that actually connects the microphone and speaker across the line. The switch is sealed inside a dust-proof plastic box and seldom causes problems. If problems do arise, they can normally be cured by thoroughly cleaning the contacts with a chemical cleaner.

In electronic telephones, the hookswitch may be nothing more than a simple spst microswitch that con-

nects an input transformer (and related circuitry) across the line. A jumper wire or ohmmeter can easily spot a defective hookswitch.

The next component is the handset. Time was when the handset was a unit on its own, apart from the main body of the telephone and tethered with a coiled cord. Today, we see more and more integration of the telephone itself into the handset, as witnessed by the trend in one-piece telephones.

Other than occasional failure of a microphone or speaker, little can be said about this part of the telephone. Traditional handsets have removable cups that allow for easy replacement of defective elements. One-piece designs must be dealt with accordingly. More and more, electret mike ele-

ments are supplanting the carbon mike, particularly in electronic telephones, so be alert to it.

The final element is the speech network itself. Because the telephone is a current operated device, it's sensitive to all resistive influences—including those in the link itself. The amount of current flowing through your telephone depends on the resistance of the wires connecting your telephone to the exchange. The farther you are from the battery, the higher the line resistance, and the less current available to you. This creates the effect that the current in short loops is relatively high, tending to make voices too loud, while in long loops the current is relatively low, forcing users to raise their voice.

To counteract this effect, the telephone contains automatic compensation circuits that adjust the current through the transmitter and receiver so that performance on a very long line is equal to that on a short line. Inside the traditional telephone instrument is a network of coils, resistors, and capacitors that make up the equalization network.

At the heart of the this network is a variable resistor called a varistor that works in a manner just the opposite that of a resistor. Larger current flowing through it, increases its resistance, while smaller current, reduces its resistance. Placing a pair of varistors in series with the line, causes the negative-resistance characteristics of the varistors to stabilize current flow and minimize the effects of line resistance. Should you note any problems with this network, replacement of the entire network is recommended.

In the electronic telephone, a special circuit called an automatic gain control, or agc, compensates for line resistance by sampling the incoming signal and adjusting the gain of the electronic amplifier accordingly. Troubleshooting the network and amplifier portion of an electronic telephone is similar to repairing any electronic instrument. Voltage measurements and signal tracing are a must. **ME**