
# Telephone Technology

## (Part I)

***A look at elements that make up the telephone instrument and how they work together***

**By Stephen J. Bigelow**

The ordinary telephone has become a vital part of our everyday personal and business lives. Consequently, when a problem arises with the instrument, the interface for a device that depends on it (a computer modem, facsimile machine, etc.) or the phone system itself, it is an extremely disruptive event.

As a technological force that we deal with regularly, you should have a basic understanding of how this marvel works so that you will be able to remedy many phone problems yourself, properly interconnect devices to it, and have the underpinning knowledge to follow rapid technical changes occurring today in telephone electronics.

In this first article of a two-part series, emphasis is on the telephone instrument's component parts and how they work together to form our telephone communications system.

### *Component Parts*

Standard telephone instruments are manufactured in a great variety of shapes and convenience features. Nevertheless, every instrument has only five basic elements in it, as illustrated in Fig. 1.

(1) HOOKSWITCH. This is nothing more than a mechanical-activated device that connects (or disconnects) the transmitter, receiver and dial units into the voice circuit. A hookswitch is always activated by the weight of the handset resting on a plunger as it sits in the cradle. It can be as simple as a set of on/off contacts in an electronic telephone instrument or a much more sophisticated device with multiple sets of contacts.

(2) DIAL UNIT. This is the device used in the instrument to signal the local exchange as to who—or more correctly, what number—is being called. Three technologies are currently used to signal the Central Office (CO) as follows:

*Rotary Dial.* This is a mechanical device that merely interrupts the flow of current entering the instrument by means of a *rotary* dial, shown in Fig. 2(A). Thus, it is called pulse dialing. The number of interruptions in line current corresponds to the digit being dialed. When the dial plate is rotated from its rest position, the off/normal contact set of the dial closes to mute the audio at the receiver so that annoying clicks and noises are not heard. When the dial plate is released from the digit position to which is was rotated, the pulse contact set, shown schematically in Fig. 2(D), opens and closes to send the desired number of pulses.

Each pulse transmitted back to the Central Office must be within specific time limits for the CO to correctly interpret it. Typically, a pulse is 0.1 second in duration. It will break contact for 0.06 second and make contact for 0.04 second (referred to in telephone company parlance as a 60/40 pulse ratio), as shown in Fig. 2(E). If you could make and break the hookswitch connections with just the correct timing, it would be possible to dial out in rotary fashion without rotating the dial plate. Rotary dials pulse out at 10 pulses per second (pps) and will be interpreted by *any* Central Office.

*Dual Tone Multi Frequency* (DTMF). This method uses a predetermined set of tones, called Touch Tone, to signal to the Central Office the digits of the number being dialed. Although the technology to implement DTMF dialing is as common today as is traditional rotary technology, DTMF tones can be used only by Central Offices that are equipped to handle them.

Two assemblies make up a DTMF dialing unit: the pushbutton keypad or mechanical assembly and the tone-generating printed-circuit assembly. A pair of frequencies, unique to each button, is generated whenever a button is pressed on the "dial" keypad. These frequency pairs are detailed in Fig. 3. Pressing any given button causes the frequencies listed both horizontally and vertically to be generated simultaneously. For example, pressing the *5* button generates 1,336-Hz horizontal and 770-Hz vertical tones; pressing *9*, 1,477- and 852-Hz tones; etc.

Frequencies generated by a DTMF keypad must be accurate to within 2 percent of their specified values for the entire life of the keypad. Also, the minimum time a tone must be present for the Central Office to interpret and respond to it is 0.05 second.

*Pulse Dialing*. Also called Tele-Pulse dialer, this mechanism is commonly used in many newer electronic telephone instruments. It has a 12-button keypad, the same as the DTMF keypad, but its internal electronic circuitry sends pulses to the Central Office instead of tones. This hybrid dialer combines the convenience and speed of DTMF and the universality of rotary dialing.

With pulse dialing, you can dial much faster than the time it takes for the instrument to pulse out each digit dialed because Tele-Pulse circuits have built-in memory modules that store the digits keyed in, in the proper sequence. It is this memory capability that makes possible the memory and redial features found in newer electronic telephone instruments. Though many Tele-Pulse circuits are switchable to 20 pulses per second, the Central Office must be capable

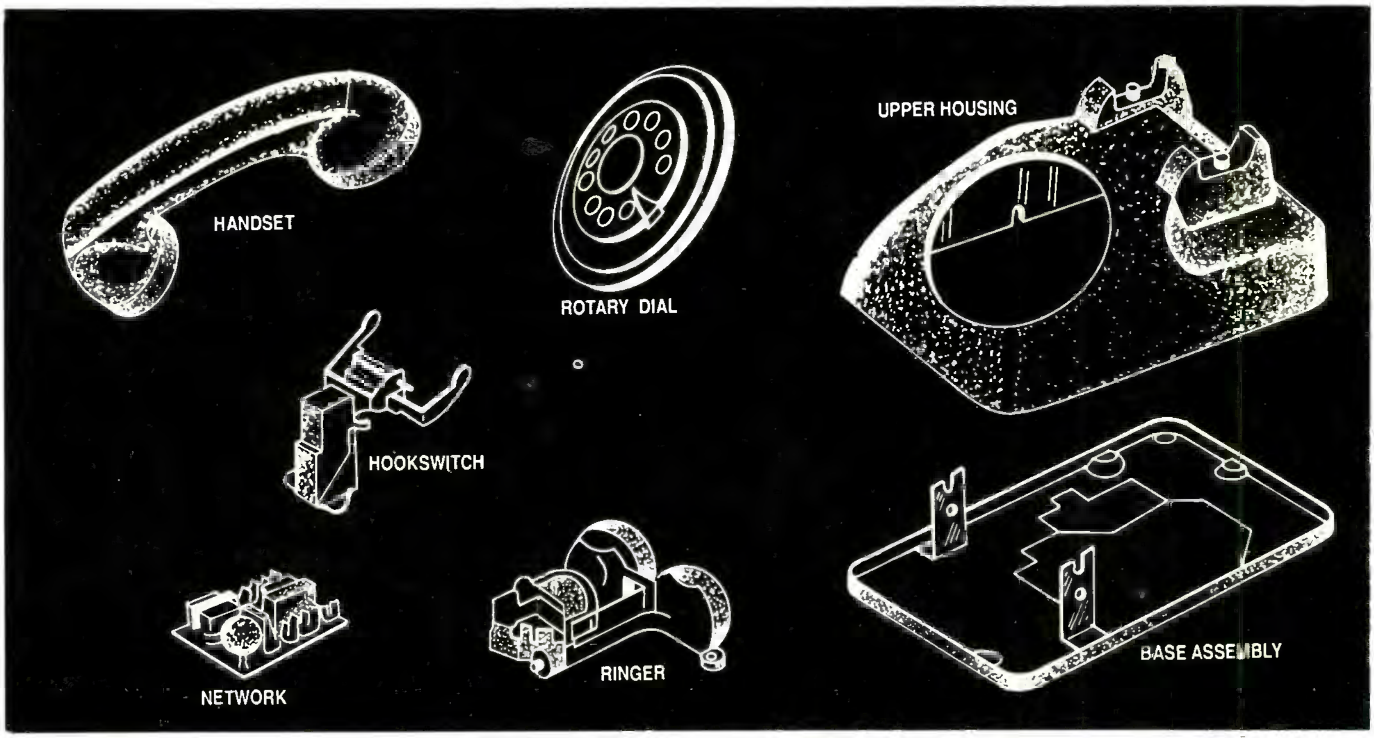
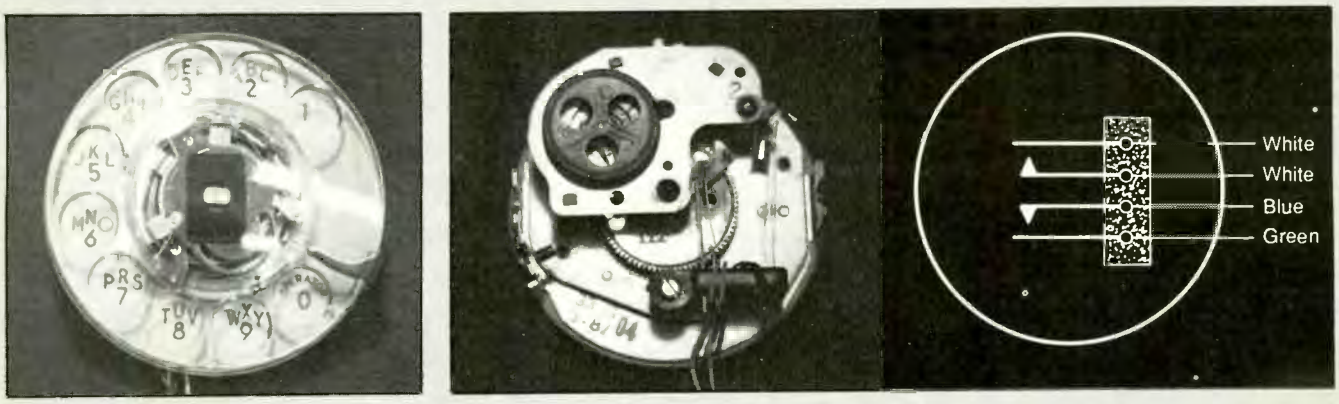



*Fig. 1. Drawings show variety of elements that make up a conventional rotary-dial telephone instrument.*




(A) (B)

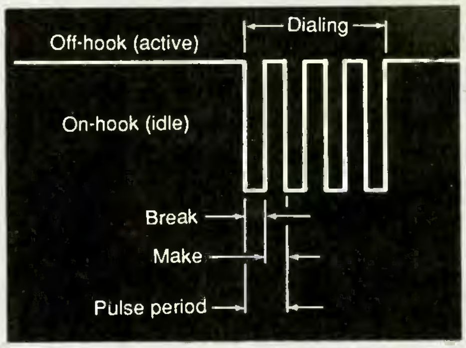



*Fig. 2. In (A) a typical rotary dial is depicted; (B) is a rear-view photo of the dial mechanism and a schematic diagram of its contacts; and (C) is a graphical depiction of the rotary dial pulses.*

(C)

of accommodating pulses at this faster rate.

(3) NETWORK. Tie points for all elements in the telephone instrument are provided by the network. This element filters and amplifies voice signals, houses a capacitor that is used in the ringer circuit, filters out noise and voltage spikes and provides loss compensation and line balance between the "tip" and "ring" sides of the incoming telephone line. Line balance provides a ground reference to the phone line.

(4) RINGER. This element informs the user that a caller is waiting on the line. Ringers can be electronic devices in which an integrated circuit is used to detect the ring-signal bursts delivered by the Central Office and a buzzer that generates the audio sound that alerts the recipient to an incoming call. Texas Instruments' TCM1506 is ideally suited as a telephone ringer device.

A conventional telephone instrument may use electromechanical bells, but modern phones generally use an all-electronic ringer assembly like the one shown in Fig. 4.

A conventional electromechanical ringer consists of little more than a coil of wire wound around an iron core to create an electromagnet. A capacitor with a value of about 0.1 microfarad in series with the coil dc isolates the ringer from the telephone line so that the coil will not draw loop

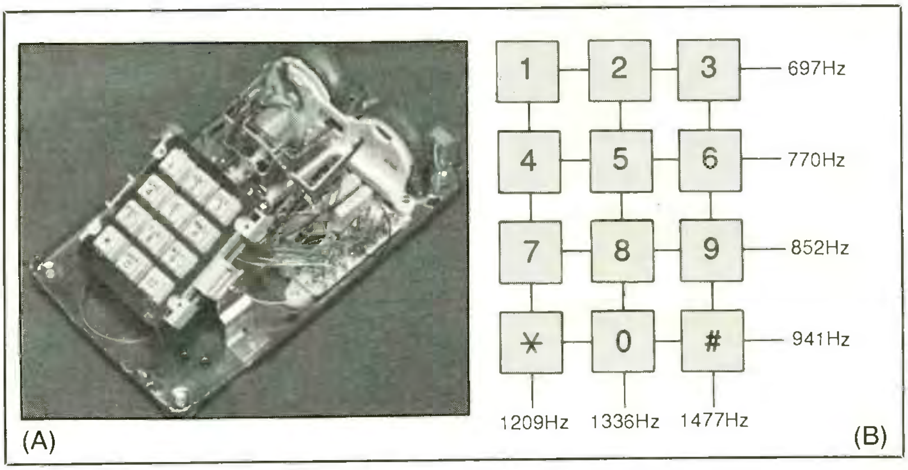
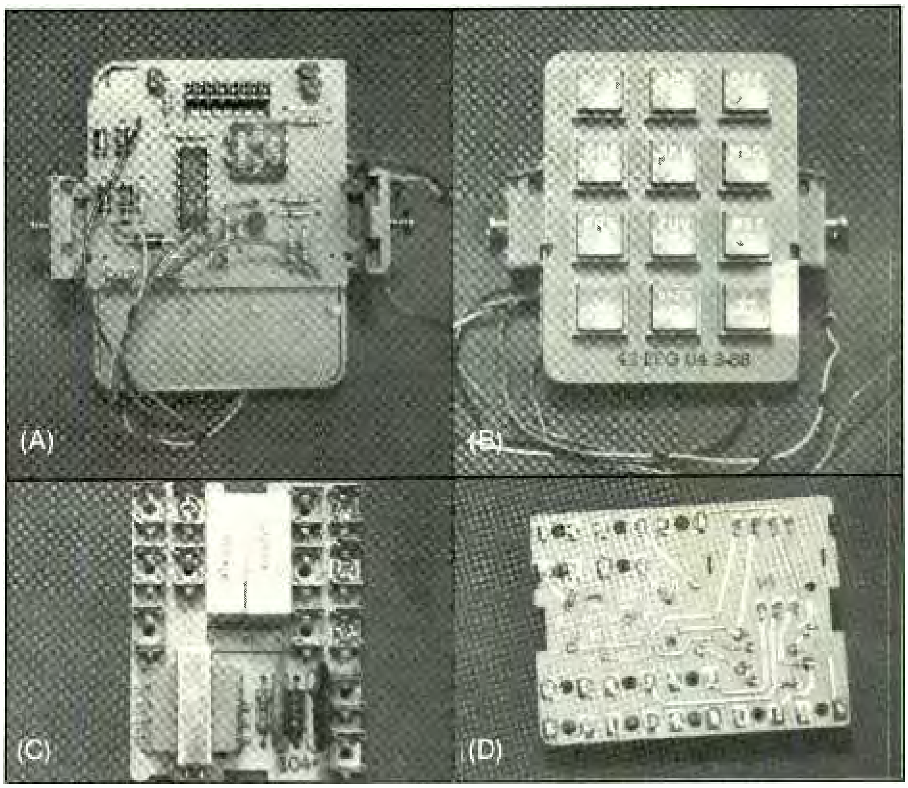



*Fig. 3. The DTMF Touch Tone keypad mounted in a standard telephone instrument in (A) shows network, dual ringer and hookswitch assemblies, while (B) illustrates the frequency pairs generated by each key closure.*




Shown in (A) and (B) are front and rear views of a 4200 EPG DTMF-type dial pad assembly, while in (C) and (D) are shown front and rear views of standard 2500-type network assembly.

current when the phone is on-hook. The capacitor passes only the ac ring signal when it appears on the line.

Central Offices in the United States signal telephones by means of an ac voltage whose magnitude can range from 90 to 120 volts rms. For most telephone instruments, the frequency of the ring signal is 20 Hz. The on/off intervals of this signal are called the "ringing cadence." In the U.S. this cadence is broken up into 2-second on and 4-second off intervals, as in Fig. 5(A). In other countries, like the United Kingdom, the cadence is a bit more complicated and consists of dual bursts of 0.4 second separated by a 0.2-second delay, as shown in Fig. 5(B). Each dual burst is separated by a 2-second pause.

The most common type of ringer used in conventional telephone instruments is the straight-line, or non-frequency-selective type that rings at *any* ring-signal frequency. On a party line, where several customers share the same telephone line, a different ring frequency is used to alert each customer to their incoming calls. A frequency-selective ringer in each subscriber's instrument on a party line assures that only one instrument rings when a specific number is dialed. Party lines are of only passing interest here because they are not very popular in the U.S. today.

(5) HANDSET. In the handset assembly are located the transmitter and receiver units for the telephone instrument.

The receiver is an electromechanical device that recreates the transmitted audio-frequency sounds the originating instrument sends over the telephone network. It consists of a rigid metal diaphragm placed over a permanent magnet and a coil of wire wrapped around the magnet. As voice-signal current flows through the coil, the resulting magnetic field interacts with the permanent magnet's field and causes the diaphragm to vibrate. Sound energy created by this vibration is a fairly faithful reproduction of the original voice.

The transmitter converts sound vibrations into an electrical current that varies in amplitude and frequency in step with the sound energy impinging on the microphone element. Like the receiver, the transmitter is essentially a rigid metal diaphragm mounted over a capsule containing carbon granules. As sound energy strikes the diaphragm, the capsule is expanded and compressed to cause resistance changes in the carbon granules. These changes in resistance cause voice-signal current to vary, thus creating an electrical signal that is transmitted through telephone network equipment to the phone at the other end of the line.

Electronic telephones may use new electrodynamic and electret microphones in place of the traditional carbon-granule element. Such microphones are rugged and low in cost, making them ideal for telephone applications.

Modern telephones that have built-in speakers and microphones provide the convenience of "hands-free" operation and come with a "mute" feature. In its simplest form, the MUTE button, when pressed, turns off the external microphone in the instrument so that no sound at all is transmitted to the party at the other end of the line.

These, then, are the five major elements that make up any telephone instrument. They are summarized in Fig. 6.

## *Central Office*

Your local Central Office is the common point to which all telephones in your local exchange are wired and which provides the means by which you can connect through to parties located outside your local CO, as il-

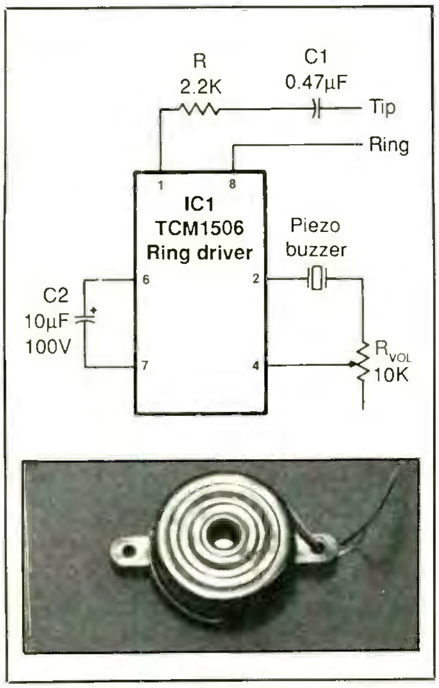



*Fig. 4. A typical all-electronic ringer circuit built around a Texas Instruments TCM1506 ring-driver IC. Also shown is a photo of a piezoelectric buzzer typically used in telephone ringer applications.*

lustrated in Fig. 7. It is the Central Office that generates the ring signal, dialtone and −48 volts dc required to power and operate your telephone instrument and all others connected to it. The Central Office also interprets the signals from your telephone's dial pad and performs all switching functions that connect your instrument to the instruments of other parties being called.

Your Central Office has a unique number that identifies it to the telephone network. It is the so-called "exchange" and consists of the first three digits of your telephone number, exclusive of any prefixes and area code. For example, if your number is 555-1234, your telephone instrument is connected to Central Office number 555. With four digits remaining in the seven-digit number, your local Central Office can handle up to 10,000 instruments with unique numbers (555-0000 to 555-9999).

Voice signals travel between the telephone instrument and Central Office over a single pair of wires that are traditionally identified as the "tip" and "ring" conductors. These names originated in early telephone installations wherein all "switching" was done by operators who manually plugged and unplugged cables terminated in phone jacks to make the instrument-to-instrument connections. The jacks into which these plugs were plugged had two contacts: the "tip" which made contact with the ball-like tip on the phone plug and the "ring" that made contact with the barrel-shaped common portion of the plug. In modern usage, the tip conductor is always color-coded green, the ring conductor always red.

With the telephone instrument's handset on-hook, −48 volts dc appears across the tip and ring conductors connected back at the Central Office, as shown in Fig. 8(A). With the phone on-hook, the instrument is in its "idle" state and no current is drawn by it. The weight of the handset resting on the hookswitch keeps the dial unit, transmitter, receiver and network disconnected, leaving only the ringer connected across the telephone line.

Lifting the handset from the cradle closes the hookswitch and places the remainder of the instrument's elements across the line. The loop voltage on the line now drops to about −6.5 volts dc and a loop current begins to flow. (Loop current can range from 15 to 30 milliamperes.) When the Central Office detects this current, it knows that your phone is off the hook and sends down the line a continuous dialtone, as depicted in Fig. 8(B). The standard dialtone is a mixture of 350- and 440-Hz frequency tones. When you hear the dialtone, you can begin dialing. As you dial, your instrument sends back to the Central Office pulses that correspond to the digits of the number being dialed, as shown in Fig. 8(C).

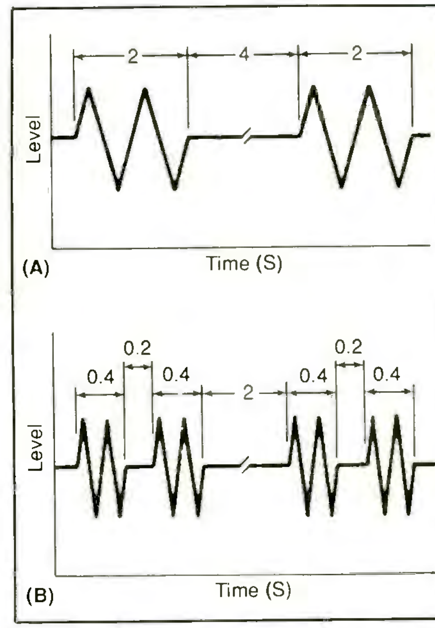



*Fig. 5. Ringing cadence used in U.S. and Europe (A) and in United Kingdom (B).*

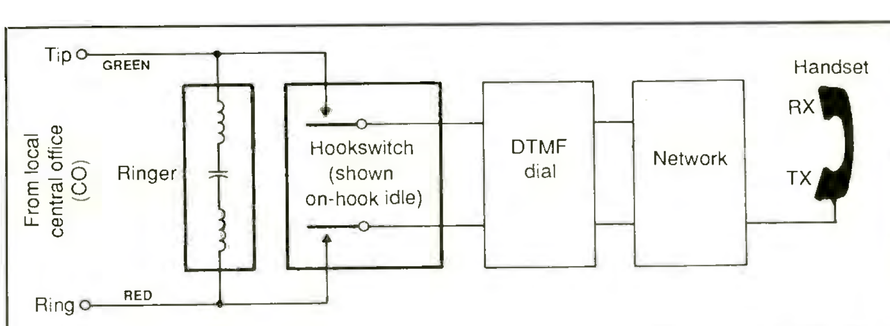



*Fig. 6. Simplified diagram of a conventional single-line telephone.*

The destination phone (the party you are calling) is specified by the sequence of the digits dialed. When the Central Office receives the first digit or pulse, it removes the dialtone from the line. Then, after all digits have been dialed, the Central Office checks to see if that station is active or not.

If the instrument you dialed is busy (off-hook), the Central Office sends a busy signal back to your phone, as in Fig. 9(A). A typical busy signal is made up of 480- and 620-Hz tones that are generated for 0.5 second, with 0.5-second pauses between each pulse.

If you dial a phone that is on-hook, the Central Office sends to it a ring signal and to your phone a ringback signal. The ringback signal is a mixture of 440- and 480-Hz tones that are generated at a rate of 2 seconds on and 4 seconds off, as shown in Fig. 9(B). When the party being called lifts his instrument's handset, the Central Office connects together the two stations and stops all signaling. Conversation can now take place, as in Fig. 9(C).

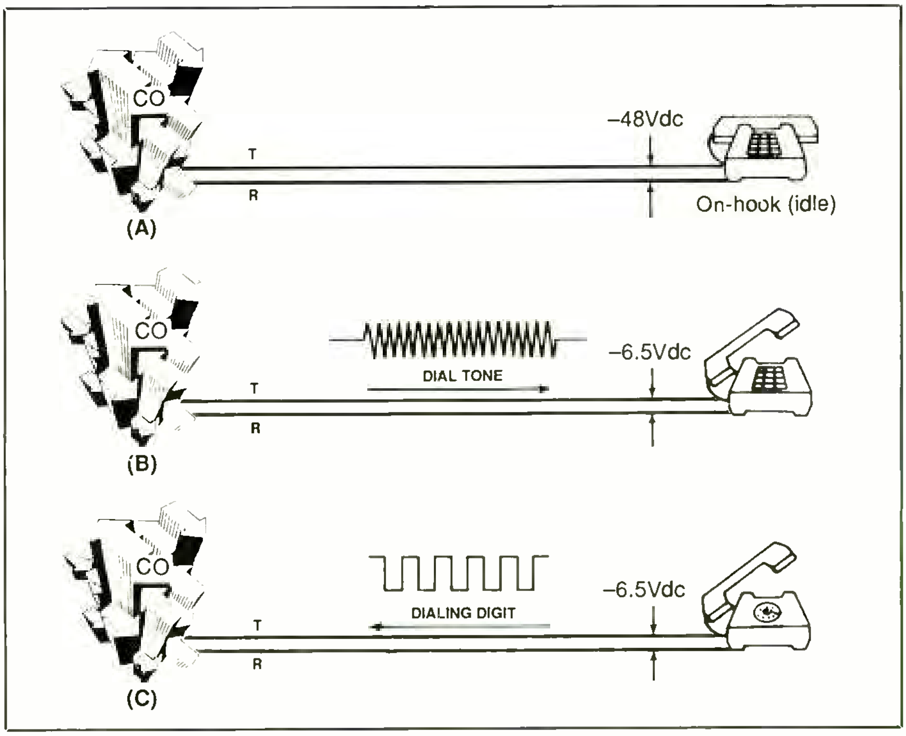



*Fig. 8. These drawings show originating station conditions: (A) on-hook; (B) off-hook and drawing a dialtone; and (C) off-hook and dialing out digits.*

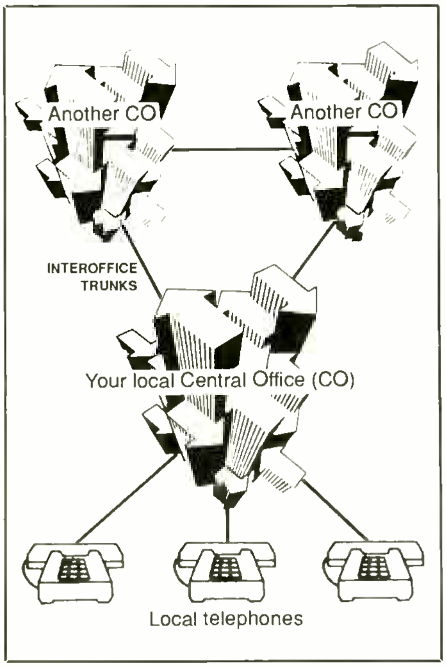



*Fig. 7. All local phones connect to a Central Office, which is responsible for interconnecting instruments within its exchange area and connecting its local phones to other Central Offices for out-of-area calls.*

Many modern multi-line telephone instruments now feature a "hold" function that makes it possible to have more than one line ring at the instrument. There will be additional keys on the instrument that permit selection of each individual line. Alongside or nearby will be the HOLD button.

The hold function is essentially a device that draws loop current to keep a line open but disconnects the network, dial, transmitter and receiver if you hang up. When a line is on hold, you can actually hang up or access another line to hold a conversation with another party.

When a HOLD button is pressed, a resistor is connected across the telephone line to draw current. At the same time, mechanical linkages cause the line in use to disconnect from the circuit. As long as the resistor is across the line, drawing current, the line from the Central Office will remain open and the instrument at the distant end will remain connected (assuming, of course, that it remains off-hook).

## *Installation*

Installing a telephone instrument in a location where a jack does not exist is a fairly simple, straightforward procedure. To begin, you need an RJ11 or RJ14 modular-type jack. Many retailers, such as department, hardware and Radio Shack stores carry an assortment of jacks to suit just about any given installation requirement, as well as cables, connectors and tools for telephone installation work. Tools needed to do the job include a slotted-blade screwdriver, diagonal cutters, a staple gun to secure exposed cable, and a drill with a long bit if you need to run cables through walls or/and floors. You may also want to have handy a multimeter to

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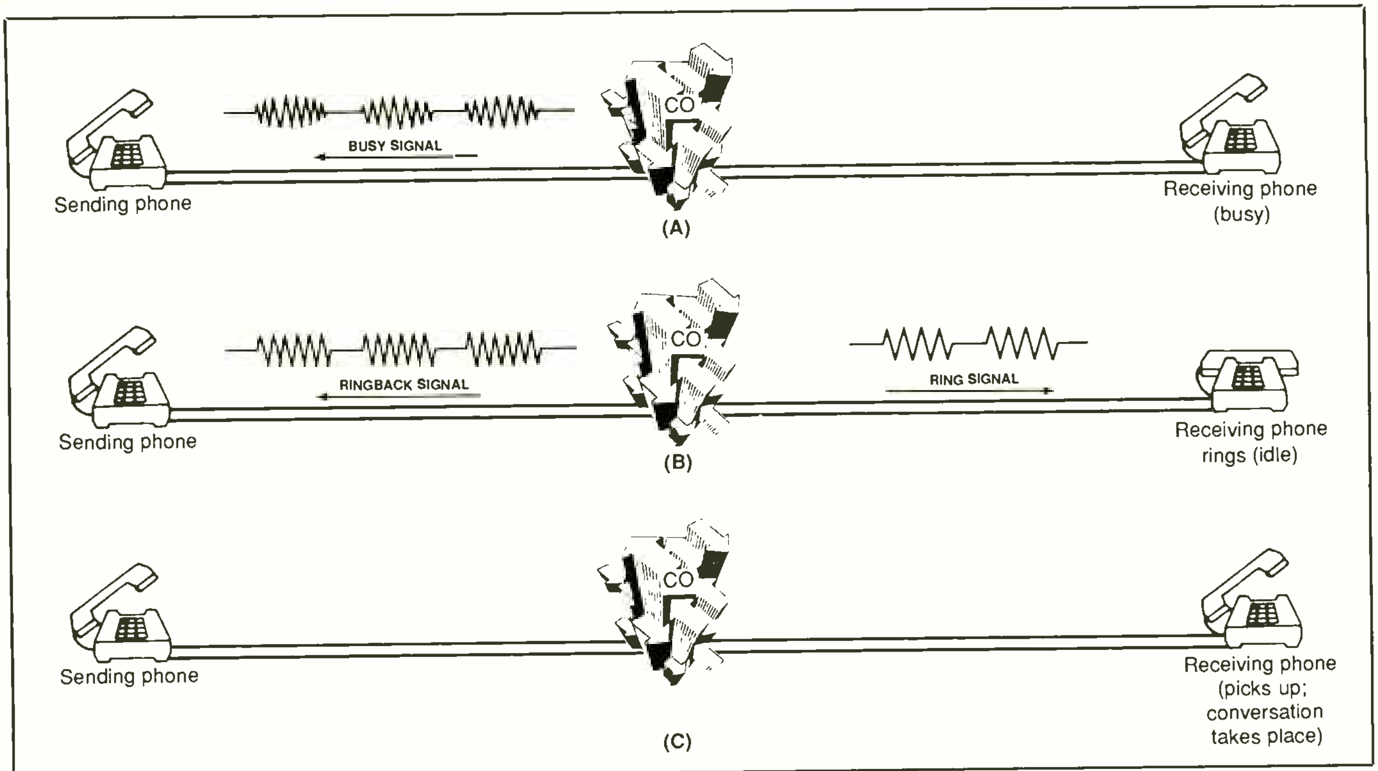


*Fig. 9. Central Office returns to an originating instrument a busy signal or a ringback signal when the phone being called is (A) off-hook or (B) on-hook. It makes a through connection (C) when the receiver of the instrument being called is picked up.*

check your wiring when you are done with the installation.

The installation procedure is as follows:

(1) Choose a convenient location in which to mount the new modular jack. A secure surface, such as a wooden baseboard, is always a good choice. If you must mount the jack on a masonry surface (plaster, sheetrock, etc.), secure it in place with plastic screw anchors. When deciding on a mounting location for the jack, always steer clear of ac wiring and plumbing, especially if you must drill through walls or floors. A typical installation is shown in Fig. 10.

(2) Decide now from where you are going to take the telephone signal. The easiest place may be an existing jack in another nearby room, a hall, etc. Route the cable that will connect the new jack to your existing telephone wiring along a path where you will be able to hide the cable if you can, or where it will not be obtrusive if it must be out in the open, such as along floor molding and around door frames.

(3) Remove the cover from the box at which you are going to make the connections to the new jack to expose wiring and terminals of the connector block. If the pick-off is to be from an existing box to which the incoming telephone line is connected, remove the jack's protective cover. If you are taking the telephone line for your new phone installation from a wall-mounted jack, remove the jack from the wall.

(4) Loosely run telephone cable from the new jack to the pick-off source, snaking it through walls and floors as needed. Leave 12 inches or so of slack at both ends of the cable run.

(5) Carefully remove about 5 inches of outer plastic jacket from the cable at the source end. If you use a utility knife or diagonal cutters to do this, make sure you do not cut through or nick any of the conductors inside the plastic jacket. Having removed the plastic jacket, you will see four conductors with green, red, yellow and black insulation. Strip ½ inch of insulation from all four conductors at this end of the cable.

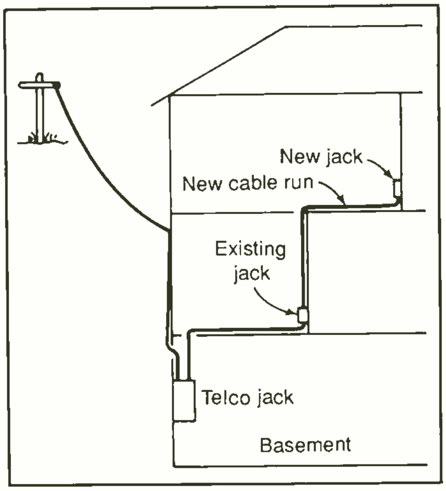


*Fig. 10. A typical residential telephone wiring scheme.*