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Inside Telephony Wiring

Introduction

Over the past nine issues of *DigiPoints*, we have discussed current and evolving terminal equipment and its interconnection. In particular, the issue on Home Networks noted that the most prevalent, highly supported, and fastest growing method of interconnection of devices in the home is via existing phone wiring. Given the importance of this wiring media, it is important that cable telecommunications technical personnel understand the standards for connectors, media, and installation of phone wiring.

This issue of *DigiPoints* covers phone wiring installation inside a residence. It discusses the following items as they relate to single family residences, multiple dwelling residential units, and home office installations:

- Demarcation Point (DEMARC)
- Wiring Topology
- Wiring Media
- Jacks
- Installation Procedures

Importance of Inside Copper Phone Wire

Looking at the history of telephone plant, it is apparent that copper wire has remained the mainstay of telephony media inside the home despite numerous changes in telephone outside plant and the shift of responsibility for inside wiring. Early in the history of telephone communications, dial tone came to the residence via twisted pair wire. Inside the home, telephones were connected to the network through copper wire running to an interface device. The original purpose of the interface device was to protect equipment at the subscriber's location from lightning. The copper wire in the home was installed and owned by the telephone company.

In the 1960s, telephone companies improved their distribution networks by deploying pair gain devices. This new equipment increased the maximum distance from a subscriber to the serving telephone office and the number of customers that could use one pair of wires. In the 1980s, the telephone companies transferred ownership of inside wiring to their customers as part of divestiture. Further changes to the outside telephony distribution plant have occurred in the past 20 years, including extension of fiber optics closer to the home and introduction of alternate local service providers, including the cable telecommunications industry. Inside the home, the number and type of terminal devices attached to the telephone network has increased dramatically. Copper wire pairs, however, are still used to deliver the majority of voice and data information to these terminals in the subscribers' homes.

Characteristics of Residential Copper Phone Wiring

The standard phone wire found in a residence is four untwisted, unshielded wires in a plastic sheath. It is called D-Station or Quad-wire. (See Figure 1.) Note that of the four wires, only two, the "tip and ring," are needed to connect a voice or data terminal to the network. The other two are "extra" and may be used for:

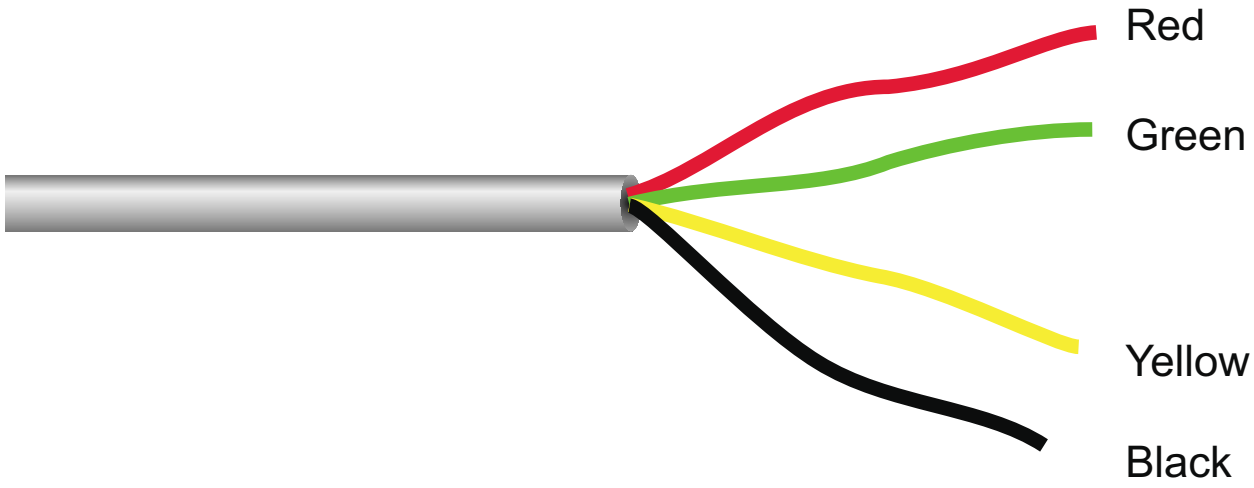

Figure 1: D-Station or Quad-Wire

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- Spare wire, in case one of the other wires is damaged.
- Transmission of telephony power (-48 VDC, not commercial 110 VAC), for auxiliary device operation, such as lighting buttons on a terminal.

The standard manner of connecting D-Station wire is to use the RED and the GREEN wires as the "tip and ring". The tip and ring terminology is a holdover from the days of the telephone switchboard. Because RED and GREEN are standard colors for these leads, in theory the installer can extend loops by connecting red to red and green to green. Unfortunately, field installations will have several variations in the colors used for tip and ring. (See Figure 2).

Standard Colors	Variation A	Variation B	Variation C
Red	Blue (White Bands)	Blue (White Bands)	Blue
Green	White (Blue Bands)	White (Blue Bands)	White (Blue Bands)
Yellow	Orange (White Bands)	Orange (White Bands)	Orange
Black	White (Orange Bands) Green (White Bands) White (Green Bands)	White (Orange Bands)	White (Orange Bands)

Figure 2: Field installations will have several variations in the colors used for tip and ring

For example, the two extra wires in the Quad-wire may also have been used to install a second telephone line. This frequently works without any problems. However, it can induce cross talk (inductive coupling of the lines, resulting in a user on one line being able to hear the conversation of a user on the other line.) Because of this susceptibility to cross talk, D-Station or Quad-wire should never be used for multiple lines, multiple line sets, key telephone systems, digital (ISDN) voice/data terminals, or data applications. Twisted pair wiring is the preferred media for these applications.

The standard in commercial installations, and in new homes where data applications are likely to be found, is a jacketed unshielded cable that contains four twisted pairs. The advantages of twisted pair and how they are achieved will be discussed later. For the time being, however, note that there are different grades of twisted pair, and not every grade is suitable for high-speed data application.

As mentioned earlier, in most single-family residences, twisted pair has not been used for telephony wiring. D-Station wire is the most common media — so common that it can be purchased at the local hardware, grocery, or drug store. Since homeowners can obtain D-station wire so easily and at a reasonable cost, they usually do not take much time to learn proper installation techniques, and unwittingly introduce potential trouble conditions. Kinked wires, for

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example, can develop into broken wires. Wires run near electric motors or 110 VAC circuits are susceptible to inducing AC hum into the telephone circuit. Problems can also develop when the consumer departs from the norm, and uses speaker wire or lamp cord to carry the signal.

The good news is that D-wire is optimized for most simple installations of residential telephony. It carries the full range of voice grade signals (100 – 4,000 Hz) and the DC used for signaling and line supervision. It is also easy to install with basic tools.

Tools and Supplies for Residential Telephony Installation

Many telephony installation tools are already part of a cable installer's toolkit. Most applications will require the equipment listed below, grouped by the task where it is used.

- Installation of new wire and jacks:
  - Flashlight
  - Stapler and staples
  - Level
  - Stud sensor
  - Drill and drill bits, including long shaft and carbide tip bits
  - Measuring tape
  - String and weight
  - Hand-held vacuum cleaner
- Telephony Wire and Jack Preparation:
  - Wire cutter and stripper appropriate for 18–24 gauge wire
  - Screw drivers – standard, and phillips
  - Set of nut drivers in commonly used sizes (1/8-, 1/4-, 3/8-, 1/2-, 5/8-inch)
  - Scotchlok crimpers used to connect the wire to the plugs
  - Pliers – needle nose, curved needle nose
  - Utility knife
- Testing and Troubleshooting:
  - Installer's line set (a.k.a.: butt set)
  - Tone generator (toner)
  - Volt-Ohm Meter

The use of this test equipment is discussed later.

Finally, the installer will need supplies to complete the installation, such as jacks, wire, faceplates, clips, and screws.

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Single Family Residential Telephony Installation

Inside installation begins at the Network Interface Device (NID) or Network Interface Unit (NIU). Examples of these are shown in Figures 3 and 4. This is the demarcation point that the installer or the homeowner can monitor to confirm that there is dial tone coming from the service provider's network equipment. Although the terms NID and NIU are generally interchangeable, for the rest of this issue, we will refer to the cable company's device as the NID, and the telephone company's device as the NIU. For cable telecommunications installation, it is assumed that the coaxial cable has already been installed to the NID and that the installer has properly installed the unit and all connections to power and ground.

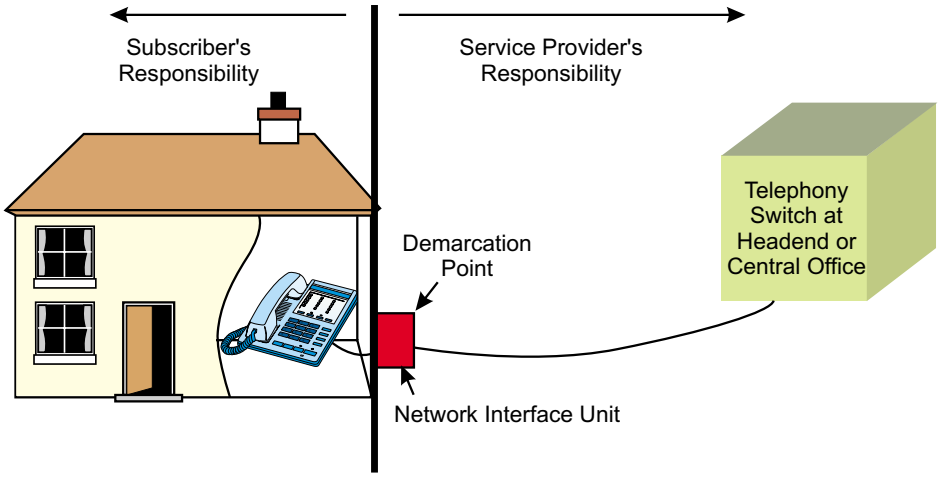

Figure 3: Network Interface Device (NID)

The remainder of the installation job is simplified if the installation is taking place at a residence that already has telephone service. In this case, the customer is transferring all or part of their service to the cable company and existing inside wiring may be reused.

Figure 4: Network Interface Unit (NIU)

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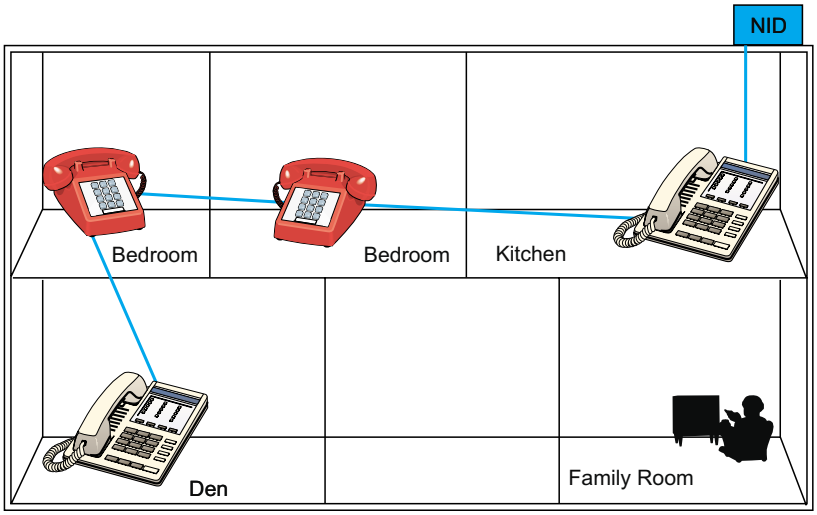

Figure 5: Loop Method

Beyond the demarcation point, there are two basic methods of installing residential station wiring. The first is called the Loop Method (Figure 5), where the person installing the telephone jacks runs a continuous strand of wire from jack to jack throughout the house. Loop wiring is the least costly method because it is easy to do, and requires the least wiring. It is also more difficult to troubleshoot and modify, since every telephone is literally an extension of the previous telephone[1]. The second method is the homerun or star method (Figure 6), where there is a separate cable run to each telephone jack.

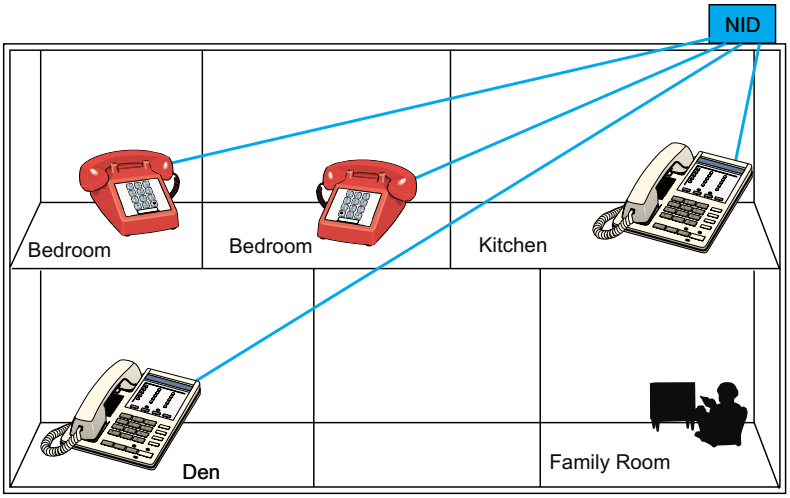

Figure 6: Homerun or Star Method

1 As indicated in the Home Networking issue of *DigiPoints*, in terms of data networks, loop wiring is a branch topology.

Most field telephony installations are hybrids of loop and star wiring (Figure 7). Because there are no guarantees that any of the installation work has been done correctly, it is imperative that the installer check and document the presence or lack of dialtone at every jack prior to performing any installation work. This is an important test even if the only task is to move wiring from the existing service provider's NIU to the cable company NID. Only by checking the status of each voice and data terminal jack before starting any work does the installer know what was working before the installation work began. A simple list of rooms with jacks, such as that shown in Figure 8, is a helpful job aid, and can be used in a discussion with the customer to verify all jacks have been examined.

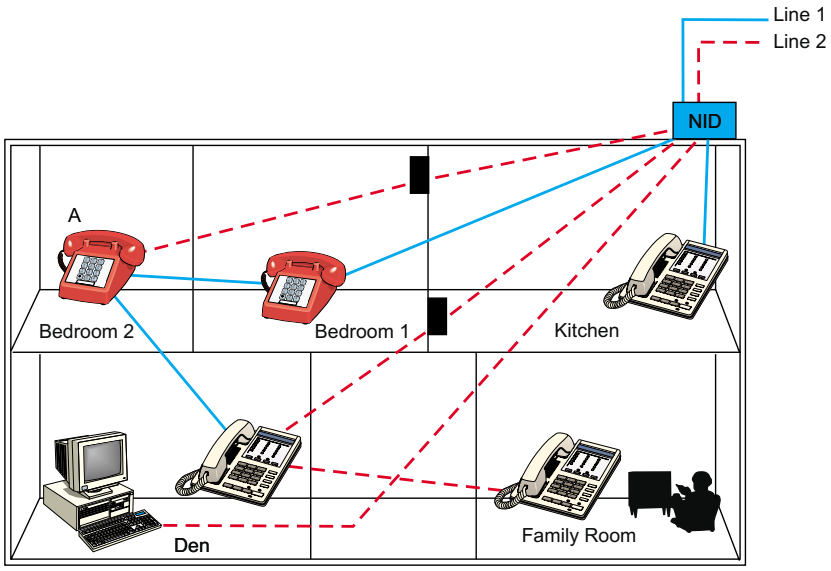

Figure 7: Hybrids of Loop or Star Wiring

Installers need to be aware that residential customers may have multiple lines entering the home. Each line will have its own phone number, and the customer's telephones may terminate one, two or possibly more lines[2]. In addition, the installer will encounter facsimile machines, telephony modems for computers, multi-line telephone sets, multiple appearances of different lines, etc. The customer may only wish to move one line to the new service or, alternately, want to keep one line with the current service provider. Testing for dialtone at the jack using a butt set (described later), rather than by just verifying dialtone at existing equipment, avoids the difficulty of needing to understand the operation of various types of customer equipment.

2 The use of the term "line" here refers to both the physical connection to the network and the telephone number assigned.

Room	Number of Jacks	Dialtone (Y/N)
Bedroom 1		
Bedroom 2		
Bedroom 3		
Bedroom 4		
Kitchen		
Den		
Family Room		
Basement		
Other		

Figure 8: Installer Checklist

The easiest installation is one in which everything is left in place and only the main line is changed. Once dial tone/service has been confirmed at the cable company NID, the installer merely needs to disconnect service on the customer's side of the NIU provided by the other service provider (e.g., the local telephone company) and make the connection to the new service at the cable company NID. This requires identifying the appropriate terminations at the entrance to the residence, but would not require any new or changed wiring beyond that point.

The next easiest installation would be if the installer were adding a line (i.e., Line 2 in Figure 7) strictly for service to only part of the residence. The installer would need to run new wiring (home run) to the new jacks being installed for this service. A variation would be where a new line was being installed and the new service was being extended to only a limited number of the existing jacks. If the existing wiring is a homerun to each of the desired jacks, the installation is still relatively straightforward: the installer merely needs to identify the pairs from the jacks to the demarcation point and move the demarcation point termination to the new NID. Unfortunately, real life is seldom this easy.

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Once again, refer to Figure 7. The telephone labeled A is connected to a jack that is one point on a loop run. If the customer has requested the new line to only appear at A, a new homerun must be made to a new jack for phone A, since A is currently an extension of the line in bedroom 1. Reuse of the existing jack is not recommended, since the connection between bedroom 2 and the den must be removed, along with the connection to bedroom 1. Once this happens, if the customer wants a line from the existing service provider to appear at the multiline set in the den, the customer must arrange for a new homerun to a jack in the den. Needless to say, in any of these situations, once the installer works on any part of the wiring system, it is the installer's responsibility to make sure everything is connected and working correctly before departing. Thus, the need to be able to troubleshoot the system[3].

For readers who want more detail on residential wiring, this subject is covered by EIA/TIA-570-A. (EIA is the Electronic Industries Alliance, and TIA is the Telecommunications Industry Association).

Telephony Installer Test Equipment

Three pieces of equipment are crucial to completing a telephony installation: a tone generator and associated probe, a volt-ohm meter, and a lineman's test set. The tone generator and lineman's test set are shown in Figure 9.

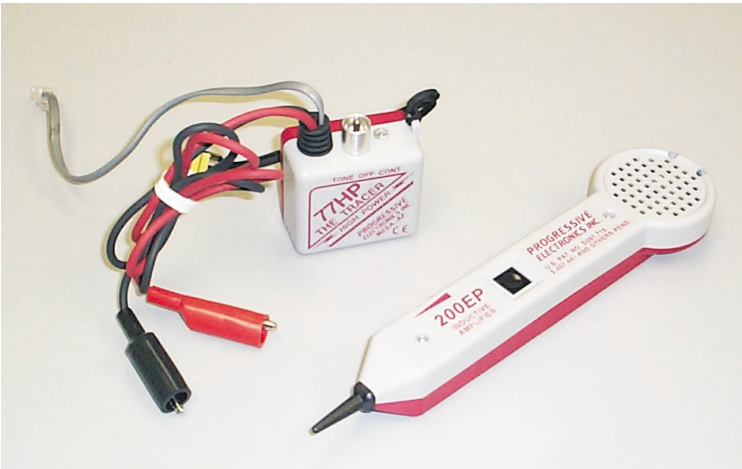

Figure 9a: Tone Generator

3 This example highlights the difficulties involved in installing new service for a customer that wants to also keep service with the incumbent service provider. The cable company would probably want to limit its support to wiring associated with the cable company's lines; however, reusing existing jacks requires the installer to disconnect wiring to jacks served by the other provider. For these reasons, operators usually try to market a total commitment to phone service from the cable company. Many operators carry the philosophy further still and will only install service to the demarcation point, leaving the responsibility for inside wiring to the consumer.

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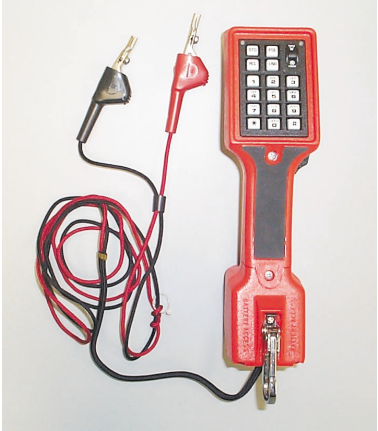

Figure 9b: Lineman's Test Set

The tone generator and probe together are used to identify specific wires, their route and location, and where the wires are broken or terminated in the system. The tone generator transmits current of a specific frequency down a wire. The inductive probe detects the tone as it travels along the wiring. The probe can detect and monitor the tone without actually being physically connected to the wire itself; thus it works through walls or where multiple wires are found.

There are a variety of tone generator test sets available, including those that can send multiple distinct tones which the probe can detect down different wires. Multitone capability makes it possible for the installer to track multiple paths in a wiring system. Obviously, an installer working in single family residences would need a less sophisticated model than one working in larger multiple dwelling unit or commercial buildings. It is worth noting that because the probe is inductively coupled to the wire, the tone generator and probe test sets do not work with wire that is in a conduit nor with shielded twisted pair wiring.

A volt-ohm meter provides a simple way to test for opens and shorts in the wiring system. It can also quickly determine if two wires are crossed or shorted to each other.

The lineman's test set, also known as a "butt set," is a versatile device that looks like a telephone handset[4] This piece of equipment allows the installer to bridge onto wire pairs for the purposes of dialing out, receiving calls, or just to listen to the line in order to make a subjective judgement of the quality of the received signal. Some of these lineman test sets can also provide information on polarity and line voltages.

These three pieces of equipment are most useful in initial tests of existing wire, prior to new service installation. Figure 10 illustrates typical fault conditions which may be encountered.

4 Several versions of the origin of the term "butt set" exist, but the following two seem most logical. The tool is used to "butt in" on a line, and it is commonly worn on the installer's belt near the lower posterior part of the body.

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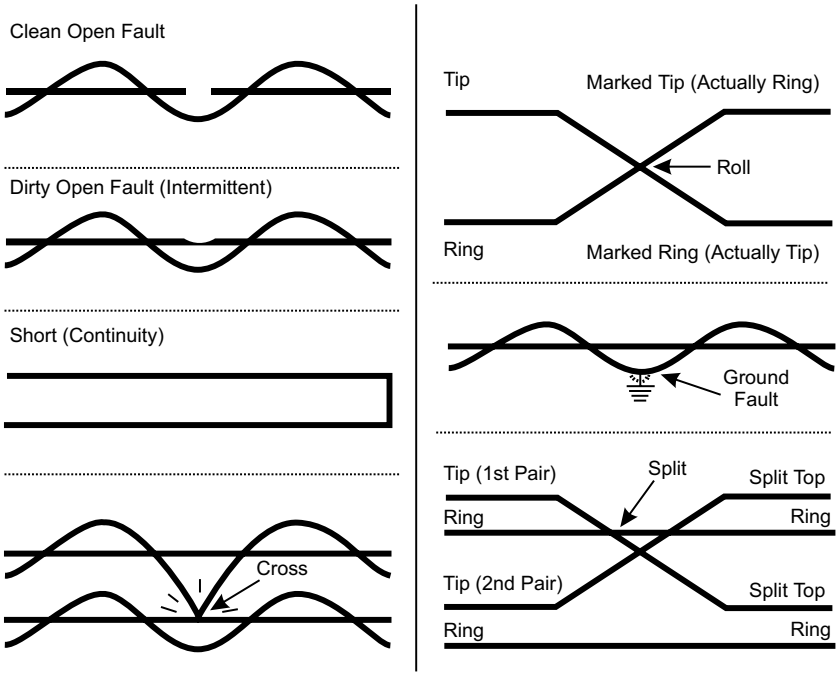

Figure 10: Typical Fault Conditions

Troubleshooting After Installation

Three basic problem conditions can materialize after installation work. These are: no dial tone, noise on the line, and dial tone continues when a number is dialed.

No dial tone

If the installer cannot detect dial tone at the telephone jack, the first thing to do is to make sure there is dial tone at the NID. This is accomplished by isolating the home wiring from the network at the NID and using the installer's butt set to detect the presence of dialtone at the NID. A typical cable telephony NID has an RJ-11 telephony jack where the installer can disconnect house wiring by either unplugging an RJ-11 connector that is within the NID and replacing it with the RJ-11 connector attached to the lineman's test set, or by inserting an RJ-11 connector from the lineman's test set into a special RJ-11test jack.. If dialtone is found at the NID, the installer can begin troubleshooting inside the house.

Since the installer confirmed that each jack was working PRIOR to doing any work, the assumption is that there is continuity up to the connection to the jack. The next action is to check the work that was performed for loose connections or broken wires. If this checks out, the installer will want to check the wire between the jack and the NID for continuity, ensuring no opens have been introduced into the line during the installation. In addition, the installer will want to confirm that wires were not inadvertently crossed. The tone generator and probe are useful in identifying crosses.

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Hidden problems that may cause the trouble to persist are bad jacks or previous work that went bad as the installer was working on the wiring system. It is possible that when working around a jack or connection that the installer jarred or pulled something loose.

Noise on the line

Noise on the line can be caused by a faulty NID or malfunctioning customer terminal equipment. Since the NID is the source of dialtone in a cable telephony system, the first step is to test for clean dialtone at the NID. The procedure is the same one used at the beginning of troubleshooting for absence of dialtone. If clean dialtone is found at the NID, the next step is to troubleshoot each jack and terminal in the house. Customer terminals at each jack in the house should be progressively disconnected, and the lineman's test set inserted at each jack to monitor the condition of the dialtone at that jack. If noisy dialtone is still present when all devices are disconnected, the problem is in the wiring.

A common source of noise in home wiring is a loose connection in a jack or wire connector. Check to ensure ALL wire connections are both clean and tight. Station wiring can be damaged relatively easily if the installer puts too much stress on it during installation. Stress on wiring can cause intermittent noise even if the wire is not completely broken. Check to see if any wiring is pinched, nicked, kinked, or stretched too tightly around a sharp corner. If any of these conditions exist, the wire is probably damaged and needs to be replaced. Also check to make sure that none of the wiring has been exposed to water. Sources of heat, such as a hot water pipe or steam pipe, can also cause static on the line. Another potential noise source is electrical interference. Make sure all telephone wires and jacks are installed clear of any electrical wiring and electric motors. Finally, even if everything else is done correctly, the telephone wire can act as an antenna and will, under certain circumstances, pick up local radio stations. A filter may be used to block this type of interference.

Dial tone continues when a number is dialed

This normally occurs when the polarity is reversed, (i.e., when the "tip" and "ring" leads are reversed). After determining that dialtone can be drawn and a number can be dialed at the NID when it is disconnected from the house wiring, the installer needs to check the polarity of the tips and rings that were installed.

Note that better, newer model touch tone telephones automatically correct for this condition. The situation can therefore exist that one voice terminal (newer) successfully breaks dial tone and another terminal (older) does not. Reversed polarity can also affect the ability to transmit the multifrequency (MF) tones used for tone dialing. True tone telephones actually produce a multi-frequency (MF) tone to signal the number being dialed. These instruments can be identified by the suffix of TE-T on the FCC registration number.

Touch dialing telephones with the suffix of TE-R on the FCC registration number do not output MF. Instead, dial pulses, as found on rotary telephones, are sent to the network., and reverse polarity will not affect the signals. Note that older, rotary dial telephones are also immune to polarity problems.

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Troubleshooting Summary

Any problems must be found and corrected when the installer does the final tests and prior to turning the system back to the customer. The testing and trouble resolution is necessary to maintain customer satisfaction, thereby protecting not only revenue dollars, but controlling expenses. The installer should constantly be watching for and correcting grounds, shorts and opens. Basic tests include:

- Visually making sure that the wire is color matched (red to red, black to black, blue-white to blue-white, etc.), that the access lines are correctly connected to the inside wiring, and that the "Tip" (+) and "Ring" (-) are connected properly.
- Confirming continuity of each cable run. The tone generator can be used to verify continuity.
- Correcting shorts, which can be caused by improperly stripped conductors or by a staple or nail.
- Correcting splits which can be caused by wires being improperly matched and cross-connected.
- Checking and correcting polarity.

Final testing confirms that the wiring system and the equipment connected to it work properly.

- Confirm that the jack(s) work with the butt set. Connect the butt set to the network via the jack(s).
- Make and receive calls to a test number. Listen for a clear connection free of clicks, scratches, pops, and other noises. Do this for each jack.
- Connect the customer's voice and data terminals to their respective jacks one at a time and confirm that the system is functioning.
- If a problem is again detected, troubleshoot and test again.

The end result of an installation must be that:

- All jacks work so that telephones can receive and make calls,
- The installed wiring is not unsightly, and
- The area is cleaned up.

Residential Multiple Dwelling Units

Most of the procedures for single family residences also apply to multidwelling units; however, because the building is shared by several tenants, there are other considerations that make the installation more complex. This section focuses on the added factors that must be taken into consideration when installing service at an apartment or condominium complex. As in the single family residence, it is assumed that the Network Interface Device has been installed properly.

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In some ways, the installation will be easier, since the living areas of multi-family units tend to be on a single level and to occupy fewer square feet. On the other hand, installation can be more difficult because of the problems associated with installing and pulling wire within shared walls.

This section will discuss the specific items that are going to impact the installer's work from the demarcation point to the customer's actual residential unit. Typically, the building wiring in existing MDUs is Category 3, unshielded twisted pair wire. Figure 11 provides an example of how this could be set up for a larger multiple dwelling unit (MDU). Underground fiber-optic cable from the cable company is entering the building from the right and terminating at a fiber node in an equipment room[5]. In this case, optical-to-electrical conversion occurs within the MDU. Coax from the fiber node completes the distribution for video signals within the MDU, similar to the way a distribution network is built in outside plant for single family residential service. Taps and/or amplifiers can be installed in small wiring closets on each floor of the building.

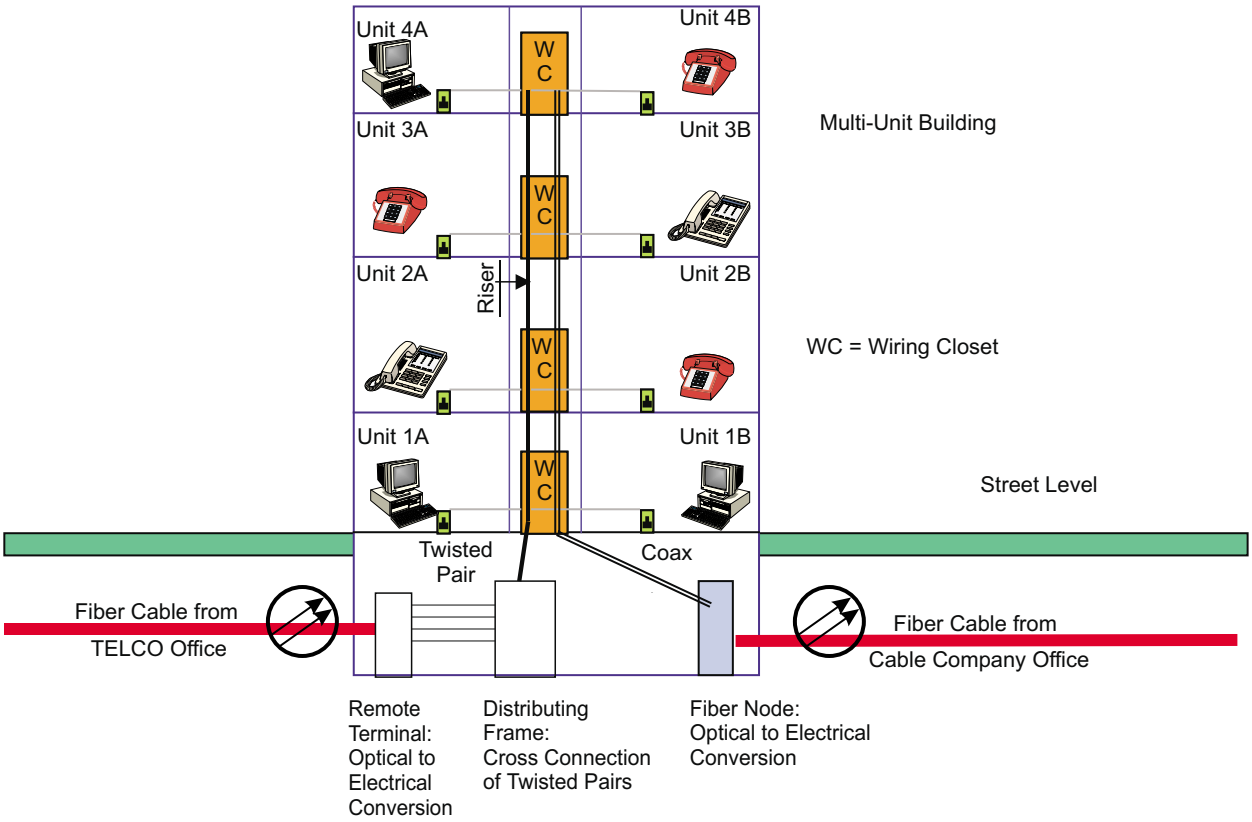

Figure 11: Multiple Dwelling Unit (MDU)

5 The example of a fiber node at the building entrance is not the only way for the cable company to provide service to the building. The assumption in our example is that the operator has fiber installed up to that point. A more common alternative would be to enter the building with coax distribution cable, terminated at a distribution amplifier.

In Figure 11, telephone service enters from the left of the building, also via fiber cable[6]. The fiber terminates at a telco Remote Terminal (RT) which is part of a loop carrier system.[7] Twisted pair subscriber line connections on the subscriber side of the RT are extended to a distribution frame. The distribution frame is the point where cross-connections may be made between semi-permanent connections to telephone line terminations and pairs of subscriber wires going to individual living units. In most cases, it is not actually a frame of equipment, but a simple mounting of a connector block to a wall or panel.

For both cable and telephone service, the lines from the equipment in the basement to the subscribers have been prewired during building construction. They are routed through a building riser between floors, and may be terminated at intermediate wiring closets at each floor. The ownership of this prewired building distribution system can be a point of contention between potential providers of communications services.

In the best case (for cable), the building owner has retained ownership of all telephony wiring from the basement through the building, including the distribution frame in the basement. However, in many cases, the telephone company has obtained ownership to wiring up to, and including, the equipment within the wiring closets at each floor, or has a maintenance contract for the wiring with the building owner. In these cases, it may be necessary for the cable company to rewire the building distribution to provide service. Often, the costs involved are beyond the potential for near-term profitability, and the cable operator may elect to not provide telephony service.

In this example, however, assume that the building owner has retained the ownership of the building wiring, and has elected telephony service from the cable company. The installer will have mounted the cable company's Multidwelling Unit NID on a wall or rack in the basement, and must cable it to the existing building wire. We also assume the NID has been properly provisioned and powered, and is fully functional.

The installer could expect typical riser wiring to be Unshielded Twisted Pair (UTP). In general, the wiring will be solid conductor of 22 – 24 AWG, bundled within a large cable with pair counts from 2 to 1800 pairs. Wires and bundles of wires within the cable are color coded to aid identification of individual cable pairs. Table 1 shows the standard color code assignment for pairs within a bundle, and Table 2 shows the color coding for binders of 25 pairs within a 600 pair cable.

6 Here again, the example of fiber to the building is only one way for the telephone company to provide service. A fiber connection would tend to be more prevalent in large buildings, located in denser, metropolitan service locations. Copper T-1 lines would be more typical in suburban service areas.

7 The remote terminal would most likely be a Next Generation Digital Loop Carrier (NGDLC). For purpose of comparing telephony and cable architectures, recall that this type of device is part of cable's circuit switched HFC telephony solution, embedded in a Host Digital Terminal.

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Pair Number	Tip Conductor	Ring Conductor
1	White/Blue	Blue/White
2	White/Orange	Orange/White
3	White/Green	Green/White
4	White/Brown	Brown/White
5	White/Slate	Slate/White
6	Red/Blue	Blue/Red
7	Red/Orange	Orange/Red
8	Red/Green	Green/Red
9	Red/Brown	Brown/Red
10	Red/Slate	Slate/Red
11	Black/Blue	Blue/Black
12	Black/Orange	Orange/Black
13	Black/Green	Green/Black
14	Black/Brown	Brown/Black
15	Black/Slate	Slate/Black
16	Yellow/Blue	Blue/Yellow
17	Yellow/Orange	Orange/Yellow
18	Yellow/Green	Green/Yellow
19	Yellow/Brown	Brown/Yellow
20	Yellow/Slate	Slate/Yellow
21	Violet/Blue	Blue/Violet

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22	Violet/Orange	Orange/Violet
23	Violet/Green	Green/Violet
24	Violet/Brown	Brown/Violet
25	Violet/Slate	Slate/Violet

Table 1: Color Code for 25 Pair UTP Cables

Note: The first color is the insulation color, and the second color is a marking stripe on the insulation. For tightly twisted pairs, the tip conductor may be the first color, and the ring conductor may be the second conductor, with no other markings.

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Pairs	Group Binder	Color
1-25	1	White/Blue
26-50	2	White/Orange
51-75	3	White/Green
76-100	4	White/Brown
101-125	5	White/Slate
126-150	6	Red/Blue
151-175	7	Red/Orange
176-200	8	Red/Green
201-225	9	Red/Brown
226-250	10	Red/Slate
251-275	11	Black/Blue
276-300	12	Black/Orange
301-325	13	Black/Green
326-350	14	Black/Brown
351-375	15	Black/Slate
376-400	16	Yellow/Blue
401-425	17	Yellow/Orange
426-450	18	Yellow/Green
451-475	19	Yellow/Brown
476-500	20	Yellow/Slate
501-525	21	Violet/Blue
526-550	22	Violet/Orange
551-575	23	Violet/Green
576-600	24	Violet/Brown

Table 2: Color Code for Cable Bindings Within a 600 Pair Cable

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UTP is also described in terms of categories and levels. This method of rating has been developed by the Electronics Industries Association (EIA) and the Telecommunications Industry Association (TIA). The ratings exist because of industry requirements to know the carrying capacity, [i.e., the speed or frequency capacity (rated bandwidth)] of twisted pair cable. The document covering cable ratings by category is EAI/TIA-568A. This document also covers jacks, patch panels, and cross-connect blocks. UTP categories and applications up to Category 5 are shown in Table 3 below:

Category-Level	Uses	Supported
CAT 1	Voice, Low Speed Data	1 MHz
CAT 2	Low Speed LAN, 4 Mb/s Token Ring	4 MHz
CAT 3	10 Base T Ethernet, 100 Base T4, 100 VG Any LAN	10 MHz
CAT 4	16 Mb/s Token Ring	20 MHz
CAT 5	100 BaseTX, ATM, TP-PMD	100 MHz

Note: Each category supports the capabilities of the proceeding categories, (e.g., CAT 4 supports CAT 1 – 4).

Table 3: EIA/TIA-568A Cable Specifications

Category 3 UTP is the minimum grade of cable that should be used in today's new voice installations. CAT 1 and CAT 2 are not acceptable; these categories will be found in older installations. CAT 5 wire is an unshielded twisted pair system that can carry high data rates, (e.g., LAN speeds) for short distances if the wire is installed correctly, including CAT 5 rated connectors and jacks.

For the sake of this discussion, the assumption is that the installer will be accessing the telephony twisted pairs from the distributing frame in the basement. The cross-connection point will probably consist of either a 66 or 110 block. (See Figure 12.) These blocks are built with an insulation displacing connector (IDC), that cuts through the wire insulation as part of the installation process. A special punch down tool is required for the connection to be made properly.

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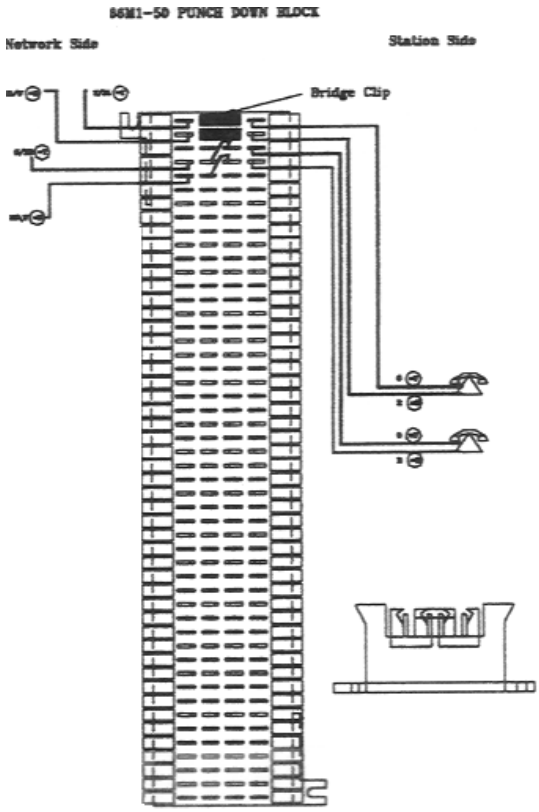

Source: Cable-Tec Expo 1997 Proceedings Manual

Figure 12: The cross-connection point will probably consist of either a 66 or 110 block.

The subscriber pairs may or may not be labeled. Even if the pairs are labeled, labeling can be incorrect. Therefore, a good place to use the tone generator and probe to ensure that the pair picked actually terminates in the appropriate unit and jack. It will be necessary to obtain access to the subscriber's apartment from the building owner. Put the generator on the cable pair appearance in the apartment and find where it terminates on the cross-connect, similar to the way line continuity was determined for a single family residence.[8]

Once the appropriate pair to the apartment has been verified, the installer can continue the work as if working in a single family residence. The troubleshooting requirements are the same as in the single family residence.

8 If there is an intermediate wiring closet in the path to the living unit, the installer could also connect the toner at the connection block in the wiring closet. In this case, the installer could compare pair colors to help identify the correct pairs. However, it would still be necessary to verify continuity to the jacks in the actual living unit.

MDU Installation Summary

The following are some basic rules to follow in order to obtain a good installation at an MDU.

- Minimize length of cable runs; minimize the number of connections on a line and do not splice cable runs away from the wiring closets or distribution frame.
- Protect cable from damage by concealing it; do not, however put it under rugs where heavy furniture can later damage it.
- Firestops, bonding, grounding must conform to local fire, building, and electrical codes plus company policies and procedures.
- CAT 5 wire is recommended.
- Document all connections. Tag wires at demarcation points and at the wiring closets.
- For appearance, new jacks should be mounted at same height as electrical outlets. Jacks for wall mounted phones are 48 – 52 inches from the floor.
- If new riser wiring is required, do not run unshielded telephone cable parallel to power wiring and do not use same bore holes. For the same reasons, do not run telephone wire and electric power wire in the same conduit.
- Avoid sharp bends, nicks, and kinks in the wire.
- Install 4-pair to each outlet, conforming to the EIA/TIA standards.
- Match wire colors of tip and ring pairs and maintain polarity.
- Leave approximately 18-inches of spare wire at the outlet.
- Check for grounds, opens, and shorts.
- Test.

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Home Office

Home offices may be found in single family or multidwelling units. Here, industry literature often uses two new acronyms: SOHO and SOHOT. These stand for Small Office/Home Office (SOHO) and Small Office/Home Office Telecommuter (SOHOT). Home office locations usually have the following basic requirements:

- At least one telephone line for voice traffic.
- A second line for fax/data traffic.

The installation for this configuration is similar to what has already been discussed. However, in this type of installation, it is important to maintain the homerun architecture, to use twisted pair versus quad-wire, and to have a readily accessible point, cross-connect or some other distribution device in the wiring system. This makes it easier for either the installer or the customer to check out trouble, rearrange connections, and to isolate failures. Figure 13 shows a possible configuration. In this case, the lines for the home office are brought to a patch panel (small cross-connect) inside the home office for final distribution within the office. This particular arrangement makes moves and changes within this room relatively easy.

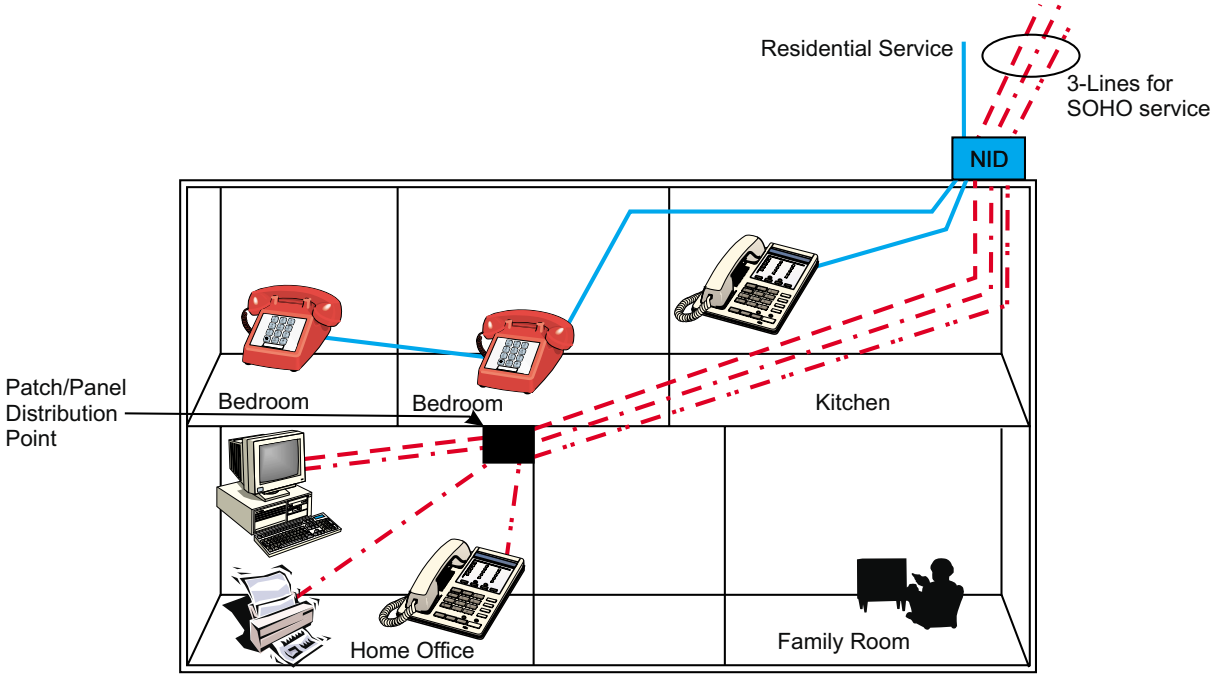

Figure 13: A possible home office configuration

Summary

The installation of residential telephony wiring is similar, but different than coax wiring for cable television service. Many tasks, such as mounting wall outlets and fishing wire, are the same. Other tasks, such as pair identification and continuity checking are different due to telephony's paired wiring. Multiple Dwelling Unit installations are more complex than single family installations in that subscriber pairs are bundled in large cables which are routed through the MDU in a structured wiring system. Wiring closets on each floor may contain intermediate cross-connect points for the cable, as pairs are routed to individual living units.

For both single family and multidwelling unit installations, verification of continuity between the telephony service entry at the demarcation point and the jacks within the living unit is a necessary starting point. For single family dwellings, the installer can and should verify that all existing jacks have working telephony service prior to disconnection from the incumbent service provider. In multiple dwelling units, the wiring from the service provider may have been disconnected prior to the installer's arrival, and the only way to verify connection from the distribution frame to the living unit is with a tone generator-probe combination.

Troubleshooting after installation may be necessary if the new service is not working properly. Common problems are no dialtone, inability to break dialtone, and noise on the line. The installation is not complete until all trouble conditions are cleared.

In today's converged communications environment, it will be increasingly important for cable telecommunications installers to become proficient in single family and multidwelling unit residential telephony installation and home office installation.

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Learning Just Enough to Be Dangerous: Glossary

66 BLOCK–This is also called a 66-type IDC termination block. It is commonly used in voice applications as a termination and distribution point. A 66MI-50 block provides space to terminate 25 pairs or 50 wires.

CAT 3–The minimum standard for wiring in today's voice installations. CAT 3 wiring is unshielded twisted pair. CAT 3 cable is wound with 5 – 7 twists per foot. It is rated to carry 10 MHz.

CAT 5–The recommended standard for telephony wiring. CAT 5 UTP is sometimes called "datagrade" twisted pair. CAT 5 cable is manufactured with 12 – 14 twists per foot. It is rated to carry 100 MHz.

DEMARC–Demarcation Point – that point that identifies the boundary between the service provider's network and the customer's wiring and equipment.

D-STATION WIRE–Also called Quad-wire, is a type of wire consisting of four insulated copper conductors held loosely together in a plastic sheath. This low-cost wire is used by telephone companies in home installations for basic voice service. It is available at consumer stores for "self help" telephone installation by consumers.

HOMERUN METHOD–This describes an installation method where each telephone jack is wired back to a common point without any intermediary cross-connects. Thus, the wire runs from the telephone jack to a point that is typically close to the NID. The signal from the network is cross-connected to the wire going to the jack at this entry point. Also, any cross-connects to other telephone jacks in the residence are also made from this point. This technique provides a relatively quick and easy way to do troubleshooting and repair. The Homerun method is also known as the STAR wiring method.

IDC–Installation Displacement Connection. This technique uses a punch down tool in conjunction with a connector in such a way that the insulation is cut/displaced when the wire is forced into the connection, which consists of two closely spaced metal contacts. When the wire is forced between these contacts a solid electrical and mechanical connection is made without having to strip the wire. An example is the 66-Block termination.

JACKS–These are the devices that are typically mounted in the wall to which the voice terminals (telephones) and data terminals are plugged into in order to connect to the network. Today, these are modularized to allow quick connection of standardized plugs. Common jacks used are the RJ-11, RJ-45, and F-81.

LOOP METHOD–This describes an installation method where cross-connections to other telephone jacks are made at the telephone jack itself. A single transmission path, a pair of wires, can branch out to multiple locations from any telephone jack. It can seriously impede troubleshooting and repair.

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NID–The Network Interface Device is a unit furnished by the service provider at the customer's location. It is used to electrically isolate the network from the customer's wire. It provides protection from lightening and other voltage overloads. It also provides a test point into the customer's wiring system and into the network. The NID is the DEMARC.

NIU–Network Interface Unit; see NID.

NOISE–Any unwanted signal on a transmission path.

TIP & RING–The Tip (+) and the Ring (-) are hold over terms from the days of operators, switchboards, and the patch cords used to connect calls. These patch cords had plugs at either end. These plugs had three contacts: TIP, RING, and SLEEVE.

TWISTED PAIR–Two-wires (a pair) twisted around each other. The twisting improves overall performance and reduces problems such as cross talk. Twisted pair for inside wiring applications is typically provided in sheaths of four or more sets of pairs (e.g., eight wire or more). How the wire is twisted determines its performance characteristics. Twisted pair is rated in categories, such as CAT 3. The higher the category number, the greater the bandwidth potential. The observable difference between a CAT 3 cable pair and a CAT 5 cable pair is the number of twists per foot (CAT 5 has more). When these pairs are bundled into bigger cables (e.g., eight pair) the observer can also see a difference in the way the pairs are twisted around each other.

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Testing Your Knowledge

1. What is the difference between twisted pair and D-Station Wire and which is the preferred wire for installations?

2. Name and describe the two different techniques or methods used in running wire for telephones in residential buildings? Which is the preferred method? Why is it preferred?

3. What does the acronym "NID" mean, and what is the purpose of this device?

4. What is the significance of the term "Category" as it relates to wire, and what is the recommended "Category" to be used in today's installations? Why?

5. What is a SOHO and how would it be wired differently from a normal residence? How would a small office in a business park be wired?

6. What might be observed if the tip and ring were reversed?

7. What is the purpose of the tone generator? With what piece equipment is it paired?

8. Name three ways that an installer can be responsible for causing noise on the line.

9. Why is it inadvisable to run telephone wire in the same conduit as power wire or to even run it in parallel with ROMEX™ type electrical wire. (Note: ROMEX™ is a type of electrical wire that some building codes permit to be used and which does not have mechanical protection.)

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Answers in Volume III, Issue 9 Questions

1. A customer has a TV with only an antenna (RF) connection. You cleverly route the DVD player (which has no RF output) through the customer's VCR (which does have RF output), but the picture darkens and lightens when playing DVDs. What is the problem and how can you fix it?

   The VCR is being affected by Macrovision. You can solve the problem by using a standalone RF modulator, or by passing the signal through a device that removes the Macrovision signal, or by suggesting that the customer buy a new TV.

2. What connection will provide the customer with the best picture?

   Component video is slightly better than s-video. Component progressive video, or digital video, once they become more widely available, are an improvement on component analog.

3. What connection will provide the customer with the best audio?

   A digital audio connection (either S/PDIF coax or Toslink optical).

4. You have connected the customer's DVD player with a digital audio cable to their Dolby Digital receiver, but the display on the receiver indicates that only 2-channel stereo or 4-channel Dolby Surround is being received. You have checked that a 5.1-channel track is being played on the player. What happened to the 5.1-channel Dolby Digital, and how do you fix it?

   The player is set to send PCM audio out, not Dolby Digital. You must change the settings in the player's setup menu or flip a switch on the player. Note that this applies also to DTS.

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References

The following are recommended as useful additional references on telephony wiring:

- **Inside Wiring Options** workshop paper, SCTE Cable-Tec Expo® ’97 Proceedings Manual, Volume 2, p. 41.
- **Understanding Cable Telephony**, published by ANTEC and available from ANTEC by calling 1-888-353-9473.
- ANSI/TIA/EIA 570-A and 568-A documents, available from Global Engineering Documents, 1-800-854-7179.

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