HIGH-TECH
Home Wiring

Today's custom homebuyers expect the latest technology to plug in and work without having to rewire their new home,

by Joe Stoddard

and they expect you to make it possible. So, if you're building houses in the 21st century, you had better know how to properly specify and install the cabling and devices that make home automation systems tick.

Many contractors have worked with speaker, TV, and phone wires, but data cabling is a different story; unless you've installed computer networks in office buildings, it's unlikely you're familiar with the tools and techniques required to properly install the twisted-pair cable used in home automation and networking systems.

With a modest upgrade to Category 5 cable, your customers will be ready for the information age

What is Cat 5?

The cabling used to connect most computer and data networks is known as UTP, "Category 5," or simply "Cat 5." It consists of eight color-coded conductors, covered in a PVC jacket. ("Plenum rated" Cat 5 has a Teflon or other fire-resistant coating and is used primarily in commercial construction, above dropped ceilings and other installations where fire is an issue.) The carefully engineered twists in the four pairs of 24-gauge wire are designed to reject interference and "crosstalk," as well as maximize "throughput," which make it an excellent choice for phone, security, intercom, digital computer data, and nearly any other low-voltage communication requirements. Cat 5 installation is simple and straightforward, but the

Choosing a Wiring Standard

Before purchasing connecting hardware, it's critically important to decide which wiring standard you're going to use. The standard designates which color wire from the horizontal wiring connects to which pin on the RJ-45 modular jack. If you're using a packaged solution, you'll use what the manufacturer recommends. If you're designing a system from scratch, you'll have to choose between the original EIA/TIA wiring standard T568A, or an alternative standard, T568B, which is more commonly used in the U.S. The proper wiring for each standard appears below. Note that the only difference between the two is that the orange and green pairs on the RJ-45 jack are reversed.

EIA/TIA T568A Standard Pin Color

1. White/Green
2. Green
3. White/Orange
4. Blue
5. White/Blue
6. Orange
7. White/Brown
8. Brown

EIA/TIA T568B Standard Pin Color

1. White/Orange
2. Orange
3. White/Green
4. Blue
5. White/Blue
6. Green
7. White/Brown
8. Brown

Table of Clearances

- Lightning rods and wiring: 6 feet
- Service entrance cable and distribution panels: 6 feet
- Transformers (neon lights, doorbells, etc): 1 foot
- Fluorescent lights: 1 foot
- 110-volt wiring in framing bays, parallel to data cable: 6 inches
- Ungrounded TV or radio antenna: 6 inches

Category 5 Color Scheme

	Long Notation	Shorthand
Pair 1	white-blue / blue	W-BL / BL
Pair 2	white-orange / orange	W-O / O
Pair 3	white-green / green	W-G / G
Pair 4	white-brown / brown	W-BR / BR

guidelines must be followed very carefully or the installed network won't work reliably.

Choosing a system. When it comes to home automation and home networking cabling systems, you have two choices: You can use a packaged solution such as Home Director (see "For More Information," at end of article), or you can create your own system using separate components from electrical and networking suppliers. There are some advantages to the packaged approach: one-stop shopping, good installation and technical support for both the installer and the end-user, and specialized components such as wiring enclosures designed to fit between stud bays. The downside of packaged systems is that they may limit the size of the system or the features your client is looking for. Plus, you can create the same functionality from off-the-shelf components. If you're willing to take more responsibility for the hardware, you can build a very flexible system yourself, and may save a little money in the process.

There are two often-overlooked points when selecting Cat 5 cabling and accessories. First, all the pieces of the installation should carry the same rating as your cable: If you're using Cat 5E, make sure the plugs, enclosures, and patch panels are also Cat 5E. Second, there are two common connection schemes, 568A and 568B. The difference is which color wire goes to which terminal on the connectors, and mixing them is a bad idea (see "Choosing a Wiring Standard"). If you opt for a packaged solution, the choice will be made for you. If not, use 568B. You'll find more computer-related preconfigured devices available for this standard.

Buying Cat 5 Cable

Cat 5 (and Cat 5E, for "enhanced") cable is available in both stranded and solid-wire conductors. Solid conductor is used for "structured cabling" — anything that is permanently installed in a building. Stranded conductor is used to make the patch cables that connect the devices together outside the walls.

Colors count. Cat 5 consists of four colored pairs of blue/orange/green/brown color-coded wires. Different manufacturers indicate colors differently — the easiest cables to work with have a solid color conductor paired with a white conductor. A colored stripe or long-short, short-long identifying bands run the entire length of the white wires to keep them from getting crossed (see Figure 1). Avoid cable with no markings on the white wire since it can easily be misconfigured.

Cat 5 is available in a variety of outer jacket colors.

You can use these to great advantage by running one color for network, another for phone, a third for control wiring, and so forth. The standard color scheme is:

- Blue: standard telephone
- Red: key-type commercial telephone systems
- Yellow: auxiliary, maintenance and security alarms
- Green: network connections and auxiliary circuits
- Orange: incoming phone cable and demarcation
- Silver or White: horizontal data cables, computer and PBX equipment

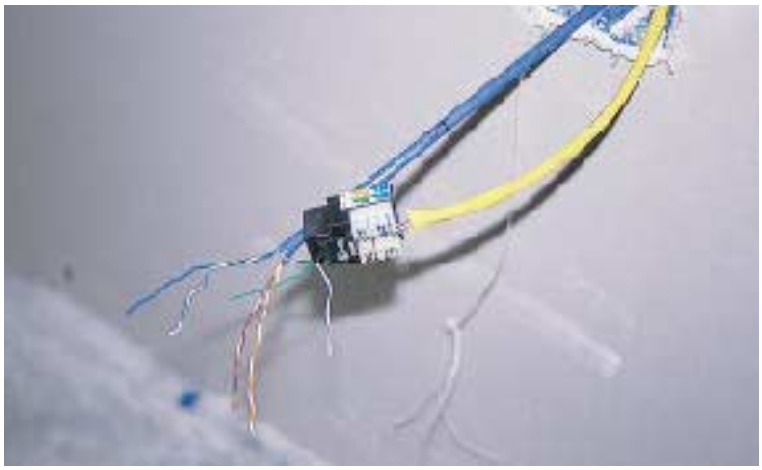

Figure 1. The four white leads bundled in every twisted-pair cable are color-coded with continuous stripes or bands to prevent misconfiguration.

Bundled cables. Specialty cable, available from home automation suppliers, combines multiple strands of Cat 5, coax, and speaker wires in one jacket. Bundled cables may save a little labor, but they are more expensive in the long run and limit the flexibility of your system. You're better off purchasing good-quality bulk cabling and running exactly what you need to each location (Figure 2).

Jacks and plugs. Computer and data networks wired with Cat 5 use RJ-45 jacks and plugs, which look like a wide version of the familiar RJ-11 telephone jack. Solid wall and surface-mount jacks are available, as well as modular systems that let you create your own configuration of TV, network, and telephone connections at a single location by snapping small Lego-like modules into a frame. The "keystone" modular system (made by various manufacturers) is very popular in commercial installations and works just as well in the home environment, but requires special cover plates. Newer QuickPort and

Figure 2. Packaged system suppliers use specially bundled cable, combining coaxial, Cat 5, and speaker cable on a single spool (above right). Using single-function bulk cable allows you to keep things simple and flexible by running only what you need to each location (above left).

Figure 3. Wire terminals snap into a special faceplate in the "keystone" modular system (left). Other systems employ decorator-style or standard duplex coverplates to unite individual jacks (above).

TechWire modular systems by Leviton and others use decorator-style or even standard duplex cover plates (Figure 3, previous page).

The Wiring Closet

All structured wiring installations involve home runs from individual devices back to a central location known as the wiring closet. This is also known as a "star topology" because everything radiates outward from a central hub. Prepackaged solutions such as Home Director feature their own wiring enclosures, which fit between studs or surface-mount much like a conventional electrical panel (Figure 4). The other option is to purchase individual punch-down blocks and patch panels that mount on a wall, in an equipment cabinet, or in a standard 19-inch equipment rack similar to what you'd use for professional stereo equipment. The individual conductors are "punched down" between thin metal contacts in the patch panel, and each cable is then connected internally to a RJ-45 jack on the panel face. From there you use short patch cables to connect to your network hubs or other devices in the rack (Figure 5). A rack system is flexible, expandable, and easy to service; the only downside is the floor space required compared with a between-the-studs enclosure.

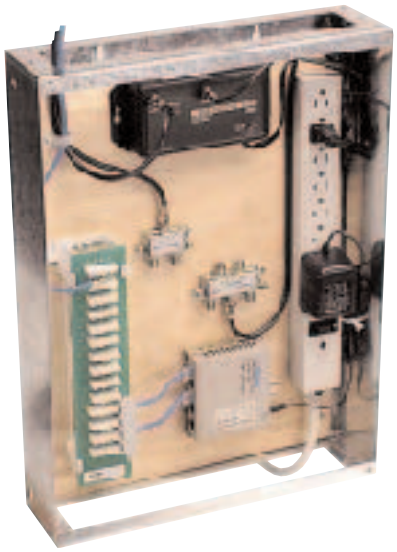

Figure 4. A structured wiring enclosure mounts discreetly between wall studs just like a standard electrical breaker panel. The powerstrip in this panel is more than 6 inches away from the phone/data punch-down block to avoid interference.

Figure 5. A rack-mount system holds individual punch-down patch panels and distribution blocks, and provides real flexibility for system configuration and expansion. Unlike a recessed panel, it requires dedicated floor space, as in a communications closet.

Planning the Installation

The wiring closet needs to be centrally located so no single run of Cat 5 wiring will be longer than 285 feet, the maximum distance for reliable performance. Don't locate your wiring closet near the electrical service panel — common practice for regular phone and TV, but the kiss of death for data networks because of electrical interference. In a conventional two-story home with stacked stairwells, the space under the basement stair is often an excellent spot for the wiring closet because it is central to the floorplan, and allows a clear shot from basement to attic.

Cat 5 *must* be used for data networks, *should* be used for phones, and *can* be used for intercom, equipment control, and security sensors. Speakers typically use 14-gauge dedicated speaker cable, and high-grade video requires RJ-6 coax. Permanent equipment locations such as smoke alarms or speakers are self-explanatory: You run the required cable to where the device is. What isn't quite as obvious is where to place network/phone nodes or mixed data/video/home automation jacks.

Many home automation specialists recommend that every multi-use outlet have two RG-6 coax video cables, two 2-pair 14-gauge speaker wires, and two Cat 5 cables — one for phone and the other for computer. In reality, you don't need video and speaker cables at every location — it's doubtful the Internet-enabled microwave will ever care about who is at the front door. However, rooms that are data-heavy, such as home offices, could require as many as six to eight separate runs of Cat 5 to accommodate multi-line phones, dedicated fax machines, and multiple computer workstations, not to mention the usual security, intercom, and control wiring. As more video and audio moves to the Internet, Cat 5 will become increasingly important. The point is, it's easier to run the cable while the studs are open.

Glossary of High-Tech Wiring Terms

568A and 568B — Cabling/wiring standards established by the Electronic Industries Association (EIA) and Telecommunications Industry Association (TIA). It describes every aspect of cable installation for both data and voice communication. 568B is the more common standard for structured wiring, 568A exists to integrate with older networks. The difference is that pairs 1 and 2 and pairs 3 and 6 are reversed in color.

Category 3, 4, 5, 5E — Electrical standards for cabling developed by the EIA and TIA. Category 3 cable offers speeds up to 16MHz and a data throughput rate up to 10Mbps (million bits per second - 10baseT); Cat 4, 20MHz/ 16Mbps; Cat 5 and 5E 100MHz/100Mbps (100baseT). Cat 3 and 4 are seldom specified today. Additionally, "gigabit" standards (1000Mbps) are under development for use with Cat 5 cable.

Coaxial Cable (Coax) — Solid copper core surrounded by insulation and a copper braid. This cable has many varieties depending on the amount of electromagnetic interference shielding allowed, and the voltages and frequencies accommodated. Coax allows high bandwidth, between 50 and 500 MHz, making it ideal for video signals. RJ-6 is the current designation for coax cable used in home automation systems.

EIA — Electronic Industries Association.

Ethernet — The most widely installed local area network technology. Now specified in a standard, IEEE 802.3. An Ethernet LAN typically uses special grades of twisted pair wires.

Hub — A "junction box" in any "star topology" network that allows computers or other network devices to communicate with each other.

IEEE — Institute of Electrical and Electronics Engineers.

IEEE 802.3xx — The set of standards that describe Ethernet cabling standards from 10 million bits per second (10baseT) to "gigabit" (1000baseT).

NIC — (Network Interface Card) This is also called a "network card" or "network adapter." This is the card (like a small circuit board) that goes inside of a computer or other network device and allows the computer to be plugged into a network.

Patch Cord — (Also called a Patch Cable.) The flexible cable that connects computers or other devices to the network or to each other.

RJ-45 — Similar to a telephone (RJ-11) plug/jack but eight pins wide, used in 10BaseT and 100BaseT Ethernet networking.

Star Topology — Network design where all cable is "home run" from each device directly to a central hub. All communications between devices in a star topology go through the hub.

STP Cable — (Shielded Twisted Pair Cable) Cable that has a foil and/or braided shield for EMI (electromagnetic interference) protection. Seldom used in Ethernet or home automation systems.

TIA — Telecommunications Industry Association.

UTP Cable — (Unshielded Twisted Pair Cable) Category 5 UTP cable with RJ-45 plugs is the most common type of cable used in Ethernet networking and home automation systems. Maximum usage length of UTP for data transmission is 100 meters.

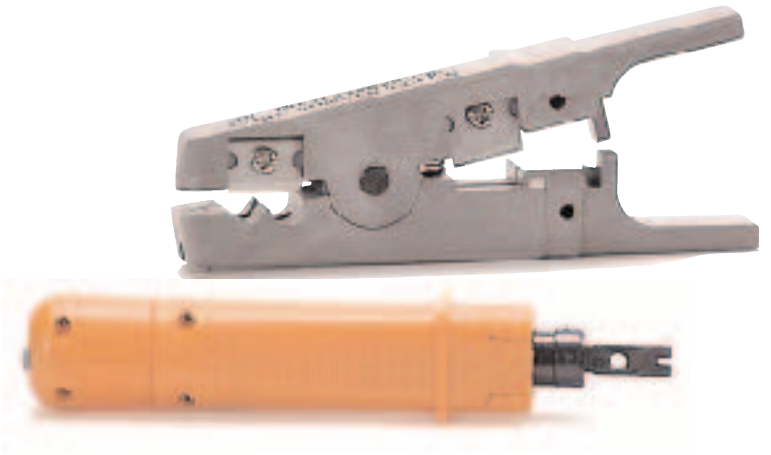

Figure 6. Special wiring requires special tools, including a round cable cutter and stripper, an impact punch-down tool, and a network tester.

Figure 7. Free-spooling wire is much easier to pay out, and less likely to kink or tangle. A site-built rig is easily made by drilling holes in a couple of studs to hold the spool on a length of pipe.

When installing Cat 5:

- Never combine phone and data on one piece of Cat 5 — always run dedicated lines for data. Mixing violates Cat 5 specification, and risks electrical interference with data transmissions.
- Include every bedroom and major living area, as well as bathrooms, hallways, and outdoor areas such as porches, garages, and swimming pools.
- Larger rooms should have a minimum of two locations to accommodate varying furniture placement.
- Even if you don't yet see the need for a network device in a given location, run the cable anyway. The kitchen of the future could require network hook-ups for every single appliance, and before long there will be dozens of gizmos we can't yet imagine that will need connection to the Internet.
- It's a good idea to provide a couple of basement-to-attic and house-to-outbuilding 2-inch PVC conduits for future expansion. Just be sure to cap off any not in use to prevent moisture problems and vermin from taking up residence.

Installation Tools

In addition to the usual electrical wiring tools, you'll need a networking tool kit with some basic gear, available from mail-order outlets for under $100 (Figure 6). The kit should include:

- A punch-down tool with No.66 and No.110 blades. This is used to seat wires in patch panels and also in certain kinds of modular jacks. No.66 terminals are generally for telephone, and No.110 for network wiring. Note that some packaged solutions use a proprietary terminal block called a KATT block which requires a special punch-down tool.
- A sheath ring cutter to remove the jacket from Cat 5 cable.
- A crimping tool for RJ-45 and RJ-11 jacks. Ratchet-action tools give the most consistent results.
- A Cat 5 cable tester (a glorified continuity tester for tracking down problems with broken cables or cross-wired connections).

Wiring Techniques

There is no rocket science necessary for installing Cat 5 cabling, but you do have to pay close attention to the rules if you expect the system to work properly when you're done.

- Mount spools of cable on broom handles, pieces of rebar, or pipe drilled through studs. Several individual runs can then be pulled at the same time without kinking or tangling (Figure 7).
- Do not use more than 25 pounds of pulling force on Cat 5 or coax cable.
- Whenever possible, stay away from insulated exterior walls with network cabling. If it's unavoid-

able, run the cable in 1-inch conduit to allow wires to be freely pulled back or added.

- Interior wall locations do not require an electrical box. Instead, use a plaster ring mounted directly on the stud. Some packaged solutions include their own version of a plaster ring. A plastic box with the back or top removed can be used on exterior walls when necessary (Figure 8).
- Loosely bundle all cables leading to the same location, using nylon or velcro cable ties. Do not attach the cable directly to studs — instead, staple the tail of the cable tie to the center of the stud (Figure 9).
- Avoid bundling wires using electrical tape, which has been known to attack some types of vinyl cable jackets.
- Don't bend Cat 5 more than 4 times its diameter — roughly a 1-inch bending radius for a single cable.
- If you must staple an individual conductor, always use insulated staples, and install them loosely.
- Leave a minimum of 18 inches of slack at outlets, and leave enough cable in the wiring closet to reach the floor.

Figure 8. Avoid wiring runs in insulated walls; if you can't, run the wire in a conduit to facilitate future pulls, and use a backless electrical box. On interior partitions, all you need is a plaster ring.

Avoiding Electrical Noise

Household wiring causes electrical interference which will disrupt data flow on network cabling and create line noise and crosstalk on telephone cable. To avoid problems:

- Don't start your home-automation wiring until the house-current wiring is installed and inspected. Aside from inspectors giving you grief because they don't know what they're looking at, all it takes is one "extra outlet" run right next to a data cable to create a problem you'll have a hard time tracking down.
- Plan the cabling to follow a main artery across the basement or attic, and pull off at right angles to individual outlets. This makes it easier to avoid interference problems with, for example, basement fluorescent shop lights or other transformers. Support bundles of cable with commercially available J-hooks, cable trays, or site-built rat races (Figure 10, next page).
- Maintain the clearances to sources of electrical interference listed in the table on page 2.
- Cross all 110-volt wiring at 90 degrees to cancel interference.
- Never run data cable and 110-volt in the same conduit.

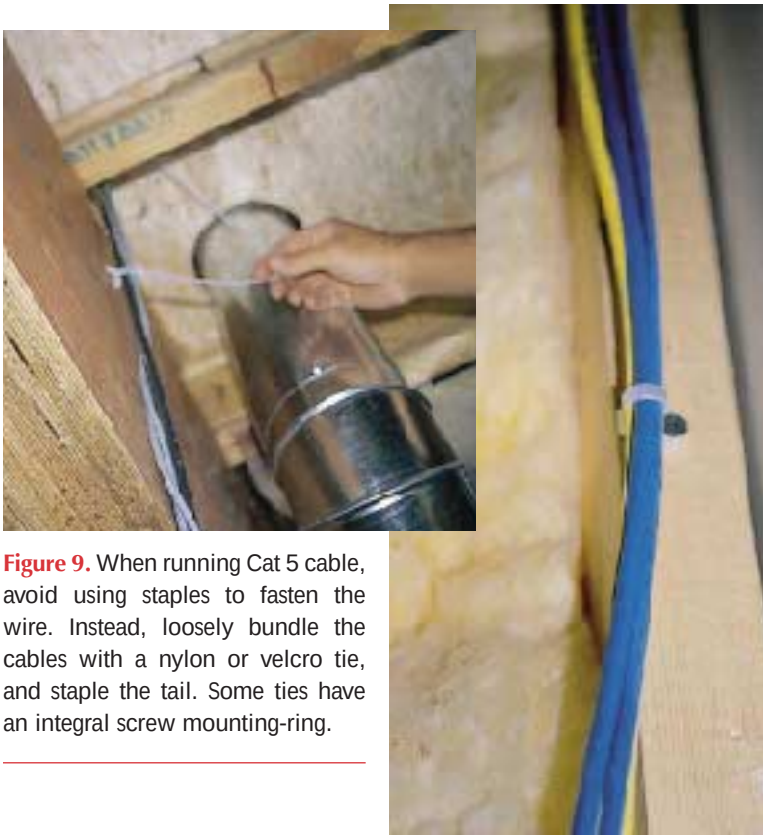

Figure 9. When running Cat 5 cable, avoid using staples to fasten the wire. Instead, loosely bundle the cables with a nylon or velcro tie, and staple the tail. Some ties have an integral screw mounting-ring.

Organizing and Labeling

A home automation system can involve hundreds of individual runs of cable terminating in

Figure 10. J-hooks support multiple cables without squeezing or cramping. These cables are being run prior to the installation of a suspended ceiling system.

the wiring closet area. There is nothing more time-consuming than trying to figure out where they all came from because you were too lazy to document them as they were installed.

- In the wiring closet, bundle all cables *by room* with nylon cable ties, labeling the bundle with a permanent tag.
- Use a small notebook to keep a written log of each cable number as you pull it. Use commercially available number tags, placing one at each end of the cable and another in the notebook with a brief explanation.
- Your careful labeling job won't do much good if all the labels wind up on the floor, so always label both ends of the cable well above where it might be trimmed off.

Making the Connections

Some installers do a beautiful job of running the cable, but then blow it when making the final device connections. Sloppy workmanship at this critical step can ruin network performance.

- Always terminate all eight conductors of every Cat 5 cable in the wiring closet.
- Terminate all eight conductors of every Cat 5 cable used for data transfer at the outlet end as well.
- When transitioning to four-conductor phone cable, use the blue/white pair to the telephone red/green, and the orange/white pair to the telephone black/yellow.
- When terminating Cat 5 cables for data use, expose no more of the conductors than necessary, and untwist the colored pairs no more than 1/2 inch.
- Use the RJ-45 connector that matches the cable used, either stranded or solid.
- Use the correct wire map — 568A or 568B — consistently throughout the installation.

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For More Information

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800/223-5546
www.belkin.com

Hubbell Premise Wiring
P.O. Box 901
Stonington, CT 06378-0901
800/626-0005
www.hubbell-premise.com

TechWire Systems
HomeTech Solutions
10600 S. De Anza Blvd
Cupertino, CA 95014;
888/257-4406
www.hometech.com

DataComm Warehouse
800/378-9083
www.warehouse.com

Home Director
991 Aviation Parkway
Suite 800
Morrisville, NC 27560
800/426-7144
www.homedirector.net

Leviton Mfg. Company
59-25 Little Neck Pkwy.
Little Neck, NY 11362
800/323-8920
www.leviton.com

Mail Order Supply Sources for Network Hardware and Cabling

Computer Discount Warehouse (CDW)
800/830-4239
www.cdw.com

Internet Resources on Home Automation

Technical FAQ on cable types and specifications:
http.//web.uvic.ca/tats/cable-specs.html

Popular Home Automation Online
http.//www.pophome.com/index.shtml