WIRING THE High-Tech House

by Helen Heneveld

Homeowners who use computers, MP3 players, digital cameras, satellite or cable television, and other electronic equipment are asking for houses that make it easier to live with these devices. They want extra phone lines, easy housewide access to their high-speed Internet connection, and the ability to listen to music or watch TV in any room in the house.

The people who know how to make this happen refer to themselves as home-technology integrators. When I started installing home automation equipment in 1989, the first thing I learned was that the part you can't see — the in-wall wiring — is the most important part of the system. Back then, there were no standards for this type of wiring, but the industry has since established standards that make it possible to install high-tech wiring without the worry that it will be incompatible with new equipment or obsolete in a few years. As a result, two-thirds of all production builders now offer structured wiring as a standard upgrade.

Structured wiring is the backbone that makes home automation work

What Is Structured Wiring?

"Structured wiring" is the term used to describe the distribution panel, low-voltage wiring, and wall outlets that tie communication devices together in a "connected" and "automated" home. Installed in a central location, the panel is linked by wire to outlets and devices in various rooms.

There is nothing new about having such wired devices as phones, intercoms, and multispeaker audio systems in a residence. But with structured wiring, the cabling for video distribution, music, phones, computer networking, security, hvac control, and lighting control is planned, installed, and managed as a single system. This allows for simpler operation from more locations within the house.

Figure 1. Structured wiring requires many cables, because each one goes directly from the distribution panel to a single receptacle or device. The cables in this panel (left) have been trimmed to length and terminated with RJ-45 and coaxial connectors. When the installation is complete, the panel will resemble the one in this manufacturer's photo (below).

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Home runs offer flexibility. One major difference between conventional and structured wiring is that in the latter arrangement all of the wires are "home run." That means each device is connected to a wire that runs all the way back to the central distribution panel (see Figure 1). In the "daisy-chained" wiring found in electrical systems, each outlet or device is connected to and affected by the one before it. Home runs increase the integrity of transmission by reducing the number of splices and connections.

Home-run wiring makes it easy to go to the distribution box (which is like a circuit-breaker panel) and reconfigure the system by unplugging a wire from one component and plugging it into another. For example, clients might keep an eye on their baby by installing a monitoring camera in the nursery. A few years later, they might want to convert that room to another use. With structured wiring, they could unplug the camera and use the existing wire to connect a computer to the Internet or a television to a cable or satellite source. Without structured wiring, the conversion would be much more difficult, because new cable would have to be fished into the room.

Distribution Panel

Similar to an electrical panel, the distribution panel is a metal box through which all of the wires pass. But, unlike an electrical panel, which sends electricity in one direction, the distribution panel functions as a hub. Any device that is wired to the panel could potentially connect to any other device on or off the property.

An empty box. Like an electrical panel, a distribution panel starts out as an empty box. But instead of breakers, different modules are added to the panel, depending on the system's various devices. For example, there are modules for phones, video, audio, data distribution, and security. A distribution panel also can be outfitted with networking components, such as a cable modem and router, and hard drives for storage of music and video data.

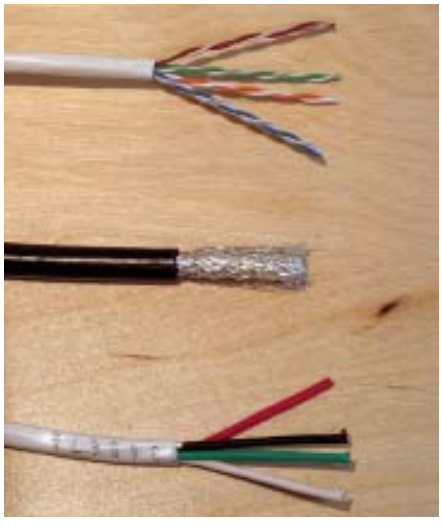
Sometimes the distribution panel is called the brain of the system, but in reality it's more like a highway interchange. The "smart" parts are the computers, control devices, and modules that plug into the panel or into outlets around the home. This makes upgrading easy: Instead of tearing open a wall to swap out a device, an old component can simply be unplugged and a new one put in its place (Figure 2, next page).

Figure 2. The module with the coaxial connectors on it is a splitter for distributing audio/video signals (right). The blank plates represent open spaces where other modules could be installed. Here (far right), the installer plugs a Cat-5e cable into a module that networks computers.

Wiring

There are several types of cable that can be used in a home system. The most common ones are Category-5e (four twisted pairs) for voice, data, audio, and control devices; RG-6 coaxial cable for video; and 16-4 stranded cable for music distribution. Security devices use either 22-2 stranded or — if the device requires power — 22-4 stranded cable. Fiber-optic cable is optional; few types of equipment use it now, but you might want to install some for future use (Figure 3).

The installation goes faster if you use bundled cable. Typically consisting of two Category-5e cables and two RG-6 coax cables (and available with fiber-optic as well), bundled cable is more expensive but takes less labor to install than individual cables.



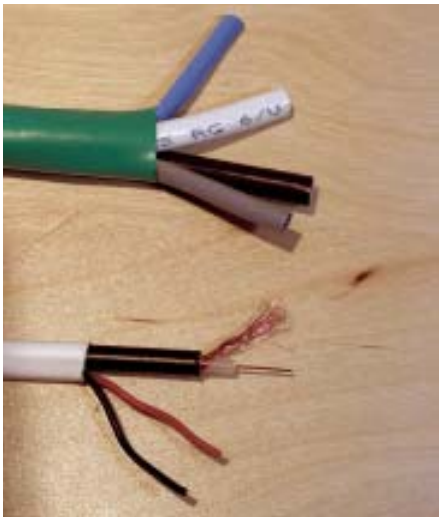


Figure 3. At left are three of the most commonly used cables: Category-5e (top), RG-6 coax (center), and 14-4 speaker wire (bottom). On the right are a bundled cable (top) and a cable for a video monitoring camera (bottom). The bundled cable contains two Cat-5e and two coax cables. The video cable contains a coax cable plus a pair of low-voltage wires to power the camera.

Wall Outlets

Wall outlets are the primary access points to the in-wall wiring. An outlet consists of a wall plate with openings for different types of connections — typically two RJ-45 jacks (for phone and data) and a pair of coaxial cable connectors. An RJ-45 jack looks like an oversized phone jack and will accept the RJ-45 plugs used for computer networking, as well as the RJ-11 plugs found on standard phone cords.

Phone. One RJ-45 could tie into a multiline phone system or allow the owners to use the telephone as an intercom between rooms. The clients could also use it to talk to someone who is at the front door, or even to unlock the door and let visitors in.

Computer. The other RJ-45 could connect the computer to the Internet, to a remote backup device such as a hard drive, or to a home network that includes printers, scanners, and other computers.

Video. The coaxial connectors bring video into and out of a room. The

homeowners could use one connector to allow a television to receive remote video sources from the distribution panel, such as cable or satellite TV or a VCR or DVD player in another room. They could use the other coax to send signals out from a monitoring camera or from another source (such as a DVD player) in that room. There could also be receptacles to connect freestanding speakers to sources elsewhere in the home. The source could be just about anything — a conventional radio broadcast, a CD, an MP3 recording, or a radio that comes in via satellite, the Internet, or cable.

Creating a Plan

Normally, structured wiring is installed right before the drywall and after all of the mechanicals. But planning for it should begin early in the job.

I start by talking with the homeowner and the builder about what systems need to be supported. The list might include — but would not be limited to — phone, video, data, music, security, hvac control, and lighting control.

Once we've determined which functions to support, it's time to decide

Wire Checklist

Prewire	Trim-Out	Test	#	Type	Source	Destination	Device	Special Instructions
			1	Cat-5e	House feeds	Distribution panel	Main feed	Phone-in
			2	RG-6	House feeds	Distribution panel	Main feed	Cable/Internet-in
			3	RG-6	Distribution panel	Attic	Antenna feed	FM
			4	RG-6	Distribution panel	Attic	Future satellite TV	Loop extra cable
			5	RG-6	Distribution panel	Attic	Antenna feed	TV UHF/VHF1
			6	RG-6	Distribution panel	Backyard	Monitoring camera	Prewire for future use
			7	16-4	Main system	Exterior deck	Speakers	Prewire for future use
			8	Cat-5e	Distribution panel	Front door	Door phone	Prewire for future use
			9	Bundled cable	Distribution panel	Great rm computer	Multiport	Phone and data/Internet
			10	Bundled cable	Distribution panel	Great rm TV	Multiport	Audio/video
			11	14-2	Main system	Great room	Left speaker	
			12	14-2	Main system	Great room	Right speaker	
			13	14-2	Main system	Great room	Center speaker	
			14	16-4	Main system	Great room	Speakers	Prewire for future rear speakers
			15	Cat-5e	Distribution panel	Guest room	Phone jack	
			16	Cat-5e	Distribution panel	Guest room	Data jack	Data/Internet
			17	RG-6	Distribution panel	Guest room	Video/TV in	
			18	RG-6	Distribution panel	Guest room	Video/TV out	
			19	16-4	Main system	Kitchen	Speakers	Ceiling placement
			20	Cat-5e	Distribution panel	Kitchen	Phone jack	
			21	Cat-5e	Distribution panel	Kitchen	Data jack	Data/Internet
			22	RG-6	Distribution panel	Kitchen	Video/TV in	
			23	16-4	Main system	Master BR	Speakers	Ceiling, loop for volume control and A/B switch, prewire for future use
			24	Cat-5e	Distribution panel	Master BR	Phone jack	
			25	16-4	Main system	Office	Speakers	Ceiling, loop for volume control and A/B switch, prewire for future use
			26	Cat-5e	Distribution panel	Office	Phone jack	
			27	Cat-5e	Distribution panel	Office	Data jack	Data/Internet

Figure 4. Installers use a checklist that lists every wire by type, use, and location to ensure they don't miss any cables.

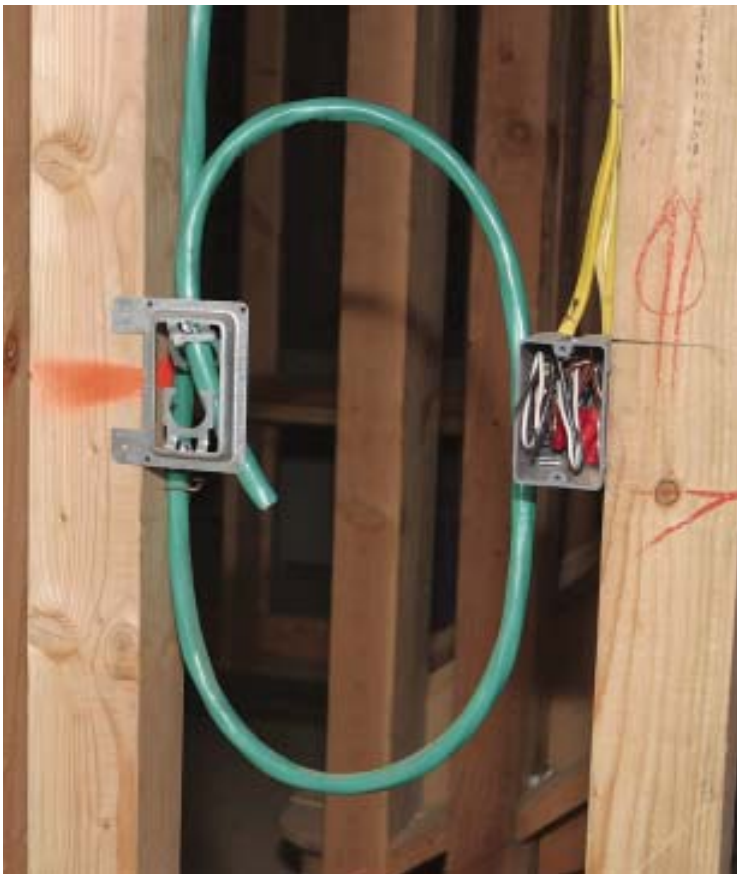


Figure 5. Low-voltage wiring does not require conventional electrical boxes. This green bundled cable goes to a mud ring (left), but it could also go to an open-back box. The cable, which contains two Cat-5e and two coax cables, will terminate at a wall plate (above) with connection points for multiple devices.

which rooms to install them in. Some components that connect to the system might be available in just a few locations, while others might be available nearly everywhere. For instance, music speakers may be desired only in the family room and kitchen, while phones, Internet, and video may need to be available in a number of locations.

There will be a lot of wires to keep track of, so to prevent confusion it's a good idea to create a chart that lists every wire by type, intended use, and where it starts and ends. I use this as a checklist to make sure nothing is missed (Figure 4, previous page).

How Much Is Enough?

I recommend installing two coaxial cables (RG-6 shielded wire) and two Cat-5e twisted-pair cables in every major room. The wires should all run to a location where they can be connected to a single gang wall plate with receptacles for phone, computer, and video (Figure 5). The client doesn't have to use all of them right away, but they will be there if needed.

A bare-bones system might include a distribution panel plus boxes (with two Cat-5e and two coaxial cables) in the master bedroom, kitchen, and living room. The homeowner would probably use it for the phone, to share an Internet connection, for network computers, and to run television off shared video sources such as a DVD player, cable, or satellite. In new construction, the installed cost would be about $375 ($75 per room plus $150 for the panel).

An average system would include all of the above, plus runs to other bedrooms and to extra rooms like the office, den, loft, and basement. In addition to phone, TV, and computer, the owner of a system like this would probably have monitoring cameras and perhaps a whole-house audio entertainment system. The wire runs still cost $75 each, but this system would require a larger, $350 panel. Assuming an additional six rooms (four bedrooms plus a den and office), the structured wiring would cost about $1,000.

A better system, containing all of the above, plus runs to more locations and fiber-optic cable for future needs, could cost $4,000 or more.

All of these prices are for new construction; unless the building has been gutted, it costs much more (two to four times more) to retrofit an existing home. The above estimates don't include the cost of modules and electronic equipment.

Future Needs

Because it's so much easier to install wiring when the walls are open, it's a good idea to install extra cable or a chase to areas where wire might be needed at some future date.

I recommend running 2-inch PVC pipe between the distribution panel and the attic, so you can get wire to rooms on the second floor. Because new entertainment equipment is being

Figure 6. Because household electrical wiring produces interference, the installers keep the blue low-voltage cables away by running them along a different ceiling joist than the Romex (left). If structured wiring has to cross high-voltage wiring, the two types of wire should cross at a 90-degree angle to minimize interference (right). In this case, the low-voltage cables above the joists are perpendicular to the household electrical wire that runs along the sides.

introduced all the time, I often run empty conduit from the distribution panel to the area where entertainment equipment (audio or home theater) might someday be located.

It's also a good idea to run speaker wiring from the distribution panel to areas where the owner might want to listen to music in the future. The volume and audio source is typically controlled by wall-mounted keypads in the individual rooms, so run Cat-5e wire to the keypad location.

Another option is to run extra wire to the thermostats so the owner can activate the hvac system remotely or avoid the hassle of using a programmable thermostat. Depending on what equipment is located outdoors, you might want to run wire or conduit there, too. With the right equipment, lawn sprinklers, pool pump, and spa heater could all be remotely operated. Other options include a door phone, outdoor speakers, and an outdoor camera for keeping an eye on the kids.

What about wireless? Wireless connections are an option for certain kinds of signals. They are a good way to share an Internet connection with a laptop that is used in multiple locations. However, a wireless connection is unlikely to be as fast or as reliable as one that is hard-wired. Also, there may be security concerns, because wireless signals do not stop at the wall of the house. Without a proper firewall, neighbors or passersby may be able to pick up the signal and access the homeowners' Internet connection or hard drive. I think of wireless as a supplement to — rather than a replacement for — a hard-wired system.

Installing the Components

Prewiring is the act of pulling all the low-voltage wires and installing the service panel and boxes. Household wiring can cause electrical interference, so it's important to keep low-voltage wiring away from it. Ideally, structured wiring should be at least 12 inches away from electrical wires; 24 inches is even better. At some point, a low-voltage wire may need to cross household wiring. When that happens, be sure to cross at a 90-degree angle to minimize the amount of electromagnetic interference.

Because many mechanical subs and

Figure 7. The best way to prewire for future speakers is to leave extra wire and loosely staple it in a zig-zag pattern across the bay. This makes it much easier to find the wire later on.

electricians are not aware of these requirements, it's important to let them do all of their rough-in work before installing structured wiring (Figure 6, previous page). I don't want an electrician coming in later and running his wires close to (or through the same holes as) my low-voltage wiring to save time. And low-voltage is more delicate than household wiring, so it's important not to staple, fold, crimp, or splice it. (Where fastening is necessary, I loosely wrap the cable — or bundle of cables — with a cable tie and then either staple or screw the loose end of the tie to the framing.)

When I'm running wire for future in-wall speakers, I like to leave some extra in the wall so that it's easier to shift the speakers' location. It's also smart to document the location of prewire items by photographing them before the drywall goes up (Figure 7).

Locating the panel. It's easier to wire the house if the distribution panel is centrally located. It can go in a closet or in the mechanical room; the important thing is to keep it at least 24 inches away from the electrical panel — 36 inches (or more) would be even better. Some of the devices in the panel may require power, so it should have a dedicated 15-amp line that enters the panel

Figure 8. Four twisted pairs of Cat-5e cable clip into the back of a wall-mounted control device (above). Once installed, the device will control the speaker volume in the room and access an audio system that is installed elsewhere in the house (left).

Figure 9. With home-run wiring, there are a lot of cables, so after installation it's important to mark each one with the same information that's on the wiring chart.

from a different end than the low-voltage wires.

I try to install the panel in a conditioned space so it will be easier to work on. Protecting the panel from temperature extremes also makes it less likely the modules will go haywire because it's too hot or cold.

Final connections. Once the drywall is up and the walls are painted, it's time to terminate the cables and install wall outlets. This part of the job includes making connections within the distribution panel and using electronic test equipment to verify that the in-wall cables are correctly connected.

Unlike electrical wires, which are stripped and screwed to terminals, low-voltage cables are terminated by clipping them into the backs of wall plates or by attaching them to pluglike coax or RJ-45 connectors (Figure 8, previous page). I use a hand-held crimping tool to press the connectors onto the cable. Once the connector is on, the cable can be attached to the wall plate or plugged into a receptacle in the distribution panel.

With several cables terminating at every wall plate, keeping track of which cable goes where can be tricky. To avoid confusion, I like to color-code my cables (cable is often available in different colors). For example, I'll run video-in with black coax and video-out with white coax. The Cat-5e wire to the boxes can be color-coded in a similar manner: gray for phone and blue for data. Color-coding the receptacles on the front of the plate (phone system gray, data jack orange, and so on) has made a lot of my clients happy. At the very least, use consistency in how you connect wall plates throughout the house — so that, say, phone jacks are always in the upper left. If you can't do that, label each receptacle.

When the cables are pulled, they come into the panel and run long. There are a lot of them, and the only way to keep track is to label each one with a marker, number tape, or write-on label. The color and type of a wire may tell me what it is, but I still need to mark where it goes (Figure 9).

Finally, I use an electronic tester to verify that the individual cables are intact and properly terminated at both ends. At this point, modules can be put in the panel, and phones, computers, and electronic devices installed in various rooms. If anything needs to be rerouted, it's just a matter of plugging or unplugging, either in a room or in the distribution panel.

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