Low Voltage Home Pre-Wire Guide

Installation Information for the Do-It-Yourselfer

By Mark Henrichs

This article is intended to present ideas, discuss experiences, and generally assist those building or remodeling a house, who plan on installing low voltage wiring for audio, video, home automation, phone, and data communications. It is based on the adventures of our family doing such wiring ourselves on a new home, but is hopefully usable by others contemplating similar wiring tasks. This article is not intended by any means to be an authoritative source on any topic discussed. Information contained here must be used with the understanding that the author is not liable for omissions, errors, or misunderstandings in any way.

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See this article online at:
http://www.WildTracks.cihost.com/homewire

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Introduction

Wiring Design Goals and Caveats

The design of the house wiring discussed in this article is based, of course, on our goals for our new home. Therefore, the design details reflect our desires, budget, and priorities; yours will probably be quite different, so keep our goals in mind as you read.

*Our personal wiring design and implementation was intended for **us**, non-fanatics who enjoy high quality, but wish to balance budget against results.*

Our basic goals in wiring the house were to plan for anything we thought we might want even in the distant future, since this house is planned to be our retirement home. Thus, we wanted to put in all the wiring we could think of now while the house was being built so we did not have to do major renovations to obtain the features we might like to be able to have later in life (when we could hopefully afford full implementation). Not all wiring will be used for existing components; some may never be used unless we win the lottery. Neither of us are "fanatics" about audio, video, automation, or computers, though we both enjoy high quality components and environments. We use high-end equipment for music (mostly classical and jazz), but are not overly compulsive about being true audiophile "snobs". The whole-house audio system was designed to be more than intercoms could provide, but not the ultimate system. We both use personal computers in business and at home, but it's not our life. We enjoy spending less time with mundane tasks, so some automation is nice, but we are not true home automation freaks or tinkerers (though I wish I had more time for such tinkering). I have experimented with X-10 since years ago, but currently own only a few lighting controls.

Remember that our wiring design and implementation is for non-fanatics who enjoy high quality, but wish to balance budget against results (bang for buck). Also, the information gathered here is based on interpretations and extrapolation of information from many sources, some of which were conflicting. However, I believe we have a good quality installation with room for growth and expansion in the future.

Standards and proprietary wiring systems were considered, but conventional methods chosen.

Since CEBus standards use mostly conventional wiring types and schemes, I reviewed their specifications for home automation guidelines to follow. I felt that following these standards as guidelines would give me adequate future automation enhancement paths without committing to a single standard that may not pass the test of time. Following mostly conventional standards made it easier to work with contractors and subcontractors on fulfilling my requirements, yet could meet my (somewhat conservative) desire for supporting future technological advances in home control. Note that my information for CEBus installation specifications was based on the 1992 release, 3rd edition. I am sure more recent standards have been released, and I don't know if the updates affect the wiring I installed. However, I believe most of the latest changes affect the device communications protocols more than the wiring hardware, so I have confidence I am pretty well covered.

Information Sources

*Since I've been asked a few times, here is some information on **SoundTrack**. SoundTrack is a chain of stereo stores in Colorado, which also carries in-wall wiring and controls. In Denver, they have a "Custom Home Division" which designs and installs whole-house audio and home theaters. SoundTrack is affiliated with a chain of stores outside Colorado under the name **Ultimate Electronics**, carrying the same line of products. This chain exists as far east as Tulsa OK, and is also in Nevada, Utah, New Mexico, Idaho; it is not available on the West coast. You can contact the SoundTrack in Denver at:*

2553 South Colorado Blvd.
Denver, CO 80222
(303) 759-5401

My contact there was Rick Duhaime (system designer for the Custom Home division).

Sources for the information in this article include (in no particular order):

- Audio/Video installation information obtained from consultants at local A/V stores like *SoundTrack* (Custom Home division) and *Listen Up*.
- Articles from the last two years (1993 & 1994) of Electronic House magazine (P.O. Box 339, Stillwater, OK 74076-0339, USA; 405-624-8015)
- *An Installer's Guide to CEBus Home Automation*, 1992, 3rd edition; Parks Associates, 5310 Harvest Hill Road, Suite 235, Lock Box 162, Dallas TX 75230-5805, USA; 214-490-1113. Provides CEBus standards.
- News articles on *comp.home.automation* on the Internet
- Information published in sales catalogs from home automation companies such as Home Automation Laboratories (HAL - no longer in business) and Home Automation Systems, Inc. (HAS), whose catalogs contained articles recommending wiring schemes and control systems (infra-red repeater systems, speaker impedance matchers/switches).
- Interviews with local friends and acquaintances in the field of data communications who have had experience with wiring their own homes or businesses.
- Local wire supply house support personnel.
- Our general building contractor, electricians, etc.

Thanks to all the above for the information and help!

Low-Voltage Wiring Related Web Sites

- *Low Voltage Home Pre-Wire Guide* (http://www.WildTracks.cihost.com/homewire) – The online version of this very guide you are now reading
- *Wiring Your Home For Automation* (http://www.smarthome.com/wiring.html) – From Home Automation Systems, Inc.
- *CEBus Technology Home Page* (http://www.cebus.org/) – Information from the CEBus Industry Council
- *Home Tech Solutions* (http://www.derossi.com/hometech/home/index.html) – Low voltage and phone wiring guides
- *Able Communications* (http://www.ablecomm.com/) – Phone system installation and wiring, especially for Panasonic phone systems
- *Network Cabling Standards* (http://www.siemon.com/modular.html) – Modular jack wiring schemes for different standards

- *The Phone Man* (http://www.geocities.com/SiliconValley/Pines/4116/) – Do-it-yourself wiring for second or third phone line, etc.
- *Whole House Audio Tutorial* (http://www.gohts.com/learn/audio.html) – Designing, prewiring, and installing whole-house audio, & *TechWire*
- *A/V Switcher for Cat5 Wire* (http://www.wireless-experts.com/pragmatc/cats8by8.htm) – An alternative for DVD quality distribution, with PDF catalog (http://www.wireless-experts.com/pragmatc/pdf/cats2.pdf)

General Home Automation Web References:

- *Home Automation Index* (http://www.infinet.com:80/~dhoehnen/ha/list.html) – Categorized list of links
- *Electronic House* (http://www.electronichouse.com/) – The home automation magazine
- *Popular Home Automation* (http://www.pophome.com/) – Home automation magazine for the Do-It-Yourselfer
- *Home Automation Systems, Inc.* (http://www.smarthome.com/index.html) – A catalog for home automation supplies
- *comp.home.automation* (news:comp.home.automation) – The newsgroup for home automation
- *WWW Home Page for comp.home.automation* (http://web.cs.ualberta.ca:80/~wade/HyperHome/) – Includes hyper-linked X-10 FAQ
- *X-10 FAQ Download* (ftp://ftp.scruz.net/users/cichlid/public/x10faq) – Download site for latest X-10 FAQ
- *X-10 Products & Technology FAQ* (http://www.homation.com/x10faq/) – HomAtion's X-10 FAQ

Audio System Design

The wiring for the whole-house audio system and the media room was designed professionally, with installation and component selection and hook-up to be done by ourselves.

The design for the whole house audio system and the media room ("home theater" to-be, perhaps) came mostly from *SoundTrack*'s Custom Home consultant. SoundTrack is a chain of audio/video stores in Colorado. They have a "Custom Home" division in Denver whose purpose is to design and install custom audio systems for home theaters and whole-house audio. I paid about $300 for the consultant to design and draw up a nice set of wiring schematics for both the media room and the whole-house audio system (though he later said he would not do plans on such a scale for a mere $300 anymore). The $300 for design was later directly and completely credited against components purchased by me from SoundTrack (such as volume controls and speakers, or audio components such as amplifiers or A/V distribution systems). Thus, it is kind of an "enforced" way of ensuring that we come back to them to buy at least some equipment. Though other local shops (such as Listen Up) also provide consulting services without the "formal" up-front monetary commitment, I was very impressed with SoundTrack's formal CAD-generated schematics and wiring lists. I was provided with an overall schematic of the whole house, including all speakers, volume controls and A/B switches, and TVs. In addition, a separate schematic page was generated for each room showing each wire (with it's wire type designation) and the component for which the wire was destined. A very accurate estimate of total wire length needed for the project was listed, based on house plans I supplied, along with each wire type's description and cost.

Normally, SoundTrack installs their own wire according to their design. However, to save costs, I wanted to do the wiring ourselves with the help of friends and relatives. Since SoundTrack sometimes generates the schematics for remote sites where their installers do not normally go, they were willing to just provide the schematics for the $300. Their original rough estimate for the entire house was about $2600 (material and labor) for the pre-wire installation, about half of which would be installation (later he estimated about $800-$1000 for installation labor alone). He figured it would take two experienced installers 2 days to do the audio wiring. However, this original design was not the complete version we ended up installing (for example, it included only a single run of coax to each TV, where we actually installed two runs per TV), and did not cover phone/data wiring. The $300 I paid for the design included a considerable amount of consulting time (three in-person consultations on the design and many phone calls) and the consultant was available on-call during our actual installation. I thought it was well worth the price, especially since it was later applied toward equipment (but not wire, a low-profit item).

General Features and Wiring Layouts

Feature/Layout Description

Home-run wiring was used to increase future flexibility for phone, audio, video and data

Our new house is about 6000 square feet (we are finishing about 4000 sf, but wired for the future to cover the other 2000 in case we can ever afford to finish it all). Most sources recommend a central location for “home-run” wires, providing greatest connection versatility. Home-run speaker wires, for example, allow either all speakers in the house to carry the same music (with impedance matchers and/or multiple amplifiers with the same audio source) or, with more expensive audio distribution equipment (future enhancements?), zoned music to allow different music in different rooms depending on the wishes of the room occupant. Home-run phone lines allow the use of central PBX systems (such as the Panasonic KX-T30810 phone system) where each phone has its own extension number. Centralized phone lines still allow multiple phones on the same extension by common connections at the central punch-down blocks, or even full-house single-line connections, but provides flexibility in changing the configuration that would not be available in more conventional daisy-chained phone wiring schemes. A central home-run twisted pair wiring scheme for a Local Area Network (LAN) allows star-configuration network connections (10BaseT, etc.) anywhere in the house. Home-run video cables allow either single-source video distribution via signal splitters and video amplifiers, or sophisticated multi-source video distribution with the right equipment. In any of these cases, the simpler less expensive alternative are available to start, but more sophisticated (and expensive) alternatives are open for future enhancements; flexibility is the key.

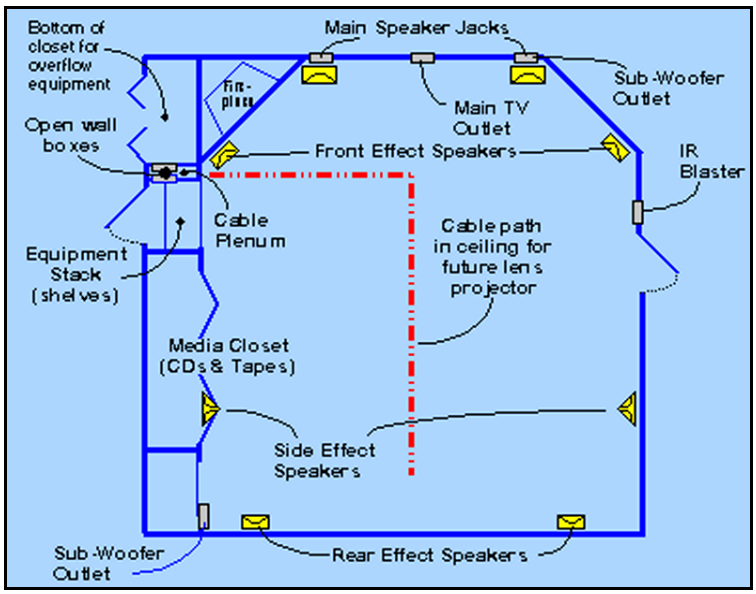
The ideal might be to have everything, including audio, video, phone, and data, going to one central location; Node 0 in CEBus lingo (actually, CEBus uses “Node 0" specifically for hardware that does switching and connecting at the central location, but I use it here to indicate the location where such equipment would be installed). However, we wanted our audio equipment to be located in our media room for shortest wire length to the most critical listening area and for greatest local control of the equipment. There was no clean way to put all the other equipment (future LAN servers, video distribution equipment, phone PBX, security control system, etc.) in our media room, so I chose to put a second node in the basement for video distribution (not source, which stayed in the media room), phone and LAN. The security system was put in yet a third location to make its location less obvious to an intruder. Therefore, our Node 0 is located in the basement, but we have a central “Node 1” for audio distribution, and a third smaller “Node 2” for security. Nodes 1 and 2 are connected via appropriate wiring to Node 0. A/V equipment is linked to Node 0 via three coax and three signal-level cables from Node 1; video sources are switched in the media room and piped to the basement for distribution. The signal-level cables could be used in the future for keeping a PA-system or separate whole-house source system (music source) in the basement and piping the results up to the media center for audio distribution.

I had discussed with consultants a further breakdown to separate some of the whole-house audio into first-floor and second floor systems; this could be done acceptably by sending the source audio signals through high-quality shielded signal-level cable from the media room to an upstairs central amplifier location for upstairs distribution. This would have reduced the number of wires going all the way downstairs to the media room, but would possibly reduce future distributed music possibilities. Both consultants said this would be a viable alternative if only single source audio distribution was desired, but I opted for the more versatile central audio distribution.

We prefer the higher quality of the whole-house audio system instead of piping music around with an intercom. We plan to use a versatile phone system like the Panasonic PBX for paging and inter-room voice communication

We purposely did not install an intercom system. We preferred the higher quality of the whole-house audio system instead of piping music around with the intercom. And we liked the greater versatility of using the Panasonic PBX phone system for paging (using speaker phones) or ringing all phones in the house to have the other person pick up on any phone to talk. The phone system will also be used with door phones so a visitor can push an outside "doorbell" button, ring all the phones in the house, and we can talk to the visitor from any convenient telephone. We may also use the system to allow us to answer someone at a driveway gate from any phone, and enter a code on the phone pad to remotely open the gate for them. Why use an intercom system, introducing yet another piece of equipment?

Media Room / Home Theater



The media room is the location of our main audio and video equipment. We built the room with an equipment stack (shelves) on the left wall with a standard room door through the wall behind the equipment stack shelves. This door, accessible from the exercise room on the other side of the wall, allows us to easily get to the back of the equipment to arrange and re-arrange the normal jungle of patch and interconnect cables associated with A/V equipment. On one of the side walls inside the shelf area of the stack, we had the framers put in a vertical "plenum" from floor to ceiling (7" deep) so we could run all the whole-house and media room A/V cables to the ceiling of the media room (the floor is concrete slab, but I had previously run a 2½" electrical conduit from the stack area to the basement for future changes/enhancements). On the shelf side of the plenum wall, I put two double-gang wall boxes, one about 14" above the floor and the other about midway up the wall (about 45" from the floor). The backs of these boxes were cut off, giving about a 4" square hole in the wall at each height for all the wires. On the exercise room side right next to this equipment stack was a closet, so I put two similar wall boxes low in the closet for "spill-over" equipment, such as whole-house amplifiers and/or impedance matchers, infra-red control boxes, etc. – things that do not frequently need to be seen or operated manually. With the plenum of wire in between the shelves and the

closet, I can move the ends of the cables from one location to the other, or run any needed patch cables between the two locations. Even with all the cables run to this location, the media room shows a clean stack of equipment and all the interconnect cables can be easily accessed and neatly organized from the exercise room. We ended up with more than 80 in-wall cables altogether at this Node 1, for the media room and whole-house audio. If all the cables were tied together tightly in a single bundle, it would be about 4" or 4½" in diameter.

Switched outlets for the equipment stack make it easy to turn groups of equipment on or off as needed

For electricity to power the equipment stack and the room, two dedicated 20 amp circuits were run by the electrician. One is to power just the equipment stack, and the other is to power the whole-house audio amplifiers and the media room wall outlets. I had the electrician put two switched circuits in both the equipment shelf wall and the adjacent closet. One switch provides power for the equipment stack (one outlet in the shelf wall and one outlet in the closet) and the other switch provides power for the whole-house audio system (another outlet in the shelf wall and another outlet in the closet). In addition, a third outlet in each location provides non-switched power, giving me a total of three outlets in each location (triple-gang wall boxes). This way I can turn on all the equipment in the stack with one switch, with or without turning on the whole-house audio system. The switches and shelf outlet box were located on the shelf wall *opposite* the cable plenum to ensure electrical noise does not interfere with all the cabling. The one thing I would have done differently if I had it to do over again is to connect ½ of the wall outlets at the sub-woofer locations to one of the switched circuits. This would allow powered sub-woofers to be turned off at the same time as the rest of the equipment.

Wire was installed to allow support of several possible sound system standards, for now and the future

We currently have an audio sound processor, and may someday upgrade to a audio/video sound processor. Since I don't know whether we might get THX sound or 70MM, in addition to Dolby Surround Sound, I tried to wire for all possibilities. Our current sound processor and a few others (notably Yamaha) use two front effect speakers, and most all also (or only) use two rear effect speakers. However, THX systems are supposed to use side effect speakers, located at the same room depth as the listener. Each of these speakers has a "double" driver (cone), one angled toward the front of the room and the other angled toward the rear, so the sound always comes indirectly to the listener. The listener sits in the "null" position. Each speaker box (containing the two drivers) is driven with one set of external wires like a normal speaker, but they are usually set in a "dipolar" connection internally, so when one driver is pushing, the other driver is pulling; they are 180 degrees out of phase. A switch may allow them to be driven either in-phase or out-of-phase, as desired. Anyway, to cover the possibility of using this type of speaker for THX effects, I installed wires to the expected listening position on each side wall of the room (about the same distance from the front wall as I expected the chairs or couch to be). In addition, I installed speaker wires to high wall locations in front for front effects speakers and also high on the rear wall for rear effects speakers. All effects speaker wires were located so the speakers could be mounted 7½' from the floor (we have a 10' ceiling in the media room). I put two wall outlet boxes low on the front wall for floor standing main speakers (right/left), and ran heavier speaker wire to them. A center-channel speaker cable was run to a

center outlet box, the same one used for TV cables. And, finally, I installed signal-level wires (not speaker wires) to the right front corner (floor level), and to the left rear corner for the possible addition of a sub-woofer. I used two locations so that we could test for the best sound after the room was finished, and use the best location for whatever sub-woofer we got depending on the final room acoustics. Since the sub-woofer is expected to be the normal self-amplified type, the signal-level wires were used instead of normal speaker wires, and an electrical outlet was provided near the sub-woofer jacks to power the speaker.

The media room was wired to support either a front-located monitor or a ceiling-mount projector

We currently use a 35" tube television monitor for our main TV, but may someday upgrade to a larger rear-projection monitor or a lens projector. For the current TV monitor and possible rear-projection TV, I ran three runs of coax and three runs of signal-level stereo wire for the antenna, external 1, and external 2 input to the TV (coax for video, signal-level wire for right/left audio). I also ran a high-quality pre-terminated Super VHS (S-Video) cable for clean signal from satellite or our SVHS camcorder. This was a standard pre-made Monster Cable level 3 S-Video cable, 8 meters (about 25') long, purchased again from SoundTrack (expensive - about $100). Finally, SoundTrack recommended running a 4-conductor 22 gauge stranded wire cable to major TV locations for possible ELAN or AudioEase control, so I ran this too. All these cables, including the center-channel speaker cable, were run from the equipment stack through the wall studs to the center of the front wall, where I put another cut-off double-gang wall box. I left the cables long enough to extend into the room a few feet so I can just directly terminate them for TV connection.

In case we can ever do a real home theater with a ceiling-mounted lens projector monitor (triple-lens tube projector or LCD projector), I ran cables according to SoundTrack's and Listen Up's advice. I used four coax cables (for Red, Green, Blue, and Sync signals – or, any one could be used for composite video instead), two signal-level cables (stereo audio in / audio out), and a 22-gauge 4-conductor cable for ELAN/AudioEase compatibility. I also ran a 22-gauge 8-conductor (4-pair) wire between the projector location and the ceiling above the front wall for a 12-volt signal from the projector to control an electric projection screen to drop from the ceiling (optional). Actually, a 16-gauge 2-conductor wire was recommended for this, but I had the 22-8 and can always double up the conductors. I had the electrician install two electric outlets in the ceiling, one at the screen location and one at the projector location. The guideline the consultant told me to use for the projector location was one and a half times the screen width back from the screen. For example, if you use a 6' wide screen, the projector would be mounted 9' from the screen. Since it is unlikely that we will install such a projector in the near future, I just "buried" the wire in the ceiling and took photographs of its location. I ran the wiring between the ceiling joists from mid-room along the length of the room toward the back to ensure that I could later get to the wire regardless of what distance from the screen I ended up putting the projector. I just suspended the cables between the joists and made them long enough that I could cut a hole in the ceiling, reach through and pull the ends of the wires back to wherever the hole ended up. That way I could decide on the screen width (and therefore the distance back from the screen for the projector) at a later date.

Support was included for infra-red remote controls, for use both in the media room and throughout the house

Since the equipment stack is on the side of the room, it may be possible that an infra-red (IR) remote may not be able to hit all the equipment well. Also, since some of the equipment may be put in the closet next to the stack, it may not be accessible to IR. Therefore, SoundTrack suggested adding an IR receiver on the front wall – I put it high on the wall to one side to make it out of the way of a projection screen if we put one in. Also, since we may want to control the equipment using IR repeaters in other rooms of the house, I put an outlet high on the wall opposite the equipment stack (right wall) for an IR blaster. Actually, I plan on trying a device called “Leap Frog”, which is a small unit that attaches with velcro to the front of an IR remote control, intercepts the remote's IR signals, and converts them to a radio wave (RF) signal, which is transmitted to a receiver in the media room equipment stack. The receiver then converts and re-transmits IR signals to the equipment via small IR transmitters (up to four extenders) that are placed in front of the equipment. A friend of mine uses this system and says it works great! It is inexpensive – about $50-$60 for the receiver and one remote control attached converter, about $15 for each additional remote converter. However, in case this does not work in our large house (the transmitters are claimed to work up to about 100'), I did the wiring for an IR repeater system (similar system, but IR receivers are mounted in the walls, convert and transmit the signal via hard wire to the equipment stack base unit, and converted back to IR transmitting to the equipment via equipment-mounted IR transmitters or the IR blaster across the room from the equipment). This same wiring can also be used for multi-zone control keypads in the future.

I also ran a special satellite cable from the media room stack to the outside for a big dish satellite (we live in the mountains). In case we decide to use DSS or Primestar at some time, I also ran two coax cables into the attic where we can later run them outside for these small-dish satellite systems. And, since our new location can receive a couple of local stations, I ran a coax and a rotator wire (Radio Shack, about $5) to the attic where we have room to install an antenna.

Whole-House Audio

Standard speaker wiring was chosen over other possibilities like 70-volt and twisted pair

Whole-house audio was run from the media room's equipment stack / closet location. SoundTrack's design, based on successful installations in numerous houses of different scales, is to use is to use speaker switching boxes that switch from 4 to 8 speaker pairs off one (or two) amplifier(s) using impedance matching transformers, **not** resistive loads. The design of these impedance-matching boxes is claimed to result “in no power loss and maintains the amplifier's damping factor”, according to one manufacturer's specifications. These switch/impedance matcher boxes are made by several high-end audio companies, including Sonance, Xantech, and Niles, so I believe they should work well. Wiring is run from the audio source to this switch box, then one cable set to a room-located volume control (which is a stepped transformer, not a variable resistor), then from the volume control to each stereo speaker. Using this type of system, you can listen to several pairs of speakers driven by the same amplifier without harm to the amp. Of course, you may need a powerful amp to drive several pairs of speakers, so multiple amps might still be a good idea if many speakers are to be driven at

once. An A/B switch in some rooms allows the expensive in-wall speakers to be used as higher quality speakers for local audio sources, such as enhanced TV sound from TVS that have an amplifier built in for external speakers, or a small stereo system used just for that room.

Growth potential lies in the ability to add equipment for zoned audio, where someone in one room can listen to a different audio source than someone in another room. Using the same centralized audio wiring scheme, multiple amps and switchers are used for the sources. Each audio zone has a keypad that is used to select the music source, and the selected source is switched to the requesting volume control/speaker system(s). This type of system is very expensive (the zone keypads alone, depending on capability, run from about $250 to $450 each!), so we will not use it unless the prices come down quite a bit. However, with the same wiring, simpler (and cheaper) systems provide some limited control. For example, using an infra-red repeater system, an infra-red receiver (about $75-$85) can be put in the wall box and use the same wire to transmit to an IR blaster (about $65) in the media room, allowing control of the single-source audio from anywhere an IR receiver is installed. An IR remote is pointed at the IR receiver in the desired room, and the command is transmitted to the IR blaster in the media room to allow control of any piece of equipment in the stack. More sophisticated IR control systems are also available. There are also keypads that mount in the same wall boxes that just emulate a learning IR remote; you “teach” the keypad the IR commands (like programming a universal IR remote), and punching the pre-labeled keys then transmits the command through the wire to the same IR blaster. This avoids lost remotes and looks more professional, but the keypads are still about $250 each. In summary, lots of different methods of control are available using the same keypad/IR wiring in the house. BTW, this type of control is called IRBus by CEBus.

Signal-level cable was installed only in selected locations

I also ran signal-level cable to special TV outlet locations in rooms where we might some day want to provide a secondary source for whole-house audio. For instance, in the library we might want a stereo system where we can change CDS while we sit and listen in that room. To allow the rest of the house to listen to those CDS also, the signal could be piped to the media room from the library and switched there to the whole-house amplifier(s). SoundTrack actually specified this cable to be run to *each* TV location for possible signal-level sources to be sent to each TV, as a possible scheme used by ELAN or AudioEase. However, since this is not yet a standard, I don't plan on using ELAN or AudioEase, and this is the most expensive wire we bought, I limited this type of cable run to just the library. But, it is something to think about.

Powerline, Video, Phone, and Data

The design for video, phone, and data is based on CEBus specifications where they made sense to me. Since the “workhorse” of CEBus is the Powerline bus (PLBus), I made the assumption that if it would work with X-10, it should work with CEBus. Therefore, I did little with the high-voltage design other than having the electrician bring power to the light switches and then run the switched leg to the light, instead of running power to the light and the switch leg to the switch. This ensured that power (and

ever-present signal path through the switch boxes) was available at each switch location regardless of the switch location; it ensured that a neutral wire was available at each switch box (needed for flourescent or high-current X-10 switches). The electrician was already familiar with X-10 installations, so I left most of the details to him. See the section *Surge Protection and Bridges* (page 28) for other X-10 considerations. Also see the *Power line Control* section of Appendix A (Feedback) for comments from others on this topic.

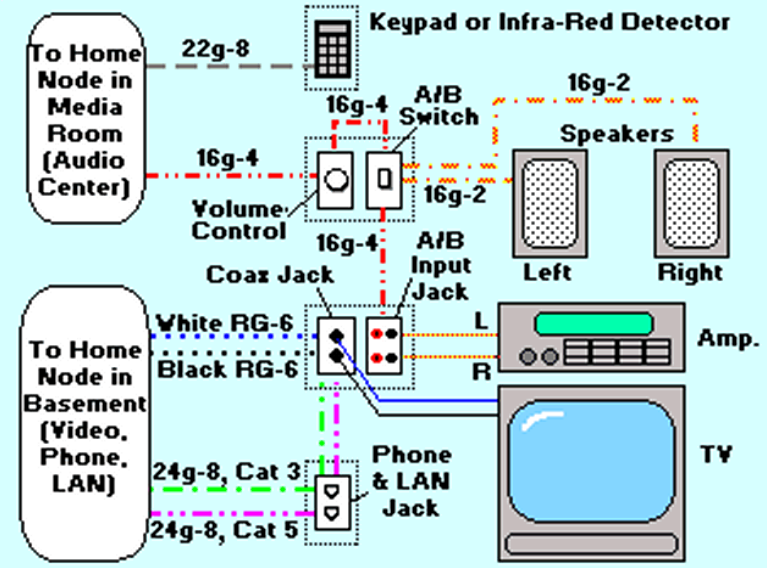
Two runs of coax cable were run to each expected TV location in the house

CEBus uses coaxial cable for TVS, FM receivers, security cameras, etc.; they call this the CXBus. It consists of two coax cables in parallel to each outlet. The External cable is used for external sources such as cable TV or satellite, and the Internal cable carries internal sources such as VCR and camera signals. Other sources also recommend two coax cables to each outlet, and suggest that until a fully accepted standard is common one coax could be used for cable/satellite and the other for a central video tape player, allowing some inexpensive source selection at the TV via input selection on the TV. Some people suggest coax for line-level inputs, such as audio. Also, S-Video can be distributed long distances using a **pair** of coax; see HomeTech's solution for long S-Video runs (http://www.gohts.com/video/svideo.html).

CEBus uses twisted pair wiring (TPBus) for phone, data, and programming (like HiFi or an intercom). They talk about using the TPBus for stereo sound, but I chose to use the 16 gauge speaker wire scheme since it was more familiar to me and matched my consultant's successful experience. To ensure adequate future expansion of either voice or data, I ran two 4-pair TP cables to both TV and phone locations. This usually gave me at least two outlet locations (one TV outlet box, one phone outlet box) in each major room and bedroom at which I could connect phone, data, or both. I wanted to reserve one 4-pair cable for possible high-speed LAN connections (which could possibly use all 8 wires in the case of 100MBit LANs), and to ensure complete separation of data cross-talk, and use the other 4-pair for multiple phone extensions and/or low-speed LAN or other data links (such as a short-haul modem for non-LAN printer distribution, etc.). CEBus specifies separate 4-pair cables for phone and TPBus to avoid unwanted signal pick-up between phone and other services. This wire is relatively inexpensive (5-10 cents per foot, depending on category; see the *Wire Type/Cost Chart* on page 19). I know one person who ran 25-pair cable to each room to allow for RS-232 serial connections, etc., in addition to category 5 LAN 4-pair cable to each room.

Schematic of Typical Full Room Wiring

This layout is what we typically used for a bedroom or the library; other rooms had more or less the same layout, depending on use. The top half shows the whole-house audio connections in a room, sourcing from the media room Node 1. The bottom half shows video, phone, and LAN sourcing from the basement Node 0. In the diagram, the cable runs are numbered in the form xxg-y, where “xx” is the wire gauge and “y” is the number of conductors. The dotted lines surround one or more devices or wires that we put in each electrical wall box. For instance, both the volume control and the A/B switch were put in the same double-gang wall box; the keypad went in its own single-gang (or double-gang) wall box.



A four-conductor speaker wire cable was run to the volume control, then to an A/B switch if that room had a second audio source (such as a TV's external speaker connector or a secondary stereo system). Two separate two-conductor speaker cables were then run from the A/B switch (or directly from the volume control if no A/B switch was used), one to each stereo speaker. Where an A/B switch was provided, another four-conductor speaker cable was run to the wall box where four banana jacks (2 for right, 2 for left) were to be placed for the second audio source. This was usually the same (double-gang) wall box to which the video cables were run since this location would probably be the best place to put a small secondary stereo system, or we could use a TV's (amplified) external speaker connection as the secondary sound source.

The 22 gauge 4-pair cable was run from the media room to all rooms that might need an infra-red receiver or a future music zone source selection keypad. This was a single-gang box in smaller locations like bedrooms, or a double-gang box for more key areas, like the Great Room or Library, where a larger keypad with more features may be desirable.

The two coax cables, the phone cable, and the LAN cable were run together from the basement to the TV wall box location. From this box, the phone and LAN were usually looped through the box then run to the phone wall box location. Allowing access to the phone and LAN cables from the TV box provided an alternative location for either service, but only if needed. I will probably just leave these wires looping through these boxes and not terminate them unless I find I need them, but at least they will be there if it proves convenient. Since my phone wall boxes were usually located across the room from the TV box, this allowed greater distribution of the cables. I still used only a double-gang box in the TV locations (one outlet for both video connectors, the other for the four audio banana plugs used for secondary A/B switch source) since Leviton has a wide range of data/phone modules that could be used if the data or phone cables are later needed. Leviton's Telcom Category 5 line and QuickPort® products allow just about

any needed configuration of F connector jacks, phone, category 3 or 5 modulars, BNC, or even fiber optics; up to four mix/match jacks can be put into one outlet device or single-gang box.

See the *Telephone and Cable Outlets* section on page 35 for more on wall jack options, which might influence the type of boxes you install. Also, see the *Conduit* section under the *Feedback* section (Appendix A) for more thoughts about installation possibilities.

Wire Types and Sources

Cable Ratings

Cable is selected for UL ratings, wire gauge, noise rejection, and desired quality

All the wire that I used was UL rated as either Level 2 or Level 3 (CL2 or CL3). This is a fire rating for the outer insulation jacket of the cable. Though I don't know the numbers, it certifies that the cable insulation will not burn for a certain amount of time at a certain high temperature. Check your local building code for requirements in your area, but Level 2 is accepted in many areas, and Level 3 is good for most all areas in the US. Local building codes will probably require at least some UL level rating. UL rated wire is marked on the wire itself, usually something like "(UL) CL3" for level 3 wire, which is what is marked on the Monster Cable audio wire I used. Twisted pair cables may be marked "(UL) MPR/CMR" or "(UL) CPP OR MPP" or the like, depending on plenum-rated or non-plenum rated cable; see the section on *Phone and Data Cable* (page 18) for details.

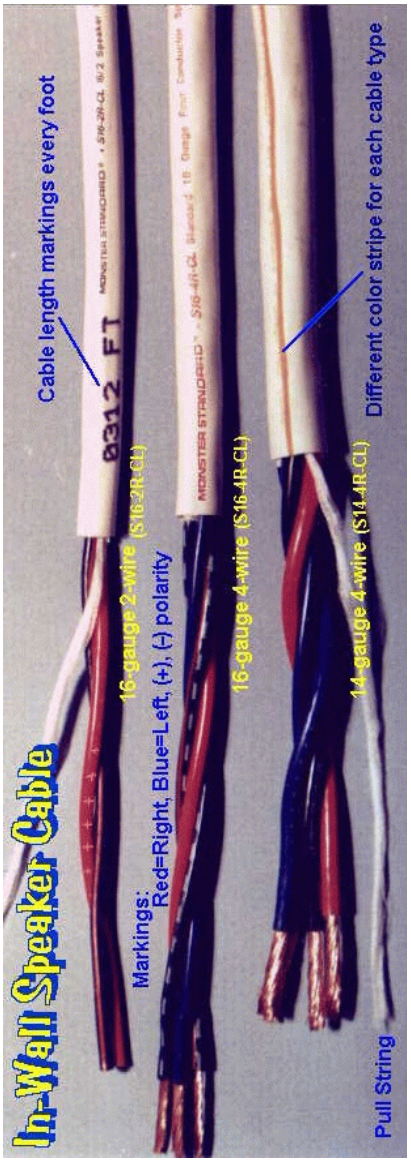
Another reason to use wire designed for in-wall use is that it is made for greater noise tolerance due to the usual proximity to electrical wires (AC) in walls. This is done with shielding and/or by twisting pairs of signal wires. I don't know the exact scientific details behind the twisted pair theory, but the idea is that noise induced by half of the twist is "nullified" (in theory) by the other half of the twist. Long runs of signal wires can get noisy if the wires run perfectly parallel to each other.

Also, AC current in 120 (or 220) volt lines produces a magnetic field in wires running parallel to the AC current. This produces hum on audio wires or noise on data wires. Twisted wire pairs help reduce this noise. Perhaps someone else can contribute a better (and more accurate?) description. All I know is that twisted pairs help reduce induced noise, whether it is audio signal cables or data cables. Wire routing is the greatest prevention for AC-induced noise, since crossing the AC line at 90 degrees (right angles) does not produce noise from that line; see the section on *Wire Routing and Installation* (page 21).

Cable jackets may be different materials to meet different UL ratings, but is generally rated for either normal in-wall installation or plenum installation. Commercial buildings usually use plenum-rated wire because at least some of their runs are through air plenums (such as the space above suspended ceilings) associated with heating and cooling systems (HVAC). Building code usually requires plenum-rated wire in such ducts to ensure a fire is less likely to cause burning insulation to contaminate the air system. Plenum

rated wire is jacketed in material like teflon instead of the PVC usually used for non-plenum rated wire. Since homes seldom have duct systems where wire is run, PVC is usually acceptable, especially when put in walls. Therefore, all the audio/video cables discussed here are PVC, not plenum rated. Since plenum-rated cable is usually almost twice as expensive as PVC cable (at least in my area), I also used PVC for twisted pair cabling.

Most of the A/V wire we used was Monster Cable®. They manufacture high-quality cable for speaker wiring, signal level wiring, and coaxial cable, all for in-wall installation. Believe it or not, the prices (in bulk, normally 500 or 1000 foot spools) are fairly reasonable. For instance, quad-shielded coax cable from Radio Shack in bulk (1000 foot spool) is about 18 cents per foot; Monster Cable quad coax cost me 24 cents per foot (with large quantity discounts), and the difference in quality is like day and night (see the comparison photo). All the Monster Cable is marked every foot with the amount of cable left on the spool. This made it very easy to estimate length of wire runs and remaining wire on the spool. All wire had white jacketing with color-coded stripes for each wire type (red stripe for 16-gauge 4-pair, black stripe for 16-gauge 2-pair, etc.). This made it much easier to quickly tell which wire you are running or had run.

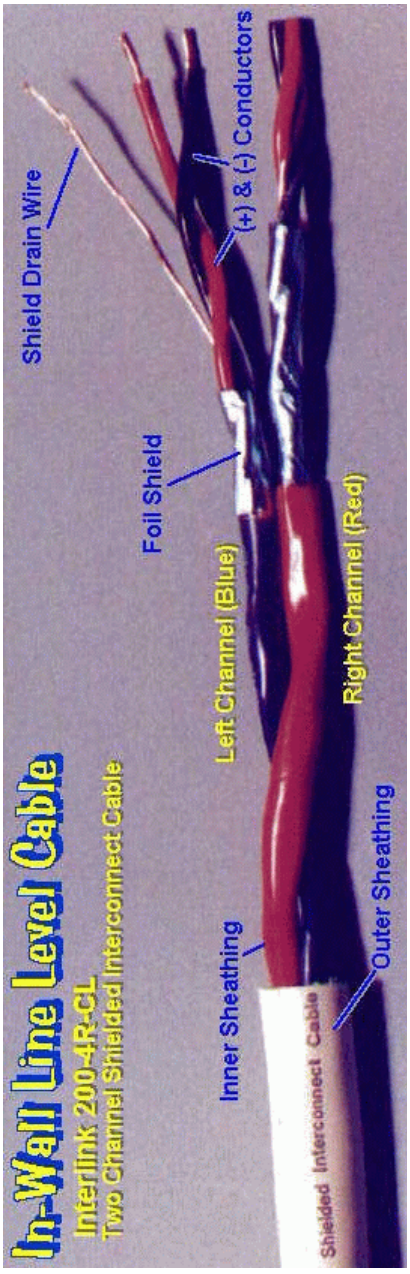


Whole House Audio

With the above discussion about induced noise in mind, Monster Cable® makes a series of in-wall rated audio cables [called Monster Standard™] that I used for my in-wall speaker cables and audio signal level cables. I used a two-pair (four conductor) cable from my central audio cabinet to each volume control, for right/left speaker pairs. The four wires are twisted together and covered by the UL-approved PVC jacket. This is certainly easier to run than two separate speaker wires! From the volume control, a separate 2-conductor cable was run to each speaker (Monster Cable again, one twisted pair in the same jacket). I used 16 gauge wire for all whole-house audio systems. I know, I know, 16 gauge wire may be considered too small by some factions, but remember, I am not fanatical about audio, this is not for super high-fidelity in each room, and the music is likely to be background music and not ear-blasting. Besides, this is the design used successfully by SoundTrack for many custom homes. Also, Monster Cable claims (I am told) that their 16 gauge wire is comparable to other 14 gauge wire anyway. So, except for the media room and the main speakers in our Great Room, we used 16 gauge wire. Monster Cable also makes 14 gauge and 12 gauge in-wall pairs and quads, though the 12 gauge is several times the cost of 14 gauge.

By the way, I know that the subject of speaker cable quality is a hot topic, guaranteed to invoke a lot of lively discussion. Some people think that high-quality cable (like Monster Cable) is a waste of money, and zip cord (ordinary lamp cord) may work as well. However, remember that zip cord does not meet most building code for in-wall installation, and may not last over the years as well as cable designed and manufactured for in-wall use. Look at the photo here, and note the heavy PVC sheath (jacket) around the internal wires, which are themselves separately insulated. This outer sheathing protects the cable during installation and makes the cable last

longer. The nylon pull string helps keep the wire from stretching as much while pulling through wall studs. And finally, the twisting of the wires inside the cable sheathing should help reduce noise that could be induced from adjacent electrical wiring, which is more of a problem inside a wall. Regardless of the name brand, cable designed for in-wall use seems worthwhile to me for the extra cost for something as hard to replace as in-wall wiring. Just my opinion...



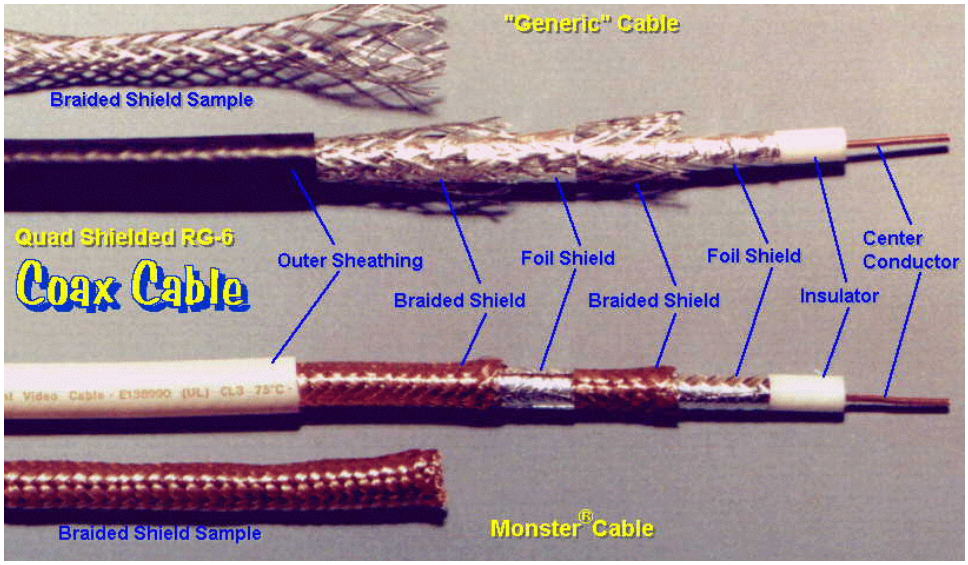
For signal-level wiring (such as source signals from a CD to the amplifier, source for a sub-woofer, or other RCA-jack terminated signals for pre-amplified source input), Monster Cable makes an *Interlink 200-4R-CL Standard Two-Channel Shielded Interconnect Cable*. This is about a 20-gauge wire pair cable, substantially heavier than any normal pre-made RCA-jack type signal cable. Actually, this cable is two pairs (4 conductor) for right/left channel, and **each** pair is shielded separately then jacketed. Both pairs are then covered by an outer UL-approved PVC jacket for in-wall installation. If the 20-gauge nature of this wire seems small, try dissecting a standard patch cable normally provided with a CD player or similar equipment for connection to the amplifier – talk about hair-thin wires!

Media Room Audio

Since most critical listening and higher volumes are used in the media room, SoundTrack designed in larger gauge speaker wires for the main speakers - 14 gauge wire pairs. However, due to a shortage of this Monster Cable size at the time, SoundTrack substituted 4-conductor cable instead of 2-wire for the same price. This actually provided a benefit beyond what I had planned, since it allowed doubling up the wires for the main speakers; I will just use two conductors for each speaker pole connection instead of one, making the effective gauge of the wire considerably more than even a single 12-gauge wire! Considering the cost of 12-gauge wire, this provided a super main speaker wire relatively inexpensively. As a bonus (and something worth considering for your own system, regardless of the wire gauge used), the four wire cable could be used to drive bi-wired speakers, where one amplifier output is used to drive just bass frequencies (one speaker pair) and another is used to drive high frequencies (the other speaker pair). Some speakers are made this way since such a large percentage of the amplifier's power is needed for bass. With the separation of the power going to the bi-wired speaker, the 14 gauge wires (separated) should be more than adequate to drive the speakers cleanly at high power. Thus, a four-conductor cable for each speaker would make a very versatile installation for either standard or bi-wired speakers, providing future expansion of your system. To continue this concept, four-conductor 16 gauge wire was used for the seven (front pair, rear pair, side pair, and single center channel) surround speakers in the media room instead of the two-conductor 16 gauge wire recommended by SoundTrack. The SoundTrack consultant informed me that Monster Cable's 16 gauge wire is the only 16 gauge wire approved for THX certified sound systems (normally, 14 gauge wire for surround speakers is required for THX certification).

Video Coaxial Cable

CEBus recommends the use of RG-6 coaxial cable for the two pairs run to each TV location. RG-6 uses a larger gauge center conductor (18 gauge) and has a foil shield in addition to the braided shield compared to RG-59. RG-59 is the standard coax cable used for cable TV installations and the like, until recently. RG-6 has a lower loss at higher frequencies than RG-59. However, I have found that there are different grades of RG-6 cable, depending on manufacturer and cable specifications. Most consultants and sources recommended **quad** shielded cable, which is made of a foil shield covered by a braided shield covered by a second foil shield covered by a second braided shield. In addition, the braided shield may consist of different coverage, measured in percentage of coverage. For example, a 30% braid is a much looser braid made of fewer strands of copper or aluminum than a 60% braid. A 60% braid is very tightly woven. Finally, the center conductor may be made of solid copper or copper-covered steel. The copper-covered steel is used to provide greater rigidity when the center conductor is inserted and re-inserted into a coax jack, since the F-connectors used for coax termination use the center conductor as the "pin" for the connection (others have disagreed with me on this). However, I feel more comfortable with solid copper conductor (copper is a better conductor, does not get worn off with multiple insertions, and is not as subject to manufacturing quality control during the copper plating operation) – my opinion only. Monster Cable makes the best quad-shielded RG-6 coax cable I have seen. It uses a 60% (or higher, it appears) all-copper braid for both braid shields, has a solid copper center conductor, and is quite flexible and tough.



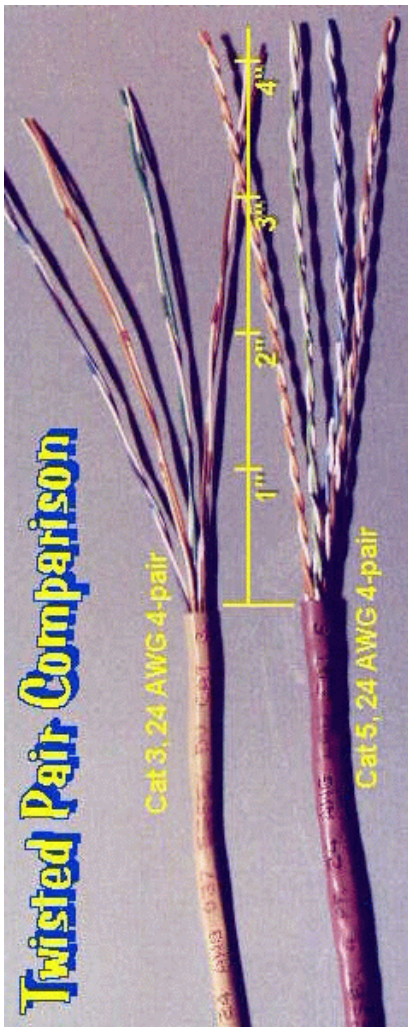
Two runs of coax were made from Node 0 to each TV location (why **two** runs? See *Powerline, Video, Phone, and Data* on page 11). To make it easier to distinguish between the two coax wires, several sources recommended using either different colors for the two coax wires, or using different manufacturers. Since Monster Cable only uses white coax, I chose to use a different manufacturer for the second coax wire. I still used quad shielded RG-6 coax, and the wire (also purchased from SoundTrack) was supposed to be of quality similar to Monster Cable coax, but was a little cheaper (2 cents per foot less than Monster). However, after I installed most of the wire, I stripped an end to look at it and was disappointed. Where the Monster coax was tightly braided with copper (about 60% coverage braid), the other coax was loosely braided (about 30% coverage braid) with aluminum alloy wire strands (see the Comparison photo above). If I had it to do over again, I

would probably stick with the Monster coax for the small difference in price, and just carefully mark both ends of the second wire for identification.

Phone and Data Cable

Phone and data (LAN connections, infra-red audio control data, etc.) wire is normally 24 gauge (AWG) twisted pair cables with four pairs of wires (8 conductor). Solid conductor wire is used to allow connecting to 66 or 110 punch-down blocks at the central node, for easy and versatile interconnection. CEBus specifies 24 gauge 4-pair for both phone and TPBus. I could not find much more than this for TP wire specifications in the CEBus book, so I discussed LAN and related cable requirements with several sources who had experience in LAN and phone installations (IS department technical people and installers, wire distributors, etc.).

In addition to the UL level rating for wire (level 2 and 3 fire rating required for in-wall installation), twisted pair cabling is rated by a "category" specifying essentially the number of twists each pair has per unit of length. I never really found the specifications for the actual count of twists per foot for each category, but it really boiled down to the most common types of wire being category 3 and category 5 TP cables. Cat 3 cable is commonly used for 10BaseT wiring, which is 10 Megabit per second LAN specifications often used for Ethernet networks. Cat 5 cable is much more tightly twisted, and can support up to 100 Megabit networks (Token Ring, Asynchronous Transfer Mode, etc.). Most companies are moving toward installing cat 5 wiring to plan for such 100 Mbit systems; if it is good enough for 100 Mbit systems, it is good enough for me! Cat 3 wire is usually better than what phone companies install in houses for phone wire (phone cables don't really need much twist), so I used it for phones. So why did I install both? Well, though this is relatively cheap wire, cat 5 wire is still about twice as expensive as cat 3; I wanted two separate cables to avoid cross-talk; and the cat 3 cable I got was tan colored while the cat 5 cable was purple, so it was easy to distinguish during installation and maintenance. Of course, this was only valid since I needed multiple 1000' spools of cable; if you only need one spool, it may be more economical to just get one spool of cat 5 cable. I did not use shielded cable since everyone I talked to thought unshielded was fine as long as I was using cat 3 or cat 5 (shielded cable is much more expensive). BTW, yes, there is a category 4 cable, but it is not used much due to the more common use of category 5 for high-speed LANs.



The category rating is usually printed on the TP cable jacket, and usually spelled out like *CATEGORY 5* or *CAT. 3*. You can easily see the difference between cat 3 and 5 by removing a few inches of the outer jacket to see the twisted pair wires inside. Cat 3 wire does not have very well distinguished twists to the pairs (blue and white/blue are a pair, green and white/green a pair, etc.) unless you strip about a foot or so of the jacket. Cat 5 wires are very tightly twisted (a couple of full twists per inch) and the pairs can be easily distinguished and separated as pairs.

In addition to the category printed on the cable jacket, the fire rating with codes like *MPP* (MultiPurpose Plenum), *CMP* (CoMmunications Plenum), *CMR* (CoMunications Riser), *MPG* (MultiPurpose General purpose), etc.

This is usually not critical, unless you need plenum rated cable (in which case you should look for codes like *CPP/MPP*) – just ask for category 3 or category 5 four-pair 24 AWG wire that is UL level 2 or 3 rated, depending on code in your area.

Wire Type/Cost Chart

Wire Type	Cost/ft.	Total Length
16g-4*	$ 0.490	2,000'
16g-2*	$ 0.320	1,500'
14g-4*	$ 0.440	400'
IL200*	$ 0.540	800'
RG-6*	$ 0.240	2,000'
RG-6	$ 0.220	1,000'
22g-4	$ 0.080	1,200'
22g-8	$ 0.160	2,000'
24g-8:3	$ 0.044	3,000'
24g-8:5	$ 0.095	2,000'

* Monster Cable brand

This chart illustrates the wire types I installed, the lengths I used, and my cost per foot. Wire types with an asterisk (*) indicate Monster Cable brand. Note that the Monster Cable prices reflect a volume discount; full retail prices seemed to be about twice the amounts shown below. Also, the price I paid for the S14-4 wire was the price that would normally have been for S14-2, but SoundTrack was out of stock on the 2-conductor wire and just substituted the 4-conductor wire at the same price. The descriptions below indicate how the wire was used.

Wire Types:

- 16g-2* – 16 gauge 2-conductor speaker cable, used for individual speaker runs from the volume control (or A/B switch) to the right or left speaker.
- 16g-4* – 16 gauge 4-conductor speaker cable, used for right/left speaker pair runs to each room, connecting the amplifier to the volume control. Also used with A/B switches to go from a wall input receptacle (4 banana plugs) to the A/B switch.
- 14g-4* – 14 gauge 4-conductor speaker cable, used for main speakers in media room and for main speakers in great room. Price listed below is for 2-conductor cable.
- IL200* – 20 gauge signal-level (InterLink) cable, intended for source connection (such as between a CD player and the pre-amp). Used for audio connections to main TV and future projector (such as right/left audio in or out, using RCA plugs). Also used to connect powered subwoofers, and as secondary whole-house audio source from library and office stereo system.
- RG-6* – White Monster Cable quad-shielded coaxial cable, used for one (primary) coax connection to TVs and for multi-source connections to main TV in media room. Also used for main external signal inputs, such as satellite or antenna.
- RG-6 – Black generic quad-shielded coaxial cable, used for second (secondary) coax connection to TVs.
- 22g-4 – Stranded 22 gauge 4-conductor wire, used for ELAN or AudioEase compatibility on main TV systems and for security system Passive Infra-Red (PIR) detectors.
- 22g-8 – Solid 22 gauge 8-conductor twisted pair wire, used for keypad/IR locations, weather monitor sensor, security system keypad, and main telephone run from outside phone company junction box.
- 24g-8:3 – Solid 24 gauge 8-conductor twisted pair wire, category 3, used for phone jacks, door phones, and extra PIR control (cheap way of

providing possible X-10 connection to optional secondary switch of PIRs).

- 24g-8:5 – Solid 24 gauge 8-conductor twisted pair wire, category 5, used for future Local Area Network or other data links.

Purchase Sources

I purchased most of the audio and coax wire from SoundTrack because they would sell it in any length, I could return any length that I did not use (not just in multiples of 500 or 1000 feet), and their prices were very comparable to mail-order with the volume I purchased. I did purchase a spool of Monster cable (4-conductor 16 gauge) from Home Automation Systems, Inc. (HAS, mail order, http://www.smarthome.com/8515.html), but the savings were not really enough to justify the gamble that I might be stuck with too much wire I could not return for credit, so I was conservative in purchasing mail-order. Also, I goofed and did not read the fine print on another two-conductor spool I purchased from HAS; it was not rated for in-wall installation. They gracefully credited me for the return of the roll, though.

I purchased the telephone and LAN cable (both category 3 and 5 four-pair twisted pair) from a wire warehouse called Allwire, Inc. in Denver (303-295-0106). Their prices were quite a bit lower than other local houses, often by 50% or more; so shop around for prices. They sold both 500 foot and 1000 foot spools or dispenser packs, and always had it on hand.

I had a hard time finding 22 gauge wire. None of the wire houses stock it normally; they consider 22 gauge telephone-type wire a “dinosaur”, saying it has been replaced by 24 gauge. For the 22 gauge wire I needed (as recommended by SoundTrack for keypad/infra-red wiring), SoundTrack sold me what I needed. However, it was considerably more expensive (about three times the cost of comparably rated 24 gauge). Even SoundTrack had trouble getting me more than my original order – it was delayed by over a week.

See *Cable Sources and Prices* in the *Feedback* section (Appendix A) for sources and prices found by others.

Wire Routing and Installation

Wall Boxes

Running three miles (15900') of cabling proved to be quite a challenge! The keyword here is "planning". Foresight and organization will make all the difference. Here are the tips we learned, some from others, some from our adventures.

Plan out your wall box locations first. A good spot for volume controls, A/B switches, keypads or IR receivers is near a light switch to keep groups of switches together in a room. However, you may want to mount the volume control and A/B switch near the head of a bed in a bedroom. Keep the audio controls on studs across from the switches (one stud away) to avoid the AC interference. We put the double-gang box for the volume control & A/B switch at the same level as light switches (44" from floor to bottom of box) and put the keypad/IR box just above the volume and A/B box (closer to eye level), since you are more likely to need to see the keypad, either to read the keys on the pad or to read an LCD display. Keypad/IR boxes were put 52" above the floor (BTW, we put thermostats at this same height for consistency). Use a single-gang wall box for infrequently used keypad locations and double-gang boxes where you may want to install a larger keypad with more features. We put TV and phone boxes at electrical outlet heights (13" from floor), again at least one stud bay away from AC outlets.

> **NOTE** – strange as it may seem, cut the backs off all boxes for which a volume control is destined! You can also use “mud rings” to serve the same basic purpose, but make sure they have screw holes for mounting the volume controls. Some volume controls are very deep, and do not fit even the deep electrical wall boxes (I had 3" deep boxes). The volume controls that I looked at (Niles) had a circuit board that just did not fit. SoundTrack installers cut the backs off *all* their boxes with a band saw before going on site.

Routing Around Electrical

The main thing to watch in routing low-voltage signal cable is avoiding high-voltage AC wiring. It is OK to cross low voltage signal and speaker wires at 90 degrees to electrical wiring (cross perpendicularly), but avoid running parallel and close to electrical wiring. This will cause noise in speakers (at low volumes) and could cause data errors in data lines. Everyone told us to do the low-voltage wiring **after** the electrician has finished his pre-wire! I heard several “horror stories” about running speaker wires then later finding the electrician liked the holes that had already been drilled, and used the speaker wire holes for his electrical wire. One installer even drilled holes through many joists to get a path, went back to where he started the holes, and found the electrician filling his new holes with electrical runs. If you do any wiring on outside walls, make sure you do it before insulation!

Unfortunately, there is often very little time between the completion of the electrical pre-wiring and the start of insulation and drywall. We were unable to start our wiring after the electrician due to scheduling; in fact, we started before the electricians. Fortunately, the electricians were very understanding about our wiring (a rare attitude, according to my contacts), and were very

conscientious about crossing at right angles and not running parallel to our wires. Even so, we had to re-run some cable paths when the electricians ran too close, especially on long runs. The rule of thumb in this case is, if there is an easy path and a hard path, take the hard path because the electrician *will* take the easy path.

Avoid running low-voltage cabling close to and parallel with AC power cables – where parallel runs are necessary, keep good distance between them and keep these runs as short as possible

I have heard several differing views on the minimum separation between parallel runs of AC and low-voltage cabling – anywhere between 6 inches and 4 feet, depending on who you talk to. In the CEBus Installer's Guide under twisted pair installation, they say keeping 6 inches between the TPBus and AC wiring is good. However, I've heard that AC wires produce a field 18" out from the wire. Others say to keep 3 to 4 feet away. Therefore, I tried to keep at least the 3-4 feet where I could, but dropped down to 16" for shorter runs. You will frequently want to run wires to a box near a switch or floor outlet, so running along the opposite stud (16" centers) in a bay to get to the outlet is common. And, the “no parallel runs” rule can be violated for short distance if absolutely necessary, such as to get over a door frame or tight locations that leave no alternatives. SoundTrack says that Monster audio cable can run up to 10 feet parallel to AC (1 foot from the coax), coax can run 25 feet (or much more for Monster coax), and other low voltage wire can run about 2 feet without much chance of problems. You should never run the cable in the same holes as AC for parallel runs – keep at least some separation, and keep parallel runs very short. Low voltage wiring should also never go into the same wall box as AC.

Drilling Holes

For drilling holes through wall studs, use auger bits, not spade bits. Augers have a screw-tip to pull the bit through, and they cut the hole cleanly while taking out large chunks for a quick hole. I purchase two bits – a 5/8" bit, which allowed room for the two coax and phone/LAN cables for the typical TV outlet, and a 1" bit for all the wires in a room, leaving a little to spare. Don't use a bit larger than the 1", and center the hole in the stud. If the edge of the hole gets closer to the edge of the stud than about 1", you should apply a nail plate to protect the wires from drywall screws. A good 3/8" electric drill should drive the 5/8" auger bit through a single stud (good 12 volt battery operated drills worked for us for a few holes here and there, but you need a second battery to keep on the charger), but you will probably want to rent a heavy duty ½” right-angle drill for lots of stud holes, doubled-studs, and the 1" bit. However, plan out your routes before renting the drill and spend time up-front getting all the holes drilled first to avoid excessive time renting the drill. If you use a standard drill (instead of the right-angle drill), you will not be able to get straight holes through the walls (due to the length of the drill/bit combo), and pulling the wires will be more difficult and may increase the chance of damage to the wire due to the angled nature of the holes. I could not find anyone who could tell me how many holes can be drilled vertically in a wall stud, even for a load-bearing wall. Neither the electrician nor the contractor could tell me for sure, though they seemed to think that it was not critical – they recommended keeping the holes at least a foot apart. For horizontally-running support studs, it seemed OK to even drill

most of one out. However, check your local building code. I kept my number of holes to a minimum just to ensure wall integrity.

*Be sure to check your **local** building codes for regulations about the number of holes you can drill in a stud, allowable locations for drilling joists, and for codes on drilling structural laminated wood beams!*

For major cross-house runs through joists, a 2" or 2½" hole saw is useful. A lot of wire will go through a 2½" hole – we ran most all of our first-floor audio cables through a single run of 2½" holes in floor joists. When drilling through floor joists, keep your holes away from the supported ends of the joists since that is where the sheer force is located. I was told to keep holes away from the bearing point at least three times the height of the joist. Therefore, for an 8" joist, don't drill closer to the bearing point than 24". From there, for every foot from the bearing point, you can drill a cumulative 1" diameter hole. Thus, two feet from the bearing point you can drill a two inch hole. There must be some limit to this rule of thumb, since an 8" hole in an 8" joist 8 feet from the end doesn't work, but the basic idea seems logical. In our case, things were a little safer since we used TJI ("Silent Floor") joists. These are those "I" beam-like joists built of plywood 2x2s top and bottom with particle board "webbing" between. These tolerate more holes since the joist has compressive force on the top 2x2 and expansion force on the bottom, and the particle board webbing doesn't do much except hold the two together. Therefore, holes kept in the center of the webbing are not as critical. However, the sheer force is still on the ends of the joist and you should not drill close to the ends of joists. In spite of these guidelines, I found the electricians and plumbers did not always follow them. But, I kept to the guidelines so as not to compound any issues. Of course, local building codes prevail.

Several sources warned me not to **touch** laminated wood beams (lam beams). I was told that drilling a single hole in a lam beam could have the inspectors require tearing out the beam and replacing it! Lo and behold, one day I noticed two holes the electricians had bored through one of the lam beams! The contractor just said we would have to get a letter from the structural engineer accepting those holes, but he had the electrician stop drilling lam beams. The electrician said he did it all the time with no question, except in some towns (the horror story about tearing out the beam came from someone who built in one of these towns). So again, check not only local building codes but the attitude of local inspectors before drilling lam beams (or steel beams). I completely avoided putting my own holes in lam beams just in case.

Planning Routes and Pulling Cable

We spent more time finding routes for runs and individual locations than we did actually drilling holes and pulling cable. Plan main cable runs along the full length of the house from which you can split out individual runs. Make sure these main runs are *well* away from AC runs (electricians will be putting in such main runs, too) due to the length and number of signals that would be affected by noise. Ensure that such main runs (or any smaller runs) do not get blocked by a lam beam or steel beam, and that they can hold all the wire. A good, easy location is across the lower member of roof trusses. You can tape together the ends of several wires going along the run, tie a string to the end, tie a weight to the other end of the string, and just toss the weight over a few truss members then pull the wire across. This saves the

time of climbing a step ladder, feeding the wires, back down the ladder, drag it a few feet, back up, etc., etc., etc. When pulling through trusses, do not pull the cables through the center of a "V" section – the wire will settle in the bottom of the "V", and settling of the house or expansion/contraction may pinch the cables, possibly causing shorts or cuts years down the road. When pulling the cable, either through holes in studs or across trusses, pull slowly. Pulling too fast will friction-heat the wood, and when you stop pulling the hot wood can melt or burn the PVC cable jacket. And, of course, don't yank or pull the cable too tight, especially around corners or areas that might get pinched or kinked – it's not worth breaking a wire, which may not be found until it is way too late.

Use a logical numbering scheme for labeling cables

A numbering scheme for the cables is useful. SoundTrack recommended using three digits on each cable. The first digit for the floor, and the second two as sequential numbers for types of wires (00-20 for speakers, 21-30 for keypad, 31-50 for coax, etc.). However, I found it more useful and convenient to use the first digit for the node location (0 for basement, 1 for media room, 2 for security center, 3 for all other point-to-point wires) and the other two digits just sequential regardless of wire type. I kept a log of all wires run, and the sequential listing grouped the cables by room (110-116 all went to the same room, for example). We numbered both ends of the wire with a fine-point permanent marker, directly on the white jacket of larger cables and on white electrical tape for smaller wires or black cable. After I set up the centers and finalize the exact locations of the cut ends on the mounting boards there, I will re-number the cables neatly with pre-printed number tape or a label printer (I use a Casio; similar to the popular labelers by Brother). You can get the number tape from 3M in spools of individual numbers, or from other companies in booklets of number strips. Look in your local electrical supply stores for these numbering tapes. I will cover the taped numbers with clear heat-shrink tubing for permanence. After running all the cables, go back and check off each and every number in your log against *both* ends of the cables – I found a couple marked with the wrong number on one end, and a couple not marked at all. If you don't find these until the drywall is up, it will be harder to trace the cables! Use a continuity checker if necessary to test those unknowns (strip two wires in a cable at one end, twist them together, then test for continuity between those wires at the other end). See page 28 under the *Miscellaneous Wiring Ideas* section for how I used Sidekick for Windows to organize my wire charts containing the numbering records.

Plan how multiple assistants will work together, to save time

If you have several people helping you run cables, organization during the cable pulling is even more important. We often ended up with a couple of people scratching heads and planning a route around AC cables, lam beams, and congested locations, while everyone else sat around waiting to drill holes and run wire. Plan the main routes and many of the individual routes in advance; paint or mark the paths on the joists and ensure you don't get trapped by impassible lam beams 3/4 of the way to the destination. After planning and marking runs, *then* rent the right-angle drill and bring in the crews. One person is usually enough to run the drill – start that person first. We found two people the ideal for each run of wire-pulling. There's a lot of back-and-forth running to get around corners with only one person, and three people are too many except for long runs. We borrowed a cable spooler rack

to put several spools on and put it at the central node. You can also use the electrician's trick of nailing a piece of conduit horizontally between two wall studs and putting the spool on the conduit. Tape together as many cables as practical (for example, a full package of the two coax, phone, and LAN destined for one room's TV outlet, or several speaker cables with keypad/IR wires going to a group of bedrooms through the same chase). Use two step ladders when feeding through joists, and have one feed wire through to the other, leap-frog a step ladder, etc.

After running the wires, staple them to the studs to avoid getting a wire pinched between the drywall and the stud. For individual cables, I found the Arrow T-59 stapler invaluable. It uses a plastic-insulated staple that is curved on the inside to just exactly fit an RG-6 coax cable. It also works well for the speaker wires – a little loose for the 16-2 and a little tight for the 14-4 and IL200, but works for these too if you are careful. For bundles of cables, use those plastic insulated staples (hammer needed) used for AC electrical wire. I also used the metal electrical wire staples, but didn't drive them deep enough to pinch the cable. Keep the cables in the middle of the stud to avoid an angled drywall screw or one that just misses the stud (believe me, they miss the stud frequently).

After you run the wires to an open-back wall box like for a volume control, tape all the wires together so they can't get lost below the box. Staple cables close to outlet boxes to also reduce the possibility of lost cables. Drywall installers will push the wires out the back of the box to get them out of their way. I also put little sandwich baggies over the cable ends in each box after wiring to prevent texturing and plaster from messing up the cables and labeling. Stuff all cable ends completely into the boxes to avoid damage during drywall.

Clearly mark special cables, and photograph all locations of hidden cables

If you use surface-mount speakers, drive a nail into a stud at the location you will terminate the wire and tape the wire to the nail so it sticks out into the room. Dry wall installers are notorious for hiding anything they can behind the dry wall. The nail with the wire is a more sure indication that the wire must be brought through the wall. Don't rely on a walk-through with the planner – it's the guy driving the nails you must guide. If you use recessed wall speakers, locate the wire where you want it, coil it, and **photograph and document** its location. Putting speakers on outside walls may not be a good idea, but if you do it, make sure you pull the wire through the insulation after the insulators hide it from you. SoundTrack recommends getting the drywall up, or even finished, before cutting the hole for in-wall speakers so you can carefully fine-tune where you want the speaker on finished surfaces instead of a visually different set of studs. Other sources recommend installing a "hole guide" before the drywall goes up so that the drywall installers will cut and finish the hole for you. However, I've found that these hole guides cost anywhere from $10 each to $40 for a mounting bracket per speaker! I'm going to stick to the speakers that include the mounting bracket in the price of the speaker (Polk has some nice ones; we purchased their top-end in-wall model AB 805 speakers for about $390 per pair, and their mid-quality in-wall AB 705 speakers for about $290 per pair). See the section on *Finishing the Installation* for details on the mounting process (page 29). Surround-sound speakers should be mounted about seven feet from the floor (avoiding direct sound to the ear), and normal audio

in-wall speakers should be installed about ear level (to ensure direct sound). These are ideals, and what you really do will probably depend on how it looks in that room, or other limitations of the room layout.

I estimate we spent about 42 people-days (8-hour days) on the whole pre-wire project, which was almost 16,000 feet. Of course, this included a lot of head-scratching while planning routes, some inefficient use of many people the first weekend while we got organized, and some post-installation time doing checking and verifications.

Miscellaneous Wiring Ideas

While planning wiring needs, here are some of the things I ran wire for, some just in case I wanted to install them later.

- Door phones. The Panasonic phone system supports separate door phones at front and rear doors. The person at the door pushes a "doorbell", ringing all phones in the house. You pick up the closest phone and talk to the person at the door. They respond through a built-in microphone in the door phone. Run 24 gauge twisted pair (4 conductors needed) up to 370', 22 gauge to 590' (specs for the Panasonic unit). Even if you don't do door phones, you will probably want a door bell and the same wire should work.

Have you thought about outdoor wiring? Speakers, driveway gates, door phones, weather station, surveillance cameras, security...

- Gate control wire from driveway gate to basement. Such gate controls may be a speaker-phone (like above) or just a low-voltage switch wire. I ran multiple runs of 24 gauge wire to an outside weatherproof box, where I can later connect to an underground cable to the gate.
- Speakers to the outside patio and / or hot tub location (subwoofer too?).
- Coax and high-voltage AC to outside locations for video camera – front door, driveway, etc. I located both coax and AC under an eave for this – the AC may also be useful for outside Christmas lights.
- Be sure to put a phone outlet near any location you may put a satellite receiver; some of the satellite systems (DSS and PrimeStar) connect to the phone line to automatically dial up the service late at night to transmit billing information for "pay-per-view" movies watched. Some data may also be downloaded to your receiver. I put a jack (LAN & phone) in the closet next to the media room equipment stack. Also, we put a phone outlet in a central closet near some shelves so we could put in a cordless phone. This puts the base of the cordless phone, with its antenna, out of sight but centrally located for best reception throughout the house.
- Twisted pair wires for a weather station. I ran 22 gauge 4-pair wire for a Davis weather monitor from a desk location near the kitchen to the attic space where I can run the sensor wires to the weather mast at a later date. I also ran a LAN wire from the monitor location to the office so I

could hook the weather monitor to the PC via serial connection (either directly to the RS-232 port or through a short-haul modem).

- Extra LAN wiring in the office. Since my wife and I will be sharing the office using two desks, I installed two outlets on opposing walls and ran separate LAN and phone cables from them to the basement (Node 0). I also ran another LAN cable between the two office outlets since we might start off our LAN system by just connecting the two PCs together, without going all the way into the basement and back. I have an outlet near bookshelves so we can have a small stereo for music in the office, and ran from here to the A/B switch as the second audio source. I also ran signal-level cable from the wall box near the desks to that stereo shelf box so I could hook up the PC's sound card and/or my MIDI keyboard to the stereo system. I can then use the room's speakers for PC or MIDI keyboard sound through the stereo system! Finally, I ran a signal-level cable from the office stereo location to the media room (like the library) so I could second-source the whole-house audio from the office stereo. For more fun, this could allow PC sound or MIDI keyboard sound to be piped throughout the whole house, if desired ;).
- Something I did not think of before wiring – with TV receivers in PCs becoming popular, it might be desirable to make sure coax is run close to locations where PCs may be located to pipe central video signals to the PC.
- Security system wiring. This topic is too broad with too many alternatives to discuss here. However, consider an extra pair of wires to passive infrared (PIR) sensors or contacts for Normally Open (NO) connection to X-10 or other utility purposes (one pair for 12v power, one pair for Normally Closed security sensor contacts, and one pair for optional Normally Open utility switches, such as X-10 lights when the security system is not armed but lights are desired when people motion is detected). Only some detectors have the second NO switch.
- Another little issue I did not think of and wish I had; if you finish your garage (wallboard) and have a garage door opener, you may wish to put in the door opener wiring before drywall. Ours got strung up on top of the drywall, and it looks ugly. Make sure you run the wires to the door-bell button for the opener *and* any wiring to any blockage sensor(s) at the door itself.

Run empty conduit in key locations for future technology or unanticipated needs

- To cover future wiring that I could not foresee (including fiber optics in the far future, perhaps?), I ran an empty 1½" plastic electrical conduit from the basement (Node 0) up into the attic to allow possible future wire additions to rooms accessible to the attic (most others would be accessible from the basement). I had also run an empty conduit underground to the media room, which was on concrete slab, before the slab was poured.
- Don't forget to photograph your wiring before insulation and/or drywall! Use a tape measure (I used a surveyor's tape – it has large numbers that can be read on a photo) held or taped at locations such as "buried" wires for future speaker locations, or wall locations that you

may want to record for future wall modifications. Try to take each photograph with "landmarks" so you will know what room and part of the room is in the photo a couple years down the road; it all looks very different with finished walls instead of bare studs! A video tape of all wiring may also be useful since it is easier to figure out what room and wall is being photographed by panning around the room. The photos and video will be useful in the future for determining what areas to avoid and what to do for future renovations.

Be sure to carefully document your wiring scheme and cable labeling

- I used the "cardfile" feature of *Sidekick for Windows* to organize the wiring scheme I used in the A/V, phone, and LAN wiring of the house. I set up label number, room name, destination node, and wire type as fields in the cards. I then sorted them differently based on the type of list I wanted, and set up custom print list patterns based on the sort patterns. Now I can print a list of all outlets and wires by room name (for when I want to go into a room and find a particular wire connection), another list by node (so I can go to the central node and know what each wire is by its numbering label), and a list for each wire type (so I know where each telephone wire is when modifying a telephone connection, for example). All this with a common "database" of wiring data that is easily maintained and printed! It worked very well, and was very easy to do with Sidekick.
- Just a side note on gas fireplaces – they can be wired for electronic ignition, or use a pilot light with no electric. Our contractor did no wiring, being used to the pilot light system, but installed electronic ignition. He just barely caught it in time to add the AC electric before drywall, but we might have done things differently if we had caught it earlier.
- We have a wine cellar (in the basement with no heat; keeps the temperature a perfect 56 degrees farenheit), a wet bar in the great room, and some authentic British beer pulls. What is more natural in such an English Tudor home than to run high-grade food-quality flexible plastic tubing from the bar to the cool wine cellar for fresh home-brewed beer straight from the tap?! Talk about home automation! BTW, the basement also has a utility sink and counter near the wine cellar where we can brew our own beer on a hot plate.

Be sure to see the appendix *Feedback and Your Contributions* for ideas and suggestions from others.

Surge Protection and Bridges

Discuss surge protection and X-10 bridging with your electrician **before** he designs and installs the circuit breaker box. X-10 bridges, which bridge X-10 signals across the two legs of the 220 volt service so devices on one half can talk reliably to the other half, take up two circuit breaker locations (one on each leg). This started to cramp the circuit breaker panel for us. Also, some whole-house surge protectors (see below) also take up two breaker locations.

Whole-house surge protection is cheap insurance from proximity lightening strikes

We have been bitten by close lightning strikes that took out one of our audio amplifiers once. Therefore, and to protect X-10 and other devices throughout the house, we purchased a whole-house surge protector. A consultant ("Mr. Lightning", a local firm that installs lightning protection on houses) recommended a unit, but it cost almost $400. I found a surge protector (called Transient Voltage Surge Suppressor, or TVSS) with the same specifications (680 Joules surge current, 50,000 amps, instantaneous response time) made by Leviton, available from Home Automation Systems for $172.80 (see http://www.smarthome.com/4860.html). From the enclosed installation instructions for this Leviton unit, it connects across two circuit breakers, but these two circuit breakers can be shared with circuits. I plan on sharing the two dedicated circuit breakers reserved for the X-10 bridge. However, the lightning consultant said his unit required dedicated circuit breakers, so check on this before filling up your circuit breaker panel.

Even with whole-house protection, consider additional protection for your expensive A/V equipment

The lightning consultant also recommended multiple surge suppressors as secondary backups and to catch anything that gets through the whole-house TVSS, so we will install additional high-quality surge suppressors (in multiple-outlet power strip format) on the A/V equipment stack and the computer systems. These suppressors have a guarantee to replace the protected equipment itself, as well as the suppressor, if the suppressor allows it to be destroyed, so it is good insurance. Shop around for these to ensure adequate protection, since there are many cheap ones on the market that are really just extension power strips with very little protection. I use one called IsoBarfrom a company called TrippLite, who has been in this business for quite a while. I have an 8-outlet noise filter and surge suppressor (model IB-8) for which I paid over $100, but I recently saw a 4-outlet IsoBar for $39.95 from Computer City; it seemed to have the same equipment replacement guarantee.

See the *Feedback* section (Appendix A) for thoughts and ideas from others about surge suppressors. There's quite a bit of information and controversy about these.

BTW, the lightning consultant says that it commonly costs $1200 to $3000 for good lightning protection for a house (to protect against direct strikes), and heavy-duty ground wiring and multiple rods should be designed and installed about the same time as the electrical wiring is being done (before drywall).

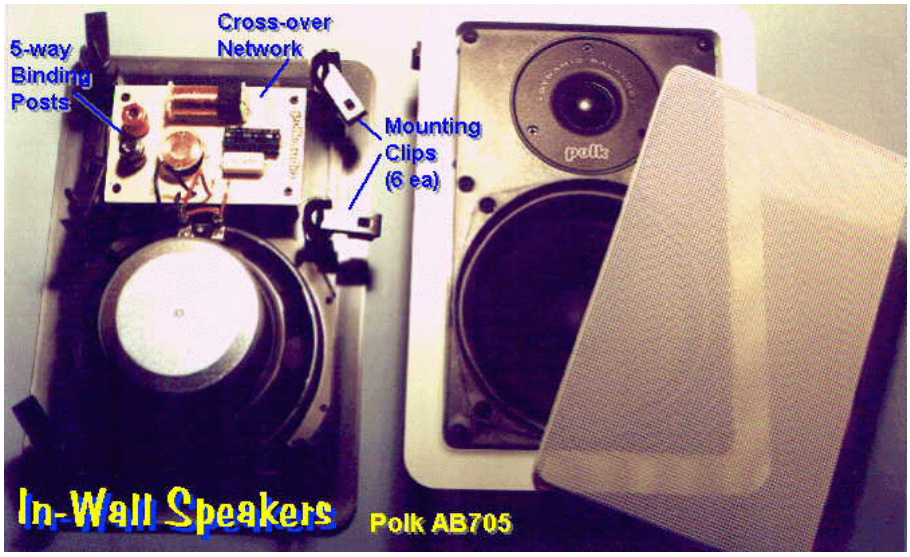
Finishing the Installation

We haven't finished installing everything we wired for; we might never get there! However, here are the products we used and the installation methods we used for what we have installed so far.

Speakers

As I mentioned before (page 25, second to last paragraph of the section), some in-wall speakers use mounting guides or brackets (usually extra cost) that are installed at the time drywall goes up. However, we used Polk

speakers that had the mounting brackets included with the frame of the speaker, and did not require pre-installed guides. From the photographs and measurements taken before drywall went up, I then measured the completed walls, adjusted slightly for the looks of the finished room, used the templates included with the speakers to mark the hole size and location, and cut out holes for the speakers with a drywall saw. After all the time that the wires had been hidden by drywall, it was really a relief to see those speaker wires behind the wall, right where I expected them to be! With the Polk speakers I used, connecting the speakers was a simple matter of stripping the wires and inserting them into the 5-way bindings of the speaker (just like a floor-standing speaker). I set the speaker frames into the drywall and tightened the screws, which swung the mounting clips over the back of the drywall and clamped the speaker frame tight against the drywall for a secure mount. I have also been able to easily remove the speakers when necessary.



We used the smaller 705 speakers (shown here) for smaller rooms like bedrooms and the office (and even above the jetted tub in the bathroom!). For larger rooms where more bass might be needed, we used the Polk AB805 speakers, which are similar to the 705 except they have an extra woofer, making them the same width but longer (woofer, tweeter, woofer in a line). We stayed with the same manufacturer and model series to try to keep tonal qualities of the sound similar as people walk through the house.

Though it is not really recommended that speakers be mounted on outside walls, I had to do so in one room. I mounted them on the slope of a cathedral ceiling where there was quite a bit of depth, but I had to displace some insulation for the back of the speaker. The vapor barrier was the biggest issue, since I wanted to make sure the back of the speaker never got damp. I had to cut the existing vapor barrier plastic (on the room side of the insulation) to make room for the speaker, but taped a larger piece **behind** the cut hole to ensure that any moisture between the insulation and the plastic would run on the other side of the speaker. Thus I still have insulation on the outside (but some pushed back to make room for the back of the speaker), the patched plastic barrier, then the speaker. No problems so far.

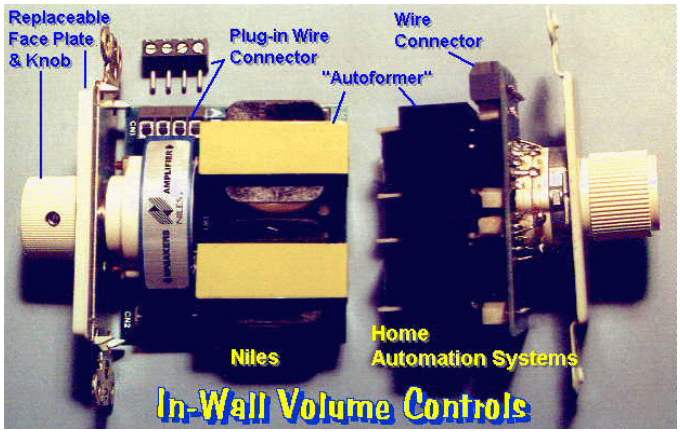
Another tricky place was ceiling mounted speakers where the attic was above the ceiling. Here I built insulated “boxes” above the speaker locations after drywall installation and before the blown insulation was put into the attic space. I built the boxes between ceiling joists using 2" foam insulation panels, or “blue board”, left over from the insulation used under the foundation. I just cut end panels 3.5" high (the thickness of the ceiling joists) and ran them between the joists, and nailed a top cover over the joists and end panels. I ran the speaker cables into this chamber and sealed all joints with caulk to make sure the blown insulation would never get into the

speaker chamber. This gave me about a 15"Wx18"Lx3.5"D sealed chamber for each speaker without heat loss. After completion of the house, I went back and cut in the speaker holes just as for a wall mount location.

So, you ask, how does all this sound now with music running through? Great! (did you expect me to say otherwise?) It **is** interesting to note the differences in sound due to room acoustics. The above two locations have identical speakers (the Polk AB805s), but sound different. Though it is possible that the mounting differences cause some of the sound differences due to the sound chamber effects, I believe it is more the room acoustics. The speakers with the blue board chambers are in a very large room with an 18 foot high ceiling and one full glass wall. With all that glass, this room is very "live", especially with higher frequencies. The sound here is fantastic, and is great for parties! The other room with the smaller space behind the speakers is not as large, with wood paneled walls, and the sound is not so open. However, in this room the sound is probably more "accurate", without frequency shifts. This might be a better room for critical listening. Though I was hoping, by having the same speakers, to have consistent tonal qualities as you walk around the house, the room acoustics do make a noticeable difference. But having high-quality music throughout the house is really nice! Put the sound system in early!

See the *Feedback* section (Appendix A) for thoughts and ideas about *In-Wall Speakers* and other *Sound Systems* issues from others.

Volume Controls and A/B Switches

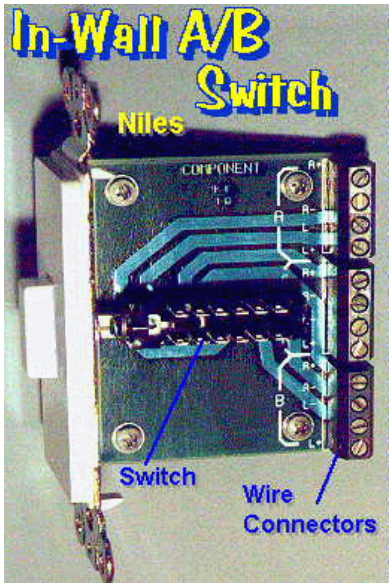


We used high-quality Niles volume controls for each set of speakers. These are 12-step **transformer** controls, not resistive loads, so there should be little efficiency loss. The 12 steps include full off (open), 10 steps of the transformer, and full on (direct connect). Each volume control connects back at the amplifier through a 6-speaker impedance matching switch (I used a Niles cabinet-mount unit). We use a large industrial amplifier that can easily handle the power required for six speakers at the volumes we use for ambient music. I bought a different brand of volume control from Home Automation Systems (see their volume control page at http://www.smarthome.com/8250.html) to see the difference. See the photo at left here for a comparison of the Niles and the one from HAS. The Niles appears to be a little better made and has a wider dynamic range, but is much more expensive (about $65). You can also replace the trim plate and knob of the Niles easily, allowing more versatility with room color changes (it is available in white, almond, bone, and black).

Some specs for the Niles VCS-2D volume control (See HAS's page at http://www.smarthome.com/8250.html for the specs on their controls):

- 42 dB range of attenuation: -3dB per step on lower half of range (high volumes), -6dB per step on upper half
- Frequency response: 20 Hz to 20 kHz +/-1.2 dB

- 60 Watts/channel “peak music power” (yeah, I know, somewhat meaningless w/o an RMS rating)
- Removable wire connectors for easier attachment and replacement (see photo above)
- Isolated left and right channel grounds
- Ten year parts and labor warranty

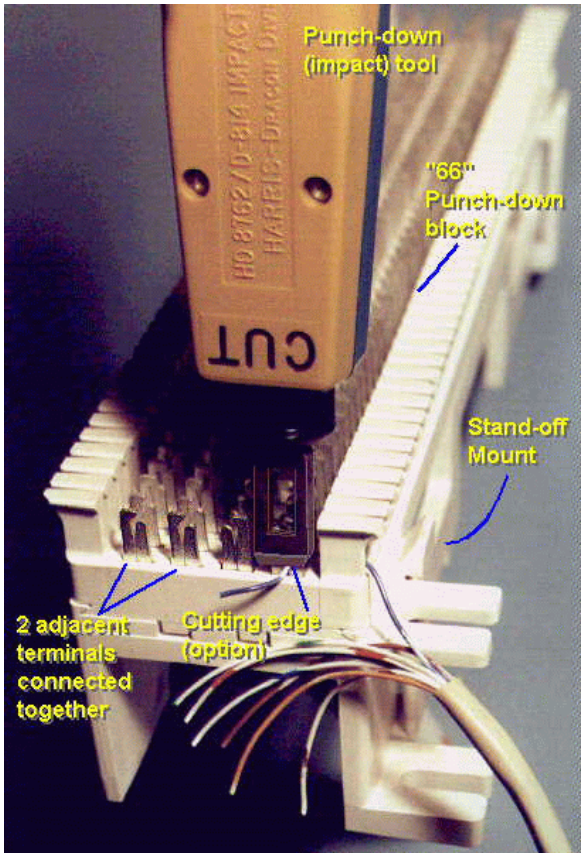


I could not find much selection for in-wall speaker A/B switches, but again used Niles (model ABA-1D). These switches handle 350 watts/channel, are flat between 20 Hz and 20kHz, and also have isolated left/right channel grounds. See the schematic section on page 13 for how I wired these switches in. I thought the prices for these switches were outrageous for such a simple device (about $40 each!), but I haven’t found a good-quality alternative. Niles also has switches for selection of multiple speaker sets (set A, set B, or both from same audio source) and for speaker or headphone selection (headphone jack placed in A/B switch cover), models AB-2D and HS-1D, respectively.

Be careful about some (usually less expensive) switches that may use a hard-wired connection as a “common” between right and left channel speakers (**non**-isolated left/right channel grounds). This saves the cost of switching a set of connections, but some amplifiers cannot handle having one wire of each speaker connected together. After all, why have four wires to each speaker pair if three would do? This could cause some expensive amplifier failures, and would be especially heinous if you forgot about such switches when replacing your whole-house amplifier with one that was not so forgiving! Keep those wires separate throughout the whole house, and don’t inadvertently wire two together by using the wrong A/B switch.

Telephone Hub

I used two 66 punch-down blocks for our central phone hub in the basement. These are blocks of 50 rows of connectors, 2 pairs on each row. Each pair consists of two terminal posts (or “clips”) connected together internally, allowing connection of one phone wire to another wire. Thus you can terminate 100 wires on each block (50 rows x 2 pairs). A “punch-down” tool presses the unstripped wire onto the post, which cuts through the insulation to make solid connection between the wire and the connector's post. Depending on which end of the tool blade you use, you can either just punch down the wire onto the connector for chaining a wire between connectors, or you can punch **and** cut the end of the wire for termination of the in-wall wires all in one easy step. See the closeup below to see how this works.

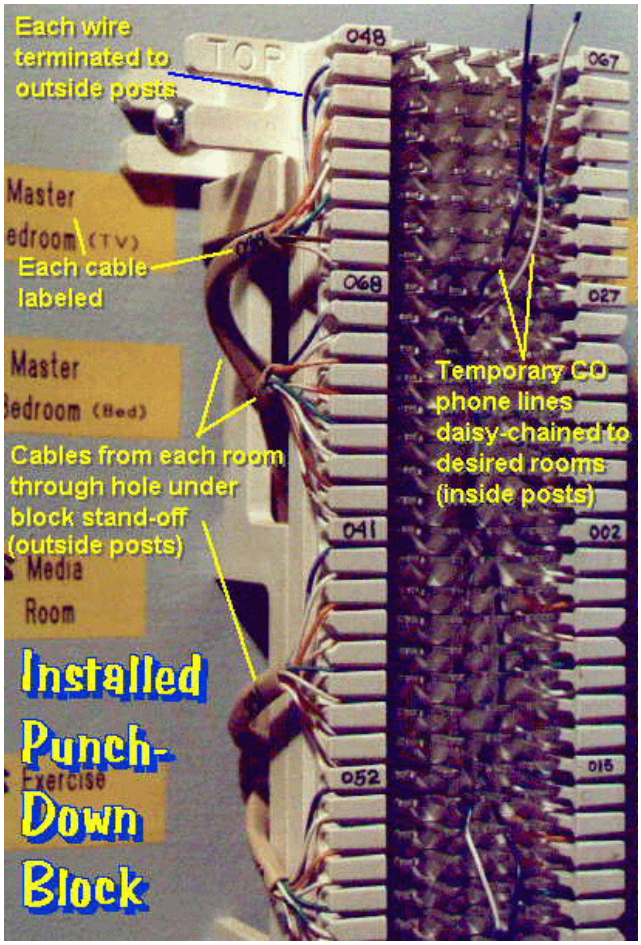


The punch-down tool can either be a simple handle with a tip, or an impact (spring-loaded) tool. The simpler ones are cheaper (about $20-$30 or so), but the impact ones ($50-$70 - I paid $65 for mine at Graybar Electric in Denver) very nicely “stamp” the wire into place and (optionally) cleanly cut the wire end. You can usually get an additional tip for the 110 type punch-down blocks, which are also used in commercial phone installations and/or for data (LAN) type connections. Though the 66 blocks are now available in Cat 5 models (just shorter posts), the 110 blocks are usually preferred for high-speed data connections. I used the 66 blocks (mine are Cat 5) for phone connections because they seem sturdier and easier to undo/redo, and I will probably be making relatively frequent changes. I will use the 110 blocks for my LAN connections.

I bought my Siemon model S66M1-50 blocks from Graybar for $6.42 each, with additional mounting brackets for $1.22 each. These blocks contain just the connector posts without any jacks or connectors. I mounted the 66 block on a 3/4" painted plywood panel on studs in the basement. I ran all the house phone cables behind the panel, and brought them through holes drilled in the panel behind the 66 block mounting location. This hides and protects the cables. The mounting brackets raise the blocks, allowing room behind the block for routing the cables from the holes to the 66 block. I brought each cable to one side or the other of the block, and terminated each of the eight wires per cable to the outside post of a connector pair. I used the inside post for the connection to the incoming (CO, or Central Office) phone line, which will be the line from the PBX in the future.

We don't have a PBX system yet, so I just have all needed lines temporarily jumpered at the block, so all phones are connected in parallel, by daisy-chaining the incoming phone wires between phone jack cable connections. To do this, use the non-cutting end of the punch-down tool. You flip the tip over in the tool handle - one end has a rounded edge and a cutting edge, the other end has two rounded edges. When using the tip with the non-cutting end, the wire is not cut off; you can punch down the same wire on multiple posts to connect several wires. So, I daisy-chained the

incoming line to all the phones I needed (blue/white to blue/white, white/blue to white/blue).



See the close-up here to see how I connected house wires and CO wires to the block. Note that I labeled each cable with the cable number on the block itself, and the room designation on the plywood next to where the cable comes out of the panel. I kept the color pairs together, starting with the primary phone line (blue pairs) then the secondary (orange), etc. See the *Wiring Telephone Jacks* section on page 36 for details on color codes at wall jacks.

After I wired my block, I found out that the standard for wire installation on these blocks is as follows:

1st Pair	White/Blue (white with blue stripe) Blue/White (blue with white stripe)
2nd Pair	White/Orange (white with orange stripe) Orange/White (orange with white stripe)
3rd Pair	White/Green (white with green stripe) Green/White (green with white stripe)
4th Pair	White/Brown (white with brown stripe) Brown/White (brown with white stripe)

As you can see from the photograph, I got the sets of pairs in the right order (blues, oranges, greens, browns), but I had swapped the order of each pair (blue/white instead of white/blue, etc.). Oh, well, as long as I keep it consistent it should work fine.

The block wiring scheme I used should work fine for making one connection to each house wire, which is probably all that is needed. However, if you need to connect more than one wire to any of the house wires, do **not** try to put two wires into one post; you may get flaky connections. Instead, plan on using another block or a different part of the block as a "patch panel", where you use multiple connectors for each destination wire. For example, you can daisy-chain a wire to one post of several connectors to act as a "bus", then use the second post of each connector to jumper to the needed connection.

See the *Feedback* section (Appendix A) for more ideas on installing *Phone and LAN Connections*. For information on wiring for a LAN, see The Siemon Company's Network Cabling Standards (including color codes for RJ-11, RJ-45, and others). This is on their web page at http://www.siemon.com/modular.html. HAS has some information on their 66 blocks (http://www.smarthome.com/8610.html) and punch-down tool. MicroWarehouse has a DataComm catalog with tools and panels, etc. (see their *Central Site Wiring* section on their site at http://www.warehouse.com/datacomm/).

Telephone and Cable Outlets

A/V and Combination Wall Jacks

I am using outlets with wall plates that match the Decora style, since building supply houses around here and in the home automation catalogs seem to carry the best supply (variety) in the Decora style. For A/V connections in these styles, the standards seem to be four (or two) banana jacks in one plate, and two F connectors in a separate plate. Therefore, in my standard locations I used double-gang boxes here for these "standard" parts. The typical "hybrids" I've seen seem to only combine two or three RCA jacks (for signal-level connections) with a single coax F jack. See *Wires, Cables, and Wall Plates* from HAS (http://www.smarthome.com/wirelist.html) for some photo examples and prices.

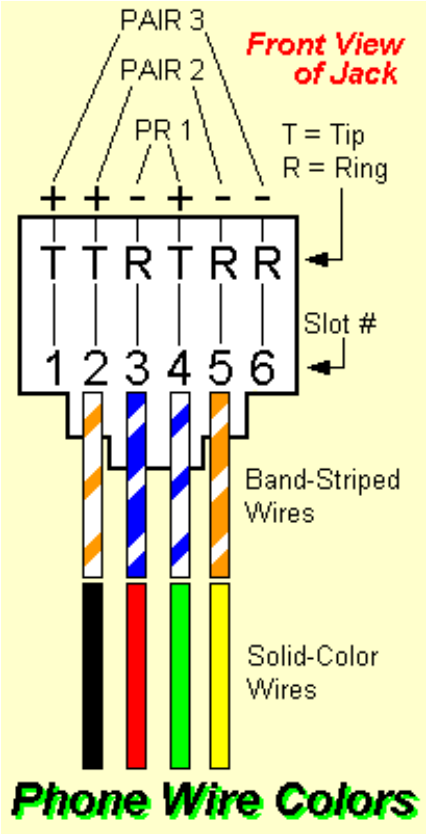
Leviton's "Quick-Port" line of wall jacks provide great versatility in building custom wall junction box arrangements

However, there are some (more expensive) versatile options. Leviton has a line of "mix and match" snap-in modular jacks for the decora style wall plates. A mounting plate holds two jacks of your choice. Available jacks include 6 or 8 conductor phone jacks, 8 conductor Cat 3 or 5 jacks, coax F connectors, BNC coax connectors, or even fiber optic couplers into two locations in the wall plate. Sets of two 4 or 6 terminal phone jacks, or one phone jack and one F-connector (cable TV), are available at home improvement warehouses like Home Depot. These include the mounting plate for two jacks, the two jacks, and the cover wall plate. I bought the double phone unit (Leviton catalog #801-41666) for $8.33, and the phone/cable unit (Leviton catalog #801-41658) for $7.33. Home Automation Systems has a wider range of these components (at least, they certainly look exactly the same – see their photos at http://www.smarthome.com/8551.html), which should be able to snap into these Leviton plates.

Another option for more versatile and condensed installations is a wall plate system from Leviton that allows mix-and-match of up to **four** jacks in a single-gang box. However, these use the standard oval-shaped electrical outlet format instead of the Decora, and I am sure they cost a lot more since they are for commercial applications (I have not checked prices). Also, I don't know if they had banana plug jacks, which would be used for the A/B input jacks.

Another possibility I thought of (but have not yet tried) for combining different types of wall plates was to use a phone plate and just drill two holes for the F-connector coax jacks, since all the wall plates I've seen for these just use a splice or feed-through type of F connector. These feed-through connectors can be purchased separately and cleanly installed in a simple hole in a wall plate. I was planning on using this as a back-up for some locations where I might need more than the double-gang box, but didn't want to go to a larger size box. This might work where you want two coax connections as well as a phone connection.

Wiring Telephone Jacks



The following chart and this diagram are from Leviton's industry standard charts for **telephone** connections and colors. Note that this is **not** always the same as wiring standards for data communications lines, which depend on the LAN protocol used. The phone jack diagram below follows 6P6C (USOC), or RJ-11, guidelines for two and three pair phone jacks. Such diagrams usually represent the front view of the female wall jack, as you would see it from the outside after installation in the wall. I've only shown the two-pair color scheme, since this is usually all that is needed for home phones. In fact, only the first (blue) pair is really needed for most phones, but 2-line phones and special phones like the Panasonic PBX programming phone use two-pair wiring. At locations like our office where we may use two phone lines (one for voice, one for modem/fax), I will use the 3rd and 4th pair to wire a second phone jack in the same box, using the same jack wiring as below, but substituting the green pair and the brown pair for the blue pair and orange pair, respectively.

In the chart below, the two-color stripe color scheme follows the standard designation where the primary wire color is listed first followed by the stripe color. For instance, "White/Blue" means "mainly white wire with a blue stripe", or "white **with** blue." This color scheme is used with standard 4-pair phone cables. The single color in parentheses represents the older solid-color phone wire colors, sometimes still marked or used on the in-wall phone connectors or in the wires of the external flat phone cables used to connect your phone to the wall jack. The slot numbers next to the Tip and Ring indicators are usually marked on the jack. Note that the slot numbers (and solid color cross references) are for the common 4 and 6 terminal telephone jacks **only**, and would not apply to 8 terminal data jacks; the PAIR 4 section is for color reference only.

STANDARD 4-PAIR WIRING COLOR CODES		
1st Pair	Tip (+), slot 4 Ring (-), slot 3	WHITE/BLUE (Green) BLUE/WHITE (Red)
2nd Pair	Tip (+), slot 2 Ring (-), slot 5	WHITE/ORANGE (Black) ORANGE/WHITE (Yellow)
3rd Pair	Tip (+), slot 1 Ring (-), slot 6	WHITE/GREEN (White) GREEN/WHITE (Blue)
4th Pair	Tip (+) Ring (-)	WHITE/BROWN BROWN/WHITE
NOTE: For 6-wire jacks use pair 1, 2 and 3 color codes. For 4-wire jacks use pair 1 and 2 color codes.		

After wiring all the wall outlets I needed, I tested them at the jacks with an inexpensive phone jack tester, available at many of the home improvement centers for about $5. These testers are a small box with a phone plug on one end. An LED on the box glows green if the jack is wired correctly, or red if the polarity is wrong. The LED stays off if no connection is found.

THE END – Best Wishes on your wiring project!

Appendix A – Feedback and Your Contributions

The following comments have been taken from some e-mail sent to me regarding topics in this article, and from postings in the comp.home.automation news group that I thought would be useful to people researching low-voltage wiring and related topics. Please note that I have not verified all of the comments that have been made here. I have done minimal editing, other than restructuring sentences to match the context of this page and fixing a typo here and there.

Please note that I've organized the message threads and e-mail by general topic. They are not necessarily organized strictly by message thread, so the context in which some are written may be off a little. Also, though I tried to retain all names and e-mail addresses of respondents, I failed to get them all. Sorry!

Any feedback on the contents of this article are welcome. If you have any suggestions about the contents or format, or if you find any errors, let me know at the e-mail address below.
Also, if you would like to contribute any of your own experiences in pre-wiring your home, or have additional ideas or suggestions on this topic, I would be willing to add your information to this section. In this way, we could compile additional ideas and experiences in one location. Just write up what you would like to include and send it to me via e-mail (markh@mcdata.com). I'll do what I can to incorporate your information (including your name and e-mail address for reference) on a timely basis.

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See this article online at:
www.WildTracks.cihost.com/homewire

In This Section:

Cable Sources and Prices A–2
Conduit A–5
Finding Cables in Walls A–7
Power line Control A–8
Phone and LAN Connection A–10
Sound Systems A–15
In-Wall Speakers A–17
Surge Suppressors A–20
HVAC Wire Colors A–24
Miscellaneous Comments A–24

*(Note: In the following threads, the comments in the left margin in **bold italics** are questions posted, with responses following in the right column next to the questions)*

Cable Sources and Prices

In the process of researching twisted pair cable, I came across a product by Belden called “Data Twist 350" ($176.00 per 1000'). It keeps the twist of the pairs consistent by bonding each pair individually within the overall jacket, much the way “zip cord” is bonded. It has a claimed throughput of 350 Mbps. Belden also claims it far exceeds Category 5 standards for data transmission and will serve as a perfect conduit for future data intensive applications.

I have also come across a network cabling system by Panduit called PAN-NET which seems to be just the ticket. It includes patch bays, faceplates, and modular terminations for all manner of connectors and cables. The faceplates are modular and come in an assortment of attractive styles, sizes, and colors.

I plan to have two runs of RJ45 to each breakout, one for phone X 2/data/intercom and the other for an Ethernet LAN as well as two lines of RG6 for video distribution.

Has anyone had any experience with these products? They are my choice at this point unless I learn something to the contrary from the group. Also, Will this type of scheme serve me in the future as an ISDN distribution system?

StageDog, stagedog@aol.com

I just received a catalog for “Global DataCom” which seems to have some good prices on modular wall plates with RJ12, RJ45, BNC, F and other connector blocks. They also have bulk Category 3 four-pair PVC insulated cable for $.10 per foot in 100+ foot lengths, and category 5 four-pair for $0.14/ft. They don't seem to have RG-6 though. I haven't ordered from them yet, so can't report on service. I got my four-pair cable from my employers' telecom department. They gave me a 1000' box and measured the length remaining when I brought it back with their TDR, and charged me accordingly. They get category 3 four-pair for about $40/1000'.

Ralph Stirling, stirra@wwc.edu

I don't know who does mail order cable, but we may be able to help. While it is not something that we have done in the past, we are exploring the various mail order markets. RG-6 Quad Shield would go for about $0.30 per foot and 4-pair UTP Cat 5 about $0.25 per foot, plus shipping.

Tom D. Brown , Olympic Security & Communications Systems, tombro@eskimo.com

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If you happen to be in Seattle, Greybar Electric, has cat 5 cable at their will call desk for about $125/1000' box. They also have all the crimpers, connectors, jack, etc. on the shelf for considerably less than the network companies. Of course, they primarily handle power and phone stuff, so you are on your own when designing your network.

Larry Barello, lbarello@accessone.com

What are the going mail order rates for 100/ft of RG-6 Coaxial and UTP Category 5 cable prices. I'm estimated at least 300 feet of each in order to wire 3 rooms per floor in a 3000sq/ft house. Can you recommend any companies that handle mail order customers?

I strongly suspect that 300 feet will be way too little for the size of your house. If you do dual coax runs of RG-6 and you home run the cable to your basement (or some node), chances are you will need closer to 800 feet.

I bought my cable from Anixter. Only problem is that you will need 1000 foot rolls. (Also, my prices were the same as the prices they charged my company, which regularly buys lots of wire from them; so your mileage may vary.)

RG-6 was $150/1000' for Belden double shielded, and $190 for quad-shielded; however, if you are doing dual coax runs, I strongly suggest you get two rolls (of 500' maybe); it should cut down the installation time considerably. I ended up buying two 500' rolls of Comscope quad shielded RG-6 from my cable company.

Also, Home Depot will sell you 500' rolls of double shielded RG-6 for around $80.

4 pair Cat 3, 24 awg was $45/1000'
4 pair Cat 3, 22 awg was $70/1000'
4 pair Cat 5, 24 awg was $120+/1000'

Other cable prices from Home Depot: I ended up buying 500' rolls of 14 awg speaker cable for $36 apiece. 22 awg was $26 for 500'. They sold 16 awg Monster cable at a price that was significantly lower than Monster Cable's recommended price of 40 cents/foot.

R. Bharat Rao, bharat@scr.siemens.com

After reading a post here, I called Comm/Scope and got some information on their RG6 Quad Shield coax. After seeing it, and being amazed at their reasonable price (if you need 1000ft of it!) I had my father-in-law's company order a spool. It should arrive sometime early next week (my spool weighed 44 pounds. :-)

Here is some information for anyone interested, since there was some question about its quality because of its low cost.

Comm/Scope offers "standard shield", "tri-shield" and "super shield", the latter which is commonly referred to as quad shield. Since everyone recommends quad shielded cable, I'll only provide details on that.

****** Begin Comm/Scope Data Sheet Quote Mode ******

The quad shield cable is constructed as follows, from the inside out: Center conductor, dielectric, bonded aluminum foil shield, aluminum braided shield, aluminum foil shield, aluminum braided shield, jacket.

18 gauge copper-covered steel center conductor, foamed polyethylene dielectric, inner-shield aluminum-polypropylene-aluminum laminated tape with overlap bonded to dielectric; outer shield of 34 AWG bare aluminum braid wire; jacket of black polyvinyl chloride or polyethylene (flooded). Nominal O.D. 0.272"

Nominal impedance 75 ohms, nominal velocity of propagation 85%

- *Extended Reach(TM), 20 db minimum, SRL, 5-1000 MHZ*
- *> 120dB RF shielding*

- *NEC CATV (V), CATVR (R), or CATVP rated*
- *Available with co-extruded tracers*
- *Black; neutral and other colored PVC jackets available at extra charge*
- *Integrated messenger, burial designs*
- *Advanced corrosion protection available*

Available 6-series Bonded Foil Super-Shield Construction / 60% + 42% Braid

- *F6SSV Bonded foil, 60% braid, non-bonded tape, 42% braid, PVC jacket*
- *F6SSVV Bonded foil, 60% braid, non-bonded tape, 42% braid, flame-retardant PVC jacket. Meets NEC Article 820 V rating.*
- *F6SSVM Bonded foil, 60% braid, non-bonded tape, 42% braid, PVC jacket, .072 messenger.*
- *F6SSEF Bonded foil, 60% braid, non-bonded tape, 42% braid, flooded for underground, PE jacket.*
- *F2-6SSVV Dual-run, bonded-foil, 60% braid, non-bonded tape, 42% braid, flame-retardant PVC jacket. Meets NEC Article 820 V Rating.*
- *F6SSVV-APD Bonded foil, 60% braid, non-bonded tape, 42% braid, flame-retardant PVC jacket, amorphous polypropylene flooding compound (non-flowing)*
- *F6SSVV-C.D. Bonded foil, 60% braid, non-bonded tape, 42% braid, flame-retardent PVC jacket, hydrophobic dry powder moisture displacement.*

****** End Comm/Scope Data Sheet Quote Mode ******

Since my installation was indoor, I didn't need any of the flooding/moisture protection cable, and the representative (who was extremely helpful, BTW) recommended the F6SSVV cable. The 1000 ft. spool came to around $100 for that particular "model" of cable.

Judging from these specifications, I expect it is a very high quality cable, and I look forward to receiving it. I have also since found out that the local cable company (which recently strung fiber throughout the service area) is installing Comm/Scope RG6 Quad Shield in all new installations. So if they are using it, it is probably OK. :-) The F2-6SSVV dual would have been nice, but they have a 1000ft. minimum, unless they have "short spools" in stock. I plan on winding half of mine on another spool and pulling two runs at once...

I should disclaim that I have no affiliation with Comm/Scope, other than as a so-far very satisfied customer who thought other might be interested in this information. Their number is 1-800-540-CATV, and it is often busy. :-)

Eddy J. Gurney, eddy@mich.com

In your document on coax cable, you recommend solid copper center conductor as preferred over copper clad steel. You state that copper is a better conductor, which is true. However, for transmission of RF frequencies

(for standard CATV, the bandwidth is 5-1000 MHz), only the outer portion of the conductor carries the signal. This is known as the "skin effect." Therefore, copper-clad steel provides the same low signal loss as a solid copper conductor. In addition, you get the strength and rigidity of steel. As for the quality control aspect you mention, billions of feet of copper clad steel are manufactured each year under very exacting quality standards. While low quality copper/steel products may exist, any quality cable manufacturer will provide a product that meets the full requirement for video transmission. In short, unless the cable is required to deliver power in addition to video signals, copper clad steel is a superior product over solid copper center conductors for coax cable.

Chris Story, Plant Manager - Coaxial Drop Cable CommScope, Inc.

A source for computer cable is:

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Data Comm Warehouse
172 Oak Street POB 301
Lakewood, NJ 08701-9885
(800) 328-2261
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Newark Electronics sells Belden cables and Belden just came out with a new line to address the Audio/Video market. Newark also sells connectors. The components are listed in Catalog 113. Phone number is (800) 298-3133, ext. 22.

Michael Caron, mrc@cadre.com

Just wanted to add a source for info on wiring that I just used in my own house. Leviton publication "EIA/TIA-568a". I found it very useful.

Patrick Nelson, pnelson@mail.coin.missouri.edu

I'm in the process of building a new home and would like to install Cat 5 UTP for a home based LAN. In the past, I've read that one good way to ensure flexibility for later wiring changes is to run conduit to each of the jacks so that wiring can easily be removed and attic. The problem, however, is that this house will not have an attic so I will be unable to run the conduit from the conduit down the inside of the walls from the attic. Does anyone have a suggestion on how I might be able to get around this problem? I'd like our builder to install something now so I don't have to tear anything up later. Thanks....

Jesse W. Asher,
jasher@dreadnaught.eng.paradyne.com

Conduit

As long as you can have conduit installed to/from where you need it, you could always feed nylon string through the conduit and tie it off at both ends. Use a string that is twice the conduit run, so it can be pulled back and forth. For low voltage wiring this should be no problem. I do it in LV stuff when I might add wires latter. You could even do this with metallic or plastic flex conduit.

Clark Martin, cmartin@rahul.net

Another useful tip, if you've got conduit and forgot to pull a drawstring through it when it was first installed, is "beer pipe". Not sure what it's proper name is, its a polythene pipe about 1/4" diameter commonly found as plumbing for CO2 and beer in bars. It's stiff enough that you can push it through several yards of conduit past already-installed wires, and flexible/soft enough to not do any damage. If you succeed in getting it through, you can then tape your wires and a drawstring for future use onto the far end and pull it back.

Nigel Arnot, nra@maxwel.ph.kcl.ac.uk

Use a cheap plastic grocery bag with a lite string tied to it, and literally suck it thru the conduit with a shop vac on the other end. Works for me.

Ronan McAllister, ronan@au.oro.net

Very interesting article, but I must ask why you did not use SMURF tube (flexible non-metallic tubing – called Smurf because it is primarily blue in color)? It is somewhat more difficult to work with and of course more expensive than free stringing cable, but it gives you the FLEXIBILITY to change or upgrade at any time later on. Just thought I'd ask as I do computer system prewiring and always use SMURF or PVC.

jstick@gate.net

Put everything in smooth-wall plastic conduit to a central point. Include a pull rope along with the cable. Why? Assume that whatever you put in will be obsolete in 10 years. The conduit and pull rope will allow you to pull in the replacement.

At the central point put a 4'x4'x 3/4" or 1" exterior plywood backboard (for the network hub, the phone stuff (a lot of people are purchasing the 6-line/16-ext Panasonic mini-pbx) and the alarm stuff. Put a quad outlet box on the backboard, and have a separate circuit for this box. This way something else in the house overloading and popping the breaker won't drop the network, phone system or the alarm panel.

For today's networks, I'd pull 3 or 4 runs of cat-5 to a double-gang box. You can run Ethernet or phone over the cat 5. I used to recommend a run of cat 3 (for a phone line) along with the 5, but I changed my mind. Cat 5 has dropped in price, and an extra run of it is cost-effective vs buying a box of cat 3 along with the cat 5.

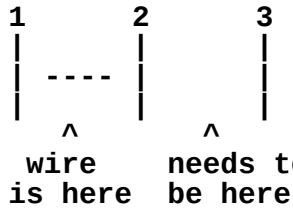
Always pull twice as many runs as you think you will need. Wire is cheap. Labor to put it in is not - esp. if the drywall is up.

Here's a tip: mark up a fishtape with footage marks: paint bands every 25' or so. Run the tape from the outlet to the central point. Note the length. Take your box of cat5 and measure off twice that much, and fold it in half. Loop the fold through the fishtape hook and pull the tape back. Cut the wire off the tape when it gets there. Bingo: two runs to that location. To identify which is the “A” wire or the “B” wire, just short the blue-white (i.e. the first pair) of one of them, and find the short at the other end.

Mike Morris, morris@grian.cps.altadena.ca.us

Finding Cables in Walls

Ack! I made a mistake in running some speaker wire in my daughter's bedroom. I ran it to the wrong opening between the studs!



Ok, if I ran the wire down the stud marked #2 there's no problem since I can just (carefully) drill through from the other side and pull the wire through. If I ran it down #1 I am out of luck for that wire. In my notes I didn't mark which studs I ran the wire down and in the video I made I can't see because of the insulation.
Any ideas how I can find where the wire is?

Bill Seurer

Yes there is hope but you will need to purchase a fox and hound set which is an electronic device used by alarm installers and phone techs. It is connected to the wires to be traced and an inductive amplifier is used to locate the wires behind the drywall. The device can be purchased from an alarm distributor or phone system distributor.

They cost about 90 bucks for a good quality unit like the Progressive 200EP inductive amp and the 77m tone test set the two pieces work together and are also available as a set I believe the set is called the 700hp. But call a dist. called ADI they will sell with a credit card and are very reputable their number is 800-233-6261 If you have any questions please E-mail and I will try to help. BTW this is what I do for a living so I do know what I'm talking about. Good luck!

Jason Spangler, pst@access.digex.net

Attach a "walky-talky" antenna to the wire. Use the second "walky-talky" (with the antenna withdrawn) to locate the wire. When you are close to the wire you will get some feedback. I forget whether you have to be transmitting on one "walky talky" or not. I have done this before and it works. You will have to play around a bit to get it working.

Rob Mudry, rmudry@bnr.ca

I'd like to add my 2 cents worth to "finding cables in walls". The current suggestions are a fox-and-hound set or a pair of walky-talkys. Being cheap, I didn't want to buy either, so here's what I did. It worked great!

Make your own fox-and-hound set using a small AM radio, like a walkman, and an RF noise generator, like an electromechanical buzzer (the kind that makes sparks when it's buzzing). (I didn't have a buzzer, so I made my own using a SPDT relay with a 5-volt DC coil and hooked the coil through the normally closed contacts to a 6v lantern battery.) Connect the known end of the wire you want to trace, to one terminal of the buzzer. (Be sure to do this before connecting the battery, so you don't get zapped by the inductive kick of the coil.) The lost wire will then be radiating broadband RF noise. Tune the radio between stations on the AM band and move it near where the wire might be. You'll find that this is surprisingly accurate. When I cut my hole in the wall, the wire was right there!

Dave Strieter, strieted@agcs.com

An Ounce of Prevention...

One other comment: If you are thinking of putting boxes in behind the drywall, and not having holes cut for them, don't! But if you must, take precautions to make sure you can find them later. On a floor plan, draw the locations of the boxes, noting the distance from the nearest wall and from the floor or ceiling. Also, I would suggest putting a fairly strong magnet in each box, so you can use a compass to easily zero in on the location when you want to access it later. There were some discussions here about ways to locate wires in walls using various transmitters and receivers, but nothing is easier than a pointer that keeps pointing at the box.

Jim Thatcher, thatcher@itsnet.com

Use a camcorder to videotape all of the walls before the sheetrock goes up. You would then know that the box is nailed to the left or right hand side of any given stud, and that is easy to find with an electronic stud sensor. Of course you would have to keep track of the height of the box, perhaps writing it on the stud with a marker.

Dave Thayer, dave@gamera.bogus.domain

The absolute coolest and neatest trick I have ever heard was to use slide film. Take a slide film picture of the wall before the sheetrock is hung. Then when you want the location of a box or wire, project the slide onto the wall from the same location the camera was in.

Result: Instant Super Man X-Ray vision of the wall! The location of every stud, box, wire and nail is pin pointed. When projecting, you can use light switches and wall sockets as fiduciary marks to line up your slide.

Edward Cheung, Ph.D., edward.cheung@gsfc.nasa.gov

Power line Control

Next year sometime we are planning on building a new house. Obviously, we would like to make this a well wired and ready for automation house :)

My main thing is to make the house wiring configurable. At any time I want to be able to make THIS wall switch now control THESE outlets, and THIS dimmer now control THOSE lights instead of THESE. So far the most affordable and most configurable system I've seen is the HCS (Home Control System) from Steve Ciarcia and Micromint ? I can't remember, and I don't have the brochure in my hands.

It seems like there are three main methods.

- Wire the outlets in conventional fashion, but use switchable outlets. Don't connect the wall switches to the outlets at all. Run the control wires for the outlets and wall switches to the HCS in the basement or to a central "room controller" connected to the main HCS via RS422.
- Wire the outlets in conventional fashion, using X10 controllable outlets. Use the HCS to send the X10 signals over the power lines. Run the control wires for the wall switches down to the basement to a "room controller" for input to the HCS.
- Instead of wiring outlets in a ring circuit, drop each power line down to the basement to a large relay board. Have the circuit breakers on the panel terminate in this board, each handling, say, 5 relays. Use the HCS to control the lot, power, dimming etc. Wall switches same as above.

I'm sure that I've missed other methods. Anyone have any ideas ?

In any case, there are various features to these kinds of wiring methods. For instance, you wouldn't have to run power to the wall switches, just the actual outlets. The wall switches could be low power decorator variants connected

via twisted pair to the inputs of the HCS, so you wouldn't need conduit, or heavy mounting boxes.

The HCS system has remote modules for collecting inputs and providing outputs that communicate with the main HCS via RS422. By running say 4pair or 8pair all over the place, you could have all sorts of flexibility as to control signals, thermostats, small LED indicators for wall switches or what have you.

For configurability, I want to be able to do things like this:

- Define several wall switches in the house that change their function after dark to "emergency lights on". Say one of the switches by the bed turns on every light in and out of the house. By day it just does the lamps over the bed.
- Have motion detectors that activate different functions depending on time of day, brightness, house alarm status or whatever. Say the one over the garage just pings a small beeper during the day, but actually logs the activity when the alarm system is active. It could pulse a light at night too.
- Have a switch that acts as a normal light during the day, but at night releases the doggie door solenoid.

Ideas or comments? How about the wiring schemes?

Responses:

Both Echelon's LonWorks and the proposed CEBus have Power line technology which will allow you to use standard AC wiring in your house for automation/control networking. Both also accept standard twisted pair wiring. Echelon's also accepts twisted pair wiring to transmit BOTH power and data.

Chances are that if you wire your house for sound, phone, power, and data, you'll be covered for control as well. Don't forget, IR transceivers are also available. So no matter who wins the home automation war you'll be all set.

PS - I wouldn't be too concerned with the Smart House consortia. Any system requiring custom wiring for both new and retrofit installations has a business plan written for them by a competitor!

I'm building a house, and I've got my list of X10 wall switch modules all ready to go! [...] I just noticed that, other than incandescent, the switches in there say "Neutral required."

This is because an appliance-module-style switch cannot depend on being powered by a trickle of current through the thing it switches. So it needs neutral. (Now if only we could find a source here in Montreal that sold such appliance-style modules in a wall-switch housing....)

But, in talking with the electrician where I'm building a house, they are two-wire switches. Knowing NOTHING about this kind of thing, will the neutral required switches work where the incandescent, 2-wire switches are expected?

Yes, if neutral happens to be available in the box; no, if not. Wall switches are sometimes wired with neutral-&-hot coming to the box and neutral-&-switched-hot heading off from the box to the thing controlled; this variant will be usable. They are, however, sometimes wired with neutral-&-hot going to the load (e.g., overhead lamp box) and hot-&-load from there to the switch; in this form, neutral is usually not available at the switch box. (If the box contains multiple things or has more wires running through it, neutral may be available from another wire. All neutrals are normally connected together at the power service entrance, so you can expect it to **work** to use that neutral. But it's conceptually sleazy and may not be code, so I don't recommend it - besides, you may be setting yourself up for something akin to ground loops if there's significant current carried on that neutral. Note that you cannot assume all hots are equivalent in the way you can assume all neutrals are equivalent; houses often have 220V hot-to-hot service, split into two 110V-to-neutral poles which are further subdivided at the breaker box into the various hot supply wires.)

der Mouse, mouse@collatz.mcrcim.mcgill.edu

The reason that some switching modules require a neutral wire is that they actually contain a relay as the load switching device. The modules that do not require a neutral wire use a thyristor device called a triac and rely on the fact that a small amount of current can always flow through the filament of an incandescent device to keep X10 communications going. Inductive load type appliances (such as flourescent lighting and motor operated devices) that are plugged into a normal switching module generate a 'back emf' voltage as the magnetic field collapses that can damage the thyristor device when switched off. Therefore, the neutral wire is needed to keep the X10 communications going and to operate the relay which isolates the AC load from the X10 electronics. In response to the question, the 'neutral required' switches will work for all loads (as long as a neutral is available) but you loose the dimming capability at that device since a relay is 'on' or 'off'.

Rick Rago, rago@tellabs.com

Phone and LAN Connection

For the Cat 5 stuff, I suggest using ATT 110 blocks. They are space efficient and are made just for Cat 5. These are available through any telecommunications vendor. A good start would be Graybar and Anixter. These companies have sales offices in major cities. I believe Anixter also has a web site, just do a search. Siemons also manufactures the 110 blocks and has a good catalog.

The way the wire a system like this is you first punch down all your permanent stuff such as all the in wall wiring, the incoming phone lines, the PBX and computers. After you punch down a cable, you use a 4 pair connecting block to hold the 8 conductors down. The preferred order of wires is as follows:

white with blue stripe
blue with white stripe

white with orange stripe
orange with white stripe

white with green stripe
green with white stripe

white with brown stripe
brown with white stripe

Now, you just cross connect your stuff any way you want. For this, use 22 gauge solid telephone wire. You can also ask Graybar/Anixter for cross connect wire. This may seem like an inefficient way of doing things but, it makes it easy to grow and change things around. One last thing, mark things down. Note where wires go. You may remember today but, try remembering where a wire goes next year.

Joe Uribe, joeuribe@ix.netcom.com

(for phones...) I have generally punched all conductors down on 66 blocks- there are now some Cat 5 versions available. For the 61610, I used a 66 block prewired to 2 amphenols, and two "octopus" adaptors – a matching amphenol with 12 4c modular pigtails.

The first octopus plugs into Sta 11-22. The second plugs into 23-26, CO 1-6 and the door interface (leaves 1 spare).

I then use jumper wire to cross-connect the house cable blocks to the connectorized block. This makes a very neat installation, and allows you to split pairs on the house cables, or rearrange stations later without disturbing the house connections.

Orrin Charm, OrrinC@ix.netcom.com

You will always find more Ethernet items than you have ports. Get one size larger than you think you will need now.

(Note: Color codes below refer to section on order of wires, above)

The color code continues with white-grey, then starts over with red-blue, red-orange, red-green, red-brown, then red slate. Then black-blue, black orange.... Then Yellow-blue, yellow orange... Then Violet-blue, violet orange... Just in case you stumble upon a piece of 12-pair or 25 pair... BTW, I suggest that you ask the phone co to run you a 6-pair or two pieces of 3-pair to the pole/curb box.

22 ga wire is too big in diameter - it will rape some manufacturers, 110 blocks. Check the spec - most say to use 26 ga wire.

I'd rather use extra blocks and keep it simple.

I keep a 3-ring binder in the wiring closet, with a page for every block. The left side of the page is for the left side of the block, and the right side of the page for the right side of the block. There is a spreadsheet file that produces the pages. On the blocks the left side is the permanent connections, and the right side is the jumpers. On the page the left side is the permanent connections, with details (i.e. which room/wall/jack), and the right side has

the current connections, with pointer notes to the page with the other end of the jumper. Example page 6 might be the northwest bedroom east wall jack plate, with 4 jacks in it: jack 1 is the phone, jack 2 is the answering machine, and jack 3 is the PC Ethernet. On page 6 you have a list of pairs 1-25 on the left, and pairs 1-25 on the right. Like below:

BLOCK: 6 OTHER END AT: NW BEDROOM EAST WALL

PAIR	LOCATION	ASSIGNMENT	OTHER END
1	JACK A	RJ-11 PAIR A	EKS PORT 1
2	JACK A	RJ-11 PAIR B	EKS PORT 1
3	RFU		
4	RFU		
5	JACK B	RJ-11 PAIR A	EKS PORT 14
6	JACK B	RJ-11 PAIR B	EKS PORT 14
7	RFU		
8	RFU		
9	JACK C	RJ-45 PAIR A	HUB PORT 3
10	JACK C	RJ-45 PAIR B	HUB PORT 3
11	JACK C	RJ-45 PAIR C	HUB PORT 3
12	JACK C	RJ-45 PAIR D	HUB PORT 3
13	JACK D	RJ-45 PAIR A	NO CONNECTION
14	JACK D	RJ-45 PAIR B	NO CONNECTION
15	JACK D	RJ-45 PAIR C	NO CONNECTION
16	JACK D	RJ-45 PAIR D	NO CONNECTION

Pairs 17-25 are not shown. They could be for another jack group in the same room, or another room.

“RFU” means “Reserved for Future Use”. “EKS” is “Electronic Key System” - the telephone company generic term for a system like the Panasonic.

Note that the first 3 columns are filled out when the place is initially wired, and usually won't change very much. The last column is what gets changed the most, so I have the layout such that about 1/4 of the width of the page is open for handwritten notes as I change things. As I make a change, I mark up the pages as I do it. When I am done, I go diddle the spreadsheet file, and print replacement pages, which are 3-hole punched and put in the book RIGHT THEN. No, I do not wait until the next day - that's how books get outdated. I also back up the spreadsheet file to a floppy which goes in a pocket in the book.

There are pages for the Panasonic phone system: one shows the block for the extensions, another shows the block for the phone lines. There is a page for every block; even one that shows the 12-pair cable to the phone company protector.

The page that shows the hub block would show the ports in sequence, with a notation that port 3 appears in the NW bedroom, east wall, jack 3.

The Panasonic has several pages; one for the extensions, and one for everything else: the phone lines, the music-on-hold, the printer port, the door speakers, the P.A. speakers (under the eaves by the front and rear yards), etc. The page that shows the extensions has them in sequence, and that page shows that port 1 goes to the NW bedroom ,east wall, jack 1, and port 14 goes to the NW bedroom ,east wall, jack 2.

Note that the multi-jack wall plate manufacturers know that people sometimes have strange ideas and want to do strange things. ALl sell blank

slugs for the plates, to fill up the 6th hole in a 5 jack/6-hole plate. These slugs can be /drilled for non-standard connectors: I once had a request to put a RJ-11 plug on a pendant push-button cable. The customer had an invalid aunt who needed a panic button. Extra jacks will come in handy – run extra cable!

Mike Morris, morris@grian.cps.altadena.ca.us

I think that the 110 blocks are easier to work with, and just as fast to install as 66 blocks. They provide for much nicer labeling of circuits than 66 blocks, they are cleaner to punch onto for cross-connecting and easier to trace cross-connects between blocks than 66 blocks. Also, standard 66 blocks will not slice the insulation of CAT5 wire reliably; this is why some non working circuits will work when you squeeze the connector together - you are forcing the connector through the insulation. 110 Blocks will cut through the CAT5 insulation correctly and reliably. Siemon's does make special 66 blocks that work with CAT5 wire but they are just as expensive as 110 blocks and the labeling advantages of 110 blocks are worth the time and effort to learn how to correctly install them. Also, the installation of the CAT5 wire is critical if you are going to use it for high speed applications, CAT5 wire installed incorrectly is not much better than CAT3 wire. If you are not going to spend the money for high quality CAT5 certified connectors (not all CAT5 connectors are created equal.) and install it according to CAT5 specifications than you might as well not bother spending the money for CAT5 wire, just go with CAT3 wire and connectors.

Chris Nicholson, chris@lanlines.com

We recently upgraded our small (server & 3 workstation) LAN and PBX (an old Panasonic KX-T61610) phone system. I made two major departures from the norm and have so far been quite happy.

- Instead of a punchdown block I used the AllenTel Versatap line (available through Graybar) of patch panels, jack housings and modular snap-in jacks.
- I also used a single 25-pair Category 5 cable for all the runs. So much for the "Star" layout! (It IS star in funtionality, it just doesn't look like it - more on that later). There is a central "junction box" on which a 24-Port Patch Panel is mounted. This patch panel is basically a flat steel plate that accepts Modular Jacks. The Modular Jacks are little pieces with the appropriate female connector on the front (they make these in everything imaginable – from RJ11 to BNC to Fiber Optic!) and punch down connections on the back.

Two 25-pair cables are attached to the jacks on this panel – one from the TelCo Interface (4, plus 1 ISDN/analog) and one out to the LAN/Phone lines. The front has RJ11/45 jacks as needed:

4 – RJ11: out to the COs on PBX

1 – RJ11: out to a 3Com ISDN LAN Modem (which then goes to the PBX from POTS)

8 – RJ11: in from PBX for extensions (several other go directly from the PBX to equipment right nearby – such as a cordless phone base, a 3Com Dual Analog Router, and a “Ringer” (for our wood shop).

3 – RJ45: in from 10/100 8-port Ethernet Hub (this hub connects the server, ISDN LAN Modem, Dual Analog Router and to the rest of the network)

One 25 Pair cable goes from the junction box and past each workstation. At each workstation I split open the casing and cut the wires needed for that location. These then were terminated into modular jacks (RJ11/45 as needed). There are many jack housings available, so for a simple workstation a 2-place housing provides one RJ11 and one RJ45 for phone and LAN connection. A more complex one might provide one LAN and two or three Phone lines, etc.

This wouldn't be feasible for a large installation, but in a small area where you can run the cable around the room(s) it works great. Since even 100BaseTx only needs 2 pairs there is a possible minimum of 12 LAN or PBX Phone connections from the Junction Box to various places. Since FAX, answering machine, modems and non-system phones only need one pair, we ended up with 3 LANs, 3 system phones, 5 single-pair phones, and have 8 pairs left over. Instead of having 3 Ethernet wires and 8 Phone lines to try and run through an existing location, we just have one cable. We also have the flexibility to add up to 4 more RJ45/PBX's or 8 standard RJll connections anywhere along the way - without re-stringing line or trying to work through/around walls, furniture, etc.

This system provides a lot of flexibility, and ease of changing things around - which is important to me in a growing, changing business. I don't think we sacrificed anything, and it wasn't any more expensive over-all than a more traditional method would have been. I don't know how clear this picture is, because what I did is so different than the usual. I'd be happy to try and explain things further if you'd like.

BTW, I got a lot of information from the Hubbell Premise Wiring catalog (they have a section front with wire pair color standards, wire assignments, layout guidelines and a whole bunch of other stuff) and the folks at our local Graybar office (Rutland, VT) were also very helpful. One potential trouble resulted from the fact that in a 25 pair cable you only have one set of standard wire colors available, the rest are Violet/Orange, Orange/Violet, etc. The Hubbel catalog showed all the pairs and it made it easy to sort out which ones to use for what. I have them all marked down for future reference.

Thanks again for a great site,

David N. Waldmann, Vice President, Vermont Hardwoods,
David@vermont-hardwoods.com

Sound Systems

Chad wrote:
First, what type of amp should be used to distribute a signal throughout multiple rooms, driving a diverse multitude of speakers?

To answer your exact question:

You want an amplifier that supports what is called a 70 volt line. This allows you to run relatively small wire to many different speakers while still carrying a decent amount of power efficiently, and allows you to hook up basically any number of speakers without worrying about impedance mismatches.

Anywhere you desire a speaker you connect a special transformer that matches the 70v line to the lower speaker impedance. Generally these have several taps on the primary for the amount of power you wish to feed the speaker - e.g. 2 watts, 5 watts, 10 watts. The secondary has several taps to match your speaker impedance (4, 8, 16 ohms).

But consider – with this scheme, Mom in the kitchen, Jr. in the playroom and Dad in the den all have to listen to the same program. Is that what you have in mind?

Some folks put individual small amplifiers on each speaker and feed them from a switching matrix which allows each amplifier to listen to one of several programs at will.

I guess a lot depends on how you intend to use it and what power levels you have in mind... ???

And then there is this comment from a fellow a couple of days ago about the 70V system...

From: stagedog@aol.com (StageDog)

Newsgroups: comp.home.automation

Subject: Re: 70V Speakers

Date: 15 Jun 1995 01:25:16 -0400

I am a sound engineer with 20 yrs experience in making things louder at remote locations. Unless you are going to use the system for a page / announce system only, I would not recommend 70V equipment.

The frequency response of most of the components of these types of systems (>160hz-<10000hz) usually lend themselves more to the PA system in a bus station than to today's digitally recorded music program (20hz-20000hz). Although I am sure it could be done, I have never seen a stereo 70V system and expect it would be simpler to distribute media signals in a more conventional fashion (shielded twisted pairs or modulated video) and use a small stereo system in each room.

On the other hand if less than hi-fi mono sound quality is acceptable, you can cover a lot of space with a single 70V system.

StageDog, stagedog@aol.com

Second, what type of wire should be used for distributing signals throughout multiple rooms, such as line level instruments, or regular CD players (example) The know-it-all at the hardware store said "Regular speaker wire." Na, I'll pass on that recommendation. Is it RG-58,59??????

For line level signals you'd definitely want some kind of shielded wire. I imagine that either RG-58 or 59 would do the job at audio frequencies - whichever you feel like using. If you feel expensive or paranoid about signal quality you might consider getting twisted pair shielded microphone cable, but I doubt you'd hear any difference.

If your power needs are modest (10-30 watts/speaker) I'd consider lumping all your amplifiers together in a central closet or two and running the wire from the amps to the speakers in the rooms. Speaker wires are far less sensitive to external signal (noise) pickup than line level wires. You also would run less chance of getting ground loops through different parts of the house and different circuits.

You know, I'd be really interested in comments from people who have done it both ways concerning how it worked for them. - ie did you have ground loops? Hum/noise pickup? Would you do it that way again?

(1st way - central closet with amps, speaker wire to the speakers in the rooms.)

(2nd way - feed line level signals to each room and have an amplifier in the room.)

David Meed, dmeed@nbnet.nb.ca

I'm in the planning stages of setting up "whole house audio" to be controlled by my HCS system. Most of the system seems straight forward, except for one long cable run. Basically, I need to run a cable from a line level audio output of a TV to an input on my preamp. The cable would be about 60 feet long (run in the crawl space under the house). Any thoughts on what would work, or do I need to rethink my plans.
Mike DeHaemer,
dehaemer@svpal.svpal.org

Your best bet would be a two-pair shielded cable, 22ga. This is a fairly standard custom installation cable. Use a pair at each channel, and tie the shields to the RCA connector shell at the preamp end only.

If you still get AC hum or other noise, Sonance makes a pair of Unbalanced/Balanced/Unbalanced line converters, the LS1 and LR1. The LS1 hooks up to the TV and converts the unbalanced line level outputs to a balanced line, which connects to the two-pair cable. At the receiver, the LR1 converts the signal back to RCA connectors. They work great for long runs, and you can connect many receivers to one sender with no degradation.

They list for $170 and $145 respectively, but you can probably get them for less. Sonance is at 800-582-7777 (I used to work there, but don't anymore)

Another alternative is a ChannelPlus FM stereo modulator. This unit would convert the TV sound to a spare FM radio frequency, which you could send back up the cable to any FM receiver in the house.

Finally, I've had great luck using the speaker output from the TV to drive the line level cable, and connect the other end to the Aux input of a receiver or amp. You may want to throw a 16ohm resistor across the line, but it's usually not necessary. At reasonable volume levels, the **voltage** level to the speakers is about the same as the line level – the difference is impedance, therefore power. I used to run my extension systems that way, then I got a pair of the Sonance puppies – sounds about the same, but I feel better 'cause I spent money on it!

The only thing to look out for is whether the line level or speaker level outputs bypass the TV volume control. If they do, you may have to keep adjusting the remote unit whenever you change the TV volume.

Make sure the cable is well twisted – it's the twist, not the shield that reduces AC hum pickup!

Orrin Charm , OrrinC@ix.netcom.com

What alternatives are there for Audio/Video distribution?

Take a look at http://www.gohts.com/home/index.html . There, they have a way of distributing S-Video over Coaxial cable. I suppose this might work for a single strand of Twin-axial cable (still researching it) but this is one way to distribute the higher resolution video such as from DVD.

Here is what I got off of usenet for Audio distribution over long distance (I am talking about the RCA type connections, not the speaker wire).

Audio Control makes the BLD-10 and BLR-10 balanced line receiver pair designed specifically for audio. It is designed to work with CAT5 and will take two stereo (or four mono) RCA inputs and put them on the UTP cable. The signals can be sent up to 1000 feet with no noise or frequency roll-off. This is an active circuit, not passive like a balun. It has an adjustable signal gain and comes with a 5 year warranty. This is simply the BEST solution for sending audio down CAT 5 wiring with no signal degradation or noise pickup!

[...]S-Video splits into two RCA connectors, not one (it is a four-wire connection). The balun solution or the Audio Control solution will let you push S-video (4-wires) and stereo (4-wires) onto a single CAT5 strand. And it is a lot cheaper. You could get a “mono” balun for $85 US. Don't be fooled by the “mono” description. All a balun is doing in transferring the signal from one connector to another. A “mono” balun uses all four wire pairs, and costs the same as a “stereo” balun, which only uses three wire pairs.

Woody Woodward, woodward@hiddencove.net

I would like to suggest a different alternative using the latest technology that our company had developed which allows DVD quality audio/video and IR information routing on a single category 5 cable. With the hub router approach, up to 8 A/V sources can be routed to 16 zones in a house. The entire system is plug and play and there are no ground loops, hum, noise pick-ups or other problems. Please visit the website www.wireless-experts.com and check out the CATS product line or down load the Cats2.pdf catalog .

prasanna shah, pshah@wireless-experts.com

In-Wall Speakers

I’ve heard several ways of doing in wall speakers and I was wondering what others who have them think. I’m interested in new construction. The simplest ones just "clip" onto the edges of a hole cut in the drywall. One audio place I talked to suggested building a special box around the speaker to improve the sound.
Bill Seurer

For new construction, many in-wall speaker companies offer brackets that span two studs, and the speaker is attached to that bracket after the walls are up. Speakers that clip onto the sheetrock are primarily designed for installation into existing homes where access to the studs is less convenient.

As for the boxes, my understanding is that they can serve two functions. In some areas, enclosures are required for all electrical devices, so the box is used to meet code (not applicable in most areas of US). The other function involves use in wall with “blown-in” type insulation. In this condition, the

box prevents the insulation from settling against the speaker cone and dampening the output by absorbing their energy.

It is also my understanding that the use of these boxes typically creates a rear/side surfaces which reflect sounds back against the cone, resulting in a very slight distortion (most people won't detect it without sensing equipment), and that ideally, a sound absorbing material such as insulation, placed around but not against the rear of the speaker, is most ideal.

David Gaddis , creator@hometeam.com

I've also wondered how to maximize the sound quality of a built in speaker system. I have heard systems that sound good and not so good when mounted directly 'clipped' into the drywall. I suspect that any in wall mounted system will be a compromised system from free standing enclosed speakers.

The price of the same sized built in speaker systems seems to vary quite a bit. How can you assess the differences in sound. We could use a showroom in our local areas to compare these systems.

Harold Ennulat, Hennulat@mmm.com

The price varies because the quality varies. Some people may mistakenly believe that all 6x9 speakers are the same, just priced differently. In fact, it is the way that they are engineered that determines their quality, not just how big they are or how many watts they are rated for.

The main variables come in the driver and cones. a more powerful driver is capable of more distinct sound waves generated to the cone. The cone itself is also very important. There is usually a rubber dampening material around the perimeter of the cone. When sound waves are initially generated at the core of the cone, they travel down the cone to the edges. If they are not dampened well at that location, they can reflect back up the cone towards the core and distort the new sounds which are being generated. The ability of the speaker to dampen these sound waves instead of reflecting them depends upon such things as the size, shape, and material of this rubber dampening.

Consequently, you should not assume that all speakers of the same size and rating should sound alike, but you can assume as the old saying goes, you get what you pay for.

As for determining quality before a purchase, the simplest way might be by reading one of the speaker comparison articles regularly printed in such magazines as Home Theater or Audio Video Interiors. Alternately, you can learn a lot by attending the CES shows and visiting their demo rooms, or you can by test equipment and test each model for yourself.

David Gaddis , creator@hometeam.com

Or you can install back-boxes specifically designed for speakers. One problem, though, is the lack of such boxes for wall use. Most are designed to go into the ceiling. I have installed, and we are a dealer for, Tannoy audio loudspeaker systems. The CMS series are designed around the Atlas/Soundolier BQ818BX enclosure. The speaker and the rear bass porting were actually engineered with the box for optimum audio quality. It is tough to out-perform a Tannoy, but they don't yet make an in-wall unit. Too bad.

Tom D. Brown , Olympic Security & Communications Systems, tombro@eskimo.com

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I've had a couple of pairs of in-walls in my house for around 3 years. They're the ones designed for existing walls, and have a metal bracket that slips into the hole in the drywall. 4 screws go through the speaker assembly and pull the bracket tight against the back of the wall. The installation was real easy (except for climbing through the insulation in the attic to pull the wires), and they sound great. Perhaps not quite on par with a pair of freestanding speakers, but then they were a lot cheaper! My local home automation dealer carries Polk and I think a couple of other brands of better (i.e., more expensive) in-walls that sound really impressive.

Off hand, I can't see why adding a box around the speaker would be a problem. In fact it might help reduce the amount of bass vibration transmitted through the wall to the room behind the speakers. Be sure and consider that when you decide which wall to install the speakers in. External walls would be best from that point of view, although the insulation in the wall may make it harder to fit the speaker in. You might want to get in touch with some of the speaker manufacturers to see if they have any building tips.

Joel Davidson, joel@austin.ibm.com

With most in-wall speakers, the wall and the room will be as important as the speaker in determining the sound quality. Listening to speakers in an audio showroom will tell you very little about their performance in your living room.

I listened to an awful lot of in-wall speakers when I worked at Sonance. Some sounded different on different days, or depending on where in the wall they were mounted. You could certainly hear the difference between a 6" full-range and a 3-way system with a 12" woofer and rare-earth tweeter, but those fine subtleties that audiophiles love to talk about endlessly were meaningless to discuss unless the room was considered.

Ease of installation and aesthetics seem to be the main factors in choosing in-walls.

BTW, the most amazing in-wall speakers I heard were the Sound Advance speakers. These get installed in the framing, the drywaller tapes them to the adjacent drywall, and they get painted or wallpapered just like the rest of the wall. They are COMPLETELY INVISIBLE! Even when they are playing, you can only find them by tapping on the wall (the diaphragm doesn't sound like sheetrock). Just don't try to hang a picture on one. The imaging was impressive, and they play pretty loud, although I'd probably want to use a subwoofer if I really want volume. You don't want to risk blowing them up.

The Sound Advance (completely invisible) speakers come from:

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Sound Advance Systems, Inc.
3202 S. Shannon St.
Santa Ana, CA  92704
714-556-2378, FAX: 714-556-5425
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Or leave an e-mail note for John Stiernberg, who's a consultant for them, at: JA Stiern@aol.com

Tell him I mentioned his name.

Orrin Charm , OrrinC@ix.netcom.com

Talking about loudspeakers is like talking religion...there are some real fanatics out there!

When I was looking for some in-wall speakers to use in my kitchen ceiling, I went down to the local stereo emporium to listen to some. There were speakers that ran from $350 up to 650 per pair. They were all mounted in a display “wall” which was supposed to emulate the standard wall cavity.

Yes, when played loud, one could A-B the different units and hear subtitle differences...i.e., tighter bass or more transparent highs. But, for the money, one was not buying very much...typically an 8 inch woofer and 1 or 1.5 inch soft dome tweeter with an open back to the unit. I thought that wall speakers would have a carefully engineered enclosure that would eliminate the unknown effects of an open wall cavity. One could get far better sound, for the same money with the “wood” enclosure free standing models. I left the store somewhat dismayed...feeling that all the top name speakers were just that - names (like KEF, ADC, etc) without much real value.

On the way home, I stopped by the local Rat Shack store and looked at what they offered. Hmmmm, a unit with an 8 inch woofer and soft dome tweeter with crossover...looks just like one of the expensive ones I just saw at the audio store...hmmm.

I decided to take a chance and bought a pair for $200.

After some trepidation about what they would sound like, I got them installed and cranked up the stereo...WOW! They sound every bit as good a the high end units (and Rat Shack isn't known for low prices either). My wife, with the critical ear, was really pleased. My know it all brother-in-law came over and said they sounded real good - “what are they” he asked. I replied, “Oh a pair of KEFs”. “Hmmm”, he said, “you always get better sound with the top brands.” I just smiled...and to this day he thinks they are KEFs.

NO! I have no interest in Rat Shack and I'm not bad mouthing KEF...only telling of my experiences with in-wall speakers. Be true to your own ears and not the salesman's.

William R. Hester, whester@du.edu

One last question regarding the building of my new house. I just noticed a Leviton Whole-House Surge Suppressor with EMI/RFI filters. I suppose since I’m going to have so much X10 stuff (including wall switch modules), it is advisable to get one of these or something like it?
Barry

Surge Suppressors

That depends, of course, on the quality of your power. X10 devices, unlike mechanical switches, are very sensitive to surges. Here in Houston, Texas, we have lots of thunder storms and I have had 3 switches out of 6 installed fail within 6 months. I watched one die coincidence with (and presumably as a result of) a lightning flash. One wholesaler who has been in the X10 business, who has a degree in electrical engineering, and who strikes me as knowledgeable, suggested that the Leviton surge suppressor would help me. Based on that, I have purchased one (from him). I was intending to install it

myself, but looking at it and my panel, I am intimidated. If I was building a new house, I sure as heck would have one installed then while all the other wiring was being done. (They are kind of big and ugly and you do need to be able to see yours to make sure the indicator LEDs are on indicating continued protection.)

It is a standard Leviton part (Leviton # 51120-1) so I assume an electrical contractor could get it lots of places. I got mine from “Off The Shelf” (1-800-458-6423) and paid $171. Off The Shelf claims to be a wholesaler, and to sell only to retailers. I don't know how strict they are about this, however.

Question about whole house protector... What happens to the unit after a hit? Does the unit get wiped out / destroyed? Or does it survive and need to be reset? Does some part have to be replaced? If so, can it be replaced by the homeowner. How much $?

There is no provision for reset or repair of the unit in the accompanying literature. I sure as heck HOPE it doesn't die after each thunder storm! There are two LEDs on the front, and if either goes out, you are supposed to replace the unit. Replacing the unit is a lot easier than installing it in the first place; I would feel 100% comfortable with replacement, but I am considering having an electrician do the original installation. As I understand it, if the unit dies, your house keeps working but you no longer have any protection; e.g. you are right where you were before you installed the thing.

You are absolutely correct. The surge protector should survive all but a lightning strike on your side of the distribution transformer. If you ever see the LEDs out, you should be very happy you installed it, as it probably saved you more than it cost.

All surge suppressors that I know of eventually loose their ability to stop surges. The surge choking circuitry takes a hit each time a surge comes in, and loses some resistance.

Stick with a quality device which uses avalanche diode technology, rather than cheap MOVs (metal oxide varactors), and you won't have that problem.

There is a company that builds industrial lightning and surge suppression equipment for the RF industry. a group of their products deals with protecting AC incoming lines. They can protect small devices and whole houses. The equipment is designed to protect a radio site from a DIRECT lightning strike! Maximum specs, < 5 nano sec response, clamp voltage depends on unit. Also spec'd to a 45,000 amp strike. This equipment also does EMI/RFI filtering. It also does NOT interrupt power during the surge event. 99% of the protection equipment shunts the load to ground momentarily cutting power to the load.

The company is called PolyPhaser Corp. you can request a catalog at 1-800-325-7170. The equipment is on pages 35-39. If you are building a home then the IS-IL120-SP-XX would be for you. Specify amp rating for XX. Standard ratings are 100 Amps / phase, 200 Amps/phase and 400 Amps/phase. This device hooks into your incoming power lines before your breaker box. If you have questions the I can be reached, bert@halcyon.com. We use their equipment to protect our computer system at work. Protects the AC power, coax LAN and telephone lines.

Rumor has it that many surge suppressors kill X10 signals dead. The rumor goes on to state that Mr. Leviton is a real X10 nut, and so insists that all Leviton surge suppressors be X10 friendly. I was told explicitly by my supplier that all of the (Leviton) surge suppressors he sells are X10 friendly.

I'll contribute some fact a.k.a. my own experiences. I have a CP-290. I want to keep it hooked up to my computer. At the same time I don't want a surge coming through the AC lines to go through the CP-290 into my motherboard.

I tried plugging the CP-290 into my UPS and my Triplite surge suppressor. Neither would allow X-10 signals to pass. When I connected the CP-290 to an outlet strip that has only MOV's X-10 signals did pass.

So here's my dilemma: I can leave the CP-290 plugged into the MOV protected power strip and take my chances or I can unplug the CP-290 from the serial port except when I need to program it.

Or I can try and find a surge suppressor that works on an RS-232 connection.

I recently had one surge that came in over the phone line. Fortunately the only thing that blew was the fuse in the surge suppressor. I'd rather not take any chances. :-)

I have a serial surge protector in my hands right now. It has a db25 on each end and looks like a gender changer or null modem. It is made by Tenmax, part # 83-830. I can't remember where I got it, maybe Radio Shack? I guess I should install it. It's not doing much good in my hand :)

Be very careful with the surge suppressors that come in the db25 block or what ever. 99% of these surge protectors ONLY protect 2 pins! You must make sure that ALL internal wiring is protected! The surge can couple onto the other wires and bypass your protector that is only protecting 2 pins!

Example. I am working with a company that has data terminals, they use 6 position, 6 conductor cable and RJ-11 connectors (standard phone line cable!) They had surge protectors on the host covering their terminal lines. The host STILL got fried because the protector only protected 4 of the 6 lines. The surge coupled into the unprotected line and passed right by the protector. You may say but I only use 4 wires for data and a ground. I don't use the sixth wire. The surge does not care!

ALSO when looking at surge protection for anything remember, the less number of conductors, the MORE surge the remaining lines are going to take. Example. you take a 6KV, 20KVA strike (this covers the 80 percent of strikes) your have six conductors. The surge couples into all six wires. Each wire takes 1/6th of the surge. Now same strike because these are the common ones, but you have a 4 conductor cable. Each conductor takes 1/4 th the surge. SO don't be fooled when you have a db25 protector that only protects 4 wires. There are still 21 other wires in the cable that are unprotected and as soon as the surge passes the protector it will couple back into the supposedly protected lines and fry your equipment.

Dave, bert@halcyon.com

PS I read a previous post about the diodes over MOVs and that the diodes don't break down. WRONG. This is marketing hype. The reason they say theirs will work longer is because they cram more diodes into the package so that it takes longer to fry all the diodes. 2nd. Diodes have a higher clamp voltage than MOVs witch means your equipment gets a higher voltage spike. 3rd Diodes have a slower turn on time. You must have something that turns

on in LESS THAN 5 NANO SECONDS! Other wise by the time your protections triggers it will only clamp on the TRAILING edge of the surge and the damage has already been done.

I've got a suppressor with 2 RJ11 jacks for serial protection. I never see it, so I don't remember the name, but I'm thinking it's Panamax. Do be aware that some suppressors that have RJ11 jacks simply pass 'em through and do NO suppression on the line at all! Just because it looks good on the outside doesn't mean it's good on the inside.

I sell Panamax for the company I work for. They are very expensive but they provide an insurance policy of $5 million in a lifetime coverage for any equipment plugged into them. They handle from 480-670 joules of energy and claim a clamping time of <1ns. They have protectors available for phone, networks, coax, satellite dishes and more. I have opened them and compared with cheaper suppressors, there is a definite difference.

BTW... The phone jacks on all Panamax suppressors are RJ45 (6 wires). On the network suppressors, all six wires are connected when needed. On some of the phone suppressors, only the two middle wires are connected (one phone line). On their Supermax suppressor, intended for computers, the four middle wires are connected to protect two phone lines.

Keith

Just a little further information for you. Transtector Systems, Inc. Manufactures excellent TVSS, actually the best I've seen. I say this because they use a unique technology called SASD as opposed to Triplite using MOVs. MOVs are viewed as a disposable product because they wear out over time and use. Of course Triplite won't tell you this, but any of the companies who manufacture MOVs will, ie. GE, Seimens.

Also, you may want to look into how many "insurance policies" have been paid on damaged equipment by Triplite; I've heard it's around 2% are paid. Now, out of 20,000 claims that's only about 400. The fact that MOVs do wear out is probably why you were recommended multiple or backup units. That way when your primary fails, which it will, you'll have secondary. Not only that but if you take a direct lightning hit nothing on this earth will stop it. I learned this information after several experiences with Triplite, and Panamax. I have been installing home theatre & automation systems for several years as well as Office automation solutions. You can contact Transtector Systems at 1-800-882-9110, or E-mail @ ttor.comtch.iea.com.

srfspud@aol.com

Talked with Transtector about the TVSS units. For my home application, the cost would be between $3500 and $4000 ... up to $5K for the top-o-the-line unit. The actual window he gave me was $3K to $5K dependant upon the phase, amperage, and max voltage on the circuit ... so the $3K bottom is the significant number for most folks. The nomenclature for their device is CPS-2. Spoke with George, who seemed very knowledgeable about the subject, and he indicated that the MOV units like the one in Home Automation Inc. would "only" have a life expectancy of about 15 years ... my advice would be to replace the $173 Leviton unit every 5 years if you

need peace of mind that your electronic components are safe from all but a direct hit.

Don Reinke, reinke@cira.colostate.edu

HVAC Wire Colors

What is each color for going from the thermostat to the HVAC? ex. AC, HEAT, FAN, 5v... Is this pretty much standard?
nate@eskimo.com

It's pretty standard:

```
RED = 24VAC
GRN = FAN
WHT = HEAT
YEL = COOL
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Sometimes

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BRN = 24VAC Common
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On a heat pump, white is HEAT/COOL and Yellow is the reversing valve. Blue, Orange and other colors may be used for 2nd Stage Heat / Cool.

Orrin Charm , OrrinC@ix.netcom.com

As with any "standard" the first rule is not everyone follows the standard:-) It is important to identify the function of each wire by the schematic or first hand knowledge of the unit or thermostat.

These are the terminal designations for a Honeywell T87F thermostat (the round one) and the "standard" colors for an eight wire cable.

```
RED      R   24VAC CONTROL POWER
GREEN    G   FAN
YELLOW   Y   COOLING
WHITE    W   HEATING
YELLOW   P   COMPRESSOR (HEAT PUMP)
ORANGE   O   COOLING AUX (REVERSING VALVE FAIL TO HEAT)
BLUE     B   HEATING AUX (REVERSING VALVE FAIL TO COOL)
BROWN        24VAC COMMON (NOT USED BY THE T87F)
```

The cooling or heating aux terminals are energized any time the system switch is in cooling or heating respectively.

When a four or five wire cable is used the standard quickly mutates. For example when a four wire cable with red, green, yellow and white is used with some heat pumps the white is on the O or B terminal.

Charles Smith, ads@netzone.com

Miscellaneous Comments

Is it possible to install speaker wire in an already build house...
Neel

Yes, assuming you want to run a star configuration or home run from a central point for example from where your audio equipment is located, you can run speaker wire up to your attic and then down through the walls to a speaker wall outlet plug. Or you can run speaker wire down to the cellar and back up through the wall floors. You need some special equipment like longer drill bits, or a flex bit to angle corners. You'll also need string or wire

(optionally with a weight) to fish through walls, floors, ceilings, (studs and joists).

If you want some really good advice, contact somebody who knows how to run telephone wire in a home. Electricians know how to do this, but the independent telephone jocks really know how to pull a wire through anything without disturbing the plaster, paneling, etc.

Jack Golfer, jackgolfer@aol.com

What is the best way to splice speaker wires?

There is no hard rule. I am a pro audio engineer and I would tin (coat) the stripped ends with solder, twist and solder them together, apply wire nuts, and tape the whole mess up. Be sure your amplifier is not connected and isolate the conductors from each other completely, a short with the amp on would probably cook the output section of your amplifier. This should work fine and NEVER come apart. If anyone says that the solder will melt under load, ignore them. Speaker wires do not build up any heat. When someone says that the solder will affect audio quality, ignore them. Only your dog or pet bat would notice the difference. (Do use solder intended for electronic applications however).

StageDog, stagedog@aol.com

I ran 2 RG6 & 2 Cat 5 to 2 locations in each bedroom as we planned to use then as offices. Actually, it was just 2 long runs, not 4, because I ran to a box close to the wiring closet, then pulled out about 2 feet (shoving most of the 2 feet out the back of the box), then snaked it back under the floor to a box on the far side of the room. This was wherever I set up TV & phone / network, regardless of what side of the closet or door I am on, I have a clean line. I saved a good deal of cable this way, and still have flexibility as to location. The only potential problem is if I use the “close” location first, then decide to use the “far” location leater, I'll have to splice the cut cable back together.

Another drywaller note: I tried to set my “future” boxes back at the edge of the studs, so they didn't stick out the standard 1/2" inch that the boxes I wanted exposed were. What I got was very haphazard. They cut out all those that stuck out 1/2", but also cut out about half those that weren't to be. So I have a bunch of white cover plates where I will someday have speaker jacks.

Final drywaller note: Drywallers now use a mini-router to cut outlets. This mini router will chew up anything you have coiled in a box. Imagine my dismay when I found my RG6 chewed through to the center conductor 2" from the back of the box. I was kind of stuck - I didn't even have enough excess to get a F connector on, let alone reach the back of a cable jack faceplate. Thank goodness I had slack in the walls - although a few were kind of rough, and I'm not sure the stretching won't come back to haunt me someday. My advise, leave half your excess in the box where it should be, but make sure you have at least 4 inches of slack BEHIND the box to cover for any cuts you may get.

Tom Campbell, tcampbel@nando.net

Just a suggestion for whenever you have walls open – Put in empty outlet boxes at baseboard and switch heights and run 1" PVC pipe to the attic or

basement for all the *future* stuff. Plastic boxes are cheap, thin wall PVC is too. Two gang boxes are even better. You can cover them up with blank plates, and you'll be so happy you provided them. If you do this, be careful to plug the pipes lest you generate a massive and expensive flow of air between the wall cavity and the basement.

I've often wondered why up-scale new homes frequently have intercoms. The technology is obsolete, essentially not repairable, and not compatible with anything else. Why not install a decent small key system like a Panasonic and use door box extensions for the door bells? The wiring will be standard phone stuff, the system can later be upgraded easily, and you'll only have one "thing" in each room, a speaker-phone.

My response relates not to the AC wiring/circuits, but rather to prewiring comm & data & control into your new house...something you'll never get a second chance to do correctly again. Make sure you install additional outlet boxes (with 1/4" phono jacks - makes a very neat/clean interface) in every room (some rooms need two) and wire them up for both channels of stereo, coax or at least two pair of twisted/(and possibly shielded wire - for data, and possibly another for intercom. Additionally, if you have an outside antenna, include a control cable (usually 5/7 wire) for the rotor (I forgot to do this in mine!). I just bought standard blank wall plates and custom mounted any of the required H/W and it all blended in very well (makes the wife happy!).

I've got one idea which I think I could not find on your list. It is convenient to install at the same time as other wiring – set in a centralized vacuum cleaner system. It requires 5cm plastic pipe set into the wall (as straight as possible) and a parallel low voltage cable for remote control, before drywall. It may be important for allergic people as absolutely all exhaust is evacuated out, or for somebody who is sensitive to the noise. The main unit can be localized in a cellar, for example. I do not discuss costs; they are negligible, as I construct my house in Poland. They were about 5 times higher only than my electrician charged me for the same length unit of standard electric cabling.

Zbigniew Was, wasm@surya11.cern.ch

I did 2500 sq ft with 8000 ft of wire, which maps pretty close to your measurement. Some labor estimates I have which you did not include in your materials are about 12 person-days to run the wire (7 hour days).

For motion detectors: Locate wires for motion detectors in the corners of your rooms, about 6-7 feet high, so the units are not facing any large windows, mirrors (signal bounces back), or each other. Most motion detectors can handle 6 wires – 2 for power, 2 for motion signal, and 2 for tampering with the unit.

For info on Fast-Ethernet, contact Intel at 1-800-538-3373 x132 and ask for EtherExpress Pro/100 adapter information. I think they have the first product that uses it (may require two runs of Cat5 cable for 100MHz Fast-Ethernet).

Michael Caron, mrc@cadre.com

For Panasonic phone systems, try *The Mart*, an advertising magazine for the telecom industry. For a sample copy, call (800) 864-1177.

- Never pull less than 14 gage wire in that the average 16 gage is too few strands and the result is too much signal loss and sound degradation. My personal favorite is 14 gage Vampire Wire, in that it has 105 strands of nearly oxygen free copper per conductor.
- CEBus by US Tec requires that you use their cable. They won't guarantee the end result if you pull your own configuration of cable.
- IR is neat, but the newer direction to go is RF, which means NO wires need be run unless it's a monstrous sized home, then it would be for remote locating the receivers / transmitters in the attic area closer to the system or room where the remote is to operate.

Jon Blaha, Audio Video Odyssey, 813-784-1911

To get wire from one end of the house to the other "through" an eventual vaulted ceiling I installed two 3" pulleys, used a quarter inch nylon rope and had at it.

This was used for an approximate 50' distance and worked fine. I left it in place when I was done and have already used it to pull one wire I forgot. Secure the end of your wire to the rope at one pulley, go down to the other pulley and run it back to you. Worked Great and will continue to be of benefit.

With 3500' of wire I had forgot about the massive amount of work terminating all those ends with RG6 connectors and telephone connectors, etc...

PS: I got RG6 1000' rolls for $70/ea from an Electrical company that was doing a big development...guy says to me...geez I can get it all day at this price..you pay my price and I don't mind helping you....others may try to find such a source?

Also got my 4 wire from him at $36 / 1000'

Ken Coon, kencoon@cyberfind.com