FOA Reference For Fiber Optics
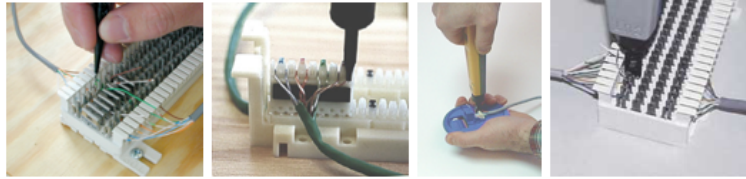
Premises Cabling
UTP Cable Installation
Virtual Hands-On

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This FOA virtual hands-on tutorial on fiber optics is aimed at helping understand the hands-on activities used in UTP installation. It is copyrighted by the FOA and may not be distributed without FOA permission.

Unshielded twisted pair cabling as described in the TIA-568 standard (ISO 11801 worldwide) has been the standard for connecting devices to network and telephone cabling in buildings. Since Voice over IP (VoIP) became more widely used, network and telephones are using the same cabling. Power over Ethernet more recently allowed powering remote devices like VoIP phones and wireless access points over the network cabling.

This presentation will discuss the processes of installing and terminating UTP cabling.

UTP Cabling Components

Pair - Color
1 - Blue
2 - Orange
Separator
3 - Green
4 - Brown
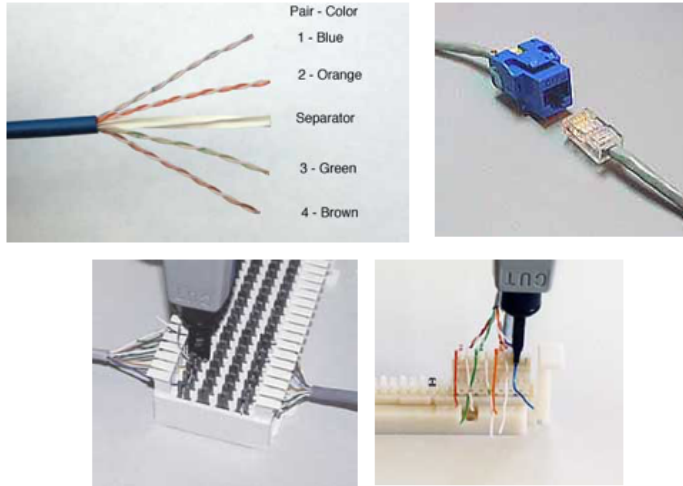
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These are the components that are the basic hardware of structured cabling. It's based on a four pair unshielded twisted pair cable(upper left) rated by performance from Cat 3 to Cat 8, modular 8-pin plugs and jacks (upper right, often erroneously called a RJ-45, the AT&T designation for a modular 8 pin connector with a specific pin configuration), and two types of punchdown blocks, the 66 block (lower left) used mainly for telephone cabling and the higher-density 110 block (lower right) used as the style of punchdown for modular jacks.

UTP Cable Design

- The frequency performance is determined by twists in the pairs
- Note differences in telephone wire (top), Category 3 and Category 5e
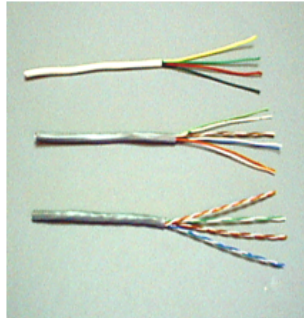
From the top, 2-pair telephone wire, Category 3 and Category 5e cables.

The basic component of "568" is the cable. For most horizontal connections, it will be 4-pair unshielded twisted pair (UTP) cable.

Most UTP cables are comprised of eight 24 AWG solid copper wires, twisted into four pairs. Each pair is color coded for identification.

There are cables comprised of 25, 50 and 100 twisted pairs that are primarily used for telephone connections. They are used to reduce the number of cables run between closets and can be more quickly terminated on punchdown blocks.

DVVC-Chapter 4

UTP Cable Design

- All pairs are color-coded
- Stripe is "tip"
- Solid is "ring"
- *This is Cat 6 with a divider between pairs*

Pair - Color
1 - Blue
2 - Orange
Separator
3 - Green
4 - Brown
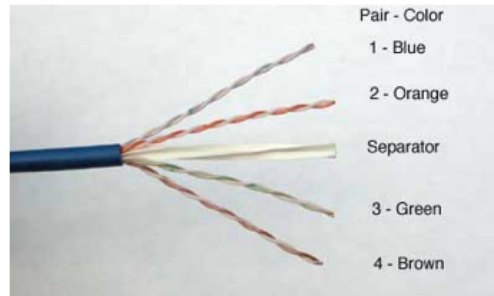
Why "tip" and "ring"? It refers to the phone Plug like this!

Tip
Ring

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Here is a Cat 6 cable with a divider that separates the four pairs to reduce crosstalk.

The color codes are important for correct termination in punchdowns, jacks and plugs.

Look carefully and you can see each pair has a different twist rate. Higher performance cables have higher twist rates. Each pair is twisted at a different rate to prevent crosstalk. Think of the pair as an antenna - twisting pairs at different rate tunes them for different frequencies, reducing crosstalk. The performance of the cable will fit it into three categories, called Category 3, 5, 5e, or 6, depending on its high frequency capability.

DVVC-Chapter 4

Cable Trivia: Tip & Ring

- Stripe is "tip" - and was connected to the tip contact of the old phone plug
- Solid is "ring" and was connected to the ring around the shaft of the phone plug as the other contact

Tip

Ring

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Cabling trivia: 'Tip' and 'Ring' refer to the old phone plug. The white wire with the color stripe was always connected to the tip of the phone plug and the color wire was connected to the ring on the plug, creating the nomenclature that has persisted to date.

DVVC-Chapter 4

Installation - Pulling Cable

- Most cable is purchased in boxes of 1000 ft.
- Pull directly from box to install
- Do not pull out of box before installing - it will tangle!

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Cables come in several styles of boxes designed to allow easy pulling directly from the box. Note on the box you are using the proper placement of the box for pulling to insure the cable is not twisted or kinked when pulled from it.

The most efficient way to pull horizontal cables is to pull bundles. Using drawings of the area, determine where all work areas are located and establish several consolidation points or clusters to pull from. Place all the cable boxes in the drop area and mark each as to the final location. "Post it" notes are good temporary labels for the boxes.

Most boxes contain 1000 feet of cable, and the cable jacket is marked periodically with a length number. When you first use the cable, mark the length on the box with a permanent marker so you can always calculate how much cable is left in the box!

If the cables are on reels, set up a stand with an axle to allow the cable to unroll. Do not feed the cable off the sides of a spool as it will twist and kink. Two chairs and a short length of conduit or a broomstick can be a makeshift axle, and some contractors use jackstands and a piece of conduit. Cable "trees" are also available at reasonable prices.

DVVC- Chapter 7

Pulling Cables

- Single cable - tape loop on end for pulling rope
- Bundles
  - Tape bundle
  - Loop pull rope through bundle behind tape
  - Tape at end
- Ready to pull cable
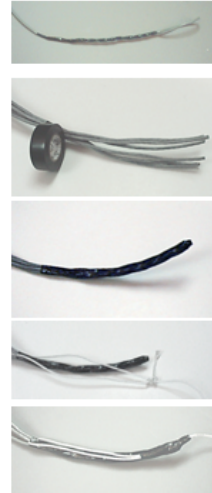
7

Pulling Cables

For a single cable - use electricians tape to make a loop on the end to attach a pulling rope

For cable bundles

Tape bundle for about 6-8 inches on the end

Loop the pull rope through bundle behind tape

Tape the pull rope at the end

Now you are ready to pull cable

Pulling Into Conduit

- Cable may be damaged by hacksawed end of conduit, so special nylon bushings are used to prevent abrasion
- Use lubricant if long pull with high friction
- Make short pulls through intermediate boxes

8
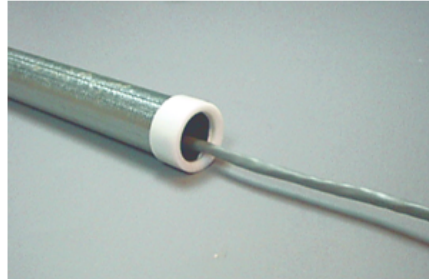
Pulling Into Conduit

Cable may be damaged bythe rough hacksawed end of conduit, so special nylon bushings are used to prevent abrasion

Use lubricant if long pull with high friction

Make short pulls through intermediate boxes

Hanging Cable

- You cannot lay cable on ceiling tiles or grids
- Use cable trays or j-hooks
- To prevent kinks, do not lay cable bundles in wire hooks
- Use wide j-hooks
- Do not overload trays or hooks
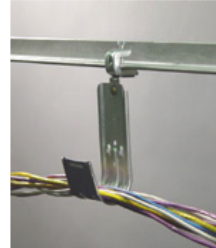
Hanging Cable

You cannot lay cable on ceiling tiles or grids - it violates codes
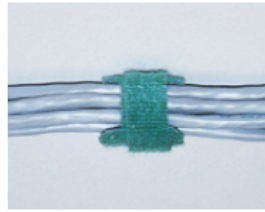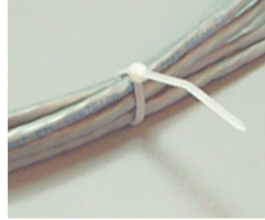
To prevent kinks, do not lay cable bundles in wire hooks used for electrical cables

Use wide j-hooks that spread out the load on the cables

Do not overload the j-hooks as it can damage cables on the bottom

Bundling Cable

Be careful with cable ties - too tight and it wil crush the cables, perhaps enough tol cause crosstalk failure

If you use cable ties, do not use cable tie "guns" to set them - hand tighten and cut off ends to prevent future tightening

Preferably use "hook and loop" fasteners now widely available

Hook and loop fasteners can be reopened for adding or removing cables

Installation - Wiring Closet

- Max pulling tension is only 25 pounds
- Watch for kinks - especially around corners
- Use special cable trays, hooks, etc. designed to prevent kinks or tight bends

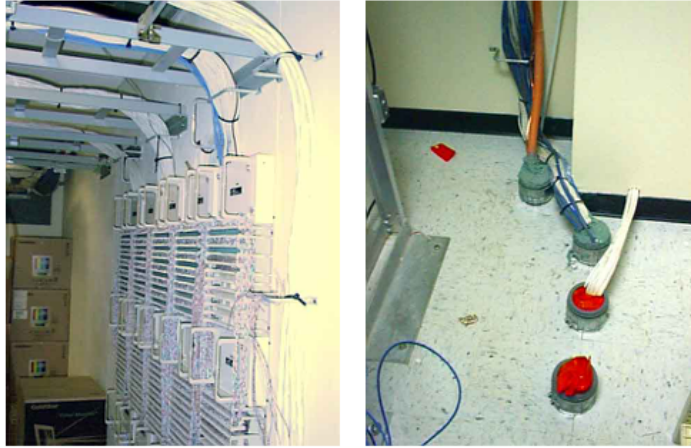© 2020, The Fiber Optic Association, Inc.

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The typical installation of communications cabling is in an office building. There are communications wiring closets on every floor, and several if the floor covers a large area. A main communications closet will have the primary communications equipment (PBX, network routers, etc.). Cables will run from the wiring closet to work areas overhead above a suspended ceiling. Wiring closets will be connected by multiple cables run overhead or in risers.

In our typical installation, the horizontal cables will be pulled between the wiring closet and the work area above a suspended ceiling. This pull will involve routing the cables around everything else already there, including other cables, HVAC systems, light fixtures, etc. It is usually easier in new construction since the tiles are not in place. The procedure involves gaining access, determining the best route for the cables, running a handline, affixing cables to the handline and pulling the cables.

The performance of the cabling network is heavily dependent on the installation. Components have been carefully designed and exhaustively tested to meet or exceed the requirements of TIA/EIA 568. If the cable is not properly installed, performance will be degraded.

DVVC- Chapter 7

Installation Details

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The closet or equipment room can be anything from a broom closet with communications hardware mounted on the wall to giant rooms with raised floors full of racks of equipment and cable trays connecting them. This makes describing this part of the installation difficult, so we'll offer some generalities.

The layout of the room will be dictated by the space available and the equipment to be installed. Someone will layout the area and specify where all the hardware will be installed. The installation of cable trays, racks, etc. is so vendor specific that the best advice is read the directions.

All hardware should be installed before any cabling begins. Once all the hardware is installed, the cable can be pulled in an terminated at the proper locations.

All penetrations of firewalls require firestopping to meet fire codes. This can be done with permanent foam-in firestopping material or removeable material available in bags if more cables are to be installed in the future

DVVC-Chapter 7

Documentation

- Mark boxes for cable length to always know how much is left in box
- Mark cables on both ends to be able to trace when terminating

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Mark the cables with a permanent marker with the same identification at both ends. Doing it exactly the same each time will make later identification of the cable in the closet easier and make tracing unnecessary.
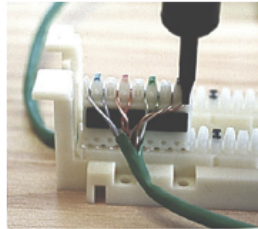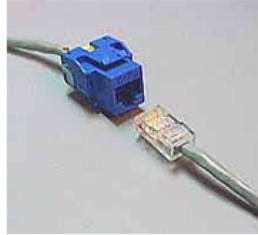
Remember you need to mark on both ends of the cable.

The really good way to do it is to mark it three times: at 6" from the end for the first termination, at 1' from the end in case it needs retermination, and 3' from the end to be on the service loop.

DVVC-Chapter 7

UTP Cable Termination

- Plugs and jacks
- 110 blocks
- 66 blocks

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The proper termination of Category rated cable is mandatory to maintain the performance specified by EIA/TIA 568 standards and expected by users. Proper cable pulling and handling during installation are important to maintain cable performance. But most problems with cable installations occur at terminations. If you do not maintain the twists right up to the terminations or do not properly terminate the IDC connections, the performance of the cable will be compromised. Remember you must use only equal Categoryrated components for every part of the network cabling !

The majority of terminations are made with standard insulation-displacement (IDC) connections, using 110 punchdowns on jacks or crimped RJ-45 connectors. Almost every manufacturer now has alternative design plugs, jacks and patch panels that do not require tools. Each of these have their own termination procedure, which while similar to the normal terminations, requires following their instructions exactly.

IDC Termination

- Plugs, jacks, 66 and 110 punchdown blocks use insulation-displacement contacts - IDC
- IDCs cut insulation, make contact with wire
- Creates airtight seal around contact
- Use punchdown tool to terminate

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All the connections in structured cabling use insulation displacement connectors (IDC). An IDC connection uses two blades (shown in gray) to cut through the cable jacket (blue) and connect to the conductor (yellow). The contacts and the jackets make a airtight seal that prevents corrosion, enhancing the reliability of the connection.

IDC contacts use a "punchdown tool" to push the wire into the contacts and cut off the excess wire.

IDC Termination

- Use punchdown tool to terminate by cutting insulation, make contact with wire
- Top: 66 block
- Bottom: 110 block
- See other VHOs for plugs and jacks, 66 and 110 blocks.
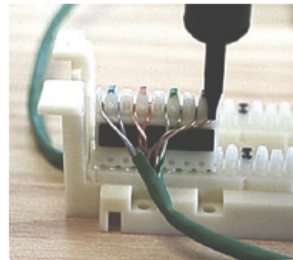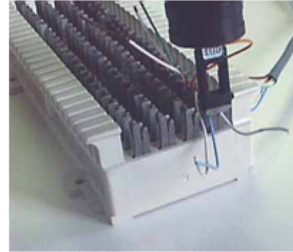
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IDC contacts use a "punchdown tool" to push the wire into the contacts and cut off the excess wire.

Most punchdown tools have replaceable blades so you can change from 66 to 110. And most blades have one end that cuts and one that simply punches down, in case you are daisy-chaining telephones.

Plugs and Jacks

- Plugs and jacks are "8-pin modular connectors
- Commonly called "RJ-45", which is another type of termination color code (USOC)

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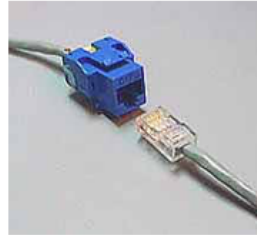
The 8-pin modular plug and jack used in structured cabling are sometimes called a RJ-45, which is incorrect. The RJ-45 uses a different pin configuration, called USOC (Universal Service Order Code), the AT&T designation for the pinout(see DVVC, Chapter 9 or Uncle Ted's Guide for details.)

Jacks

- Individual jacks for wall outlets or small patch panels
- Rows of jacks in patch panels for rack mounting in large telecom closets
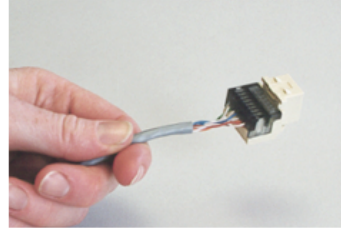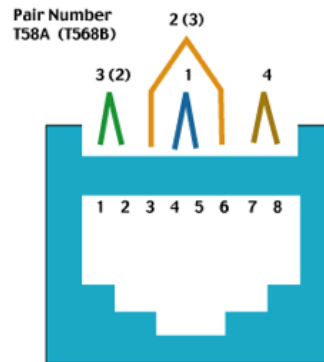
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The cables can be terminated in an individual jack for use in a wall outlet or small patch panel, or in a large patch panel typically used in telecom closets. Both terminate with 110-style punchdowns on the back.

Jacks - T568A

- Two 568 wiring schemes:
  - T568A - **THIS ONE >**
  - T568B
- Differ by reversal of pairs 2 and 3
- T568B is more common
- Don't mix!
- *View looking into jack*

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TIA/EIA 568 recognizes two pinouts for a jack or plug. They differ in the reversal of pairs 2 and 3. This scheme, called T568A, has pair 3 (green) on pins 1-2 and pair 2 (orange) on pins 3-6.

The two schemes exist because most users started with this scheme, while AT&T used a pinout where the two pairs were reversed. When the standard was written, no one wanted to give up their scheme, so both ended up in the standard!

Of course, there is no performance difference in the two - and you can't tell any difference unless you look closely at the pin configurations and color codes. Only one thing will cause a problem - terminating one end of a cable with one and the other end with the other. Then you end up with crossed pairs and network equipment ends up connecting transmitter to transmitter and receiver to receiver, which is obviously not going to work!

There is one instance when you want this "crossover" - connecting two computers directly without a hub or switch. Hubs and NICs have reversed transmitters and receivers to allow connection over direct connection cables, so connecting like devices requires a crossover cables.

Jacks - T568B

- Two 568 wiring schemes:
  - T568A
  - T568B - **THIS ONE >**
- Differ by reversal of pairs 2 and 3
- T568B is more common
- Don't mix!
- *View looking into jack*
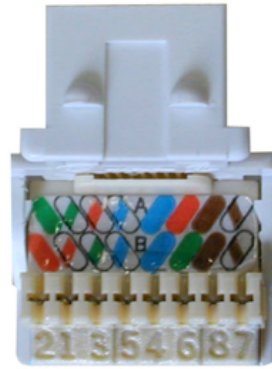
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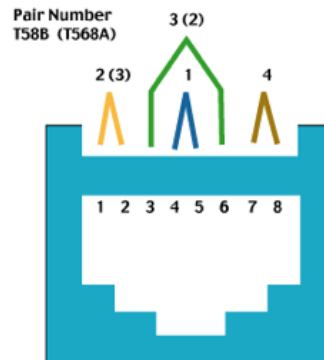
Note that the T568B termination has pair 2 (orange) on pins 1-2 and pair 3 (green) on 3-6, just the reverse of T568A. Casual surveys seem to indicate that the "B" termination is more popular.

Whether A or B is used is irrelevant, but within one building or campus, one should be consistent and prevent other installers adding cables or doing moves, adds or changes from using the other type.

The pair configuration of the 568A and B terminations are the same as the USOC (DVVC-Chapter 4) phone configuration for pairs on pins 3-6 and 4-5, so the two center pairs can be used for two telephone lines compatible with normal two line POTS phones. The other two pairs are separated to reduce crosstalk. Using pairs 2 and 3 is the best for crosstalk performance.

Jacks

- Typical jacks use 110 punchdowns for termination
- Most Cat 5/5e/6 jacks are marked for both T568A and T568B
- Cat 3 are unmarked
- Pinouts are not what you expect!
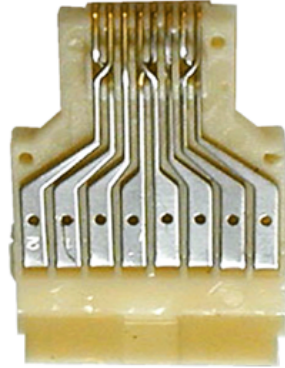
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While the jacks all will terminate in either 568A or 568B terminations (and USOC for that matter), they generally have color coding on the back of the jack to show you how to order the wires for termination. BE CAREFUL! The jacks often include both 568A and 568B color coding (and it's small!),

So be sure you use only the correct color code for that jack and don't get confused halfway through the job. Also since they often have "twists" inside the jack to reduce NEXT, the order of the wires on the back of the jacks is sometimes different from the normal order for a RJ45 plug! Make sure you know you have the wires correctly ordered according to the jack requirements!

Twists Inside Jacks

- Pinouts on most Cat 5/5e/6 jacks are not what you expect!
- Internal twists reduce crosstalk at high frequencies - change pinouts for pairs 1-3-4 by reversing solid/stripe

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Here is what the inside of a Cat 5/5e/6 jack looks like. The internal connections are not just straight lines, but actually have twists in three of the pairs where the connections on a single pair are next to each other. Just like the pairs in the cable have twists, the internal connections have twists to reduce signal emission and crosstalk. This is why the color codes on a Cat 5/5e/6 do not follow the color codes you expect!

Twists Inside Jacks Affect Pinouts

- Compare the pin assignments for the jack (Cat 5e) to the standard T568B termination and the photo of the internal connections

EIA/TIA 568B

1 2 3 4 5 6 7 8
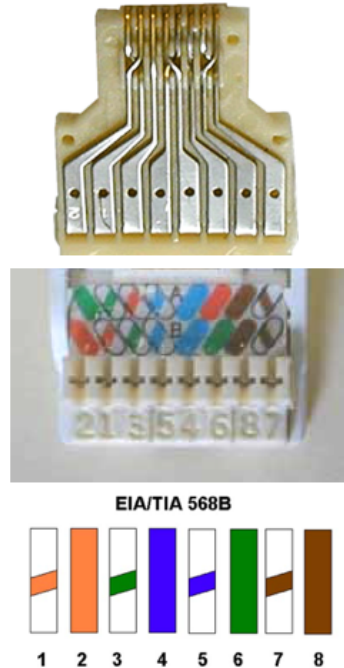
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Compare the pin assignments for the jack (Cat 5e) to the standard T568B termination. Note that just like the top photo, pins 3 and 6 are unaffected, but other pairs are reversed.

Be sure to follow the pin assignments on the jack!

Punching Down Jacks

- Terminate jacks with 110 punchdown tool
- Make sure the color codes match whichever wiring scheme is being used in the install (T568A or T568B)
- Don't mix them up!

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Tools required: Jacket stripper, cable cutter or crimp tool and punchdown tool with 110 blade (CUT side), small screwdriver. (optional, hand holder for jack.)

Strip off about 2 inches of the jacket

For each pair, untwist just enough wire to place each wire in the punchdown slot. Remember it must be untwisted less than 1/2 inch (13mm). As little as possible for Cat 6!

Place the jack in the special fixture to hold it securely.

Punchdown the wire to terminate it and cut off the excess wire

Repeat for all other wires.

Snap on the protective covers provided.

110 Blocks

- Terminate jacks with 110 punchdown tool
- The pair order is
  - 1 (blue)
  - 2 (orange)
  - 3 (green)
  - 4 (brown)
- Stripe wire (tip) before the solid (ring)
- Don't mix the color codes up with jacks - not same as T568a/b!
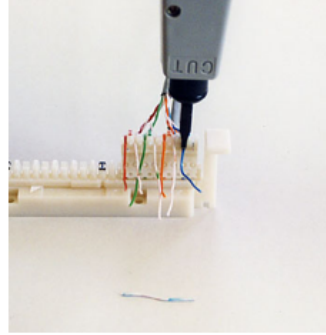
25

Tools required: Jacket stripper and Punchdown tool with 110 blade (CUT side)

Strip about 2 inches of jacket off the cable using the jacket stripper.

Separate the pairs (but DO NOT UNTWIST) in the proper order.

For each pair, untwist just enough wire to place each wire in the punchdown slot. Remember it must be untwisted less than ½ inch after termination.

Place the wires in the slots on the wiring block in color coded order: Blue, Orange, Green, Brown, with the while wire of each pair first. Some installers remember the order of the colored pairs as BLOG for BLue-Orange-Green (with Brown follow5ing by default!), but some 110 blocks have color coding on the block itself. Remember the white wire of the pair always goes first.

Punchdown with the tool, with the "CUT" side of the blade on the side where the end of the wire exits the 110 block

110 Blocks

- Attach connecting block on top of base using punchdown tool. Connecting block has IDC contacts internally
- Punchdown wires on top of block
- Match color codes on each pair

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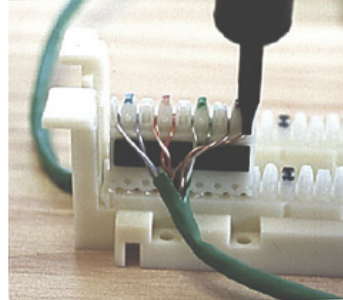
You have probably noticed the 110 block has no connector contacts. The contacts are in the connecting block. There is an insulation displacement contact for each wire on one side of the connecting block that inserts into the 110 block after all the wires are punched down. On the other side, the connecting block looks like the 110 block, but this time there are IDC contacts inside the block to connect to the second cable you wish to terminate with the first cable already punched down. The block also has color coding to prompt you as to which pair goes where.

Attach the connecting block to the 110 block you just punched wires into as shown above.

Position the block with the color coding matching the wire pairs and so the IDC connectors are in the proper location over the wires in the 110 block.

Push the connector firmly down until seated fully and all wires are properly terminated. Use the punchdown tool to help seat the block, working form one end first.

Punchdown the second cable on top of the connecting block in the same order as the cable below.

66 Blocks

- Terminate jacks with 66 punchdown tool
- The pair order is
  - 1 (blue)
  - 2 (orange)
  - 3 (green)
  - 4 (brown)
- Stripe wire (tip) before the solid (ring)
- Don't mix the color codes up with jacks!
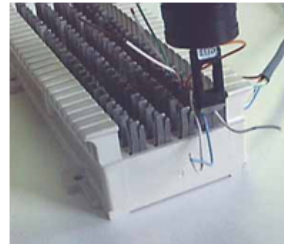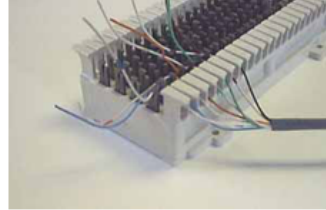
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The Cat 3 installation for telephones is almost exactly like the Cat 5 for LANs, except you will usually use a "Type 66" block. The 66 block has rows of four punchdown positions, with each side being a permanently connected pair. In use, the outside positions are used to terminate cable pairs, while the inside positions are used to terminate cross-connect wires. If the connection is directly across the row, a bridging clip can be used to save wiring time

Tools: Jacket stripper, Punchdown with 66 blade ("cut" side out)

Strip off about 4 inches of jacket.

Untwist the pairs but keep pairs together.

Following the same color code as Cat 5 (remember BLOG? blue-orange-green, then brown, white wire first), punch down each wire into a position on the end of one row on the block

66 Blocks

- Connect directly across the block with bridging clips
- Use wire if not straight across

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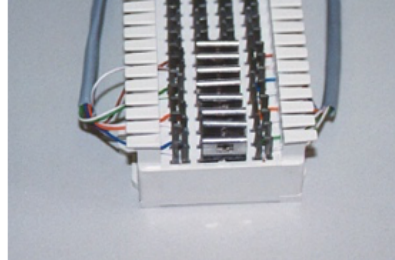
The punchdown tool works almost exactly like it did on the 110 block. Make sure you use the 66 blade end that says cut, so it will cut off the excess wire. And make sure the cut side is on the side of the position that has the excess wire to be cut off!

After you have terminated one Cat 3 cable to the 66 block, terminate the other Cat 3 cable to the position on the other side of the block with the color-coded wires in the same rows.

Now you can use bridging clips to connect the rows to complete the connection. Optionally, you can cut a short length of cable, pull out the wires, untwist them, then use them to punch down on the inner positions as cross-connect wires. You can get "bridging wire" also, and it's what you need it the cables and wires do not match up across the block. Using wire, you can connect any wire to any other wire at any location on the block.

Punchdown Color Codes

- All 4 pair cables are terminated on punchdown blocks in pair order:
- Pair 1 - blue
- Pair 2 - orange
- Pair 3 - green
- Pair 4 - brown
- Remember with the mnemonic BLOG = Blue-Orange-Green-brown
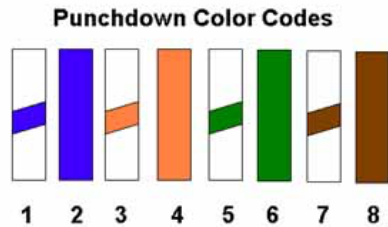
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Color Codes For Punchdown Blocks

All 4 pair cables are terminated on punchdown blocks in pair order:
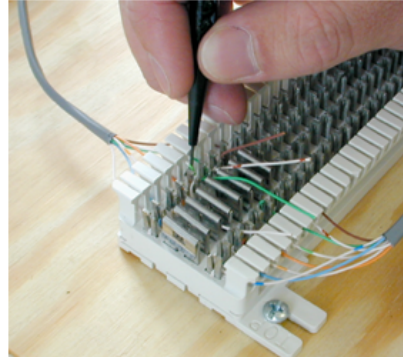
Pair 1 - blue

Pair 2 - orange

Pair 3 - green

Pair 4 - brown

Remember with the mnemonic BLOG = Blue-Orange-Green-brown

The Spudger

- The essential installer's tool
- Helps route wires
- One end can be used to start wires in punchdowns
- Use hook to pull off IDC contacts
- Costs a buck!

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When you have to remove a wire from a punchdown block or the punchdowns on a jack, you should have a "Spudger." A spudger is a long pencil-sized plastic tool with a wire hook on one end and a rudimentary punchdown on the other.

The wire is designed to allow picking out one wire on a punchdown block and pulling it out of the IDC contact. The punchdown tool on the other end is great for starting wires in the proper location so they hold in place while being punched-down.

This tool costs about $1 each, so make sure you have one!

Plugs

- You do not want to do this normally - buy patchcords!
- If you do…
  - Untwist pairs
  - Arrange wires according to correct color codes
  - Slide fully into plug
  - Crimp
- Make sure you test!
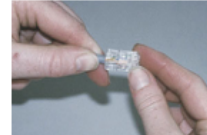
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Tools: Jacket stripper, cable cutter, modular connector crimper

Use the jacket stripper to strip approximately 2 inches of jacket off the cable.

Separate the pairs by fanning them out.

Use a small screwdriver to untwist the pairs by inserting the screwdriver between the wires in the pair near the cut end of the jacket and pull outward, untwisting the wires back to the end of the jacket.

Use your fingers to straighten the wires as much as possible.

Place the wires in color coded order for a 568A or 568B connector. *You can use either 568A or 568B pair configuration, as long as you use the same for both ends of the patchcord!*

When you have aligned the wires correctly, hold them flat between your fingers and wiggle them back and forth to make them as flat and straight as possible.

Using the cable cutter, cut the wires to the proper length. Make sure the wires do not get out of order and make sure the ends are cut square!

Plugs

- Trust us - you do not want to do this normally - buy patchcords!
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  - Untwist pairs
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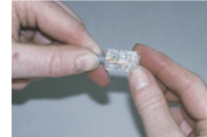
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Attaching plugs (cont.)

The wires must be cut square to make sure all wires are crimped properly.

Place the connector onto the cable by inserting the wires into the connector channels and sliding them all the way in. Make sure the wires butt up against the inside front wall of the connector.

Place the assembled connector into the crimper with jaws for the RJ45. When the connector is properly positioned, squeeze the tool handles to allow one full ratchet cycle until the tool completely closes and opens again.

To remove the connector after crimping, press down on the connector key and pull the connector out of the tool. Finally, inspect the completed crimp. All pins should be fully crimped and of the same height.

Note:Patchcords are usually stranded wire. Plugs for stranded wire are different than solid wire. Make sure you have the right plug!

Keep The Pairs Twisted!

- Most performance parameters of UTP cabling depend on the twists in the pairs
- Must not untwist more than 1/2 inch (13 mm) under any circumstances
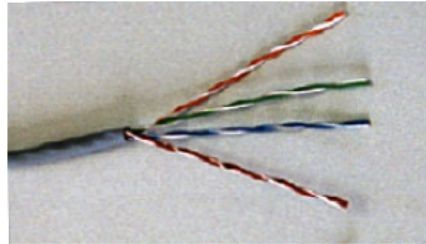
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FOA Guide For Fiber Optics
Virtual Hands-On

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See other VHOs for plugs and jacks, 66 and 110 blocks.