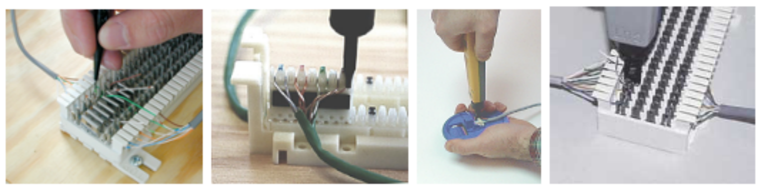
FOA Reference For Fiber Optics



Premises Cabling
UTP Cable Testing
Virtual Hands-On

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This FOA virtual hands-on tutorial on premises cabling 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 (PoE) 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.

Certifying UTP Cable Performance

- Wiremap
- Length
- Attenuation
- Crosstalk
- Propagation Delay and Delay Skew
- Return Loss
- Tracing with a toner
- Testing as network

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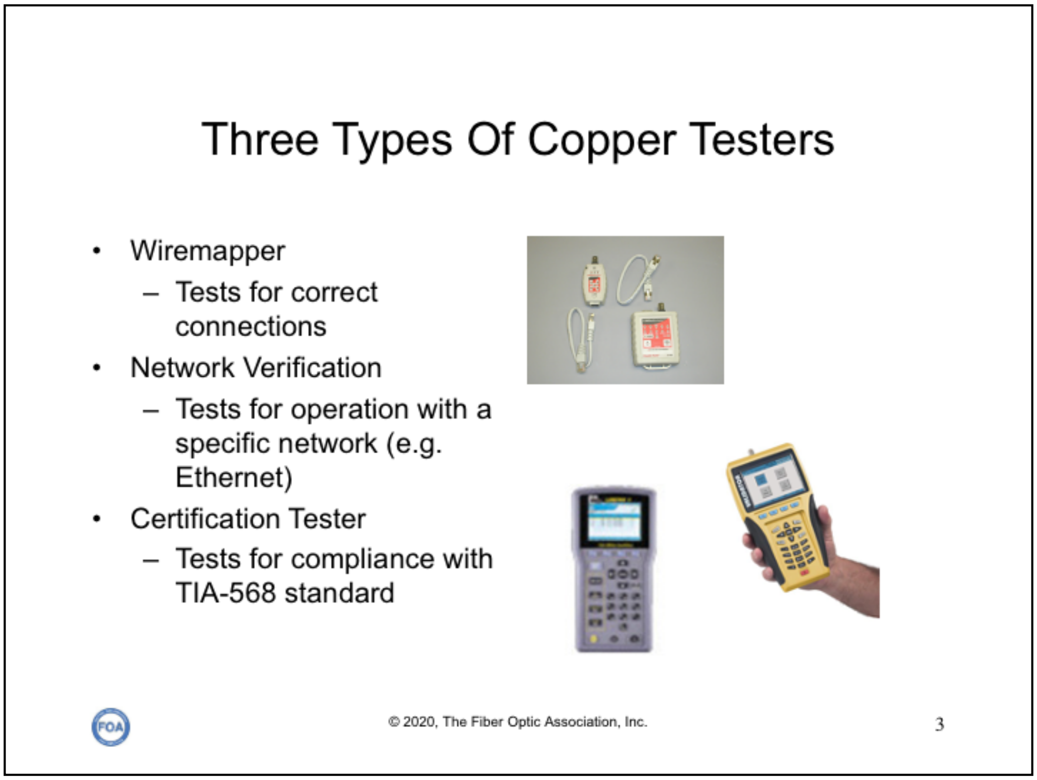
Once you have completed terminating the cables, you must test them. The first stage of testing is to use an instrument called a wiremapper to test for correct connections or the wire map. If you are testing for full Category-rated performance, you will need a “Certification Tester” also. The certification tester tests the wire map, then the length to insure it is within the limits of 568, then it will test for attenuation and, crosstalk over the full frequency range of the cable type. Finally, it will measure the time for signals to travel down the cable and calculate delay and delay skew.

Most installers use wiremappers for preliminary testing, often providing one to each installer, so wire map problems can be corrected before the expensive Certification Tester is used for performance testing. Since 3-5% of the links typically have some wire map problem, it is usually more cost effective to find wire map problems before using the Cat 5 tester.

If the documentation is not complete or you are trying to find cables from an earlier installation, a toner will allow you to trace cables anywhere in the network.



There are now three types of copper cabling testers:

Wiremapper

Tests for correct connections, that is no opens or shorts, crossed pairs, etc.

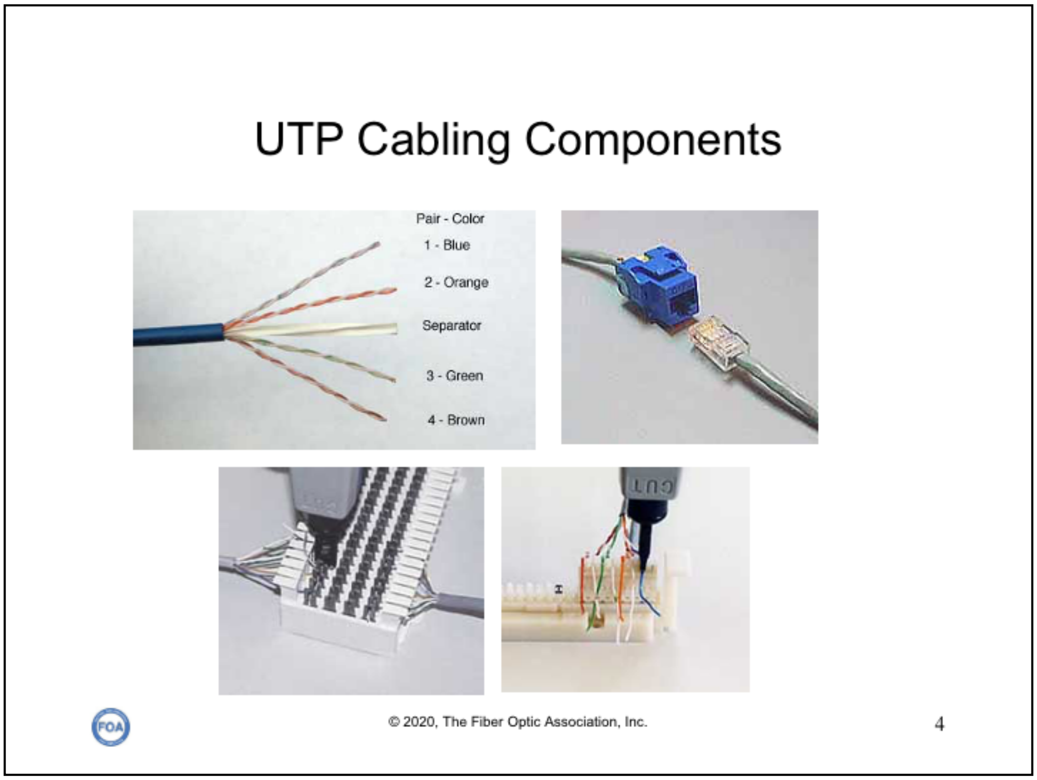
Network Verification

Tests for operation with a specific network (e.g. Gigabit Ethernet) by using a network chip with diagnostics to see if the cable plant works with that particular network.

Certification Tester

Tests for compliance with TIA-568 standard. If the cable plant is 568 compliant, it should work with any network specified to operate on that network.

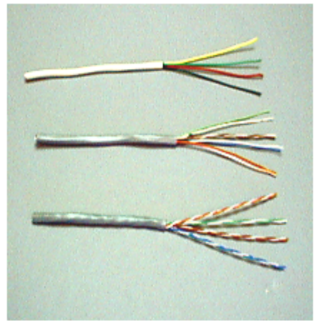
Generally, wiremappers are inexpensive, verification testers are moderately expensive and certification testers are very expensive if they are designed for the latest versions of UTP cabling.



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



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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

Cable Trivia: Tip & Ring

- The wire with the stripe is “tip” - and was connected to the tip contact of the old phone plug
- The solid wire is “ring” and was connected to the ring around the shaft of the phone plug as the other contact

Why "tip" and "ring"? It refers to the classic phone plug like this!

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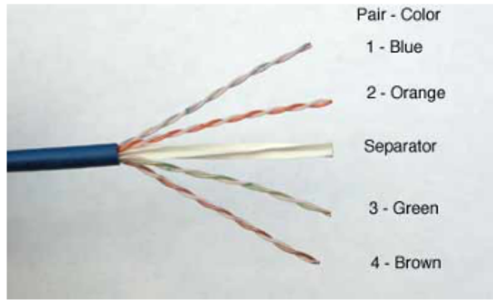
Cabling trivia: ‘Tip’ and ’Ring’ refer to the old phone plug. The white wire with the color stripe was always connected to the tip of the phone plug and the color wire was connected to the ring on the plug, creating the nomenclature that has persisted to date.

DVVC-Chapter 4

UTP Cable Design

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



Why "tip" and "ring"? It refers to the phone Plug like this!

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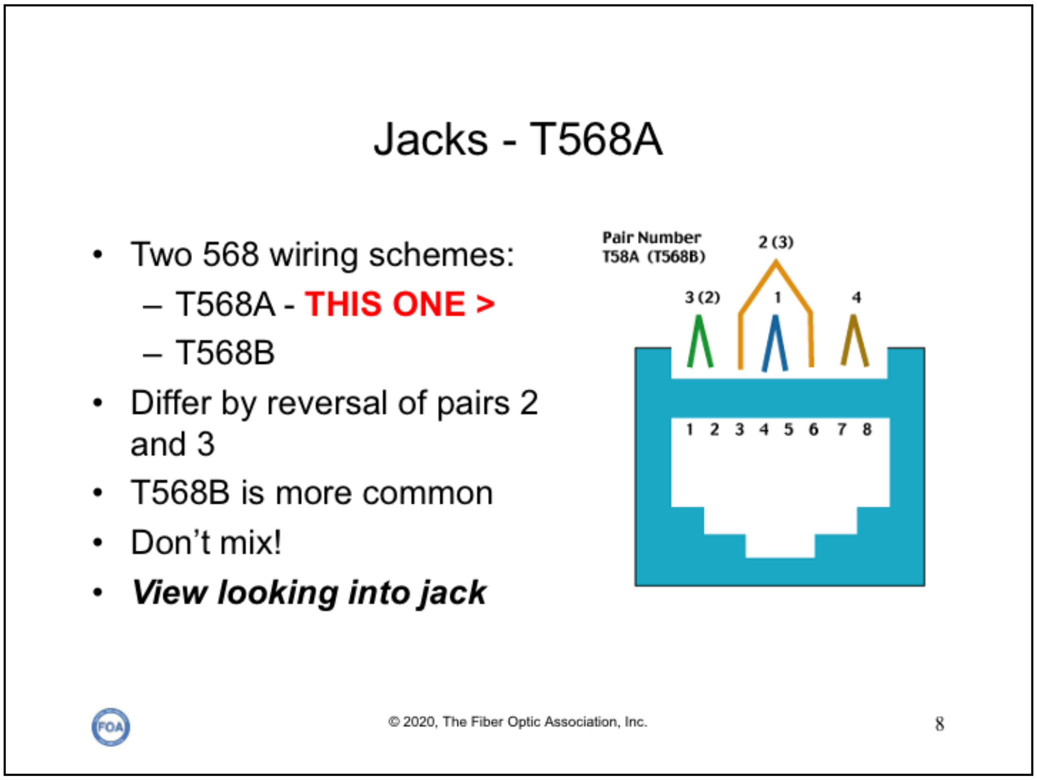
Here is a Cat 6 cable with a divider that separates the four pairs to reduce crosstalk.

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

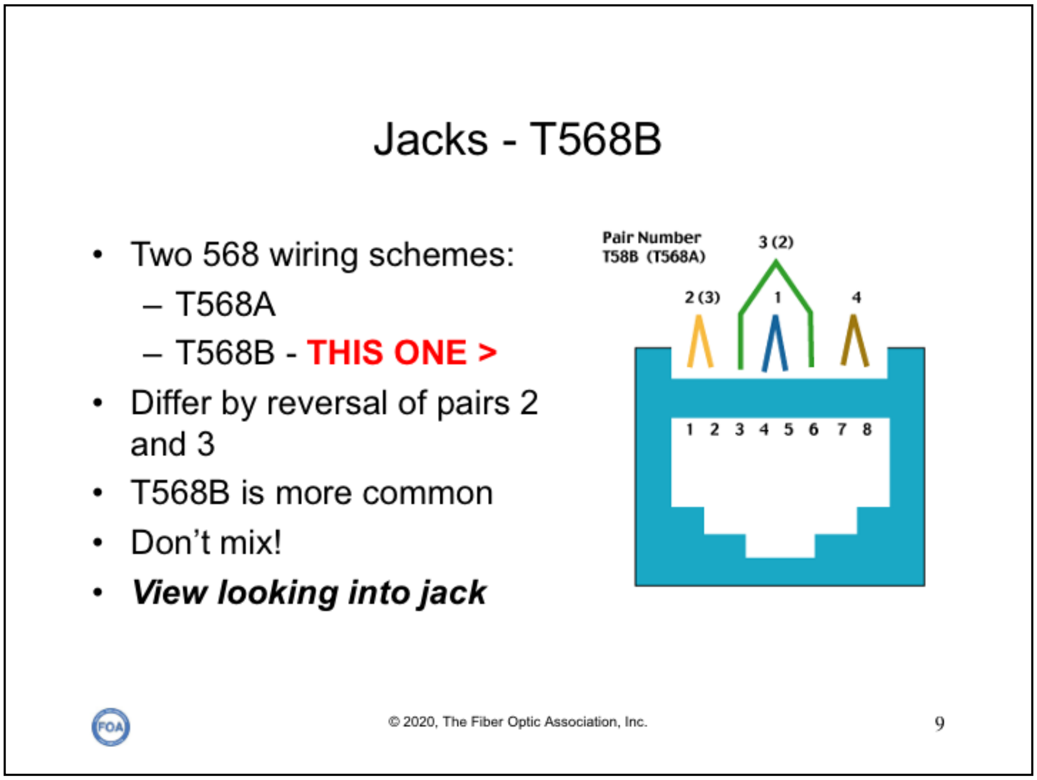


TIA/EIA 568 recognizes two pinouts for a jack or plug. They differ in the reversal of pairs 2 and 3. This scheme, called T568A, has pair 3 (green) on pins 1-2 and pair 2 (orange) on pins 3-6.

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.



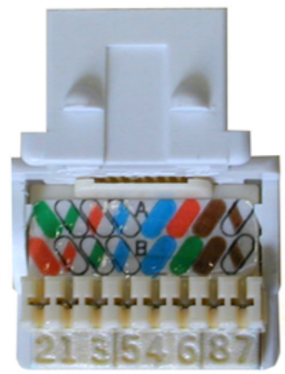
Note that the T568B termination has pair 2 (orange) on pins 1-2 and pair 3 (green) on 3-6, just the reverse of T568A. Casual surveys seem to indicate that the "B" termination is more popular.

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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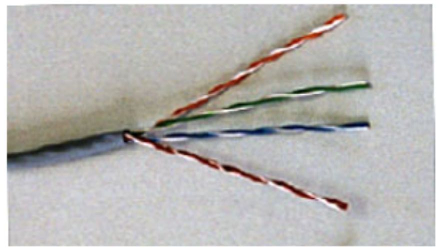
While the jacks all will terminate in either 568A or 568B terminations (and USOC for that matter), they generally have color coding on the back of the jack to show you how to order the wires for termination. BE CAREFUL! The jacks often include both 568A and 568B color coding (and it's small!),

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!

Keep The Pairs Twisted!

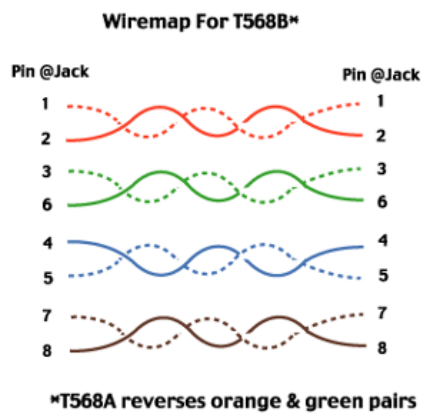
- Most performance parameters of UTP cabling depend on the twists in the pairs
- Must not untwist more than 1/2 inch (13 mm) under any circumstances



Most performance parameters of UTP cabling depend on the twists in the pairs. The installer must not untwist more than 1/2 inch (13 mm) under any circumstances

Verifying UTP Cable Connections

- Wiremap
- All wires connected to the proper pins at both ends of cable
- Use wiremapper or certification tester



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Wire mapping includes all tests for correct connections. The correct pairs of wires must be connected to the correct pins, according to the color codes defined by the standards (usually TIA 568A or 568B mapping.)

Most wiremap problems will occur at the connections. Physical examination of the connections should find the fault. Wire map errors fall into several basic categories:

A short is where two conductors are accidentally connected and an open is where one or more wires are not connected to the pins on the plug or jack. Opens can also occur due to cable damage. A time domain reflectometer (TDR) test will show the distance to the fault to assist in its location. Certification testers include a TDR for fault location.

Reversed pairs occur when the conductors (tip and ring) are reversed in the pair.

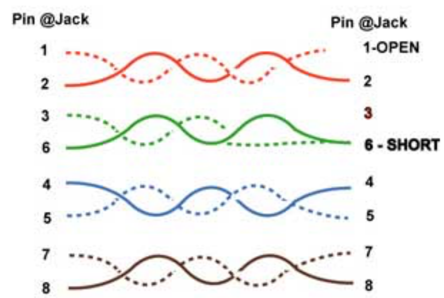
Transposed or crossed pairs occur when both conductors of one pair are reversed with both conductors of another pair at one end.

Split pairs are where one wire each of two pairs are reversed on both ends. This happens when a BLOG color code from a punchdown block is used on a jack.

Wiremap – Shorts and Opens

- Shorts – usually 2 wires punched down to the same pin
- Opens – wires not properly punched down or tool reversed and cuts wrong side of pin

Wiremap For T568B* - Short or Open



*T568A reverses orange & green pairs

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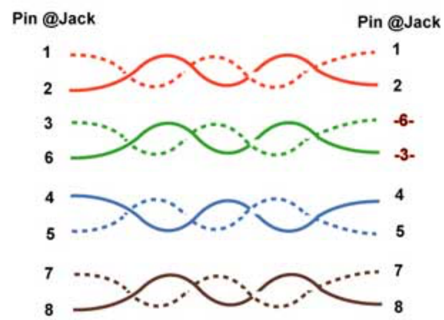
Shown here, pair 2 (orange) is open because tip is not connected.
Pair 3 (greeen) is shorted on pin 6.

A short is where two conductors are accidentally connected and an open is where one or more wires are not connected to the pins on the plug or jack. Opens can also occur due to cable damage. A time domain reflectometer (TDR) test will show the distance to the fault to assist in its location. Certification testers include a TDR for fault location.

Wiremap – Reversed Pairs

- Reverse pairs – tip (the striped wire) and ring (the solid wire) are reversed

Wiremap For T568B* - Reversed Pair



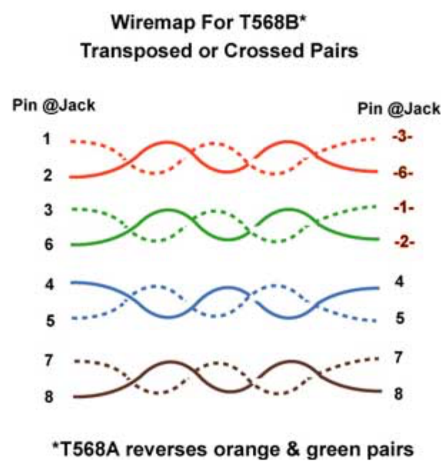
*T568A reverses orange & green pairs

Pair 3 (green) has tip and ring reversed.

Reversed pairs occur when the conductors (tip and ring) are reversed in the pair.

Wiremap – Crossed Pairs

- Transposed or crossed pairs – two pairs are transposed at the connection
- Often caused by mixing T568A and T568B color codes which reverses pairs 2 and 3



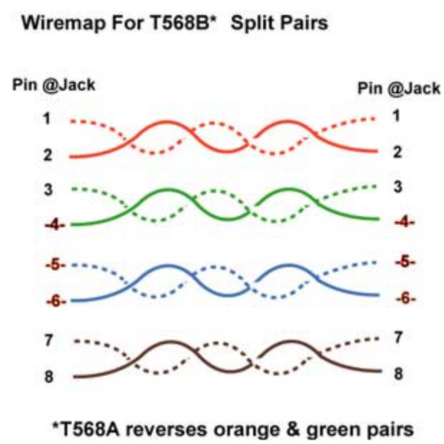
Pair 2 (orange) and pair 3 (green) are crossed, connected to each others pins.

Transposed or crossed pairs occur when both conductors of one pair are reversed with both conductors of another pair at one end.

The usual cause of crossed pairs is one end is terminated at T568B and the other end T568A, where pairs 2 and 3 are reversed.

Wiremap – Split Pairs

- Split pairs – signals are sent on one wire of 2 pairs, causing unbalance
- Usual cause is mixing plug/jack color codes with punchdown block color codes



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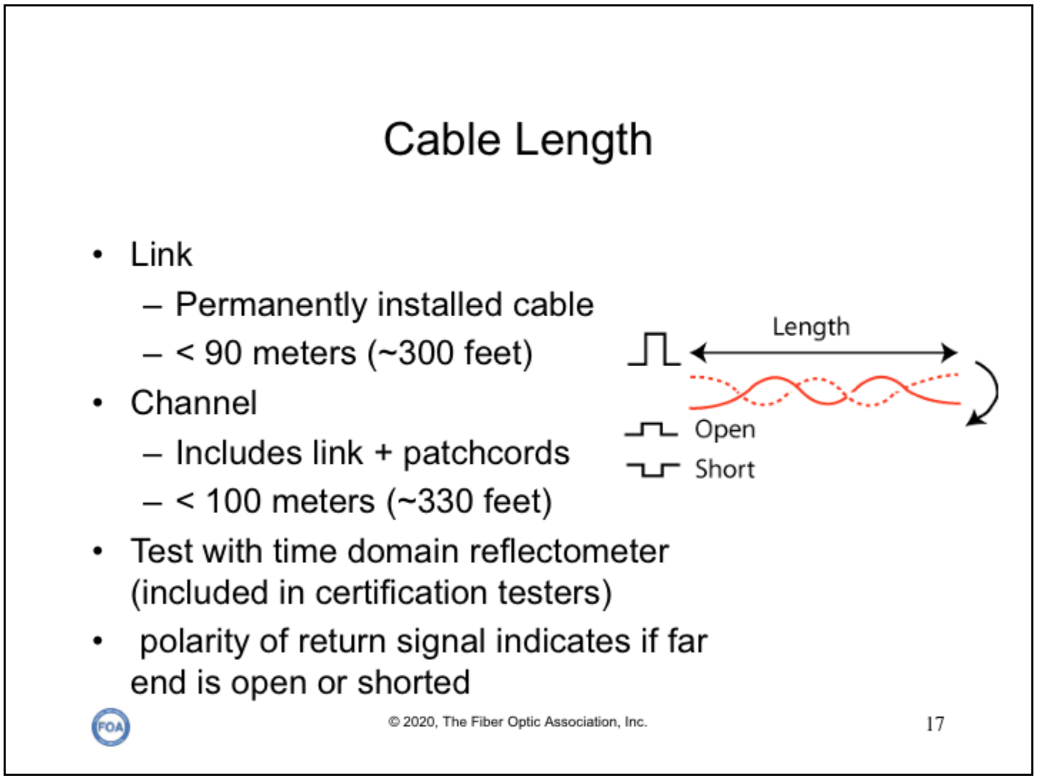
Split pairs are where one wire each of two pairs are reversed on <u>both</u> ends. This happens when a BLOG color code from a punchdown block is used on a jack.

Here pairs 1 (blue) and 3 (green) are connected such that a DC wiremap tester will test OK, but the signals are being carried on one wire of two pairs, so the cables are unbalanced.

Split pairs are often caused by the wires being punched down on a jack using the color codes for punchdown blocks.



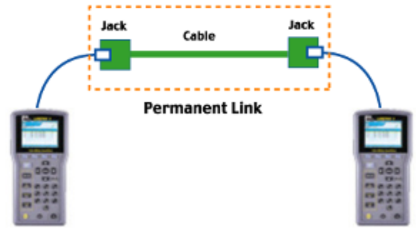
Cable length needs to be known to verify the length is within the limitations of the design standards and for future reference in moves, changes or troubleshooting. The length of the cable can be estimated by measuring resistance as noted above, or tested accurately by using a time domain reflectometer (TDR).

Time domain reflectometry works like radar, sending an electrical pulse down the cable to an open end, where the signal is reflected back to the transmitting end. By knowing the characteristic speed of the signal in the cable, called the nominal velocity of propagation (NVP) and the round trip transit time, you can calculate the length of the cable.

The NVP is an average value; actual cable samples may vary as much as 10% among production lots. Even each pair, which has different twist rates to reduce crosstalk, will have a different velocity of propagation, varying as much as 3-4% and a different physical length. Add to this the inherent inaccuracy of the instrument, another 2-3%, and you see the measurement is a good approximation of the length, but not an exact measurement. All testers will measure and report the length of each pair.

UTP Cable Certification

- Certification Testing
  - Performance tested to TIA 568 standards for Category
- Permanent Link
  - Tester includes special patchcords calibrated with reference plug
  - Test at all frequencies for each category



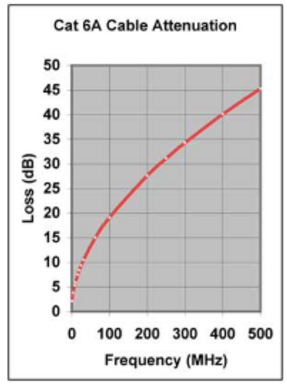
Certification testing is testing the cabling to the performance specifications of the relevant cable standards like TIA 568 or ISO 11801. Certification testing means testing wiremap plus all the dynamic characteristics of the cable, including all the cable and terminations, over the full specified frequency range for the category rating of the cabling.

To reduce instrument error, the standards committees have specified a test (the permanent link test) that calls for calibrated test connectors (plugs) in the measurement.

These testers will automatically test all the parameters set by the standards and record data for troubleshooting or printing reports for the user.

UTP Cable Certification

- Attenuation
  - Higher at higher frequencies
  - Testers scan frequencies



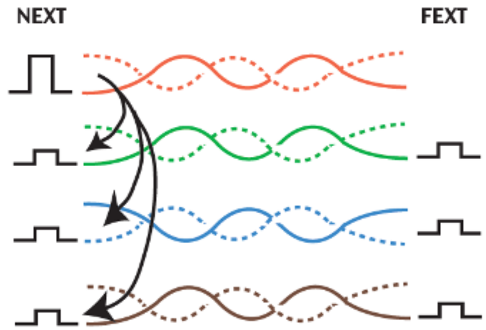
As an electrical signal travels down the cable the impedance causes attenuation. At the far end the signal will be smaller than at the transmitter. It is important that the attenuation be less than a specified value so the received signal is of adequate strength for proper data transmission.

Attenuation is expressed in dB (decibels) where 20 dB is an attenuation factor of 10. Like everything else we have discussed, attenuation is a function of frequency, increasing at higher frequencies, and must be tested a operating frequencies. Testers will test at the frequencies specified in the category of cable being tested, up to 16 MHz for Cat 3, 100 MHz for Cat 5 and Cat 5e, 200-250 MHz for Cat 6.

Measuring attenuation requires an instrument at each end of the cable, one to transmit a known value signal and one at the far end to measure the signal level and calculate the attenuation. Pass/fail criteria are set by 568.

UTP Cable Certification

- Crosstalk
  - NEXT - near end
  - FEXT - far end (ELFEXT)
  - Powersum - 3 pairs to other pair
  - Maintain twists!
  - Alien: adjacent cables

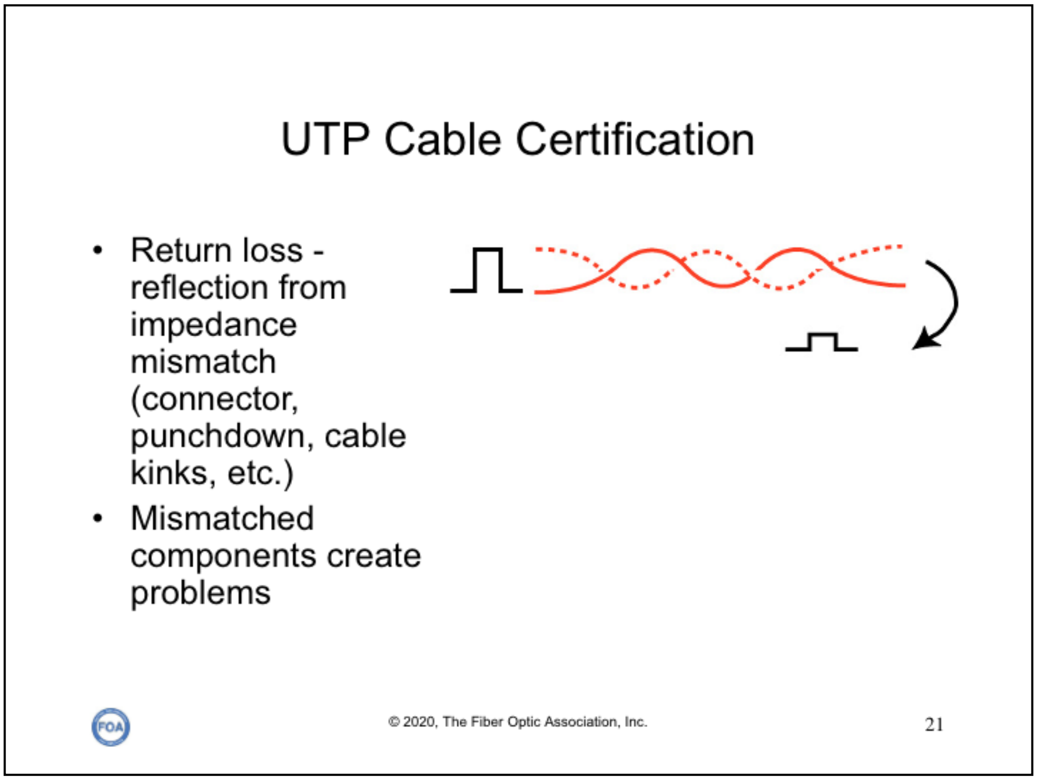


In a cable that has four pairs of electrical conductors, whenever one pair is carrying signals, it may couple some of its energy into an adjacent pair. If a signal is being transmitted from the other end, that signal may be compromised by interference from the crosstalk. Each pair works like an antenna; the pair carrying a signal is the transmitter and every other pair is a receiver. Like everything else, crosstalk is frequency dependent, so must be tested over the full frequency range specified for the category of cable being installed. It is at the connectors where crosstalk is most critical. The twist of each pair must be maintained to within 1/2 inch or 13 mm of the connection points to prevent crosstalk.

Testing crosstalk is quite simple. Transmit a signal on one pair, measure the coupled signal on another pair, calculate the crosstalk in dB, just like attenuation. As with attenuation, pass/fail criteria are set by 568.

Each pair must be tested against all the other pairs for six tests total, and the test must be repeated at both ends of the cables for a valid test. Power Sum NEXT is also calculated, including the coupling from the other three pairs to the fourth.

With the advent of Cat 6A for 10G Ethernet, the cables are used up to 500 MHz. This is causing crosstalk to adjacent cables in bundles or cable trays (alien crosstalk), creating a very difficult and time-consuming test.



Impedance is the "resistance" of the cable at the frequency of signals transmitted. Return loss refers to reflections that occur at changes in impedance, which occurs primarily at terminations. These reflections can cause errors in signal transmission if they are too large. UTP cable is specified to have a nominal impedance of 100 +/-15 ohms. For high speed data, both impedance and return loss are functions of the signal frequency, and impedance tends to decrease with frequency.

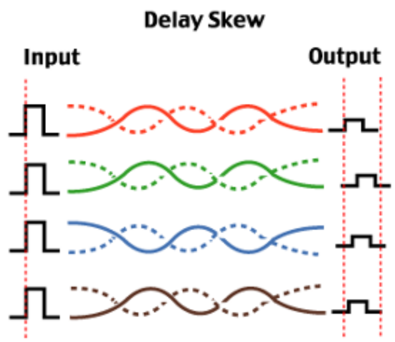
Cables, connectors and other hardware for high speed networks are designed to have very consistent impedance to prevent reflections. For cable, that means having the size of the conductors, twist of the pairs and insulation materials carefully controlled.

You may hear the term "structural return loss" referring to the reflections caused by variations of the impedance of the cable itself along its length. Even variations in production of cable can result in varying impedance causing reflections.

At connectors, the twist of each pair must be maintained to within 1/2 inch (13 mm) of the connection points or less to prevent undesirable reflections.

UTP Cable Certification

- Delay Skew - difference in time signals take to travel down pairs
- Important for networks like 1000Base-T or 10Gbase-T that use all 4 pairs



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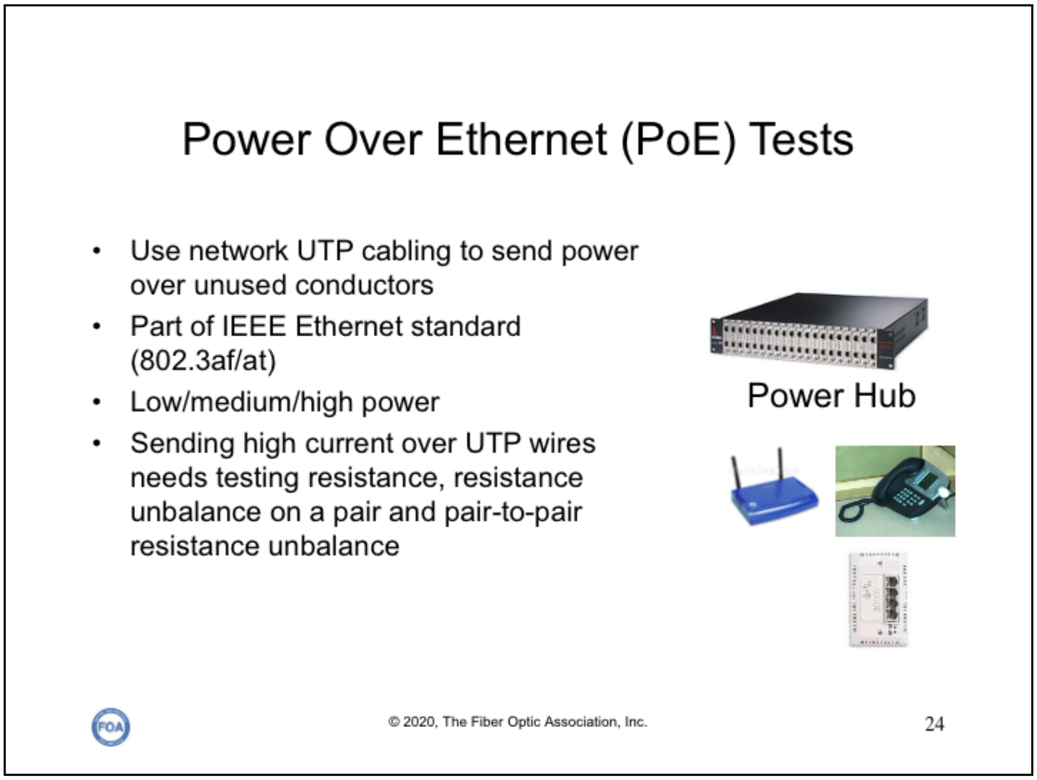
Propagation delay (or simply delay) is a measure of the time it takes for an electrical signal (traveling at about 2/3 the speed of light) to reach the far end of the cable. Testers measure delay as part of the process of measuring length.

Since each pair has a different length due to the twist rate and different NVP, there will be variations among the four pairs. This is not a problem with most networks, as the signals are carried on only one pair in each direction. However, high speed networks (1000 MB/s and higher) are using four pairs in each direction, so if the parallel signals arrive too far apart, data errors will occur.

UTP Cable Certification

- Alien Crosstalk
- Crosstalk from one cable to another in bundled cables
- Affects Cat 6/6A used for 10 Gigabit Ethernet
- Dependent on cable design

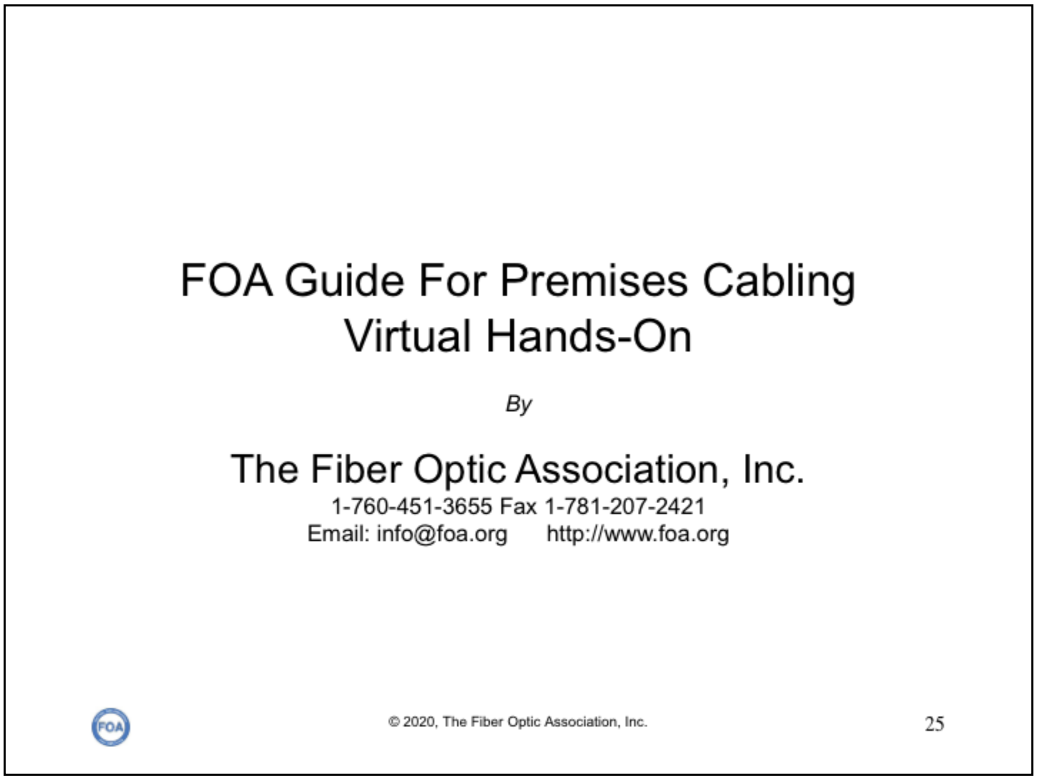
The development of augmented Cat 6 (Cat 6a) cable for use on 10 Gigabit Ethernet links added a new test. The cable is so precisely made, especially the rate of twist in the pairs, that cable pairs can interfere with the same pair in other cables nearby. This added a new test for Cat 6A which is called "Alien Crosstalk."
Performing this test is time consuming and is highly dependent on the physical location of cables. Some controversy regarding the relevance of this test exists in the industry, with some cabling vendors not requiring it.



The Power over Ethernet standard allows using network UTP cabling to send power over unused conductors to power remote devices that need power to operate.

It is part of the IEEE Ethernet standard (802.3af), not a cabling standard, but was developed with the cabling system manufacturers and is considered in cabling standards. It is relatively low power compared to electrical wiring, but three power levels make it adequate for the classes of devices considered. Useful for powering remote Wireless access points, VoIP phones, hubs or switches without local power access.

PoE uses a 48 volt power supply and requires cable of Cat 5 rating or higher. Power may be delivered using what are called midspan devices, dedicated PoE power supplies that can be plugged into links or even patch panels, as well or endspan devices, typically switches designed to provide power as well as function as an Ethernet switch.



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