Wheatstone Corporation
Technical Documentation

The Role of Wiring Integrity on WheatNet-IP Network Reliability

A Review of Gigabit Ethernet Network Cabling Requirements and Common Installation Practices

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Introduction

Whether you are building a brand new gigabit network for audio transport, expanding a simple fast Ethernet network, or just making some patch cables for your current network the same general rules apply. By building and maintaining your network the "right way" you ensure the long term reliability of this fundamental but critical part of your IP based audio distribution system. This document will explain the process of selecting the components and building the cabling infrastructure that will be the backbone of your high speed audio data network.

Network Speed

Any discussion of building a wiring plant for an audio over IP system should start with a clear understanding of what will be connected to the system now and in the foreseeable future. The WheatNet IP Blade hardware was designed to utilize the 1000 Base T Gigabit Ethernet standard exclusively as the transport mechanism for all audio i/o and mix engine traffic. Certain mixing and routing control devices as well as general purpose PC's on the network continue to use Fast Ethernet 100BASE–TX connectivity. With this in mind, the wiring plant we will discuss must support gigabit connectivity from end to end.

Ethernet Wiring Standards

While it is true that you could install a basic Ethernet network without knowing anything about standards – short of the RJ45 wiring scheme – installers of Ethernet networks for professional use in commercial spaces which are subject to official inspector review will find the standards information invaluable. Interested parties may wish to obtain a copy of the current (as of 2009) TIA/EIA 568-C standard which supercedes the widely used 568-B standard. Note that the standard is updated periodically to reflect improvements and changes in materials and technologies, and to include feedback from various installers and equipment manufacturers.

The following is a brief description of the C revision standard published in 2009.

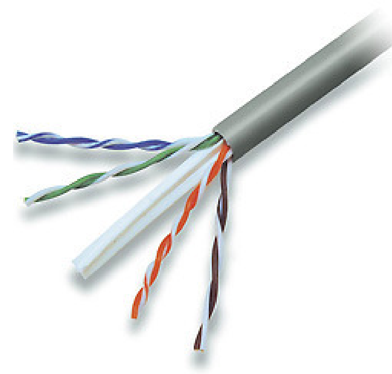
The TIA-568-C.0 standards document will cover cabling requirements, structure, topologies, distances, installation, performance and testing.

TIA-568-C suite of standards breakdown:

TIA-568-C.0 Generic Telecommunications Cabling for Customer Premises
TIA-568-C.1 Commercial Building Telecommunication Cabling Standards – Part 1 General Requirements
TIA-568-C.2 Balanced Twisted-Pair Telecommunications Cabling and Components Standard (release date: TBA)
TIA-568-C.3 Optical Fiber Cabling Components Standard

TIA/EIA stands for a joint alliance between the Telecommunications Industry Association and the Electronics Industry Alliance.

Category Cable Selection



Gigabit Ethernet requires the use of CAT5e or CAT6 (Class E) cabling and supporting infrastructure to help guarantee the performance of your WheatNet-IP system. If you are building a new audio network it makes technical sense to install a CAT6 based system that leaves you bandwidth headroom for future growth. As of this writing in early 2010 Gigabit networks are already replacing Fast Ethernet networks, a 10 GbE standard using CAT6A wiring is already in place, and a 100 GbE standard using emerging CAT7 (Class F) wiring is on the horizon.

The sheer number of vendors and options for category cable is staggering. A recent internet search for "CAT 6 cable" yielded nearly 11 million results!
Before looking for a vendor let's review some of the key factors involved in choosing the right UTP cable for Gigabit Ethernet applications:

- Price
- Application
- Performance
- Quality
- Availability
- Price ☺

Seriously, the network cabling you choose will determine the overall performance of the audio network – choosing a cable based solely on price is probably not the best choice. Purchasing a quality category cable from a well known and trusted cable manufacturer provides the performance foundation your audio network needs and gives you peace of mind.

Cable Selection Parameters
This is a summary of the most important parameters you will have to specify or review when selecting category cable:

- Category- CAT5e, CAT6, or CAT6A
- Conductor Type – solid or stranded
- UL® Fire Rating – General purpose, Riser, or Plenum
- Number of pairs – single 4 pair, multi 4 pair bunches, etc.
- Technical Specifications
- Color

Let's look at each of the cable selection parameters.

Category Rating - CAT5e or CAT6?
Since you are building a 1000MbE (Gigabit Ethernet) network you need to use CAT5e, CAT6, or higher. Note that CAT5e, while able to support Gigabit Ethernet does so with little room for error. Superior high speed crosstalk performance of CAT6 means that it will easily handle Gigabit and will also support the emerging 10GbE standard with some distance limitations.
The CAT6A (augmented) cable system is designed for 10GbE networks and is not the same as CAT6. CAT6 and CAT6A also use different connectors.

Wire Conductor Type

Solid conductor wire is designed for Permanent Links – the "horizontal" runs between wiring closets, rack rooms to studios, wall plates to patch panels, etc. Solid core wire has lower attenuation which means the signal will be stronger and the cable runs can be cut at or near the maximum allowed distance of 100 meters. Care must be taken while installing solid core wire to avoid bends and kinks that cause signal degradation and loss of performance due to cracking or fracturing of the wire.

Stranded conductor wire is more flexible and is well suited for patch cords and connecting devices to wall plates. Stranded core wire has higher attenuation than solid core and should not be used for long runs. In general keep the use of stranded conductor wire to a minimum.

Wire Gauge

All CAT5e and CAT6 cable will fall in the 24-22 AWG range. Typical spec sheets for commercially available bulk CAT6 UTP cable calls out a nominal AWG of 23.

UL® Fire / Flame Test Ratings

The National Electrical Code (NEC) requires the use of UL® listed products to meet the requirements of various articles within the code. Be sure the cable you install has a UL rating printed on the jacket to avoid inspection problems.

Fire ratings are there for a very good reason – the safety of building occupants and the firefighters. Specifically, plenum rated cables (CMP) are designed with fire retardant jacket materials that emit less smoke and no toxic fumes when burned. In a commercial building, fumes created by burning cables in the plenum area of an HVAC system can be inadvertently distributed throughout the building through the air handling system. Toxic fumes released in plenum areas can be extremely dangerous to both occupants and firefighters in other areas of the building.

It is the responsibility of the network cabling installer to check with all concerned parties and local authorities about materials compliance.

Communications Cable Ratings

Category cables for commercial spaces come in three major UL® ratings - general purpose (CMG), riser rating (CMR), and plenum rating (CMP). It may appear easier to just buy plenum cable to be on the safe side but at last check plenum cable is two to three times as expensive as riser rated cable. When purchasing cable stick with UL® riser or plenum rated cable.

- Plenum Rating UL® (CMP) – use anywhere; plenum spaces, drop ceilings; highest rating; highest cost.
- Riser Rating UL® (CMR) - for use in sealed vertical risers between floors, use in walls, horizontal runs.
- General Rating UL® (CMG) – ok for stranded patch cable use; not recommended for commercial installs.

When is Plenum - UL® (CMP) - Cable Required?
A commercial building space is considered a plenum when that space is designed to be part of an HVAC system and facilitates the flow of heated/conditioned air, whether as a source or return. A typical case is the space above a drop ceiling that is used as a return. Even if the space is not designed or designated as a plenum it can still become part of an active plenum by accident, neglect, or environmental conditions. Should ductwork above a drop ceiling become damaged, disturbed or otherwise un-sealed, the dead space above a drop ceiling is now a plenum. For maximum fire safety, it is best to assume that all drop ceiling spaces are plenums even if they are not officially designated as such. Cables run in plenum spaces must meet UL® (CMP) rating.

Physical Application
When considering the physical application, you are looking at where and how the category cabling will be installed- in cable trays, below raised floors, in drop ceilings, in conduit or vertical risers, etc. The type of wire you need to purchase will depend on your physical plant layout and where the cables will be located. In some cases you may wish to purchase bulk cable with different fire ratings in order to satisfy building codes and to save money.

Number of Pairs
Depending on your application you may opt to run multi-pair cable to various drop points like studios or control rooms. CAT5e/6 cable may be purchased in bundles of multiple pair cables. For example a multi pair bundle dropped from the rack room to each control room may be able to service the audio network, office LAN, and the phone system.

Color Coding
It makes a lot of sense to install a unique color of category cable for the audio network's LAN wiring and patch cables. Color coding network cabling by type of service makes it easier to find and trace elements of the network in the future. Look for jacket color options when deciding on a cable. Another use of color coding is to order plenum and riser cable in two different colors to make it easier to identify each type onsite.

Cost
By all means shop around but the old adage "you get what you pay for" certainly applies to the cutthroat bulk category cable market. CAT5e cable and components are cheaper but lack the performance benefits of CAT6, especially in noisy environments.

Technical Specifications
All cables will claim to meet the required Category specs. Look for third party testing seals from labs like UL, ETL, and 3P, and request detailed datasheets if the specs on a vendor's website are thin. Testing results for frequencies above 250MHz are sometimes included to show the cable's "headroom" with certain parameters. Look for cables that exceed the Category's electrical specs and also offer something extra like superior bend radius and pull strength limits.

CAT6 Cable Specification Sheet Example

ABA Elite Cable

Product Specifications

Elite 1000X™ CAT6E 600 MHz LAN 4 *UTP Cable

Construction: *Unshielded Twisted Pair

Item #	Flame Rating	Jacket	Color	Wt. Lb. /	Wt.Kg	O.D.	Packaging Put-Up
TUR2404N70xx-S	CMR	PVC Riser	xx	32	14.51	6.00 ± .2mm	1000' Reelex
TUP2404N70xx-S	CMP	Plenum	xx	36	16.33	6.00 ± .2mm	1000' Reelex

xx= (BU) Blue, (BK) Black, (GY) Grey, (WH) White, (YE) Yellow, (RE) Red, (GR) Green

Industry Standard

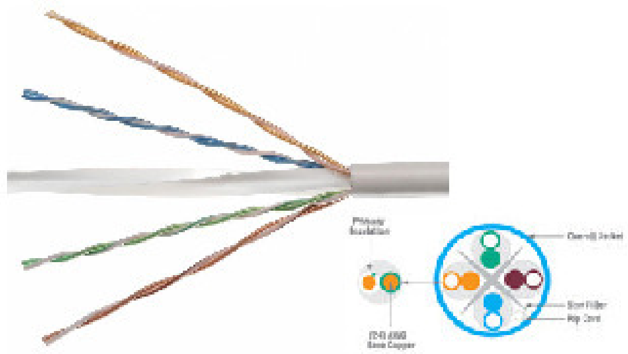
UL/cUL Listed CMR, CMP
UL, ETL and 3P Verified to Standards
ISO/IEC-11801
NEMA WC 63.1

Material Descriptions:

Conductor: 23AWG bare solid copper(Plenum) / 24AWG bare solid copper(PVC Riser)
Insulation: FRPE (CMR), FEP (CMP)
Ripcord: Under jacket
Jacket: FRPVC

Applications:

Gigabit Ethernet
ATM 622 or higher
Broadband video
(77 channels, 600MHz)



Product Electrical Characteristics:

Impedance:	100±15ohms
Mutual Capacitance (max. nf/1000ft):	56
DC Resistance (max. Ohms/1000ft):	28.6
DC Resistance Unbalance of a pair:	5% max
Propagation Delay Skew:	25 nS/100M
Capacitance Unbalance (Pair to Ground):	330pf/Km max
Normal Velocity of Propagation:	66%-70%
Attenuation-to-Crosstalk Ratio: At 100MHz:	26.5dB/min. At 155MHz: 18.4dB/min. At 250MHz: 7.5dB/min.

Frequency MHz	ATT Max	NEXT Min	ACR Min	PS.NEXT Min	PS.ACR Min	ELFEXT Min	PS.ELFEXT Min	R.L. Min
1	2	76.3	74.3	74.3	72.3	67.8	64.8	20
4	3.8	67.3	63.5	65.3	61.5	55.7	52.7	23
8	5.3	62.8	57.5	60.8	55.5	49.7	46.7	24.5
10	6	61.3	55.3	59.3	53.3	47.8	44.8	25
16	7.6	58.3	50.7	56.3	48.7	43.7	40.7	25
20	8.5	56.8	48.3	54.8	46.3	41.7	38.7	25
25	9.5	55.3	45.8	53.3	43.8	39.8	36.8	24.3
31.25	10.7	53.9	43.2	51.9	41.2	37.9	34.9	23.6
62.5	15.4	49.4	34	47.4	32	31.8	28.8	21.5
100	19.8	46.3	26.5	44.3	24.5	27.8	24.8	20.1
155	25.1	43.5	18.4	41.5	16.4	23.9	20.9	18.8
200	29	41.8	12.8	39.8	10.8	21.7	18.7	18
250	32.8	40.3	7.5	38.3	5.5	19.8	16.8	17.3
300	36.4	39.2	2.8	37.2	0.8	18.2	15.2	16.8
400	43	37.3	-	35.3	-	15.7	12.7	15.9
550	51.8	35.2	-	33.2	-	12.9	9.9	14.9
600	54.5	34.6	-	32.6	-	12.2	9.2	14.7

RoHS

Termination

The Truth about “RJ-45” Connectors

It is that small plastic plug that connects your computer to the world through your ISP that you never think twice about – the RJ45 connector, right? Not quite.

Strictly speaking, the term “registered jack” (RJ) is an interface standard created by the FCC in the early 1970’s whose purpose was to establish standard methods for separating premise wiring from the Bell system’s wiring. Registered jacks were deployed by the Bell Telephone System as Universal Service Order Codes (USOC - pronounced u-sock). Each RJ-xx code describes the jack, plug, and wiring method.

The actual RJ-45 USOC has only a passing similarity to modern Ethernet cabling (i.e. TIA/EIA Category cables terminated with eight pin-eight conductor -8P8C- connectors according to the TIA/EIA 568A or B wiring pattern) in that they both use a similar looking 8P8C modular jack and plug. The RJ-45S standard calls for a special 8P8C modular “notched” jack, a “keyed” female plug, and uses a single wire pair for signal and a second pair for a programming resistor. While “true” RJ45 connections are extremely rare, the name is entrenched forever, much like the term “RCA” refers to the “phono jack” standard introduced by Radio Corporation of America in the early 1940’s to allow the connection of monaural phonographs to a receiver and is still in use today. So much for history.

Choosing Termination Products

Choose a single component manufacturer for patch panels, wall plate inserts, etc. and stick with them exclusively for all parts of the system. This is especially true with CAT6 products. Professional installers have learned the hard way that mixing and matching parts can lead to problems at certification time. Impedance differences between different makes of termination hardware can lead to CAT6 certification test failures.

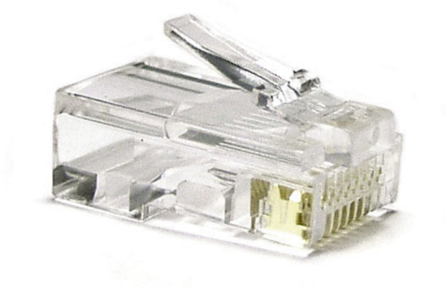
Choosing RJ-45 Connectors

Choosing the correct RJ-45 connectors for your installation is a relatively simple task. The first rule applies to choosing a connector for the category rating of the wire you are installing. CAT6 cable requires CAT 6 connectors because of the differences in each conductor’s insulation thickness and to meet certain crosstalk specifications. CAT 6 insulation is thicker than CAT 5 so CAT 5 connectors may not bite into the conductor very well when crimped, causing open or intermittent mating. Make sure you follow these simple rules to avoid headaches later.

- Buy RJ-45s compatible with the Category type of the cable – CAT5e, CAT6, etc.
- Buy patch panels, wall outlet inserts, etc from the same manufacturer.
- Solid conductor cable uses connectors designed for solid cable.
- Stranded conductor cable uses connectors designed for stranded cable.
- Avoid connectors that claim to do both.
- Buy connectors with load bars. Load bars are small plastic separators that you slide wires through first. They space wires evenly in a pattern that helps lower crosstalk.

Solid vs. Stranded Connectors

CAT6 RJ-45 Connector for solid wire



CAT6 RJ-45 Connector for stranded wire

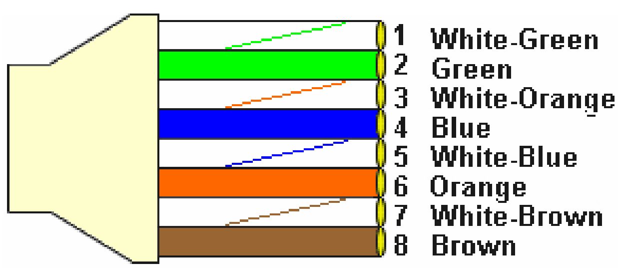
You have to look closely to see the difference between these two connector type examples. Terminating a category cable with the wrong modular connector can lead to intermittent problems with the cable channel. Keep connector stock well labeled and separated.

RJ-45 Wiring Schemes

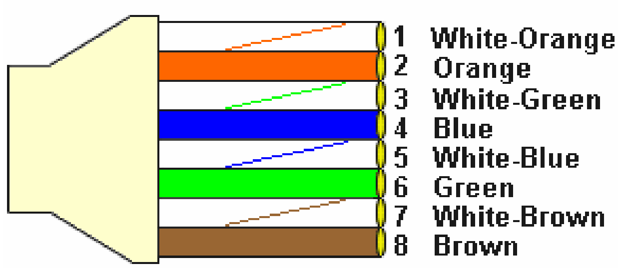
All of your CAT6 cabling will be terminated to RJ-45 connectors or patch panels. The entire system should be wired “straight” through with one of the TIA/EIA 568 wiring schemes. Pick one scheme and stick to it throughout the installation. Which one makes no difference since they will work the same as long as each end is wired the same way.

TIA/EIA-568A and TIA/EIA-568B Wiring Patterns – What’s the difference?

Having two wiring scheme standards has been the source of much confusion among UTP installers. Here is the difference



568A CABLE END



568B CABLE END

The only difference between the T568A and T568B wiring patterns is that the GREEN and ORANGE pairs are flipped.

As long as you wire each cable the same way on each end - T568A **or** T568B - they will work in any system.

The reason there are two versions is to provide a standard way of wiring CAT5 crossover cables. A CAT5 crossover cable has T568A on one end and T568B on the other end.

CAT 6 Crossover cables require all 4 pairs to be crossed. See next section.

Ethernet Cable Signals and Pin Outs

As described above there are two Ethernet cable wiring schemes – T568A and the T568B. A straight through cable connects devices like PC's, printers, WheatNet IP Blades, etc., to wall outlets and on to an Ethernet switch. A cross over cable is used to connect two devices back to back (peer-to-peer) without an Ethernet switch. All fixed, permanent link Ethernet wiring in your network should be terminated straight through.

The following tables illustrate which signals appear on each wire:

Standard, Straight-Through Wiring (both ends are the same):

RJ45 Pin #	Wire Color (T568A)	Wire Diagram (T568A)	10Base-T Signal 100Base-TX Signal	1000Base-T Signal Gigabit
1	White/Green		Transmit+	BI_DA+
2	Green		Transmit-	BI_DA-
3	White/Orange		Receive+	BI_DB+
4	Blue		Unused	BI_DC+
5	White/Blue		Unused	BI_DC-
6	Orange		Receive-	BI_DB-
7	White/Brown		Unused	BI_DD+
8	Brown		Unused	BI_DD-

Straight-Through Cable Pin Out for T568A — Bi-directional Pairs

OR

RJ45 Pin #	Wire Color (T568B)	Wire Diagram (T568B)	10Base-T Signal 100Base-TX Signal	1000Base-T Signal Gigabit
1	White/Orange		Transmit+	BI_DA+
2	Orange		Transmit-	BI_DA-
3	White/Green		Receive+	BI_DB+
4	Blue		Unused	BI_DC+
5	White/Blue		Unused	BI_DC-
6	Green		Receive-	BI_DB-
7	White/Brown		Unused	BI_DD+
8	Brown		Unused	BI_DD-

Straight-Through Cable Pin Out for T568B — Bi-directional Pairs

The AUTO MDIX feature of Ethernet ports on switches and NIC's automatically switches the balanced transmit and receive signals on the RJ-45 connector to the correct pins of the Ethernet transceiver IC.

Notice that for a CAT5 wired crossover cable wired with the A pattern on one end and B on the other, the transmit and receive signals are flipped.

Crossover Cables

Crossover cables are rare in gigabit applications because virtually all 1000 BASE T Ethernet interfaces and switches support the automatic crossover feature AUTO-MDIX.

In a CAT 6 crossover cable, the green and orange pairs are crossed and then the blue and brown pairs are crossed. An off the shelf CAT5 or CAT 5e crossover cable will not work with 1000BASE T gigabit devices because they only swap the green and orange pairs.

Crossover Cable (T568B):

RJ45 Pin # (END 1)	Wire Color	Diagram End #1	RJ45 Pin # (END 2)	Wire Color	Diagram End #2
1	White/Orange		1	White/Green	
2	Orange		2	Green	
3	White/Green		3	White/Orange	
4	Blue		4	White/Brown	
5	White/Blue		5	Brown	
6	Green		6	Orange	
7	White/Brown		7	Blue	
8	Brown		8	White/Blue	

Crossover Cable Pin Outs

Note: This crossover cable layout is suitable for 1000Base-T operation, all 4 pairs are crossed. It will also work in 10/100Base TX applications.

How to tell the difference between a CAT6 and CAT 5 Patch Cable

CAT-6 End

CAT-5/5e End

Avoid Installation Problems

Problems resulting from poorly installed Ethernet wiring may not be obvious and can prove hard to pinpoint. This is especially true when the problems are intermittent or happen while no one is watching. It is easier to blame a piece of hardware than the wiring of it.

In a typical office network, suspect wiring can cause a variety of problems - files may take a long time to print, internet connections can be slow or drop out completely due to timeouts, computers may intermittently disappear from workgroups, etc. Workloads for some of these non- real time applications may be recoverable whereas, in a real time audio over IP system, this loss of connectivity can render the affected part of the system unusable. Further, the data rates on a given link may be relatively slow with just a few channels playing but later on, higher data capacities initiated by higher audio channel distribution can hit a breakpoint and cause intermittent loss of audio due to the cable channel's inability to handle increased bandwidth.

The good news is that all these problems are avoidable by employing correct installation techniques.

Problems Reports from the Field

Here is a short list of problems encountered in the field at various installations. All of these problems could have been found and corrected by the end user or cable installer if testing and certification was done. In a case where the wrong category cable was installed the entire network had to be re-wired correctly.

Typical Symptoms

- Intermittent connectivity or link lights.
- Random yellow question marks appear on Blade icons in the Navigator GUI.
- Surfaces temporarily lose control of audio from the engine.
- In Navigator yellow indicators appear instead of green at some cross points.
- Meters freezing.
- Intermittent audio drop outs in certain Blades.
- PC driver's time of day clock freezes.
- PC driver signals would sometimes not appear in the GUI.
- Random CRC errors for suspect links reported on the Ethernet switch.

Typical Problem Sources

- Cheap CAT5 patch cables purchased from the bargain bin at a local computer store.
- CAT 5 cabling was installed because it was purchased at "close out" sale.
- Maximum run lengths were exceeded and cable was not CAT5e or 6.
- Improper or poor termination of cabling on patch panels.
- Use of stranded connectors on solid cables and vice versa.
- RJ-45 wiring pattern is wrong.
- Cables wired with only 2 pairs (4 conductors) - would work for 10/100 connections.

UTP Installation Do's and Don'ts.

The following is a list of guidelines that can help you successfully complete any UTP installation. This list summarizes installation tips, advice, and standards information that apply to the installation of all UTP cabling.

	Planning the Installation
Do	Before starting an installation determine the fire code and building code laws and rules that apply to *your* installation of UTP cable and follow them completely.
Do	Survey your site to determine cable routing pathways, get “ballpark” cable run measurements, identify potential wall plate and wire closet locations, and identify firewalls and plenum spaces.
Do	Design your UTP cable runs in a Star Configuration. For example, all network links are homeruns to one central patch panel or Ethernet switch. In large Core/Edge networks, all “local” devices connect to a local Edge switch. Each Edge switch then connects back to the Core patch panel and Ethernet switch via one or more “trunks”.
Do	Prepare a spreadsheet of all UTP cable runs giving each a unique temporary number. This will be a useful tool for planning support methods, cable testing, and “blue lining” the job.
Do	Decide on the TIA/EIA T568A or T568B wiring scheme before you begin work and stick to it. If in doubt use the T568B method as it is most common.
Do	Be aware of EMI- electro magnetic interference- sources when choosing the route your UTP cable bundles or homeruns will follow. EMI sources are typically high voltage devices like transformers, switching power supplies, AC motors, fluorescent light fixtures, 220/480VAC power feeds, AC breaker boxes, etc. Do not parallel UTP on AC power feeder conduit.
Do	Use Plenum rated cable (CMP) in all drop ceilings and designated plenum spaces. Use Riser rated cable (CMR) sometimes called PVC in vertical runs in cable risers between floors.
Do	Decide on UTP cable support methods and materials based on the quantity of cable you will install. Some combination of cable trays, J hooks, insulated T-59 staples, or other cable fasteners will depend on the amount of cable and the installation space.
Do	Use solid core wire for all home runs between floors, wire closets, and wall plates. Use stranded core wire only for short patch cables.
	Pulling Cable and Installation Methods
Do	Go easy while pulling UTP cable; the TIA/EIA 568 standard specifies a maximum of 25 pounds of force.
Do	Install plastic or rubber grommets to protect cables from being cut on sharp edges passing through metal studs, furniture, enclosures, etc.
Do	In tight conduits use a lubricant like AquaGel that is designed for pulling UTP cable. Lubricant will make the job significantly easier and prevent damage to the cable that can result in certification test failure.
Do	Temporarily label every UTP cable with the same number at both ends as it is being pulled.
Do	Cross reference temporary numbers in spreadsheet to confirm testing and create permanent labels.
Do	Keep track of each cable’s length by noting the start and end length makings printed on the cable jacket. To figure the length, subtract the end value from the start value.

Do	Limit UTP horizontal or vertical section runs to a maximum of 300 feet. This will give you room to add slack, patch cords and panels that add up to no more than the maximum distance of 328 feet.
Do	Bend UTP cable gradually to traverse corners. The TIA/EIA 568B standard calls for a minimum bend radius of 4 times the cable diameter. Never hard bend UTP to make a 90° turn.
Do	Be sure to support cables and bundles with a proper cable support system like J hooks , cable trays, or insulated staples.
Do	Be sure to leave a few feet of slack at the device end or wall plate. Leave at least double that at the wire closet or rack room end to accommodate unforeseen rack layout changes.
	Termination and Fasteners
Do	When terminating UTP to an RJ-45 or patch panel make sure there is no more than 0.5"(one half inch) untwisted wire. Untwisting too much increases crosstalk and can cause the link to fail certification testing. Maintain pair twists right up to the jacket edge.
Do	Use CAT6 rated RJ-45 connectors with load bars when terminating CAT 6 cables to limit crosstalk.
Do	Use Velcro cable ties with minimal force to secure UTP bundles; do not over tighten.
Do	Use “110” punch blocks and category components rated for the wire you are using.
Do	Use a cable tester to verify termination and wiring pattern.
Do	Be sure to fire stop any firewall penetrations with a caulk or other material that meets ASTM E-814 standards.
Do	Certify the audio network installation end to end for CAT5e or 6 compliance with the proper test equipment.

	What NOT to do during your Installation
Don’t	Use stranded core wire for anything but patch cables.
Don’t	Crush UTP cable with plastic ties. Use Velcro ties and flame retardant ties where required.
Don’t	Double punch, “Y”, “T”, or try to repair a UTP cable at any point. Run a new cable.
Don’t	Yank, tug, strain, bend, step on, kink, crush or stretch the UTP cable.
Don’t	Apply lubricants to UTP cable jackets unless they are designed for use with the cable’s jacket material. Certain undesirable lubricants can break down jacket material over time.
Don’t	Run or fasten UTP cables along electrical conduits.
Don’t	Lay cables directly on ceiling tiles, light fixtures, or other electrical equipment.
Don’t	Stretch cables taut to prevent sagging or to make a required distance. Use a proper support system or run a new cable.
Don’t	Deviate from the 568A or 568B wiring scheme you have selected for the installation.
Don’t	Crush cables with metal staples. Use a T-59 insulated staple gun.

Testing and Certification

There are three levels of testing in the professional data communications cable installation world: Certification, Qualification, and Verification.

Each level provides a higher degree of parameter testing with Verification being the lowest and Certification being the highest. As one might expect, the complexity of tests and the cost of required test equipment become progressively higher with each level of testing. Every installation should use some combination of these test methods to help get the job done quickly and correctly.

Certification testing will guarantee that the cabling system is in compliance with the TIA/EIA 568B and other industry standards. Any broadcast engineer who installs an Ethernet audio network should plan on certifying the network infrastructure prior to bringing the WheatNet-IP hardware online. Certification testing erases a huge unknown - does the network I just installed meet the 1000BASE-T specifications? You simply don't know until it is certified.

Certification can save wasted hours of debugging during the audio system testing phase and will root out hidden problems before they can affect your station's on-air product. If your station or group's IT department doesn't already own a datacom cable analyzer with CAT6 certification capabilities consider renting one or hiring a third party to certify your audio network. Certification testers are pricey, running anywhere between $6K-$10k.

Qualification testing is a relatively new class of testing brought on by the availability of a newer class of lower cost but powerful test tools. A step lower than certification, qualification can be used on new or existing installations to see if certain classes or types of services will run on the installed cabling and Ethernet switches. Qualification analyzers bring bandwidth, port configuration, cable fault, length, and wiremap testing together but do not run the full series of crosstalk tests that certification tools do. Qualification testers can be purchased for about $1000.

Verification tools are essential for pre-testing all wall outlets, patch cables, horizontal runs between patch panels, and equipment racks. These low cost tools help make sure that the basic wire maps are correct before you attempt certification testing. Other tests may include shorts, opens, and wire length. An integral tone generator is useful in tracing lost cables ala the "fox and hound" method. This type of tester is useful for routine testing during the initial termination phase of the build-out but by no means should this be the end of the wiring plant testing.

Remember- the network you are building is the backbone of the entire WheatNet-IP network audio system. Nobody wants to lose advertising revenue for any reason, but especially not because of a cracked wire or bargain bin patch cable.

Certification Parameters Tested
Certification testing is completed by performing a series of Category cable specific tests on all permanent links and channels. A permanent link refers to any length cable run that is installed in walls, ceilings, etc., and connects the work area wall plates or devices to an equipment room housing patch panels or punch blocks. A channel refers to the entire path from a device to an Ethernet switch, router, etc., and includes the patch cable that connects each end of the run device to wall plates or patch panels.

A wiring system can only be certified when all channels have been tested.

Certification tests for data communications cabling include length, wiremap, attenuation, DC loop resistance, and return loss. Detailed analysis also includes a series of crosstalk tests which verify that all of the components in the Permanent Link or Channel are TIA/EIA-568-B.2-1 compliant to the applicable category standards.

Crosstalk testing begins with near end (NEXT) and far end (FEXT) tests. Near end and far end crosstalk measurements drive a 100MHz test signal onto a single pair of wires and measure the other pairs one at a time to see how much signal is bleeding over. The Power Sum crosstalk measurements are tougher tests because they add up the total crosstalk from all active pairs. Power sum crosstalk measurements apply to gigabit networks because gigabit interfaces use all 4 pairs to send and receive data. Power sum measurements do not apply to 10/100 networks because only two pairs are used. Alien Crosstalk measurements apply to 10GbE CAT6A systems and measure within cable bundles and patch panels. See the Glossary of Common Terms section for definitions of each parameter specified in the table.

Typical Category Cable Specifications

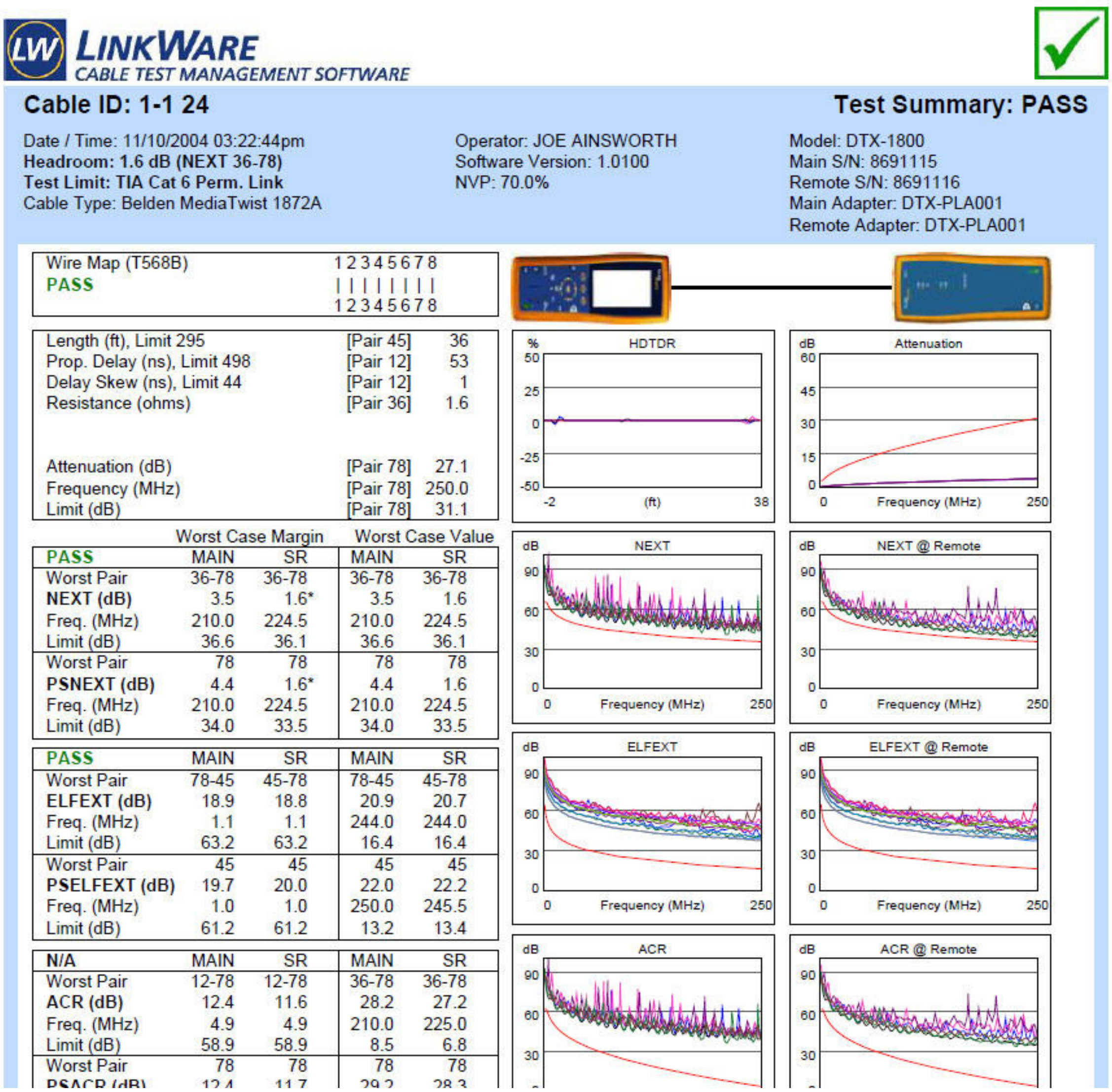
Category 5, 5e, 6 & 7 Cable Comparison

	CAT5 (Obsolete)	CAT5e	CAT6	CAT6a	CAT7 (Proposed)
Frequency	100 MHz	100MHz	250 MHz	500 MHz	600 MHz
Attenuation (min. at 100 MHz)	22 dB	22 dB	19.8 dB	- -	20.8 dB
Characteristic Impedance	100Ω ±15%	100Ω ±15%	100Ω ±15%	- -	100Ω ±15%
NEXT (min. at 100 MHz)	32.3 dB	35.3 dB	44.3 dB	27.9 dB	62.1 dB
PS-NEXT (min. at 100 MHz)	NA	32.3 dB	42.3 dB	- -	59.1 dB
EL-FEXT (min. at 100 MHz)	NA	23.8 dB	27.8 dB	9.3 dB	Not available
PS-ELFEXT (min. at 100 MHz)	NA	20.8 dB	24.8 dB	- -	Not available
PS-ANEXT (min. at 500 MHz)	- -	- -	- -	49.5 dB	- -
PS-AELFEXT (min. at 500 MHz)	- -	- -	- -	23.0 dB	14.1 dB
Return Loss (min. at 500MHz)	16 dB	20.1 dB	20.1 dB	8.0 dB	14.1 dB
Delay Skew (max. per 100m)	NA	45 ns	45 ns	- -	20 ns
Networks Supported	100BASE-T	1000BASE-T	1000BASE-T & TX	10GBASE	100GB future

Documentation
A well labeled and documented Ethernet network is your best friend. Take the time to label each cable at both ends with a unique identifying number. A second line or label indicating the destination is extremely helpful when troubleshooting. A comprehensive spreadsheet with columns for wire number, source end equipment / location, destination end equipment /location, and a notes area is invaluable when testing, troubleshooting, or adding and moving cables.

Certification test equipment provides a means for generating compliance testing reports, usually by downloading test data collected onsite to a PC for formatting, storage, and printing.

Typical Fluke Certification Test Results



LINKWARE CABLE TEST MANAGEMENT SOFTWARE

Cable ID: 1-1 24 — **Test Summary: PASS**

Date / Time: 11/10/2004 03:22:44pm
Headroom: 1.6 dB (NEXT 36-78)
Test Limit: TIA Cat 6 Perm. Link
Cable Type: Belden MediaTwist 1872A

Operator: JOE AINSWORTH
Software Version: 1.0100
NVP: 70.0%

Model: DTX-1800
Main S/N: 8691115
Remote S/N: 8691116
Main Adapter: DTX-PLA001
Remote Adapter: DTX-PLA001

Wire Map (T568B) 1 2 3 4 5 6 7 8
PASS 1 2 3 4 5 6 7 8

Length (ft), Limit 295	[Pair 45]	36
Prop. Delay (ns), Limit 498	[Pair 12]	53
Delay Skew (ns), Limit 44	[Pair 12]	1
Resistance (ohms)	[Pair 36]	1.6
Attenuation (dB)	[Pair 78]	27.1
Frequency (MHz)	[Pair 78]	250.0
Limit (dB)	[Pair 78]	31.1

	Worst Case Margin		Worst Case Value	
PASS	MAIN	SR	MAIN	SR
Worst Pair	36-78	36-78	36-78	36-78
NEXT (dB)	3.5	1.6*	3.5	1.6
Freq. (MHz)	210.0	224.5	210.0	224.5
Limit (dB)	36.6	36.1	36.6	36.1
Worst Pair	78	78	78	78
PSNEXT (dB)	4.4	1.6*	4.4	1.6
Freq. (MHz)	210.0	224.5	210.0	224.5
Limit (dB)	34.0	33.5	34.0	33.5
PASS	MAIN	SR	MAIN	SR
Worst Pair	78-45	45-78	78-45	45-78
ELFEXT (dB)	18.9	18.8	20.9	20.7
Freq. (MHz)	1.1	1.1	244.0	244.0
Limit (dB)	63.2	63.2	16.4	16.4
Worst Pair	45	45	45	45
PSELFEXT (dB)	19.7	20.0	22.0	22.2
Freq. (MHz)	1.0	1.0	250.0	245.5
Limit (dB)	61.2	61.2	13.2	13.4
N/A	MAIN	SR	MAIN	SR
Worst Pair	12-78	12-78	36-78	36-78
ACR (dB)	12.4	11.6	28.2	27.2
Freq. (MHz)	4.9	4.9	210.0	225.0
Limit (dB)	58.9	58.9	8.5	6.8
Worst Pair	78	78	78	78
PSACR (dB)	12.4	11.7	29.2	28.3

Glossary of Common Terms

Key Definitions	
UTP (Unshielded Twisted Pair)	Used primarily for data transmission in local area networks (LANs), UTP network cable is a 4-pair, 100-ohm cable that consists of 4 unshielded twisted pairs surrounded by an outer jacket. Each pair is wound together for the purposes of canceling out noise that can interfere with the signal. UTP cabling systems are the most commonly deployed cable type in the U.S.
F/UTP (foil unshielded twisted pair)	F/UTP cable consists of four unshielded twisted pairs surrounded by an overall foil shield. F/UTP has also been referred to as ScTP (screened twisted pair) and FTP (foiled twisted pair). F/UTP cable is not as common as UTP, but is sometimes deployed in environments where electromagnetic interference (EMI) is a significant concern. With shielded systems, the foil shield must maintain continuity throughout the entire system.
S/FTP (shielded foil twisted pair)	S/FTP consists of four foil-shielded twisted pairs surrounded by an overall braided shield. This fully shielded cable is often referred to as PiMF (pairs in metal foil), or SSTP. It is the primary cable type deployed in Europe, but rarely seen in the U.S. With shielded systems, the foil shield must maintain continuity throughout the entire system.
Category 5 Cable	Category 5e cable is an enhanced version of Category 5 that adheres to more stringent standards (see comparison chart below). It is capable of transmitting data at speeds of up to 1000 Mbps (1 Gigabit per second).
Category 6 Cable	Category 6 cable was designed to perform at frequencies of up to 250 MHz and offers higher performance for better transmission of data at speeds up to 1000 Mbps (see comparison chart below). Some properly installed Category 6 cable will also support 10 Gigabit speeds, but likely with limitations on length.
Augmented Category 6 (6A) (Work Area Outlet)	Category 6A cable is the latest twisted-pair cable type defined in February 2008 under the newest version of the TIA 568-B standard (568-B.2-10). Category 6A operates at frequencies of up to 500 MHz and can support transmission speeds at 10 Gigabits per second (Gbps).
Category 7	Prior to Category 6A cable, Category 7 cable was designed to transmit data at 10-gigabit speeds. Category 7 cable is an F/STP (PiMF) cable that includes shielding for individual pairs and the cable as a whole. Category 7 is terminated with RJ-45 compatible GG45 connectors or TERA connectors, and it is rated for transmission frequencies up to 600 MHz. This cable type is rarely installed in the U.S.
RJ45 Jack	The RJ45 jack is an 8-conductor, compact, modular jack used to

	terminate UTP data cable. RJ45 jacks are engineered to maintain specific Category 5, 5e, 6, or 6A performance, and therefore must match the category of the cable they are terminating.
Patch Panel	A Patch Panel is a series of RJ45 jacks condensed onto a single panel. Common panel configurations include 12, 24, 48, and 96 ports. Patch panels are typically deployed where horizontal cables converge, and are used to interconnect or crossconnect links to a network switch or hub.
Patch Cable	A Patch Cable is a cable assembly that consists of a length of UTP cable with an RJ45 male connector crimped onto each end. This cable assembly is used to provide connectivity between any two RJ45 jacks. The two most common uses for patch cables are for connecting patch panel ports to other patch panel ports or to switch ports, and for connecting the work area outlet (jack) to the computer or other networked device.
Star Configuration	In a Star Topology, network links are distributed from one central switch or hub. This configuration provides and easy-to-understand layout, offers a centralized management point, and ensures that if one network link fails, all others can still function.
ANSI/EIA/TIA-568B Standard	This standard was published in 2001 to replace the 568A standard, which is now obsolete. The original purpose of the EIA/TIA 568 standard was to create a multiproduct, multivendor, standard for interoperable connectivity. The 568B standard sets minimum requirements for the various categories of cabling. The most recent version of the 568B standard (568B.2-10) published in February 2008 defines the requirements of twisted-pair cabling to support 10 Gigabit transmission. The 568 "standard" is not to be confused with 568A or 568B wiring schemes.
568A and 568B Wiring Schemes	When we refer to a jack or a patch panel's wiring connection, we refer to either the 568A or 568B wiring scheme, which define the pin-pair assignments for terminating UTP cable. The only difference between 568A and 568B is that pairs 2 and 3 (orange and green) are swapped. For more information, see the following section on wiring schemes.
Bend Radius	Bend radius is the minimum radius a cable can be bent without kinking it, damaging it, or shortening its life. The minimum bend radius for Category 5, 5e, and 6 cable is four times the cable diameter, which is approximately 1 inch. When cabling is bent beyond this specified minimum bend radius, it can cause transmission failures. All pathways must maintain the minimum bend radius wherever the cable makes a bend.
Firestopping	Firestopping is the sealing of holes made in fire walls and floors during cable installation. Firestopping materials and products are

	designed to restore the fire rating to what it was before penetrating the wall or floor.
Wiremap	This is the most basic test that can be performed on a UTP network link. Wiremap tests for continuity between two devices. Whether using 568A or 568B wiring scheme, all eight pins of each device should be wired straight through (pins 1 through 8 on one end are connected to pins 1 through 8 on the other end). A wiremap test also tests for opens, shorts, grounding, and external voltage.
Crosstalk	Crosstalk is the "bleeding" of signals from one pair in a cable onto another pair through induction (wires need not make contact because signals are transferred magnetically). Crosstalk is an unwanted effect that can cause slow data transfer, or completely inhibit the transfer of data signals. Crosstalk is minimized by the twisting of the pairs in the cable. Fiber Optic cable is the only cable medium that is 100% immune to the effects of crosstalk or EMI.
Electromagnetic Interference (EMI)	Similar to crosstalk, EMI is an unwanted signal that is induced into the cable. The difference is that EMI typically comes from a source that is external to the cable, such as an electrical cable or device.
Near-end Crosstalk (NEXT)	NEXT is a testing parameter that measures the crosstalk from an interfering pair transmitting at the same end of a network link.
Far-end Crosstalk (FEXT)	FEXT is a testing parameter that measures the crosstalk from an interfering pair transmitting from the other end of the link. FEXT is measured as Equal Level FEXT (ELFEXT), which compensates for attenuation by subtracting it from the interfering pair.
Power Sum NEXT (PSNEXT)	PSNEXT is the sum of the NEXT induced on a pair from all other adjacent pairs. PSNEXT is a more stringent measurement than NEXT because it measures the total possible crosstalk from multiple pairs in the same cable, not just the crosstalk from one pair to another pair. PSNEXT is only critical in high-speed networks that transmit data over multiple pairs.
Power Sum ELFEXT (PSELFEXT)	Like PSNEXT, PSELFEXT is the sum of the ELFEXT induced on a pair from all other adjacent pairs. PSELFEXT is only critical in high-speed networks that transmit data over multiple pairs.
Attenuation	Attenuation is the loss of signal over the length of a network link due to the resistance of the wire plus other electrical factors that cause additional resistance (impedance and capacitance for example). A longer cable length, poor connections, bad insulation, a high level of crosstalk, or EMI can all increase attenuation. For each category of cable, the TIA-568B standard specifies the maximum amount of attenuation that is acceptable in a network link.

Attenuation to Crosstalk Ratio (ACR)	ACR is probably the most important result when testing a link. ACR is the difference between the signal attenuation and the near-end crosstalk, representing the strength of the attenuated signal in the presence of crosstalk. If ACR is not high enough, errors will occur or the data signal can be lost. Power Sum ACR (PSACR) is calculated in the same way as ACR, but uses the PSNEXT results rather than NEXT.
Return Loss	Return Loss is the difference between the power of a transmitted signal and the power of the signal reflections caused by variations in link and channel impedance.
Propagation Delay	Propagation Delay tests for the time it takes for the signal to be sent from one end of a link and received by the other end.
Delay Skew	Only a critical parameter in high-speed networks that transmit data using multiple pairs, Delay Skew is the difference in time between the fastest arrival of a data signal on a pair and the slowest. Signals divided over multiple pairs need to reach the other end within a certain amount of time to be re-combined correctly.

568B Standard Published in 2001, the TIA-568-B standard sets minimum requirements for the various categories of cabling and methods for installation. The 568-B "standard" is not to be confused with 568A or 568B wiring schemes, which are part of the standard. **TIA 568 C Standard** Published in 2009 is the most recent version. This is published as a set or in four parts, C.0, C.1, C.2, and C.3.	**568A & 568B Wiring Schemes** When we refer to a jack or a patch panel's wiring connection, we refer to either the 568A or 568B wiring scheme, which define the pin-pair assignments for terminating UTP cable.