PEARSON IT CYBERSECURITY CURRICULUM

SIXTH EDITION

NETWORKING ESSENTIALS

A CompTIA® Network+ N10-008 Textbook

Save 10% on Exam Voucher
See Inside

JEFFREY S. BEASLEY
PIYASAT NILKAEW

NETWORKING ESSENTIALS: SIXTH EDITION
A COMPTIA NETWORK+ N10-008 TEXTBOOK

INSTRUCTOR EDITION

JEFFREY S. BEASLEY AND PIYASAT NILKAEW

Pearson

Networking Essentials: Sixth Edition

Instructor Edition

ISBN-13: 978-0-13-745582-9
ISBN-10: 0-13-745582-8

Library of Congress Control Number: 2021913557

ScoutAutomatedPrintCode

Trademarks

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Pearson IT Certification cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.

Warning and Disclaimer

Every effort has been made to make this book as complete and as accurate as possible, but no warranty or fitness is implied. The information provided is on an "as is" basis. The authors and the publisher shall have neither liability nor responsibility to any person or entity with respect to any loss or damages arising from the information contained in this book.

Special Sales

For information about buying this title in bulk quantities, or for special sales opportunities (which may include electronic versions; custom cover designs; and content particular to your business, training goals, marketing focus, or branding interests), please contact our corporate sales department at corpsales@pearsoned.com or (800) 382-3419.

For government sales inquiries, please contact governmentsales@pearsoned.com.

For questions about sales outside the U.S., please contact intlcs@pearson.com.

EDITOR-IN-CHIEF
Mark Taber

DIRECTOR, ITP PRODUCT MANAGEMENT
Brett Bartow

DEVELOPMENT EDITOR
Marianne Bartow

MANAGING EDITOR
Sandra Schroeder

PROJECT EDITOR
Mandie Frank

COPY EDITOR
Kitty Wilson

INDEXER
Ken Johnson

PROOFREADER
Abigail Manheim

TECHNICAL EDITOR
Chris Crayton

PEER REVIEWERS
DeAnnia Clements
Osman Guzide
Gene Carwile
Dr. Theodor Richardson

PUBLISHING COORDINATOR
Cindy Teeters

DESIGNER
Chuti Prasertsith

COMPOSITOR
codeMantra

ABOUT THE AUTHORS

Jeffrey S. Beasley is a professor emeritus in the Information and Communications Technology program at New Mexico State University, where he taught computer networking and many related topics. He is coauthor of *Modern Electronic Communication*, ninth edition, the author of *Networking,* second edition, and *co-author of Networking Essentials,* fifth edition, and *A Practical Guide to Advanced Networking*.

Piyasat Nilkaew is the director of Computing and Networking Infrastructure at New Mexico State University and has more than 20 years of experience in network management and consulting. He has extensive expertise in deploying and integrating multiprotocol and multivendor data, voice, and video network solutions. He is co-author of *Networking Essentials,* fifth edition, and *A Practical Guide to Advanced Networking.*

ABOUT THE TECHNICAL REVIEWER

Chris Crayton is a technical consultant, trainer, author, and industry-leading technical editor. He has worked as a computer technology and networking instructor, information security director, network administrator, network engineer, and PC specialist. Chris has authored several print and online books on PC repair, CompTIA A+, CompTIA Security+, and Microsoft Windows. He has also served as technical editor and content contributor on numerous technical titles for several of the leading publishing companies. He holds numerous industry certifications, has been recognized with many professional and teaching awards, and has served as a state-level SkillsUSA final competition judge. Chris tech edited and contributed to this book to make it better for students and those wishing to better their lives.

DEDICATIONS

This book is dedicated to my family: Kim, Damon/Heather, and Dana/Sam. —Jeff Beasley

This book is dedicated to my family: Boonsong, Pariya, June, Ariya, and Atisat. —Piyasat Nilkaew

ACKNOWLEDGMENTS

I am grateful to the many people who have helped with this text. My sincere thanks go to the following technical consultants:

- Danny Bosch and Matthew Peralta for sharing their expertise with optical networks and unshielded twisted-pair cabling
- Don Yates for his help with the initial Net-Challenge software

I would also like to thank my many past and present students for their help with this book:

- Abel Sanchez, Kathryn Sager, and Joshua Cook for their work on the Net-Challenge software; Adam Segura for his help taking pictures of the steps for CAT6 termination; Marc Montez, Carine George-Morris, Brian Morales, Michael Thomas, Jacob Ulibarri, Scott Leppelman, and Aarin Buskirk for their help with laboratory development; Josiah Jones and Raul Marquez Jr. for their help with the Wireshark material; and Ariya Nilkaew for her help with revising and editing many of the captured pictures

- Aaron Shapiro and Aaron Jackson for their help testing the many network connections presented in the text
- Paul Bueno and Anthony Bueno for reading through an early draft of the text

Your efforts are greatly appreciated.

We appreciate the excellent feedback of the following reviewers: Phillip Davis, DelMar College, Texas; Thomas D. Edwards, Carteret Community College, North Carolina; William Hessmiller, Editors & Training Associates; Bill Liu, DeVry University, California; and Timothy Staley, DeVry University, Texas.

Our thanks to the people at Pearson for making this project possible. Thanks to Brett Bartow for providing us with the opportunity to work on the sixth edition and for helping make this process enjoyable. Thanks to Marianne Bartow, to all the people at Pearson IT Certification, and also to the many technical editors for their help editing the manuscript.

Special thanks to our families for their continued support and patience.

—Jeffrey S. Beasley and Piyasat Nilkaew

WE WANT TO HEAR FROM YOU!

As the reader of this book, *you* are our most important critic and commentator. We value your opinion and want to know what we're doing right, what we could do better, what areas you'd like to see us publish in, and any other words of wisdom you're willing to pass our way.

We welcome your comments. You can email or write to let us know what you did or didn't like about this book—as well as what we can do to make our books better.

Please note that we cannot help you with technical problems related to the topic of this book.

When you write, please be sure to include this book's title and author as well as your name and email address. We will carefully review your comments and share them with the authors and editors who worked on the book.

Email: community@informit.com

READER SERVICES

Register your copy of *Networking Essentials*, Sixth Edition at www.pearsonitcertification.com for convenient access to downloads, updates, and corrections as they become available. To start the registration process, go to www.pearsonitcertification.com/register and log in or create an account.* Enter the product ISBN 9780137455928 and click Submit. When the process is complete, you will find any available bonus content under Registered Products.

*Be sure to check the box that you would like to hear from us to receive exclusive discounts on future editions of this product.

2

CHAPTER

Physical Layer Cabling: Twisted-Pair

Chapter Outline

2-1 Introduction
2-2 Structured Cabling
2-3 Twisted-Pair Cable
2-4 Terminating Twisted-Pair Cables
2-5 Cable Testing and Certification
2-6 10 Gigabit Ethernet over Copper
2-7 Troubleshooting Cabling Systems
Summary
Questions and Problems

Objectives

- Describe the six subsystems of a structured cabling system
- Define horizontal cabling
- Define UTP and STP
- Define the categories of UTP cable
- Describe the difference in the T568A and T568B wire color orders
- Describe the procedure for placing RJ-45 plugs and jacks on twisted-pair cable
- Describe how to terminate twisted-pair cable for computer networks
- Define the basic concepts of planning a cable installation for an office LAN
- Describe the procedure for certifying a twisted-pair cable for CAT6 and CAT5e
- Describe the issues related to running 10 Gigabit Ethernet over copper
- Describe the basic steps for troubleshooting cable problems

Key Terms

physical layer cabling
angled physical contact (APC)
ultra-physical contact (UPC)
EIA
TIA
campus network
TIA/EIA 568-B
Gigabit Ethernet
full-duplex
CAT6a
10GBASE-T
coaxial
BIX
RJ-45
RJ-11
F-type
building entrance
entrance facilities (EF)
equipment room (ER)
telecommunications closet
telecommunications room (TR)
backbone cabling
horizontal cabling
TCO
work area
main cross-connect (MC)
intermediate cross-connect (IC)
cross-connect
horizontal cross-connect (HC)
work area outlet (WO)
terminated
8P8C
patch cable
UTP
CAT6/6a
CAT5e
balanced mode
Fast Ethernet
network congestion
bottlenecking
Gigabit Ethernet
full-duplex
CAT7/7a and CAT6a
10GBASE-T
STP
EMI
T568A
T568B
color map
TX
RX
straight-through cable
wiremap
crossover cable

Key Terms continued

link	IEEE 802.3an-2006 10GBASE-T	ELTCTL
full channel	Alien crosstalk (AXT)	LCL
attenuation	PSANEXT	TCTL
near-end crosstalk (NEXT)	PSAACRF	multilevel encoding
crosstalk	F/UTP	hybrid echo cancellation circuit
10GBASE-T	TCL	

Physical Layer Cabling
The media interconnecting networking devices

This chapter examines the twisted-pair media used to link computers together to form a local area network (LAN). This media is called **physical layer cabling**. The term *physical layer* describes the media interconnecting networking devices. In this chapter you will gain an introductory understanding of the cable media, including the category types, the steps for terminating cables, cable testing, certification, and troubleshooting. The main focus is on the use of UTP cable in computer networks, although an overview of shielded twisted-pair (STP) is presented as well. (Fiber-optic cable, which also plays an important role in modern computer networks, is thoroughly examined in Chapter 3, "Physical Layer Cabling: Fiber Optics.") A network technician or engineer needs to have a good understanding of how physical layer cable is being used and its specific application.

Other types of cabling you might encounter in computer networking are RG-6 and possibly RG-59. These types of cables, called *coaxial cables*, are primarily used to connect satellite systems or cable television and modems. Cable terminations for these types of cable include F-type and BNC connector types. Another type of coax cable is called twinaxial. This is a type of coaxial cable that contains two inner conductors rather than one.

The following are some of the connector types used with physical layer cabling:

- **UTP coupler:** This small device, which is used to connect two UTP cables, is also called an *inline coupler*. UTP couplers can be used to couple twisted-pair cabling and RJ-11 phone lines but can introduce signal degradation.
- **BNC connectors:** BNC stands for Bayonet Neill–Concelman. This type of connector is a quick-connect connector for coaxial cable that was commonly used with thinnet Ethernet cabling.
- **Fiber coupler:** These couplers come in a variety of styles that support single-mode and multimode fibers. These devices allow a single fiber to be split into two outputs, and multiple input fibers can be combined into one output fiber.
- **APC and UPC:** The difference between these two types of connectors is the fiber endface. An **angled physical contact (APC)** endface is polished and has an 8-degree angle. An **ultra-physical contact (UPC)** endface is polished and has no angle. APC and UPC connectors are easily identified by their color: APC adapters are green, and UPC adapters are blue.

Angled Physical Contact (APC)
A green fiber connector whose endface is polished and has an 8-degree angle

Ultra-Physical Contact (UPC)
A blue fiber connector whose endface is polished and has no angle

- **Fiber-to-coaxial connector:** This device is used to convert an optical signal carried over fiber to an electrical signal carried over coaxial cable. A typical application for this type of connector is coupling cabling that carries digital optical signal to a digital coaxial cable.

2-1 INTRODUCTION

This chapter begins with an overview of structured cabling. This section defines the six subsystems of a structured cabling system and focuses on the basic issues associated with horizontal cabling or wiring a LAN. Next, the basic operational characteristics of UTP cable are examined. The discussion includes an examination of the various categories of UTP cable currently available. Following that is an overview of constructing twisted-pair patch and horizontal link cabling. This chapter discusses the tools and techniques for properly terminating UTP cabling for twisted-pair Ethernet such as CAT5e, CAT6, CAT6a, CAT7, and CAT8. It also provides an introduction to testing and certifying Ethernet cables. This chapter includes several examples of cable test data and how to interpret the test results. The chapter concludes with a section on troubleshooting computer networks, with a focus on cable or physical failures.

Table 2-1 outlines the CompTIA Network+ objectives related to this chapter and identifies the chapter section that covers each objective. At the end of each chapter section you will find a review with comments on the Network+ objectives presented in that section. These comments are provided to help reinforce your understanding of each Network+ objective. The chapter review also includes "Test Your Knowledge" questions to help you understand key concepts before you advance to the next section of the chapter. At the end of the chapter you will find a complete set of questions as well as sample certification exam-type questions.

TABLE 2-1 **Chapter 2 CompTIA Network+ Objectives**

Domain/Objective Number	Domain/Objective Description	Section Where Objective Is Covered
1.0	**Networking Fundamentals**	
1.2	Explain the characteristics of network topologies and network types.	2-2
1.3	Summarize the types of cables and connectors and explain which is the appropriate type for a solution.	2-2, 2-3, 2-4, 2-6
1.4	Given a scenario, configure a subnet and use appropriate IP addressing schemes.	2-2
1.6	Explain the use and purpose of network services.	2-2
1.7	Explain basic corporate and datacenter network architecture.	2-2, 2-4
2.0	**Network Implementations**	
2.1	Compare and contrast various devices, their features, and their appropriate placement on the network.	2-4
2.3	Given a scenario, configure and deploy common Ethernet switching features.	2-3, 2-5, 2-6

Domain/Objective Number	Domain/Objective Description	Section Where Objective Is Covered
3.0	**Network Operations**	
3.1	Given a scenario, use the appropriate statistics and sensors to ensure network availability.	2-3, 2-5, 2-6
3.3	Explain high availability and disaster recovery concepts and summarize which is the best solution.	2-4
5.0	**Network Troubleshooting**	
5.2	Given a scenario, troubleshoot common cable connectivity issues and select the appropriate tools.	2-3, 2-4, 2-5, 2-6, 2-7
5.3	Given a scenario, use the appropriate network software tools and commands.	2-4

2-2 STRUCTURED CABLING

This section defines the six subsystems of a structured cabling system. Students should be able to identify the purpose of each subsystem. The focus of this section is on issues associated with horizontal cabling.

The first major standard describing a structured cabling system for computer networks was TIA/EIA 568-A, implemented in 1995. **EIA** is the Electronic Industries Alliance, a trade organization that lobbies for the interests of manufacturers of electronics-related equipment. **TIA** is the Telecommunications Industry Association, a trade organization that represents the interests of the telecommunications industry. The wiring standards for modern computer networks are defined by the TIA/EIA 568 standard. The most important addendum to the TIA/EIA 568-A standard is Addendum 5, published in 1999, which defines the transmission performance specifications for four-pair 100-ohm Category 5e twisted-pair cabling. TIA/EIA adopted Category 6 (CAT6) cable specifications in June 2002 as part of TIA/EIA 568-B. This is the type of cabling recommended for use in today's computer networks. CAT6a was adopted in 2018 for 10Gbps speed. CAT7 and CAT8 twisted-pair cables are the latest additions but are not in wide use. The latest TIA/EIA standard is TIA/EIA 568-D.

The TIA/EIA 568-A standard defines the minimum requirements for the internal telecommunications wiring in buildings and between structures in a **campus network**. A campus network consists of interconnected LANs within a limited geographic area such as a college campus, military base, or group of commercial buildings. As mentioned earlier, TIA/EIA 568-A has been revised and updated many times, and in 2000 the standard **TIA/EIA 568-B** was published. TIA/EIA 568-B has three parts:

- **TIA/EIA 568-B.1:** Commercial Cabling Standard, Master Document
- **TIA/EIA 568-B.2:** Twisted-Pair Media
- **TIA/EIA 568-B.3:** Optical Fiber Cabling Standard

Within the TIA/EIA 568-B Commercial Standard for Telecommunication Pathways and Spaces are guidelines defining the six subsystems of a structured cabling system:

- **Building entrance:** The building entrance is the point where the external cabling and wireless services interconnect with the internal building cabling

EIA
Electronic Industries Alliance, a trade organization that represents the interests of manufacturers of electronics-related equipment.

TIA
Telecommunications Industry Association, a trade organization that represents the interests of the telecommunications industry

Campus Network
Interconnected LANs within a limited geographic area

TIA/EIA 568-B
The standard that defines the six subsystems of a structured cabling system

Building Entrance
The point where the external cabling and wireless services interconnect with the internal building cabling

in the equipment room. It is used for both public and private access (for example, telco, satellite, cable TV, security). The building entrance is also called the **entrance facilities (EF)**. Both public and private network cables enter the building at this point, and typically there are separate facilities for the different access providers.

- **Equipment room (ER):** The ER is a room that contains complex electronic equipment such as network servers and telephone equipment.
- **Telecommunications closet:** The telecommunications closet is the location of the cabling termination points that includes the mechanical terminations and the distribution frames. The connection of the horizontal cabling to the backbone wiring is made at this point. This is also called the **telecommunications room (TR)**, or telecommunications enclosure (TE). In some older systems, the network administrator might encounter two types of punchdown blocks in the telecommunications closet: a 66 block and a 110 block. These types of terminations use insulation-displacement connectors (IDCs) to terminate twisted-pair cables and are commonly used in telephone systems but not computer networks. The wire termination on IDCs requires the use of a punchdown tool. Other tools that can be used are the Krone tool, which is a punchdown tool used for inserting wire into punchdown blocks and insulation displacement connectors. Another tool is the BIX tool, which is used to terminate various wires on BIX blocks and connection products.

Entrance Facilities (EF)
Another name for the building entrance

Equipment Room (ER)
A room that contains complex electronic equipment such as network servers and telephone equipment

Telecommunications Closet
The location of the cabling termination points that includes the mechanical terminations and the distribution frames

Telecommunications Room (TR)
Another name for the telecommunications closet

Note

One room can serve as the entrance facility, the equipment room, and the telecommunications closet.

- **Backbone cabling:** Backbone cabling is cabling that interconnects telecommunications closets, equipment rooms, and cabling entrances in the same building and between buildings.
- **Horizontal cabling:** Horizontal cabling is cabling that extends out from the telecommunications closet into the LAN work area. Typically, the horizontal wiring is structured in a star configuration running to each area's telecommunications outlet (**TCO**), which is the wall plate where the fiber or twisted-pair cable terminates in the room. In some cases, the TCO terminates telephone, fiber, and video in addition to data into the same wall plate.

Backbone Cabling
Cabling that interconnects telecommunications closets in the same building and between buildings

Horizontal Cabling
Cabling that extends out from the telecommunications closet into the LAN work area

TCO
Telecommunications outlet, the wall plate where the fiber or twisted-pair cable terminates in a room

Note

Cable management—which involves keeping cables in order and tangle free—is important with any type of physical layer cabling. A well-managed cable system helps extend the life of cables and is more reliable.

- **Work area:** The work area is the location of computers and printers, patch cables, jacks, computer adapter cables, and fiber jumpers.

Work Area
The location of computers and printers, patch cables, jacks, computer adapter cables, and fiber jumpers

Figure 2-1 shows an example of the structure for a telecommunications cabling system. It shows the connection of the carriers (telco, ISP, and so on) coming into the ER, which is the space set aside for the carrier's equipment contained in the **main cross-connect (MC)** or **intermediate cross-connect (IC)**. The EF consists of the cabling, connector hardware, and protection devices that are used as the interface between any external building cabling and wireless services with the equipment room. This area is used by both public and private access providers (for example, telco, satellite, cable TV, security). The ER and EF space is typically combined with the MC equipment room.

Between the MC and the IC is the campus backbone cabling (listed in Figure 2-1 as the interbuilding backbone cabling), which provides connections between the MC and IC. A **cross-connect** is a space where one or multiple cables are connected to equipment or other cables. For example, you could be bringing in 60 UTP cables, with 50 that are cross-connected to a switch and 10 that are cross-connected to a backbone cable going to another location. Typical connections between the MC and IC are single-mode and multimode fibers and possibly coax for cable TV, although most installations are migrating to fiber. The building backbone cabling (that is, intrabuilding backbone cabling) makes the connection between the IC and the telecommunications closet (TC) and **horizontal cross-connect (HC)**. Today this connection is CAT6 UTP or better, although it might be single- or multimode fiber or some combination. Fiber is the best choice for making these connections, although copper is still commonly used. The horizontal cabling is the cabling between the HC and the work area. It is usually CAT6 UTP or better or fiber. The standard currently specifies CAT6. Fiber is gaining acceptance for connecting to the **work area outlets (WOs)**.

Main Cross-Connect (MC)
Also called the main distribution frame (MDF) or main equipment room or campus distributor (CD), an area that usually connects two or more buildings and is typically the central telecommunications connection point for a campus or building

Intermediate Cross-Connect (IC)
Also called the building distributor (BD), the building's connection point to the campus backbone, which links the MC to the horizontal cross-connect (HC)

Cross-Connect
A space where one or multiple cables are connected to equipment or other cables

Horizontal Cross-Connect (HC)
Also called the floor distributor (FD), the connection between the building distributors and the horizontal cabling to the work area or workstation outlet

Work Area Outlet (WO)
Also called the telecommunications outlet (TO), the workstation used to connect devices (for example, PCs, printers, servers, phones, televisions, wireless access points) to the cable plant, typically with CAT5, CAT5e, CAT6, CAT6a, CAT7, CAT8, and various coaxial cables

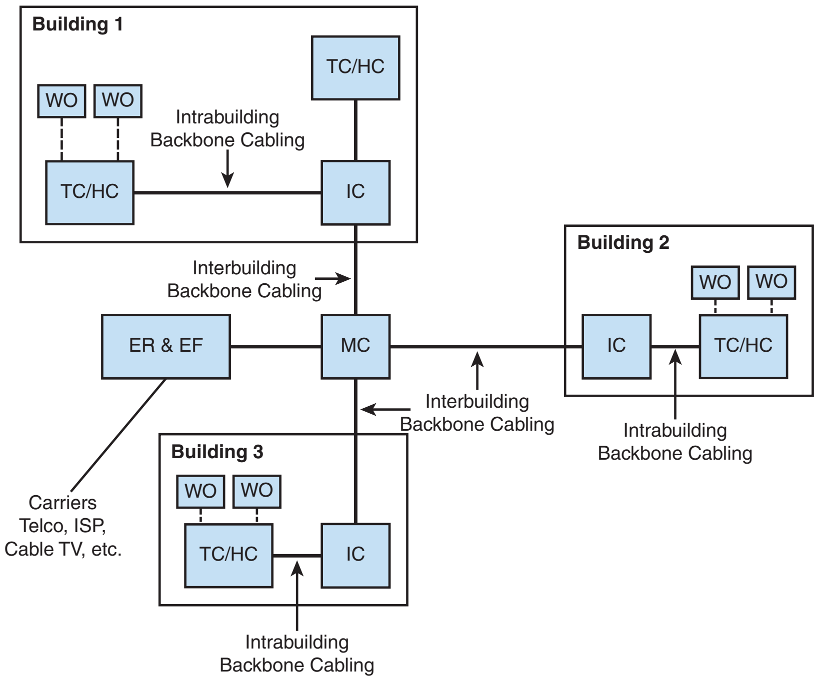


FIGURE 2-1 Telecommunications cabling system architecture.

Figure 2-2 provides a more detailed view of the cabling from the MC to the IC and the HC. This drawing shows the three levels of the recommended backbone hierarchy cabling for a computer network. The first level of the hierarchy is the MC. The MC connects to the second level of the hierarchy, the IC. The backbone cabling connects the MC to the IC and the IC to the TC/HC. The HC connects the horizontal cabling to the work area and to the WO.

Note

The focus of this chapter is on issues associated with the horizontal cabling and the work area (LAN) subsystems. This chapter addresses all six subsystems of a structured cabling system at the point where the networking concepts and related hardware are introduced. Many of the concepts covered in each structured cabling subsystem require that you have a firm grasp of basic networking to gain a full appreciation of how each network piece fits into a structured cabled system.

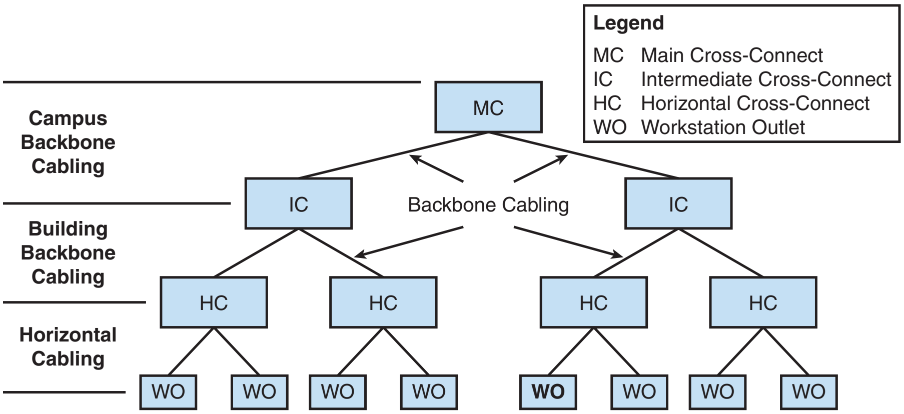


FIGURE 2-2 Campus network hierarchical topology.

Horizontal Cabling

Permanent network cabling within a building is considered *horizontal cabling,* defined as cabling that extends out from the telecommunications closet into the LAN work area. It is important to take time to plan for a horizontal cabling installation because this is where users interface with the network. There is always a substantial installation cost associated with horizontal cabling, and there is even greater cost in having to replace or upgrade a cable installation. You don't want to have to re-cable a system very often. Careful attention should be given to planning for the horizontal cabling of a LAN. It is important to make sure you fully understand your current networking needs and that your proposed plan meets the needs. You should also ensure that your plan addresses the future needs and growth of your network.

Figure 2-3 illustrates the basic blocks of a horizontal cabling system from the telecommunications closet to the computer in the LAN. The figure shows the following components, which are typically found in the telecommunications closet:

A. Backbone cabling interconnecting this closet with other closets

B. Switch or hub

C. Patch panels/patch bay

D. Patch cables

E. Cabling to the LAN (horizontal cabling)

F. Wall plate

G. Patch cable connecting the computer to the wall plate

Item E in Figure 2-3 shows the cabling leaving the telecommunications closet. The cable extends to where it is terminated at the wall plate (item F) in the LAN or work area. The term *terminated* describes where the cable connects to a jack in a wall plate, a patch panel, or an RJ-45 modular plug. In this case, the cable terminates into an RJ-45 jack in the wall plate. Figure 2-4 shows an example of an RJ-45 wall plate and patch panel.

A technique for troubleshooting cable termination is to use a toner probe. A toner probe injects a tone on a cable in a process called tone generation. You can use a speaker/sensor to verify that a tone is present at the other cable end. This technique is also very useful when you need to locate a cable end: The cable you are searching for transmits the tone.

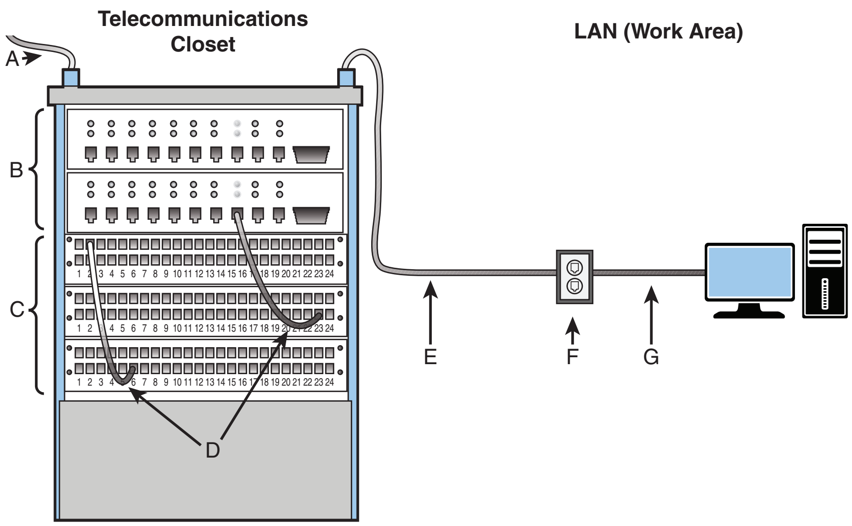


FIGURE 2-3 Block diagram of a horizontal cabling system.

Note

The proper term for the RJ-45 modular plug used in computer systems is actually **8P8C** for both male and female connectors. 8P8C, which stands for 8 position 8 conductor, is defined in ANSI/TIA-968-A and B. However, both professionals and end users typically use the term RJ-45 instead.

8P8C
The proper term for an RJ-45 modular plug

An individual cable is used to connect each connector in an outlet to the patch panel in the telecommunications closet (item F to item E in Figure 2-3). (Section 2-4, "Terminating Twisted-Pair Cables," provides more information on RJ-45 plugs and jacks.) Another 8-pin connector that uses an 8P8C modular connector is the RJ-48. This type of connector, which is commonly used with T1 data lines, typically works with shielded twisted-pair cabling. Although the RJ-45 and RJ-48 connectors look similar, they do not use the same wiring scheme, and they are intended for different data transmission applications.

In a star topology, there is an individual cable run for each outlet in the wall plate. This means that you assign one computer to each terminated outlet. A **patch cable** (item G) is used to make the physical connection from the computer to the wall plate, as shown in Figure 2-3. There is a 100-meter overall length limitation on the cable run from the telecommunications closet to a networking device in the work area. This includes the length of the patch cables at each end (items D and G) plus the cable run (item E). A general rule of thumb is to allow 90 meters for the cable run from the telecommunications closet to the work area (item E). This allows 5 meters of cable length for the work area and 5 meters for the patch cables in the telecommunications closet (item D) and the work area (item G). Figure 2-5 shows an example of the inside of a telecommunications closet.

Patch Cable
A cable used to make a physical connection from a computer to a wall plate

FIGURE 2-4 The Ortronics clarity twisted-pair system (Vlad Nordwing/Shutterstock).

Labeling is extremely important for all aspects of a computer network and data center. Each rack should be labeled to identify the purpose of the equipment installed in the rack (for example, telecommunication equipment that interfaces with the WAN connection). In addition, it is important to label each server to identify the purpose and possibly its name. Cabling should also be labeled. Both cable ends or wall plates should be labeled with some identifying marks that correspond to your building drawings. This type of labeling makes it possible for a technician to easily identify a cable and its path.

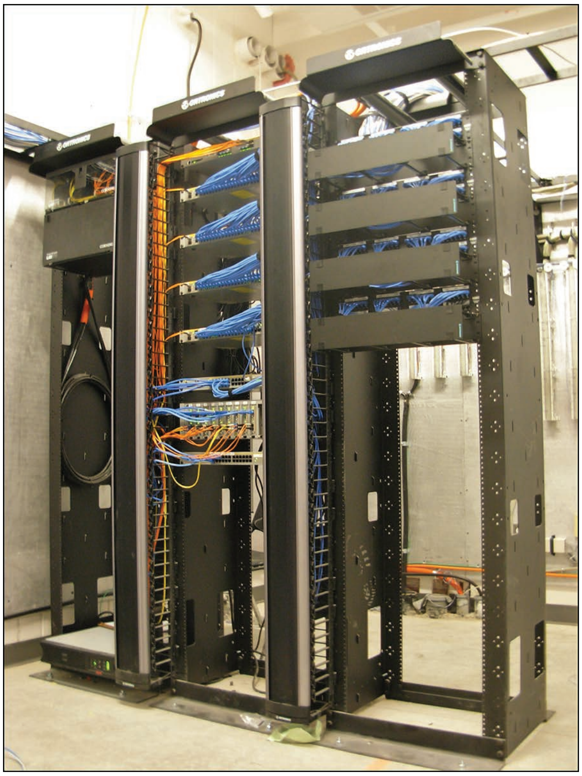


FIGURE 2-5 Inside a telecommunications closet.

Two types of labeling are commonly used in networks:

- **Port labeling:** When labeling your equipment and cabling, it is important to develop a standardized format that contains all the information you will need at a later time. Remember that your facility will eventually have a lot of equipment and cables, and being able to easily identify them will be of great benefit to the technical staff. Also make sure the labels correspond to your drawings.
- **System labeling:** System labels are important because they ensure that the technical staff are referencing the same system. A large facility will eventually have many systems doing similar tasks, and being able to identify the correct system will simplify your work.

Creating proper *rack diagrams* is also an extremely important part of documentation and rack management for a system. Racks are used in a multitude of places in network systems. Racks could be installed in closets, or there could be many racks in a data center. You can also expect to have server rack frames with air blowing over the devices for cooling. Racks must be securely installed and grounded. Rack types vary for sites, but the most common are 19-inch rack frames. There also two-post racks used for smaller telecommunication equipment. Four-post racks are typically used for servers.

A data center typically has locks on some racks for security reasons, and these racks should be located in a well-monitored area. There are also “hot” and “cold” aisles. The hot air from the equipment in the hot aisles is blown out of the racks and recirculates to the ceiling ducts. In the cold aisles, the air is pulled through the equipment by fans within that equipment.

Section 2-2 Review

This section covers the following Network+ exam objectives.

1.3 Summarize the types of cables and connectors and explain which is the appropriate type for a solution.

This section introduces some of the categories of UTP (unshielded twisted-pair) cabling.

1.7 Explain basic corporate and datacenter network architecture.

This section introduces concepts related to infrastructure and the network backbone.

Test Your Knowledge

1. What is the overall length limitation of a UTP cable run from a telecommunications closet to a networking device in a work area?
   a. 10 meters
   b. 100 meters
   c. 10,000 meters
   d. 100,000 meters
2. True or false: The six subsystems of a structured cabling system are as follows:
   - Building entrance
   - Equipment room
   - Backbone cabling
   - Telecommunications closet
   - Vertical cabling
   - Work area

   False
3. Horizontal cabling consists of which of the following basic blocks? (Select two.)
   a. Switch or hub
   b. Routers
   c. Backbone cabling
   d. Patch panel

2-3 TWISTED-PAIR CABLE

UTP cable is an important physical layer component in modern computer networks. Many networks incorporate CAT6 in their installations. The section lists the CAT6 specifications, but the fundamental issues of CAT6 are the same as for CAT5e. Many networks are already wired with CAT5/5e, and some new network connections are now installing CAT6 and higher. CAT6 provides improved network performance, and students should understand this.

The main difference between CAT5e and CAT6 has to do with transmission performance. The bandwidth increases from 100MHz with CAT5e to 200MHz with CAT6, and the CAT6 specifications provide for better noise performance to enable increased data rates. Most new installations specify CAT6 cable; it is important to use the best cable available for an installation, as long as the additional cost is justified. CAT6 specifications require that patch cables be precisely manufactured to maintain CAT6 performance. Also, CAT6 connectors look the same as CAT5e connectors, but these connectors have significantly different performance specifications. This section describes the steps for terminating both CAT6 and CAT5e.

A good task would be for students to prepare a report on CAT6/6a/7/8 cable, connectors, hardware, and testing. This would be a way for students to become aware of the latest developments related to twisted-pair cable.

Unshielded Twisted-Pair Cable

UTP
Unshielded twisted-pair

Unshielded twisted-pair (**UTP**) cable plays an important role in computer networking. The most common twisted-pair standards used for computer networking today are Category 6 (CAT6), Category 6a (CAT6a), and Category 5e (CAT5e). CAT6 cable provides data rates up to 1000Mbps over a maximum distance of 100 meters. CAT6a is an improved version of CAT6 that supports 10Gbps (10GBASE-T) Ethernet.

CAT5e cable is an enhanced version of CAT5 that provides improved performance. CAT6 provides even better performance and bandwidth of 250MHz. CAT5/5e twisted-pair cable contains four color-coded pairs of 24-gauge wires terminated with an RJ-45 connector. Figure 2-6 shows an example of a CAT5e cable terminated with an RJ-45 modular plug. CAT6 twisted-pair cable also contains four color-coded wires, but the wire gauge is 23AWG. CAT6 cable has a stiffer feel than CAT5e.

The precise manner in which the twist of CAT6/5e/5 cable is maintained, even at the terminations, provides a significant increase in signal transmission performance. CAT5/5e standards allow 0.5 inch of untwisted cable pair at the termination. CAT6 has an even tighter requirement and allows for only 0.375 inch of untwisted cable at the termination. The termination is the point where the cable is connected to terminals in a modular plug, jack, or patch panel.

CAT8/7/6/5e/5 twisted-pair cable contains four twisted wire pairs, for a total of eight wires. In twisted-pair cable, none of the wires in the wire pairs are connected to ground. The signals on the wires are set up for a high (+) and low (–) signal line. The (+) indicates that the phase relationship of the signal on the wire is positive, and the (–) indicates that the phase of the signal on the wire is negative; both signals are relative to a virtual ground. This is called a **balanced mode** of operation, and the balance of the two wire pairs helps maintain the required level of performance in terms of crosstalk and noise rejection.

Balanced Mode
A mode in which neither wire in a wire pair connects to ground

Table 2-2 lists the various categories of twisted-pair cable defined by the TIA/EIA 568-B standard. The table includes an application description and minimum bandwidth for each category.

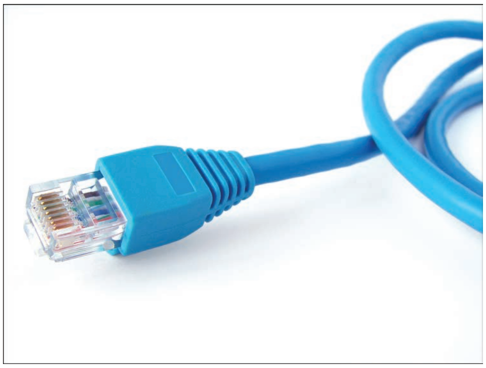


FIGURE 2-6 An example of an RJ-45 modular plug (Denis and Yulia Pogostins/Shutterstock).

TABLE 2-2 **Categories for Twisted-Pair Cable, Based on TIA/EIA 568-B**

Category	Description	Bandwidth/Data Rate
Category 3 (CAT3)	Telephone installations, Class C networks	Up to 16Mbps
Category 5 (CAT5)	Computer networks, Class D networks	Up to 100MHz/100Mbps, 100 meter length
Enhanced CAT5 (CAT5e)	Computer networks	100MHz/1000Mbps applications with improved noise performance in full-duplex mode
Category 6 (CAT6)	Higher-speed computers	Over 250MHz networks, Class E/1000Mbps networks CAT6 supports 10Gbps but at distances shorter than 100 meters
Category 6a (CAT6a)	Increased bandwidth	Over 500MHz networks, Class EA/10Gbps networks
Category 7 (CAT7)	International Organization for Standardization (ISO) standard, not an TIA/EIA standard	Up to 600MHz speed, computer networks, Class F/10Gbps networks
Category 7a (CAT7a)	ISO standard, not an TIA/EIA standard	Up to 1000MHz speed, computer networks, Class FA/10Gbps networks
Category 8 (CAT8)	Shielded UTP capable of competing with fiber optics	2000MHz /40Gbps

CAT1 and CAT2 cable specifications are not defined in the TIA/EIA 568-B standard. The first category specification is for CAT3, although CAT3 has been replaced with CAT5e or better. CAT4 is not listed in the table because the category was removed from the TIA/EIA 568-B standard as its data capacity specification is outdated. The Category 5 cable standard was established in 1991, and many computer networks are still using older CAT5 cables. Certified CAT5 cabling works well in both Ethernet and Fast Ethernet networking environments that run 10Mbps Ethernet and 100Mbps Fast Ethernet data rates. Note that the term **Fast Ethernet** is used to describe the 100Mbps data rate for Ethernet networks.

Fast Ethernet
An Ethernet system operating at 100Mbps

In some cases, users on networks experience **network congestion**, or **bottlenecking**, of data due to increased file transfer sizes and limited network bandwidth. These terms describe excessive data traffic that is slowing down computer communications even in Fast Ethernet networks. Basically, the demands on the network exceed the performance capabilities of the CAT5 cable. In fact, CAT 5 cabling is no longer recommended. The slowdown of data is of major concern in computer networks. Slowdowns mean file access time is delayed, productivity is affected, and the time required to complete a task is increased. A slowdown in a network could cost a company money. Can you imagine the consequences if a slowdown in your network caused a delay in the company's billing?

Network Congestion
A slowdown in network data traffic movement

Bottlenecking
Another term for network congestion

TIA/EIA ratified the CAT5e cabling specification in 1999 to address the continuing need for greater data-handling capacity in computer networks. The enhanced CAT5 cable (CAT5e) provides an improvement in cable performance, and if all components of a cable installation are done according to specification, CAT5e supports full-duplex **Gigabit Ethernet** (1000Mbps Ethernet) using all four wire pairs. **Full-duplex** means that the computer system can transmit and receive at the same time. TIA/EIA ratified the CAT6 cabling specification in June 2002. CAT6 cable provides even better performance and 250MHz of bandwidth, and it maintains backward compatibility with CAT5/5e. CAT6 can support 10Gbps data rates over a distance of less than 100 meters. **CAT6a** supports 10Gbps data rates up to 100 meters. The 10Gbps standard over copper is called **10GBASE-T**.

Gigabit Ethernet
1000Mbps Ethernet

Full-duplex
Refers to the capability to transmit and receive at the same time

CAT6a
A UTP cable standard that supports 10Gbps data rates over a distance of up to 100 meters

10GBASE-T
Twisted-pair copper capable of 10Gbps

Shielded Twisted-Pair Cable

In some applications, a wire screen or metal foil shield is placed around twisted-pair cable. Cable with the addition of a shield is called **STP** (shielded twisted-pair) cable. The addition of this shield reduces the potential for electromagnetic interference (**EMI**) as long as the shield is grounded. EMI originates from devices such as motors and power lines and from some lighting devices, such as fluorescent lights.

STP
Shielded twisted-pair, which has an added shield to reduce the potential for EMI

EMI
Electromagnetic interference, which originates from devices such as motors and power lines and from some lighting devices, such as fluorescent lights

The shield on the twisted-pair cable does not eliminate all potentially interfering noise (EMI), but it does greatly reduce noise interference. There is an active debate in the networking community about whether UTP or STP is superior. It is important to note that the objective of both types of cables is to successfully transport data from the telecommunications closet to the work area. Industry testing on STP cable has shown that the addition of a shield does increase the usable bandwidth of the cable by increasing the noise rejection between each of the wire pairs. However, tests have shown that there is not a significant advantage to placing a shield over a properly installed four-pair 100-ohm UTP cable. In addition, STP is more expensive, and the increased cost may not justify the benefits. For now, most manufacturers are recommending the use of UTP cable for cabling computer networks except in very noisy environments.

Category 7 (CAT7) and Category 8 (CAT8) are both shielded twisted-pair cables. Because they are shielded, they are able to operate at higher bandwidth or frequency. CAT7 can operate up to 600MHz, and can operate up to 1000MHz (that is, 1GHz). Both are capable of supporting 10Gbps up to 100 meters. CAT8 can operate over a operate up to 2000Mhz (that is, 2GHz) and is capable of supporting up to 40Gbps over a distance of 30 meters. This is because copper cabling attenuation in twisted-pair significantly increases with higher frequency. Therefore, the effective length of CAT8 has been reduced and optimized to 30 meters to reduce attenuation. The physical characteristics, cost, and speed of CAT7 and CAT8 make these options suitable for data center cabling.

A common question when selecting twisted-pair cabling is whether to use PVC or plenum. PVC (polyvinyl chloride) is commonly used as a cable insulation or jacket that consists of chemical compounds that emit toxic smoke when burned. Plenum-rated cable has special coating that emits less toxic smoke when burned. It is important to check your local regulations to make sure you install the proper cabling.

Section 2-3 Review

This section covers the following Network+ exam objectives.

1.3 Summarize the types of cables and connectors and explain this is the appropriate type for a solution.

This section presents the various types of UTP cabling used in computer networking.

2.3 Given a scenario, configure and deploy common Ethernet switching features.

This section addresses the concept of duplex operation.

5.2 Given a scenario, troubleshoot common cable connectivity issues and select the appropriate tools.

This section examines the properties of shielded and unshielded twisted-pair cables.

Test Your Knowledge

1. What is the data rate for Fast Ethernet?

    a. 10Mbps

    b. 100Mbps

    c. 1000Mbps

    d. 10Kbps

    e. None of these answers are correct.

2. What type of cable is currently recommended for LAN work areas?

   a. STP
   b. CAT6 STP
   c. CAT 5e UTP
   d. CAT6 UTP
   e. CAT5 UTP

3. What is the benefit of shielded twisted-pair cable?

   a. Ease of installation
   b. Excellent EMI protection
   c. Comparatively inexpensive
   d. Preferred by the industry for all installations
   e. None of these answers are correct.

2-4 TERMINATING TWISTED-PAIR CABLES

This section introduces techniques for terminating high-performance UTP cables. It presents important concepts such as the wiring schemes for T568A and T568B. It also discusses straight-through and crossover cables. Students should understand the importance of properly aligning the TX and RX pairs and the link light. The section concludes with the steps for terminating twisted-pair cable with RJ-45 connectors.

This section introduces techniques for terminating high-performance UTP cables. The standards TIA/EIA 568-B.2 and 568-B.2-1 define the specifications for the copper cabling hardware and copper termination. These standards specify cabling components, transmission media, system models, and the measurement procedures needed for verification of balanced twisted-pair cabling.

Within the TIA/EIA 568-B standard are the wiring guidelines **T568A** and **T568B**, which specify the color of wire that connects to each pin on a connector. The specification of the wire color that connects to each pin is called a **color map**. Table 2-3 shows the color maps specified by the T568A and T568B wiring guidelines.

T568A
Wire color guidelines specified in the TIA/EIA 568-A standard

T568B
Wire color guidelines specified in the TIA/EIA 568-B standard

Color Map
The specification of which wire color connects to each pin on a connector

TABLE 2-3 **The Wiring Color Schemes for T568A and T568B**

Pin Number	T568A Wire Color	T568B Wire Color
1	White–green	White–orange
2	Green	Orange
3	White–orange	White–green
4	Blue	Blue

Pin Number	T568A Wire Color	T568B Wire Color
5	White–blue	White–blue
6	Orange	Green
7	White–brown	White–brown
8	Brown	Brown

Figure 2-7(a) shows the placement of the wire pairs in an RJ-45 modular plug for the T568A standard; Figure 2-7(b) shows the placement of the wire pairs in an RJ-45 modular plug for the T568B standard. The pin numbers for the RJ-45 modular plug are shown at the top of the figure, and a wire color table is provided for reference. In the T568A wire color scheme, as shown in Figure 2-7(a), a white–green wire connects to pin 1, the wire color green connects to pin 2, the wire color connected to pin 3 is white–orange, and so on. Similar information is provided in Figure 2-7(b) for the T568B wiring standard. The color of the wire connected to pin 1 is white–orange, pin 2 is orange, pin 3 is white–green, and so on. This information is also shown in Table 2-3.

What is the difference between T568A and T568B? Basically, these are just two different manufacturer standards used to wire modular connector hardware. There is not a performance improvement with either one; each just specifies a particular color order. The industry tends to favor the T568A wiring order; however, either order can be used, as long as it is maintained throughout the network.

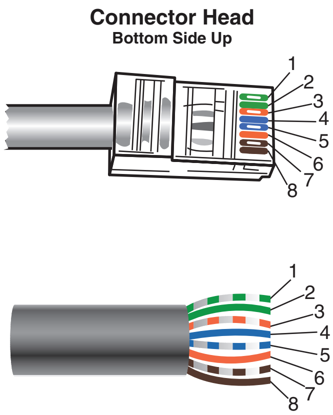
Note

For the Network+ exam, you should be able to describe the difference between the T568A and T568B wire color order. Also make sure you know what wire color configuration you are using in a network (T568A or T568B) and be sure you can specify hardware that is compatible with your selected color scheme.

Any incorrect pinout in either T568A or T568B can lead to a nonfunctioning cable.

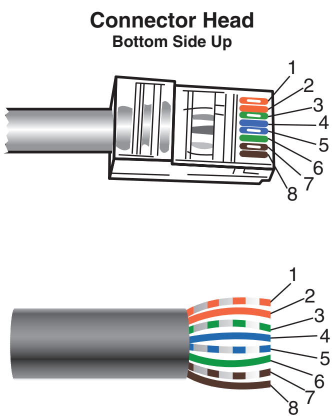
Computer Communication

As mentioned in Section 2-2, "Structured Cabling," CAT8/7/6/5e cable contains four twisted wire pairs. Figure 2-8 provides a picture of the four wire pairs. Figure 2-9 shows the signals and pin number assignments for an RJ-45 plug for CAT5e. Notice in Figure 2-9 that the transmit signals are marked with (+) and (–). The receive (+) and (–) signals are also marked in the same way. The (+) and (–) diagram symbols are typically used to indicate the positive and negative sides of a balanced wire pair. Recall from Section 2-3, "Twisted-Pair Cable," that in a balanced mode of operation, neither signal line is at ground.



#	T568A COLOR
1	White-Green
2	Green
3	White-Orange
4	Blue
5	White-Blue
6	Orange
7	White-Brown
8	Brown

(a)

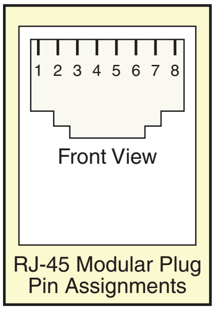


#	T568B COLOR
1	White-Orange
2	Orange
3	White-Green
4	Blue
5	White-Blue
6	Green
7	White-Brown
8	Brown

(b)

FIGURE 2-7 (a) The wiring of an RJ-45 connector and the wire color codes for the T568A standard; (b) the wiring of an RJ-45 connector and the wire color codes for the T568B standard (courtesy of StarTech.com).

FIGURE 2-8 The four wire pairs of CAT6/CAT5e.



Pin No.	Function
Pin 1	Transmit Out +
Pin 2	Transmit Out –
Pin 3	Receive In +
Pin 4	No Connection
Pin 5	No Connection
Pin 6	Receive In –
Pin 7	No Connection
Pin 8	No Connection

FIGURE 2-9 The pin assignments and signal names for an RJ-45 modular plug with CAT5e.

For computers to communicate in a LAN, the transmit and receive pairs must be properly aligned. This means the transmit (**TX**) (+) and (–) pins must connect to the receive (**RX**) (+) and (–) pins, as shown in Figure 2-10. Notice in Figure 2-10 that pins 1–2 of device A connect to pins 3–6 of device B. Pins 1–2 of device B connect to pins 3–6 of device A. This configuration is always valid when the data rates are 10Mbps or 100Mbps.

TX
Abbreviation for transmit

RX
Abbreviation for receive

In a LAN, the proper alignment of the transmit and receive pairs is managed by a switch or hub; it is not typically managed in the cable. Remember that in a star topology, all network communication travels through a switch or hub. An "X" or "uplink" on a switch or hub input port indicates a cross-connected input. This means that transmit and receive pairs are internally swapped to maintain proper signal alignment of the TX and RX pairs. Even if "X" or "uplink" is missing, the switch or hub still properly aligns the TX and RX wire pairs. There is an exception to this on many switches and hubs: Some switches and hubs have an input port that can be selected to be "straight" or "crossed." These ports are typically used in uplink applications when connecting a switch or hub to another switch or hub. If a device has a cross-connected port, a straight-through cable is used because the device is providing the alignment. Just remember that proper alignment of the transmit and receive pair must be maintained in order for the computers to communicate. Also keep in mind that if there is a TX/RX reversal of the wires, you will not see a link light.

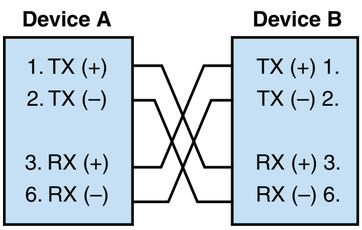


FIGURE 2-10 The proper alignment of the transmit and receive pairs in a CAT6/5e data link operating at 10Mbps or 100Mbps.

There is a difference with the signal names for the UTP cable when operating at 1Gbps and 10Gbps. At these higher data rates, the use of all four wire pairs is required, and the data is bidirectional, which means the same wire pairs are used for both transmitting and receiving data. Figure 2-11 shows the pin assignments and signal names.

Pin	1000Mbps and 10Gbps Color (T568A)	10/100 Mbps	1000Mbps and 10Gbps
1	green/white	TX+	BI_DA+
2	green	TX–	BI_DA–
3	orange/white	RX+	
4	blue	–	BI_DC+
5	blue/white	–	BI_DC–
6	orange	RX–	BI_DB–
7	brown/white	–	BI_DD+
8	brown	–	BI_DD–

(a) The pin assignments and signal names for 1Gbps and 10Gbps (T568A).

Pin	1000Mbps and 10Gbps Color (T568B)	10/100 Mbps Signal	1000Mbps Signal
1	orange/white	TX+	BI_DA+
2	orange	TX–	BI_DA–
3	green/white	RX+	BI_DB+
4	blue	–	BI_DC+
5	blue/white	–	BI_DC–
6	green	RX–	BI_DB–
7	brown/white	–	BI_DD+
8	brown	–	BI_DD–

(b) The pin assignments and signal names for 1Gbps and 10Gbps (T568B).

FIGURE 2-11 The pin assignments and signal names for 1Gbps and 10Gbps (T568A and T568B).

Straight-Through and Crossover Patch Cables

Category 8/7/6/5e twisted-pair cables are used to connect networking components to each other in a network. These cables are commonly called *patch cables*. This section demonstrates a technique for terminating CAT 8/7/6/5e cables with RJ-45 modular plugs for two different configurations of patch cables: a straight-through cable and a crossover cable. In a **straight-through cable**, the four wire pairs connect to the same pin numbers on each end of the cable. For example, pin 1 on one end connects to pin 1 on the other end. Figure 2-12 shows an example of the **wiremap** for a straight-through cable. A wiremap is a graphical or text description of the wire connections from pin to pin for a cable under test. Notice in Figure 2-12 that the transmit and receive pairs connect to the same connector pin numbers at each end of the cable—hence the name *straight,* or *straight-through,* cable.

Straight-Through Cable
A cable in which the wire pairs in the cable connect to the same pin numbers on each end

Wiremap
A graphical or text description of the wire connections from pin to pin

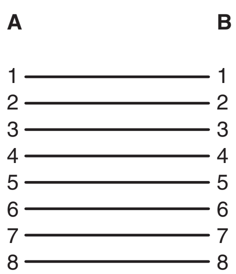


FIGURE 2-12 A wiremap for a straight-through cable.

In some applications in 10/100Mbps data links, it is necessary to construct a cable where the transmit and receive wire pairs are reversed in the cable rather than reversed by a switch or a hub. This cable configuration is called a **crossover cable**, which means the transmit pair of device A connects to the receive pair of device B, and the transmit pair of B connects to the receive pair of A. Figure 2-13 shows the wiremap for a crossover cable.

Crossover Cable
A cable in which the transmit and receive wire pairs are crossed

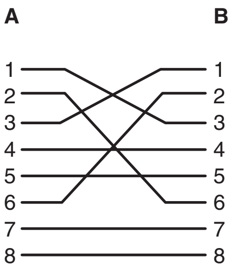


FIGURE 2-13 The wiremap for crossover cable 10/100Mbps links.

Note

The crossover cable diagram shown in Figure 2-13 is for 10/100Mbps. A Gigabit Ethernet crossover cable requires that all four wire pairs be crossed. Although this is possible, it is not practical to make a Gigabit Ethernet crossover cable because of the distance limit on untwisted wire.

Terminating CAT6 Horizontal Link Cable This section presents the steps required for terminating a CAT6 cable using the AMP SL series termination procedure, AMP SL tool, CAT6 cable, and AMP SL Series AMP-TWIST-6S Category 6 modular jacks. In this example, an RJ-45 jack is used to terminate each end of the cable. One end connects to a wall plate in the network work area. The other end terminates into a CAT6 RJ-45 patch panel, which is typically located in a LAN network closet. It is important to document your cable patching using some form of patch management. It is much easier to look up your documentation than to physically go to the site to verify the configuration.

The technical specifications and assembly requirements are more stringent with CAT6 than with earlier cable categories. Therefore, you must take more care when terminating a CAT6 cable. However, advancements in the tools and connectors have actually made it easier to terminate CAT6 compared to using the old punchdown tools.

The steps for terminating the CAT6 horizontal link cables are as follows:

1. Inspect the cable for any damage that might have occurred during installation. Examples of damage to look for include nicked or cut wires and possible stretching of the cable.
2. At the work area outlet end, add about 1 foot extra and cut the wire. (It is good to leave a little extra in case you make an error in installation and have to redo the termination. Remember that you can't splice a CAT6 cable.) Then

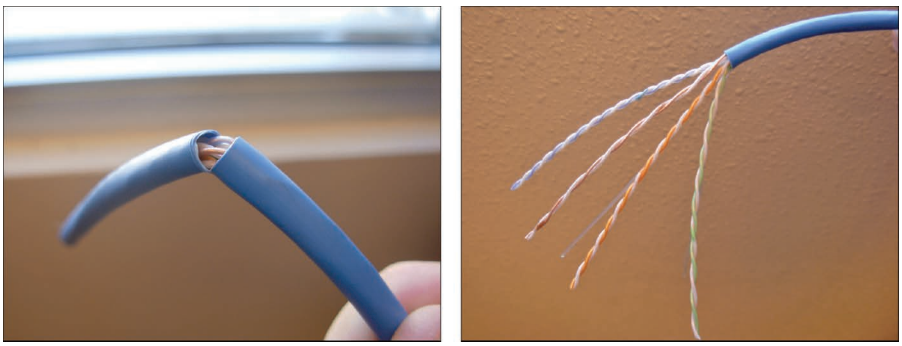
coil the extra cable and insert it in the receptacle box. At the distribution end, route the cable and create a *slack loop*—extra cable looped at the distribution end that is used if the equipment must be moved. In cases where you are having the cable pulled through ductwork or conduit by an installer, make sure to specify that extra cable length will be run. The amount will vary for each installation. In general, allow 5 meters extra in the telecommunications closet and 5 meters extra in the work area.

3. Place a bend-limiting strain-relief boot on the cable, as shown in Figure 2-14(a). (This boot is used in the last step to secure the RJ-45 jack.) Then strip approximately 3 inches of cable jacket from the UTP cable, as shown in Figure 2-14(b). Be careful not to nick or cut the wires as you do this.

(a) **(b)**

FIGURE 2-14 (a) Placing a bend-limiting strain-relief boot on the cable and (b) stripping off 3 inches of jacket from the UTP cable.

4. Remove the jacket from the UTP cable. Bend the cable at the cut, as shown in Figure 2-15(a), and remove the jacket to expose the four wire pairs, as shown in Figure 2-15(b).



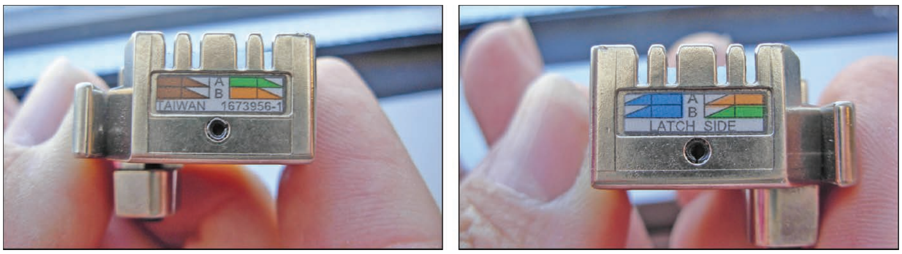
(a) **(b)**

FIGURE 2-15 (a) Separating the cut jacket from the wire pairs and (b) removing the jacket and exposing the four wire pairs.

5. Cut the plastic pull line and the string as shown in Figure 2-16(a). The plastic line adds strength to the cable for pulling, and the string is used to remove extra cable jacket, as needed. Place a lacing fixture on the cable, as shown in Figure 2-16(b), and sort the wires in the correct color order (according to either T568A or T668B) so that you can match up the sorted wire pairs with colors provided on the lacing fixture for T568A and T568B, as shown in Figure 2-17.

(a) (b)

FIGURE 2-16 (a) Removing the plastic pull line and (b) placing the lacing tool on the cable with the color-sorted cable pairs.



(a) (b)

FIGURE 2-17 The sides of the lacing tool, showing the T568A and T568B wire color connections.

6. Place the wires in the slots of the lacing tool, as shown in Figure 2-18, ensuring that the wire colors are in the order (T568A/T568B) displayed on the sides of the lacing tool.
7. Align an RJ-45 jack with the lacing fixture, as shown in Figure 2-19(a). The RJ-45 jack must be properly aligned with the wires on the lacing fixture to maintain proper color order. Figure 2-19(b) provides a close-up picture of the AMP SL series AMP-TWIST-6S modular jack. This picture shows the locations of the displacement connectors on the modulator jack.

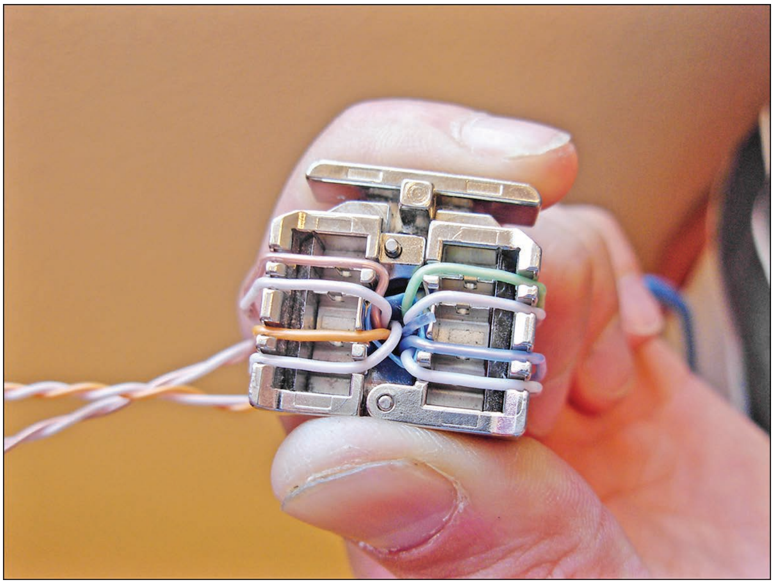
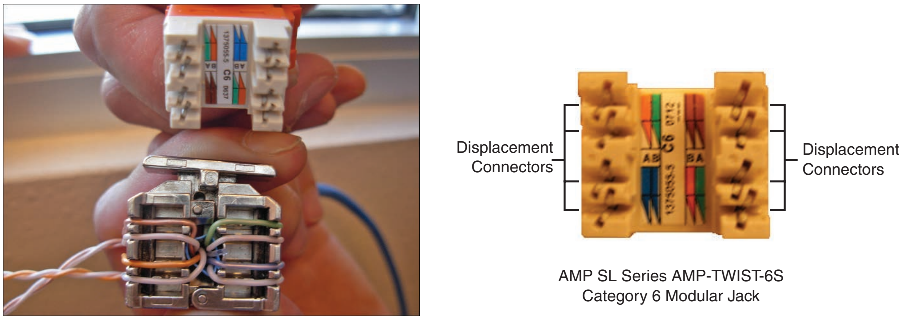


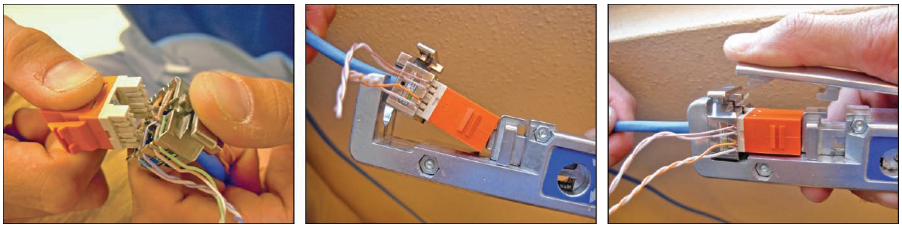
FIGURE 2-18 The routed cable wires on the lacing tool. The wire order shown here is T568B.

8. Insert the RJ-45 modular jack into the AMP SL tool as shown in Figure 2-20(a) and then insert the RJ-45 jack into the AMP SL tool as shown in Figure 2-20(b). Press the wires into the eight displacement connectors on the RJ-45 jack using the AMP SL tool, as shown in Figure 2-20(c). This technique enables you to maintain the pair twist right up to the point of termination. In fact, the untwisted-pair length is less than or equal to 0.25 inch.



(a) (b)

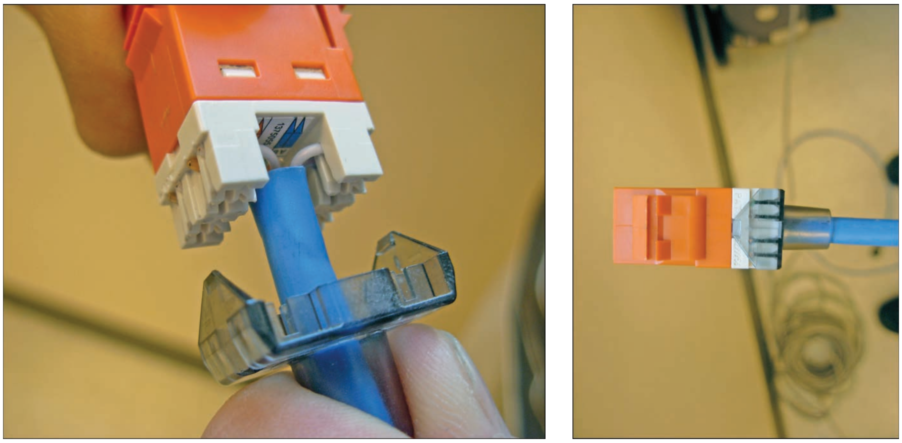
FIGURE 2-19 (a) Aligning the RJ-45 jack and the lacing fixture and (b) a close-up view of the AMP-TWIST-6S CAT6 modular jack.



(a) (b) (c)

FIGURE 2-20 (a) Aligning the RJ-45 jack with the lacing tool, (b) inserting the RJ-45 jack and the lacing tool into the AMP SL tool, and (c) using the AMP SL tool to crimp the RJ-45 jack onto the eight displacement connectors and cut the wires.

9. Connect the bend-limiting strain-relief boot to the RJ-45 jack as shown in Figure 2-21(a). Figure 2-21(b) shows the completed termination.



(a) Connecting the bend-limiting strain relief boot to the RJ-45 jack. **(b) The finished RJ-45 jack termination.**

FIGURE 2-21 (a) Connecting the bend-limiting strain-relief boot to the RJ-45 jack and (b) the finished RJ-45 termination.

Assembling the Straight-Through CAT5e/5 Patch Cable This section presents a technique for assembling a straight-through CAT5e/5 patch cable. In a straight-through patch cable, the wire pairs in the cable connect to the same pin numbers on each end of the CAT5e/5 patch cable. Figure 2-22 shows a CAT5e patch cable with RJ-45 modular plugs.

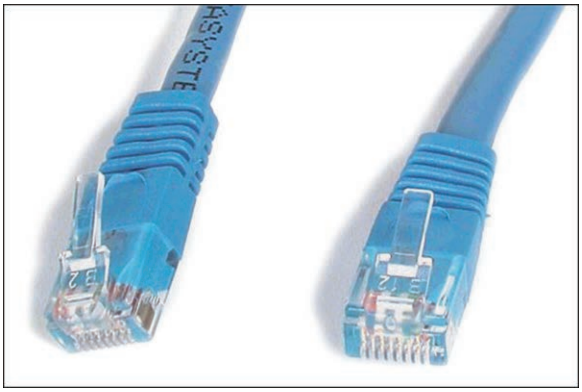


FIGURE 2-22 CAT5e patch cable with RJ-45 modular plugs (courtesy of StarTech.com).

The steps for making a straight-through patch cable are as follows:

1. Inspect the cable for any damage that might have occurred during installation, such as nicked or cut wires or stretching of the cable.
2. Measure the cable to length, add about 6 inches extra, and cut the wire. (It is good to have a little extra in case you make an error in installation and have to redo the termination. Remember that you can't splice CAT5e/5 twisted-pair cable.)
3. Use a cable stripper to strip approximately 0.75 inch of the cable jacket from the end of the cable. (Figure 2-23 illustrates how to use a cable stripper.) Remove the cable insulation by rotating the insulation stripper around the wire until the wire jacket is loose and easily removable. (Note that these cable strippers must be periodically adjusted so that the blade cuts through the outer insulation only. If the blades are set too deep, they will nick the wires, and the process must be repeated after the damaged portion of the cable is cut away. You need to be careful to not nick the insulation.)

FIGURE 2-23 An example of using the cable jacket stripper to remove the insulation.

4. Sort the wire pairs so that they fit into the connector and orient the wire in the proper order for either T568A or T568B, as shown in Figures 2-24(a) and 2-24(b). Be careful to avoid creating a split pair connection (that is, using a wire from one pair and a wire from another pair to make a connection). A split pair connection may create interference and crosstalk problems, thus preventing the cable from passing a certification test. This problem is discussed in Section 2-5, "Cable Testing and Certification."

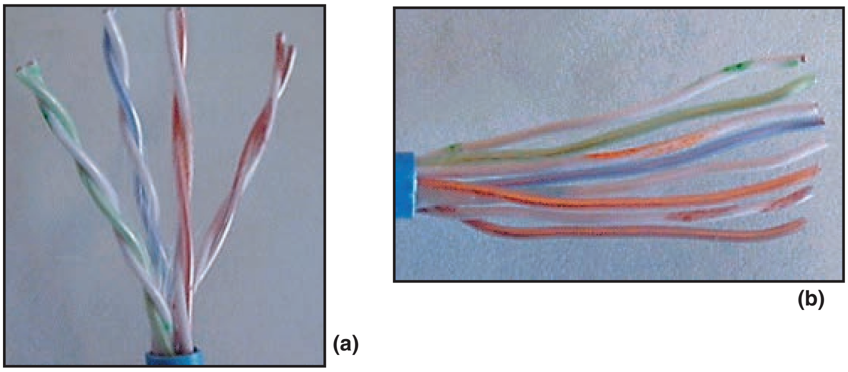


FIGURE 2-24 (a) Separating wire pairs and (b) orienting the wires.

5. Clip the wires so that they are even and insert the wires onto the RJ-45 modular plug, as shown in Figure 2-25.

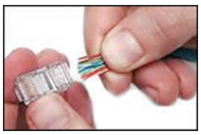
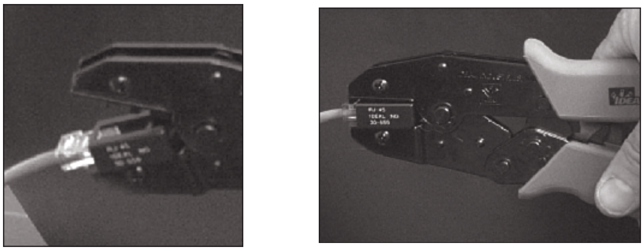


FIGURE 2-25 The clipped wires, ready for insertion into the RJ-45 plug.

6. Push the wires into the connector until you can see the end of each wire through the clear end of the connector. The wires are visible through the plastic connector, as shown in Figure 2-26. Verify that the wire order is correct.
7. Use a crimping tool (also called a crimper) to crimp the wires onto the RJ-45 plug. Insert the RJ-45 plug into the crimping tool until it stops, as shown in Figure 2-27(a). Squeeze the handle on the crimping tool all the way until it clicks and releases, as shown in Figure 2-27(b), to crimp the wire onto the insulation displacement connector pins on the RJ-45 jack.
8. Repeat steps 1–7 for the other end of the twisted-pair cable.

The next step is to test the cable, as discussed in the next section.

FIGURE 2-26 Wires pushed into the RJ-45 plug.



(a) (b)

FIGURE 2-27 (a) Inserting the connector and (b) crimping the connector.

Section 2-4 Review

This section covers the following Network+ exam objectives.

1.3 Summarize the types of cables and connectors and explain which is the appropriate type for a solution.

The termination standards for UTP cable are presented in this section.

1.7 Explain basic corporate and datacenter network architecture.

Remember that you can't splice a CAT6 cable. At the distribution end, you must route the cable and create a slack loop—extra cable looped at the distribution end that is used if the equipment must be moved.

2.1 Compare and contrast various devices, their features, and their appropriate placement on the network.

In some applications in 10/100Mbps data links, it is necessary to construct a cable in which the transmit and receive wire pairs are reversed in the cable rather than by the switch or the hub. This cable configuration is called a crossover cable, which means the transmit pair of device A connects to the *receive pair of device B, and the transmit pair of B connects to the receive pair of A.*

3.3 Explain high availability and disaster recovery concepts and summarize which is the best solution.

This section presents the pin assignments and the signal names for wiring twisted-pair cables. Figure 2-10 shows the proper alignment of the transmit and receive pairs. This is an important concept when configuring cable. This section also covers the concept of a split pair.

5.2 Given a scenario, troubleshoot common cable connectivity issues and select the appropriate tools.

The concept of a crossover cable is presented.

5.3 Given a scenario, use the appropriate network software tools and commands.

At the distribution end, you must route the cable and create a slack loop—extra cable looped at the distribution end that is used if the equipment must be moved.

5.4 Given a scenario, troubleshoot common wireless connectivity issues.

This section discusses a split-pair connection that can create interference and crosstalk problems, thus preventing the cable from passing a certification test.

Test Your Knowledge

1. True or false: The following table shows a color map and pin numbers for T568A.

Pin Number	Wire Color
1	White–green
2	Blue
3	White–orange
4	Green
5	White–blue
6	Orange
7	White–brown
8	Brown

False

2. True or false: The following table shows a color map and pin numbers for T568B.

Pin Number	Wire Color
1	White–orange
2	Orange
3	White–green

Pin Number	Wire Color
4	Blue
5	White–blue
6	Green
7	White–brown
8	Brown

True

3. How many wires are in a CAT5e/6 twisted-pair cable?

   a. 12 wires

   b. 8 wires

   c. 4 wires

   d. 6 wires

2-5 CABLE TESTING AND CERTIFICATION

Link
The point from one cable termination to another

Full Channel
All the link elements from a wall plate to a hub or switch

Attenuation
Also called insertion loss, the amount of loss in signal strength as it propagates down a wire or fiber strand

Near-End Crosstalk (NEXT)
A measure of the level of crosstalk or signal coupling within a cable, with a high NEXT (dB) value being desirable

This section discusses issues and specifications for certifying CAT6 cable. It also examines the parameters that are defined by the TIA/EIA 568-B channel specifications. The specifications presented define the basis for most twisted-pair certification. CAT7 and CAT8 promise improved performance capability, and a good task would be to ask students what is unique about certifying CAT7 or CAT8 cable. Students are likely to say that the cable and the connectors have improved performance specifications—and this is correct. This section concludes with examples of conducting CAT6 cable tests.

The need for increased data rates is pushing the technology of twisted-pair cable to even greater performance requirements and placing greater demands on accurate testing of the cable infrastructure. Twisted-pair copper cable now allows data speeds up to 40Gbps. The TIA/EIA 568-B standard defines the minimum cable specifications for twisted-pair categories.

The CAT8/7/6/5e designations are minimum performance measurements of the cables and the attached terminating hardware, such as RJ-45 plugs, jacks, and patch panels. The **link** (the point from one cable termination to another) and the **full channel** (which consists of all the link elements from the hub or switch to the wall plate) must satisfy minimum **attenuation** loss and **near-end crosstalk (NEXT)** for a minimum frequency of 100MHz. Figure 2-28 provides a graphical representation of the link and the full channel. Table 2-4 lists the CAT5e, CAT6, CAT6a, CAT7, CAT7a, and CAT8 TIA/EIA 568-B channel specifications for UTP cables.

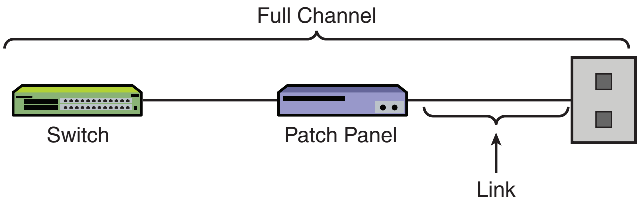


FIGURE 2-28 The link and channel areas for cable testing.

TABLE 2-4 **TIA/EIA 568-B CAT5e, CAT6, CAT6a, CAT7, CAT7a, and CAT8 Channel Specifications at 100 MHz**

Parameter	Category 5e	Category 6	Category 6a	Category 7/7a	Category 8
Class	Class D	Class E	Class EA	Class F/FA	Class I/II
Bandwidth	100MHz	250MHz	500MHz	600MHz/1000MHz	2000MHz
Insertion loss (dB)	24.0	21.3	20.9	20.8/20.3	6.5
NEXT loss (dB)	30.1	39.9	39.9	62.9/65.0	40.5
PSNEXT loss (dB)	27.1	37.1	37.1	59.9/62.0	37.1
ACR (dB)	6.1	18.6	18.6	42.1/46.1	39.74
PSACR (dB)	3.1	15.8	15.8	39.1/41.7	36.74
ACRF1 (ELFEXT) (dB)	17.4	23.3	23.3	44.4/47.4	32
PSELFEXT (dB)	14.4	20.3	20.3	41.1/44.4	32.0
Return loss (dB)	10.0	12.0	12.0	12.0/12.0	16.0
PANEXT loss (dB)*	n/s	n/s	60.0	n/s / 67.0	75
PSAACRF (dB)*	n/s	n/s	37.0	n/s / 52.0	61
TCL (dB)*	n/s	n/s	20.3	20.3/20.3	20
ELTCTL (dB)*	n/s	n/s	0.5	0/0	5
Propagation delay (ns)	548	548	548	548/548	176.8
Delay skew (ns)	50	50	50	30/30	50

*These parameters are discussed in Section 2-6, "10 Gigabit Ethernet over Copper."

The list that follows describes some of the parameters listed in Table 2-4:

- **Attenuation (insertion loss):** This parameter defines the amount of loss in signal strength as the signal propagates down the wire. It is caused by the resistance of the twisted-pair cable, the connectors, and leakage of the electrical signal through the cable insulation. Attenuation also increases with an increase in frequencies due to the inductance and capacitance of the cable. The cable test results will report a margin. Margin for attenuation (insertion loss) is defined as the difference between the measured value and the limit for the test. If the margin shows a negative value, the test has failed. A negative value is produced when the measured value is less than the limit. The limit for attenuation (insertion loss) at 100 MHz for CAT6 is 21.3 dB, for CAT6a is 20.9dB, for CAT7 is 20.8dB, for CAT7a is 20.3dB, and for CAT8 is 6.5dB.

It is also important to note that for UTP cables, there is a limit on how much the cable can be bent. This limit, called the *bend radius*, is four times the outer jacket diameter. Bends exceeding this limit can introduce attenuation loss.

Crosstalk
Signal coupling in a cable

- **NEXT:** When current travels in a wire, an electromagnetic field is created. This field can induce voltage in adjacent wires, resulting in crosstalk. **Crosstalk** is signal coupling within a cable. On analog land-line telephones, users could sometimes faintly hear another conversation; this is where the term crosstalk originated. Near-end crosstalk, or NEXT, is a measure of the level of crosstalk. The measurement of NEXT is called *near-end testing* because the receiver is more likely to pick up the crosstalk from the transmit to the receive wire pairs at the ends. The transmit signal levels at each end are strong, and the cable is more susceptible to crosstalk at this point. In addition, the receive signal levels have been attenuated due to normal cable path loss and are significantly weaker than the transmit signal. A high NEXT (dB) value is desirable.
- Figure 2-29 graphically depicts NEXT. The shaded areas show where the near-end crosstalk occurs. The margin is the difference between the measured value and the limit. A negative number means the measured value is less than the limit, and therefore the measurement fails. Crosstalk is more problematic at higher data rates (for example, 1Gbps, 10Gbps) than at lower rates. Figure 2-30 shows that CAT6 cable has a built-in separator to help minimize crosstalk among wire pairs. This separator is used to keep each wire pair a minimum distance from other wire pairs. This separator reduces crosstalk at higher frequencies and helps provide improved signal bandwidth; the cable therefore supports faster data rates. This separator also helps improve the far-end crosstalk. Note, however, that not all cable manufacturers use separators.

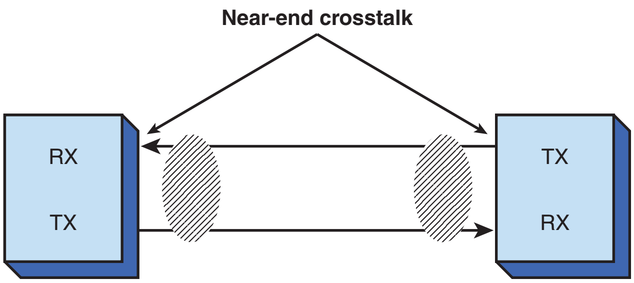


FIGURE 2-29 A graphical depiction of near-end crosstalk.

- **Power-sum NEXT (PSNEXT):** Enhanced twisted-pair cable must meet four-pair NEXT requirements, called PSNEXT testing. Basically, power-sum testing measures the total crosstalk of all cable pairs. This testing ensures that the cable can carry data traffic on all four pairs at the same time with minimal interference. A higher PSNEXT value is desirable because it indicates better cable performance.

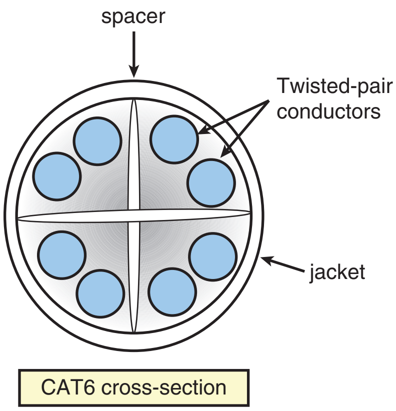


FIGURE 2-30 A cross-section of a CAT6 cable, showing the separator used to minimize crosstalk problems.

- **Equal-level FEXT (ELFEXT):** This measurement differs from NEXT in that it is for the far end of the cable. In addition, the ELFEXT measurement does not depend on the length of the cable. This is because ELFEXT is obtained by subtracting the attenuation value from the far-end crosstalk (FEXT) loss. Higher ELFEXT values (dB) indicate that the signals at the far end of the cable are larger than the crosstalk measured at the far end. A larger ELFEXT (dB) value is desirable. A poor ELFEXT value can result in data loss. Data loss prevention begins with properly terminating your cabling.
- **Power-sum ELFEXT (PSELFEXT):** PSELFEXT uses all four wire pairs to obtain a combined ELFEXT performance measurement. This value is the difference between the test signal level and the crosstalk measured at the far end of the cable. A higher PSELFEXT value indicates better cable performance.
- **Attenaution to Crosstalk Ratio (ACR):** This measurement compares the signal level from a transmitter at the far end to the crosstalk measured at the near end. A larger ACR value indicates that the cable has a greater data capacity and also indicates the cable's ability to handle a greater bandwidth. Essentially, it is a combined measurement of the quality of the cable. A higher ACR value (dB) is desirable.
- **Power-sum ACR (PSACR):** PSACR uses all four wire pairs to obtain the measure of the attenuation/crosstalk ratio. This is a measurement of the difference between PSNEXT and attenuation (insertion loss). The difference is measured in dB, and higher PSACR dB values indicate better cable performance.
- **Return loss:** An important twisted-pair cable measurement is return loss. This measurement provides a measure of the ratio of power transmitted into a cable to the amount of power returned or reflected. The signal reflection is due to impedance changes in the cable link and the impedance changes contributing to cable loss. Cables are not perfect, and there will always be some

reflection. Examples of the causes of impedance changes are non-uniformity in impedance throughout the cable, the diameter of the copper, cable handling, and dielectric differences. A low return loss value (dB) is desirable.

- **Propagation delay:** This is a measure of the amount of time it takes for a signal to propagate from one end of the cable to the other. The delay of the signal is affected by the nominal velocity of propagation (NVP) of the cable. NVP is some percentage of the velocity of light and is dependent on the type of cable being tested. The typical delay value for CAT5/5e UTP cable is about 5.7 ns per meter. The TIA/EIA specification allows for 548 ns for the maximum 100 meter run for CAT5e, CAT6, CAT6a, CAT7, and CAT7a.
- **Delay skew:** This is a measure of the difference in arrival time between the fastest signal and the slowest signal in a UTP wire pair. It is critical in high-speed data transmission that the data on the wire pair arrives at the other end at the same time. If the wire lengths of different wire pairs are significantly different, the data on one wire will take longer to propagate along the wire and arrive at the receiver at a different time and potentially create distortion of the data and data packet loss. The wire pair with the shortest length typically has the least delay skew.

Note

The power-sum measurements are critical for high-speed data communication over UTP. It has also been shown that twisted-pair cable can handle Gigabit data rates over a distance up to 100 meters. However, the Gigabit data rate capability of twisted-pair requires the use of all four wire pairs in the cable, with each pair handling 250Mbps of data. The total bit rate is 4×250Mbps, or 1Gbps—hence the need to obtain the combined performance measurements of all four wire pairs.

Section 2-5 Review

This section covers the following Network+ exam objectives.

3.1 Given a scenario, use the appropriate statistics and sensors to ensure network availability.

As discussed in this section, a larger ACR indicates that the cable has a greater data capacity and also indicates the cable's ability to handle greater bandwidth.

5.2 Given a scenario, troubleshoot common cable connectivity issues and select the appropriate tools.

This section introduces some very important cable concepts. Make sure you have a good understanding of near-end crosstalk, far-end crosstalk, attenuation, and distance limitations.

Test Your Knowledge

1. True or false: A full-channel test involves testing all the link elements from the computer through the patch panel to the wall plate.

   False

2. True or false: NEXT stands for near-end crosstalk, and a low NEXT (dB) value is desirable.

   False

3. True or false: Signals travel in a cable at some percentage of the velocity of light. The term for this is *nominal velocity of propagation*.

   True

2-6 10 GIGABIT ETHERNET OVER COPPER

Even though CAT8 can deliver 40Gbps (40 Gigabit Ethernet), it is not widely adopted in the industry because network equipment is not available to deliver 40Gbps. 10Gbps is the maximum speed over twisted-pair that network equipment can deliver. 40Gbps is more typically available over fiber-ready interfaces. This section focuses on the widely used 10Gbps Ethernet over copper. The increase in the required bandwidth for transporting a Gigabit data transfer rate is placing increased demands on the copper cable as well as the hardware used for terminating the cable ends and for connecting to the networking equipment. Three improvements are required for transmitting the higher data bit rates over copper cabling:

- Improve the cable so it can carry greater bandwidth.
- Improve the electronics used to transmit and receive (recover) the data.
- Utilize improvements in both the cable and electronics to facilitate greater bandwidths and distances

Alien crosstalk (AXT), which is an important issue at higher data rates such as with 10GBASE-T, is unwanted signal coupling from one permanent link to another. Basically, it is the coupling of a signal from one four-pair cable to another four-pair cable. Cable manufacturers are starting to offer CAT6 and higher grades of twisted-pair cable with foil over each of the four wire pairs. The designation for this type of cable is foil twisted-pair (F/UTP). Students should investigate the latest UTP cabling improvements.

Ethernet over copper is available for 10Mbps (Ethernet), 100Mbps (Fast Ethernet), 1000Mbps (Gigabit Ethernet), 10Gbps (10 Gigabit Ethernet), and now 40Gbps (40 Gigabit Ethernet). The increase in the required bandwidth for transporting a 40Gbps data transfer rate is placing greater demands on copper cable as well as the hardware used for terminating the cable ends and for connecting to the networking equipment. Three improvements are required for transmitting the higher data bit rates over copper cabling:

- Improve the cable so it can carry greater bandwidth
- Improve the electronics used to transmit and receive (recover) the data
- Utilize improvements in both the cable and electronics to facilitate greater bandwidths and distance

This section examines the changes in technology that are required to enable 10 Gigabit (10GBASE-T) data transmission over copper. It first presents an overview of 10 Gigabit Ethernet over copper. Then it examines the modifications required to the technical specs (CAT6a and CAT7/7a) for testing and certifying twisted-pair copper cable transporting 10 Gigabit data rates. Finally, this section examines how 10 Gigabit data is actually transmitted.

Overview

IEEE 802.3an-2006 10GBASE-T
The standard for 10Gbps

The standard for 10Gbps is **IEEE 802.3an-2006 10GBASE-T**. This standard was developed to support running 10Gbps data over twisted-pair cabling. It requires the bandwidth to be increased from 250MHz to 500MHz. In addition, this standard supports distances up to 100 meters. At one time, most people assumed that higher data rates would be limited to fiber optics. While that is still true for lengthy runs (over 100 meters), twisted-pair copper is finding a place in the horizontal runs from telecommunications closets to work areas.

Alien Crosstalk

Alien Crosstalk (AXT)
Unwanted signal coupling from one permanent link to another

PSANEXT
Power-sum alien near-end crosstalk

PSAACRF
Power-sum alien attenuation to crosstalk ratio

Alien crosstalk (AXT) is unwanted signal coupling from one permanent link to another; it is an important issue at higher data rates, such as with 10GBASE-T. Basically, AXT is the coupling of a signal from one four-pair cable to another four-pair cable. Figure 2-31 depicts the AXT from one four-pair cable to another four-pair cable. The other key measurements for 10GBASE-T are NEXT (PSANEXT), FEXT (PSAACRF), and return loss. **PSANEXT** (power-sum alien near-end crosstalk) and **PSAACRF** (power-sum alien attenuation to crosstalk ratio) are new measurements for NEXT and FEXT that incorporate measures for AXT. AXT is considered to be the main electrical limiting parameter for 10 Gigabit Ethernet. AXT causes disturbances in the neighboring cable. It is difficult for the electronics to cancel the AXT noise created; therefore, new cables have been developed to support 10Gbps data rates. The newer cables have improved cable separation, and new connector types have also been developed to help meet the required specifications to support 10 Gigabit Ethernet.

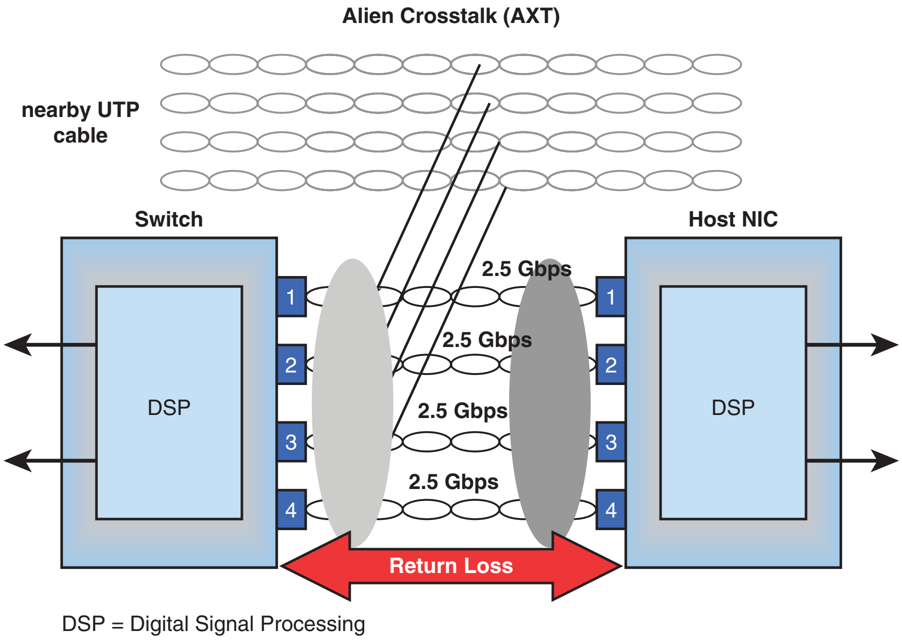


FIGURE 2-31 Alien crosstalk from a neighboring four-pair cable.

Cable manufacturers offer CAT6 and higher grades of twisted-pair cable with foil over each of the four wire pairs. The designation for this type of cable is **F/UTP**. There are two main advantages to using a shielded cable:

- A shielded cable offers better security because there is less chance that the data will radiate outside the cable.
- The foil shield helps improve immunity from EMI, radio frequency interference (RFI), and (most importantly) AXT.

F/UTP
Foil over twisted-pair cabling, a higher grade of twisted-pair cable with foil over each of the four wire pairs

Transmission of data over twisted-pair cabling relies on the signals being "balanced" over the wire pairs. The balance, or symmetry, of the signal over the wire pairs helps minimize unwanted leakage of the signal. Two parameters are defined for CAT6 and better cabling that address the issue of balanced data: **TCL** (transverse conversion loss) and **ELTCTL** (equal-level transverse conversion transfer loss). The TCL measurement is obtained by applying a common-mode signal to the input and measuring the differential signal level on the output. TCL is sometimes called **LCL** (longitudinal conversion loss). The ELTCTL value (expressed in dB) is the difference between the **TCTL** (transverse conversion transfer loss) and the differential mode insertion loss of the pair being measured. TCTL is the loss from a balanced signal at the near end to the unbalanced signal at the far end.

TCL
Transverse conversion loss

ELTCTL
Equal-level transverse conversion transfer loss

LCL
Longitudinal conversion loss

TCTL
Transverse conversion transfer loss

Newer tests include additional power-sum tests, as described earlier in this chapter: PSANEXT (power-sum alien near-end crosstalk) and PSAACRF (power-sum alien attenuation crosstalk ratio far-end). These tests have been developed to help ensure cable compatibility with data transmission and reception that require the use of all four wire pairs. Both Gigabit and 10 Gigabit Ethernet require the use of all four wire pairs.

Signal Transmission

10GBASE-T requires the use of all four wire pairs, as shown in Figure 2-32. This system splits the 10Gbps of data into four 2.5Gbps (that is, 250Mbps) data channels. This same technique is also used for 1000Mbps (that is, 1Gbps) data rates, except that the 1000Mbps signal is split into four 250Mbps data channels. The system requires the use of signal conditioners and digital signal processing (DSP) circuits for both transmission and reception. The data transmission for 10 Gigabit uses a **multilevel encoding** technique, as illustrated in Figure 2-33. The advantage of this type of encoding is that it reduces the bandwidth required to transport data.

Multilevel Encoding
A technique used to reduce the bandwidth required to transport data

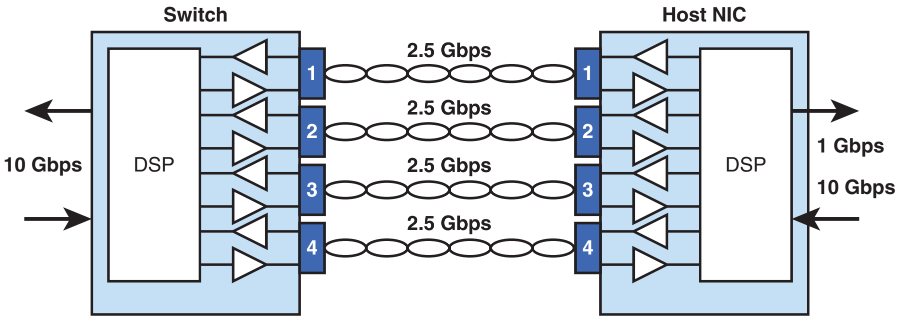


FIGURE 2-32 The four wire pairs in UTP cabling required for transporting 10GBASE-T data. This same technique is used for 1000Mbps, except the data rate for each of the four channels is 250Mbps.

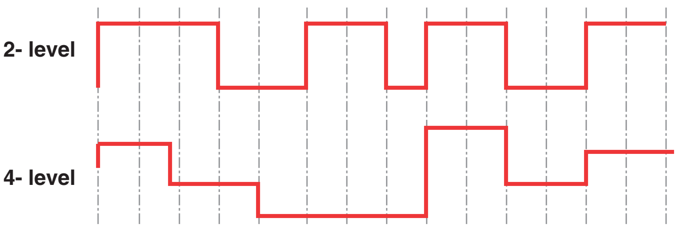


FIGURE 2-33 An example of multilevel encoding of the data streams to reduce the required bandwidth.

10GBASE-T data transmission also requires the use of DSP compensation techniques. The DSP circuitry provides many functions, such as signal conditioning and echo cancellation. Any time a signal is transmitted down a cable, part of the signal is reflected. This reflection adds to overall signal degradation and limits the performance of the system. In 10GBASE-T, the transmit and receive signals share the same wire pair. This is called *full-duplex transmission* and requires the use of a device called a **hybrid echo cancellation circuit**. The hybrid circuit removes the transmitted signal from the receive signal.

Hybrid Echo Cancellation Circuit
A circuit that removes the transmitted signal from the received signal

The final issue with 10GBASE-T signal transmission is the performance of the cable. As mentioned previously, return loss, insertion loss, and crosstalk are all key limiting issues for 10GBASE-T. Crosstalk is the most important factor. The types of crosstalk observed are AXT, NEXT, FEXT, and ELFEXT. The cabling systems that support 10GBASE-T operation with links up to 100 meters are CAT6 with the foil screen, augmented CAT6 (CAT6a), CAT7, and CAT7a.

Section 2-6 Review

This section covers the following Network+ exam objectives.

1.3 Summarize the types of cables and connectors and explain which is the appropriate type for a solution.

This section looks at running data over UTP cable at 10Gbps, based on the 10GBASE-T Ethernet standard. Probably one of the most important concepts associated with 10Gbps over twisted-pair is alien crosstalk (AXT), which is unwanted signal coupling from one permanent link to another.

2.3 Given a scenario, configure and deploy common Ethernet switching features.

In 10GBASE-T, the transmit and receive signals share the same wire pair. This is called full-duplex transmission.

3.1 Given a scenario, use the appropriate statistics and sensors to ensure network availability.

This section introduces multilevel encoding, which is a technique used to reduce the bandwidth required to transport data.

5.2 Given a scenario, troubleshoot common cable connectivity issues and select the appropriate tools.

This section looks at running data over UTP cable at 10Gbps, based on the 10GBASE-T Ethernet standard. One of the most important concepts associated with 10Gbps over twisted-pair is alien crosstalk (AXT), which is unwanted signal coupling.

Test Your Knowledge

1. The term for unwanted signal coupling from one permanent link to another is _____.
   a. near-end crosstalk
   b. alien crosstalk
   c. far-end crosstalk
   d. None of these answers are correct.
2. 10GBASE-T requires the use of which of the following in the transmission of data over UTP?
   a. High data lines
   b. Pins 4–5 and 7–8 only
   c. All four wire pairs
   d. 10 Gigabit is not possible over UTP.

2-7 TROUBLESHOOTING CABLING SYSTEMS

This section presents some test results taken from several CAT6/5e cable tests. The objective is to acquaint students with possible test results and problems they might encounter on the job.

This section examines some of the cable considerations and common issues that a network administrator may face with both CAT6 and CAT5e cable tests. It is important that a network administrator monitor all parts of a cable installation, from pulling to terminating the cable ends. A cable may fail a certification test due to multiple types of problems, such as problems with installation, cable stretching, and the cable failing to meet manufacturer specifications. This section discusses these types of problems and describes how to use certification reports to understand failures of CAT6 and CAT5e cabling.

If you obtain bad power-sum measurements or NEXT or FEXT measurements during network testing, there might be a problem with the installation. The certification report provided in Figure 2-34 indicates that this cable does not pass CAT6 certification, as shown by the X in the upper-right corner of the report. This test indicates a NEXT failure, which is most likely due to a problem at the terminations. This error is commonly due to the installer allowing too much untwisted cable at the termination point. Remember that the twist in UTP cable must be maintained to less than 0.375 inch. This certification test result should prompt you to inspect the terminations to see whether any terminations have too much untwisted cable and verify whether there is a procedure problem with the installation.

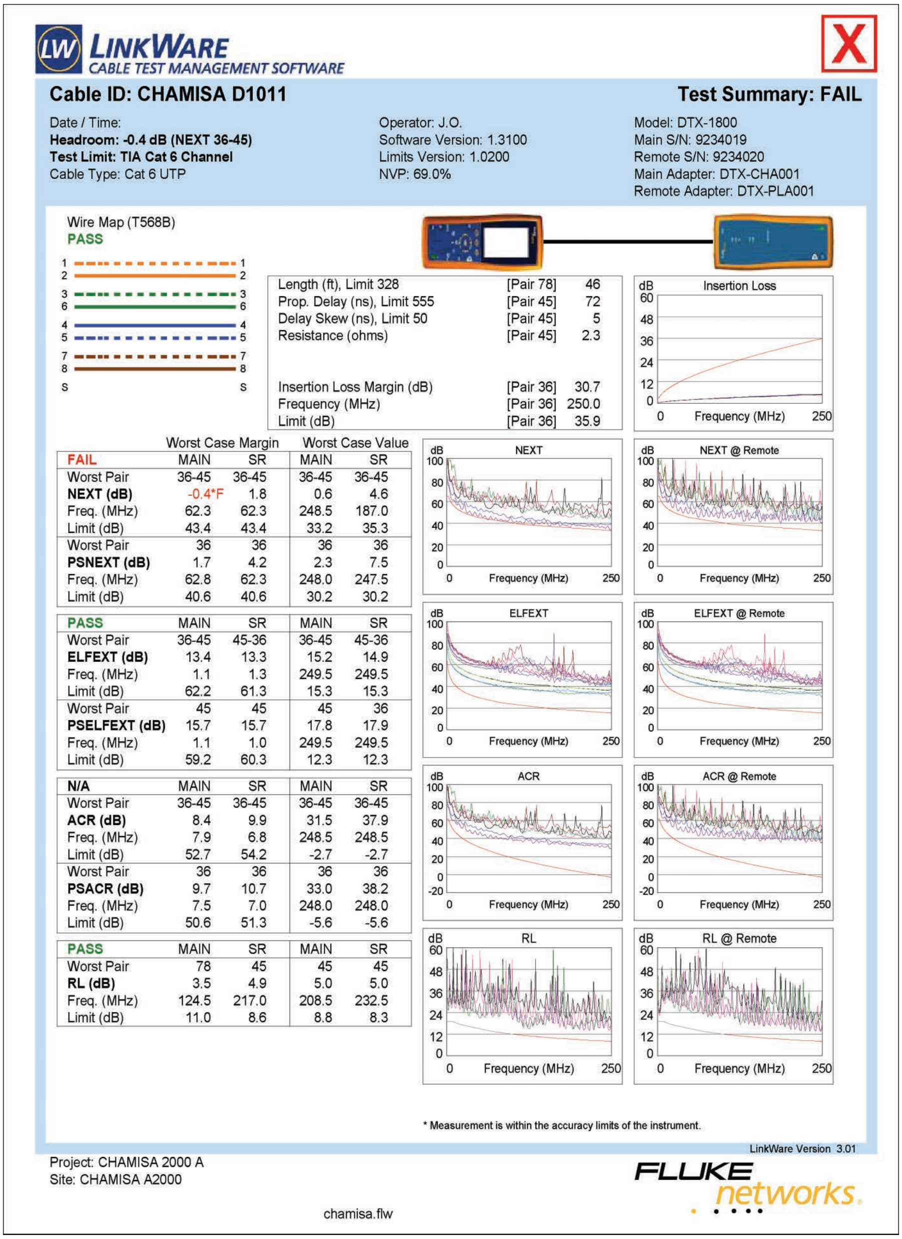
Cable Stretching

It is important to avoid stretching UTP cable because doing so changes the electrical characteristics of the cable, increasing the attenuation and crosstalk. The maximum pulling tension (expressed in lb-ft) is specified in the manufacturer's data sheets.

Cable Failing to Meet Manufacturer Specifications

Occasionally, manufacturers experience problems with cable failing to meet specifications. For example, a bad production run may cause the cable to fail to meet minimum specifications. Repeated test failures with no apparent cause could indicate that the problem is with the cable. This rarely happens, but a bad cable production run could be the culprit. As a network manager, you need to isolate the source of the problem.

Figure 2-35 shows a CAT6 certification report which indicates that the cable failed due to excessive insertion loss. The certification report shows that the cable length for pair 7–8 is 311 feet. The maximum cable length for a permanent link is 295 feet. Therefore, this cable run is too long to be certifiable.



LINKWARE
CABLE TEST MANAGEMENT SOFTWARE

Cable ID: CHAMISA D1011 | **Test Summary: FAIL**

Date / Time:	Operator: J.O.	Model: DTX-1800
Headroom: -0.4 dB (NEXT 36-45)	Software Version: 1.3100	Main S/N: 9234019
Test Limit: TIA Cat 6 Channel	Limits Version: 1.0200	Remote S/N: 9234020
Cable Type: Cat 6 UTP	NVP: 69.0%	Main Adapter: DTX-CHA001
		Remote Adapter: DTX-PLA001

Wire Map (T568B)
PASS

Length (ft), Limit 328	[Pair 78]	46
Prop. Delay (ns), Limit 555	[Pair 45]	72
Delay Skew (ns), Limit 50	[Pair 45]	5
Resistance (ohms)	[Pair 45]	2.3
Insertion Loss Margin (dB)	[Pair 36]	30.7
Frequency (MHz)	[Pair 36]	250.0
Limit (dB)	[Pair 36]	35.9

	Worst Case Margin		Worst Case Value	
FAIL	MAIN	SR	MAIN	SR
Worst Pair	36-45	36-45	36-45	36-45
NEXT (dB)	-0.4*F	1.8	0.6	4.6
Freq. (MHz)	62.3	62.3	248.5	187.0
Limit (dB)	43.4	43.4	33.2	35.3
Worst Pair	36	36	36	36
PSNEXT (dB)	1.7	4.2	2.3	7.5
Freq. (MHz)	62.8	62.3	248.0	247.5
Limit (dB)	40.6	40.6	30.2	30.2
PASS	MAIN	SR	MAIN	SR
Worst Pair	36-45	45-36	36-45	45-36
ELFEXT (dB)	13.4	13.3	15.2	14.9
Freq. (MHz)	1.1	1.3	249.5	249.5
Limit (dB)	62.2	61.3	15.3	15.3
Worst Pair	45	45	45	36
PSELFEXT (dB)	15.7	15.7	17.8	17.9
Freq. (MHz)	1.1	1.0	249.5	249.5
Limit (dB)	59.2	60.3	12.3	12.3
N/A	MAIN	SR	MAIN	SR
Worst Pair	36-45	36-45	36-45	36-45
ACR (dB)	8.4	9.9	31.5	37.9
Freq. (MHz)	7.9	6.8	248.5	248.5
Limit (dB)	52.7	54.2	-2.7	-2.7
Worst Pair	36	36	36	36
PSACR (dB)	9.7	10.7	33.0	38.2
Freq. (MHz)	7.5	7.0	248.0	248.0
Limit (dB)	50.6	51.3	-5.6	-5.6
PASS	MAIN	SR	MAIN	SR
Worst Pair	78	45	45	45
RL (dB)	3.5	4.9	5.0	5.0
Freq. (MHz)	124.5	217.0	208.5	232.5
Limit (dB)	11.0	8.6	8.8	8.3

* Measurement is within the accuracy limits of the instrument.

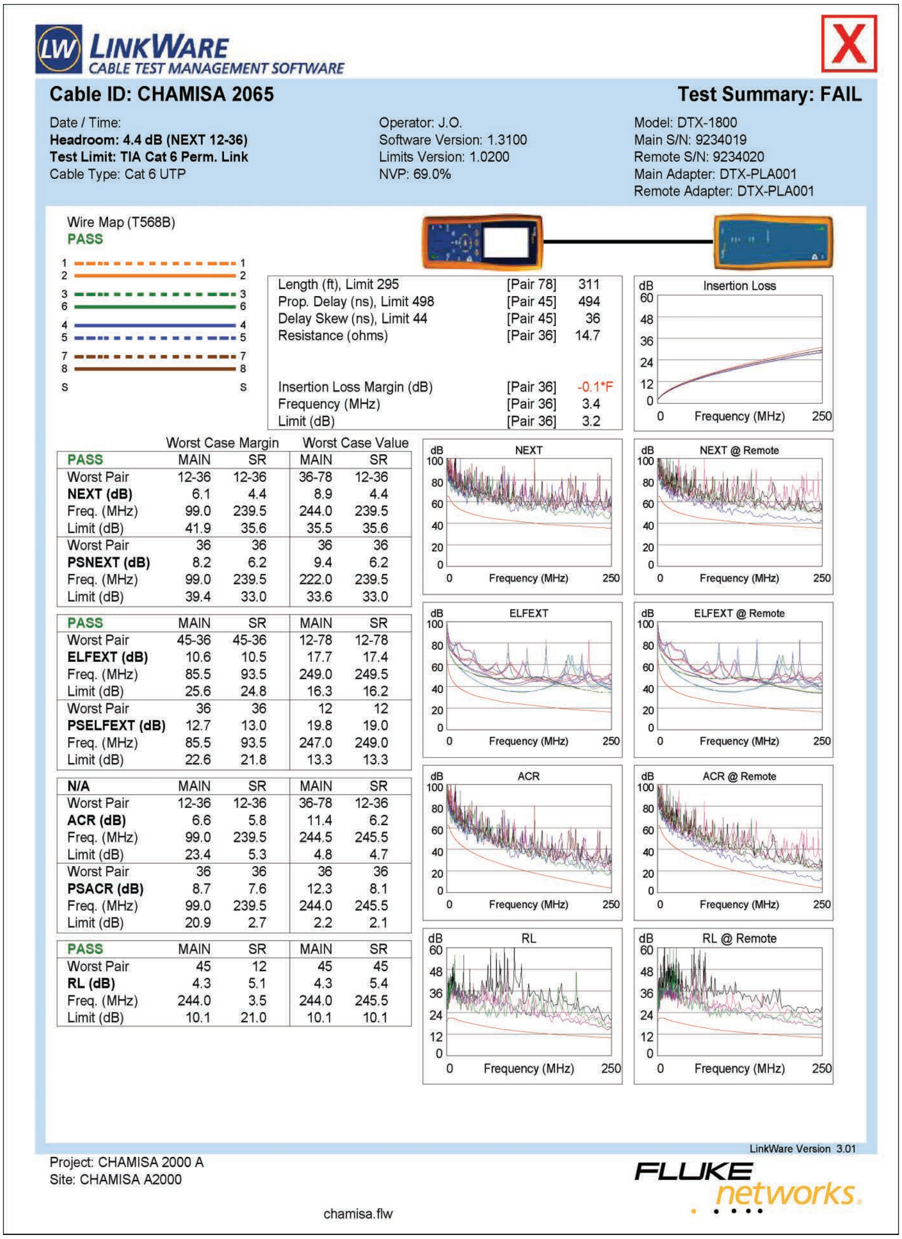
LinkWare Version 3.01

Project: CHAMISA 2000 A
Site: CHAMISA A2000

FLUKE networks.

chamisa.flw

FIGURE 2-34 DTX-1800 certification report: Failure due to a termination problem.



LINKWARE
CABLE TEST MANAGEMENT SOFTWARE

Cable ID: CHAMISA 2065 **Test Summary: FAIL**

Date / Time:
Headroom: 4.4 dB (NEXT 12-36)
Test Limit: TIA Cat 6 Perm. Link
Cable Type: Cat 6 UTP

Operator: J.O.
Software Version: 1.3100
Limits Version: 1.0200
NVP: 69.0%

Model: DTX-1800
Main S/N: 9234019
Remote S/N: 9234020
Main Adapter: DTX-PLA001
Remote Adapter: DTX-PLA001

Wire Map (T568B)
PASS

Length (ft), Limit 295	[Pair 78]	311
Prop. Delay (ns), Limit 498	[Pair 45]	494
Delay Skew (ns), Limit 44	[Pair 45]	36
Resistance (ohms)	[Pair 36]	14.7
Insertion Loss Margin (dB)	[Pair 36]	-0.1*F
Frequency (MHz)	[Pair 36]	3.4
Limit (dB)	[Pair 36]	3.2

	Worst Case Margin		Worst Case Value	
PASS	MAIN	SR	MAIN	SR
Worst Pair	12-36	12-36	36-78	12-36
NEXT (dB)	6.1	4.4	8.9	4.4
Freq. (MHz)	99.0	239.5	244.0	239.5
Limit (dB)	41.9	35.6	35.5	35.6
Worst Pair	36	36	36	36
PSNEXT (dB)	8.2	6.2	9.4	6.2
Freq. (MHz)	99.0	239.5	222.0	239.5
Limit (dB)	39.4	33.0	33.6	33.0
PASS	MAIN	SR	MAIN	SR
Worst Pair	45-36	45-36	12-78	12-78
ELFEXT (dB)	10.6	10.5	17.7	17.4
Freq. (MHz)	85.5	93.5	249.0	249.5
Limit (dB)	25.6	24.8	16.3	16.2
Worst Pair	36	36	12	12
PSELFEXT (dB)	12.7	13.0	19.8	19.0
Freq. (MHz)	85.5	93.5	247.0	249.0
Limit (dB)	22.6	21.8	13.3	13.3
N/A	MAIN	SR	MAIN	SR
Worst Pair	12-36	12-36	36-78	12-36
ACR (dB)	6.6	5.8	11.4	6.2
Freq. (MHz)	99.0	239.5	244.5	245.5
Limit (dB)	23.4	5.3	4.8	4.7
Worst Pair	36	36	36	36
PSACR (dB)	8.7	7.6	12.3	8.1
Freq. (MHz)	99.0	239.5	244.0	245.5
Limit (dB)	20.9	2.7	2.2	2.1
PASS	MAIN	SR	MAIN	SR
Worst Pair	45	12	45	45
RL (dB)	4.3	5.1	4.3	5.4
Freq. (MHz)	244.0	3.5	244.0	245.5
Limit (dB)	10.1	21.0	10.1	10.1

LinkWare Version 3.01

Project: CHAMISA 2000 A
Site: CHAMISA A2000

FLUKE networks.

chamisa.flw

FIGURE 2-35 DTX-1800 certification report: Failure due to excessive insertion loss.

CAT5e Cable Test Examples

This section presents test results for several CAT5e cable tests. There are many CAT5e horizontal cable runs already in place, and these runs support 100Mbps data rates. Therefore, it is important for a network administrator to have a good understanding of how to certify CAT5e links. The goal of this section is to acquaint you with possible CAT5e test results and problems you might encounter on the job. The procedures presented are the same for CAT6 except that the test mode of the cable analyzer must be set to CAT5e performance specifications. The testers used for conducting the CAT5e certification reports in this section are the Fluke OMNIScanner and OMNIRemote.

Test 1 UTP cable testing is not restricted to long cables. Short patch cables (around 3 feet) can and should also be tested. It's a good idea to have a record of even short patch cables meeting CAT5e requirements.

Figure 2-36 shows an OMNIScanner certification report which verifies that the cable passes the CAT5e link test. This report shows that the length of the cable tested is 3 feet.

OMNI Scanner™

PASS

OMNIScanner2 Certification Report

Circuit ID:	Pre-cut	OMNIScanner		OMNIRemote
Project:	TIA Project	50D99L00377	SW: V06.00	50E99L00037
Owner:	OMNISCANNER 2	Adapter		Adapter
Autotest:	*Cat 5E Link*	CHAN 5/5E/6		CHAN 5/5E/6
Cable:	Cat 5E UTP			
NVP:	72			
Site:	Las Cruces			
Building:	Manufacturing			
Floor:	3rd			
Closet:	315A			

	Limit	12	36	45	78
Length ft	(308)	3	3	3	3
Delay (ns):	(518)	4	4	4	4
Resistance (Ohms):	(—)	—	—	—	—

Wiremap	Expected	Actual			
OMNI:	12345678	12345678	Skew (ns):	(45)	0
Remote:	12345678	12345678	Bandwidth (MHz):		—

Attenuation Overall Margin (dB)[1] 19.9

Pairs	dB	Margin	MHz
12	0.3	21.0	97.4
36	0.4	20.1	90.7
45	0.4	21.0	97.4
78	0.3	19.9	88.4

Return Loss Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	23.8	11.4	90.7	23.4	11.2	99.0
36	23.2	10.4	80.8	22.5	10.0	88.9
45	23.1	10.1	74.7	24.2	11.0	70.7
78	23.9	11.5	91.3	24.1	12.0	99.0

NEXT Overall Margin (dB)[1] 3.0

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	62.5	18.7	19.6	61.7	14.0	11.3
12/45	59.2	21.8	48.6	46.6	14.3	99.9
12/78	93.1	33.1	1.2	52.4	20.0	99.2
36/45	50.5	8.6	25.9	45.9	3.0	22.6
36/78	56.0	13.3	23.2	53.5	9.0	18.1
45/78	51.6	14.6	51.6	47.3	14.9	99.0

ACR Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	—	—	—	—	—	—
12/45	—	—	—	—	—	—
12/78	—	—	—	—	—	—
36/45	—	—	—	—	—	—
36/78	—	—	—	—	—	—
45/78	—	—	—	—	—	—

ELFEXT Overall Margin (dB)[1] 15.3

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	60.0	22.0	12.7	60.1	22.1	12.7
12/45	55.3	16.9	12.0	74.6	16.9	1.4
12/78	69.8	30.6	10.9	85.3	30.4	1.9
36/12	60.1	22.1	12.7	60.0	22.0	12.7
36/45	46.1	20.0	49.5	76.8	20.4	1.6
36/78	64.2	28.2	16.0	48.9	28.6	97.4
45/12	74.6	16.8	1.4	73.3	16.9	1.6
45/36	76.7	20.3	1.6	45.9	20.0	51.1
45/78	71.9	15.5	1.6	73.0	15.3	1.4
78/12	85.3	30.4	1.9	69.9	30.6	10.9
78/36	48.8	28.6	97.4	64.2	28.2	16.0
78/45	73.0	15.3	1.4	53.7	15.5	12.4

PSNEXT Overall Margin (dB)[1] 4.9

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	65.7	20.4	10.4	44.8	15.5	99.9
36	49.1	10.3	25.9	44.7	4.9	22.6
45	49.8	11.0	25.9	46.1	6.0	21.9
78	50.4	14.6	39.6	50.6	11.8	26.2

PSELFEXT Overall Margin (dB)[1] 15.5

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	73.6	18.8	1.4	54.2	18.7	12.0
36	75.9	21.2	1.4	75.8	21.1	1.4
45	68.9	15.5	1.6	69.0	15.6	1.6
78	71.7	18.2	1.6	72.8	18.0	1.4

PSACR Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

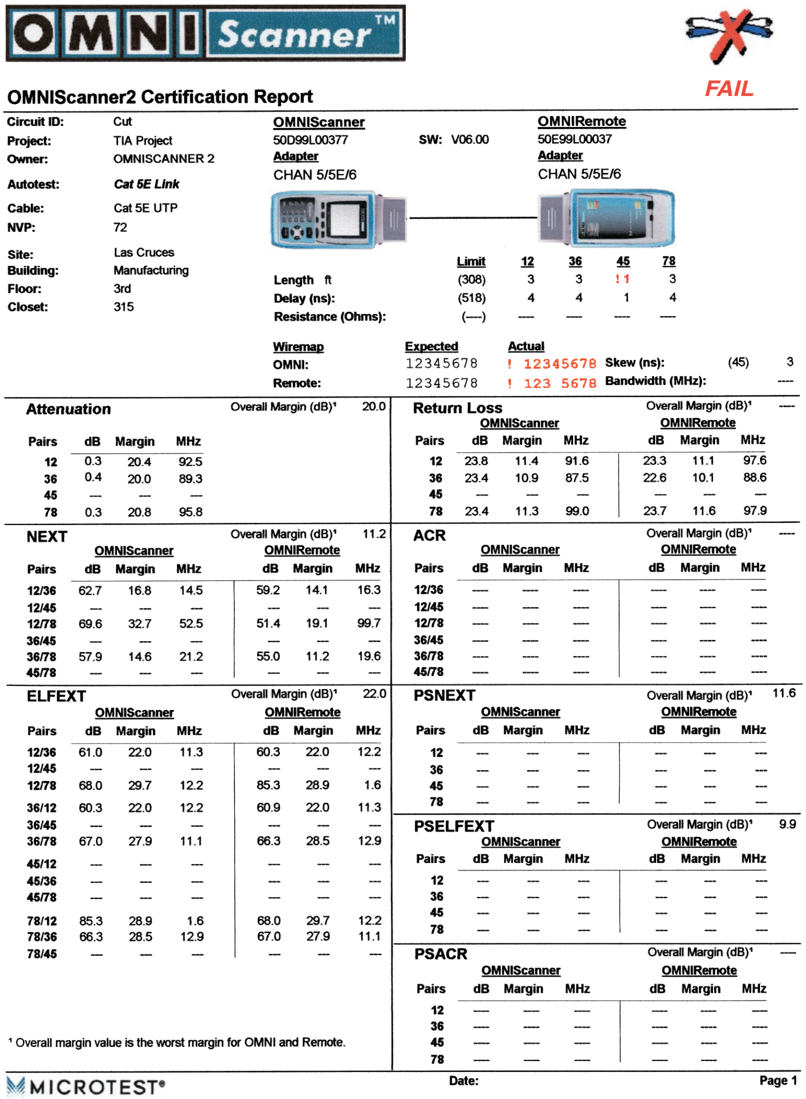
[1] Overall margin value is the worst margin for OMNI and Remote.

MICROTEST® Date: Page 1

FIGURE 2-36 The certification report for Test 1, showing that a short jumper cable passes the CAT5e link test.

Test 2 A second test on the same 3-foot cable used in Test 1 shows that the cable no longer meets CAT5e requirements (see Figure 2-37). The test results indicate FAIL. In this case, careful inspection of the cable shows that it has been cut or nicked. This underscores the importance of documenting the network installation and having a record of the cable link having been certified. Test 1 showed that the cable met specifications, but the cable has since been damaged and no longer meets the CAT5e link specifications.

In this example, the cable has failed a wiremap test. Not only is the text highlighted, but there is an exclamation point preceding the text that indicates a failure. A quick check of the wiremap test shows that the number 4 wire was not detected at the remote.



OMNIScanner™ FAIL

OMNIScanner2 Certification Report

Circuit ID:	Cut	OMNIScanner		OMNIRemote
Project:	TIA Project	50D99L00377	SW: V06.00	50E99L00037
Owner:	OMNISCANNER 2	Adapter		Adapter
Autotest:	*Cat 5E Link*	CHAN 5/5E/6		CHAN 5/5E/6
Cable:	Cat 5E UTP			
NVP:	72			
Site:	Las Cruces			
Building:	Manufacturing			
Floor:	3rd			
Closet:	315			

	Limit	12	36	45	78
Length ft	(308)	3	3	! 1	3
Delay (ns):	(518)	4	4	1	4
Resistance (Ohms):	(—)	—	—	—	—

Wiremap	Expected	Actual
OMNI:	12345678	! 12345678
Remote:	12345678	! 123 5678

Skew (ns): (45) 3
Bandwidth (MHz): —

Attenuation Overall Margin (dB)¹ 20.0

Pairs	dB	Margin	MHz
12	0.3	20.4	92.5
36	0.4	20.0	89.3
45	—	—	—
78	0.3	20.8	95.8

Return Loss Overall Margin (dB)¹ —

Pairs	OMNIScanner dB	Margin	MHz	OMNIRemote dB	Margin	MHz
12	23.8	11.4	91.6	23.3	11.1	97.6
36	23.4	10.9	87.5	22.6	10.1	88.6
45	—	—	—	—	—	—
78	23.4	11.3	99.0	23.7	11.6	97.9

NEXT Overall Margin (dB)¹ 11.2

Pairs	OMNIScanner dB	Margin	MHz	OMNIRemote dB	Margin	MHz
12/36	62.7	16.8	14.5	59.2	14.1	16.3
12/45	—	—	—	—	—	—
12/78	69.6	32.7	52.5	51.4	19.1	99.7
36/45	—	—	—	—	—	—
36/78	57.9	14.6	21.2	55.0	11.2	19.6
45/78	—	—	—	—	—	—

ACR Overall Margin (dB)¹ —

Pairs	OMNIScanner dB	Margin	MHz	OMNIRemote dB	Margin	MHz
12/36	—	—	—	—	—	—
12/45	—	—	—	—	—	—
12/78	—	—	—	—	—	—
36/45	—	—	—	—	—	—
36/78	—	—	—	—	—	—
45/78	—	—	—	—	—	—

ELFEXT Overall Margin (dB)¹ 22.0

Pairs	OMNIScanner dB	Margin	MHz	OMNIRemote dB	Margin	MHz
12/36	61.0	22.0	11.3	60.3	22.0	12.2
12/45	—	—	—	—	—	—
12/78	68.0	29.7	12.2	85.3	28.9	1.6
36/12	60.3	22.0	12.2	60.9	22.0	11.3
36/45	—	—	—	—	—	—
36/78	67.0	27.9	11.1	66.3	28.5	12.9
45/12	—	—	—	—	—	—
45/36	—	—	—	—	—	—
45/78	—	—	—	—	—	—
78/12	85.3	28.9	1.6	68.0	29.7	12.2
78/36	66.3	28.5	12.9	67.0	27.9	11.1
78/45	—	—	—	—	—	—

PSNEXT Overall Margin (dB)¹ 11.6

Pairs	OMNIScanner dB	Margin	MHz	OMNIRemote dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

PSELFEXT Overall Margin (dB)¹ 9.9

Pairs	OMNIScanner dB	Margin	MHz	OMNIRemote dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

PSACR Overall Margin (dB)¹ —

Pairs	OMNIScanner dB	Margin	MHz	OMNIRemote dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

¹ Overall margin value is the worst margin for OMNI and Remote.

MICROTEST® Date: Page 1

FIGURE 2-37 The results for Test 2, showing that the cable failed the CAT5e link test.

Test 3 A third cable test, as shown in Figure 2-38, also generates the test result FAIL. Examination of the attenuation and return loss menu shows that the cable failed to meet CAT5e attenuation and return loss specifications. The permitted attenuation in CAT5e cable is 24 dB. However, the 1–2 and 3–6 pairs have attenuation losses of 38.0 dB and 41.1 dB. Both cases greatly exceed the permitted maximum. An arrow points to these attenuation loss scores.

This cable also fails return loss testing for pairs 1–2 and 3–6. CAT5e cable permits 10 dB of return loss. The report shows that the pairs failed the return loss test at both the OMNIScanner and the OMNIRemote test unit. This cable fails CAT5e certification based on its attenuation or return loss. In fact, this cable also fails the NEXT, ELFEXT, and PSELFEXT tests. Any of these failures is sufficient to prevent this cable from being certified.

Test 4 Figure 2-39 shows the certification report for the cable tested in Test 4. Examination of the certification report shows that the cable failed the delay skew test. This cable exceeds the maximum skew allowed by TIA/EIA 568-B. In addition, this cable fails attenuation, ELFEXT, and PSELFEXT tests. The cable is not certified.

The measured delay skew of 47 ns exceeds the tester setting of 45 ns. However, the TIA/EIA 568-B standard permits a delay skew of 50 ns, so actually this cable meets delay skew requirements for CAT5e cable. Should the cable have been certified? Look at the length measurement for the 3–6 pair length. The cable is 1040 feet (317 meters) long. Remember that the maximum cable length for a CAT5e cable run is 100 meters.

Summary of CAT5e Cable Test Examples You have just seen a few examples of CAT5e link tests that provide actual test data for various cable problems that you might encounter on the job. In the tests where a failure was detected, the tester displays a FAIL screen, and the certification report identifies the problem. The following is a summary of the test results:

- **Test 1:** The certification report shows the test result PASS.
- **Test 2:** The certification report shows the test result FAIL. The report shows that the cable failed the wiremap test.
- **Test 3:** This cable test generated the test result FAIL. Examination of the attenuation and return loss shows that the cable failed to meet CAT5e attenuation and return loss specifications. The cable also failed NEXT, ELFEXT, PSNEXT, and PSELFEXT tests.
- **Test 4:** The certification report shows the cable failing the CAT5e link test. Examination of the report shows that the cable failed the delay skew measurement because the cable length exceeded the 100 meter maximum. The cable also failed the attenuation, ELFEXT, and PSELFEXT tests.

OMNI Scanner™

FAIL

OMNIScanner2 Certification Report

Circuit ID:	Split Pairs
Project:	TIA Project
Owner:	OMNISCANNER 2
Autotest:	***Cat 5E Link***
Cable:	Cat 5E UTP
NVP:	72
Site:	Las Cruces
Building:	Manufacturing
Floor:	3rd
Closet:	315A

OMNIScanner 50D99L00377 **SW:** V06.00
Adapter CHAN 5/5E/6

OMNIRemote 50E99L00037
Adapter CHAN 5/5E/6

	Limit	12	36	45	78
Length ft	(308)	45	45	47	47
Delay (ns):	(518)	64	64	66	67
Resistance (Ohms):	(—)	—	—	—	—

Wiremap	Expected	Actual
OMNI:	12345678	! 12345678
Remote:	12345678	! 12345678

Skew (ns): (45) 3
Bandwidth (MHz): ----

Attenuation

Overall Margin (dB)[1] -19.5

Pairs	dB	Margin	MHz
12	! 38.0	-16.4	99.4
36	! 41.1	-19.5	99.9
45	2.9	18.6	99.2
78	2.9	18.7	99.9

Return Loss

Overall Margin (dB)[1] -5.4

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	! 10.6	-5.3	29.3	! 10.5	-5.3	29.5
36	! 10.4	-5.4	29.8	! 10.6	-5.2	29.3
45	19.4	6.1	68.0	20.8	3.8	1.4
78	20.3	3.3	1.4	21.3	4.3	1.6

NEXT

Overall Margin (dB)[1] -37.7

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	! 22.3	-37.7	1.6	! 11.0	-36.4	11.8
12/45	56.6	5.4	6.8	54.2	3.5	7.3
12/78	69.8	9.9	1.9	70.2	10.9	2.1
36/45	39.4	4.9	74.1	56.1	3.9	5.9
36/78	68.2	9.6	2.3	68.7	9.4	2.1
45/78	59.5	15.5	19.0	57.3	13.2	19.0

ACR

Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	—	—	—	—	—	—
12/45	—	—	—	—	—	—
12/78	—	—	—	—	—	—
36/45	—	—	—	—	—	—
36/78	—	—	—	—	—	—
45/78	—	—	—	—	—	—

ELFEXT

Overall Margin (dB)[1] -30.1

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	! 26.4	-30.1	1.6	! 26.6	-29.9	1.6
12/45	67.8	16.6	2.8	37.2	16.6	93.8
12/78	80.0	22.3	1.4	80.1	22.3	1.4
36/12	! 26.6	-29.9	1.6	! 26.4	-30.1	1.6
36/45	60.8	14.7	5.0	35.4	13.0	76.3
36/78	79.9	22.2	1.4	57.9	21.2	14.7
45/12	! 8.6	-11.4	99.4	! 10.4	-9.6	99.4
45/36	! 1.9	-18.2	99.4	! 5.8	-14.2	99.9
45/78	50.3	15.5	18.3	49.8	15.2	18.7
78/12	! 14.4	-5.6	99.4	! 9.2	-10.9	99.4
78/36	! 10.4	-9.7	99.9	23.3	3.3	99.9
78/45	49.9	15.3	18.7	50.4	15.6	18.3

PSNEXT

Overall Margin (dB)[1] -34.7

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	! 22.2	-34.7	2.1	! 11.0	-33.4	11.8
36	! 22.2	-34.7	2.1	! 11.0	-33.4	11.8
45	53.1	5.3	7.3	52.0	3.7	6.8
78	66.1	9.2	2.1	66.3	9.4	2.1

PSELFEXT

Overall Margin (dB)[1] -27.1

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	! 26.6	-26.8	1.6	! 26.4	-27.0	1.6
36	! 26.4	-27.1	1.6	! 26.6	-26.9	1.6
45	68.9	14.2	1.4	33.6	14.2	76.3
78	72.0	17.3	1.4	72.1	17.4	1.4

PSACR

Overall Margin (dB)[1] ----

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

[1] Overall margin value is the worst margin for OMNI and Remote.

MICROTEST® **Date:** **Page 1**

FIGURE 2-38 The Test 3 CAT5e link test, showing failures with attenuation.

You need to examine test results to find out why a cable has failed a test. You need to know whether the problem is with the terminations, the cable layout, or the way the cable is installed. Keeping a record of the cable tests will help you isolate recurring problems.

OMNIScanner™

FAIL

OMNIScanner2 Certification Report

Circuit ID:	Long Box
Project:	TIA Project
Owner:	OMNISCANNER 2
Autotest:	***Cat 5E Link***
Cable:	Cat 5E UTP
NVP:	72
Site:	Las Cruces
Building:	Manufacturing
Floor:	3rd
Closet:	315

OMNIScanner
50D99L00377 **SW:** V06.00
Adapter
CHAN 5/5E/6

OMNIRemote
50E99L00037
Adapter
CHAN 5/5E/6

	Limit	12	36	45	78
Length ft	(308)	1068	! 1040	1050	1074
Delay (ns):	(518)	1508	! 1469	1482	1516
Resistance (Ohms):	(---)	----	----	----	----

Wiremap	Expected	Actual			
OMNI:	12345678	12345678	**Skew (ns):**	(45)	! 47
Remote:	12345678	12345678	**Bandwidth (MHz):**		----

Attenuation

Overall Margin (dB)[1] -62.1

Pairs	dB	Margin	MHz
12	! 72.7	-52.8	86.4
36	! 74.5	-54.1	89.8
45	! 80.4	-61.5	78.3
78	! 82.4	-62.1	89.1

Return Loss

Overall Margin (dB)[1] 4.9

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	23.2	7.0	26.4	27.4	10.4	2.1
36	25.2	8.2	1.4	23.3	9.1	50.7
45	20.9	4.9	27.5	24.6	7.6	12.9
78	25.4	8.4	2.3	24.6	8.6	28.0

NEXT

Overall Margin (dB)[1] 7.6

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	60.3	13.8	13.6	63.6	13.8	8.4
12/45	44.1	10.1	78.5	53.8	15.7	44.1
12/78	48.4	8.6	34.9	59.6	8.2	6.6
36/45	66.1	8.1	2.5	62.6	7.6	3.9
36/78	45.4	13.0	99.2	69.3	12.4	3.0
45/78	63.8	13.0	7.3	69.4	16.9	5.7

ACR

Overall Margin (dB)[1] ----

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	----	----	----	----	----	----
12/45	----	----	----	----	----	----
12/78	----	----	----	----	----	----
36/45	----	----	----	----	----	----
36/78	----	----	----	----	----	----
45/78	----	----	----	----	----	----

ELFEXT

Overall Margin (dB)[1] -21.1

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	! 5.1	-15.7	91.6	! 7.5	-13.5	89.8
12/45	! 9.6	-11.1	92.5	! 4.4	-17.8	78.3
12/78	! 3.0	-18.0	89.1	! 0.6	-20.4	89.1
36/12	! 13.0	-8.7	83.0	! 11.2	-9.1	96.1
36/45	! 1.4	-20.8	78.3	! 5.6	-16.1	82.8
36/78	! 8.3	-12.6	90.4	! 1.7	-19.4	89.1
45/12	! 7.7	-13.6	86.4	! 8.3	-13.0	86.4
45/36	! 5.4	-16.3	82.8	! 8.1	-13.5	82.8
45/78	! 1.3	-19.0	96.7	! 1.3	-19.7	89.1
78/12	! 8.6	-13.1	83.0	! 6.7	-14.9	83.0
78/36	! 4.7	-16.2	89.8	! 7.6	-13.4	89.8
78/45	! 1.1	-21.1	78.3	! 4.9	-17.2	78.3

PSNEXT

Overall Margin (dB)[1] 9.4

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	47.9	11.1	34.9	59.3	10.8	6.6
36	64.3	10.2	3.0	62.2	10.0	3.9
45	64.7	9.4	2.5	62.1	9.9	3.9
78	58.5	10.7	7.3	59.5	11.0	6.6

PSELFEXT

Overall Margin (dB)[1] -18.4

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	! 5.0	-13.3	86.4	! 6.2	-12.4	83.0
36	! 1.3	-16.5	91.6	! 3.4	-14.6	89.8
45	! 4.3	-14.9	78.3	! 0.7	-18.4	78.3
78	! 0.3	-17.7	89.1	! 0.8	-17.2	90.4

PSACR

Overall Margin (dB)[1] ----

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	----	----	----	----	----	----
36	----	----	----	----	----	----
45	----	----	----	----	----	----
78	----	----	----	----	----	----

[1] Overall margin value is the worst margin for OMNI and Remote.

MICROTEST® **Date:** **Page 1**

FIGURE 2-39 A CAT5e link test, showing failures with delay skew (Test 4).

Tests 1 and 2 demonstrate the importance of keeping a record of tests. In this case, the cable was certified but later failed. The documentation provided by the certification report provides evidence that the cable was functioning properly and did meet CAT5e specifications.

Wired Connectivity and Performance Issues Summary There are many other issues associated with troubleshooting wired connectivity and performance issues, including the following:

- **Open/short:** A cable may have a wire connection that is open or shorted. This issue is most often associated with patch cables and wall plates.
- **Incorrect pin-out:** This error should be easily detected when conducting a wiremap test on a terminated cable. A cable tester provides a visual indicator of the wiremap.
- **Incorrect cable type:** This problem usually occurs when data speeds increase and a cable is not designed to support the higher data rate. In addition, an application might require a shielded twisted-pair cable or a plenum-rated cable. It is important to make sure the proper cable has been used.
- **Bad port:** When troubleshooting, it might be discovered that a port is not "hot," meaning that it is not connecting to the network. You have to make sure the cable to the switch port is connected and the cable link is good. Next, you need to verify that the switch port or wall port is functional. If it isn't, it needs to be replaced.
- **Damaged cables:** This problem is usually associated with cable installation, but it can be associated with patch cables. In either case, a cable tester can be used to identify the problem.
- **Bent pins:** This condition can be associated with connectors on a computer motherboard and with a connector cable such as a DTE V.35 cable or other types of serial cables. If this condition occurs, you can carefully straighten the cable pins with needle-nose pliers.
- **Bad ports:** A poorly terminated UTP plug can be susceptible to RFI that could degrade data transfers and result in poor signal integrity. A bad or broken UTP jack can cause an intermittent network connection.

A useful tool for verifying continuity with cable wiring is a multimeter. This device is used to measure voltage, current, and resistance. A basic multimeter function related to cabling is conducting a continuity check to verify that two ends are connected.

Section 2-7 Review

This section covers the following Network+ exam objectives.

5.2 Given a scenario, troubleshoot common cable connectivity issues and select the appropriate tools.

This section presents several examples of tests and possible problems that might be encountered. Problems may result from poor installation, bad connectors, or bad cable, and a network administrator needs to have good documentation that each cable has been certified, if possible.

Test Your Knowledge

1. True or false: Patch cables are too short to be tested.

   False

2. A UTP certification report lists the following.

Pairs	12	36	45	78
Length	285	288	284	283

   What do these results indicate?

   a. The test must be repeated.
   b. There is not enough information to obtain an answer.
   c. The cable length is too long.
   d. The cable passes the length test.

3. A data problem is reported to the network administrator. The problem is found to be with the UTP network connection. Which steps could the network administrator have taken to isolate the problem? (Select two.)

   a. Visually inspect all UTP terminations.
   b. Run a cable test, using a cable tester.
   c. Use the **ping** command to verify network connectivity.
   d. Use pairs 4–5 and 7–8 to repair the connection.
   e. Contact the installer of the UTP cable to obtain a certification report.

SUMMARY

This chapter introduces the basics of horizontal cabling and unshielded twisted-pair cable. The major topics you should now understand include the following:

- The six subsystems of a structured cabling system
- The purpose of the telecommunications closet and the LAN work area
- The performance capabilities of CAT6/5e UTP
- The wiring color schemes for T568A and T568B
- The pin assignments for an RJ-45 modular plug
- The technical issues of copper over 10 Gigabit Ethernet
- The procedures for testing a CAT6/5e link
- The procedures for troubleshooting a CAT6/5e link
- How to examine and use the test results provided by a CAT6/5e link certification report

QUESTIONS AND PROBLEMS

Section 2-2

1. What is an 8P8C connector?
    a. An RJ-11 connector
    b. An RJ-6 connector
    c. An RJ-45 connector
    d. An RS-232
2. What do EIA and TIA stand for?

    EIA: Electronics Industries Alliance

    TIA: Telecommunication Industry Association
3. What are the three parts of the TIA/EIA 568-B standard?

    TIA/EIA-568-B.1 Commercial Cabling Standard

    TIA/EIA-568-B.2 Twisted-Pair Media

    TIA/EIA-568-B.3 Optical Fiber Cabling Standard
4. Identify the six subsystems of a structured cabling system.
    1. Building entrance
    2. Equipment room
    3. Backbone cabling
    4. Telecommunications closet

5. Horizontal cabling
6. Work area

5. Which subsystem does permanent networking cabling within a building belong to?

   Horizontal cabling

6. What is a cross-connect?

   A cross-connect is a space where one or multiple cables are connected to equipment or other cables.

7. What is the main cross-connect?

   The main cross-connect is the point that usually connects two or more buildings.

8. A telco and an ISP usually connect to what room in the campus network hierarchy?

   Main cross-connect (MC)

9. What is a WO, and what is its purpose?

   A WO is a work area outlet. It is the termination for a horizontal cross-connect.

10. The patch cable from a computer typically terminates into which of the following?

    a. Jack in a wall plate
    b. BNC connector
    c. Thinnet
    d. RJ-11 modular plug
    e. RG-59

11. What is the overall length limitation of an individual cable run from the telecommunications closet to a networking device in the work area?

    100 meters

12. A general rule of thumb is to allow how many meters for the cable run from the telecommunications closet to the work area?

    90 meters

Section 2-3

13. How many pins does an RJ-45 modular plug have?

    8 pins

14. What is the difference between CAT5 and CAT5e?

    CAT5e is an enhanced cable capable of carrying data at a rate of 1000Mbps. CAT5 can carry data at a rate of 100Mbps.

15. What is the data rate for Ethernet?

    10Mbps

16. What is the data rate for Fast Ethernet?

    100Mbps

17. What improvements do CAT6, CAT7, and CAT8 cable provide?

    They provide improved bandwidth, which leads to improved data rates.

18. What is the data rate for Gigabit Ethernet?

    1000Mbps

19. What is a benefit of using shielded twisted-pair cabling?

    The shield reduces the potential for electromagnetic interference (EMI).

20. Which cable type—UTP or STP—is preferred by the industry?

    Testing shows little performance improvement using STP. The additional cable and installation cost do not justify its use in all cases. Therefore, the industry usually recommends the use of UTP cable. However, this can change with higher data rates such as 10Gbps or 40Gbps.

Section 2-4

21. What are the color maps and pin number assignments for T568A and T568B?

Pin Number	T568A Wire Color	T568B Wire Color
1	White–green	White–orange
2	Green	Orange
3	White–orange	White–green
4	Blue	Blue
5	White–blue	White–blue
6	Orange	Green
7	White–brown	White–brown
8	Brown	Brown

22. What is the difference between T568A and T568B?

    T568A and T568B are two different standards for wiring modular connectors.

23. How many wires are in a CAT6 twisted-pair cable?

    8 wires

24. How many wire pairs are in a CAT6 twisted-pair cable?

4 pairs

25. In regard to a CAT6 cable, what pins in an RJ-45 connecter are used to carry data in a Fast Ethernet network?

TX (+)

TX (–)

RX (+)

RX (–)

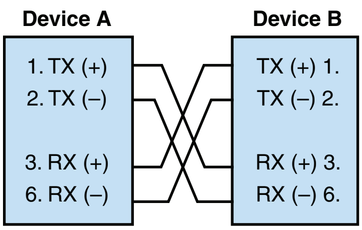
26. What does an "X" on the input to a hub or switch represent?

It indicates a cross-connected input.

27. Define the term *cross-connected input*.

A cross-connected input is an input in which the transmit and receive pairs are internally swapped to maintain proper alignment of the TX and RX pairs.

28. Draw a picture of properly aligned transmit and receive signals for a computer's data link that is running Ethernet data rates.

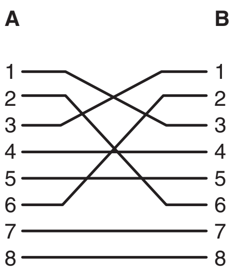


29. What is the difference between straight and cross-connected input ports?

Straight =Tx–Tx Rx–Rx

Crossed = Tx–Rx Rx–Tx

30. Draw the wiremap for a crossover CAT6 UTP cable running Fast Ethernet.



31. What is a UTP link test?

    It is a test that evaluates a cable from one cable termination to another.

32. What is a UTP full channel test?

    It is a test that evaluates all the link elements from a hub or switch through the path panel to the wall plate.

33. What does NEXT stand for, and what does it measure?

    NEXT stands for near-end crosstalk and is a measure of the level of crosstalk within a cable.

34. A NEXT measurement of 59.5 dB is made on wire pairs 1–2 and 3–6. A NEXT measurement of 51.8 dB is made on wire pairs 3–6 and 7–8. Which cable pairs have the best measured NEXT performance?

    1–2 and 3–6 have the best measured NEXT performance because a high NEXT (dB) value is desirable.

35. Define power-sum measurements.

    With power-sum measurements, all four-wire pairs are used to obtain a combined performance measurement.

36. Define propagation delay.

    Propagation delay is the amount of time it takes a signal to propagate from one end of a cable to the other.

37. Signals travel in a cable at some percentage of the velocity of light. What is the term for this?

    Nominal velocity of propagation (NVP)

38. Why is delay skew critical?

    If the wire lengths of different wire pairs are significantly different, then the data on different wires will arrive at the receiver at different times, potentially creating distortion of the data.

39. Why are power-sum measurements critical for high-speed data communication over UTP?

    High-speed data communications (such as Gigabit) require the use of all four-wire pairs, hence the need to obtain the combined performance measurement of all four-wire pairs.

40. Should the expected + loss of a 20-meter UTP cable be greater than or less than that of a 90-meter UTP cable?

    The expected + loss of a 20-meter UTP cable should be less than that of a 90-meter UTP cable.

41. What is 8P8C, and what connector type is most associated with it?

    8P8C is an 8-pin connector. The RJ-45 plug and jack are the most common 8P8C connectors.

42. What are the pin assignments for 1Gbps and 10Gbps?

    Refer to Figure 2-11.

43. What is the purpose of a lacing tool?

    A lacing tool is used to properly align the wires to make sure the untwisted wire is minimized.

Section 2-5

44. What is the limit on the bend radius for a UTP cable, and why is this limit important?

    The limit is four times the diameter of the cable. Bends exceeding this limit can introduce attenuation loss.

45. Is a high PSNEXT measurement desirable?

    Yes. It indicates better cable performance.

46. Define margin (dB) relative to cable measurements. What does it mean if the margin lists a negative value?

    The margin indicates the number of decibels by which the measured value exceeds the limit. A negative value indicates a measurement lower than the limit.

Section 2-6

47. Define alien crosstalk and draw a picture of how it can happen.

    Basically, alien crosstalk (AXT) is an unwanted signal coupling from one four-pair cable to another. See Figure 2-31 for an example of AXT.

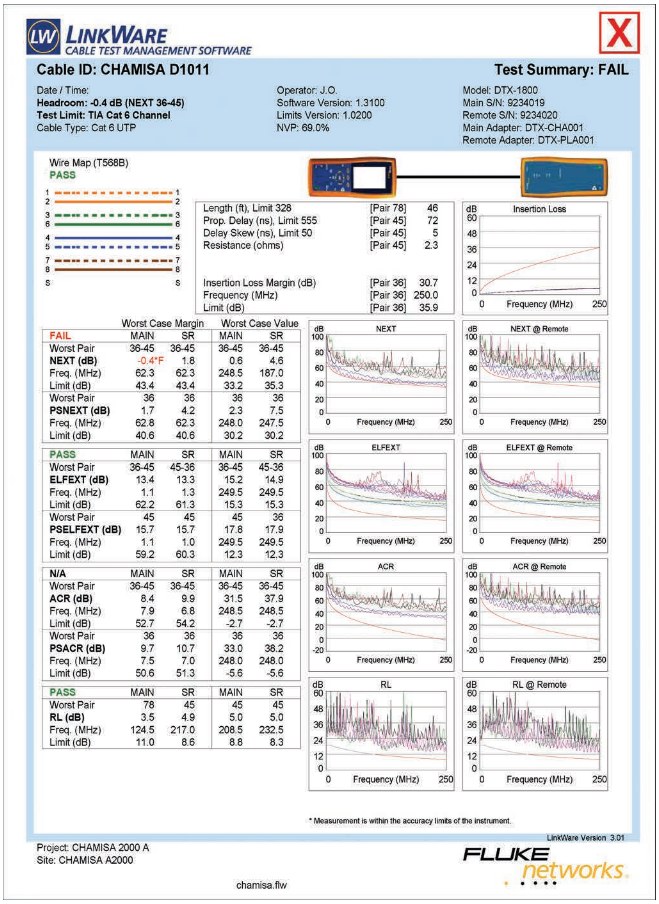
48. What is F/UTP, and what is its purpose?

    F/UTP is foil over twisted-pair cabling, and it provides improved security and noise immunity.

49. Why is balance an issue in UTP cables, and what is TCL?

    The balance or symmetry of the signal over wire pairs helps minimize unwanted leakage of the signal when transmitting Gigabit data rates. TCL, which stands for transverse conversion loss, measures the differential output signal, given a common-mode signal on the input.

50. Answer the following questions related to the certification report shown here.



	Worst Case Margin		Worst Case Value	
FAIL	MAIN	SR	MAIN	SR
Worst Pair	36-45	36-45	36-45	36-45
NEXT (dB)	-0.4*F	1.8	0.6	4.6
Freq. (MHz)	62.3	62.3	248.5	187.0
Limit (dB)	43.4	43.4	33.2	35.3
Worst Pair	36	36	36	36
PSNEXT (dB)	1.7	4.2	2.3	7.5
Freq. (MHz)	62.8	62.3	248.0	247.5
Limit (dB)	40.6	40.6	30.2	30.2
PASS	MAIN	SR	MAIN	SR
Worst Pair	36-45	45-36	36-45	45-36
ELFEXT (dB)	13.4	13.3	15.2	14.9
Freq. (MHz)	1.1	1.3	249.5	249.5
Limit (dB)	62.2	61.3	15.3	15.3
Worst Pair	45	45	45	36
PSELFEXT (dB)	15.7	15.7	17.8	17.9
Freq. (MHz)	1.1	1.0	249.5	249.5
Limit (dB)	59.2	60.3	12.3	12.3
N/A	MAIN	SR	MAIN	SR
Worst Pair	36-45	36-45	36-45	36-45
ACR (dB)	8.4	9.9	31.5	37.9
Freq. (MHz)	7.9	6.8	248.5	248.5
Limit (dB)	52.7	54.2	-2.7	-2.7
Worst Pair	36	36	36	36
PSACR (dB)	9.7	10.7	33.0	38.2
Freq. (MHz)	7.5	7.0	248.0	248.0
Limit (dB)	50.6	51.3	-5.6	-5.6
PASS	MAIN	SR	MAIN	SR
Worst Pair	78	45	45	45
RL (dB)	3.5	4.9	5.0	5.0
Freq. (MHz)	124.5	217.0	208.5	232.5
Limit (dB)	11.0	8.6	8.8	8.3

a. What is the length of pair 7–8?

46 feet

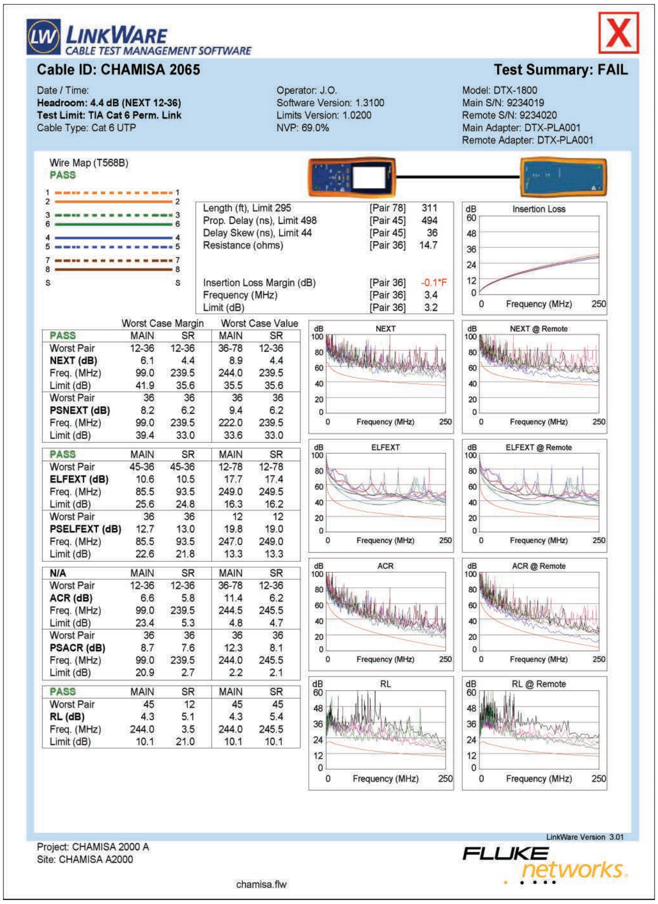
b. What is the length of pair 4–5?

72 feet

c. Why did this cable fail the test?

It failed the NEXT measurement.

51. Answer the following questions related to the certification report shown here.



LINKWARE CABLE TEST MANAGEMENT SOFTWARE

Cable ID: CHAMISA 2065 — **Test Summary: FAIL**

Date / Time:
Headroom: 4.4 dB (NEXT 12-36)
Test Limit: TIA Cat 6 Perm. Link
Cable Type: Cat 6 UTP

Operator: J.O.
Software Version: 1.3100
Limits Version: 1.0200
NVP: 69.0%

Model: DTX-1800
Main S/N: 9234019
Remote S/N: 9234020
Main Adapter: DTX-PLA001
Remote Adapter: DTX-PLA001

Wire Map (T568B)
PASS

Length (ft), Limit 295	[Pair 78]	311
Prop. Delay (ns), Limit 498	[Pair 45]	494
Delay Skew (ns), Limit 44	[Pair 45]	36
Resistance (ohms)	[Pair 36]	14.7
Insertion Loss Margin (dB)	[Pair 36]	-0.1*F
Frequency (MHz)	[Pair 36]	3.4
Limit (dB)	[Pair 36]	3.2

	Worst Case Margin		Worst Case Value	
PASS	MAIN	SR	MAIN	SR
Worst Pair	12-36	12-36	36-78	12-36
NEXT (dB)	6.1	4.4	8.9	4.4
Freq. (MHz)	99.0	239.5	244.0	239.5
Limit (dB)	41.9	35.6	35.5	35.6
Worst Pair	36	36	36	36
PSNEXT (dB)	8.2	6.2	9.4	6.2
Freq. (MHz)	99.0	239.5	222.0	239.5
Limit (dB)	39.4	33.0	33.6	33.0
PASS	MAIN	SR	MAIN	SR
Worst Pair	45-36	45-36	12-78	12-78
ELFEXT (dB)	10.6	10.5	17.7	17.4
Freq. (MHz)	85.5	93.5	249.0	249.5
Limit (dB)	25.6	24.8	16.3	16.2
Worst Pair	36	36	12	12
PSELFEXT (dB)	12.7	13.0	19.8	19.0
Freq. (MHz)	85.5	93.5	247.0	249.0
Limit (dB)	22.6	21.8	13.3	13.3
N/A	MAIN	SR	MAIN	SR
Worst Pair	12-36	12-36	36-78	12-36
ACR (dB)	6.6	5.8	11.4	6.2
Freq. (MHz)	99.0	239.5	244.5	245.5
Limit (dB)	23.4	5.3	4.8	4.7
Worst Pair	36	36	36	36
PSACR (dB)	8.7	7.6	12.3	8.1
Freq. (MHz)	99.0	239.5	244.0	245.5
Limit (dB)	20.9	2.7	2.2	2.1
PASS	MAIN	SR	MAIN	SR
Worst Pair	45	12	45	45
RL (dB)	4.3	5.1	4.3	5.4
Freq. (MHz)	244.0	3.5	244.0	245.5
Limit (dB)	10.1	21.0	10.1	10.1

LinkWare Version 3.01
Project: CHAMISA 2000 A
Site: CHAMISA A2000
chamisa.flw
FLUKE networks

a. What is the length of wire pair 7–8?

311 feet (which exceeds the maximum length for a permanent link)

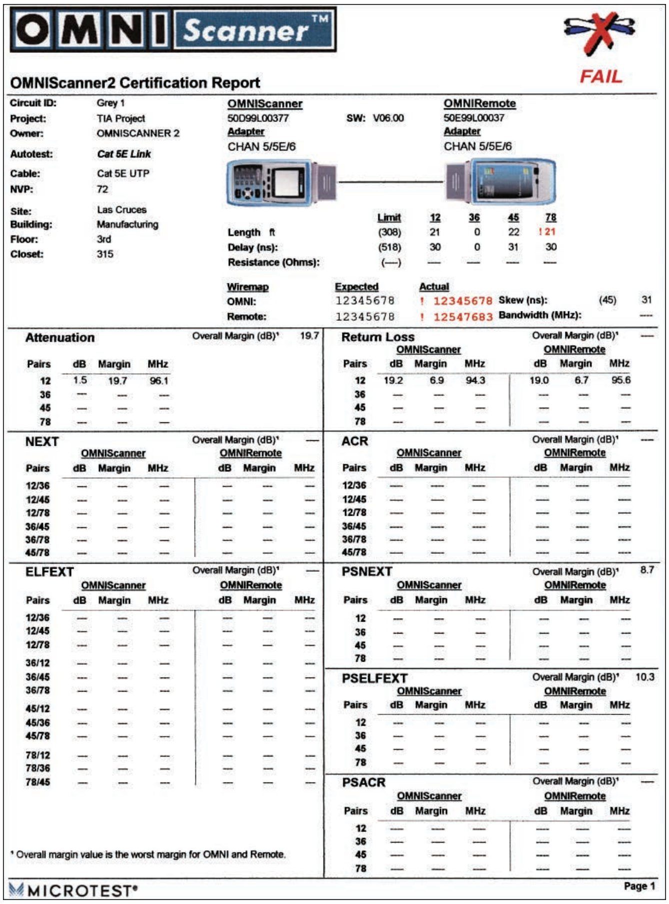
b. What is the delay skew for pair 4–5?

36 ns

c. Why did this cable fail the wiremap test?

The cable is too long.

52. Answer the following questions related to the certification report shown here.



OMNIScanner2 Certification Report — FAIL

Circuit ID:	Grey 1	OMNIScanner	OMNIRemote
Project:	TIA Project	50D99L00377 SW: V06.00	50E99L00037
Owner:	OMNISCANNER 2	Adapter	Adapter
Autotest:	*Cat 5E Link*	CHAN 5/5E/6	CHAN 5/5E/6
Cable:	Cat 5E UTP		
NVP:	72		
Site:	Las Cruces		
Building:	Manufacturing		
Floor:	3rd		
Closet:	315		

	Limit	12	36	45	78
Length ft	(308)	21	0	22	! 21
Delay (ns):	(518)	30	0	31	30
Resistance (Ohms):	(—)	—	—	—	—

Wiremap	Expected	Actual			
OMNI:	12345678	! 12345678	Skew (ns):	(45)	31
Remote:	12345678	! 12547683	Bandwidth (MHz):		—

Attenuation — Overall Margin (dB)[1] 19.7

Pairs	dB	Margin	MHz
12	1.5	19.7	96.1
36	—	—	—
45	—	—	—
78	—	—	—

Return Loss — Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	19.2	6.9	94.3	19.0	6.7	95.6
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

NEXT — Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	—	—	—	—	—	—
12/45	—	—	—	—	—	—
12/78	—	—	—	—	—	—
36/45	—	—	—	—	—	—
36/78	—	—	—	—	—	—
45/78	—	—	—	—	—	—

ACR — Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	—	—	—	—	—	—
12/45	—	—	—	—	—	—
12/78	—	—	—	—	—	—
36/45	—	—	—	—	—	—
36/78	—	—	—	—	—	—
45/78	—	—	—	—	—	—

ELFEXT — Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12/36	—	—	—	—	—	—
12/45	—	—	—	—	—	—
12/78	—	—	—	—	—	—
36/12	—	—	—	—	—	—
36/45	—	—	—	—	—	—
36/78	—	—	—	—	—	—
45/12	—	—	—	—	—	—
45/36	—	—	—	—	—	—
45/78	—	—	—	—	—	—
78/12	—	—	—	—	—	—
78/36	—	—	—	—	—	—
78/45	—	—	—	—	—	—

PSNEXT — Overall Margin (dB)[1] 8.7

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

PSELFEXT — Overall Margin (dB)[1] 10.3

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

PSACR — Overall Margin (dB)[1] —

	OMNIScanner			OMNIRemote		
Pairs	dB	Margin	MHz	dB	Margin	MHz
12	—	—	—	—	—	—
36	—	—	—	—	—	—
45	—	—	—	—	—	—
78	—	—	—	—	—	—

[1] Overall margin value is the worst margin for OMNI and Remote.

MICROTEST® Page 1

a. Why did the cable fail the test?

There are multiple errors with cable wiring.

b. Draw the wiremap diagram for this cable.

1–1 5–7

2–2 6–6

3–5 7–8

4–4 8–3

Section 2-7

53. A data problem is reported to the network administrator. The problem is found to be with the UTP network connection. What steps could the network administrator have taken to isolate the problem? (Select two.)

    a. Visually inspect all UTP terminations.
    b. Run a cable test using a cable tester.
    c. Use the **ping** command to verify network connectivity.
    d. Use pairs 4–5 and 7–8 to repair the connection.
    e. Contact the installer of the UTP cable to obtain a certification report.

Certification Questions

54. A NEXT measurement of 59.5 dB is made on wire pairs 1–2 and 3–6. A NEXT measurement of 51.8 dB is made on wire pairs 3–6 and 7–8. True or false: Pairs 3–6 and 7–8 have the best NEXT performance measurement.

    a. True
    b. False

55. True or false: In regard to CAT5e/CAT6 cable operating in half-duplex mode for Ethernet or Fast Ethernet, pins 1–2 and 3–6 are used to carry the data.

    a. True
    b. False

56. True or false: A CAT5e/6 link test tests from one termination to another.

    a. True
    b. False

57. True or false: Only two wire pairs are used to obtain a proper power-sum measurement.

    a. True
    b. False

58. True or false: Delay skew is critical because if the wire lengths of different wire pairs are significantly different, the data will arrive at the receiver at different times, potentially creating distortion of the data.

    a. True
    b. False

59. Permanent networking cabling within a building ____.

    a. is vertical cabling
    b. belongs to the work area
    c. belongs to the equipment room
    d. None of these answers are correct.

60. How many pins does an RJ-45 modular plug have?

   a. 4
   b. 6
   c. 8
   d. 16
   e. None of these answers are correct.

61. Which of the following best defines horizontal cabling?

   a. Cabling that extends out from the telecommunications closet into the LAN work area
   b. Cabling that extends out from the work area into the LAN
   c. Cabling that extends out from the backbone into the LAN work area
   d. Cabling that extends out from the equipment room into the LAN work area
   e. None of these answers are correct.

62. A UTP certification report lists the following.

Pair	12	36	45	78
Length	! 310	308	! 311	307

   What do these results indicate?

   a. The cable fails the certification test.
   b. Pairs 3–6 and 7–8 will be certified.
   c. Pairs 1–2 and 4–5 will be certified.
   d. The cable passes the certification test.
   e. The ! sign indicates that the cable pair meets or exceeds power-sum test criteria.

63. The length difference in wire pairs for UTP ____.

   a. indicates that the cable should not be certified
   b. indicates that the cable should be certified
   c. is due to the difference in the cable twists for each wire pair
   d. is due to poorly manufactured cable