

Professor Messer's  
**CompTIA A+**  
**CORE 1** 220-1101  
Course Notes

James "Professor" Messer

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## **CompTIA 220-1101 Core 1**

### **A+ Course Notes**

*James "Professor" Messer*



<http://www.ProfessorMesser.com>

## **Professor Messer's CompTIA 220-1101 Core 1 A+ Course Notes**

Written by James "Professor" Messer

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## Introduction

The CompTIA A+ certification requires a broad set of knowledge, and it covers more topics than many industry certifications. It's no surprise that the A+ certification has become one of the most sought-after industry certifications by both aspiring technologists and employers.

I hope this book helps you with your “last mile” of studies before taking your exam. There’s a lot to remember, and perhaps some of the information in this book will help jog your memory while you’re sitting in the exam room. Best of luck with your studies!

- Professor Messer

## The CompTIA A+ Certification

CompTIA’s A+ certification is considered to be the starting point for information technology professionals. Earning the A+ certification requires the completion of two exams and covers a broad range of technology topics. After earning the CompTIA A+ certification, an A+ certified professional will have an understanding of computer hardware, mobile devices, networking, operating systems, security techniques, and much more.

The current series of the A+ certification is based on the successful completion of the 220-1101 and the 220-1102 exams. You must pass both exams to earn your CompTIA A+ certification. This book provides a set of notes for the 220-1101 Core 1 exam.

### The 220-1101 Core 1 exam

Much of the 220-1101 exam is about hardware, but that’s only about a third of the overall exam content. You’ll also need to know about networking, mobile devices, and how to troubleshoot all of these technologies.

Here’s the breakdown of each domain on the 220-1101 exam:

Domain 1.0 - Mobile Devices - 15%

Domain 2.0 - Networking - 20%

Domain 3.0 - Hardware - 25%

Domain 4.0 - Virtualization and Cloud Computing - 11%

Domain 5.0 - Hardware and Network Troubleshooting - 29%

## Study Tips

### Exam Preparation

- Download the exam objectives, and use them as a master checklist:  
<https://www.ProfessorMesser.com/objectives>
- Use as many training materials as possible. Books, videos, and Q&A guides can all provide a different perspective of the same information.
- It's useful to have as much hands-on as possible, especially with network troubleshooting and operating system command prompts.

### Taking the Exam

- Use your time wisely. You've got 90 minutes to get through everything.
- Choose your exam location carefully. Some sites are better than others.
- Get there early. Don't stress the journey.
- Manage your time wisely. You've got 90 minutes to get through everything.
- Wrong answers aren't counted against you. Don't leave any blanks!
- Mark difficult questions and come back later. You can answer the questions in any order.



## 1.1 - Laptop Hardware

### Laptop hardware

- Engineered to precise specifications
  - A challenging repair
- Some laptops are easier to fix than others
  - An ongoing learning process
- Understand the process
  - The details will vary between laptop manufacturers

### Laptop batteries

- The power source when unplugged
  - May be easily replaced or require a tear down
  - Five minutes vs. one hour
- Lithium-Ion (Li-ion) and
  - Lithium-Ion polymer (LiPo) are common
  - No “memory effect”
  - Charging the battery diminishes capacity
- Different form factor for each laptop
  - Battery types and styles can vary
  - Battery technology is changing constantly

### Laptop keyboard

- The most-used component of the laptop
  - Can be easy to replace
  - A few screws and a single ribbon cable
  - May not always be this simple
- Or connect an external USB keyboard
  - Not very portable, but works in a pinch

### Laptop keys

- Some repairs might require the removal or replacement of a key cap
  - This can be a delicate procedure
- Check with the manufacturer's instructions
  - It's very easy to accidentally break the key cap or the components underneath

### Laptop memory

- Small Outline Dual In-line Memory Module (SO-DIMM)
- Memory used in laptops and mobile devices
  - Often easy to install and replace
- Some laptop memory is soldered to the system board
  - No upgrade available
  - Requires a full system board replacement

### Laptop storage

- Magnetic disk
  - Traditional spinning drive platters
  - 2.5 form factors (3.5 inch for desktops)

- SSD (Solid-state drive)
  - All memory, no moving parts
  - Silent, fast access time, less latency
  - 2.5 inch form factors
- M.2
  - Smaller form factor
  - No SATA data or power cables
  - Easy to install and replace

### Replacing laptop storage

- All internal
  - Open a cover on the back
  - Open the entire laptop
- Can be very modular
  - Two screws and the drive slides out
- M.2 drives are even easier
  - One screw - similar to RAM installation

### Migrating from HDD to SSD

- An impressive upgrade
  - Move from spinning mechanical drive to solid state memory
  - It's almost like getting a new laptop
- Install an OS on the SSD
  - Move user documents between drives
  - Install any required applications
  - Can be time consuming
- Image/clone the HDD
  - No OS installation required
  - Move everything from one to the other
- Imaging software needed
  - Sometimes included with the SSD
  - Many commercial and open source options
- Create an image file - One drive at a time
- Drive-to-drive image
  - Image directly from one drive to the other

### 802.11 wireless and Bluetooth

- Wireless network connectivity
  - Connect without wires
- 802.11
  - Local area network (LAN)
  - High speed, Internet access
- Bluetooth
  - Personal area network (PAN) - Short range
  - Connect peripherals and other nearby devices

## 1.1 - Laptop Hardware (continued)

### Biometrics

- Sign in or unlock your laptop with a fingerprint reader or face recognition
  - Something you are
- Requires additional configuration in the OS
  - Hardware required for most options
- Relatively secure
  - Faces and fingerprints are quite unique

### Near-field communication (NFC)

- Short-distance networking
  - 4 centimeters or less
  - Data transfers or authentication
- Common on mobile phones and smart watches
  - Payment method on your wrist
- Use it for authentication without typing a password
  - Hospital workstations, warehouses, manufacturing

## 1.2 - Laptop Displays

### Portable LCD

- Liquid crystal display
  - Light shines through liquid crystals
- Advantages
  - Lightweight
  - Relatively low power
  - Relatively inexpensive
- Disadvantages
  - Black levels are a challenge
  - Requires separate backlight
  - Fluorescent, LED, etc.
  - Lights are difficult to replace

### LCD technologies

- TN (Twisted Nematic) LCD
  - The original LCD technology
  - Fast response times (gaming!)
  - Poor viewing angles - color shifts
- IPS (In Plane Switching) LCD
  - Excellent color representation
  - More expensive to produce than TN
- VA (Vertical Alignment) LCD
  - A good compromise between TN and IPS
  - Good color representation
  - Slower response times than TN

### OLED

- Organic Light Emitting Diode
  - Organic compound emits light when receiving an electric current
- Thinner and lighter
  - Flexible and mobile - no glass needed
- No backlight
  - The organic compound provides the light
- Tablets, phones, smart watches
  - Very accurate color representation
  - A bit higher cost than LCD

### Wi-Fi antennas

- Multiple antennas
  - WiFi main and aux / Bluetooth
- Antenna wires wrap around the laptop screen
  - It's up high!

### Webcam

- Video capture - Built-in camera and microphone
- Usually includes both audio and video
  - Specialized drivers and software

### Microphone

- Built-in to the laptop display
  - Useful for video calls
- Not good for non-casual use
  - Analog or USB microphones can help

### Fluorescent vs. LED backlighting

- LED-backlit LCD display
  - Backlight is LEDs instead of fluorescent
  - LEDs around the edge of the screen
  - An array of LEDs behind the screen
  - The latest laptops are LED-backlit
- CCFL - Cold Cathode
  - Fluorescent Lamp
  - Higher voltage and power needed
  - Added thickness to the display
  - No longer a common backlight
  - Older laptops will use these

### Backlight and inverter

- LCD displays need a backlight
  - Fluorescent lamp/LED to LCD display to your eyes
- Some laptops have inverters - Turn DC into AC
- Verify backlight
  - Look closely and use a flashlight
- May need to replace the LCD inverter or display
  - Choose carefully

### Digitizer

- Use a pen-like device as input
  - Stylus input - Useful for graphical input
- Used commonly on laptop / tablets
  - Or hybrid devices

### Touchscreen

- Merge laptop and tablet input
  - Digitizer responds to touch - No keyboard required
- But often still available
  - Many options for input - Use the best one for the job

## 1.3 - Connecting Mobile Devices

### Connecting mobile devices

- Phones and tablets
  - Many different ways to connect
- Wired and wireless connectivity
  - Standards and options change through the years
- Used for synchronization, connectivity, backup, and identification
  - Sometimes simultaneously

### USB

- Universal Serial Bus
  - High-speed wired communication
  - Used for charging and data transfers
- Micro-USB
  - A smaller USB connection
  - Common now worldwide
- Older devices may use Mini-USB
  - Slightly larger



### USB-C

- 24-pin double-sided USB connector
  - Used for both hosts and devices
- Acts as a USB 2.0/3.0/3.1/4 connection
  - Different signals can use the same connector
- Can transmit other signals
  - DisplayPort, HDMI, Thunderbolt

### Lightning

- Apple proprietary
  - 8-pin digital signals
  - iPhone and iPad devices
- Some advantages over Micro-USB
  - Higher power output for phones and tablets
  - Can be inserted either way
  - Simpler design

### Serial interfaces

- DB-9 - also called DE-9
- Commonly used for RS-232 signals
  - Recommended Standard 232
  - An industry standard since 1969
- Serial communications standard
  - Traditionally used for modem connections
- Now used as a configuration port
  - Switches, routers, firewalls, etc
  - Use a USB to DB-9 converter cable

### NFC

- Near Field Communication
  - Send small amounts of data wirelessly over a limited area
- Built into your phone
  - Payment systems, transportation,in-person information exchange
- Access token, identity “card”
  - Short range with encryption support

### Bluetooth

- High speed communication over short distances
  - PAN (Personal Area Network)
- Connects our mobile devices
  - Smartphones
  - Tethering
  - Headsets and headphones
  - Health monitors
  - Automobile and phone integration
  - Smartwatches
  - External speakers

### Hotspot

- Turn your phone into a WiFi hotspot
  - Your own personal wireless router
  - Extend the cellular data network to all of your devices
- Dependent on phone type and provider
  - May require additional charges and data costs



Lightning plug

## 1.3 - Mobile Device Accessories

### Touch pens

- Touchscreen pen / touch screen stylus / capacitive stylus
  - Activate the interface without actually touching it
- Handwriting
  - Note taking, signatures
- Precise selection
  - Easier to see the screen

### Active stylus

- Digital stylus
  - A more advanced writing tool
- The stylus communicates directly to the device
  - Pressure sensitivity, programmable buttons, etc.
- Must be compatible with the tablet
  - e.g., Apple iPad uses an Apple Pencil

### Drawing pad

- Use an active stylus with an external digitizer
  - Very precise input

### Trackpad

- Replace the mouse
  - Useful in tight working areas
  - Common on laptops
- External options
  - Battery powered
  - Bluetooth connected
- Drag and tap
  - Or use multiple finger input for right-clicking, zooming, and window control
- Enable and disable
  - Avoid inadvertent mouse clicks and movements

### Headsets

- Hands-free audio - Earphones and microphone
- Wired
  - USB connections are common on laptops
  - Connects to 3.5 mm TRRS (tip-ring-ring-sleeve) connector
  - Analog audio jack
  - iPhone can use Lightning port
- Wireless - Bluetooth headsets

### Speakers

- Mobile audio - Battery powered
- Wireless connection - Bluetooth link
- Stereo sound - Small package

### Camera / webcam

- Internal or external
  - Commonly external on desktops, internal on laptops/tablets/phones
- Accessible from multimedia applications, photo utilities, and video conferencing
  - Real-time video communication

### Docking station

- Docking station
  - Use external keyboard and mouse
  - Extend existing laptop interfaces
  - Add additional functionality
  - Desktop adapter cards
  - Avoid cable issues

### Port replicator

- Port replicator
  - Similar to a docking station
  - Does not commonly have an expansion card option
  - Usually connects using USB

## 1.4 - Cellular Standards

### Cellular networks

- Mobile devices
  - “Cell” phones
- Separate land into “cells”
  - Antenna coverages a cell with certain frequencies
- 2G networks
  - GSM - Global System for Mobile Communications
  - CDMA - Code Division Multiple Access
- Poor data support
  - Originally used circuit-switching
  - Minor upgrades for some packet-switching

- 90% of the market
  - Originally an EU standard
  - Worldwide coverage
- Used by AT&T and T-Mobile in the United States
  - Move your SIM card (Subscriber Identity Module) from phone to phone
- Original GSM standard used multiplexing
  - Everyone gets a little slice of time

### CDMA

- Code Division Multiple Access
  - Everyone communicates at the same time
  - Each call uses a different code
  - The codes are used to filter each call on the receiving side
- Used by Verizon and Sprint
  - Handsets are controlled by the network provider
  - Not much adoption elsewhere

### GSM

- Global System for Mobile Communications
  - Mobile networking standard

## 1.4 - Cellular Standards (continued)

### 3G technology

- 3rd Generation
  - Introduced in 1998
- Upgraded data connectivity over 2G
  - Incremental 3G updates improved speeds
  - Usually several megabits per second
- Bandwidth improvement allowed new functionality
  - GPS
  - Mobile television
  - Video on demand
  - Video conferencing

### 4G and LTE

- Long Term Evolution (LTE)
  - A “4G” technology
  - Converged standard (GSM and CDMA providers)
  - Based on GSM and EDGE (Enhanced Data Rates for GSM Evolution)
  - Standard supports download rates of 150 Mbit/s
- LTE Advanced (LTE-A)
  - Standard supports download rates of 300 Mbit/s

### 5G

- Fifth generation cellular networking
  - Launched worldwide in 2020
- Significant performance improvements
  - At higher frequencies
  - Eventually 10 gigabits per second
  - Slower speeds from 100-900 Mbit/s
- Significant IoT impact
  - Bandwidth becomes less of a constraint
  - Larger data transfers
  - Faster monitoring and notification
  - Additional cloud processing

### Updates

- PRL (Preferred Roaming List) updates
  - CDMA networks (i.e., Verizon, Sprint)
- Allows your phone to connect to the right tower
  - Can be updated over the air (OTA)

### Hotspot

- Turn your phone into a WiFi hotspot
  - Your own personal wireless router
  - Extend the cellular data network to all of your devices
- Dependent on phone type and provider
  - May require additional charges and data costs

## 1.4 - Mobile Device Connectivity

### Bluetooth pairing

- Connect a Bluetooth device
  - Built-in security - Use or verify a PIN
- Pair the devices one time
  - Future connections should be automatic
- Check with the manufacturer
  - May prefer a specific sequence
  - Discoverable mode isn't always obvious

### Bluetooth pairing process

- Enable Bluetooth on both devices
  - Android and iOS: Settings / Bluetooth
- Set devices to discoverable mode
  - May require key sequence on Bluetooth device
- Select discovered device
  - Many devices may appear!
- Enter or confirm PIN
  - Should be the same on both devices
- Test connectivity
  - Devices should now communicate

### GPS (Global Positioning System)

- Created by the U.S. Department of Defense
  - Over 30 satellites currently in orbit
- Precise navigation - Need to see at least 4 satellites
- Determines location based on timing differences
  - Longitude, latitude, altitude

- Mobile device location services and geotracking
  - Maps, directions
  - Determine physical location based on GPS, WiFi, and cellular towers

### MDM (Mobile Device Management)

- Manage company-owned and user-owned mobile devices
  - BYOD - Bring Your Own Device
- Centralized management of the mobile devices
  - Specialized functionality
- Set policies on apps, data, camera, etc.
  - Control the remote device
  - The entire device or a “partition”
- Manage access control
  - Force screen locks and PINs on these single user devices

### MDM configurations

- Corporate email configuration
  - User does not need to configure anything
  - The MDM makes the changes on the device
  - Account details, server address, communication method
- Two-factor authentication
  - Require specific authentication types
  - Biometrics, pseudo-random authentication app
- Corporate applications
  - Allow or restrict app installation
  - Prevent unauthorized app usage

## 1.4 - Mobile Device Configurations

### Configuring a mobile device

- Many settings are preconfigured
  - Telephone / Text messaging
- Email
  - Everyone handles email services differently
  - Corporate email configurations can vary
- Data synchronization
  - Based on data rates and speeds
  - Important for backup and recovery

### Microsoft 365

- Outlook, Exchange
  - Microsoft's email service
  - Usually the same for Hotmail and Outlook.com
- Authenticate to Microsoft 365
  - Username, password
- Select the items to synchronize
  - Changes in Outlook will appear on the mobile device
- Same process for Google Workspace
  - Formerly known as G Suite

### iCloud

- Integrated into iOS and iPadOS
  - Provide an iCloud username and password
- Select synchronization options
  - Extensive customization
- Synchronize to macOS
  - Use your desktop, laptop, or mobile device

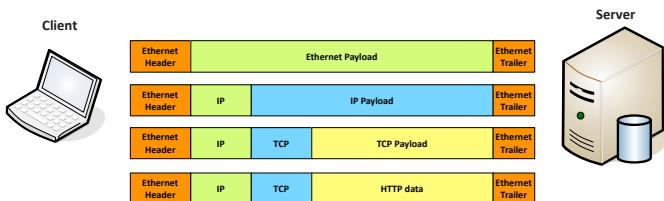
### Synchronizing data

- Data types
  - Mail
  - Pictures, music, video
  - Calendar
  - Contacts
- Data caps and transfer costs
  - Cellular vs 802.11
  - Enable or disable network connections
  - Control the use of cellular downloads

## 2.1 - Introduction to IP

### A series of moving vans

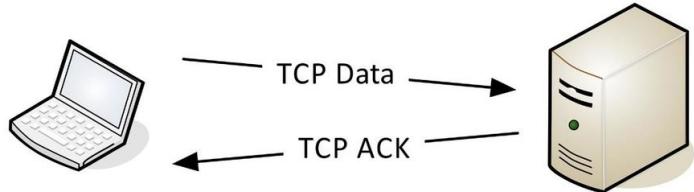
- Efficiently move large amounts of data
  - Use a shipping truck
- The network topology is the road
  - Ethernet, DSL, cable system
- The truck is the Internet Protocol (IP)
  - We've designed the roads for this truck
- The boxes hold your data
  - Boxes of TCP and UDP
- Inside the boxes are more things
  - Application information



### TCP and UDP

- Transported inside of IP
  - Encapsulated by the IP protocol
- Two ways to move data from place to place
  - Different features for different applications
- OSI Layer 4
  - The transport layer
- Multiplexing
  - Use many different applications at the same time
  - TCP and UDP

### TCP - Transmission Control Protocol Communication



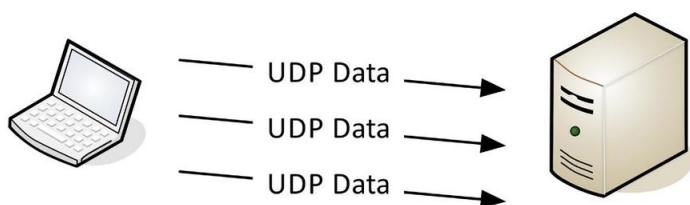
### TCP – Transmission Control Protocol

- Connection-oriented
  - A formal connection setup and close
- “Reliable” delivery
  - Recovery from errors
  - Can manage out-of-order messages or retransmissions
- Flow control
  - The receiver can manage how much data is sent

### UDP – User Datagram Protocol

- Connectionless - No formal open/close to the connection
- “Unreliable” delivery
  - No error recovery
  - No reordering of data or retransmissions
- No flow control
  - Sender determines the amount of data transmitted

### UDP - User Datagram Protocol Communication



## 2.1 - Introduction to IP (continued)

### Why would you ever use UDP?

- Real-time communication
  - There's no way to stop and resend the data
  - Time doesn't stop for your network
- Connectionless protocols
  - DHCP (Dynamic Host Configuration Protocol)
  - TFTP (Trivial File Transfer Protocol)

### Communication using TCP

- Connection-oriented protocols prefer a "return receipt"
  - HTTPS (Hypertext Transfer Protocol Secure)
  - SSH (Secure Shell)
- The application doesn't worry about out of order frames or missing data
  - TCP handles all of the communication overhead
  - The application has one job

### Speedy delivery

- The IP delivery truck delivers from one (IP) address to another (IP) address
  - Every house has an address, every computer has an IP address
- Boxes arrive at the house / IP address
  - Where do the boxes go?
  - Each box has a room name
- Port is written on the outside of the box
  - Drop the box into the right room

### Lots of ports

- IPv4 sockets
  - Server IP address, protocol, server application port number
  - Client IP address, protocol, client port number
- Non-ephemeral ports – permanent port numbers
  - Ports 0 through 1,023
  - Usually on a server or service
- Ephemeral ports – temporary port numbers
  - Ports 1,024 through 65,535
  - Determined in real-time by the client

### Port numbers

- TCP and UDP ports can be any number between 0 and 65,535
- Most servers (services) use non-ephemeral (not-temporary) port numbers
  - This isn't always the case
  - It's just a number.
- Port numbers are for communication, not security
- Service port numbers need to be "well known"
- TCP port numbers aren't the same as UDP port numbers

## 2.1 - Common Network Ports

### Port numbers

- Well-known port number
  - Client and server need to match
- Important for firewall rules - Port-based security
- A bit of rote memorization
  - Becomes second nature after a while
- Make sure you know port number, protocol, and how the protocol is used

### FTP - File Transfer Protocol

- tcp/20 (active mode data), tcp/21 (control)
  - Transfers files between systems
- Authenticates with a username and password
  - Some systems use a generic/anonymous login
- Full-featured functionality - List, add, delete, etc.

### SSH - Secure Shell

- Encrypted communication link - tcp/22
- Looks and acts the same as Telnet

### Telnet

- Telnet – Telecommunication Network - tcp/23
- Login to devices remotely
  - Console access
- In-the-clear communication
  - Not the best choice for production systems

### SMTP - Simple Mail Transfer Protocol

- SMTP - Simple Mail Transfer Protocol
  - Server to server email transfer - tcp/25
- Also used to send mail from a device to a mail server
  - Commonly configured on mobile devices and email clients
- Other protocols are used for clients to receive email
  - IMAP, POP3

### DNS - Domain Name System

- Converts names to IP addresses - udp/53
  - www.professormesser.com = 162.159.246.164
- These are very critical resources
  - Usually multiple DNS servers are in production

### DHCP - Dynamic Host Configuration Protocol

- Automated configuration of IP address, subnet mask and other options - udp/67, udp/68
  - Requires a DHCP server
  - Server, appliance, integrated into a SOHO router, etc.
- Dynamic / pooled
  - IP addresses are assigned in real-time from a pool
  - Each system is given a lease and must renew at set intervals
- DHCP reservation
  - Addresses are assigned by MAC address in the DHCP server
  - Manage addresses from one location

## 2.1 - Common Network Ports (continued)

### HTTP and HTTPS

- Hypertext Transfer Protocol
  - Communication in the browser
  - And by other applications
- In the clear or encrypted
  - Supported by nearly all web servers and clients

### POP3 / IMAP

- Receive emails from an email server
  - Authenticate and transfer
- POP3 - Post office Protocol version 3
  - tcp/110
  - Basic mail transfer functionality
- IMAP4 - Internet Message Access Protocol v4
  - tcp/143
  - Includes email inbox management from multiple clients

### SMB - Server Message Block

- Protocol used by Microsoft Windows
  - File sharing, printer sharing
  - Also called CIFS (Common Internet File System)
- Using NetBIOS over TCP/IP (Network Basic Input/Output System)
  - udp/137 - NetBIOS name services (nbname)
  - tcp/139 - NetBIOS session service (nbsession)
- Direct over tcp/445 (NetBIOS-less)
  - Direct SMB communication over TCP without the NetBIOS transport

### SNMP - Simple Network Management Protocol

- Gather statistics from network devices
  - Queries: udp/161
  - Traps: udp/162
- v1 – The original
  - Structured tables
  - In-the-clear
- v2 – A good step ahead
  - Data type enhancements
  - Bulk transfers
  - Still in-the-clear
- v3 – A secure standard
  - Message integrity
  - Authentication
  - Encryption

### LDAP

- LDAP (Lightweight Directory Access Protocol) - tcp/389
- Store and retrieve information in a network directory
  - Commonly used in Microsoft Active Directory

### RDP - Remote Desktop Protocol

- Share a desktop from a remote location over tcp/3389
- Remote Desktop Services on many Windows versions
- Can connect to an entire desktop or just an application
- Clients for Windows, macOS, Linux, Unix, iPhone, Android, and others

Protocol	Port	Name	Description
FTP	tcp/20, tcp21	File Transfer Protocol	Sends and receives files between systems
SSH	tcp/22	Secure Shell	Encrypted console access
Telnet	tcp/23	Telecommunication Network	Insecure console access
SMTP	tcp/25	Simple Mail Transfer Protocol	Transfer email between mail servers
DNS	udp/53, tcp/53	Domain Name System	Convert domain names to IP addresses
DHCP	udp/67, udp/68	Dynamic Host Configuration Protocol	Automate the IP address configuration process
HTTP	tcp/80	Hypertext Transfer Protocol	Web server communication
HTTPS	tcp/443	Hypertext Transfer Protocol Secure	Web server communication with encryption
POP3	tcp/110	Post Office Protocol version 3	Receive email into a email client
IMAP4	tcp/143	Internet Message Access Protocol v4	A newer email client protocol
NetBIOS	udp/137	NetBIOS name service	Register, remove, and find Windows services by name
NetBIOS	tcp/139	NetBIOS session service	Windows connection-oriented data transfer
SMB	tcp/445	Server Message Block	Windows file transfers and printer sharing
SNMP Query	udp/161	Simple Network Management Protocol	Gather metrics and manage network devices
SNMP Trap	udp/162	Simple Network Management Protocol	Receive alerts from network devices
LDAP	tcp/389	Lightweight Directory Access Protocol	Directory services
RDP	tcp/3389	Remote Desktop Protocol	Graphical display of remote devices

## 2.2 - Network Devices

### Network devices

- Many different devices and components
  - All have different roles
- Some of these functions are combined together
  - Wireless router/switch/firewall
- Compare different devices
  - Understand when they should be used

### Routers

- Routes traffic between IP subnets
  - Makes forwarding decisions based on IP address
  - Routers inside of switches sometimes called “layer 3 switches”
- Often connects diverse network types
  - LAN, WAN, copper, fiber

### Switches

- Bridging done in hardware
  - Application-specific integrated circuit (ASIC)
  - Forwards traffic based on data link address
- Many ports and features
  - The core of an enterprise network
  - May provide Power over Ethernet (PoE)
- Multilayer switch
  - Includes routing functionality

### Unmanaged switches

- Very few configuration options
  - Plug and play
- Fixed configuration
  - No VLANs
- Very little integration with other devices
  - No management protocols
- Low price point
  - Simple is less expensive

### Managed switches

- VLAN support
  - Interconnect with other switches via 802.1Q
- Traffic prioritization
  - Voice traffic gets a higher priority
- Redundancy support
  - Spanning Tree Protocol (STP)
- Port mirroring
  - Capture packets
- External management
  - Simple Network Management Protocol (SNMP)

### Access point

- Not a wireless router
  - A wireless router is a router and an access point in a single device
- An access point is a bridge
  - Extends the wired network onto the wireless network
  - Makes forwarding decisions based on MAC address

### Patch Panels

- Combination of punch-down blocks and RJ-45 connectors
- Runs from desks are made once
  - Permanently punched down to patch panel
- Patch panel to switch can be easily changed
  - No special tools
  - Use existing cables

### Firewalls

- Filters traffic by port number
  - OSI layer 4 (TCP/UDP)
  - Some firewalls can filter based on the application
- Can encrypt traffic into/out of the network
  - Protect your traffic between sites
- Can proxy traffic
  - A common security technique
- Most firewalls can be layer 3 devices (routers)
  - Usually sits on the ingress/egress of the network

### Power over Ethernet (PoE)

- Power provided on an Ethernet cable
  - One wire for both network and electricity
  - Phones, cameras, wireless access points
  - Useful in difficult-to-power areas
- Power provided at the switch
  - Built-in power - Endspans
  - In-line power injector - Midspans

### PoE switch

- Power over Ethernet
  - Commonly marked on the switch or interfaces

### PoE, PoE+, PoE++

- PoE: IEEE 802.3af-2003
  - The original PoE specification
  - Now part of the 802.3 standard
  - 15.4 watts DC power, 350 mA max current
- PoE+: IEEE 802.3at-2009
  - Now also part of the 802.3 standard
  - 25.5 watts DC power, 600 mA max current
- PoE++: IEEE 802.3bt-2018
  - 51 W (Type 3), 600 mA max current
  - 71.3 W (Type 4), 960 mA max current
  - PoE with 10GBASE-T

### Hub

- “Multi-port repeater”
  - Traffic going in one port is repeated to every other port
- Everything is half-duplex
- Becomes less efficient as network traffic increases
- 10 megabit / 100 megabit
- Difficult to find today

## 2.2 - Network Devices (continued)

### Cable modem

- Broadband
  - Transmission across multiple frequencies
  - Different traffic types
- Data on the “cable” network
  - DOCSIS (Data Over Cable Service Interface Specification)
- High-speed networking
  - Speeds up to 1 Gigabit/s are available
- Multiple services
  - Data, voice, video

### DSL modem

- ADSL (Asymmetric Digital Subscriber Line)
  - Uses telephone lines
- Download speed is faster than the upload speed (asymmetric)
  - ~10,000 foot limitation from the central office (CO)
  - 52 Mbit/s downstream / 16 Mbit/s upstream are common
  - Faster speeds may be possible if closer to the CO

### ONT

- Optical network terminal
  - Fiber to the premises
- Connect the ISP fiber network to the copper network
  - Demarcation point (demarc) in the data center
  - Terminal box on the side of the building
- Line of responsibility
  - One side of the box is the ISP
  - Other side of the box is your network

### Network Interface Card (NIC)

- The fundamental network device
  - Every device on the network has a NIC
  - Computers, servers, printers, routers, switches, phones, tablets, cameras, etc.
- Specific to the network type
  - Ethernet, WAN, wireless, etc.
- Often built-in to the motherboard
  - Or added as an expansion card
- Many options - Single port, multi-port, copper, fiber

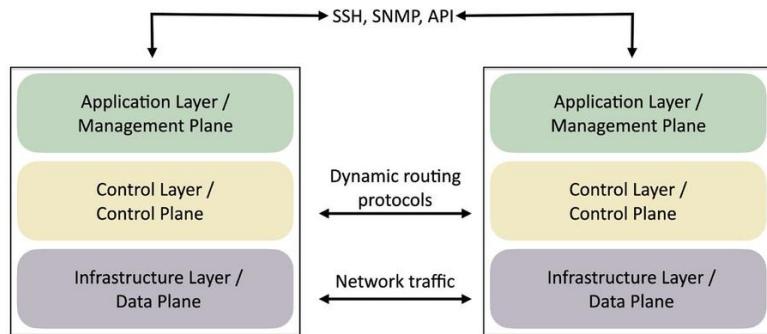
## 2.2 - Software Defined Networking

### SDN (Software Defined Networking)

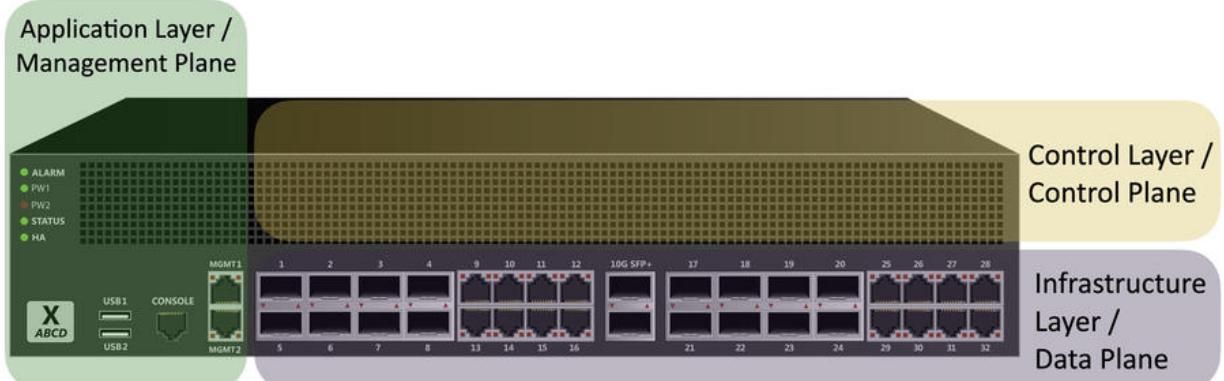
- Networking devices have different functional planes of operation
  - Data, control, and management planes
- Split the functions into separate logical units
  - Extend the functionality and management of a single device
  - Perfectly built for the cloud
- Infrastructure layer / Data plane
  - Process the network frames and packets
  - Forwarding, trunking, encrypting, NAT
- Control layer / Control plane
  - Manages the actions of the data plane
  - Routing tables, session tables, NAT tables
  - Dynamic routing protocol updates

- Application layer / Management plane
  - Configure and manage the device
  - SSH, browser, API

### SDN data flows



### Extend the physical architecture



## 2.3 - Wireless Network Standards

### Wireless standards

- Wireless networking (802.11)
  - Managed by the IEEE LAN/MAN Standards Committee (IEEE 802)
- Many updates over time
  - Check with IEEE for the latest
- The Wi-Fi trademark
  - Wi-Fi Alliance handles interoperability testing

### 802.11a

- One of the original 802.11 wireless standards
  - October 1999
- Operates in the 5 GHz range
  - Or other frequencies with special licensing
- 54 megabits per second (Mbit/s)
- Smaller range than 802.11b
  - Higher frequency is absorbed by objects in the way
- Not commonly seen today

### 802.11b

- Also an original 802.11 standard - October 1999
- Operates in the 2.4 GHz range
- 11 megabits per second (Mbit/s)
- Better range than 802.11a, less absorption problems
- More frequency conflict
  - Baby monitors, cordless phones, microwave ovens, Bluetooth
- Not commonly seen today

### 802.11g

- An “upgrade” to 802.11b - June 2003
- Operates in the 2.4 GHz range
- 54 megabits per second (Mbit/s) - Similar to 802.11a
- Backwards-compatible with 802.11b
- Same 2.4 GHz frequency conflict problems as 802.11b

### 802.11n (Wi-Fi 4)

- The update to 802.11g, 802.11b, and 802.11a
  - October 2009
- Operates at 5 GHz and/or 2.4 GHz
  - 40 MHz channel widths
- 600 megabits per second (Mbit/s)
  - 40 MHz mode and 4 antennas
- 802.11n uses MIMO
  - Multiple-input multiple-output
  - Multiple transmit and receive antennas

### 802.11ac (Wi-Fi 5)

- Approved in January 2014
  - Significant improvements over 802.11n
- Operates in the 5 GHz band
  - Less crowded, more frequencies (up to 160 MHz channel bandwidth)
- Increased channel bonding - Larger bandwidth usage
- Denser signaling modulation
  - Faster data transfers
- Eight MU-MIMO downlink streams
  - Twice as many streams as 802.11n
  - Nearly 7 gigabits per second

### 802.11ax (Wi-Fi 6)

- Approved in February 2021
  - The successor to 802.11ac/Wi-Fi 5
- Operates at 5 GHz and/or 2.4 GHz
  - 20, 40, 80, and 160 MHz channel widths
- 1,201 megabits per second per channel
  - A relatively small increase in throughput
  - Eight bi-directional MU-MIMO streams
- Orthogonal frequency-division multiple access (OFDMA)
  - Works similar to cellular communication
  - Improves high-density installations

	Frequencies	Maximum MIMO streams	Maximum theoretical throughput (per stream)	Maximum theoretical throughput (total)
<b>802.11a</b>	5 GHz	Not applicable	54 Mbit/s	54 Mbit/s
<b>802.11b</b>	2.4 GHz	Not applicable	11 Mbit/s	11 Mbit/s
<b>802.11g</b>	2.4 GHz	Not applicable	54 Mbit/s	54 Mbit/s
<b>802.11n</b>	5 GHz / 2.4 GHz	4 x MIMO	150 Mbit/s	600 Mbit/s
<b>802.11ac</b>	5 GHz	8 x DL MU-MIMO	867 Mbit/s	6.9 Gbit/s
<b>802.11ax</b>	5 GHz / 2.4 GHz	8 x DL and UL MU-MIMO	1,201 Mbit/s	9.6 Gbit/s

## 2.3 - Wireless Network Standards (continued)

### Long-range fixed wireless

- Wireless access point in a house with the stock antennas
  - You might get a range of 40 to 50 meters
- Try connecting two buildings located miles from each other
  - Fixed directional antennas and increased signal strength
- Outdoors
  - Minimal signal absorption or bounce
- Directional antennas
  - Focused, point-to-point connection
- Wireless regulations are complex
  - Refer to your country's regulatory agency
- Frequency use
  - Unlicensed 2.4 GHz or 5 GHz frequencies
  - Additional frequencies may be available
  - Additional licensing may be required
- Signal strength
  - Indoor and outdoor power is usually regulated
  - Outdoor antenna installation is not trivial
  - Get an expert, be safe

### RFID (Radio-frequency identification)

- It's everywhere
  - Access badges
  - Inventory/Assembly line tracking
  - Pet/Animal identification
  - Anything that needs to be tracked
- Radar technology
  - Radio energy transmitted to the tag
  - RF powers the tag, ID is transmitted back
  - Bidirectional communication
  - Some tag formats can be active/powered

### NFC (Near field communication)

- Two-way wireless communication
  - Builds on RFID, which is mostly one-way
- Payment systems
  - Major credit cards, online wallets
- Bootstrap for other wireless
  - NFC helps with Bluetooth pairing
- Access token, identity “card”
  - Short range with encryption support

## 2.3 - Wireless Network Technologies

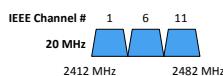
### 802.11 technologies

- Frequency
  - 2.4 GHz or 5 GHz
  - And sometimes both
- Channels
  - Groups of frequencies, numbered by the IEEE
  - Non-overlapping channels would be ideal
- Regulations
  - Most countries have regulations to manage frequency use
  - Spectrum use, power output, interference requirements, etc.

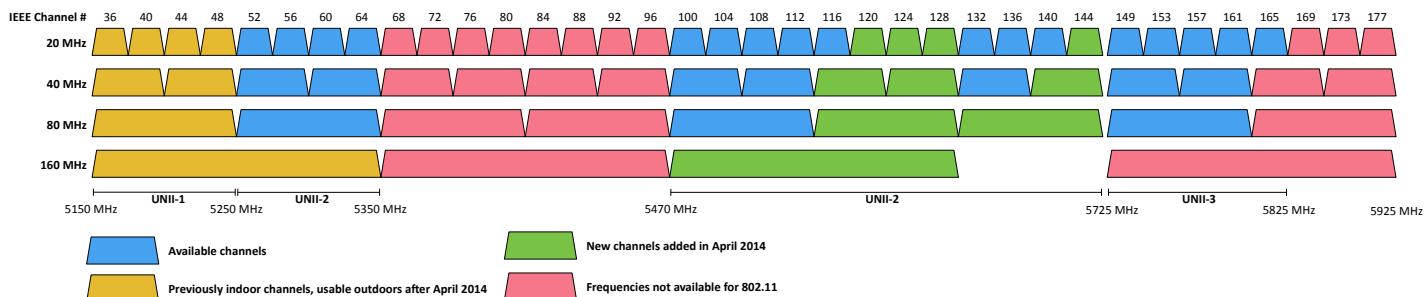
### Bluetooth

- Remove the wires
  - Headsets, speakers, keyboards / mice
- Uses the 2.4 GHz range
  - Unlicensed ISM (Industrial, Scientific and Medical) band
  - Same as 802.11
- Short-range
  - Most consumer devices operate to about 10 meters
  - Industrial Bluetooth devices can communicate over 100 meters

## 2.4 GHz Spectrum for 802.11 - North America



## 5 GHz Spectrum for 802.11 - North America



## 2.4 - Network Services

### DNS server

- Domain Name System
  - Convert names to IP addresses
  - And vice versa
- Distributed naming system
  - The load is balanced across many different servers
- Usually managed by the ISP or IT department
  - A critical resource

### DHCP server

- Dynamic Host Configuration Protocol
  - Automatic IP address configuration
- Very common service
  - Available on most home routers
- Enterprise DHCP will be redundant
  - Usually running on central servers

### File server

- Centralized storage of documents, spreadsheets, videos, pictures, and any other files
  - A fileshare
- Standard system of file management
  - SMB (Server Message Block), Apple Filing Protocol (AFP), etc.
- The front-end hides the protocol
  - Copy, delete, rename, etc.

### Print server

- Connect a printer to the network
  - Provide printing services for all network devices
- May be software in a computer
  - Computer is connected to the printer
- May be built-in to the printer
  - Network adapter and software
- Uses standard printing protocols
  - SMB (Server Message Block), IPP (Internet Printing Protocol), LPD (Line Printer Daemon)

### Mail server

- Store your incoming mail
  - Send your outgoing mail
- Usually managed by the ISP or the IT department
  - A complex set of requirements
- Usually one of the most important services
  - 24 x 7 support

### Syslog

- Standard for message logging
  - Diverse systems, consolidated log
- Usually a central logging receiver
  - Integrated into the SIEM
- You're going to need a lot of disk space
  - No, more. More than that.

### Web server

- Respond to browser requests
  - Using standard web browsing protocols - HTTP/HTTPS
  - Pages are built with HTML, HTML5
- Web pages are stored on the server
  - Downloaded to the browser
  - Static pages or built dynamically in real-time

### Authentication server

- Login authentication to resources
  - Centralized management
- Almost always an enterprise service
  - Not required on a home network
- Usually a set of redundant servers
  - Always available
  - Extremely important service

### Spam

- Unsolicited messages
  - Email, forums, etc.
- Various content
  - Commercial advertising
  - Non-commercial proselytizing
  - Phishing attempts
- Significant technology issue
  - Security concerns, resource utilization, storage costs, managing the spam

### Spam gateways

- Unsolicited email
  - Stop it at the gateway before it reaches the user
  - On-site or cloud-based

### All-in-one security appliance

- Next-generation firewall, Unified Threat Management (UTM) / Web security gateway
- URL filter / Content inspection
- Malware inspection
- Spam filter
- CSU/DSU
- Router, Switch
- Firewall
- IDS/IPS
- Bandwidth shaper
- VPN endpoint

### Load balancers

- Distribute the load
  - Multiple servers
  - Invisible to the end-user
- Large-scale implementations
  - Web server farms, database farms
- Fault tolerance
  - Server outages have no effect - Very fast convergence

## 2.4 - Network Services (continued)

### Load balancer features

- Configurable load - Manage across servers
- TCP offload - Protocol overhead
- SSL offload - Encryption/Decryption
- Caching - Fast response
- Prioritization - QoS
- Content switching - Application-centric balancing

### Proxy server

- An intermediate server
  - Client makes the request to the proxy
  - The proxy performs the actual request
  - The proxy provides results back to the client
- Useful features
  - Access control, caching, URL filtering, content scanning

### SCADA / ICS

- Supervisory Control and Data Acquisition System
  - Large-scale, multi-site Industrial Control Systems (ICS)
- PC manages equipment
  - Power generation, refining, manufacturing equipment
  - Facilities, industrial, energy, logistics
- Distributed control systems
  - Real-time information
  - System control
  - Requires extensive segmentation
  - No access from the outside

### Legacy and embedded systems

- Legacy systems
  - Another expression for “really old”
  - May also be “really important”
  - Learning old things can be just as important as learning the new things
- Embedded systems
  - Purpose-built device
  - Not usual to have direct access to the operating system
  - Alarm system, door security, time card system

### IoT (Internet of Things) devices

- Appliances
  - Refrigerators
- Smart devices
  - Smart speakers respond to voice commands
- Air control
  - Thermostats, temperature control
- Access
  - Smart doorbells
- May require a segmented network
  - Limit any security breaches

## 2.5 - IPv4 and IPv6

### IP addressing

- IPv4 is the primary protocol for everything we do
  - You probably won’t configure anything else
- IPv6 is now part of all major operating systems
  - And the backbone of our Internet infrastructure

### IPv4 addresses

- Internet Protocol version 4
  - OSI Layer 3 address

### IPv6 addresses

- Internet Protocol v6 - 128-bit address
  - 340,282,366,920,938,463,463,374,607,431,768,211,456 addresses (340 undecillion)
  - 6.8 billion people could each have 5,000,000,000,000,000,000,000,000 addresses

### Networking with IPv4

- IP Address, e.g., 192.168.1.165
  - Every device needs a unique IP address
- Subnet mask, e.g., 255.255.255.0
  - Used by the local device to determine its subnet
  - The subnet mask isn’t (usually) transmitted across the network

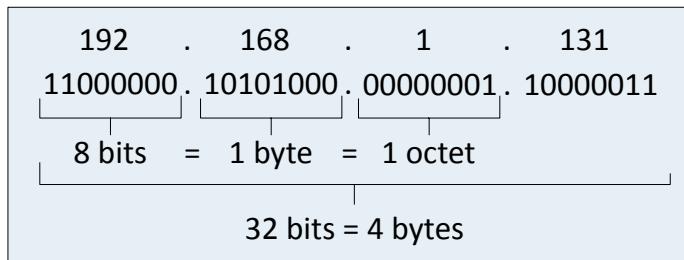
- Default gateway, e.g., 192.168.1.1
  - The router that allows you to communicate outside of your local subnet
  - The default gateway must be an IP address on the local subnet

### DNS servers

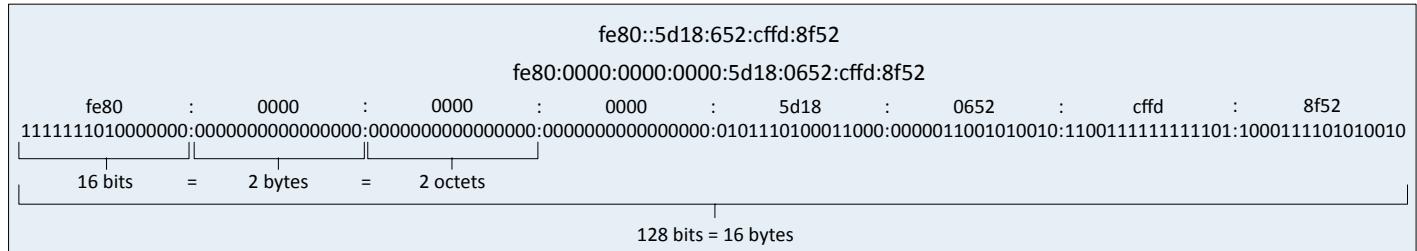
- We remember names
  - professormesser.com, google.com, youtube.com
- Internet routers don’t know names
  - Routers only know IP addresses
- Something has to translate between names and IP addresses
  - Domain Name Services
- You configure **two** DNS servers in your IP configuration
  - That’s how important it is

## 2.5 - IPv4 and IPv6 (continued)

### IPv4 addresses format



### IPv6 addresses format



## 2.5 - Assigning IP Addresses

### DHCP

- IPv4 address configuration used to be manual
  - IP address, subnet mask, gateway, DNS servers, NTP servers, etc.
- October 1993 - The bootstrap protocol (BOOTP)
- BOOTP didn't automatically define everything
  - Some manual configurations were still required
  - BOOTP also didn't know when an IP address might be available again
- Dynamic Host Configuration Protocol (DHCP)
  - Initially released in 1997, updated through the years
  - Provides automatic address / IP configuration for almost all devices

### The DHCP Process (DORA)

- **Step 1: Discover** - Client to DHCP Server
  - Find all of the available DHCP Servers
- **Step 2: Offer** - DHCP Server to client
  - Send some IP address options to the client
- **Step 3: Request** - Client to DHCP Server
  - Client chooses an offer and makes a formal request
- **Step 4: Acknowledgment** - DHCP Server to client
  - DHCP server sends an acknowledgment to the client

### Turning dynamic into static

- DHCP assigns an IP address from the first available from a large pool of addresses
  - Your IP address will occasionally change
- You may not want your IP address to change
  - Server, printer, or personal preference
- Disable DHCP on the device
  - Configure the IP address information manually
  - Requires additional administration
- Better: Configure an IP reservation on the DHCP server
  - Associate a specific MAC address with an IP address

### Avoid manual configurations

- No DHCP server reservation
  - You configure the IP address manually
- Difficult to change later - You must visit the device again
- A DHCP reservation is preferable
  - Change the IP address from the DHCP server

### Automatic Private IP Addressing (APIPA)

- A link-local address - No forwarding by routers
- IETF has reserved 169.254.0.0 through 169.254.255.255
  - First and last 256 addresses are reserved
  - Functional block of 169.254.1.0 through 169.254.254.255
- Automatically assigned
  - Uses ARP to confirm the address isn't currently in use

## 2.6 - DNS Configuration

### Domain Name System

- Translates human-readable names into computer-readable IP addresses
  - You only need to remember [www.ProfessorMesser.com](http://www.ProfessorMesser.com)
- Hierarchical
  - Follow the path
- Distributed database
  - Many DNS servers
  - 13 root server clusters (over 1,000 actual servers)
  - Hundreds of generic top-level domains (gTLDs) - .com, .org, .net, etc.
  - Over 275 country code top-level domains (ccTLDs) - .us, .ca, .uk, etc.

### DNS lookup

```
professor@Odyssey ~ % dig www.professormesser.com

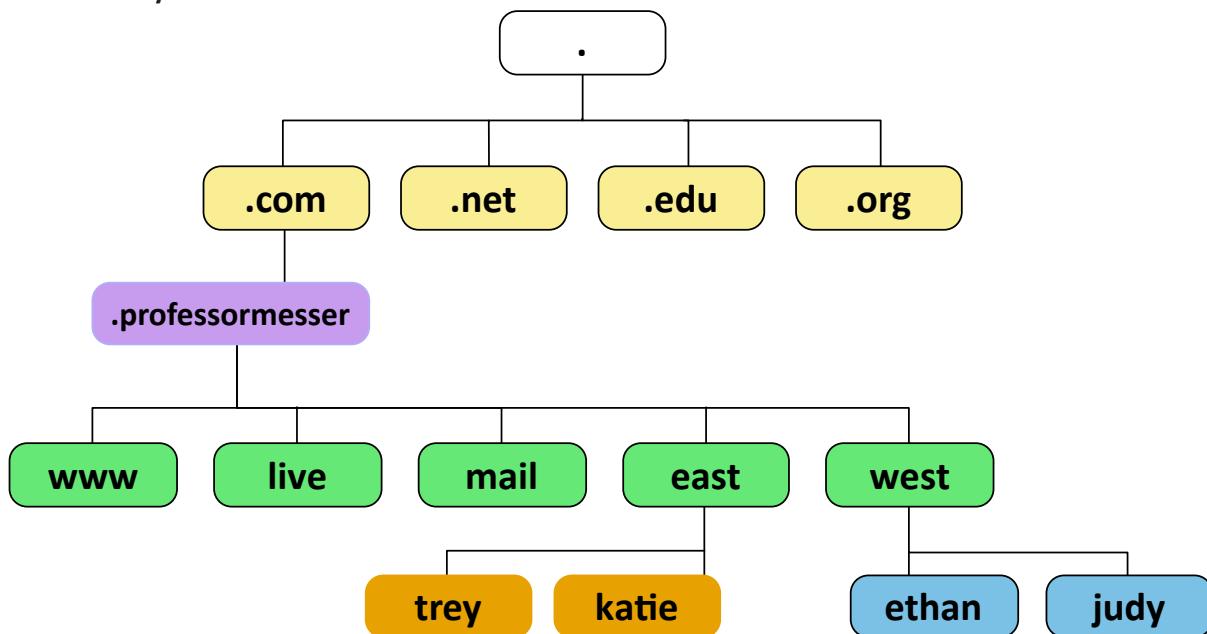
; <>> DiG 9.10.6 <>> www.professormesser.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 58050
;; flags: qr rd ra; QUERY: 1, ANSWER: 3, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
;; EDNS: version: 0, flags:; udp: 512
;; QUESTION SECTION:
;www.professormesser.com. IN A

;; ANSWER SECTION:
www.professormesser.com. 300 IN A 104.22.72.108
www.professormesser.com. 300 IN A 172.67.41.114
www.professormesser.com. 300 IN A 104.22.73.108

;; Query time: 42 msec
;; SERVER: 9.9.9.9#53(9.9.9.9)
;; WHEN: Thu Jun 17 09:17:26 EDT 2021
;; MSG SIZE rcvd: 100
```

### The DNS hierarchy



### DNS records

- Resource Records (RR)
  - The database records of domain name services
- Over 30 record types
  - IP addresses, certificates, host alias names, etc.
- **These are important and critical configurations**
  - Make sure to check your settings, backup, and test!

### Address records (A) (AAAA)

- Defines the IP address of a host
  - This is the most popular query
- A records are for IPv4 addresses
  - Modify the A record to change the host name to IP address resolution
- AAAA records are for IPv6 addresses
  - The same DNS server, different records

<a href="http://www.professormesser.com">www.professormesser.com</a>	IN A	162.159.246.164	; Professor Messer
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## 2.6 - DNS Configuration (continued)

### Mail exchanger record (MX)

- Determines the host name for the mail server - this isn't an IP address; it's a name

```
; This is the mail-exchanger. You can list more than one (if
; applicable), with the integer field indicating priority (lowest
; being a higher priority)
IN MX      mail.mydomain.name.

; A list of machine names & addresses
jack.mydomain.name.   IN A      123.12.41.40 ; Windows 10
mail.mydomain.name.   IN A      123.12.41.41 ; Linux (main server)
sam.mydomain.name.   IN A      123.12.41.42 ; Windows 11
```

### Text records (TXT)

- Human-readable text information
  - Useful public information
  - Was originally designed for informal information
- Can be used for verification purposes
  - If you have access to the DNS, then you must be the administrator of the domain name
- Commonly used for email security
  - External email servers validate information from your DNS

### Viewing TXT records with nslookup

```
professor@Odyssey ~ % nslookup -type=txt google.com
;; Truncated, retrying in TCP mode.
Server:          9.9.9.9
Address: 9.9.9.9#53

Non-authoritative answer:
google.com        text = "docusign=1b0a6754-49b1-4db5-8540-d2c12664b289"
google.com        text = "v=spf1 include:_spf.google.com ~all"
google.com        text = "apple-domain-verification=30afIBcvSuDV2PLX"
google.com        text = "globalsign-smime-dv=CDYX+XFHUw2wm16/Gb8+59BsH31KzUr6c1l2BPvgKX8="
google.com        text = "facebook-domain-verification=22rm551cu4k0ab0bxsw536tlds4h95"
google.com        text = "google-site-verification=TV9-DBe4R80X4v0M4U_bd_J9cpOJM0nikft0jAgjmsQ"
google.com        text = "MS-E4A68B9AB2BB9670BCE15412F62916164C0B20BB"
google.com        text = "docusign=05958488-4752-4ef2-95eb-aa7ba8a3bd0e"
google.com        text = "google-site-verification=wD8N7i1JTNTkezJ49svvWW48f8_9xveREV4oB-0Hf5o"
```

### Sender Policy Framework (SPF)

- SPF protocol
  - A list of all servers authorized to send emails for this domain
  - Prevent mail spoofing
  - Mail servers perform a check to see if incoming mail really did come from an authorized host

### Create DNS Record

TYPE  
TXT

HOSTNAME  
@

CONTENT  
professormesser.com. 300 IN TXT "v=spf1 include:mailgun.org ~all"

### Domain Keys Identified Mail (DKIM)

- Digitally sign a domain's outgoing mail
  - Validated by mail servers, not usually seen by the end user
  - The public key is in the DKIM TXT record

```
; DKIM TXT records
; owner class ttl TXT "attribute-name=attribute value"
1517680427.professormesser._domainkey.professormesser.com. IN 300 TXT
("v=DKIM1;t=s;p=MIGfMA0GCSqGSIb3DQEBAQUA4GNADCBiQKBgQDqCUQ5dpKOtwqdE2k8HaC0qg+v+f"
 "3y30BCzNz5IfFExtk+sTBiDcGWicapUzkgc4tN0boHBw57APzNInmjH9yZn15TB"
 "Tftavc44nXidu28LzsJGWVvYYxoFR5DuBoi/zIOHv6YDUpDxJa9knZABTOWLS2F"
 "YtK9dwAMaOZdtTB0hQIDAQAB")
```

### DMARC

- Domain-based Message Authentication, Reporting, and Conformance (DMARC)
  - Prevent unauthorized email use (spoofing)
  - An extension of SPF and DKIM
- You decide what external email servers should do with emails that don't validate through SPF or DKIM
  - That policy is written into a DMARC TXT record
  - Accept all, send to spam, or reject the email
  - Compliance reports can be sent to the email administrator

### Create DNS Record

TYPE  
TXT

HOSTNAME  
@

CONTENT  
v=DMARC1;p=none; sp=quarantine; pct=100; rua=mailto:dmarcreports@example.com;

## 2.6 - DHCP Configuration

### Scope properties

- IP address range
  - And excluded addresses
- Subnet mask
- Lease durations
- Other scope options
  - DNS server
  - Default gateway
  - VOIP servers

### DHCP pools

- Grouping of IP addresses
  - Each subnet has its own scope
  - 192.168.1.0/24
  - 192.168.2.0/24
  - 192.168.3.0/24
  - ...
- A scope is generally a single contiguous pool of IP addresses
  - DHCP exceptions can be made inside of the scope

### DHCP address assignment

- Dynamic assignment
  - DHCP server has a big pool of addresses to give out
  - Addresses are reclaimed after a lease period
- Automatic assignment
  - Similar to dynamic allocation
  - DHCP server keeps a list of past assignments
  - You'll always get the same IP address

### DHCP address allocation

- Address reservation
  - Administratively configured
- Table of MAC addresses
  - Each MAC address has a matching IP address
- Other names
  - Static DHCP Assignment, Static DHCP, Static Assignment, IP Reservation

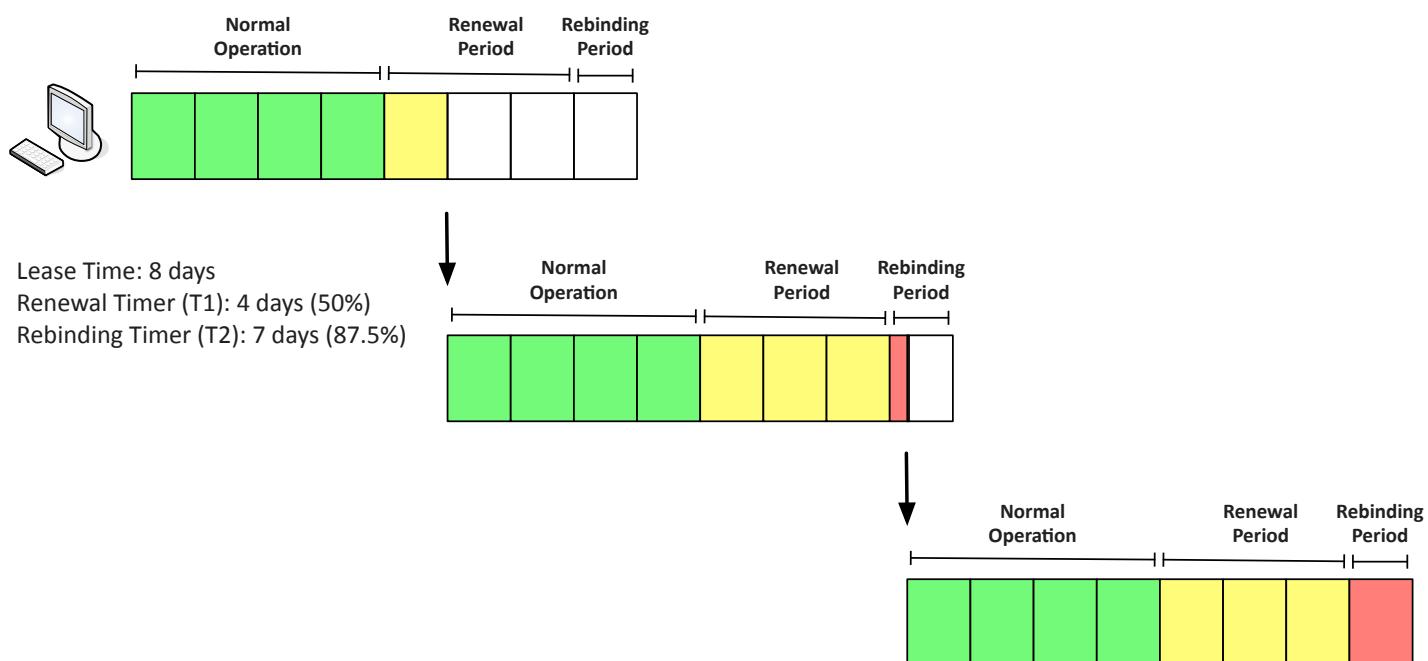
### DHCP leases

- Leasing your address
  - It's only temporary
  - But it can seem permanent
- Allocation
  - Assigned a lease time by the DHCP server
  - Administratively configured
- Reallocation
  - Reboot your computer
  - Confirms the lease
- Workstation can also manually release the IP address
  - Moving to another subnet

### DHCP renewal

- T1 timer
  - Check in with the lending DHCP server to renew the IP address
  - 50% of the lease time (by default)
- T2 timer
  - If the original DHCP server is down, try rebinding with any DHCP server
  - 87.5% of the lease time (7/8ths)

### The DHCP lease process



## 2.6 - VLANs and VPNs

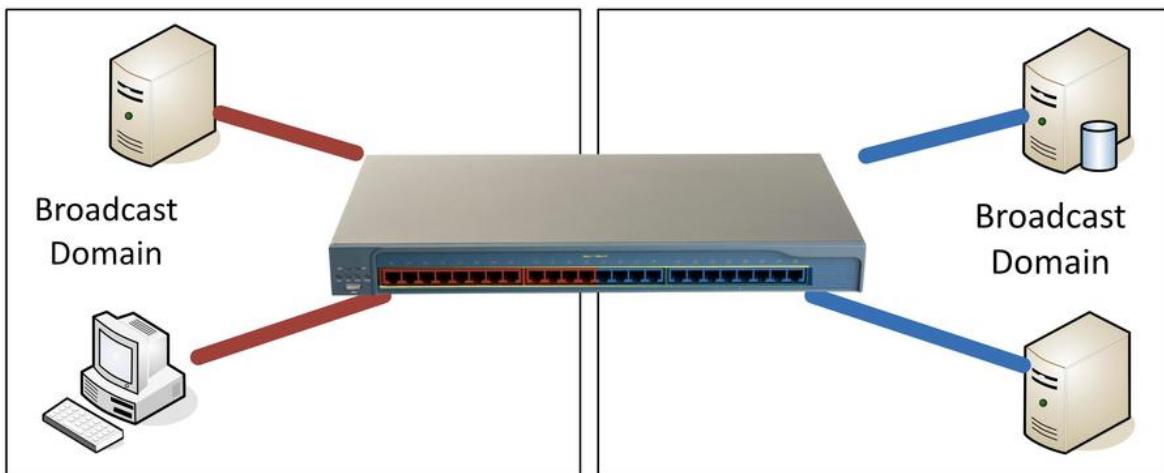
### LANs

- Local Area Networks
- A group of devices in the same broadcast domain



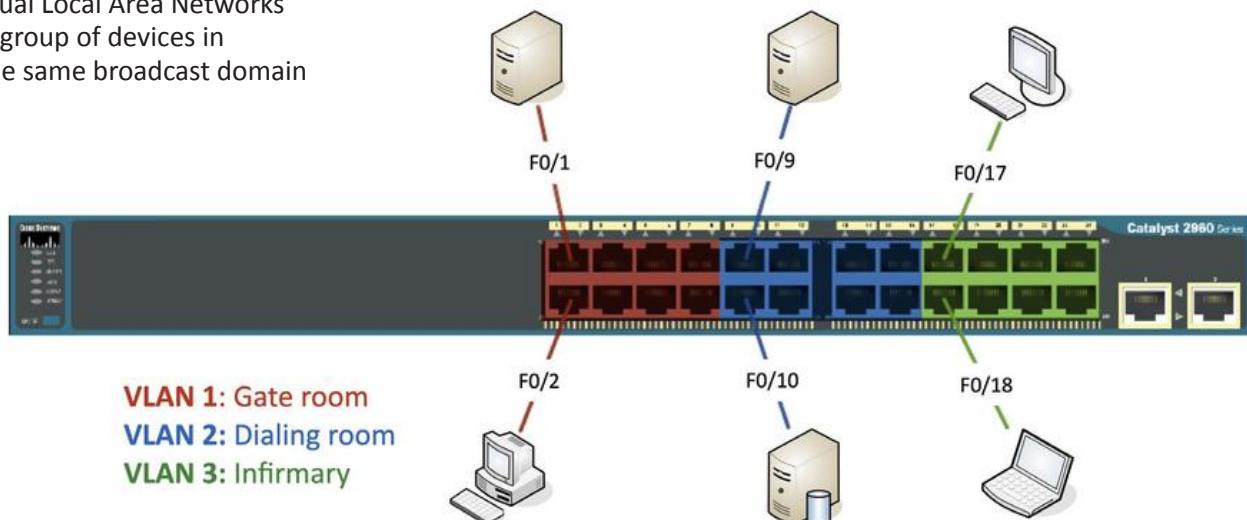
### Virtual LANs

- Virtual Local Area Networks
- A group of devices in the same broadcast domain
- Separated logically instead of physically



### Configuring VLANs

- Virtual Local Area Networks
  - A group of devices in the same broadcast domain



## 2.6 - VLANs and VPNs (continued)

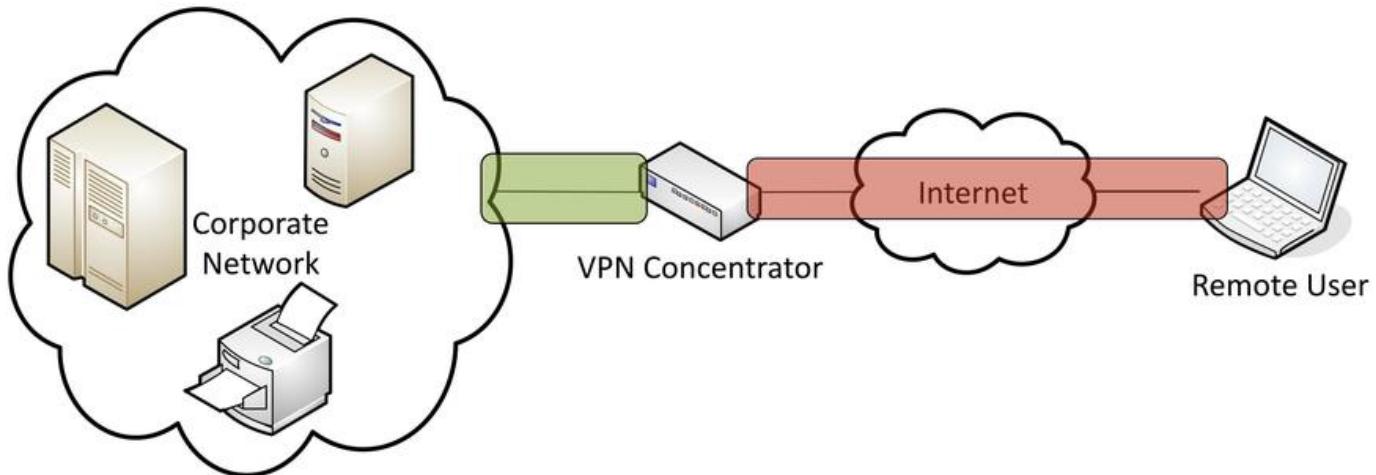
### VPNs

- Virtual Private Networks
  - Encrypted (private) data traversing a public network
- Concentrator
  - Encryption/decryption access device
  - Often integrated into a firewall
- Many deployment options
  - Specialized cryptographic hardware
  - Software-based options available

- Used with client software
  - Sometimes built into the OS

### Client-to-Site VPNs

- On-demand access from a remote device
  - Software connects to a VPN concentrator
- Some software can be configured as always-on



## 2.7 - Internet Connection Types

### Satellite networking

- Communication to a satellite
  - Non-terrestrial communication
- High cost relative to terrestrial networking
  - 50 Mbit/s down, 3 Mbit/s up are common
  - Remote sites, difficult-to-network sites
- High latency
  - 250 ms up, 250 ms down
  - Starlink advertises 40 ms and is working on 20 ms
- High frequencies - 2 GHz
  - Line of sight, rain fade

### Fiber

- High speed data communication
  - Frequencies of light
- Higher installation cost than copper
  - Equipment is more costly
  - More difficult to repair
  - Communicate over long distances
- Large installation in the WAN core
  - Supports very high data rates
  - SONET, wavelength division multiplexing
- Fiber is slowly approaching the premises
  - Business and home use

### Cable broadband

- Broadband
  - Transmission across multiple frequencies
  - Different traffic types
- Data on the “cable” network
  - DOCSIS (Data Over Cable Service Interface Specification)
- High-speed networking
  - 50 Mbit/s through 1,000+ Mbit/s are common
- Multiple services
  - Data, voice, video

### DSL

- ADSL (Asymmetric Digital Subscriber Line)
  - Uses telephone lines
- Download speed is faster than the upload speed (asymmetric)
  - 200 Mbit/s downstream / 20 Mbit/s upstream are common
  - ~10,000 foot limitation from the central office (CO)
  - Faster speeds may be possible if closer to the CO

## 2.7 - Internet Connection Types (continued)

### Cellular networks

- Mobile devices
  - “Cell” phones
- Separate land into “cells”
  - Antenna coverages a cell with certain frequencies
- Tethering
  - Turn your phone into a wireless router
- Mobile hotspot
  - Standalone devices
  - Use your phone for other things

### WISP

- Wireless Internet Service Provider
  - Terrestrial internet access using wireless
- Connect rural or remote locations
  - Internet access for everyone
- Many different deployment technologies
  - Meshed 802.11
  - 5G home internet
  - Proprietary wireless
- Need an outdoor antenna
  - Speeds can range from ~ 10 to 1,000 megabits per second

## 2.8 - Network Types

### LAN

- Local Area Network
  - Local is relative
- A building or group of buildings
  - High-speed connectivity
- Ethernet and 802.11 wireless
  - Any slower and it isn’t “local”

### WAN

- Wide Area Network
  - Spanning the globe
- Generally connects LANs across a distance
  - And generally much slower than the LAN
- Many different WAN technologies
  - Point-to-point serial, MPLS, etc.
  - Terrestrial and non-terrestrial

### PAN

- Personal Area Network
  - Your own private network
  - Bluetooth, IR, NFC
- Automobile
  - Audio output
  - Integrate with phone
- Mobile phone - Wireless headset
- Health
  - Workout telemetry, daily reports

### MAN

- Metropolitan Area Network
  - A network in your city
  - Larger than a LAN, often smaller than a WAN
- Historically MAN-specific topologies
  - Metro Ethernet
- Common to see government ownership
  - They “own” the right-of-way

### SAN

- Storage Area Network (SAN)
  - Looks and feels like a local storage device
  - Block-level access
  - Very efficient reading and writing
- Requires a lot of bandwidth
  - May use an isolated network and high-speed network technologies

### WLAN

- Wireless LAN
  - 802.11 technologies
- Mobility
  - Within a building
  - In a limited geographical area
- Expand coverage with additional access points
  - Downtown area
  - Large campus

## 2.8 - Network Tools

### Cable crimper

- “Pinch” the connector onto a wire
  - Coaxial, twisted pair, fiber
- Connect the modular connector to the Ethernet cable
  - The final step of the process
- Metal prongs are pushed through the insulation
  - The plug is also permanently pressed onto the cable sheath



### Crimping best practices

- Get a good crimper
  - And a good pair of electrician's scissors / cable snips
  - And a good wire stripper
- Make sure you use the correct modular connectors
  - Differences between wire types
- Practice, practice, practice
  - It won't take long to become proficient

## 2.8 - Network Tools (continued)

### WiFi analyzer

- Wireless networks are incredibly easy to monitor
  - Everyone “hears” everything
- Purpose-built hardware or mobile device add-on
  - Specializes in 802.11 analysis
- Identify errors and interference
  - Validate antenna location and installation



### Tone generator

- Where does that wire go?
  - Follow the tone
- Tone generator
  - Puts an analog sound on the wire
- Inductive probe
  - Doesn't need to touch the copper
  - Hear through a small speaker



### Using the tone generator and probe

- Easy wire tracing
  - Even in complex environments
- Connect the tone generator to the wire
  - Modular jack, coax, punch down connectors
- Use the probe to locate the sound
  - The two-tone sound is easy to find

### Punch-down tools

- “Punch” a wire into a wiring block
  - 66 block, 110 block, and others
- Can be tedious
  - Every wire must be individually punched
- Trims the wires during the punch
  - Very efficient process



## 3.1 - Network Cables

### The importance of cable

- Fundamental to network communication
  - Incredibly important foundation
- Usually only get one good opportunity at building your cabling infrastructure - Make it good!
- The vast majority of wireless communication uses cables
  - It has to plug in somewhere

### Twisted pair copper cabling

- Balanced pair operation
  - Two wires with equal and opposite signals
  - Transmit+, Transmit- / Receive+, Receive-
- The twist is the secret!
  - Keeps a single wire constantly moving away from the interference
  - The opposite signals are compared on the other end
- Pairs in the same cable have different twist rates

### Punch-down best-practices

- Organization is key
  - Lots of wires,
  - Cable management
- Maintain your twists
  - Your Category 6A cable will thank you later
- Document everything
  - Written documentation, tags, graffiti

### Cable testers

- Relatively simple
  - Continuity test
- Can identify missing pins
  - Or crossed wires
- Not usually used for frequency testing
  - Crosstalk, signal loss, etc.



### Loopback plugs

- Useful for testing physical ports
  - Or fooling your applications
- Serial / RS-232 (9 pin or 25 pin)
- Network connections
  - Ethernet, T1, Fiber
- These are not cross-over cables



### Taps and Port Mirrors

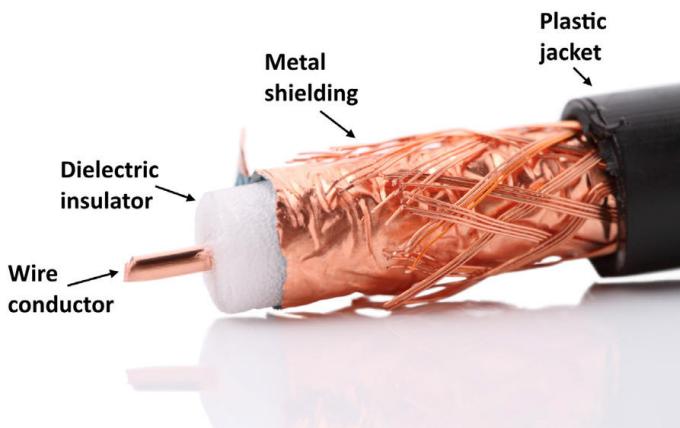
- Intercept network traffic
  - Send a copy to a packet capture device
- Physical taps
  - Disconnect the link, put a tap in the middle
  - Can be an active or passive tap
- Port mirror
  - Port redirection, SPAN (Switched Port ANalyzer)
  - Software-based tap
  - Limited functionality, but can work well in a pinch

Ethernet Standard	Cable Category	Maximum Supported Distance
1000BASE-T	Category 5	100 meters
1000BASE-T	Category 5e (enhanced)	100 meters
10GBASE-T	Category 6	Unshielded: 55 meters Shielded: 100 meters
10GBASE-T	Category 6A (augmented)	100 meters

## 3.1 - Network Cables (continued)

### Coaxial cables

- Two or more forms share a common axis
- RG-6 used in television/digital cable
  - And high-speed Internet over cable



### Plenum-rated cable

- Traditional cable jacket - Polyvinyl chloride (PVC)
- Fire-rated cable jacket
  - Fluorinated ethylene polymer (FEP) or low-smoke polyvinyl chloride (PVC)
- Plenum-rated cable may not be as flexible
  - May not have the same bend radius
- Worst-case planning
  - Important concerns for any structure

### Unshielded and shielded cable

- UTP (Unshielded Twisted Pair)
  - No additional shielding
  - The most common twisted pair cabling
- STP (Shielded Twisted Pair)
  - Additional shielding protects against interference
  - Shield each pair and/or the overall cable
  - Requires the cable to be grounded
- Abbreviations
  - U = Unshielded
  - S = Braided shielding
  - F = Foil shielding
- (Overall cable) / (individual pairs)TP
  - Braided shielding around the entire cable and foil around the pairs is S/FTP
  - Foil around the cable and no shielding around the pairs is F/UTP

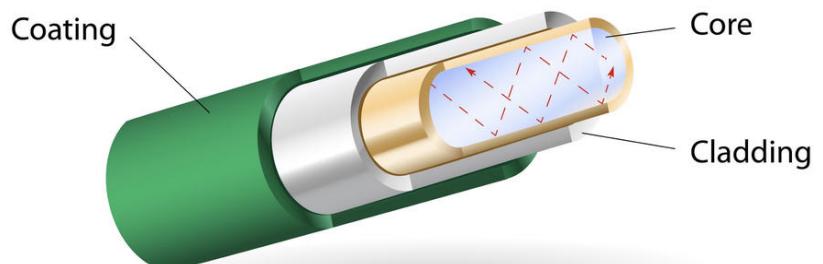
### Direct burial STP

- Overhead cable isn't always a good option
  - Put the cable in the ground
- Provides protection from the elements
  - Designed to be waterproof
  - Often filled with gel to repel water
  - Conduit may not be needed
- Shielded twisted pair
  - Provides grounding, adds strength
  - Protects against signal interference

## 3.1 - Optical Fiber

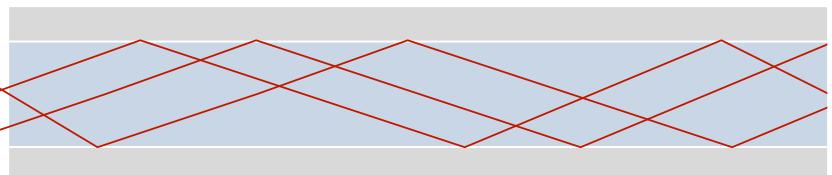
### Optical fiber communication

- Transmission by light
  - The visible spectrum
- No RF signal
  - Very difficult to monitor or tap
- Signal slow to degrade
  - Transmission over long distances
- Immune to radio interference - There's no RF



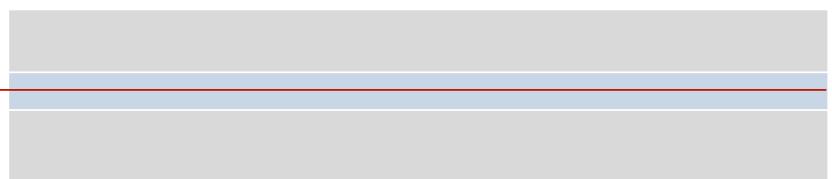
### Multimode fiber

- Short-range communication
  - Up to 2 km
- Relatively inexpensive light source
  - i.e., LED



### Single-mode fiber

- Long-range communication
  - Up to 100 km without processing
- Expensive light source
  - Commonly uses lasers



## 3.1 - 568A and 568B Colors

### Structured cabling standards

- International ISO/IEC 11801 cabling standards
  - Defines classes of networking standards
- Telecommunications Industry Association (TIA)
  - Standards, market analysis, trade shows, government affairs, etc.
- ANSI/TIA-568: Commercial Building Telecommunications Cabling Standard
- <http://www.tiaonline.org>
- Commonly referenced for pin and pair assignments of eight-conductor 100-ohm balanced twisted pair cabling
  - T568A and T568B

### T568A and T568B termination

- Pin assignments from T568-B standard
  - Eight conductor 100-ohm balanced twisted-pair cabling
- T568A and T568B are different pin assignments for 8P8C connectors
  - Assigns the T568A pin-out to horizontal cabling
- Many organizations traditionally use 568B
  - Difficult to change in mid-stream
- You can't terminate one side of the cable with 568A and the other with 568B
  - This has never been the definition of a Gigabit Ethernet crossover cable

TIA/EIA 568A

1	White and Green
2	Green
3	White and Orange
4	Blue
5	White and Blue
6	Orange
7	White and Brown
8	Brown



TIA/EIA 568B

1	White and Orange
2	Orange
3	White and Green
4	Blue
5	White and Blue
6	Green
7	White and Brown
8	Brown

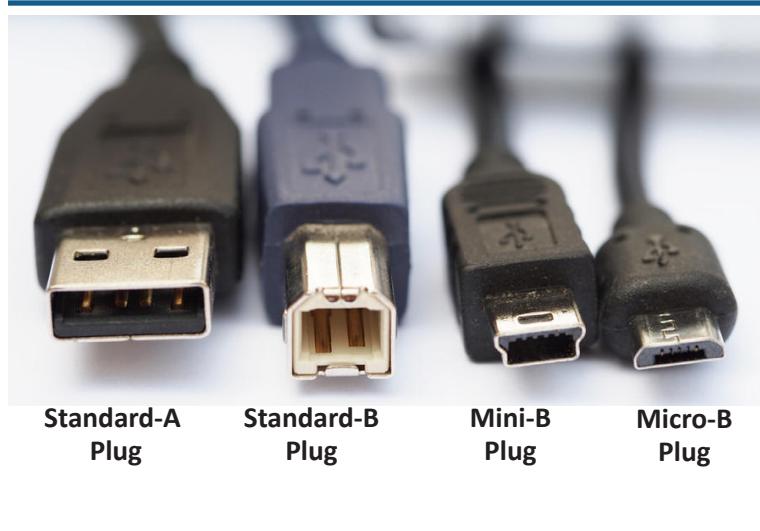
## 3.1 - Peripheral Cables

### USB (Universal Serial Bus)

- Simplify connections - Printers, storage devices, keyboard, mouse
- USB 1.1
  - Low speed: 1.5 megabits per second, 3 meters
  - Full speed: 12 megabits per second, 5 meters
- USB 2.0 - 480 megabits per second, 5 meters
- USB 3.0 - SuperSpeed
  - 5 gigabits per second, ~3 meters
  - Standard does not specify a cable length

### USB-C

- USB has a lot of different connectors
  - And they have changed over time
- Can be annoying to connect USB-A
  - Third time's the charm
- USB-C replaces all of these
  - One connector to rule them all
- USB-C describes the physical connector
  - It doesn't describe the signal

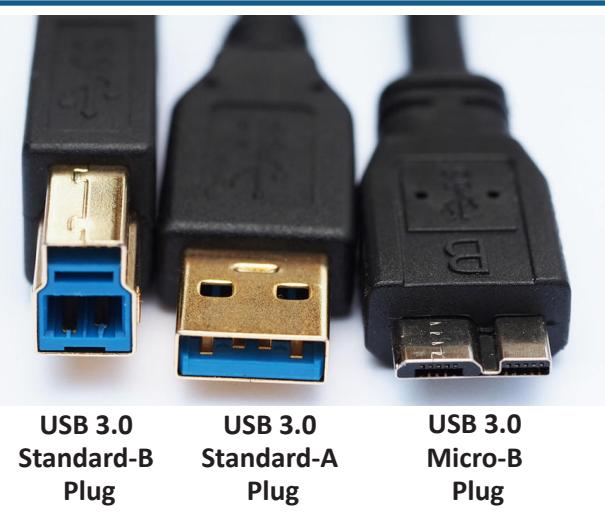


Standard-A  
Plug

Standard-B  
Plug

Mini-B  
Plug

Micro-B  
Plug



USB 3.0  
Standard-B  
Plug

USB 3.0  
Standard-A  
Plug

USB 3.0  
Micro-B  
Plug

### 3.1 - Peripheral Cables (continued)



Micro-B  
Plug

USB-C  
Plug

Standard-A  
Plug

#### USB versions and naming

- There's a lot to keep track of
  - The names keep changing
- The standard doesn't change
  - Just the names

#### USB 3.1

- Released July 2013
  - Doubled the throughput over USB 3.0
- USB 3.0 is USB 3.1 Gen 1
  - SuperSpeed USB - 5 Gbit/sec
- USB 3.1 is USB 3.1 Gen 2 - SuperSpeed+
  - Twice the rate of USB 3.0/USB 3.1 Gen 1

#### USB 3.2

- USB 3.2
  - Released September 2017
  - Bandwidth can double with USB-C cables
  - Uses an extra “lane” of communication associated with the flip-flop wires in USB-C
- USB 3.0 -> 3.1 Gen 1 -> USB 3.2 Gen 1
  - SuperSpeed USB 5 Gbps (single lane)
- USB 3.1 -> 3.1 Gen 2 -> USB 3.2 Gen 2
  - SuperSpeed USB 10 Gbps (single lane)

#### Thunderbolt

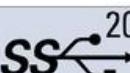
- High-speed serial connector
  - Data and power on the same cable
  - Based on Mini DisplayPort (MDP) standard
- Thunderbolt v1
  - Two channels
  - 10 Gbit/s per channel, 20 Gbit/s total throughput
  - Mini DisplayPort connector
- Thunderbolt v2
  - 20 Gbit/s aggregated channels
  - Mini DisplayPort connector
- Thunderbolt v3
  - 40 Gbit/s aggregated throughput - USB-C connector
- Maximum 3 meters (copper)
  - 60 meters (optical)
- Daisy-chain up to 6 devices

DB-9 / RS-232 Connector



#### Serial console cables

- D-subminiature or D-sub
  - The letter refers to the connector size
- Commonly used for RS-232
  - Recommended Standard 232
  - An industry standard since 1969
- Serial communications standard
  - Built for modem communication
  - Used for modems, printers, mice, networking
- Now used as a configuration port

USB 3.2 Name	USB 3.1 Name	USB 3.0 Name	Marketing Name	Maximum Speed	Logo
USB 3.2 Gen 1	USB 3.1 Gen 1	3.0	SuperSpeed USB 5Gbps	5 Gbit/sec	
USB 3.2 Gen 2	USB 3.1 Gen 2		SuperSpeed USB 10Gbps	10 Gbit/sec	
USB 3.2 Gen 1x2				10 Gbit/sec	
USB 3.2 Gen 2x2			SuperSpeed USB 20Gbps	20 Gbit/sec	

## 3.1 - Video Cables

### VGA (Video Graphics Array)

- DB-15 connector
  - More accurately called DE-15
- Blue color
  - PC System Design Guide
- Analog signal
  - No digital
  - Image degrades after 5 to 10 meters



### HDMI (High-Definition Multimedia Interface)

- Video and audio stream
  - All digital, no analog
  - ~ 20 meter distance before losing too much signal
- 19-pin (Type A) connector
  - Proprietary connector

HDMI



### DisplayPort

- Digital information sent in packetized form
  - Like Ethernet and PCI Express
  - Carries both audio and video
- Compatible with HDMI and DVI
  - Passive adapter
  - DisplayPort → HDMI
  - DisplayPort → DVI

DisplayPort



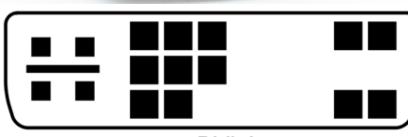
### DVI (Digital Visual Interface)

- Single and dual link
  - Single link; 3.7 Gbps (HDTV at 60 fps)
  - Dual link; 7.4 Gbps (HDTV at 85 fps)
  - No audio support
- DVI-A
  - Analog signals
- DVI-D
  - Digital signals
- DVI-I
  - Integrated
  - Digital and analog in the same connector

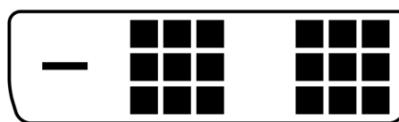
Mini DisplayPort



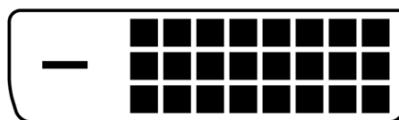
### DVI (Digital Visual Interface)



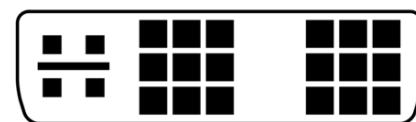
DVI-A



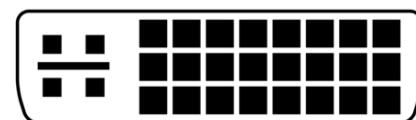
DVI-D (Single Link)



DVI-D (Dual Link)



DVI-I (Single Link)

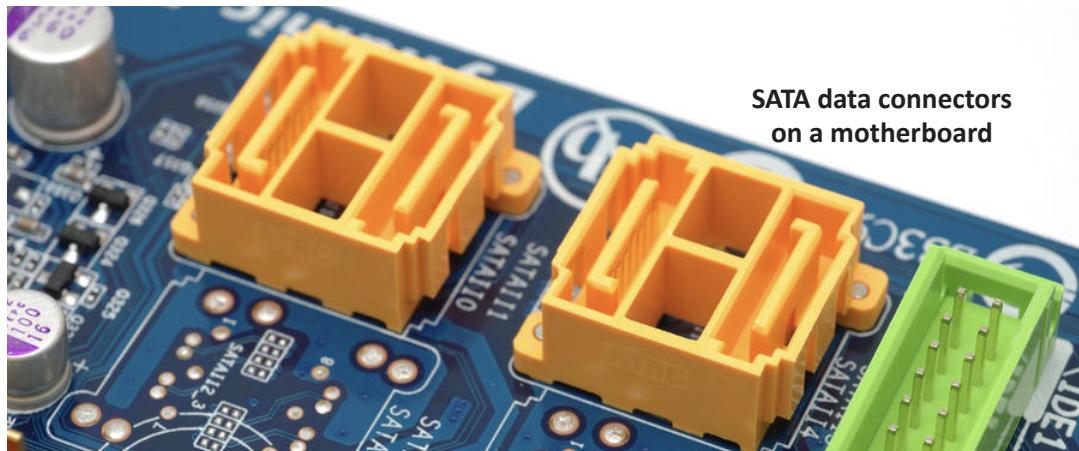
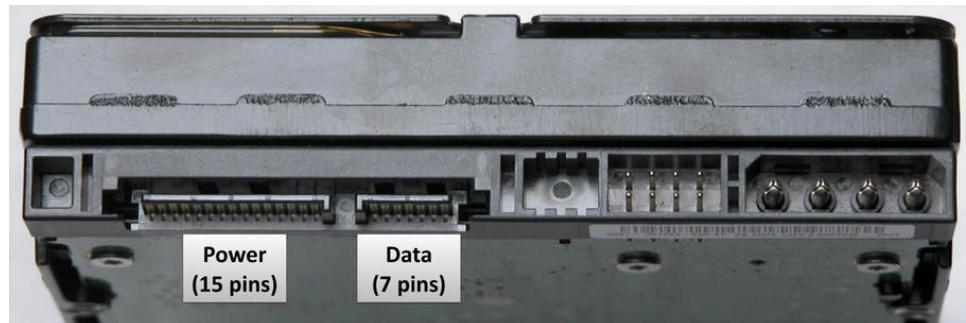
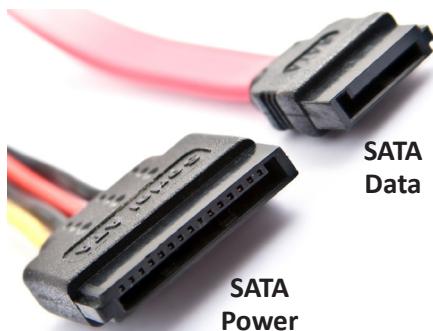


DVI-I (Dual Link)

## 3.1 - SATA Device Cables

### SATA (Serial AT Attachment)

- SATA Revision 1.0 - SATA 1.5 Gbit/s, 1 meter
- SATA Revision 2.0 - SATA 3.0 Gbit/s, 1 meter
- SATA Revision 3.0 - SATA 6.0 Gbit/s, 1 meter
- SATA Revision 3.2 - SATA 16 Gbit/s, 1 meter
- eSATA (external SATA)
  - Matches the SATA version - 2 meters



## 3.1 - SCSI Device Cables

### The SCSI standard

- Small Computer Systems Interface
  - Not really “small” any longer
- Originally designed to string many peripherals together onto a single cable/controller
  - Up to 16 devices in a SCSI “chain”
- Many different formats
  - Fast SCSI, Ultra SCSI, Ultra Wide SCSI, Ultra2 SCSI,
  - Ultra3 SCSI, Ultra-320 SCSI, Ultra-640 SCSI,
  - iSCSI (SCSI over IP)
- Parallel and serial options

### SCSI advantages

- Not just for hard drives
  - Scanners, tape drives, CD-ROM drives
- Many devices on a single bus
  - 8 on narrow bus, 16 on wide bus

### SATA

- One power cable and data cable per device
  - One-to-one

### eSATA cable

- External device connections
  - Uses the SATA standard
- Similar in size to SATA
  - Connectors are physically different

### SATA data connectors on a motherboard

- Very intelligent interface functionality
  - Much of the difficult configuration work is done between the SCSI devices

- Industry longevity
  - Well supported in the enterprise
  - A standard drive for virtual systems

### SCSI ID and logical unit (LUN)

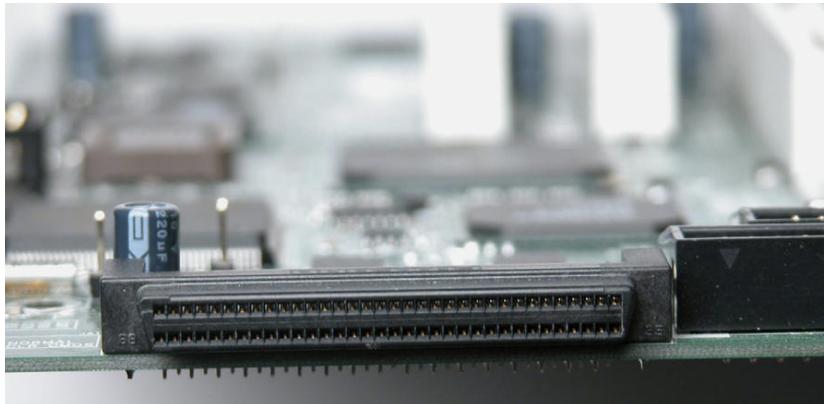
- Every SCSI device on a single bus is assigned a separate ID number
  - SCSI ID 0 (SCSI controller), ID 2 (hard drive), ID 3 (CD-ROM)
- Logical units (LUNs) are defined within each SCSI ID
  - Separate drives in a storage array or virtual machine
- The signal at the “end” of a physical SCSI bus is terminated
  - Can be internal to the device or a separate termination device
- Serial attached SCSI (SAS) devices have no jumpers, terminators, or settings.

### 3.1 - SCSI Device Cables (continued)

#### Serial attached SCSI

- Move from parallel to serial
  - Increased throughput
  - Similar to the move from PATA to SATA
- Point-to-point connection
  - No more daisy chains

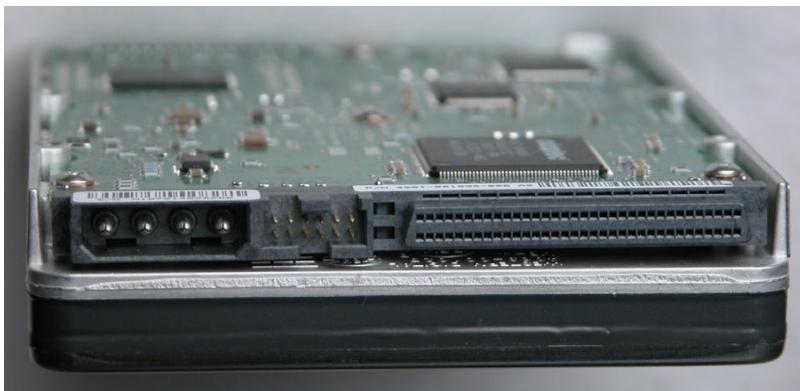
- No termination required
  - The bus has two devices on it
- The control and management of SCSI
  - The speed of a serial connection



Motherboard SCSI connector



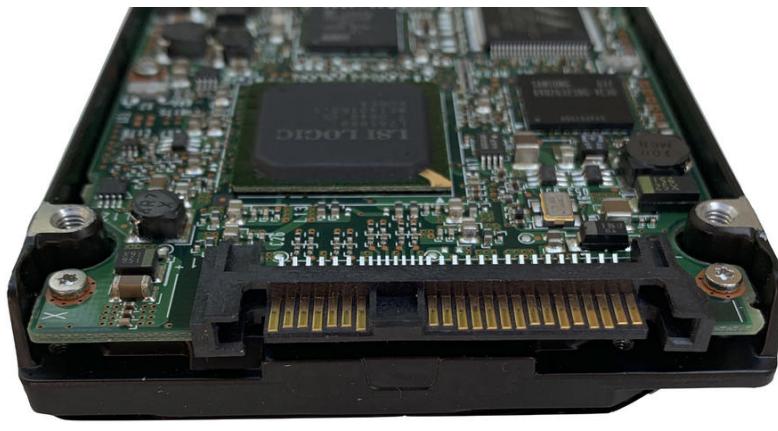
Internal SCSI cable and connectors



Hard drive with Molex power connector,  
jumpers, and SCSI connector



Internal SCSI Cable



2.5" SAS hard drive



High-density internal SAS connector

## 3.1 - PATA Drive Cables

### The PATA Standard

- Parallel AT Attachment
  - Remember the PC/AT?
- An evolutionary process
  - Circa 1999
- Originally called Integrated Drive Electronics (IDE)
  - A Western Digital invention
  - 2nd generation called EIDE (Enhanced IDE)
- The evolution
  - Promised faster speeds
  - From 16 MB/s through 133 MB/s
  - Additional devices
- Now called Parallel ATA (PATA)



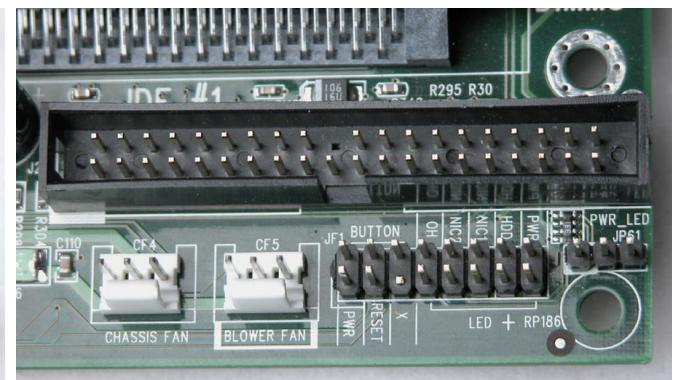
Hard drive with PATA connector, jumpers, and Molex power connector



PATA data cable



SATA data cable



Motherboard PATA connector

## 3.1 - Adapters and Converters

### Adapters and converters

- The best laid plans...
  - Need an adapter
- Convert between different connectors
  - Electrically compatible
- Convert from one format to another
  - You need Ethernet but you only have USB
- A good temporary fix
  - Or a good permanent one

### DVI to HDMI

- DVI-D and HDMI are electrically compatible
  - HDMI is backward-compatible with DVI-D
  - No signal conversion required
  - No loss of video quality

### DVI to VGA

- DVI-A includes analog signals
  - Backward compatible with VGA
  - Only 640 x 480 is officially supported
- May only need an adapter - Analog to analog
- VGA to DVI digital will need a converter
  - Check your interface specifications

### USB to Ethernet

- Some laptops don't have an Ethernet connection

### USB-C to USB-A

- Merge the new with the old- Use your older peripherals

### USB hub

- Connect many devices - High speed USB connectivity



DVI-A



VGA



USB to Ethernet adapter

## 3.1 - Copper Connectors

### RJ11 connector

- 6 position, 2 conductor (6P2C)
  - Some cables will wire additional conductors
  - Telephone or DSL connection

### RJ45 connector

- Registered Jack type 45
- 8 position, 8 conductor (8P8C)
  - Modular connector - Ethernet

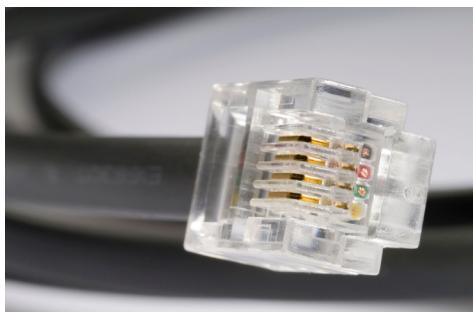
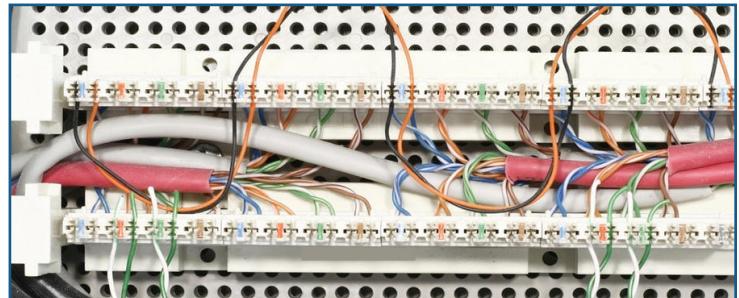
### F-connector

- Cable television
  - Cable modem
  - DOCSIS  
(Data Over Cable Service Interface Specification)
- RG-6 cable - Threaded connector

### Punchdown block

- Wire-to-wire patch panel
  - No intermediate interface required
- Wires are “punched” into the block
  - Connecting block is on top
- Additional wires punched into connecting block
  - Patch the top to the bottom

110 block



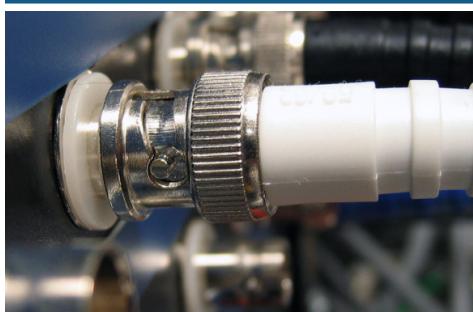
RJ11



RJ45



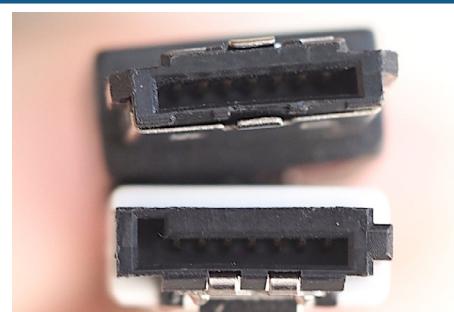
DB-9 / RS-232 Connector



BNC connector



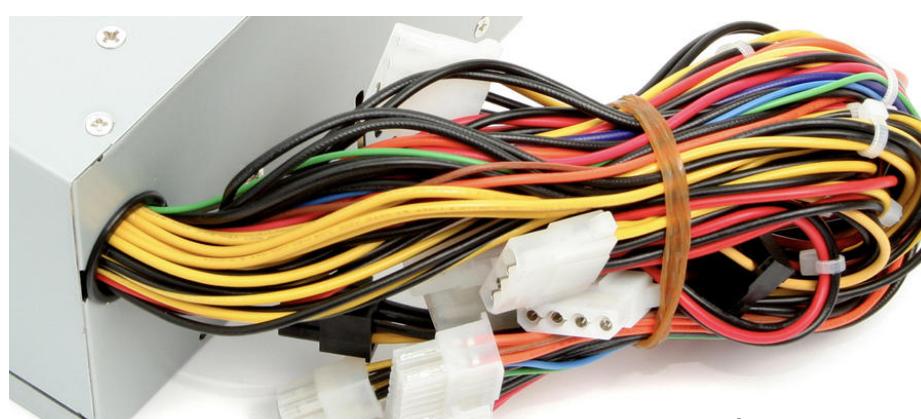
F-connector



eSATA and SATA connectors



Molex connector



Power supply connectors

## 3.1 - Copper Connectors (continued)

### USB-C

- 24-pin double-sided USB connector
  - Used for both hosts and devices
- Used for USB, Thunderbolt
  - Interface is the same, signal can vary

### Molex connector

- 4-pin peripheral power connector
  - Molex Connector Company
  - AMP MATE-N-LOK
  - Provides +12 V and +5 V
- Power for many devices in the computer case
  - Storage devices
  - Optical drives
  - Fans
  - Other peripherals

### Lightning

- Apple proprietary
  - 8-pin digital signals
  - iPhone, iPad, iPod devices
- Some advantages over Micro-USB
  - Higher power output for phones and tablets
  - Can be inserted either way

### DB-9

- D-subminiature or D-sub
  - The letter refers to the connector size
- Commonly used for RS-232
  - Recommended Standard 232
  - An industry standard since 1969
- Serial communications standard
  - Built for modem communication
  - Used for modems, printers, mice, networking
- Now used as a configuration port
  - Management or Console port

## 3.1 - Fiber Connectors



LC - Local Connector



ST - Straight Tip



SC - Subscriber Connector

## 3.2 - An Overview of Memory

### What is memory?

- Random Access Memory (RAM) is the most common
  - But it's not the only kind of memory
- RAM is not referring to hard drive or SSD storage
  - Don't mix the two terms
  - Data is stored permanently on the drive
- Data and programs can only be used when moved to RAM

### RAM (Random Access Memory) slots

- Memory types have changed through the years
  - Driven by standardization and technology
- One of the most important components of your computer
  - Speed, speed, speed
- Every motherboard is different
  - Check your documentation

### DIMM

- DIMM - Dual inline memory module
  - Electrical contacts are different on each side
- 64 bit data width

### SO-DIMM

- Small Outline Dual In-line Memory Module
  - About half the width as a DIMM
- Used in laptops and mobile devices

### Dynamic Random Access Memory (DRAM)

- The memory on the DIMM
- Dynamic
  - Needs constant refreshing
  - Without refreshing, the data in memory disappears
- Random access
  - Any storage location can be accessed directly
  - Unlike magnetic tape

### SDRAM

- Synchronous DRAM (SDRAM)
- SDRAM is synchronous with the common system clock
  - Queue up one process while waiting for another
  - Classic DRAM didn't wait for a clock signal

## 3.2 - An Overview of Memory (continued)

### Double Data Rate 3 (DDR3) SDRAM

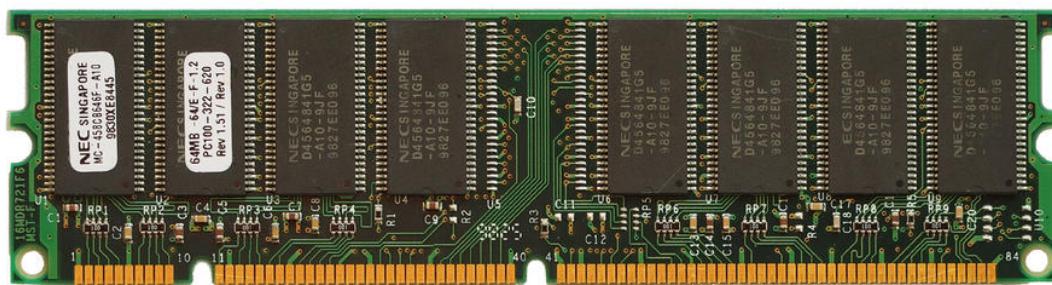
- Twice the data rate of DDR2
  - Larger chip capacities - Maximum 16 GB per DIMM
- No backwards compatibility
  - Speed brings sacrifice

### Double Data Rate 4 (DDR4) SDRAM

- Speed increases over DDR3
  - Faster frequencies
  - Maximum 64 GB per DIMM
- Again, no backwards compatibility

### Double Data Rate 5 (DDR5) SDRAM

- Faster data transfers between the memory module and motherboard
  - Maximum of 64 GB per DIMM
- The key has moved - No backwards compatibility

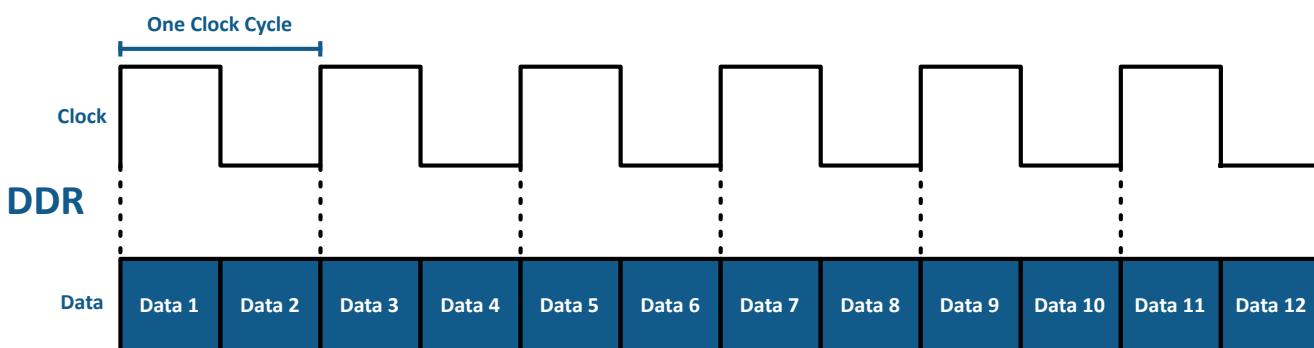
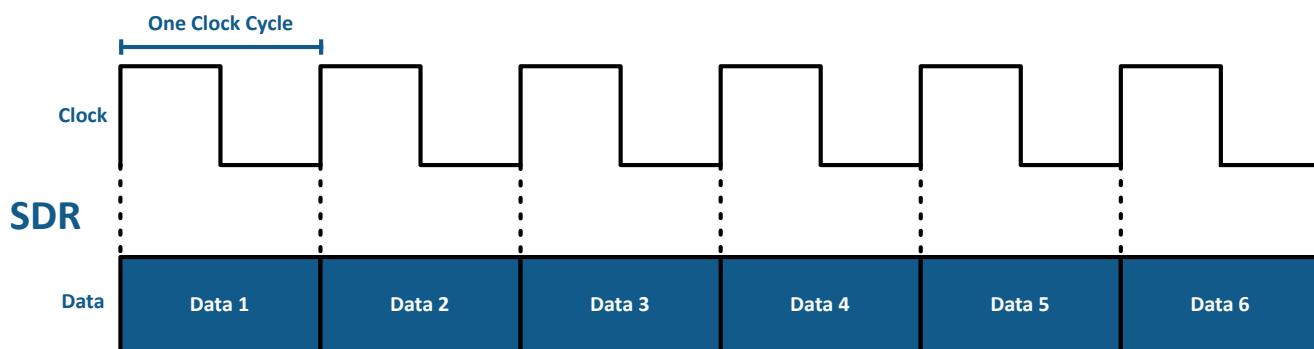


**DIMM**  
(Dual Inline  
Memory Module)



**SO-DIMM**  
(Small Outline Dual  
Inline Memory Module)

### SDR vs. DDR



## 3.2 - Memory Technologies

### Virtual memory

- Different names - Virtual RAM, swap file, etc.
- Swap currently unused application data to storage
  - Free up space for other applications
- Managed automatically by the operating system
  - Some configuration settings are available

### Multi-channel memory

- Dual-channel, triple-channel, or quad-channel
- Memory combinations should match
  - Exact matches are best
- Memory module slots are often colored differently

### Memory that checks itself

- Used on critical computer systems
  - VM servers, database servers, any server
- Parity memory
  - Adds an additional parity bit
  - Won't always detect an error
  - Can't correct an error
- Error Correcting Code (ECC)
  - Detects errors and corrects on the fly
  - Not all systems use ECC
  - It looks the same as non-ECC memory

## 3.3 - Storage Devices

### Hard disk drives (HDD)

- Non-volatile magnetic storage - rapidly rotating platters
- Random-access
  - Retrieve data from any part of the drive at any time
- Moving parts
  - Spinning platters, moving actuator arm
  - Mechanical components limit the access speed
  - Mechanical components can also break

### Solid-state drives (SSD)

- Non-volatile memory - No moving parts
- Very fast performance - No spinning drive delays

### mSATA (Mini-SATA)

- Shrink the SATA drive into smaller devices
  - Same data, different form factor
  - Great for laptops and mobile devices
- Smaller than 2.5" SATA drives
  - No spinning drive
  - Allows for different form factors
- Was used briefly - Quickly replaced by the m.2

### AHCI vs. NVMe

- SATA was designed for hard drives
  - Uses AHCI (Advanced Host Controller Interface) to move drive data to RAM
  - SATA revision 3 throughput up to 600 MB/s
  - SSDs need a faster communication method
- NVMe (Non-volatile Memory Express)
  - Designed for SSD speeds
  - Lower latency, supports higher throughputs
  - Take advantage of NVMe with an M.2 interface

### M.2 interface

- Smaller form factor - No SATA data or power cables
- Can use a PCI Express bus connection
  - 4 GB/second throughput or faster when using NVMe PCIe x4
- Different connector types
  - Needs to be compatible with the slot key/spacer
  - B key, M key, or B and M key
  - Some M.2 drives will support both

### B-key and M-key

- M.2 doesn't guarantee NVMe
  - Your M.2 interface may be using AHCI
  - Check your documentation
- Your motherboard may only support one type of M.2 key
  - Check the documentation again

### Flash drives

- Flash memory
  - EEPROM (Electrically erasable programmable read-only memory)
  - Non-volatile memory - No power required to retain data
- Limited number of writes
  - Can still read the data
- Not designed for archival storage
  - Easy to lose or damage - Always have a backup
  - Flash memory

### Optical drives

- Small bumps read with a laser beam
  - Microscopic binary storage
- Relatively slow
  - Archival media
- Many different formats - CD-ROM, DVD-ROM, Blu-ray
- Internal and external drives
  - For those uncommon application installations



CompactFlash (CF)



Secure Digital (SD)

Flash memory



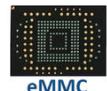
miniSD



microSD

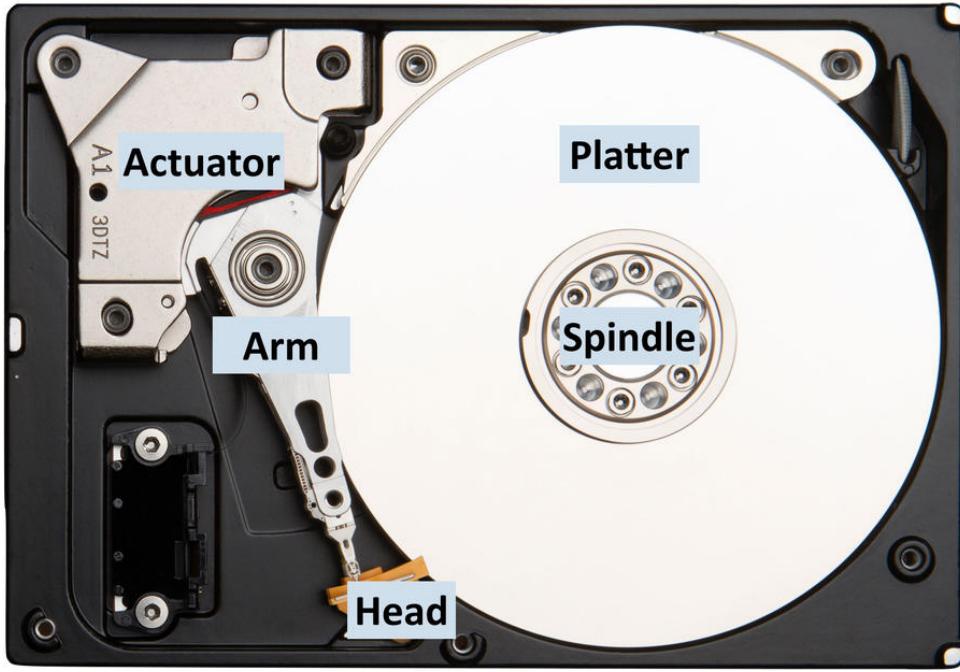


xD-Picture Card



eMMC

### 3.3 - Storage Devices (continued)



Rotational Speed (rpm)	Average Rotational Latency
15,000	2 ms
10,000	3 ms
7,200	4.16 ms
5,400	5.55 ms

### 3.3 - RAID

#### Data redundancy

- Hard drives store huge amounts of important data
- Hard drives are moving components
  - They will eventually break
- What happens to the data when the drive fails?
  - You can prepare for that
  - Use an array of drives
- RAID is not backup

#### RAID

- Redundant Array of Independent Disks
  - They're also inexpensive disks.
- Different RAID levels - Some redundant, some not
- RAID 0 – Striping
- RAID 1 - Mirroring
- RAID 5 – Striping with Parity
- Nested RAID - RAID 1+0 (a.k.a. RAID 10) - A stripe of mirrors

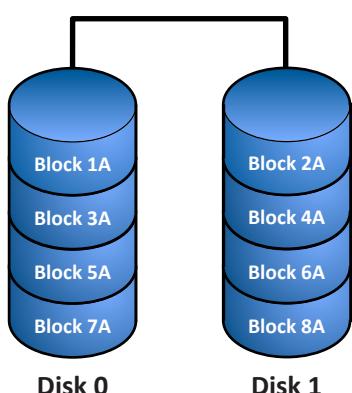
#### RAID 0 - Striping

- File blocks are split between two or more physical drives
  - High performance
  - Data written quickly
- No redundancy
  - A drive failure breaks the array
  - Raid 0 is zero redundancy

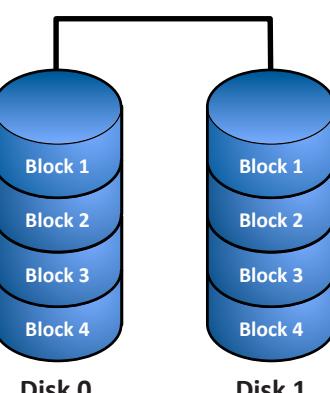
#### RAID 1 - Mirroring

- File blocks are duplicated between two or more physical drives
- High disk utilization
  - Every file is duplicated
  - Required disk space is doubled
- High redundancy
  - Drive failure does not affect data availability

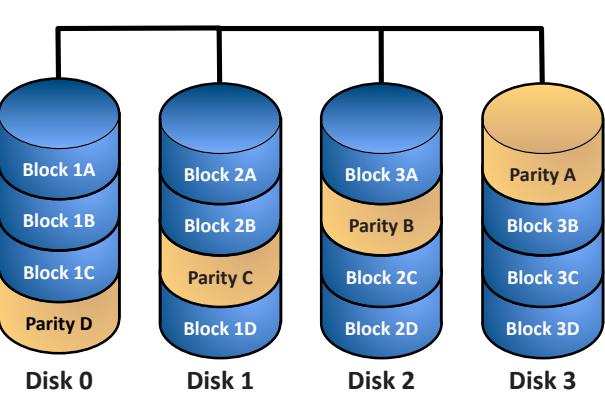
#### RAID 0 - Striping



#### RAID 1 - Mirroring

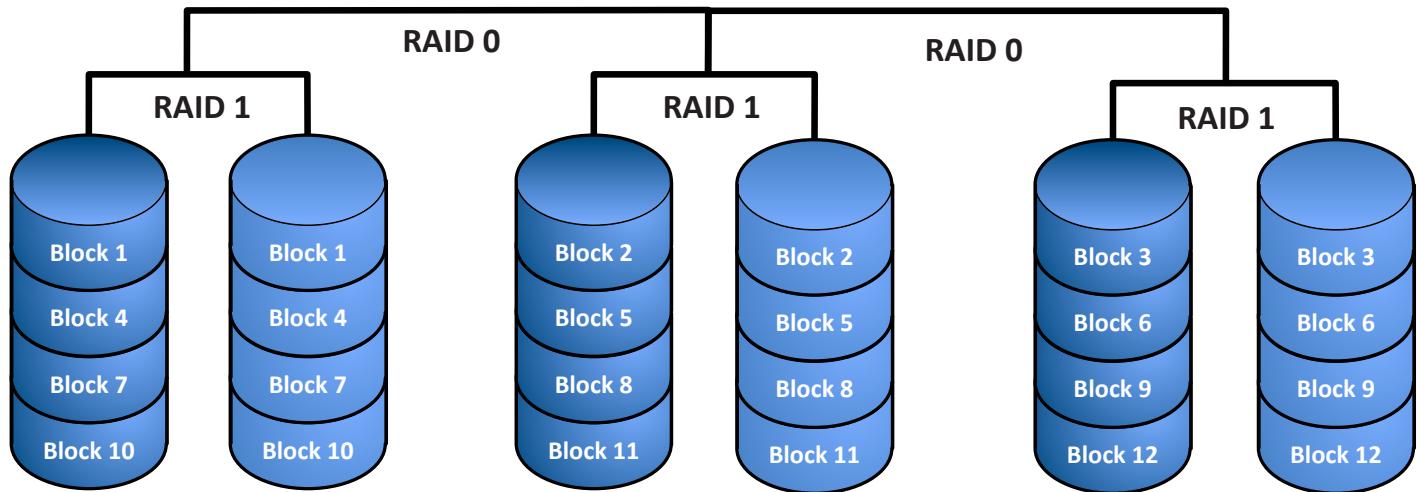


#### RAID 5 - Striping with Parity



### 3.3 - RAID (continued)

RAID 1+0 - A Stripe of Mirrors



### 3.4 - Motherboard Form Factors

#### Motherboard form factors

- Physical size - Case sizing
- Basic layout - Room for small changes
- Power - Standard connectors
- Airflow - Increasingly important
- Wikipedia: There are 40 different motherboard types categorized!

#### What you need to know

- CompTIA exam objectives:
  - “3.4 - Given a scenario, install and configure motherboards, central processing units (CPUs), and add-on cards.”
- Focus on which motherboard would be the best choice for a scenario
  - Memorizing the dimensions of the motherboard probably isn’t the most important thing
  - ATX or ITX

- Which motherboard would you choose?
  - Media center, video editing, thin client, etc.

#### ATX form factor

- Advanced Technology Extended
  - Standardized by Intel in 1995
  - Seen many updates over the years
- Power
  - 20 pin connector
  - 24 pin connector, additional 4/8 pin connector

#### ITX form factor

- A series of low-power motherboards
  - Developed by VIA Technologies in 2001
  - Small form factor
- Mini-ITX is screw-compatible with ATX
  - Fits almost any enclosure
- Small form factor uses
  - Single-purpose computing, i.e., streaming media

### 3.4 - Motherboard Expansion Slots

#### A computer bus

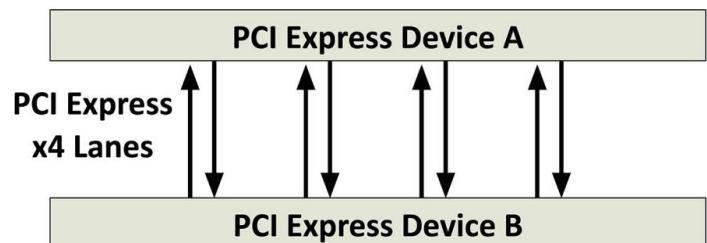
- Communication path - A city of technology
- Internal PC growth - Independent pathways
- System expansion - Additional capabilities

#### Conventional PCI

- Peripheral Component Interconnect
  - Created in 1994
- Many expansion options
  - 32-bit and 64-bit bus width
  - Parallel communication
- A common expansion interface on previous computer generations
  - PCI Express is the newer technology

#### PCI Express

- Also known as PCIe - Replaces the older PCI standard
- Communicates serially - Unidirectional serial “lanes”
  - Slower devices don’t slow down everyone
- One, two, four, eight, sixteen, or thirty-two full-duplex lanes
  - x1, x2, x4, x8, x16, x32
  - “x” is pronounced “by” (“by 4,” “by 16”)



## 3.4 - Motherboard Connectors

### 24-pin motherboard power

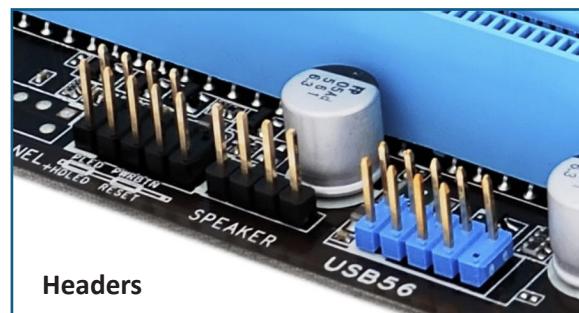
- Main motherboard power
  - Provides +3.3 V, +/- 5 V, and +/- 12 V
- 20 pin connector was the original ATX standard
  - 24 pin was added for PCI Express power
- You can connect a 24-pin connector to a 20-pin motherboard
  - Some cables are 20-pin + 4-pin

### 4-pin ATX

- 4-pin ATX +12 V power
  - ATX12V Advanced Technology Extended motherboards
- Additional 12 volt power for older motherboards
  - Used primarily for CPU
- May be labeled ATX12V, P4, or CPU
  - And keyed for the appropriate connector

### Headers

- A pin header
  - A simple electrical interface
  - The connector is attached to the header
- Many different uses
  - Power, peripheral connections, lights, and buttons



## 3.4 - Motherboard Compatibility

### Intel and AMD

- Two solid CPU manufacturers
  - The differences are subtle
- Cost
  - AMD tends to be a bit less expensive
- Different sockets
  - The motherboard is designed for a particular CPU
- Choosing a side
  - Historically, AMD is value and Intel is performance
  - This is a dynamic technology segment

### Server motherboards

- Multisocket
  - Supports multiple physical CPU packages
  - Split the load
- Memory slots - Supports 4+ modules
- Expansion slots
  - Many slots and different sizes
- Overall size
  - Designed for a rack-mounted system
  - Larger ATX-sized system

### Desktop motherboards

- Can range from full-size motherboards to compact or monitor-only systems
  - We can do a lot with increasingly smaller systems
- Single CPU - Reduces cost and complexity
- Memory slots - Usually two or four
- Expansion slots - May have limited options

### Mobile motherboards

- Laptops - Small and light
- CPUs - Limited in speed - Thermal throttling
- Limited system modification
  - Memory, CPU, functionality
- Portability - Smaller devices
  - Low power consumption

### System board

- Proprietary - Built to fit
- Replacement isn't easy
  - Swap the entire board
- Most components are on the system board

## 3.4 - The BIOS

### BIOS - Basic Input/Output System

- The software used to start your computer
  - The firmware - System BIOS, ROM BIOS
  - ROM or flash memory
- Initializes CPU and memory - Build the workspace
- POST - Power-On Self-Test
- Look for a boot loader - Start the operating system

### Legacy BIOS

- The original / traditional BIOS
  - It's been around for more than 25 years

- Older operating systems talked to hardware through the BIOS
  - Instead of accessing hardware directly

- Limited hardware support
  - No drivers for modern network, video, and storage devices

### UEFI BIOS

- Unified Extensible Firmware Interface
  - Based on Intel's EFI (Extensible Firmware Interface)
- A defined standard - Implemented by the manufacturers
- Designed to replace the legacy BIOS
  - Need a modern BIOS for modern computers
  - Graphical and text-based

## 3.4 - BIOS Settings

### The secret button(s)

- Launching the system setup
  - Del, F1, F2, Ctrl-S, Ctrl-Alt-S
- Hyper-V (Windows 8/10/11)
  - Turn Windows features on and off
- VMware Workstation Player
  - <http://www.vmware.com/products/player/>
- But not VirtualBox
  - <http://www.virtualbox.org>
- Many simulators online
  - Search for “UEFI BIOS simulator”

### Fast startup

- Windows 8, 10, and 11
  - Doesn't actually shut down all the way
  - Starts up so quickly, you can't open the BIOS configuration
- From the Windows desktop
  - Hold down shift when clicking Restart
  - Settings / Update & Security / Recovery / Advanced startup / Restart now
  - System Configuration (msconfig)
- Interrupt normal boot three times
  - Presents the boot option screen

### Important tips

- Make a backup of your BIOS configuration
  - Write detailed notes
  - Take a picture
- Don't make a change unless you're certain of the setting
  - It's difficult to leave it alone
- Did I mention the backup?
  - It can save a lot of time!

### Boot options

- What happens when you power on?
  - The BIOS knows
  - Disable hardware
  - Unavailable to the operating system
  - Modify the boot order
  - Which boots first?
  - Move to the next in order
  - USB drive, SSD, hard drive

### USB permissions

- A security challenge
  - Very small storage devices
  - Very large capacities
- USB connections
  - Convenient
  - High speed
- US Department of Defense banned USB flash media for 15 months in 2008
  - SillyFDC worm

### Fans

- Computing power creates heat
  - A lot of heat
- Many different cooling fans
  - CPU fan
  - Chassis fans
- Motherboards often include an integrated fan controller
  - And temperature sensors
  - The motherboard increases and decreases the fan speeds

### Secure Boot

- Malicious software can “own” your system
  - Malicious drivers or OS software
- Secure boot
  - Part of the UEFI specification
- Digitally sign known-good software
  - Cryptographically secure
  - Software won't run without the proper signature
- Support in many different operating systems
  - Windows and Linux support

### UEFI BIOS Secure Boot

- UEFI BIOS protections
  - BIOS includes the manufacturer's public key
  - Digital signature is checked during a BIOS update
  - BIOS prevents unauthorized writes to the flash
- Secure Boot verifies the bootloader
  - Checks the OS bootloader's digital signature
  - Bootloader must be signed with a trusted certificate
  - Or a manually approved digital signature

### Boot password management

- BIOS Password / User Password
  - System won't start
  - Need the password to start the operating system
- Supervisor Password
  - Restrict BIOS changes
  - Must use supervisor password to change any BIOS configurations
- Remember your password!
  - Must reset the BIOS to recover
  - Usually a jumper

### Clearing a boot password

- Store the BIOS configuration - Your settings
- Complementary metal-oxide semiconductor (CMOS)
  - A type of memory
  - May be backed up with a battery
- Usually flash memory these days
  - Easily stored and accessed
- Reset with a jumper
  - Short (connect) two pins on the motherboard

## 3.4 - BIOS Settings (continued)

### The “CMOS” battery

- Not needed for today's flash-based storage
  - Maintains older BIOS configurations
  - May only be used to maintain date/time
- A bad battery will require a BIOS configuration or date/time configuration on every boot
- On older systems, can reset the BIOS configuration by removing the battery
  - Newer computers use a jumper

### Trusted Platform Module (TPM)

- A specification for cryptographic functions
  - Hardware to help with encryption functions
- Cryptographic processor
  - Random number generator, key generators

- Persistent memory
  - Comes with unique keys burned in during production
- Versatile memory
  - Storage keys, hardware configuration information
  - Password protected / No dictionary attacks

### Hardware Security Module (HSM)

- Often used in large environments (Clusters, redundant power)
- High-end cryptographic hardware
  - Plug-in card or separate hardware device
- Key backup - Secured storage for servers
  - Lightweight HSMs for personal use (Smart card, USB, flash memory)
- Cryptographic accelerators
  - Offload that CPU overhead from other devices

## 3.4 - CPU Features

### Operating system technologies

- 32-bit vs. 64-bit - Processor specific
- 32-bit processors =  $2^{32} = 4,294,967,296$  values
- 64-bit processors =  $2^{64} = 18,446,744,073,709,551,616$  values
  - 4 GB vs. 17 billion GB
  - The OS has a maximum supported value

### Operating system technologies

- Hardware drivers are specific to the OS version (32-bit / 64-bit)
  - 32-bit (x86), 64-bit (x64)
- 32-bit OS cannot run 64-bit apps
  - But 64-bit OS can run 32-bit apps
- Apps in a 64-bit Windows OS
  - 32-bit apps: \Program Files (x86)
  - 64-bit apps: \Program Files

### Advanced RISC Machine (ARM)

- CPU architecture developed by Arm Ltd.
  - They design the chip, others license and build
- Simplified instruction set
  - Efficient and fast processing
  - Less power
  - Less heat
- Traditionally used for mobile and IoT devices
  - The lines are constantly blurring

### Processor cores

- Dual-core / Quad-core / Octa-core / Multi-core
- Multiple cores
  - Each core has its own cache
  - The entire chip may have a shared cache

### Multithreading

- Hyper-Threading Technology (HTT)
- One CPU, acts like two
  - Doesn't actually work as fast as two
    - 15% to 30% performance improvement
- Operating system must be written for HTT
  - Windows XP and later (any modern OS)

### Virtualization support

- Run other operating systems within a single hardware platform
  - Multiple operating systems share physical hardware components
- Virtualization in software was limited
  - Performance and hardware management challenges
- Virtualization added to the processor
  - Hardware is faster and easier to manage
  - Intel Virtualization Technology (VT)
  - AMD Virtualization (AMD-V)

## 3.4 - Expansion Cards

### Expansion cards

- Extend the functionality of your computer
  - You may need more than the motherboard provides
- Relatively simple process
  - Designed for end-user installation
- Install hardware - Add a card
- Install a driver - Software for the operating system

### Sound card

- Output
  - High-end audio
  - Advanced headphone amp
  - Home theater, Dolby decoding
- Multiple inputs
  - Music capture
  - Podcasting
  - Microphone

## 3.4 - Expansion Cards (continued)

### Video card

- Many CPUs include an integrated GPU
  - Video functionality is built into the CPU package
- Discrete graphics
  - The GPU is not part of the CPU
- Separate interface card - High performance

### Capture card

- Video as an input
  - Video capture, live streaming, external cameras
- High performance
  - Video bandwidths can be quite high
  - PCI Express connection

### Network Interface Card (NIC)

- Ethernet connection
  - Motherboard may not include a NIC
  - Onboard NIC may not be working
- Additional connections
  - Servers, routers, security devices

### Documentation

- Check the motherboard documentation
  - Number and type of slots
- Check the adapter card documentation
  - Minimum requirements - Hardware, software
  - Knowledge base - Any "gotchas?"
  - Support forums - What are other people saying?
- You may need to perform a driver installation before installing hardware

### Driver installation

- You checked the documentation first, right?
- Check the web for the latest version
- Uninstall previous drivers through Windows Device Manager
- Manufacturer provided setup program
- Manual installation through Windows Device Manager
- Check the Device Manager for the status - Does it work?

## 3.4 - Cooling

### Case fans

- Cool air is pulled through a personal computer
  - Always check for good airflow
- Motherboard layout becomes important
- Component location is key
  - Devices, wiring, power
- Many different sizes and styles
  - And volume levels

### On-board fans

- Designed to cool an entire adapter card
- Can be bulky
  - May take additional adapter card space
- Usually seen on high-end graphics cards

### Fan specifications

- Standard sizes
  - 80 mm, 120 mm, 200 mm, etc.
- Different speeds
  - Variable speed
- Different noise levels
  - Not all fans sound the same

### Heat sink

- Dissipate heat through thermal conduction
  - Copper or aluminum alloy
- Fins/grid increase surface area
  - Heat is then transferred to the cooler air
- They get HOT – don't touch them!
- Thermal paste creates a good contact between the chip and the heat sink

### Fanless / passive cooling

- No fans, no noise - Silent operation
- Specialized functions
  - Video servers, TV set top box, satellite receiver, media server
- Functions are very controlled
  - Carefully measured thermal tests
- Low-power components - Heat sinks

### Thermal paste

- Thermal grease, conductive grease
  - Thermally conductive adhesive
- Place between the heat sink and the component
  - Improves thermal conductivity
  - Moves the heat away from the component
- A little bit goes a long way
  - Pea-sized application

### Thermal pad

- Conduct heat without the mess - Cut to size and install
- Easy to use - Won't leak and damage components
- Almost as effective as thermal paste
  - But still very good
- Not reusable - Remove and replace

### Liquid cooling

- Coolant is circulated through a computer
  - Not a new concept
  - Automobiles, mainframe computers
- High-end systems
- Gaming, graphics
- Overclocking

## 3.5 - Computer Power

### WARNING

- Always disconnect from the power source when working on a device

- Always. Seriously.
- Some devices store a charge in capacitors
- Know how to discharge before touching

- Never connect your body to any part of an electrical system

- Do not connect yourself to the ground wire of an electrical system

- Respect electricity

- It does not respect you



### Computer power supply

- Computer uses DC voltage
  - Most power sources provide AC voltage
- Convert 120 V AC or 240 V AC
  - To 3.3 V DC, 5 V DC, and 12 V DC
- You'll know when this isn't working
  - An important component

### Amp and volt

- Ampere (amp, A) – The rate of electron flow past a point in one second
  - The diameter of the hose
- Voltage (volt, V) Electrical “pressure” pushing the electrons
  - How open the faucet is

### Power

- Watt (W) – Measurement of real power use
  - volts \* amps = watts
  - $120V * 0.5A = 60W$

### Current

- Alternating current (AC)
  - Direction of current constantly reverses
  - Distributes electricity efficiently over long distances
  - Frequency of this cycle is important
  - US/Canada – 110 to 120 volts of AC (VAC), 60 hertz (Hz)
  - Europe – 220-240 VAC, 50 Hz
- Direct current (DC)
  - Current moves in one direction with a constant voltage

### Dual-voltage input options

- Voltage varies by country
  - US/Canada – 120 volts of AC (VAC), 60 hertz (Hz)
  - Europe – 230 VAC, 50 Hz
- Manually switch between 120 V and 230 V
  - Get your meter!
  - Or use an auto-switching power supply
- Don't plug a 120 V power supply into a 230 V power source!

### Power supply output

- Different voltages
  - For different components
- Positive and negative voltage
  - Voltage is a difference in potential
  - The electrical ground is a common reference point
  - Depends on where you measure from
- At the front door of your house
  - The second floor is +10 feet
  - The basement is -10 feet
- +12 V
  - PCIe adapters, hard drive motors, cooling fans, most modern components
- +5 V
  - Some motherboard components
  - Many components are now using +3.3 V
- +3.3 V
  - M.2 slots, RAM slots, motherboard logic circuits
- +5 VSB
  - Standby voltage
- 12 V
  - Integrated LAN
  - Older serial ports
  - Some PCI cards
- -5 V
  - Available for ISA adapter cards
  - Most cards didn't use it
  - Today's motherboards don't have ISA slots



### 24-pin motherboard power

- Main motherboard power
  - Provides +3.3 V, +/-5 V, and +/- 12 V
- 20 pin connector was the original ATX standard
  - 24 pin was added for PCI Express power
- You can connect a 24-pin connector to a 20-pin motherboard
  - Some cables are 20-pin + 4-pin

### Redundant power supplies

- Two (or more) power supplies
  - Internal to the server
- Each power supply can handle 100% of the load
  - Would normally run at 50% of the load
- Hot-swappable
  - Replace a faulty power supply without powering down

## 3.5 - Computer Power (continued)

### Power supply connectors

- Fixed connectors
  - Connected to the power supply
  - May have too many connectors
  - May not have enough
- Modular
  - Add cables as needed
  - Fewer leftover wires, better airflow
  - A bit more expensive

### Sizing a power supply

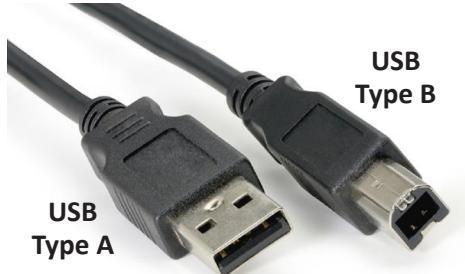
- Power supplies are rated by watts
  - Overall and by individual voltages

- Bigger isn't necessarily better
  - More expensive
  - Doesn't speed up your computer
- Physical size is relatively standard
  - Older cases and systems may have proprietary sizes
- Calculate the watts required for all components
  - CPU, storage devices, video adapter
  - Many online calculators
- Video adapters are usually the largest power draw
  - Many video card specifications list a recommended power supply wattage
- 50% capacity is a good rule of thumb
  - Power supply runs efficiently and there's room to grow

## 3.6 - Multifunction Devices

### Multifunction devices

- Multifunction devices (MFD)
  - Printer
  - Scanner
  - Fax (yes, really)
  - Network connection
  - Phone line connection
  - Print from web
- There are a lot of things that can go wrong
  - You're going to fix them



### Unboxing a device

- These can be large devices
  - Make sure you have enough room
  - Stay out of walkways
- Check the area
  - Power
  - Network
  - Accessibility

### Printer drivers

- Specific to a printer model
- Get this exactly right
- Get the right operating system drivers
  - Windows 10, Windows 11
  - Get the right version of the operating system
  - 32-bit drivers are very different than 64-bit drivers
- You can't mix and match drivers
  - It's a very specific task

### PCL or PostScript

- PCL (Printer Command Language)
  - Created by Hewlett-Packard
  - Commonly used across the industry
- PostScript
  - Created by Adobe Systems
  - Popular with high end printers
- Make sure the drivers match the printer
  - PCL printer, PCL driver
  - PostScript printer, PostScript driver
  - Wired device sharing
- USB type B
  - The most common connector
  - USB Type B on the printer, USB Type A on the computer
- Ethernet - RJ45 connector
- May include more than one option

### Wireless device sharing

- Bluetooth
  - Limited range
- 802.11 Infrastructure mode
  - Many devices using an access point
- 802.11 Ad hoc mode
  - No access point
  - Direct link between wireless devices

### Sharing the printer

- Printer share
  - Printer is connected to a computer
  - The computer shares the printer
  - Computer needs to be running
- Print server
  - Print directly to the printer
  - Jobs are queued on the printer
  - Jobs are managed on the printer
  - Web-based front-end
  - Client utility

## 3.6 - Multifunction Devices (continued)

### Configuration settings

- Duplex
  - Save paper
  - Print on both sides of the page without manually flipping over the paper
  - Not all printers can do this
- Orientation
  - Portrait vs. Landscape
  - The paper doesn't rotate
  - The printer compensates
- Tray settings
  - Printers can have multiple trays
  - Plain paper, letterhead, etc.
  - Choose the correct tray in the print dialog
- Quality
  - Resolution / Color, greyscale / Color saving

### Printer security

- User authentication
  - Everyone can print
  - Set rights and permissions
  - Printing vs. managing the printer
- Badging
  - Authenticate when using the printer
  - Your job doesn't print until you use your employee badge
  - Quick and easy

- Audit logs
  - Cost management
  - Security monitoring
  - Event Viewer / System Events
  - May be built into the printer or print server
- Secured prints
  - Printer must support secure printing
  - Define a passcode
  - Use the passcode at the printer

### Flatbed scanner

- Different form factors
  - All-in-one multifunction device
  - Standalone flatbed
- May include an ADF
  - Automatic Document Feeder
  - Multiple pages

### Network scan services

- Scan to email
  - Scans are sent to your inbox
  - Large scans can fill up your mailbox
- Scan to folder
  - Using SMB (Server Message Block)
  - Send to a Microsoft share
- Scan to cloud
  - Cloud storage account
  - Google Drive, Dropbox, etc.

## 3.7 - Laser Printers

### Laser printer

- Combine a laser, high voltage, charged ions, powdered ink, heat, and paper
- Very high quality
- Fast printing speeds
- Very complex, many moving parts, requires on-printer memory and messy on the inside

### Imaging drum

- Image is drawn onto a photosensitive drum
  - “Painted” with a laser
- Picks up toner - Transfers toner to the paper
- Can be separate from the toner cartridge or combined

### Fuser assembly

- Heat and pressure - Melt plastic toner powder
  - Permanently bond toner to paper

### Transfer belt and roller

- Color laser printers
  - Cyan, yellow, magenta, black
- Four separate toner cartridges
- Image is transferred from all cartridges to the single belt

- And then to a single transfer roller

### Pickup rollers

- Pickup paper - Should be a single page at a time
  - Problems if no paper is picked up or multiple sheets are picked
- Should be periodically cleaned or replaced

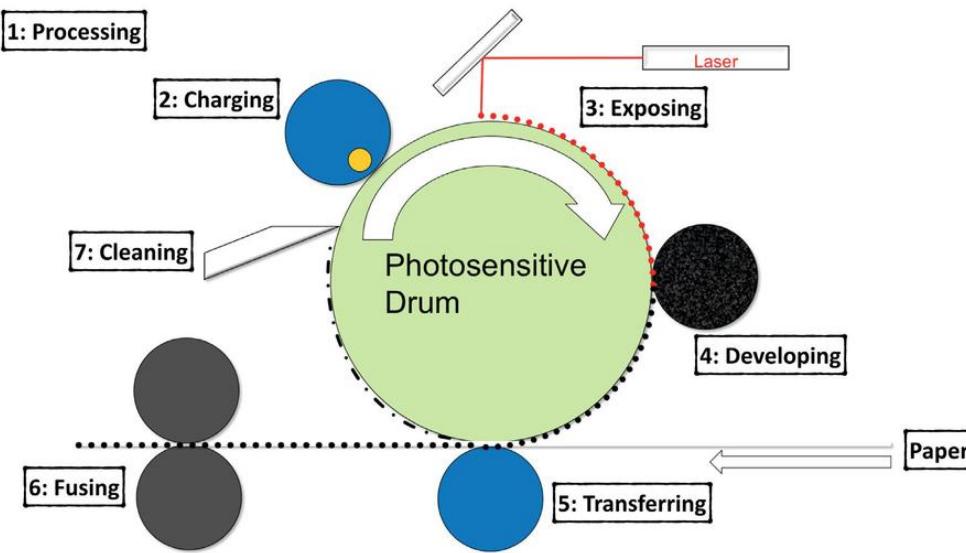
### Separation pad

- Pull just the top sheet from the paper tray
  - Not multiple sheets
- Small and inexpensive - Easy to clean or replace

### Duplexing assembly

- Printers usually print on a single side
  - Not both sides simultaneously
- Printing on both sides is a two step process
  - Print side one, print side two
- You need mechanisms to “flip” the page
  - Automatically
- Can be built-in to the printer
  - Or available as an add-on

## 3.7 - Laser Printers (continued)



### Step 1: Processing

- Build the entire page in memory

### Step 2: Charging

- Prepare the drum with a negative electrostatic charge

### Step 3: Exposing

- Write the image with the laser

### Step 4: Developing

- Add toner to the charged areas of the imaging drum

### Step 5: Transferring

- Move the toner from the drum to the paper

### Step 6: Fusing

- Heat and pressure

### Step 7: Cleaning

- Remove excess toner

## 3.7 - Laser Printer Maintenance

### Replacing the toner cartridge

- Look for the messages
  - Low doesn't mean empty
- The toner can also contain the OPC drum
  - Organic Photoconductor drum
  - Sensitive to light; keep it in the bag
- Power down the printer
  - Safety first
- Remove packing strips from the new drum
  - Replace it with the old

### Laser printer maintenance kit

- Laser printers wear out
  - All those moving parts
  - Heat and pressure
- Standard maintenance kits
  - Replacement feed rollers, new fuser unit, etc.
- When to perform maintenance?
  - Check the printer's page counter
- Power down and replace the components
  - Fuser units are HOT
- Reset the page counter when you're done!

### Replacing the toner cartridge

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  - Low doesn't mean empty
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- Reset the page counter when you're done!

### Laser printer calibration

- Different toner cartridges print with different densities
  - Some dark, some light
- Laser printer calibration can adjust the density
  - Makes it looks perfect
- Can be automated or a manual process
  - Every printer is different
  - Check the printer manual

### Laser printer cleaning

- Laser printers are dirty - All that toner and paper dust
- Check the manufacturer's recommendations
  - Water, isopropyl alcohol (IPA)
  - Don't use harsh chemicals!
- Outside - Damp cloth
- Inside - Wipe dust away
  - Don't use a normal vacuum cleaner or compressed air
  - Wash off skin with cold water
  - Clean rollers with IPA

## 3.7 - Inkjet Printers

### Inkjet (ink-dispersion) printer

- Relatively inexpensive technology
- Quiet
- High-resolution
- Expensive ink
  - Proprietary
- Eventually fades
- Clogs easily

### Ink cartridge

- Place drops of ink onto a page
  - Pulled from a set of cartridges
- CMYK - Cyan, Magenta, Yellow, Key (black)

### Print head

- Some consumer printers integrate the print head into the ink cartridge
  - Change the cartridge, get a new print head
- Others separate the ink cartridge from the print head

### Feed rollers

- Pick up and feed paper through the printer
  - Must be clean and not worn
- Duplexing
  - Print on both sides of the paper
  - Included with some printers

### Carriage and belt

- Ink cartridges are moved over the paper
  - Carriage may include its own print head
- Belt moves the carriage back and forth
  - Another moving part

### Inkjet printer calibration

- Align nozzles to the paper
  - Lines should be crisp
  - Colors should align
- Printer includes a calibration option
  - May need to make minor adjustments

## 3.7 - Inkjet Printer Maintenance

### Cleaning print heads

- Small droplets of ink - And small holes in a print head
- Clogged heads is a big issue
  - Many printers automatically clean every day
  - Output has streaks or sections of missing color
- Cleaning process can be started manually
  - Only takes a few minutes
- Some print heads/cartridges can be removed
  - Manually cleaning may help

### Replacing inkjet cartridges

- Usually separate colors
  - Cyan, Magenta, Yellow, and Key (CMYK)
  - Some cartridges will combine these
- Takes seconds to replace
  - Takes a few minutes to calibrate and prepare the cartridge
- Recycle the empty cartridge - All plastic

### Inkjet printer calibration

- Align nozzles to the paper
  - Lines should be crisp
  - Colors should not overlap
- Printer includes a calibration option
  - May need to make minor adjustments

### Clearing jams

- Lots of turns and twists
  - A jam is inevitable
- Remove tray paper
  - Any loose paper
- Remove paper from the path
  - Firm pressure, don't rip
- Check for any scraps of paper
  - Remove all loose paper

## 3.7 - Thermal Printers

### Thermal printer

- White paper
  - Turns black when heated
  - No ink!
- **VERY quiet**
  - Almost silent
- Paper is sensitive to light and heat
  - And clear tape

### Feed assembly

- Pull paper through the printer
  - Relatively small paper path

### Heating element

- Full-length heating element
  - No moving print head

### Thermal paper

- Paper covered with a chemical
  - Changes color when heated
- Cash registers, credit card terminals
  - And quiet areas
- Looks like normal paper
  - Feels a bit different

## 3.7 - Thermal Printer Maintenance

### Thermal paper replacement

- Relatively inexpensive
  - But impossible to substitute
- Different sizes
  - Not like laser printer paper - Keep a list
- Actual replacement process is easy
  - Simple paper feed
  - Small device

### Cleaning the heating element

- Liquid cleaner
  - Isopropyl alcohol (IPA)
  - Get a cleaning pen
  - Check manufacturer's recommendations
- Swab gently - Usually small areas
- Use a cleaning card
  - Cleans the head and paper pathways

### Removing debris

- Relatively small amount
  - Paper bits and dust
  - No toner!
- Blow out the printer
  - Take it outside
- Wipe it out
  - Damp cloth
- Avoid using a vacuum
  - Unless it's designed for computers
  - Resists static buildup/discharge

## 3.7 - Impact Printers

### Dot-matrix (impact) printers

- Print head with a small matrix of pins
  - Presses against a ribbon to make a mark on paper
- Good for carbon/multiple copies
- Low cost per page
- NOISY
- Poor graphics
- Relatively niche use cases

### Dot-matrix printer head

- Moves back and forth
  - Pins hit ribbon and paper
- One matrix - Must move across the page to print

### Printer ribbon

- Fabric
  - One long ribbon - Never ending circle
- Easy to replace - Once single unit
- Proprietary size - Specific to printer model

### Tractor feed

- Paper pulled through with holes on the side of the paper
  - Instead of using friction
- Continuous paper feed
  - Perforations between pages
- Holes have to line up perfectly
  - Tractor paper can be perforated to remove holes

## 3.7 - Impact Printer Maintenance

### Printer ribbon replacement

- Single ribbon - Self-contained - One long circle
- Replace when ink becomes too light
  - Ink is eventually consumed
- Designed to be modular - Replace in less than a minute

### Print head replacement

- Takes a lot of abuse - Directly hits the ribbon and paper
- Gets hot - Watch your fingers
  - Another modular part - Look for a release lever or bar
- Replace with the ribbon for the best effect
  - The output should look perfect

### Printer ribbon replacement

- Single ribbon
  - Self-contained - One long circle
- Replace when ink becomes too light
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### Print head replacement

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  - Directly hits the ribbon and paper
- Gets hot - Watch your fingers
  - Another modular part
  - Look for a release lever or bar
- Replace with the ribbon for the best effect
  - The output should look perfect

### Replacing paper

- Not as easy as a laser printer
  - Paper must feed perfectly into holes
  - Tractor feed
- Forms must be positioned correctly
  - Text needs to fit a predefined space
- Paper must feed without constraint
  - Make sure nothing is in the way

## 3.7 - 3D Printers

### 3D printers

- “Print” in three dimensions
  - Create a 3D item based on an electronic model
- Additive manufacturing
  - Build in layers to create the object
  - No machining process required
- Rapid prototyping
  - Design and create relatively quickly and inexpensively
- Deploy designs anywhere in the world
  - Or into space

### Filament printing

- Fused Deposition Modeling (FDM)
  - Melt filament to print 3D objects
  - This is probably the printing type you’ve seen
- Print a layer, move up, print another layer
  - Watch the printer create the object
- Good all-around printer
  - Larger print bed than resin printers
  - Easy to manage filament
  - Minimum of mess
  - Fewer disposal issues

### Resin printing

- Stereolithography (SLA) 3D Printing
  - Smooth and finely detailed 3D prints
- Resin is hardened using a light source
  - Ultraviolet light or a laser
  - Layers are added to the bottom
  - Entire print hangs from the build platform
- Resin must be handled properly
  - Wear protective gear
  - Take unused resin to your local hazardous materials disposal

### The print bed

- A flat adhesive surface
  - The foundation of a 3D print
  - Everything builds on that first layer
- Needs to be level and clean
  - Prints “stick” to the bed
- Filament printing
  - The print bed is the printing surface
  - Many different print bed options
- Resin printing
  - The “bed” is the location where the resin is hardened by the UV light

## 4.1 - Cloud Models

### Cloud computing

- More than just a server hosted elsewhere
  - Extend the management of applications and services
- Deploy an infrastructure in minutes
  - Create and tear down as you need
- International scope
  - Deploy in specific parts of the world
- Use only the required resources
  - Cost is based on the amount of use

### Cloud deployment models

- Private
  - Your own virtualized local data center
- Public
  - Available to everyone over the Internet
- Hybrid
  - A mix of public and private
- Community
  - Several organizations share the same resources

### Infrastructure as a service (IaaS)

- Sometimes called Hardware as a Service (HaaS)
  - Outsource your equipment
- You’re still responsible for the management
  - And for the security
- Your data is out there, but more within your control
  - Web server providers

On Premises	Infrastructure as a Service	Platform as a Service	Software as a Service
Application	Application	Application	Application
Data	Data	Data	Data
Runtime	Runtime	Runtime	Runtime
Middleware	Middleware	Middleware	Middleware
OS	OS	OS	OS
Virtualization	Virtualization	Virtualization	Virtualization
Servers	Servers	Servers	Servers
Storage	Storage	Storage	Storage
Networking	Networking	Networking	Networking
Client Managed		Provider Managed	

## 4.1 - Cloud Models (continued)

### Software as a service (SaaS)

- On-demand software
  - No local installation
  - Why manage your own email distribution?  
Or payroll?
- Central management of data and applications
  - Your data is out there
- A complete application offering
  - No development work required
  - Google Mail, Microsoft 365

### Platform as a service (PaaS)

- No servers, no software, no maintenance team, no HVAC
  - Someone else handles the platform,  
you handle the development
- You don't have direct control of the data,  
people, or infrastructure
  - Trained security professionals are watching
  - Choose carefully
- Put the building blocks together
  - Develop your app from what's available on the platform
  - SalesForce.com

## 4.1 - Cloud Characteristics

### Shared resources

- Internal cloud
  - No resources are shared
  - Build your own cloud
  - Pay for everything up front
  - No ongoing costs
- External cloud
  - Share resources with a public cloud
  - Underlying infrastructure owned by a third-party
  - Cost may be metered or up-front

### Metered and non-metered

- Metered cloud services
  - You pay for what you use
  - Cost to upload
  - Cost to store
  - Cost to download
- Non-metered
  - You pay for a block of storage
  - No cost to upload
  - No cost to download

### Cloud computing characteristics

- Rapid elasticity
  - Scale up and scale down as needed
  - Seamless to everyone
  - The cloud enables instant resource provisioning
- High availability
  - Systems are always available
  - Redundancy provides availability
- File synchronization
  - Information can be duplicated across cloud locations

### Desktop as a Service

- Basic application usage
  - Applications actually run on a remote server
  - Virtual Desktop Infrastructure (VDI),  
Desktop as a Service (DaaS)
  - Local device is a keyboard, mouse, and screen.
- Minimal operating system on the client
  - No huge memory or CPU needs
- Network connectivity
  - Big network requirement
  - Everything happens across the wire

## 4.2 - Client-side Virtualization

### Virtualization

- One computer, many operating systems
  - macOS, Windows 11, Linux Ubuntu,  
all at the same time!
- Separate OS, independent CPU, memory, network, etc.
  - But really one computer
- Host-based virtualization
  - Your normal desktop plus others
- Standalone server that hosts virtual machines
  - Enterprise-level
- Been around since 1967
  - IBM mainframe virtualization

### Legacy software and operating systems

- Need to run different application versions  
on the same system
  - Run each application instance in a separate VM
- Application only runs on a previous OS version
  - Create a VM with the older operating system

### Cross-platform virtualization

- Windows / macOS / Linux doesn't do everything
  - Each OS has strengths and weaknesses
- Run different operating systems at the same time
  - Move between each OS seamlessly
  - No rebooting
- Save time and resources
  - One physical computer

## 4.2 - Client-side Virtualization (continued)

### The hypervisor

- Virtual Machine Manager
  - Manages the virtual platform and guest operating systems
- May require a CPU that supports virtualization
  - Can improve performance
- Hardware management
  - CPU, networking, security

### Resource requirements

- CPU Processor Support
  - Intel: Virtualization Technology (VT)
  - AMD: AMD-V
- Memory - Above and beyond host OS requirements
- Disk space - Each guest OS has its own image
- Network
  - Configurable on each guest OS (standalone, NAT, bridged, etc.)
  - Virtual switch

### Sandboxing

- Isolated testing environment
  - No connection to the real world or production system
  - A technological safe space
- Virtualize development process
  - Try some code, break some code, nobody gets hurt
- Additional development features
  - Roll back to a previous snapshot
  - Run additional systems

### Building the application

- Develop
  - Secure environment
  - Writing code
  - Developers test in their sandboxes
- Test
  - A separate virtual environment for testing
  - Still in the development stage
  - All of the pieces are put together
  - Does it all work?

### Hypervisor security

- Hypervisor is a sweet spot for the bad guys
  - No significant vulnerabilities yet
- VM escaping
  - Malware recognizes it's on a virtual machine
  - Malware compromises the hypervisor
  - Malware jumps from one guest OS to another
- Many hosted services are virtual environments
  - Malware on one customer's server can gather information from another

### Guest operating system security

- Every guest is self-contained - Like a real computer
- Use traditional security controls
  - Host-based firewall, Anti-virus, anti-spyware
- Watch out for rogue virtual machines (VMs)
  - The bad guys try to install their own system
  - You're in big trouble
- Self-contained VMs provided by 3rd parties can be dangerous
  - You have no idea what's running on there

### Network requirements

- Most client-side virtual machine managers have their own virtual (internal) networks
- Shared network address
  - The virtual machine shares the same IP address as the physical host
  - Uses a private IP address internally
  - Uses NAT to convert to the physical host IP
- Bridged network address
  - The VM is a device on the physical network
- Private address
  - The VM does not communicate outside of the virtual network

## 5.1 - How to Troubleshoot

### Change management

- Change control
  - A formal process for managing change
  - Avoid downtime, confusion, and mistakes
  - Corporate policy and procedures
- Nothing changes without the process
  - Plan for a change
  - Estimate the risk associated with the change
  - Have a recovery plan if the change doesn't work
  - Test before making the change
  - Document all of this and get approval
  - Make the change

### Identify the problem

- Information gathering
  - Get as many details as possible
  - Duplicate the issue, if possible
- Identify symptoms
  - May be more than a single symptom
- Question users
  - Your best source of details
- Determine if anything has changed
  - Who's in the wiring closet?

## 5.1 - How to Troubleshoot (continued)

- Approach multiple problems individually
  - Break problems into smaller pieces
- Backup everything
  - You're going to make some changes
  - You should always have a rollback plan
- What else has changed?
  - The user may not be aware
  - Environmental changes
  - Infrastructure changes
- There may be some clues
  - Check OS log files
  - Applications may have log information

### Establish a theory

- Start with the obvious - Occam's razor applies
- Consider everything - Even the not-so-obvious
- Make a list of all possible causes
  - Start with the easy theories
  - And the least difficult to test
- Research the symptoms
  - Internal knowledge base
  - Google searches

### Test the theory

- Confirm the theory
  - Determine next steps to resolve problem
- Theory didn't work?
  - Re-establish new theory or escalate
  - Call an expert
- The theory worked!
  - Make a plan...

### Create a plan of action

- Build the plan
  - Correct the issue with a minimum of impact
- Refer to vendor instructions
  - Knowledge base, support articles
  - Documentation and manuals
- Identify potential effects
  - Every plan can go bad
  - Have a plan B
  - And a plan C

### Implement the solution

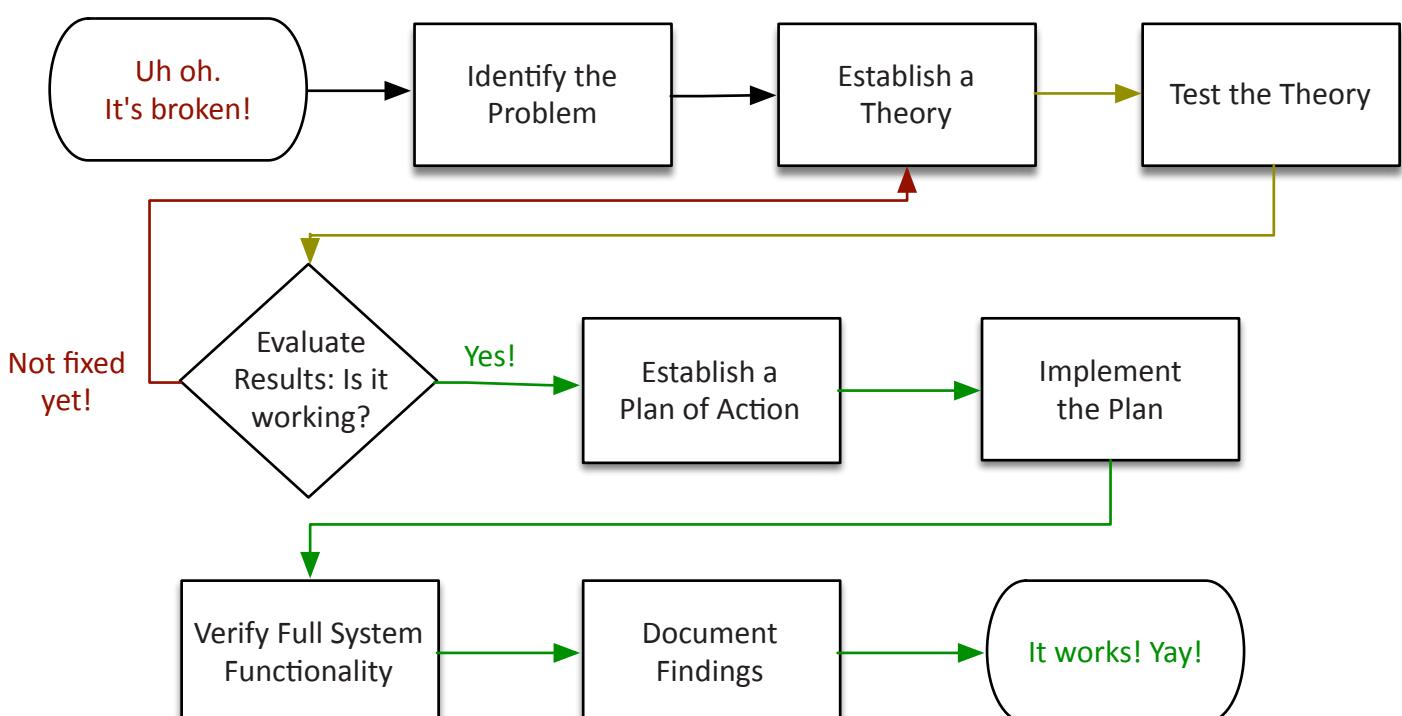
- Fix the issue
  - Implement during the change control window
- Escalate as necessary
  - You may need help from a 3rd party

### Verify full system functionality

- It's not fixed until it's really fixed
  - The test should be part of your plan
  - Have your customer confirm the fix
- Implement preventative measures
  - Let's avoid this issue in the future

### Document findings

- It's not over until you build the knowledge base
  - Don't lose valuable knowledge!
- What action did you take?
  - What outcome did it have?
- Consider a formal database
  - Help desk case notes
  - Searchable database



## 5.2 - Troubleshooting Common Hardware Problems

### POST (Power On Self Test)

- Test major system components before booting the operating system
  - Main systems (CPU, CMOS, etc.)
  - Video
  - Memory
- Failures are usually noted with beeps and/or codes
  - BIOS versions can differ, check your documentation
- Don't bother memorizing the beep codes
  - They're all different between manufacturers
  - Know what to do when you hear them

### POST and boot

- Blank screen on boot
  - Listen for beeps
  - Bad video, bad RAM, bad CPU
  - BIOS configuration issue
- BIOS time and setting
  - Maintained with the motherboard battery
  - Replace the battery
- Attempts to boot to incorrect device
  - Set boot order in BIOS configuration
  - Confirm that the startup device has a valid operating system
  - Check for media in a startup device

### Crash screens

- Windows Stop Error or Blue Screen of Death
- Contains important information
  - Also written to event log
- Useful when tracking down problems
  - Sometimes more useful for manufacturer support

### Bluescreens and spontaneous shutdowns

- Startup and shutdown BSOD
  - Bad hardware, bad drivers, bad application
- Use Last Known Good, System Restore, or Rollback Driver
  - Try Safe Mode
- Reseat or remove the hardware - If possible
- Run hardware diagnostics
  - Provided by the manufacturer
  - BIOS may have hardware diagnostics

### The spinning ball of death

- The macOS X Spinning Wait Cursor
  - Feedback that something is happening
- The spin starts, but it never stops
  - You never get back control of your computer
- Many possible reasons
  - Application bug
  - Bad hardware
  - Slow paging to disk
- Restart the computer
  - There may be details in the console logs

### Black screen

- Is the monitor connected?
  - We wouldn't ask if it wasn't a common solution
  - Check both power and signal cable
- Input selection on monitor - HDMI, DVI, VGA, etc.
- Image is dim - Check brightness controls
- Swap the monitor
  - Try the monitor on another computer
- No video after Windows loads
  - Use VGA mode (F8)

### No power

- No power
  - No power at the source
  - No power from the power supply
  - Get out your multimeter
- Fans spin - no power to other devices
  - Where is your fan power connected?
  - No POST - bad motherboard?
  - Case fans have lower voltage requirements
  - Check the power supply output

### Sluggish performance

- Task Manager
  - Check for high CPU utilization and I/O
- Windows Update
  - Latest patches and drivers
- Disk space
  - Check for available space and defrag
- Laptops may be using power-saving mode
  - Throttles the CPU
- Anti-virus and anti-malware
  - Scan for bad guys

### Overheating

- Heat generation
  - CPUs, video adapters, memory
- Cooling systems
  - Fans and airflow
  - Heat sinks
  - Clean and clear
- Verify with monitoring software
  - Built into the BIOS
  - Try HWMonitor
  - <http://www.cpuid.com/>

### Smoke and burning smell

- Electrical problems
  - The smoke makes everything work
- Always disconnect power
  - There should never be a burned odor
- Locate bad components
  - Even after the system has cooled down
  - Replace all damaged components

## 5.2 - Troubleshooting Common Hardware Problems (continued)

### Intermittent shutdown

- No warning, black screen
  - May have some details in your Event Viewer
- Heat-related issue
  - High CPU or graphics, gaming
  - Check all fans and heat sinks
  - BIOS may show fan status and temperatures
- Failing hardware
  - Has anything changed?
  - Check Device Manager, run diagnostics
- Could be anything
  - Eliminate what's working

### Application crashes

- Application stops working
  - May provide an error message
  - May just disappear
- Check the Event Log
  - Often includes useful reconnaissance
- Check the Reliability Monitor
  - A history of application problems
  - Checks for resolutions
- Reinstall the application
  - Contact application support

### Grinding noises

- Computers should hum, not grind
- Rattling - Loose components
- Scraping - Hard drive issues
- Clicking - Fan problems
- Pop - Blown capacitor

### Lockups

- System completely stops
  - Completely. Usually not much in the event log
  - Similar to unexpected shutdowns
- Check for any activity
  - Hard drive, status lights, try Ctrl-Alt-Del
- Update drivers and software patches
  - Has this been done recently?
- Low resources - RAM, storage
- Hardware diagnostics may be helpful

### Continuous reboots

- How far does the boot go before rebooting?
  - BIOS only? OS splash screen?
- Bad driver or configuration
  - F8, "Boot from last known working configuration"
- Try F8, Safe Mode
  - If system starts, disable automatic restarts in System Properties
- Bad hardware
  - Try removing or replacing devices
  - Check connections and reseat

### Inaccurate system date/time

- Bad motherboard battery
  - Often a "button" style battery
- A bad battery will require a BIOS configuration or date/time configuration on every boot
- On older systems, can reset the BIOS configuration by removing the battery
  - Newer computers use a jumper

## 5.3 - Troubleshooting Storage Devices

### Storage failure symptoms

- Read/write failure
  - "Cannot read from the source disk"
- Slow performance
  - Constant LED activity - Retry...retry...retry
- Loud clicking noise
  - The click of death
  - May also include grinding and scraping

### Troubleshooting disk failures

- Get a backup - First thing - a bad drive is bad
- Check for loose or damaged cables
- Check for overheating
  - Especially if problems occur after startup
- Check power supply
  - Especially if new devices were added
- Run hard drive diagnostics
  - From the drive or computer manufacturer
  - Preferably on a known-good computer

### Boot failure symptoms

- Drive not recognized, Boot Device Not Found
  - Lights (or no lights)
  - Beeps
  - Error messages
- Operating system not found
  - The drive is there
  - Windows is not

### Troubleshooting boot failures

- Check your cables
  - Physical problem
- Check boot sequence in BIOS
  - Check for removable disks (especially USB)
  - Check for disabled storage interfaces
- For new installation, check hardware configuration
  - Data and power cables
  - Try different SATA interfaces
- Try the drive in a different computer

## 5.3 - Troubleshooting Storage Devices (continued)

### Data loss/corruption

- Hard drives are mechanical devices
  - They will eventually fail
- Repairs are difficult and expensive
  - Dust-free environment
  - Not always successful
- An SSD may simply stop working
  - Sometimes can read but not write
- Data becomes unavailable or corrupted
  - Can be impossible to recover
- **ALWAYS HAVE A BACKUP**

### RAID not found

- Missing or faulty RAID controller

### RAID stops working

- Each RAID is different
  - Don't start pulling drives until you check the console!

### S.M.A.R.T.

- Self-Monitoring, Analysis, and Reporting Technology
  - Use third-party utilities
- Avoid hardware failure - Look for warning signs
- Schedule disk checks - Built-in to most drive arrays
- Warning signs - Replace a drive

### Extended read/write times

- A lot happens when reading or writing data
  - Memory access, communication across the bus, spinning drive access, writing or reading the data to the storage device, etc.
- Delays can occur anywhere along the way
  - Need a way to measure storage device access
- Input/output operations per second (IOPS)
  - A broad metric of maximum performance
- Useful for comparing storage devices
  - Hard drive: 200 IOPS
  - SSD: 1,000,000 IOPS

### Missing drives in OS

- OS boots normally
  - Other drives not shown - Check the BIOS
- Internal drives
  - Bad drive or disconnected cable
- External drives
  - No power to the drive or bad cable connection
- Network shares
  - Shared drives can be connected during startup
  - Option to reconnect at sign-in
  - Connected with login script

RAID	Disks Required	Failure Condition
RAID 0	2 or more	A single drive failure breaks the array with data loss
RAID 1	2 or more	Array will work as long as one drive is operational
RAID 5	3 or more	Need all drives operational but one
RAID 10	4 or more	Can lose all but one from each set of mirrors

## 5.4 - Troubleshooting Video and Display Issues

### No video image

- Is it connected?
  - We wouldn't ask if it wasn't a real solution
  - Check both power and signal cable
- Input selection on monitor
  - HDMI, DVI, VGA, etc.
- Image is dim
  - Check brightness controls
- Swap the monitor
  - Try the monitor on another computer
- No video after Windows loads
  - Use VGA mode (F8)

### Image quality problems

- Flickering, color patterns incorrect
  - You can almost work with this
- Check the cable pins
  - Especially if missing a color
- Distorted image and geometry
  - Check the OS refresh rate and resolution settings
  - Need to match the display specifications
  - Check or replace cable
- Disable hardware acceleration
  - Troubleshoot with the software drivers

## 5.4 - Troubleshooting Video and Display Issues (continued)

### Native resolution

- An LCD display is fixed
  - The number of pixels doesn't change
- A display looks best when the video settings match a display's native resolution
  - A mismatch can cause distortion
- If changing the display resolution, try using a multiple of the native resolution
  - 2560 x 1600 is the same ratio as 1920 x 1200

### Burn-in

- A problem across all monitor types
  - Some displays will pixel-shift
  - You probably won't notice it
- LCDs have "image sticking"
  - Try to remove by displaying a white screen for an extended period

### Dead pixels

- Always black
  - A manufacturing defect
- This probably isn't a problem on your side
  - Not a cable or power issue
- Clean the monitor screen
  - Damp cloth
- You'll have to replace the monitor
  - No other option

### Flashing screen

- Check the video cable connections
  - A loose cable will cause loss of signal
- Replace the video cable
  - Usually a quick fix
- The problem could be with the monitor
  - Try switching the display
- Confirm the display settings in the operating system
  - May not match the monitor

### Incorrect color display

- Colors may not be properly represented
  - Too much red, green, blue, yellow, etc.
- Monitor settings
  - Tint
  - Custom color presets
  - Factory Reset
- Driver configuration
  - Color tint
- OS configuration - Very blue
  - Night light settings

### Audio issues

- Many monitors include speakers
  - No sound, low volume
- Monitor may have audio controls
  - Check volume levels and mute status
- Confirm audio input over HDMI, DisplayPort, or Thunderbolt
  - Check the HDMI audio output in the OS
- The monitor may support other audio input interfaces
  - Check for audio jacks

### Dim image

- Monitor video settings
  - Brightness
  - Contrast
- Check the OS
  - Auto-dimming
  - Dim on battery power
  - Driver settings
- Backlight failure
  - Some or all of the light
  - May only be a section of the screen

### LCD projector troubleshooting

- Large screen projection
  - Conference rooms, large gatherings
- Not always LCD
  - But common to see LCD
- Metal-halide lamp
  - Very bright (very hot) light
  - Relatively expensive
  - (~ \$35 to \$350+ US)
- Always let bulbs cool
  - Fan will run after shutting off
  - Keep it plugged in
- Intermittent projector shutdown
  - No light output
  - Fans may continue to run
- Cooling issue
  - Fans constantly cool the bulb
  - Shuts down if temperatures are high
- Check the airflow
  - Remove any blockages
  - Clean dust from the air filters and external air input/output

## 5.5 - Troubleshooting Mobile Devices

### Poor battery health

- Replace aging battery
  - There's only so many recharges
- Bad reception
  - Always searching for signal
  - Airplane mode on the ground
- Disable unnecessary features
  - 802.11 wireless, Bluetooth, GPS
- Check application battery usage
  - iOS and iPadOS: Settings/Battery
  - Android: Settings/Battery

### Swollen battery

- Buildup of gas
  - Designed to self-contain
  - Do NOT open the battery packet/container
  - Significant fire risk
  - You'll be sorry
- Faulty battery
  - Stop using immediately
  - Dispose of properly
- Device can be damaged
  - Better than having a fire

### Broken screen

- Time for a backup - Do this first!
- Replace the screen - No easy fixes
- The glass is sharp
  - Screen protectors can help
  - Use clear tape until repaired

### Improper charging

- Check everything in the charging process
  - Cables, interfaces
- Check the cable interface
  - Remove any obstructions
- Check the cable
  - Don't use frayed or damaged cables
  - Try a known-good cable
- Verify the power adapter
  - Check with a multimeter

### Poor or no connectivity

- Cellular or Wi-Fi
  - Location, location, location
- Cellular
  - Signal strength
  - Location matters
  - Outdoor connectivity may be better
- Wi-Fi
  - Limited range
  - Interference can limit throughput
  - May need a channel/frequency configuration change

### Liquid damage

- Many phones have a Liquid Contact Indicator (LCI)
  - Turns color when liquid has been present
- Power down the phone
  - Don't power it back on. Don't do it.
- Remove the case, cards, back, and battery
  - If possible
- Putting the phone in a bag of rice doesn't actually work very well
  - Silica gel is better
- Leave it alone
  - Don't turn it on
  - Do not charge the phone
  - Don't connect it to power
  - Don't press any keys
  - Don't heat the phone
  - Don't move it around
- Wait at least a day
  - Or until the phone appears to be dry
  - And then perhaps a few hours after that
- Once you're sure, power it on
  - Hope for the best

### Overheating

- Phone will automatically shut down
  - Avoid overheating damage
- Charging/discharging the battery, CPU usage, display light
  - All of these create heat
- Check app usage
  - Some apps can use a lot of CPU
- Avoid direct sunlight
  - Quickly overheats

### Digitizer issues

- Touchscreen completely black or not responding to input
  - Screen presses do not register
- Apple iOS reset
  - Press power button, slide to power off, press power button
  - Hold down power button and Home|Volume for 10 seconds
- Android device restart
  - Remove battery, put back in, power on
  - Hold down power and volume down until restart
  - Some phones have different key combinations
  - Some phones do not have a key-based reset

## 5.5 - Troubleshooting Mobile Devices (continued)

### Physically damaged ports

- External interface - Charging and data transfer
- Rough handling and accidents
  - Damages the interface
- Not charging - Look closely
- Not modular - Requires a system board replacement

### Malware

- Always a concern
  - Even on mobile devices
  - The device type doesn't matter
- Look for symptoms
  - Unusual apps, large data transfers, pop up messages, high CPU usage, device overheating, excessive battery use

- Try a security app or scanner
  - Identify malware infections

### Cursor drift

- Random input or cursor moves without touching the device
  - Common on older screens
- Use a touch calibration app
  - Requires user input
  - Touch certain areas of the screen
- The system will adjust to the new calibration parameters
  - No more drift

## 5.6 - Troubleshooting Printers

### Testing the printer

- Print or scan a test page
  - Built into Windows, not the application
- Use diagnostic tools
  - Web-based utilities built into the printer
  - Vendor specific
  - Generic utilities

- Printer stops and shows a message
  - Gives you a chance to fix the issue

### Bad output

- Lines down the printed page
  - Inkjet: Clean print heads
  - Laser: Check for scratched photosensitive drum
- Faded prints, blank pages - Low toner or ink
- Double/echo images or speckling
  - Laser printer optical drum not cleaned properly
  - Ghost or "shadow" from previous drum rotation

- Tray selection is provided during the printing process
  - Try printing again
  - Change the defaults in the printer configuration

### Garbled print

- Bad printer driver / wrong model
  - Incorrect page description language (PCL or PostScript?)
- Verify the printer functionality
  - Check with a test page
- Bad application
  - Check the output
  - Upgrade the application

### Paper jam

- Careful when removing
  - Don't rip the paper
  - Don't damage internal components
- Paper not feeding or misfeeds multiple pages
  - Check the tray
  - Pickup rollers are part of a laser printer maintenance kit
- Creased paper
  - Problems in the paper path
  - Check the paper weight

### Toner not sticking to the paper

- Laser printer output smudges everywhere
  - Toner sticks to everything
- Toner not fused to the paper
  - Toner should be permanently melted and pressed
  - May not be hot
- Fuser problem - Replace the fuser assembly

### Multiple prints pending in queue

- Corrupted print jobs
  - Print spooler will crash
  - Most spooler configuration will automatically restart
- Problems are logged
  - Windows Event Viewer, Windows-PrintService
- One job may be causing the issue
  - Monitor the queue for details

### Incorrect paper size

- Print a letter size page
  - Accidentally send it to a legal size paper tray

### Incorrect color settings

- The output colors aren't the same as the display
  - Important for publishing and color printing
    - Calibrate the monitor
    - A third-party calibration tool will help
- Check the paper
  - Bright white paper provides good color representation
- Calibrate the printer
  - The proper amount of ink and toner

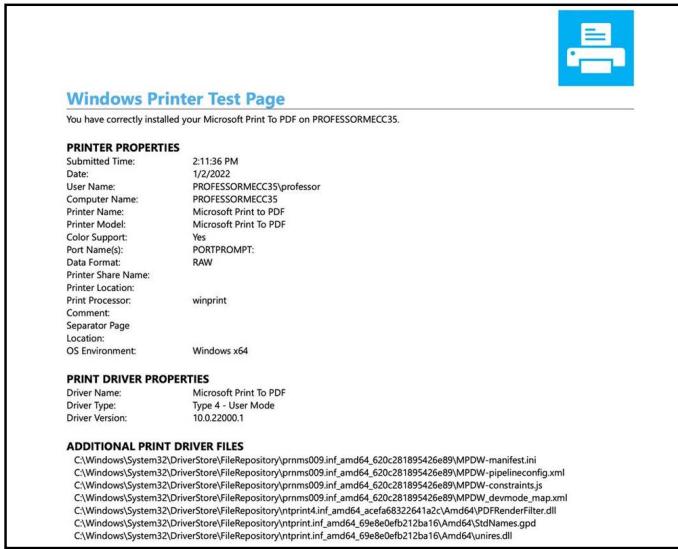
## 5.6 - Troubleshooting Printers (continued)

### Grinding noises

- Never a good sound from your printer
  - The ink is already manufactured
- Something is not operating properly
  - Paper jam - Carriage is stalled or jammed
- Each printer has a different process
  - Check the manuals for removing paper jams
  - Some inkjet printers have a particular process
- May require additional maintenance
  - Or replace the printer

### Finishing issues

- Finishing happens after the ink or toner has been applied
  - Collate, binding, etc.



Normal Windows Printer Test Page

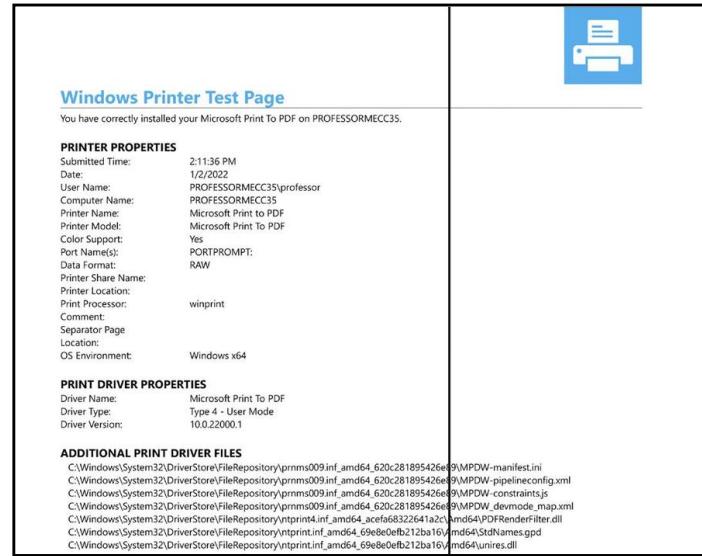
### Staple jams

- Larger printers will collate and staple groups of papers
- Each printer manufacturer has a different removal process

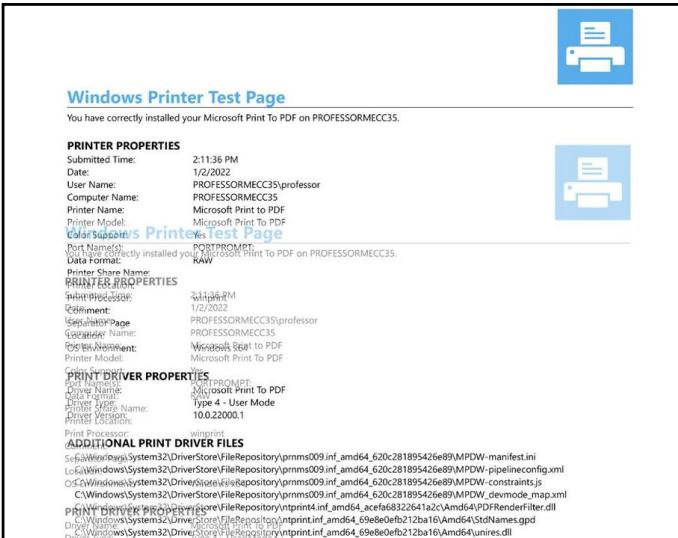
- Incorrect hole punch location
  - Verify with the printer driver
  - May require a driver update

### Incorrect page orientation

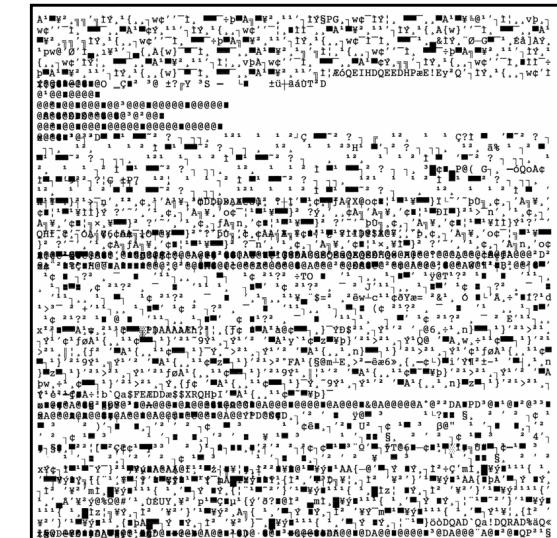
- Print a portrait page - Get a landscape print
- Check the settings when printing
  - Controlled by the print driver
  - May require a driver update
- The printer also has a default setting
  - Check the settings on the printer console



Windows Printer Test Page from a laser printer with a scratched photosensitive drum



A "ghosting" Windows Printer Test Page from a laser printer with a faulty cleaning subsystem



Printer Test Page printed with the incorrect page description language or incorrect driver

## 5.7 - Troubleshooting Networks

### No network connectivity

- Do you have a link light?
  - Is it plugged in?
- Ping loopback (127.0.0.1)
  - Is the protocol stack working?
  - Availability and intermittent connectivity
- Ping local IP address
  - Checks local configuration, adapter, and link signal
- Ping default gateway
  - Connectivity on the local network
- Ping devices on router's other side
  - 8.8.8 or 9.9.9.9

### Intermittent wireless connectivity

- Interference
  - Something else is using our frequency
- Signal strength
  - Transmitting signal, transmitting antenna, receiving antenna, etc.
- Incorrect channel
  - Usually automatic; look for manual tuning
- Bounce and latency
  - Multipath interference; flat surfaces
- Incorrect access point placement
  - Locate close to the users

### Wireless interference

- Predictable
  - Fluorescent lights
  - Microwave ovens
  - Cordless telephones
  - High-power sources
- Unpredictable
  - Multi-tenant building
- Measurements
  - Signal to noise ratio (SNR)
  - Performance Monitor

### Signal to noise ratio (SNR)

- Signal
  - What you want
- Noise
  - What you don't want
  - Interference from other networks and devices
- You want a very large ratio
  - The same amount of signal to noise (1:1) would be bad

### Limited or no connectivity

- Windows alert in the system tray
  - “Limited or No connectivity”
  - “No Internet Access”
- Check the local IP address
  - An APIPA address will only have local connectivity
- If DHCP address is obtained, perform the ping tests
  - Local gateway, remote IP address

### Jitter

- Most real-time media is sensitive to delay
  - Data should arrive at regular intervals
  - Voice communication, live video
- If you miss a packet, there's no retransmission
  - There's no time to “rewind” your phone call
- Jitter is the time between frames
  - Excessive jitter can cause you to miss information, “choppy” voice calls

### Poor VoIP quality

- High speed and low latency
  - Real-time applications are demanding
- Check the Internet connection
  - A speed test can identify slow links
- Verify the local networking equipment
  - An old router can cause significant problems
- View the network performance
  - A packet capture would be useful

### Latency

- A delay between the request and the response
  - Waiting time
- Some latency is expected and normal
  - Laws of physics apply
- Examine the response times at every step along the way
  - This may require multiple measurement tools
- Packet captures can provide detailed analysis
  - Microsecond granularity
  - Get captures from both sides

### Port flapping

- Network interface goes up and down
  - Over and over again
- Verify the cable
  - Check the wiring
- Move between switch interfaces
  - Is the flapping associated with the switch interface or the device?
- Replace bad hardware or cables
  - May require additional purchases



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