

Analog to Digital (A/D)

- ### Agenda
- What is Data?
 - The Evolution of Data Communications
 - Analog vs. Digital
 - Network Topologies
 - Network Protocols & the OSI model
 - Bridges, Routers and Gateways
 - IXC's Role In Customer Networks

Metric Measurements

k, kilo = 1,000	($10^3 \approx 2^{10}$)
M, Mega = 1,000,000	($10^6 \approx 2^{20}$)
G, giga = 1,000,000,000	($10^9 \approx 2^{30}$)
T, Tera = 1,000,000,000,000	($10^{12} \approx 2^{40}$)
m, milli = 1/1,000	
u, micro = 1/1,000,000	
n, nano = 1/1,000,000,000	
p, pico = 1/1,000,000,000,000	
Also: b = bit, B= byte (8 bits)	

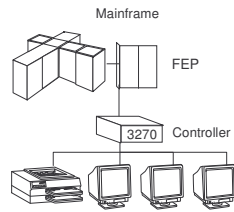
- ### What is data?
- Typically anything other than voice.
 - Computers convert letters, numbers, punctuation, etc. into digital form (on's and off's).
 - The letters, numbers, punctuation can be put together by end users to form information (a document), or can be used by programmers to create "code", which tells computers to perform specific functions.

- ### What Is Data Communications?
- Transmitting encoded information using either electrical or optical "on-off" pulses.
 - This process of interconnecting machines is handled by a mix of software and hardware which each function in one or more of the Open Systems Interconnection layers.

- ### The Evolution of Data Communications
- ENIAC (Electronic Numerical Integrator, Analyzer, and Calculator - 1946)
 - the first electronic computer
 - A stand-alone machine
 - made by the University of Pennsylvania for the U.S. Government
 - Mainframe Computer Systems (mid-50's - mid 60's)
 - Remote terminals communicate with a centralized processing system.
 - Programming required for everything.
 - A cost "Catch-22"

Mainframe Systems

- Mainframe -
- FEPs -
- Controllers -
- Terminals -



The Evolution of Data Communications

- Minicomputers (Mid 60s - Mid 70s)
 - Smaller & cheaper than mainframes
 - More accessible & designed for modification & extension
 - Gave rise to “hackers” - programming enthusiasts
- Microcomputers (Mid-70s - today)
 - Later known as PCs (personal computers)
 - Utilized an “operating system”
 - Distributed processing brought about need for more efficient networking.
 - Gave birth to LAN (Local Area Networking) industry

Data Codes

- General Description
 - Data codes represent characters
 - Rules for converting bits to characters
- Morse Code
 - Dots and dashes
- Baudot Code
 - 5-bit code

Signal Representation

- Bit rate
 - Bit - smallest unit of information
 - Binary notation
 - Data codes
 - Byte
 - Bit rate
 - Bits per second

Signal Representation

- Baud Rate
 - Baud
 - Current
 - Alternating current (AC)
 - Direct current (DC)
 - Dibit
 - Tribit

Computer Language

- Bit (a letter in a word)
 - The basic unit of data... a **binary digit**
 - Has value of either “0” (off) or “1” (on)
 - Created by computer transistors which basically turn electrical current on and off at specific intervals.
- Byte (the word itself)
 - Set of bits of specific length which represent a value (a letter, number, punctuation mark, symbol, etc.) in a computer coding scheme.
 - Nibble = 4 bit byte
 - Octet = 8 bit byte

Digital Signals are Binary (0's & 1's)

- Eight bits make a byte. Using only zeros and ones, there can be 256 possible combinations in a byte:
- 00000000 may represent 0
- 00000001 may represent 1
- 00000010 may represent 2
- 00000011 may represent 3
- and so on.

An Example in ASCII

- This course is great!

```
T      h      i      s      c
01010100 01101000 01101001 01110011 00100000 01100011

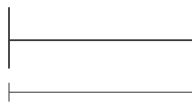
o      u      r      s      e
01101111 01110101 01110010 01110011 01100101

i      s      g
00100000 01101001 01110011 00100000 01100111

r      e      a      t      !
01110010 01100101 01100001 01110100 00100001
```

Analog Signals

- ▶ As we speak we create a wave of sound energy. This sound wave is converted into electrical energy by the telephone. Analog transmission is a sound wave being duplicated electrically and carried over a transmission path.

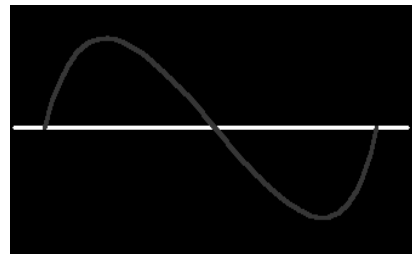


Oscilloscope

higher=closer
louder=taller

- ▶ 1 cycle = 1 Hertz (Hz)

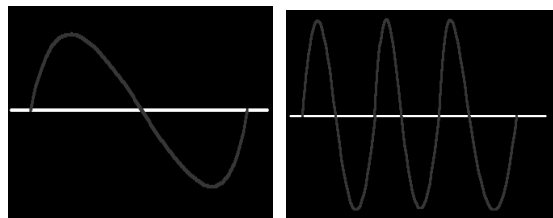
Sinusoidal Waves



The flat line represents no voltage and each cycle represents one hertz.

Frequency

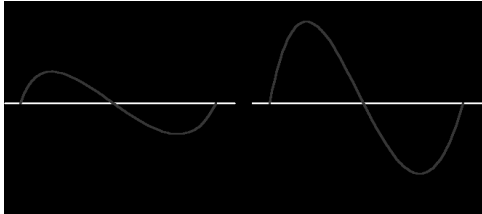
The closer together the waves are, the higher the frequency (pitch).



- Sound can be measured by frequency (pitch) and amplitude (loudness) in cycles per second.
- When converted into an electrical impulse, we use the term Hertz to refer to one cycle. KiloHertz refers to 1000 cycles, and Megahertz refers to one million cycles.

LOUDNESS

The height of the waves indicates amplitude



- Bandwidth can be thought of as the amount of electromagnetic energy that can fit in the "pipe".
- The Bell Telephone company has found that normal conversation ranges between 300 to 3300 Hz range, therefore, has a bandwidth of 3000 Hz, or 3 kHz.
- ▶ The "speed" that a service travels at is determined by subtracting the lower range from the higher range. Thus the "speed" that voice travels at within the PTN is 3000 hertz or 3kHz.

- Telephone systems divide the bandwidth into 4 kHz channels ("in band" frequency) and use a portion of the "out of band" frequency for signaling purposes.
- This 4 kHz bandwidth creates some limitations for high speed internet, videoconferencing, and other services

- Because the tone and loudness of a voice is always changing, an analog signal is unpredictable.
- Resistance in the wires diminishes amplitude as it travels over distance. This loss of energy is called "attenuation".
- An analog signal must be amplified to boost the signal. Unfortunately any noise or static will also be boosted. Amplifiers are used to boost the signal strength and are placed at 15,000 to 18,000 feet apart.

- Because of noise and other factors, the telephone network began switching to digital communications.
- Converting an analog signal into a digital signal requires an A/D (analog to digital) converter.

Digital Signals

- ▶ A series of discrete, discontinuous light or voltage pulses.
- ▶ The analog voice signal is sampled at the rate of 8,000 samples per second, and each sample is transmitted as a binary code. (0,1)
- ▶ A digital signal is predictable and produces a higher quality sound.
- ▶ As the digital signal loses strength over distance a Regenerator detects the incoming bit stream of 0's and 1's and creates a new signal that is identical to the original signal.

Bandwidth

- ▶ With digital signaling, the bandwidth refers to the number of bits per second traveling through the transmission medium. The bandwidth of a voice grade signal is 64K; while the bandwidth of a typical data circuit is 56K or 64K depending on the line coding.
- ▶ Wideband lines carry more information than Narrowband lines. Wideband refers to higher speed services than Narrowband.
 - ▶ Television and cable are carried at Wideband speeds. Lines connecting telephone offices (IOTs) use Wideband.

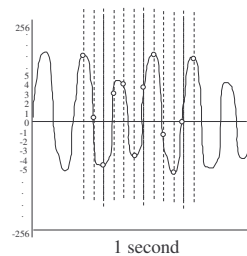
Analog to Digital

- ▶ In response to the problem of reduced voice quality, digital signaling was developed.

1. *Filter*
2. *Sample*
3. *Quantize*
4. *Code*

- Sampling is a measurement of the signal amplitude over time.
- Generally, 8000 sound samples are taken per second. Multiplied by eight bits per byte = a 64,000 bit per second data stream.

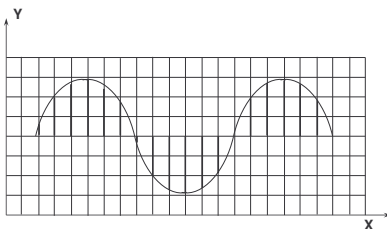
Digitizing Voice



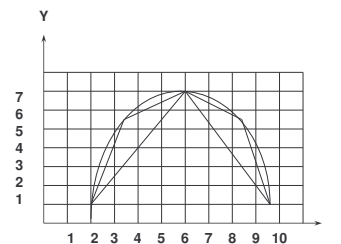
- Voice can also be transmitted as digital data
- The voltage of an analog signal is sampled 8000 times per second.
- Each sample is converted into its binary equivalent.
- Each binary sample is transmitted as a series of eight on's and off's (a byte)

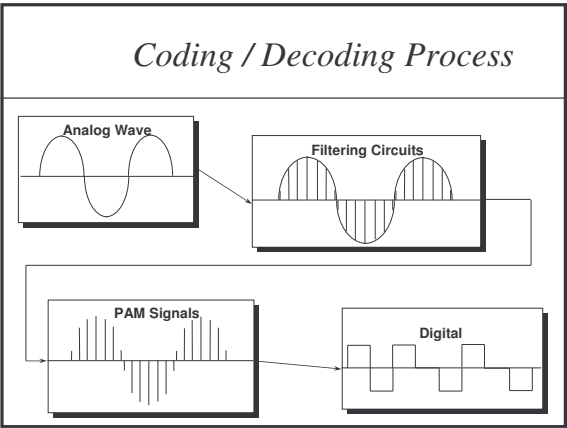
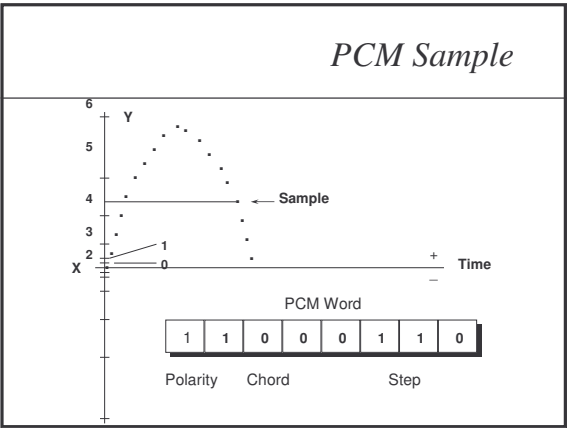
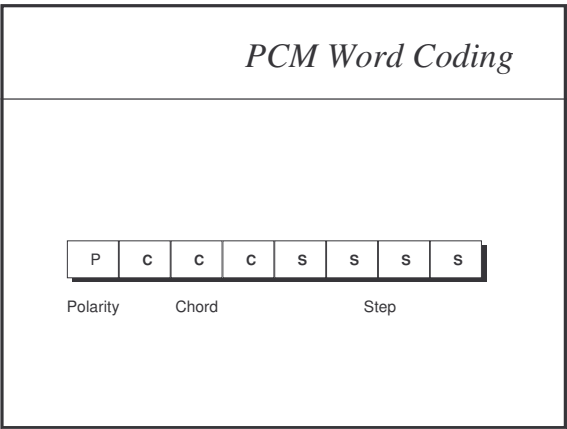
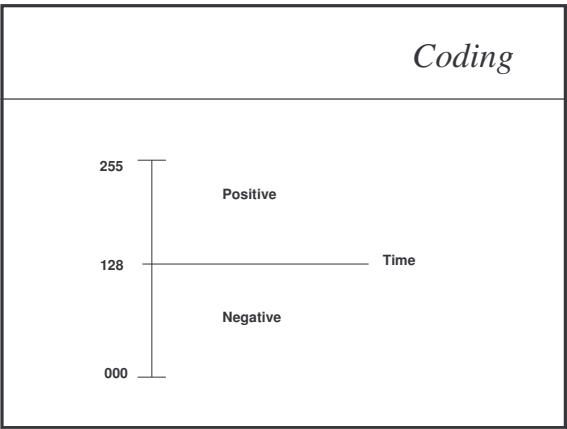
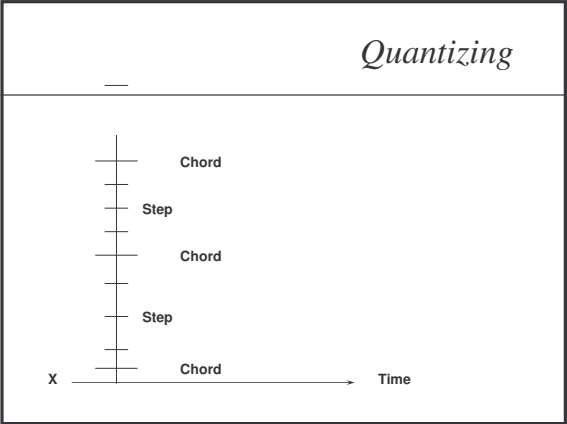
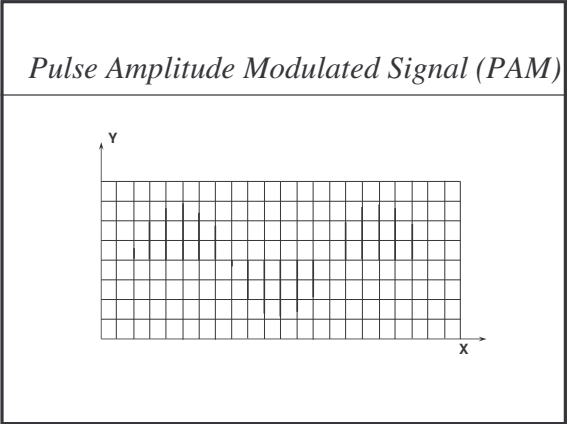
There are 256 possible sound levels. 256 combinations of 0's and 1's.

Samples



Plotting a Curve





Digital Signals vs. Analog Signals

- Modems
 - MODulator/DEModulator
 - Internal vs. external
 - PC cards
 - Modem speeds
 - PC to mainframe connection
 - Internet Service Providers
 - On-line services

- Regenerators receive the binary data, and resends the data at a much stronger level.
- Regenerators are typically placed every 5000 to 6000 feet (about one mile) apart.

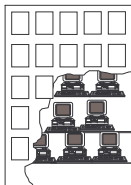
On to Networks

Network Objective

- To become familiar with basic data communications terms.
- To understand various types of Local Area Networks.
- To discuss IXC's role in a customer's data communications network.

Local Area Networks (LANs)

- The primary goal of this section is to explain how a network within a building works (A Local Area Network) BEFORE traffic is handed to a telecommunications carrier.

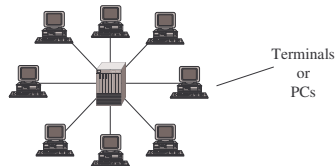


Network Topologies

- A topology is the logical layout of a network (not necessarily physical)
 - Star
 - Bus
 - Ring

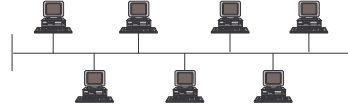
Star Network Topology

- Also known as hierarchical, this is the typical mainframe computing topology
- Hub is normally a centralized processor
- PCs were first interconnected this way



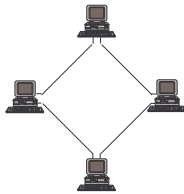
Bus Network Topology

- All PCs connected to same bus
- Data is transmitted onto the bus and each machine examines the address of the data “packet”
- Most common is Ethernet



Ring Network Topology

- Also referred to as “token ring”
- Data is passed from computer to computer until data packet reaches its ultimate destination



Network Protocols

- No matter the topology, rules for communication between devices must be followed
- These rules are called “protocols”
- Protocols define the location of certain information within the binary bit stream such as:
 - Addresses
 - Control Information
 - User Data
- Not all protocols provide the same tasks, and if they do, rarely provide them in the same fashion.

Protocol Tasks

- Segmentation and Re-assembly
- Encapsulation
- Connection Control
- Ordered Delivery
- Flow Control
- Error Detection & Correction

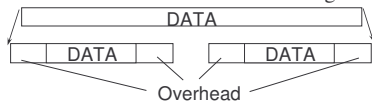
All protocols add OVERHEAD (extra bits)

ISO/OSI – Reference Model

- Int’l Standards Org. – Open Systems Interconn.
 - “All People Seem To Need Data Processing”
 - 7: Application
 - 6: Presentation
 - 5: Session (FTP, HTTP, SMTP, etc.)
 - 4: Transport (TCP = Trans. Ctl. Protocol)
 - 3: Network (IP = Internet Protocol)
 - 2: Data Link (Ethernet or Token Ring)
 - 1: Physical (Data Comm.)

Segmentation & Re-assembly (Typically OSI Layer 4)

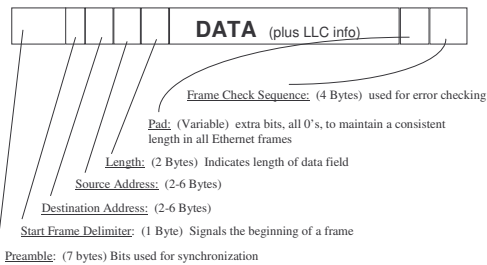
- User data is not usually sent as a large block
- Data must be broken up to cut down on
 - latency (delay)
 - retransmissions
- Individual segments are referred to as “packets”
- Packets are “numbered” to assist in reassembly in the event data units arrive in the wrong order



Encapsulation (Typically OSI Layer 2)

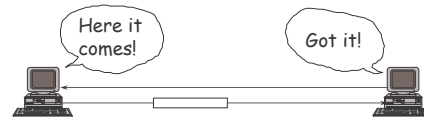
- Protocols place data into “envelopes” or “packets” which contain vital information.
- Depending on the protocol, the envelopes may contain different information.
- Standard information includes start flags, source and destination addresses, and error control information.

Encapsulation: An Ethernet Frame Example



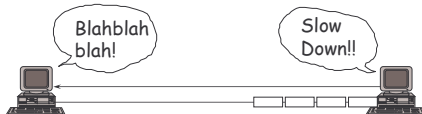
Connection Control (Typically Layer 4 & 5)

- Used in connection-oriented protocols
- As data is received, destination sends periodic acknowledgments back to sender of successful (or unsuccessful) transmissions.



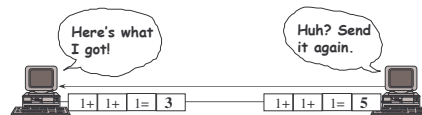
Flow Control (Typically Layer 4)

- Devices must be able to notify each other of congestion
- Usually sent from destination back to source



Error Detection & Correction (Various Layers)

- Used to check data integrity
- Frames can be numbered to check for ordered and complete delivery
- Algorithms are run by sender and receiver and compared
- Bad data is dumped or retransmitted



FYI: Protocol Differences

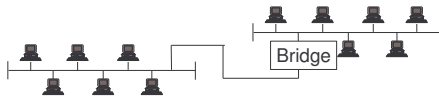
	Ethernet	Token Ring	FDDI
Data Rate	10 or 100 Mbps	4 or 16Mbps	100Mbps
Maximum Frame	1518 bytes	No limit	4500 bytes
Distance between nodes	0.5 km	10 km	2 km
Maximum length	2.8 km	10 km	100 km
Maximum nodes	1024	50	500
Topology	Bus	Ring	Dual Ring
Access	CSMA/CD	Token	Token

Other Protocol Users

- Information contained in frame “headers” is also read by other communications equipment.
 - Bridges
 - Routers
 - Gateways
- Often the functions of bridges, routers, and gateways can be found in the same piece of equipment.

Bridges

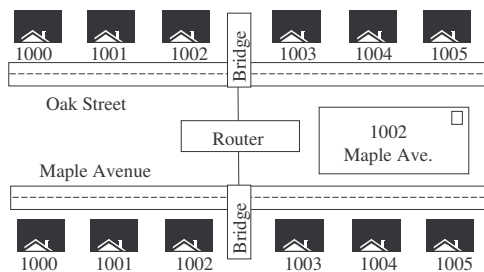
- Large networks must be broken up into segments to prevent too many nodes from creating congestion
- Bridges used to join two different network segments
- Bridges read destination address and pass packets through if destination is on the “other side”



Routers

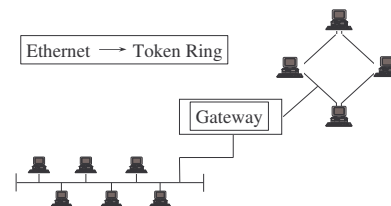
- Routers interconnect different networks by switching incoming data from one network out to another.
- Typically routers look at network addresses, bridges look at machine addresses.
- Routers support multiple protocols
 - Protocols: Ethernet, Token Ring, FDDI, TCP/IP, Frame Relay, T1, T3, ATM

Network vs. Machine Address



Gateways

- Interconnect two or more dissimilar networks.
- Works like an interpreter between protocols.

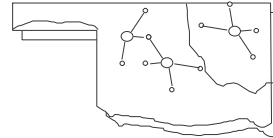


Where does the IXC fit in?

- The IXC provides transportation of data between networks located in two or more distant locations.
- All previously discussed elements typically fall under the responsibility of the customer.
- Customers can connect networks with either
 - simplex or duplex facilities
 - on packet or circuit switched networks

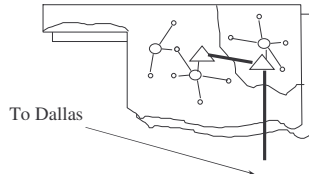
Local vs. Long Distance

- Local Exchange Carriers (Bell and others)
 - Can transport traffic within LATA boundaries
 - Must hand off traffic to a long distance carrier if traffic is crossing one or more LATA boundaries.

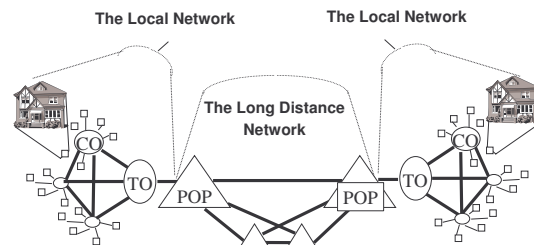


Local vs. Long Distance

- Interexchange Carriers
- Can transport traffic across LATA boundaries
 - Once traffic is moved from originating LATA to terminating LATA, IXCs pass traffic to LECs for “last mile” transmission.



The Network (A Block Diagram)



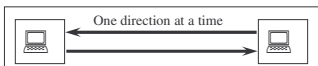
Transmission of Data

• Flow of Data

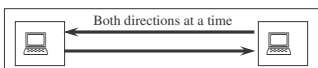
– Simplex



– Half-Duplex



– Full Duplex



How is data transmitted?

- Circuit switching
 - The process of setting up and keeping a circuit open between two or more users so that the users have sole use of the circuit until the session is terminated.
 - Private Line is one example
- Packet/Cell Switching
 - No circuit is dedicated to the users between two points
 - Data is addressed and sent to a packet switch, where it is passed to the appropriate destination
 - Frame relay and ATM are examples