Audio/Video Recording and Playback

- This diagram shows the basic processes for recording and playing back sound.

**Sound Sensor**
- The basic sound sensor is a microphone which is a transducer.
  - A device which converts one type of wave into another.
- There are five basic types of microphones:
  - Carbon (not used much anymore)
  - Dynamic
  - Ribbon
  - Condenser
  - Crystal

**Microphones**
- **Carbon**
  - A vial of carbon dust connected to a diaphragm
  - Sound waves hitting the diaphragm compress the dust changing its resistance which is turned into an electrical wave
  - Drawback: Carbon microphones need a small current to produce the electrical wave
- **Dynamic**
  - The same process as a speaker, but in reverse! $F = qvB$
- **Ribbon**
  - A thin conducting ribbon suspended in a magnetic field connected to a diaphragm
  - Sound waves hitting the diaphragm move the ribbon in the field creating an electrical wave
  - Drawback: Condenser microphones need a small battery to provide a voltage across the capacitor
- **Condenser**
  - A capacitor with one parallel plate connected to a diaphragm which can move
  - Sound waves hitting the diaphragm change the capacitance of the capacitor which is turned into an electrical wave
  - Drawback: Condenser microphones need a small battery to provide a voltage across the capacitor
- **Crystal**
  - Certain crystals (called piezoelectric crystals) change their electrical properties as they change shape
  - By attaching a diaphragm, the crystal will create an electrical wave when sound waves hit the diaphragm and compress the crystal
  - Advantage: Can be made very small
Sound Storage
• The output of the sound sensor can be directly connected to an amplifier and speaker for immediate enjoyment
• However, normally we want to record the sound for playback at a later time
  – So we must store the sound signals

Grooved Disks (Records)
• This was the original method
  – Invented in 1877 by Thomas Edison
  – Started with a grooved cylinder
  – Went to a grooved disk in 1889

Grooved Disks (Records)
• The sound vibrations are scratched as bumps and wiggles in the groove on the disk
• The height of the bumps give us the intensity of the sound, the wiggles give us its frequency

Grooved Disks (Records)
• When you playback the disk, a needle connected to magnets follows the groove and moves the magnets back and forth inside wire coils
  – This produces electrical current corresponding to the sound vibrations
• The current is amplified and used to drive a speaker

Magnetic Tapes
• This method was invented in 1898
  – Originally used steel wires not plastic tape
  – The tape consists of a thin plastic base material coated with ferric oxide powder
    – Ferric oxide contains iron, which is magnetic
  – The oxide is normally mixed with a binder to attach it to the plastic

Magnetic Tapes
• The sound wave is recorded on the tape through an electromagnet driven by the sound sensor
• The electromagnet’s field varies in time to the sound
  – which magnetizes the iron particles on the tape to match the sound patterns as the tape is pulled past the magnet

An aside: Magnetic Hard Drives
• Invented in 1950’s
• Differences between cassettes and hard drives
  – In a hard disk, the magnetic recording material is layered on an aluminum or glass disk and then polished to mirror smoothness
  – This makes it very durable compared to tape
An aside: Magnetic Hard Drives

With a tape, you have to fast-forward or reverse to get to any particular point on the tape.
- This can take several minutes with a long tape.
- With a hard disk, you can move to any point on the surface of the disk almost instantly.

An aside: Magnetic Hard Drives

In a cassette-tape deck, the read/write head touches the tape directly, eventually wearing out the tape.
- In a hard disk, the read/write head "flies" over the disk, never actually touching it.
- This eliminates wear and tear due to friction.

Problems

- There are several disadvantages with recording sound using grooved disks and magnetic tapes:
  - Both media will wear out over time.
  - The grooves in the plastic are read out by dragging a sharp metal needle through them (ouch!), which cuts into the plastic every time it is played.
  - This tape is scraped by the read head every time it is played back.

Analog Recording

- Both grooved disks and magnetic tapes are examples of analog recordings.
- Analog means "continuous":
  - The entire sound wave is recorded.
- A problem with analog recording:
  - It's difficult to mass produce!
  - Repeated playing leads to degradation of the original recording.

Analog to Digital Conversion

- A/D for short
- The process of converting a continuously varying signal (analog) into a series of approximating pulses (digital)

Analog to Digital Conversion

The A/D process starts by approximating the analog waveform with a series of equally spaced spikes.

Analog to Digital Conversion

The height of each spike is a voltage which is equal to the actual voltage at that particular time.
- If we space the spikes close enough, we can get an extremely good approximation of the original waveform using our chain of voltage spikes.

Problems

- The media are easily damaged:
  - Scratches in the tape or disk damage the sound patterns recorded.
  - The plastic grooved disks can warp due to heat and humidity.
  - The plastic tape is easy to stretch and tangle if it catches in the machinery.
  - The recordings are not "permanent".
  - If played regularly, they can last ~5 years.

Analog Recording

- This problem can be mostly (not totally) remedied by not recording the sound as an analog (continuous) signal:
  - but instead as a digital (non-continuous) signal.
- Before we can discuss the remainder of the sound storage methods:
  - we have to discuss what digitizing a signal means.
Analog to Digital Conversion

• We now encode each spike height as a number
• Example: If the voltage ranges between 0V and 1V, we might break up the range as follows:
  - 0.0V to 0.2V = 0
  - 0.2V to 0.4V = 1
  - 0.4V to 0.8V = 2
  - 0.8V to 1.0V = 3

Analog to Digital Conversion

• So we could approximately represent the analog signal over time as a series of numbers
  - Example: 00110101

Analog to Digital Conversion

• Now comes the tricky part
  - Computers can’t recognize any numbers but 0 and 1
  - So we must reduce our sequence to only 0’s and 1’s

Analog to Digital Conversion

• We do this by converting from the decimal (base-ten) number system to the binary (base-two) number system
  - Example: 00110101

Compact Disks (CD’s)

• The binary pulse train can also be recorded as a series of elevation changes above a surface
  - With a zero elevation being a 0 (“land”) and a nonzero elevation being a 1 (“pit”)  
  - This is how information is recorded on a CD
    - In a spiral track starting from the center

Compact Disks

• Example: 0 = 0V, 1 = +5V
  - This signal could be represented as an 8-bit pulse train 01101001
    - Which equals (in base-ten) the decimal number 69
  - With a zero elevation being a 0 (a “land”) and a nonzero elevation being a 1 (a “pit”)
Compact Disks

- Because of the density of information recorded in the spiral track, a very precise fine-tuned tracking mechanism is needed.
- This tracking mechanism must be sharp down to the hundreds of nanometer scale, which is the wavelength of visible light. So we use a laser!

Compact Disks

- A laser beam reflecting off the bottom of the disk is used to read the pits and lands.
- However, the laser doesn't "see" the lands or pits; it "sees" the transitions between them!

Compact Disks

- As the beam sweeps over the edge of a pit, part of the beam is on the pit and part on the land.
- Each part of the beam has a different path length (\( PLD \neq 0 \)), so the beam undergoes destructive or constructive interference depending upon the pattern of data stored on the disk.

Compact Disks

- The varying brightness of the reflected beam (due to the interference) is detected by a photocell, using the Photoelectric Effect.
- The varying brightness is turned into a series of pulses by an A/D converter, which goes on to be restored to an approximation of the original sound recorded.

Compact Disks

- The data stored on the disk can be considered a thin film, where the varying thickness of the film (the pits and the lands) stores the data pattern.
- This is all good and well, but since the spiral track is so narrow, what happens when the disk heats up and expands by more than the width of the track?

Compact Disks

- Obviously the laser would then be reading the wrong section! So a very accurate tracking mechanism is needed.
- More optics to the rescue!

Compact Disks

- Here's what is done...
- The two outer diffracted beams are supposed to stay on the lands and hence remain a constant brightness, while the central beam should vary in brightness.

Compact Disks

- If the laser gets off track, the two outer beams will start to reflect off the pits on an adjacent track or the current track, and start to vary in brightness!
- A separate photocell will detect this and adjust the laser's path to compensate.
- This is called negative feedback.
**Compact Disks**
- This method can keep the laser on a track just a couple of hundred nanometers wide—about 500 times smaller than a typical human hair!

**Solid State Devices**
- Solid state devices are those that have no moving parts—there's nothing to wear out!
- These storage devices record the digital signal in a series of electronic components called EEPROM's—Electronically Erasable Programmable Read Only Memory
- EEPROM's (a type of “flash memory”) are an electrical 2-D grid of cells—each containing two transistors at the intersection of each grid line
- Each transistor pair can store electrons for a very long time (but not forever!)—a certain number of stored electrons equals a "1", less than that equals a "0"

**Solid State Devices**
- Because solid state devices have no moving parts—they can be made extremely small and shock-resistant
- MP3 players, Ipods, Iphones, etc… all use solid state devices for storage of digital data

**Storage Comparisons**
- Analog sound pattern storage
  - Advantages
    - The entire waveform is stored yielding a more accurate reproduction
    - The storage media are cheap
  - Disadvantages
    - Mass production is limited by this loss of accuracy
- Digital sound pattern storage
  - Advantages
    - Media last a long time (Nothing lasts forever!)
    - Mass production is not limited by media wear
  - Disadvantages
    - Only an approximation to the original sound pattern is stored
    - Equipment to create original recordings is more expensive
    - The storage media are more expensive

**Audio Recording and Playback**
- Sound playback from either analog or digital storage is the same
- Two types of transducers are used:
  - Speakers
  - Headphones
Sound Playback

• There are lots of types of speakers and headphones - but most have the same basics as the microphones discussed earlier

• Interestingly, you can use a microphone as a speaker and vice versa - although not as efficiently!

Sound Playback

• The three types of speakers listed are optimized in their construction - to reproduce sound more accurately in certain frequency ranges

• Woofers are used for the low frequency range (the "bass") - Their large size is able to handle the large amplitude slower oscillating waves

• Tweeters are used for the highest frequency range (the "treble") - Their small size is able to handle the lower amplitude faster oscillating waves

• Midrange speakers handle waves not covered by the other two - Mostly the human voice range of frequencies

Sound Playback

• Good quality speakers are a combination of each of these types - all connected together

Light Sensors

• There are two basic types of light sensors used for recording video - film movie cameras - digital movie cameras

• Since we are concentrating on video, we’ll ignore still photography

Video Recording and Playback

• This diagram shows the basic processes for recording and playing back video

Film Movie Cameras

• In a film movie camera, a motor drives a continuous strip of film past a shutter at about 24 frames per second

• The shutter opens and closes once for each frame exposing the film beneath

• This creates a series of pictures on the film strip that will appear to be moving when played back at the same speed

Film Movie Cameras
Digital Movie Cameras

- A digital movie camera (or camcorder) uses a charge-coupled device (CCD) to record the “impact” of photons via the Photoelectric Effect.
- A single CCD pixel (made up of many atoms) will eject electrons when struck by photons. The number of electrons is proportional to the number of photons.

Many pixels make up a CCD array, and the electrons are shifted out of the CCD array electronically and sequentially in time, and used to form the picture after appropriate A/D conversion.

Color info is provided by using appropriate filters (RGB) on the input photons in a grid pattern.

Movie Cameras

- Note that neither of these movie camera types produce a analog (continuous) wave recording of the video.
- No one has been able to create a device yet that can do this! Even high-speed cameras have a set frame rate.

Video Recording and Playback

Video Storage

- The film from a film movie camera is the actual storage mechanism. As long as the film is stored correctly, it will last decades.
- Not stored correctly!!

Video Storage

- The digital output from a digital movie camera can be stored in several ways.
- Magnetic tapes
- Digital video disks (DVD’s)

Magnetic Tapes

- Storing video images via magnetic tape is similar to that of sound storage except way more intricate and precise.

Digital Video Disks

- Storing video images via DVD is similar to that of sound storage via CD except way more intricate and precise.
Video Recording and Playback

Video Playback
- Film playback
  - film projector
  - movie screen
- Magnetic tape playback
  - video cassette recorder (VCR)
  - television
- DVD playback
  - DVD player
  - television or computer

Film Projectors

VCR's

DVD Players

Televisions
- There are three basic types of television displays
  - cathode ray tube display (CRT)
  - liquid crystal display (LCD)
  - plasma display
- Projection displays are basically just a type of movie projector without the film!

Cathode Ray Tubes
- Cathode ray tubes create their images by firing high speed electrons at a phosphor coated screen
  - The impacting electrons excite the phosphor atoms which give off light when they return to their ground states
- The image is created by varying the intensity of the electron beam as it is scanned across the face of the screen
  - by using electric and magnetic fields! $F = qvB$

Cathode Ray Tubes
- Colors are created by using three beams and three types of phosphors (Red, Green and Blue) in a pixel grid pattern
- The three phosphor types can be impacted with electrons of varying energies to form any color!
Cathode Ray Tubes

This is called a raster scan.

Liquid Crystal Displays

- Liquid crystal displays (LCD's) use polarized light to create their images.
- Some common types of liquid crystals: lecithin, DNA, cellulose, cholesterol esters, gangliosids, paraffins, and graphite.

- A liquid crystal will normally rotate the plane of polarized light by 90°.
- But when a voltage is applied to it, the polarizing effect is removed!

- An LCD pixel consists of a sandwich of crystal between two transparent electrodes.
- An LCD pixel, when used in tandem with a set of polarizers, can be made to appear light or dark depending upon the applied voltage.

- An actual LCD display is an array of LCD pixels on top of a light source.
- Color displays are made by grouping the pixels in three's and placing a R or G or B filter in front of each pixel.
  - This allows you to make any color you want! Just like a TV screen.

- Plasma displays work like little fluorescent lights, but instead of mercury vapor laced with neon gas we use xenon vapor laced with neon gas.
- The xenon gas gives off a much more saturated light than the mercury, yielding a much sharper image.
Plasma Displays
- The xenon and neon gas is contained in hundreds of thousands of tiny cells positioned between two plates of glass.
- Three cells are combined into one pixel. Each pixel has three different phosphors (R, B, and G) to create all the colors.

Plasma Displays
- A pixel is energized by applying a voltage across the cells which release electrons into the gas.
- These electrons excite the xenon gas which gives off UV photons when it decays back to the ground state.
- The UV photons are absorbed by the phosphors which are then excited. When the phosphors decay back to the ground state, they give off visible light of the appropriate color.

Analog vs Digital vs HDTV
- Analog signals
  - Advantage: cheap
  - Disadvantages:
    - Poorer sound and picture quality
    - Larger bandwidth (one channel per signal)
    - Lower resolution
- Digital signals
  - Better sound and picture quality
  - Smaller bandwidth (multiple channels per signal)
  - Higher resolution
- High Definition signals
  - Best sound and picture quality
  - Highest resolution
  - Advantage: all or nothing
  - Disadvantages:
    - You either receive the signal or not; you don’t get a partial signal as in analog.