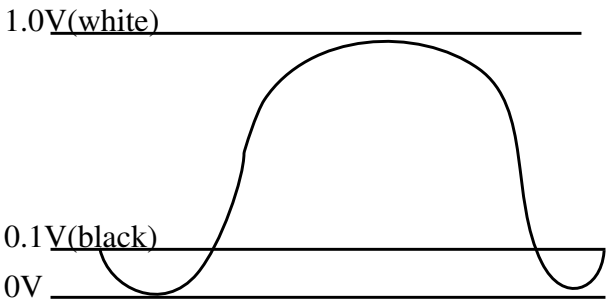
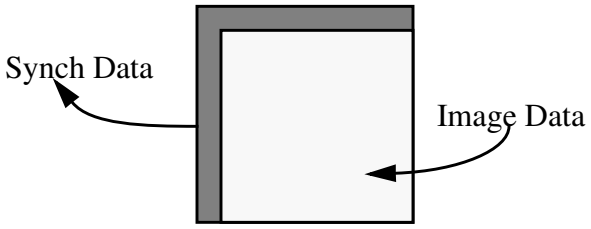
- Let black be 0.1 V, White is 1.0 V
- "Blacker than black" is range from 0 to 0.1 volts



- Horizontal sync happens at end of each line
- Vertical sync at beginning of each frame
- In effect, get a buffer around images



- Next problem: define meaning of voltage levels
- Gives rise to variety of standards: NTSC, PAL, HDTV to define the encoding of the electrical signal
- NTSC: scan line lasts about 64 microseconds, with 52 microseconds of data
- Standards were defined in world of analog electronics, so they're arcane

- **Motion**
- Digitized an image; Now how do we make it move?

1. Need about 20 images per second to make motion appear smooth
2. Need 50 to 70 flashes per second to make a series of on/off flashes appear constant (like fluorescent lights). This avoids **flicker**.

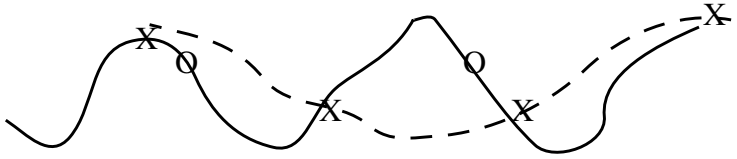
- Brighter environments (offices) need higher refresh rate; dim (cinema) need lower
- Typical refresh rate is 50 Hz (Europe) vs. 59.97 Hz (US)
- Cinema: 48Hz flash rate, 24 frames per second: conventional projector flashes each frame twice

- Samples typically stored as raw numbers (linear format) or as logarithms (u-law or A-law)
- Why use logarithms?
- Approximates perceptual uniformity
    - e.g., radio dial: turning 1/8 of a turn
    - approximately results in same volume change anywhere on the dial
    - doesn't correspond to amplitude change
    - our hearing/loudness perception is logarithmic
    - most perception of change would be at low end if a linear control

- **For next time: Digital Video**
- Encoding image as one-dimensional signal
- Raster: left-to-right, top-to-bottom, blanking intervals
- Synchronization
- Standards: NTSC, PAL, HDTV: video dimensions
- Motion:
    - frames-per-second to make motion appear smooth
    - flashes-per-second rate: to make on/off flashes seem constant
- Interlacing: divide picture into odd & even lines
- Color and grayscale

- **Monochrome Video**
- **Digitizing an Image**
- Given an image, how to convert it to electrical signal?
- Let voltage be proportional to brightness
- Voltage is one-dimensional
- Have to encode image as one-dimensional signal
- How? Scan left to right, top to bottom
- Problem: Given a signal coming in, how do we know where the upper lect corner is?
- Send sync signals to indicate beginning of a frame
- How to signal a sync?
- Solution: Don't use entire range for signal

- Detect sound by measuring pressure level at particular point



- How often to sample a sine wave?
- Once per cycle: looks like a constant value
- 1.5 times per cycle: every 0.75 cycle; looks like a sine wave of lower frequency
- Sampling theorem: if signal contains frequency components up to frequency f, then sampling frequency must be at least 2f to reconstruct the signal properly
- In practice, higher than 2f
- Typical frequencies: 8KHz to 48 KHz
- Often: 44.1 KHz -- double range of 20 kHz for human hearing

- After sampling, must convert the pressure of the sound wave to voltage levels for computer
- Transducer does this

- **Signal to Noise**
- In any analog system: voltage you want (signal) plus random fluctuations (noise)
- Noise: random fluctuations, maybe also artifacts, produced during processing of the signal

- **Signal to Noise ratio:**
- Ratio of largest signal that can be carried by system to amplitude of undesired components
- Measure of quality of measurment
- Expressed in decibels, ratio of two powers

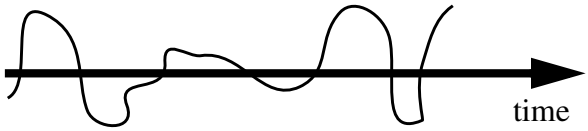
$$\text{SNR} = 10 \log_{10}(\text{signal}^2/\text{noise}^2) = 10 \log_{10}(\text{signal/noise})^2 = 20 \log_{10}(\text{signal/noise})$$

- Sample precision
    - CD quality: 16 bits
    - Telehone quality: 8 bits
    - Each bit adds 6 dB of resolution: 16 bits --> 96 dB

- Resource reservation
- MBone
- ISDN vs. hybrid fiber-coax vs. FTTH vs. Twisted pair

6. **Interactive TV (1 week)**
    - Commercial systems: SGI, HP, trials
    - Hierarchical systems
7. **Collaborative Work/Environments (1 week)**

- **Representing Digital Audio and Video**
- Today: audio, next time: video
- Microphones and cameras produce analog signals (continuous-valued voltages)



- Computers need digital signals

- **Have to digitize data: two processes**

1. Sampling: carves up "horizontal" dimension of time into discrete intervals
- Everyone does uniform sampling: at uniform intervals of time
2. Quantization: carves up "vertical" axis, which is signal strength/amplitude:
- Assigns integer to amplitude
- 8-bit quantity: divides vertical axis into 256 levels
- 16-bit: 65,536 levels

- **Digitizing Audio**
- Sound is continuous wave traveling through air
- Wave made up of pressure differences
- Normal wave properties: reflection, refraction, diffraction

- **Resources**
- Brand new Sun video server with large disk array (just arrived last week)
- Variety of storge devices: disks, solid state disk, digital linear tape
- Software and hardware compression resources
- Networking infrastructure: building a large testbed environment
    - geared towrad delivery of interactive video to the home
    - Video server with fast ethernet interface
    - ATM switches to fiber
    - Broadband integrated gateway and cable head-end
    - Cable connection to home

- **Outline of this Course**

1. **Digital Video and Compression (1.5 weeks)**
    - Digital audio and digital video basics
    - JPEG
    - MPEG
    - Scalable compression
    - MBone tools: nv, vic, vat
2. **Storage Systems, File Systems for Multimedia Data (1.5 weeks)**
    - RAID
    - Tertiary Storage
    - File systems for multimedia
    - Commercial video servers
3. **Operating Systems Issues (1 week)**
    - Real-time delivery of data
    - Synchronization
    - Middleware
4. **Databases for Multimedia (1.5 weeks)**
    - Query By Image Content
    - Building indexes on video segments
5. **Multimedia Networks (1.5 weeks)**
    - Best-effort delivery

Lecture 1: 8113
Course Overview, Digital Audio

- **Introduction**
- Primarily a paper-reading and project course
- Reading papers and participating in discussion is essential to the success of the course
- Only written assignments: paragraphs on every major paper we ead
    - 1/2 page
    - Summarizing about 5 major points
    - Pain for students, pain for me (I have to read them all!)
    - Guarantees that everyone comes prepared for the discussion
- Also, everyone will give a 30-45 minute presentationo on one of the papers
- (i.e., about half a class eriod, covers main points, critiques papers)

- **Grading**
- Paper write-ups and presentation: 40%
- Project: 60%
- To get full credit on papers:
    - Paragraphs for 80% of papers turned in on time
- Auditors: to receive credit, must turn in paragraphs on 50% of papers AND must give a paper presentation
- No exams

- **Projects**
- Small groups: 3 to 4 people per team
- Because there is a separate course on multimedia networks, projects in this class will be limited to topics such as
    - compression schemes,
    - storage architectures,
    - operating systems/file systems,
    - databases

- **Interesting time to do multimedia research at Georgia Tech**