Television

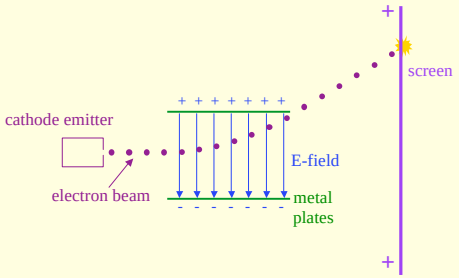
How the Pictures are Painted
How the Signal is Communicated

The Main Job

- The main job of a television is to paint a new picture 30 times a second
  - sounds hard
  - Caesar's dictum: divide and conquer
  - Can I make a dot on a screen?
  - Can I make it any color I want?
  - Can I put it in any position I want?
  - Can I scan across and make many dots in a row?
  - Can I do this all fast enough?
  - Can I find anything decent to watch?

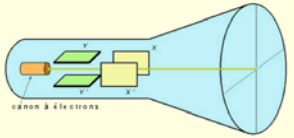
Making a dot where we want it

- TV "tube" shoots an electron beam at a phosphor screen
  - electric or magnetic fields deflect the beam
  - phosphor lights up (glows) when hit by electrons



Getting two dimensions

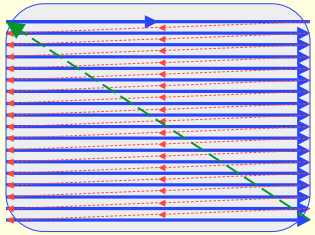
- Now orient two sets of plates orthogonal to each other and you can deflect left-right AND up-down
- If you "sweep" the electric field on one set of plates (let's say the left-right), you will draw a "trace" across the phosphor screen
- This is how an oscilloscope works:
  - the beam is repeatedly swept left-to-right at a constant rate
  - meanwhile, an input signal "tells" the up-down plates what to do
  - end result is a time-trace of what the input signal did
  - beam is turned off for return trip to left



TVs use coils of wire instead of plates, steering electrons with magnetic fields rather than electric fields

Drawing the Picture

- Scan, or *raster* the beam from left to right to make a horizontal stripe of the picture
- Turn off beam, and do a "carriage return/line feed"
- Upon arrival at lower right, scoot back to upper left with beam off
- Now do it all over again…



TVs on TV

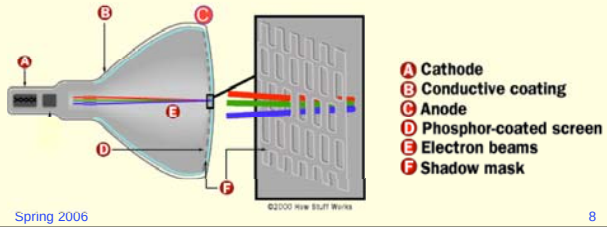
- Often when you see a TV or a monitor *on TV*, you see a dark band moving slowly down the screen
  - Or a fast flicker of a computer monitor
- This is because the video camera is *also* recording 30 frames per second
  - strobes the screen mid-paint
  - dark band is faded phosphor from earlier paint job
  - the slow motion is due to camera not being exactly at 30 Hz
    - if it were exactly so, the band would appear frozen

Monkey with Brightness

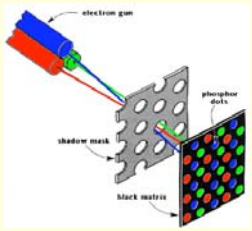
- The electron beam is generated from a hot electrode
  - called a **cathode**
  - cathode is heated by a filament, like a light bulb
  - thermionic effect: boiling off electrons
  - electrons are attracted by positive plate, and collimated by magnetic field
- The intensity of the electron beam depends on the *current* through the cathode
  - vary the current → vary the brightness

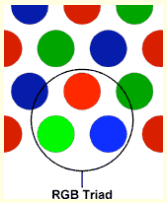
Making Color

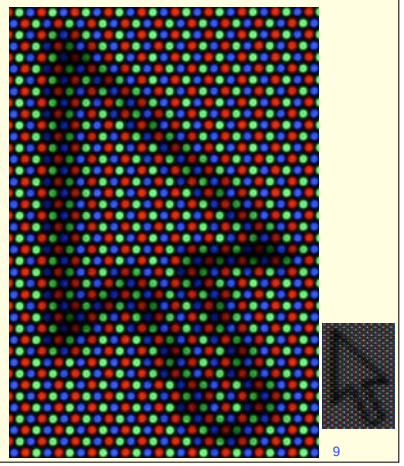
- So far we can paint black and white pictures (actually grayscale) by varying brightness
- Generating color requires three tricks:
  - use colored phosphors (red, green, blue) instead of just white
  - use three separate electron guns, one for each color
  - mask the phosphor screen so that the green gun can only hit green phosphor, etc.



RGB Triads

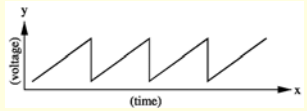






Numerical Logistics

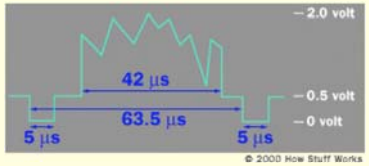
- Need to paint a new picture every 33 ms
  - but 30 Hz update might appear to flash
  - solution: interlace → draw *every other line* in 1/60th of a second, then go back and fill in the gaps
  - appears completely smooth to our eyes
- Need to paint 525 lines total
  - that's how many are in each frame
  - and doing this 30 times per second means 15,750 lines per second
  - means horizontal sweep has 15.75 kHz frequency
    - it's the high-pitched whine you hear when a TV is on



This is the way you have to modulate the horizontal steering mechanism to raster lines

Telling the TV what to do

- The video signal (such as what comes from your DVD or VCR) tells the TV how and when to sweep



  - Every 63.5 µs, get a signal to start a new line (5 µs dip)
    - called horizontal sync
  - At bottom of screen, get 400 µs dip to signal arrival at bottom
    - called vertical sync
  - In between is brightness information:
    - E.g., 2 V means white, 0.5 V means black

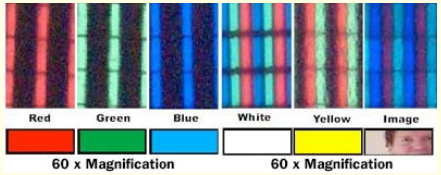
Frequency Allocation

- TV channels require 6 MHz of bandwidth each
  - 2, 3, 4 cover 54–72 MHz
  - 5, 6 cover 76–88 MHz
  - 7–13 cover 174–216 MHz
  - 14–83 cover 470–890 MHz (UHF)
- Amplitude modulation (AM) + all kinds of sneaky tricks
  - had to add on color after-the-fact
  - basically treat video signal as waveform, and AM accordingly
  - audio is FM (Frequency Modulation), however

A Vestigial picture sideband
B Video carrier
C Fully transmitted picture sideband
D Sound carrier

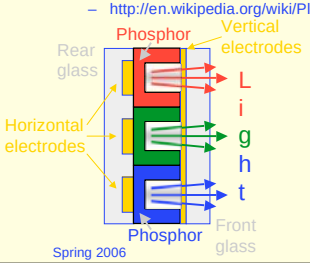
Liquid Crystal Displays (LCDs)

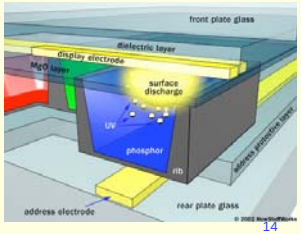
- LCD displays use totally different technology
  - LCD is backlit with fluorescent tubes (usually around side)
  - each pixel "addressed" with horizontal conductor on back, transparent vertical on front, forming matrix of connectivity
  - amount of current through pixel determines its brightness
  - filters in front of R, G, B pixels create color
  - each pixel usually has own transistor (TFT on glass!) and capacitor to switch and hold charge



Plasma Displays

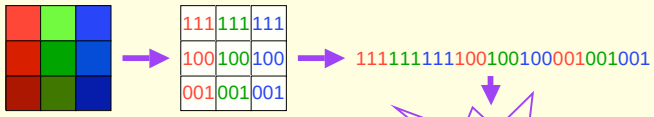
- Plasma is an ionized gas
  - atoms of neon and xenon have an electron stripped off
- Electrons collide with phosphor, which gives off light
  - Plasma displays use the same phosphors as CRTs, accounting for the extremely accurate color reproduction
- Burn-in is a problem: static images burn the phosphor, to leave a permanent "ghost"
  - http://en.wikipedia.org/wiki/Plasma_displays



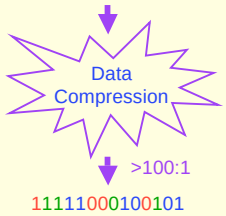


High Definition Television (HDTV)

- All digital (except in Japan)
- Similar to DVD encoding
  - Digital Versatile Disk, née Digital Video Disk



Data Compression
- Advanced micro-computers
- Two-dimensional Fourier Transforms
- Variable length encoding
- Motion estimation
- Differential encoding
- Backward prediction



References and Assignments

- Extensive support for this lecture from:
  - http://electronics.howstuffworks.com/tv.htm
- Read pp. 478–488, 495–496 (for Thursday, 5/25)
- HW 6 due 5/25: 13.E.19, 13.E.21, 13.E.22, 13.E.24, 13.E.25, 13.E.26, plus additional required problems accessed via assignments web page
- Q/O #4 due Friday (5/26) by 6PM