



Television

How the Pictures are Painted
How the Signal is Communicated

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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?

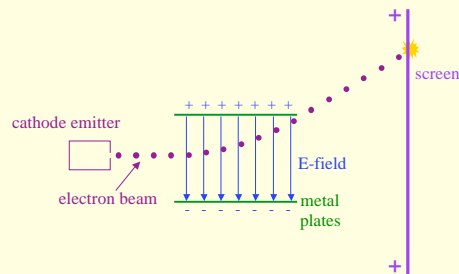
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Making a dot where we want it

- 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



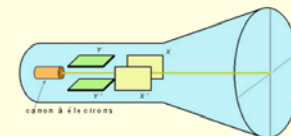
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Getting two dimensions

- 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

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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...

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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

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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

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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.

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RGB Triads

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The diagram shows an electron gun on the left with three colored cathodes (red, green, blue) emitting beams through a shadow mask onto phosphor dots on a screen. A black matrix separates the dots. Below, a close-up of an RGB triad shows three subpixels (red, green, blue) arranged in a triangle.

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Numerical Logistics

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- **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

The graph shows a sawtooth wave representing the horizontal steering mechanism. The y-axis is labeled 'voltage' and the x-axis is 'time'. The wave rises linearly and then drops sharply, repeating this pattern.

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

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Telling the TV what to do

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

The graph shows a video signal waveform. The y-axis has levels for -2.0 volt, -0.5 volt, and 0 volt. The x-axis shows time intervals: 5 μs for horizontal sync, 63.5 μs for a line, and 42 μs for a video line. A large dip at the bottom represents vertical sync.

- 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

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Frequency Allocation

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- **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

The diagram shows a frequency spectrum from 0 to 6.25 MHz. A purple shaded area represents the video signal, with a central peak at 1.25 MHz and sidebands extending to 5.75 MHz. Labels A, B, C, and D indicate different components: A (Vestigial picture sideband), B (Video carrier), C (Fully transmitted picture sideband), and D (Sound carrier).

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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

60 x Magnification 60 x Magnification

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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

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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

>100:1

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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

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