Multimedia

- Video Signals -

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Overview

- **Video Signals**
  - Devices: Cameras and Displays
  - Color
  - Signal
  - Standards
  - Digital Video

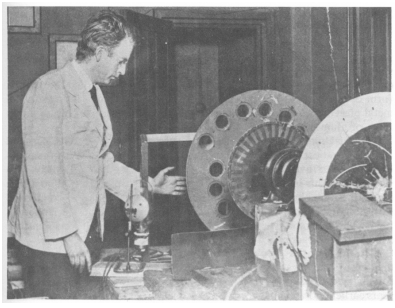
Video

- **Principle of TV and Video**
  - Transform of changing 3D-scene into 1D data stream
    - Projection of 3D to 2D
    - Sequential Zig-Zag scanning of 2D region
    - Digital: Sampling and quantization of 1D-signal
    - Transmission
  - And back ... as far as possible
- **Dimensions of Video Data**
  - Space: 2D image
  - Time: frames
  - Data values: 3 color channels

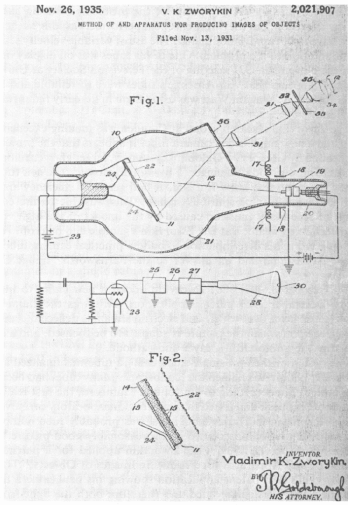
  ➔ Coherence of values over space and time

Video

- **Analog Camera**
  - From mechanical to electronic
  - Camera was *the* key to make TV work



John Logie Baird, 1925



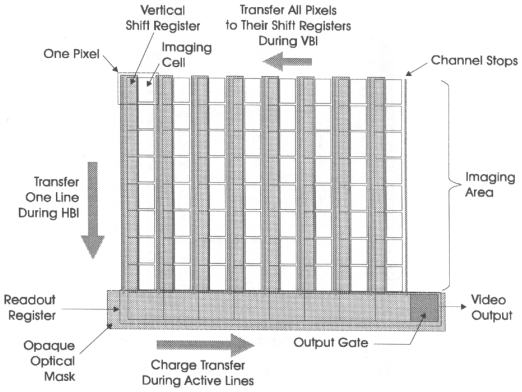
Zworykins Iconoscope patent, 1935

Courtesy: Abramson History of TV

Video

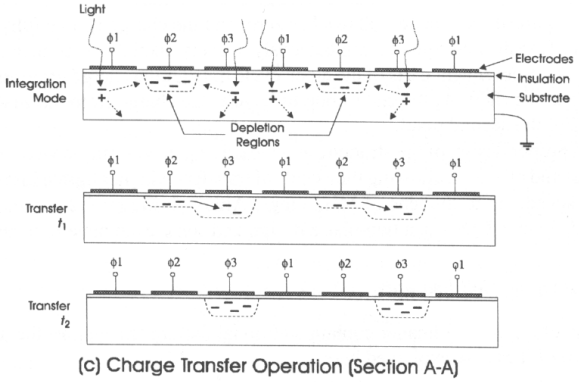
- **Digital Camera**
  - Charge Coupled Device (CCD)
    - Special production process
    - Analog charge transport
      - Need special frequencies
    - One ADC at the end
  - CMOS imagers
    - Use standard CMOS process
    - Amplifier & ADC & processing at pixel
    - Less quality (still), but cheaper

CCD



Video

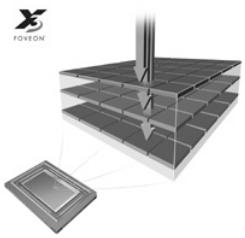
- **CCD-Principle**
  - Exposure and integration of electrons
  - Analog transport of electrons through CCD
    - Three different electrodes per pixel



(c) Charge Transfer Operation (Section A-A)

Video

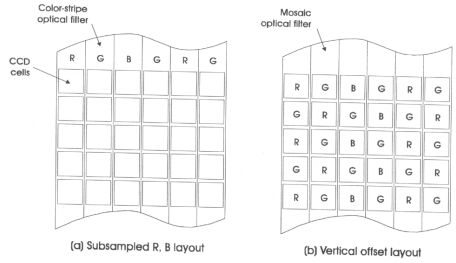
- **Color Video Sensors: 1-chip**
  - Optical color filters for each pixel
    - Stripe pattern
    - Bayer pattern
    - Loss in resolution
  - Stacked filters (Foveon X3)
    - Wavelength dependent absorbtion



Foveon X3 Sensor

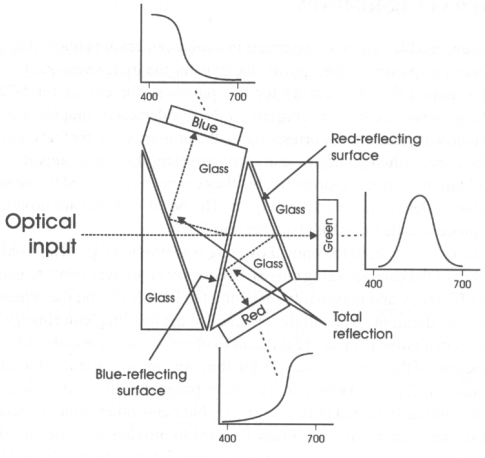
R	G	R	G	R	G
G	B	G	B	G	B
R	G	R	G	R	G
G	B	G	B	G	B
R	G	R	G	R	G
G	B	G	B	G	B

Bayer pattern



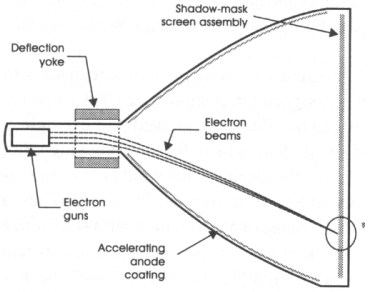
Video

- **3 sensor design**
  - Full resolution
  - Use of dichroic filters
  - Significantly more expensive
- **Dichroic Filter**
  - Coated glass
  - Reflect one part of spectrum, pass other



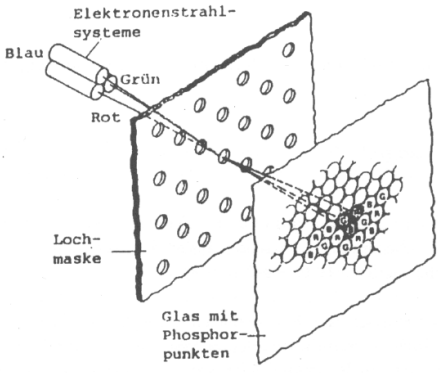
Cathod Ray Tube (CRT)

- **CRT (Braunsche Röhre)**
  - Phosphoreszence
    - But no Phosphor:
      R: Europium yttrium vanadate,
      G: Zinc cadmium sulfide,
      B: Zinc sulfide
  - Excited with electron beam
    - Tungsten fillament (slow e^-)
    - Control grid (negative)
    - Focussing
    - Deflection
      - Electrostatic (fast, e.g. Oszilloscope)
      - Electromagnetic (better focussion, graphics)
    - Accelleration (~20 KV)



Shadow Mask

- **Color Display**
  - Multiple electron beams
  - Shadow mask
  - Projection of mask onto screen
  - Color raster
  - Low intensity
  - No correspondence between shadow maskand pixels !!!



Liquid Crystal Display (LCD)

- **Use of Nematic Molecules**
  - Elliptic form
  - Rotates polarization if oriented across light direction
  - Orient due to
    - Grooves in surfaces
    - Electric field
  - In combination with polarizing filters
    - Light switch/valve

Liquid Crystal Display (LCD)

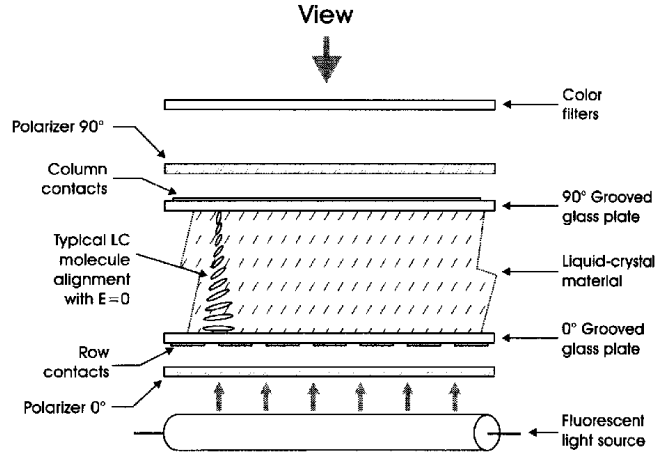


Figure 10.3 *Structure of an LCD panel. From A. F. Inglis, and A. C. Luther,* Video Engineering, Second Edition, *McGraw-Hill, New York, 1996, reproduced with permisston of The McGraw-Hill Companies.*

Digital Micromirror Displays

- **Digital Micromirror Devices**
  - Modulation of light with many tiny mirrors
  - 2D SRAM Cells
    - Electrostatic movement of micro mechanical mirror on top
      - ± 10 degree
  - Grayscale through temporal integration
    - Fast switching: time on versus time off
  - Color
    - Three DMDs
    - Time sequential with rotating color wheel

Digital Micromirror Displays

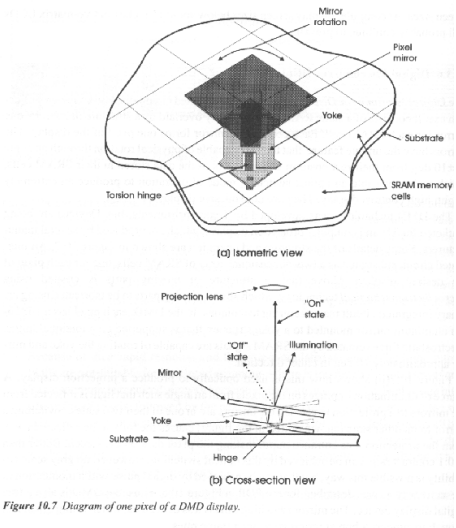
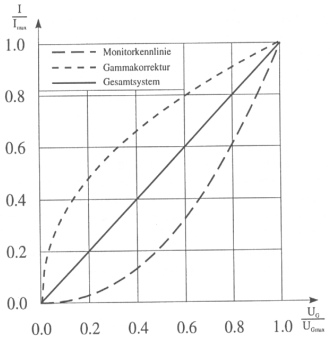


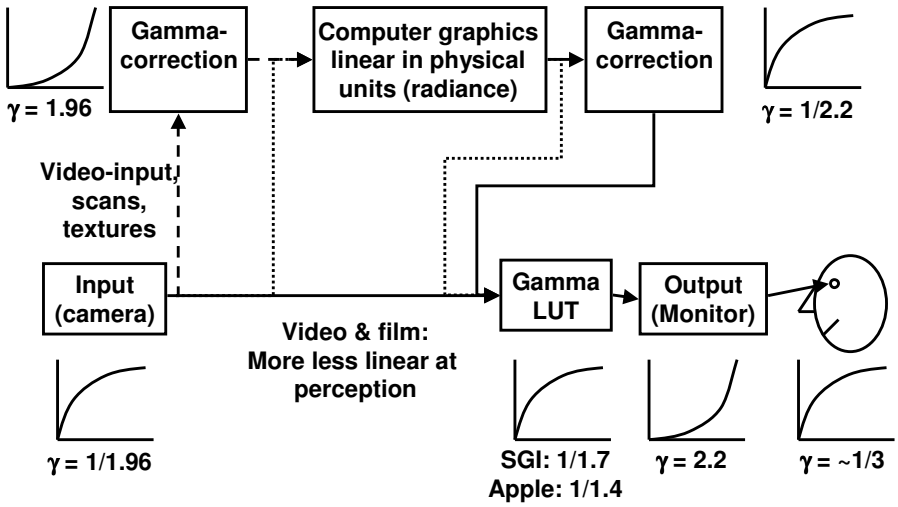
Figure 10.7 Diagram of one pixel of a DMD display.

Gamma

- **Display Gamma**
  - Intensity I of electron beam is non-linear with respect to the applied voltage U
  - Best described as power law
    - $I = U^{\gamma}$
    - ➔Gamma-Factor γ = ~2.2 due to physical reasons
- **Gamma correction**
  - Pre-correct output values to achieve linear curve
  - Quantization loss if value represented with less than 12 Bit



Gamma from beginning to end



Color Spaces

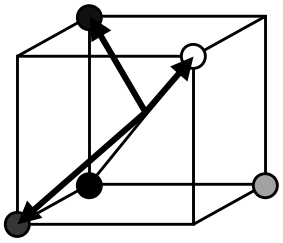
- Gamma:
  - Video operates in perceptional uniform space
    - $I' = I^{\gamma}$ mit $\gamma = 1/2.2 = 0.45$
  - Graphics (should) operate in linear light space
- Luma not Luminance
  - $Y' \neq Y$ (from standardized CIE color space)
- Color space: YUV?
  - RGB, R'G'B' needs primaries and white point
  - Y' B'-Y' R'-Y' ITU Rec. 601 or Rec. 709 color space
  - $Y'P_bP_r$ ditto, color normalized to [-.5, .5]
  - $Y'C_bC_r$ ditto, head room, digital
  - Y'UV, Y'IQ NTSC only (scaled and rotated for better modulation on carrier)

Color Spaces

- **R´G´B´**
  - Three primary colors (Red, Green, Blue)
  - Values are not gamma-corrected (Note: $R \neq R'$)
  - Problem
    - Need to transmit all channels equally
    - But humans are more sensitive to brightness than color
- **Several color standards for video**
  - NTSC (National Television Standards Committee)
  - EBU (European Broadcasting Union, for PAL)
  - ITU (International Telecommunication Union)
    - Close to today´s cameras and monitors
    - Uses D65 as white point

Color Spaces

- **$Y'P_bP_r$ (often called YUV)**
  - Basic color space used in NTSC and PAL
  - Separation in one brightness and two color signals
    - "Color difference signals"
  - Y'_{601}= 0.299 R´ + 0.587 G´ + 0.114 B´
  - P_b = 0.493 * (B´-Y´)
  - P_r= 0.877 * (R´-Y´)
  - Given RGB in [0,1]
    - $0 < P_b < 0.872$
    - $0 < P_r < 1.236$
  - Overshooting OK
    - Analog signals
    - 75% brightness and 100% saturation yields pure video color



Color Spaces

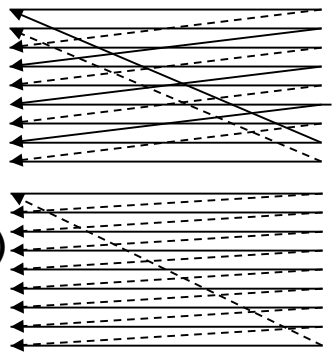
- **$Y'P_bP_r$ (cont.)**
  - R´= Y´ + 1.140 V
  - G´= Y´ - 0.394 U – 0.581 V
  - B´= Y´ + 2.032 U
- **$Y'C_bC_r$**
  - Color space of used in most digital video
    - Recommendation ITU-R BT.601
  - Scaled and offset from $Y'P_bP_r$
  - Assumes full range RGB
    - Different version with range of [16, 235] (headroom)
  - Y´= 0.257 R´ + 0.504 G´ + 0.098 B´ + 0.062
  - C'_b= -0.148 R´ - 0.291 G´ - 0.439 B´ + 0.5
  - C'_r= -0.439 R´ - 0.368 G´ - 0.071 B´ + 0.5

Color Spaces

- **Operations on Video Samples**
  - Careful: We are operating in a non-linear space
    - Gamma
    - But certain operations are still possible
  - Typical operations
    - Changing brightness
    - Changing color saturation
    - Changing hue (rotation of color difference signals)
- **Conversion**
  - Often converted values cannot be represented
  - E.g.: R´G´B´(1,1,1) → YC_bC_r(235, 128, 128) →
  - Add color: YC_bC_r(235, 128, 128) → R´G´B´(0.6, 1.29, 0.56)

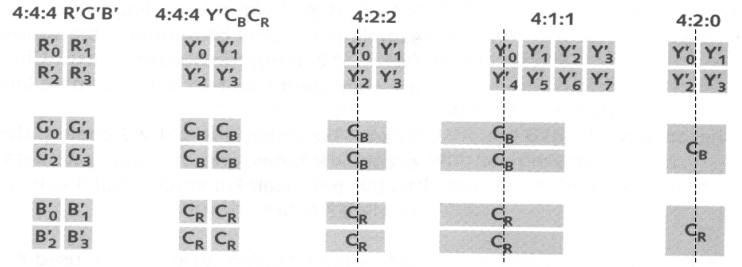
Sampling/Scanning

- **Interlaced Scan (TV)**
  - 1 frame (1/30s) = 2 fields (1/60s)
  - Less data per image refresh
  - Different exposure time per frame
  - Problems: flicker, tearing
- **Progressive Scan (Computer)**
  - No tearing, more flicker
    → higher refresh rates
  - Simpler computations



Sampling/Scanning

- **Subsampling of Color**
  - Humans are less sensitive to changes in color
  - Different sampling rate of color
    - 4:4:4 Equal sampling
    - 4:2:2 Horizontal sub-sampling by 2
    - 4:1:1 Horizontal sub-sampling by 4
    - 4:2:0 Horizontal and vertical sub-sampling by 2



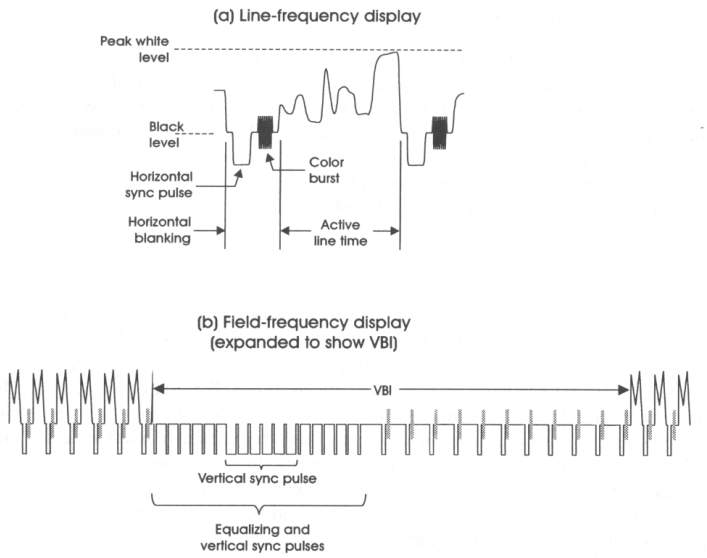
Video Signal

- **Transport of**
  - Serialized image signal
  - Must include horizontal and vertical sync signals
- **Component Signal**
  - Separate wire for each color channel
  - Original Signal
    - R, G, B, HS, VS
  - Original Signal with separate sync
    - R, G, B, S
  - Integrated sync (usually on green)
    - R, G, B
    - Also on VGA or in SCART adapter
  - Same with color difference signals YC_bC_r

Video Signal

- **Composite Signal**
  - Combines color signals (crosstalk, deterioration)
  - Y/C, S-VGA
    - Separate luma and color
  - Composite, FBAS (Farbbild, Austast, Sync.)
    - Basisband
  - TV-Signal
    - Modulated onto carrier signal (channel)
  - Synchronization signal
    - Horizontal
      - Inserted between lines (horizontal retrace of beam)
      - Also contains high frequency “color burst” signal
    - Vertical
      - Inserted between lines (vertical retrace of beam)
      - Also used for equalization of signal

Composite Video Signal

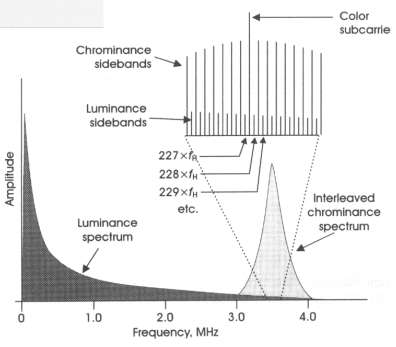


Video Standards

- **NTSC - The Old Standard**
  - **1940/41: FCC forms NTSC (National Television System Committee)**
  - **Field/frame rate: 60/30 Hz (PAL: 50/25)**
  - **Lines: 525 interlaced (7x5x5x3) ⇒ 15.750 kHz**
  - **Interlacing: bandwidth/flicker/resolution**
  - **Synchronization by H/V sync pulses**
  - **Video bandwidth: 4.2 MHz in 6 MHz channels**
  - **Sound: FM @ 4.5 MHz (=2000/7 line rate)**

Video Standards

- **Adding Color to NTSC**
  - **Color encoding added to NTSC in 1953**
  - **Separation of Luma Y' and Color**
  - **Color coded on sub-carrier @ 455/2 line rate**
  - **Line rate adjusted by 1001/1000 (29.97 fps)**
    - Cross talk between color and sound
      - Sound at 286 x line rate (2002/7=286)
    - Drop frame time code
  - **Insufficient separation of luma and color**
    - Dot crawl
    - Hanging dots



Digitized Video

- $4f_{SC}$-Format:
  - Sampling rate 14.318 MHz (= 4x subcarrier freq.)
  - Samples: 910 samples/line, 768 samples/active line
  - Easy reconstruction of color
  - Everything is sampled
  - Perfect copies - used in studio
  - No processing of video possible
  - Different for NTSC, PAL, etc

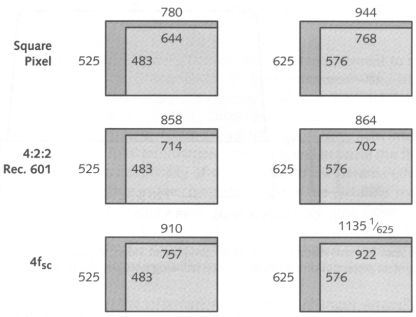
Digitized Video

- ITU-R 601-4 (601)
  - Often called SDI (Serial Digital Video, only for transm.)
  - Sampling frequency: 13.5 MHz
  - Common multiple of NTSC/PAL line rate (6x 2.5 MHz)
  - Samples:
    - NTSC: 864 s/l 720 or 704 s/al 525 l
    - PAL: 858 s/l 720 or 704 s/al 625 l
  - YC_bC_r color space, 4:2:2 sub-sampling
  - 10bit standard (with an 8bit mode)
  - Synchronization with special digital codes
  - Ancillary data in H/V blanking intervals

Digital Video

- **Computer Resolution**
  - VGA 640x480
  - SVGA 800x600
  - XGA 1024x768
  - SXGA 1280x1024
  - UXGA 1600x1280
- **Resolution (ADTV)**
  - SDTV
    - 640x480 (60p, 60i, 30p, 24p)
    - 704x480 (60p, 60i, 30p, 24p)
  - HDTV
    - 1280x720 (60p, 30p, 24p)
    - 1920x1080 (60i, 30p, 24p)

(p: progressive, i: interlaced)



Digitized Analog Video (inner numbers specify active samples corresponding to active area)

Note: Horizontal sampling is arbitrary

Literature

- **Books**
  - Charles Poynton, *A Technical Introduction to Digital Video*, Wiley, 1996
  - Arch Luther, *Principles of Digital Audio and Video*, Artech House, 1997
  - Arch Luther, *Video Camera Technology, Artech House*, 1998
  - Albert Abramson, *The History of Television -- 1880 to 1941*, Mc Farland, 1987