Lecture 13
6.111 Flat Panel Display Devices

Outline

- **Overview Flat Panel Display Devices**
  - How do Displays Work?
  - Emissive Displays
  - Light Valve Displays
- **Display Drivers**
  - Addressing Schemes
  - Display Timing Generator
  - Gray Scale / Color Schemes

Applications of Flat-Panel Displays

SMALL FORMAT

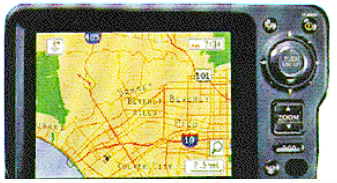
Medical Defibrillator

Courtesy Apple

iPhone

Courtesy Palm

Personal Digital Assistant



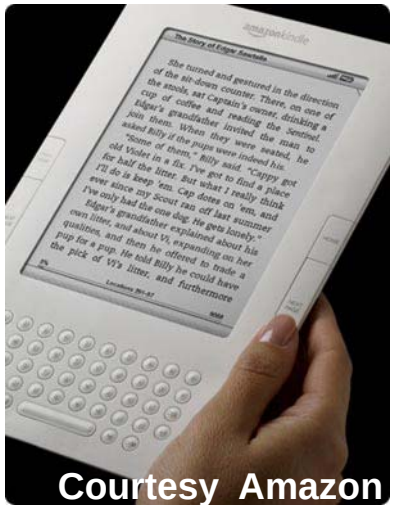
Car Navigation & Entertainment

LARGE FORMAT

Courtesy of PixTech

Courtesy Apple

Desktop Monitor (color)



Courtesy Amazon

Electronic Book

Large Screen Television (color)

Some Display Terminologies

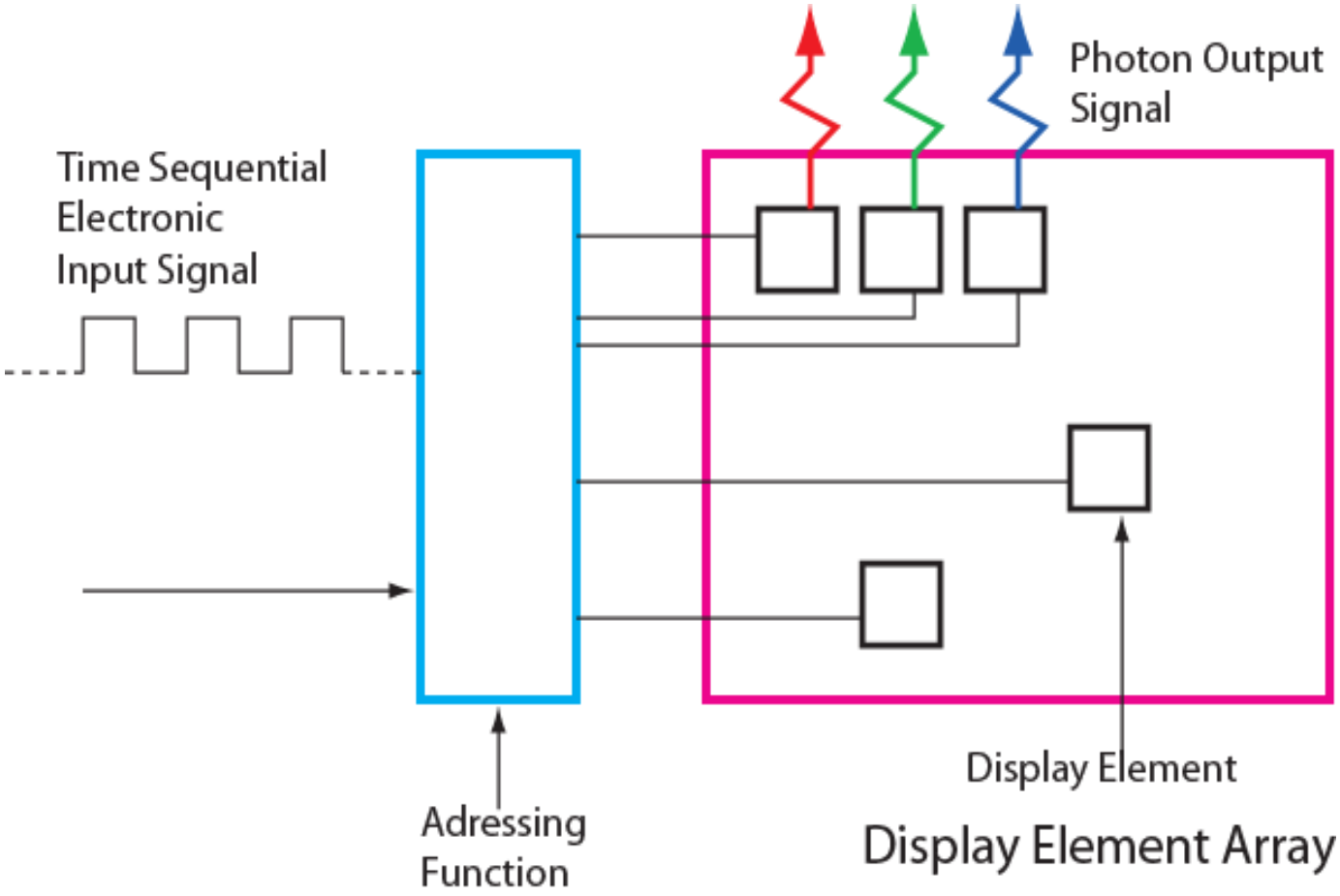
Term	Definition
Pixel	Picture element—The smallest unit that can be addressed to give color and intensity
Pixel Matrix	Number of Rows by the Number of Columns of pixels that make up the deisplay
Aspect Ratio	Ratio of display width to display height; for example 4:3, 16:9
Resolution (ppi)	Number of pixels per unit length (ppi=pixels per inch)
Frame Rate (Hz)	Number of Frames displayed per second
Viewing Angle (°)	Angular range over which images from the display could be viewed without distortion
Diagonal Size	Length of display diagonal
Contrast Ratio	Ratio of the highest luminance (brightest) to the lowest luminance (darkest)

Information Capacity of Displays
(Pixel Count)

Resolution	Pixel	Ratio
Video Graphic Array (**VGA**)	640 x 480 x RGB	4:3
Super Vedio Graphic Array (**SVGA**)	800 x 600 x RGB	4:3
eXtended Graphic Array (**XGA**)	1,024 x 768 x RGB	4:3
Super eXtended Graphic Array (**SXGA**)	1,280 x 1,024 RGB	5:4
Super eXtended Graphic Array plus (**SXGA+**)	1,400 x 1,080 x RGB	4:3
Ultra eXtended Graphic Array (**UXGA**)	1,600 x 1,200 x RGB	4:3
Quad eXtended Graphics Array (**QXGA**)	2048 x 1536 x RGB	4:3
Quad Super eXtended Graphics Array (**QSXGA**)	2560 x 2048 x RGB	4:3

Display Devices, No. 21, Spring 2000, p. 41

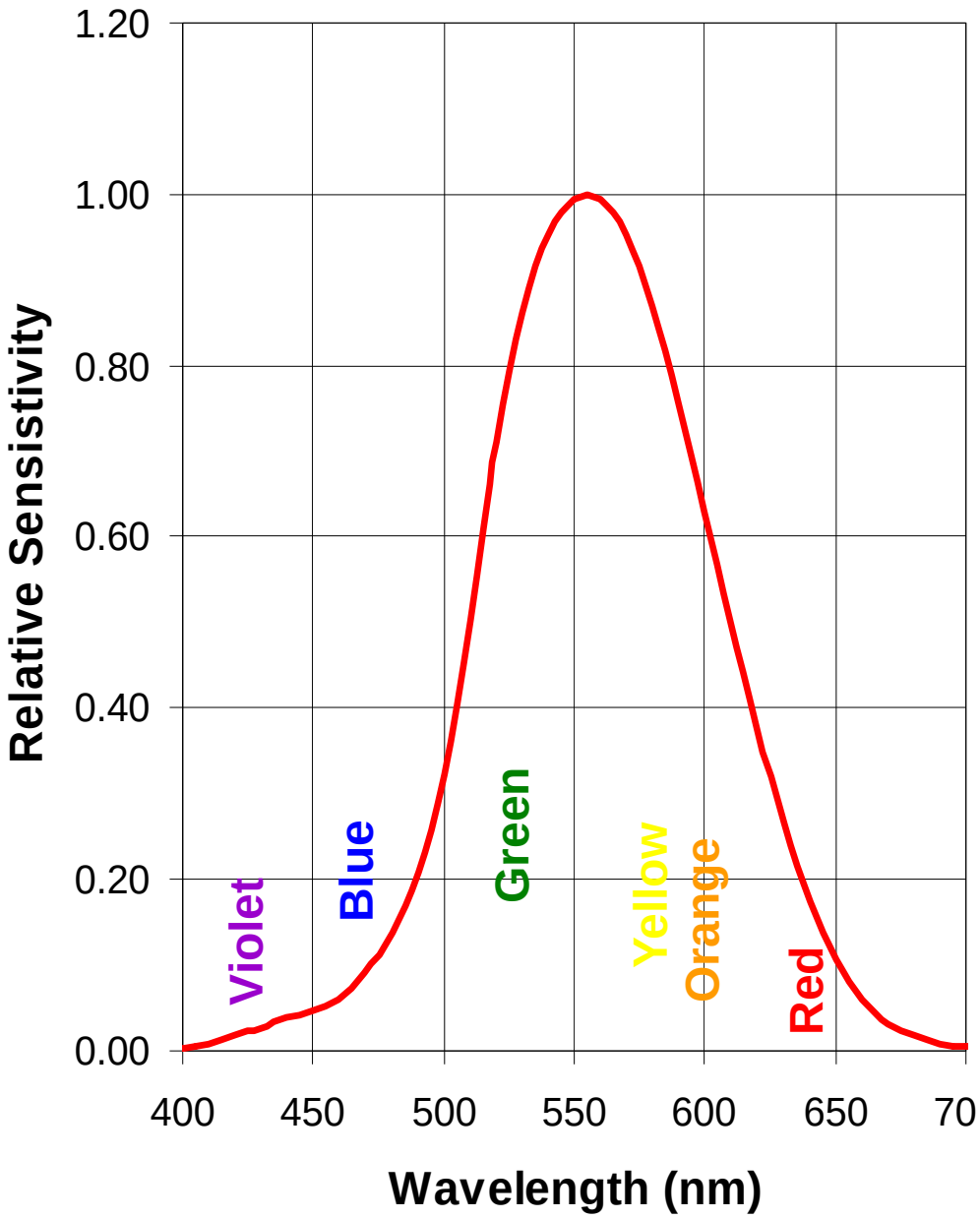
How Do Displays Work?



Pankove

- "Time Sequential Electrical Signals" converted into images.
  - Signals routed to the display elements (similar to memory addressing)
  - Pixels convert the electrical signal into light of color and intensity (inverse of image capture)

Human Eye— Spectral Response



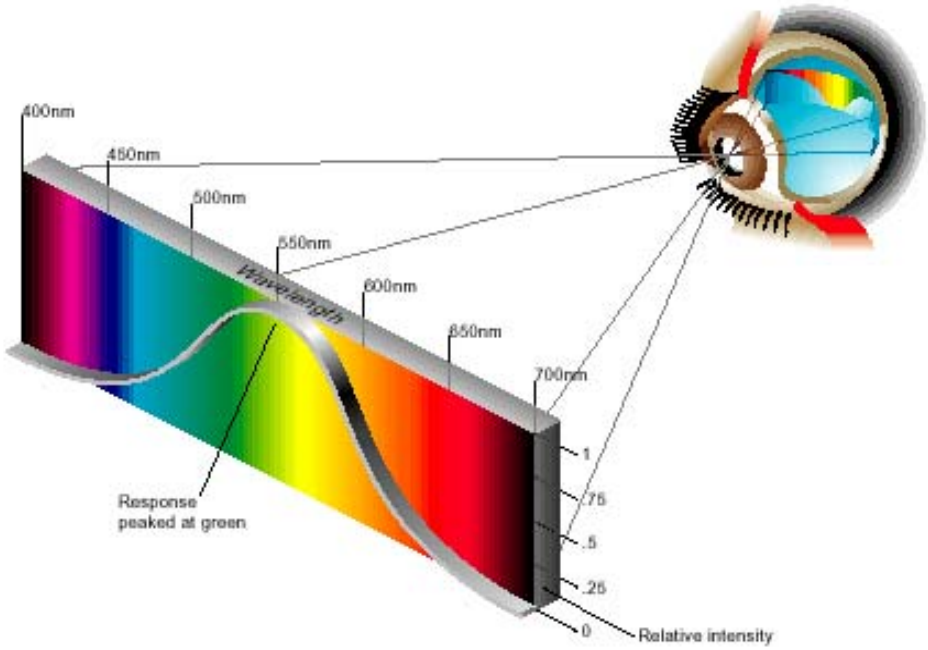


Figure 15. CIE Photopic Curve (Spectral Sensitivity of the Human Eye).

Classifications of Displays by Technology

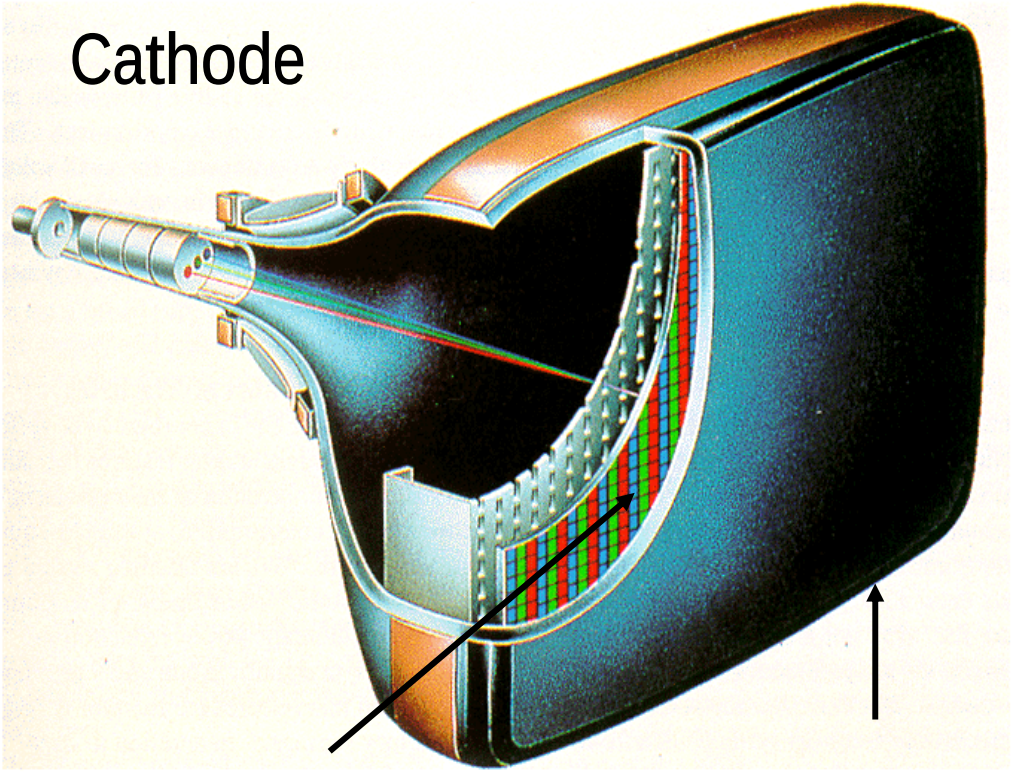
- Displays could be classified into two broad categories
  - Light Generation (Emissive Displays)
  - Light Modulation (Light Valve Displays)

- Emissive Displays generate photons from electrical excitation of the picture element (pixels)
  - Cathode Ray Tubes (CRTs), Organic Light Emitting Displays (OLEDs), Plasma Displays (PDs)

- Light Valve Displays spatially and temporally modulate the intensity pattern of the picture elements (pixels)
  - Liquid Crystal Displays (LCDs), Digital Light Processors (DLPs), Electrophoretic Displays (EPDs)

Cathode Ray Tube

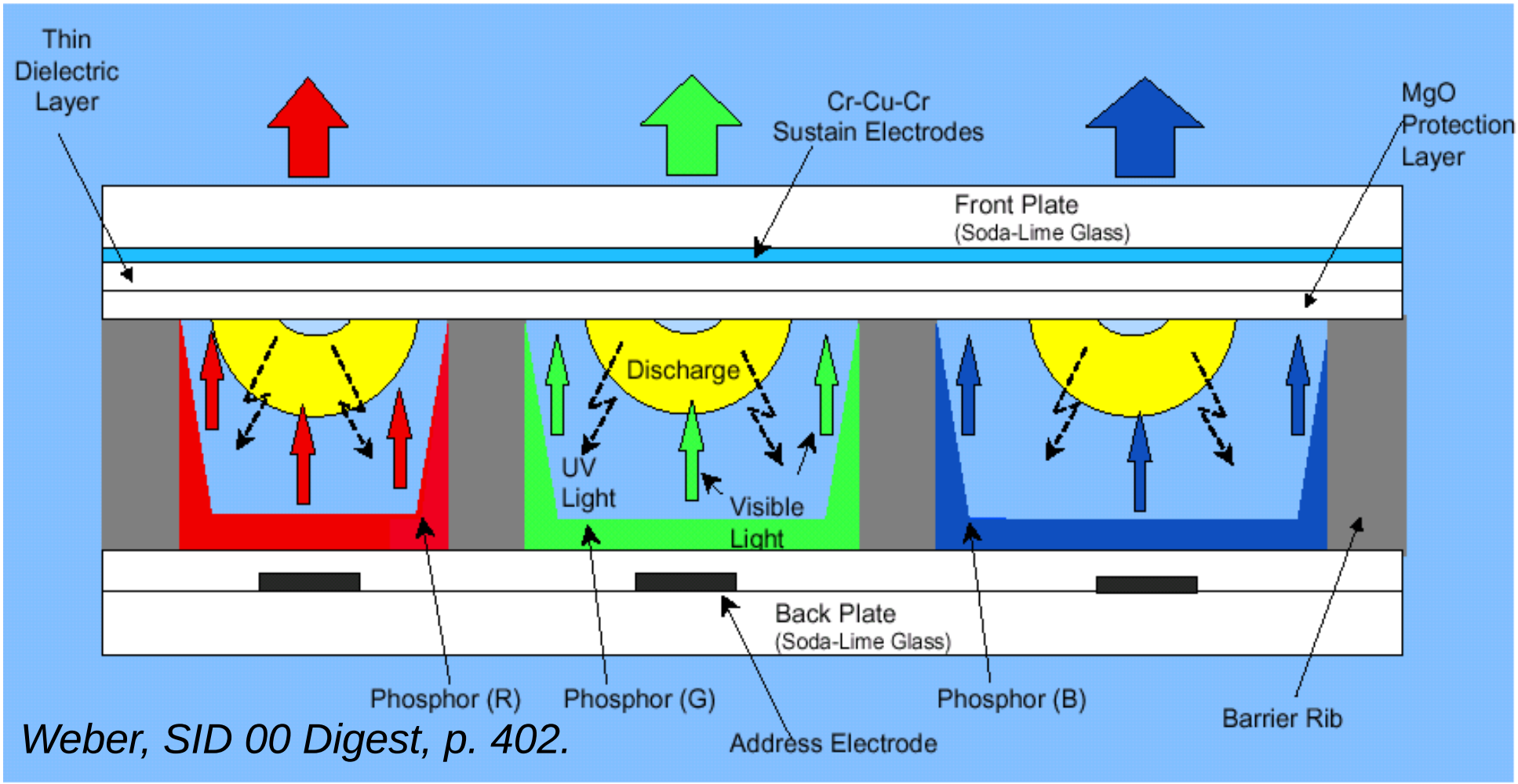
CRT Display



Courtesy of PixTech

Electrons beam “boiled off a metal” by heat (**thermionic emission**) is sequentially scanned across a phosphor screen by magnetic deflection. The electrons are accelerated to the screen acquiring energy and generate light on reaching the screen (**cathodoluminescence**)

Plasma Displays



Weber, SID 00 Digest, p. 402.

- Electrons are accelerated by voltage and collide with gasses resulting in ionization and energy transfer
- Excited ions or radicals relax to give UV photons
- UV photons cause hole-electron generation in phosphor and visible light emission (**photoluminescence**)

Organic Light Emitting Diode

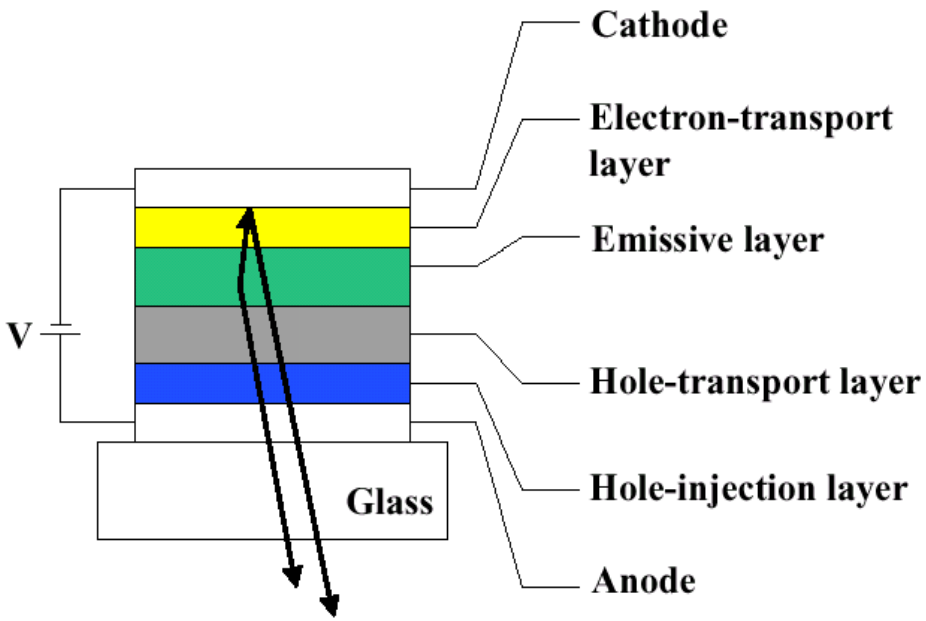


Figure 1. A typical OLED multilayer device structure

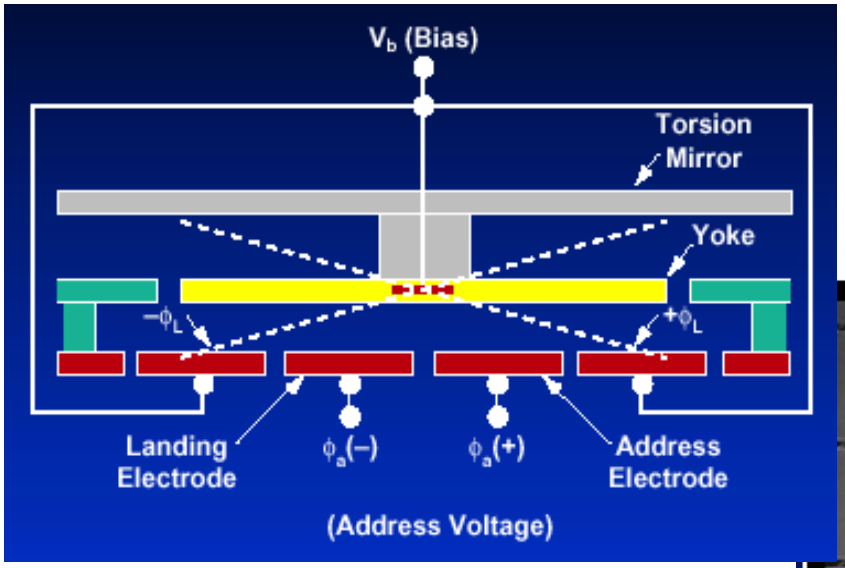
Rajeswaran et al., SID 00 Digest, p. 974

17-inch Active Matrix OLED

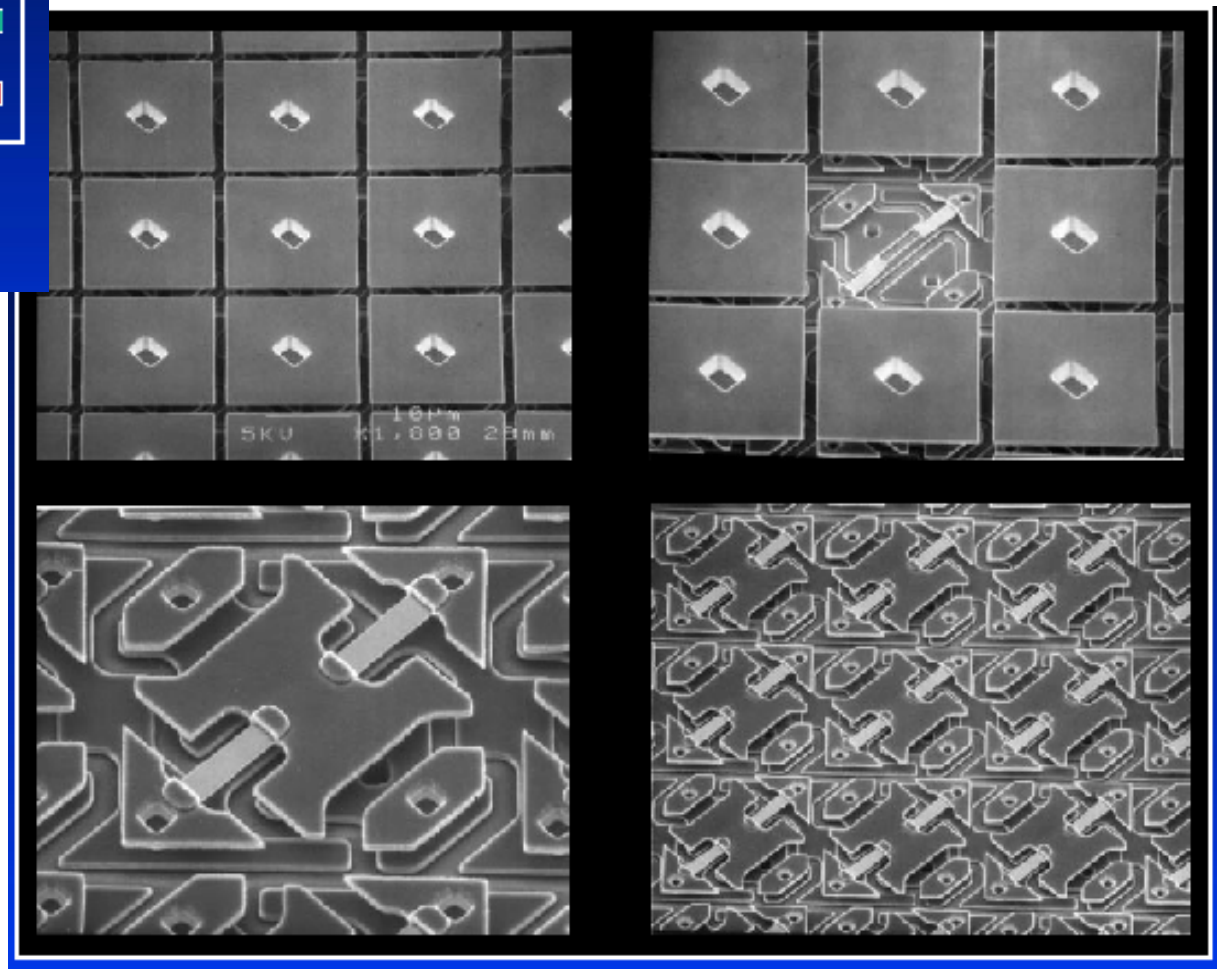
H.-K. Chung et al., SID 05 Digest, p. 956

electroluminescence

Digital Mirror Device



Courtesy of Texas Instruments

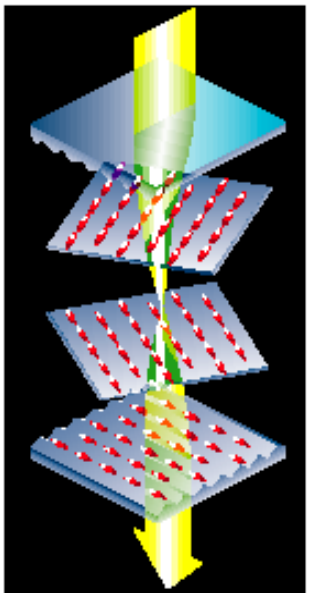


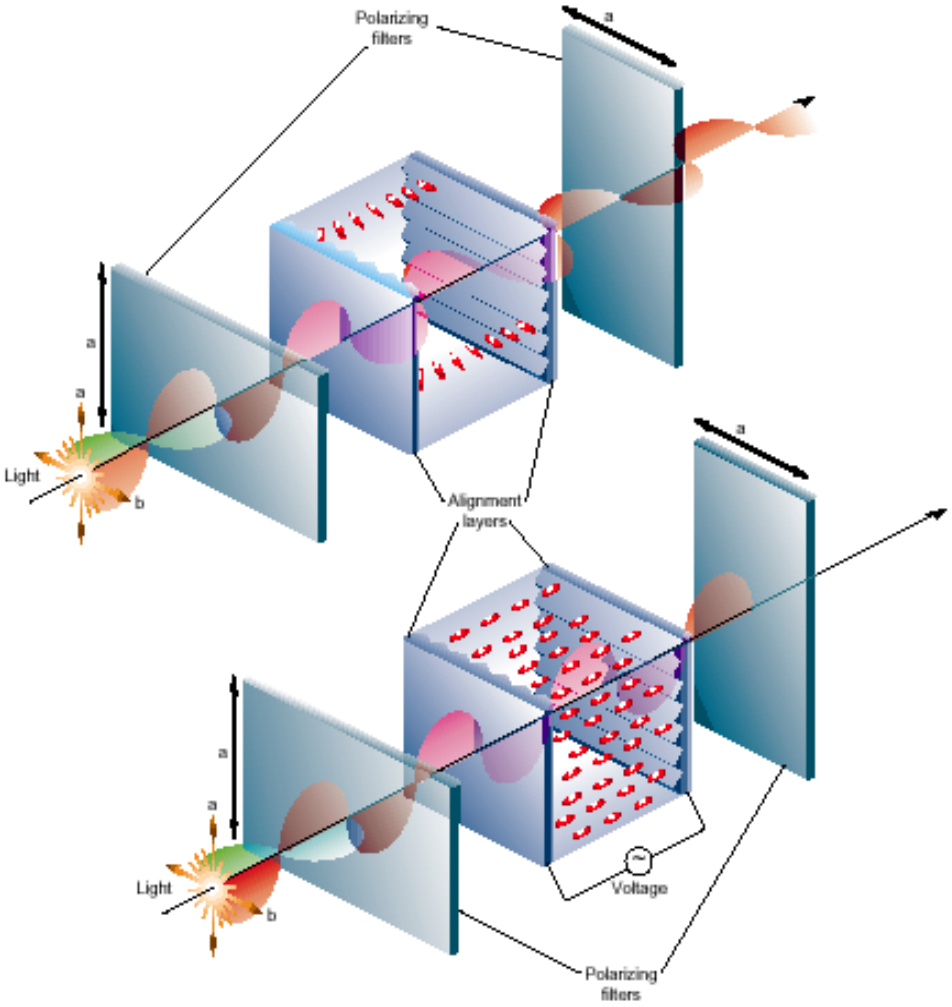
Applied voltage deflects Mirror and hence direct light

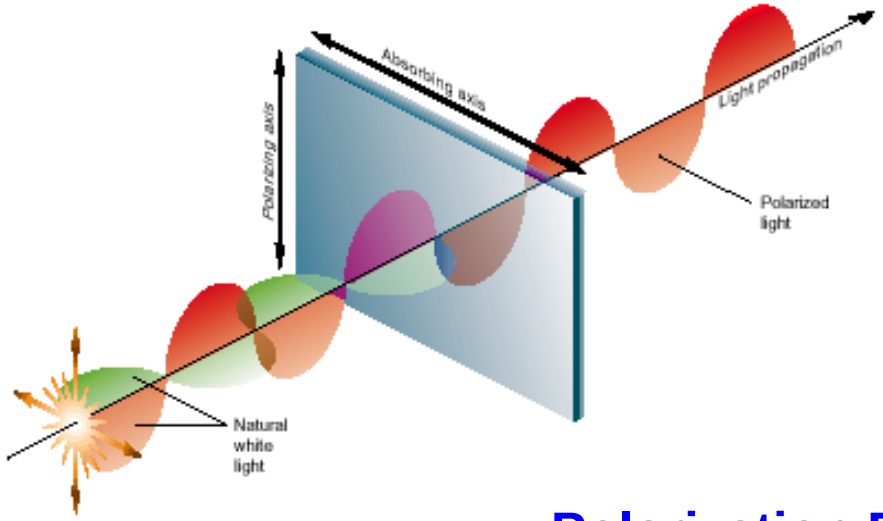
Reflective Light Valves

Liquid Crystal Displays

Liquid Crystals rotate the plane of polarization of light when a voltage is applied across the cell



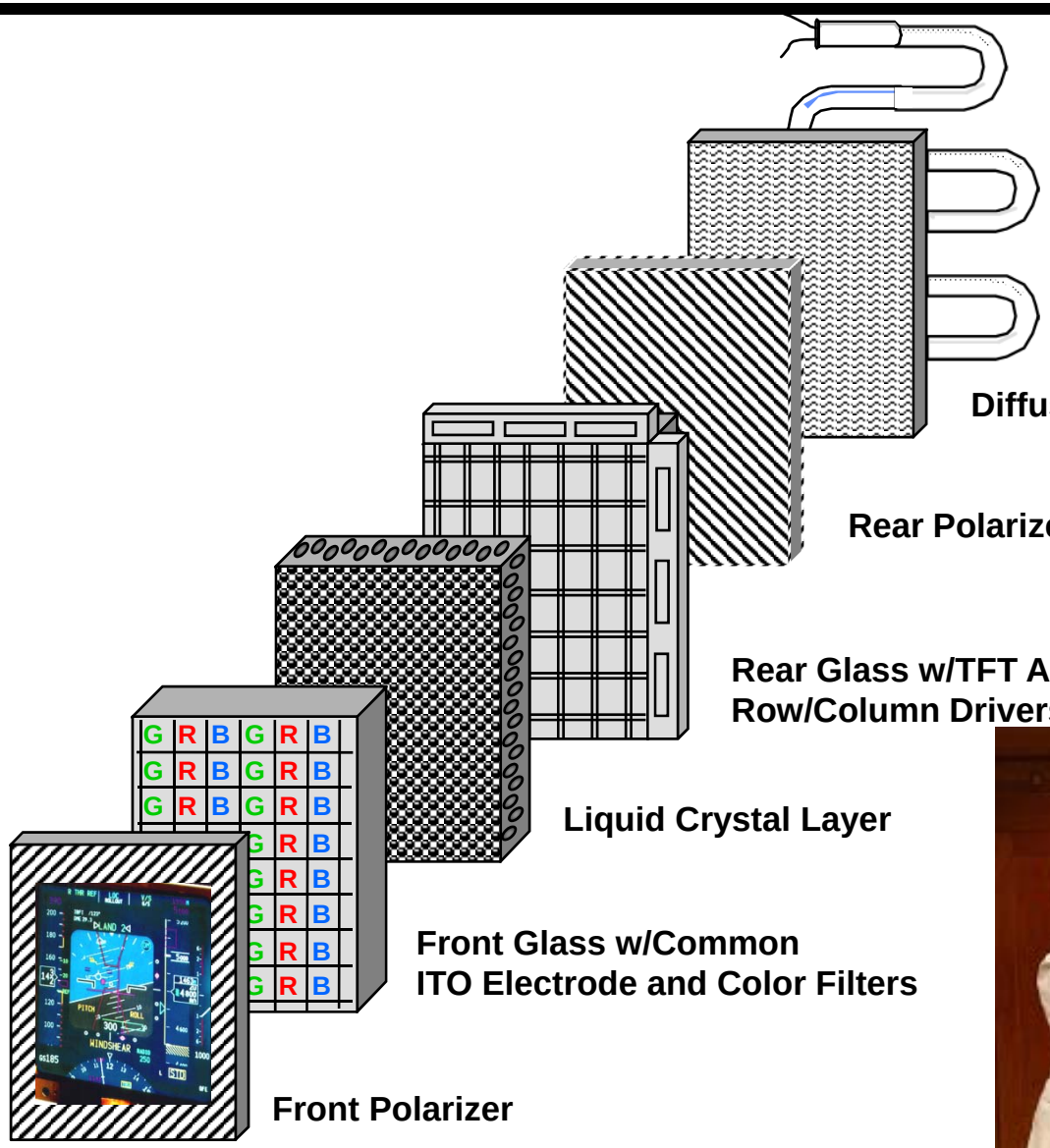




Polarization Rotator

Courtesy of Silicon Graphics

TFT AMLCD



82” TFT AMLCD

K. Sarma

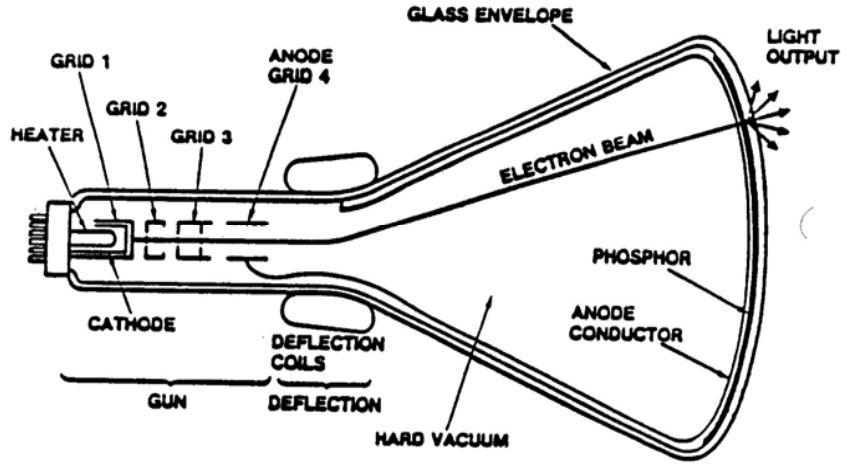
SID 05

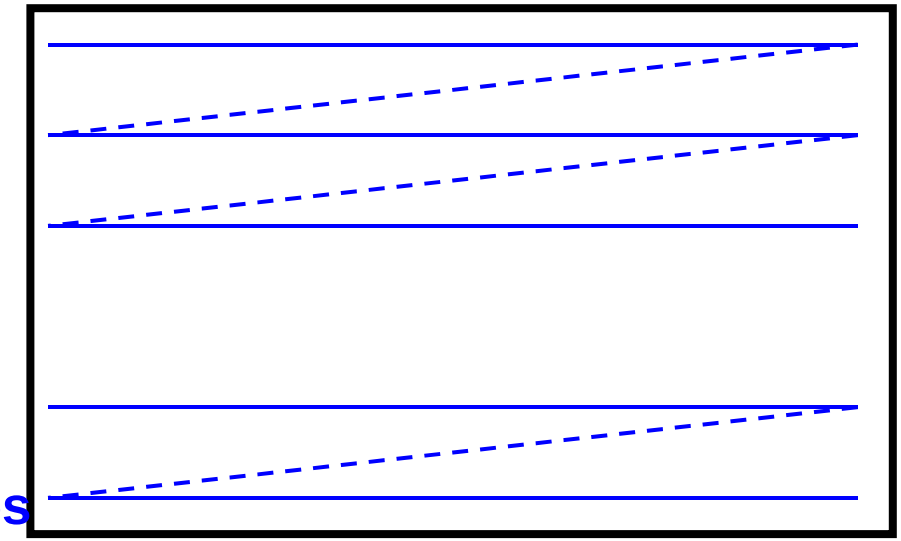
Standard Display Addressing Modes

- **Sequential Addressing (pixel at a time)**
  - CRT, Laser Projection Display
- **Matrix Addressing (line at a time)**
  - Row scanning, PM LCD, AMLCD, FED, PDPs, OLEDs
- **Direct Addressing**
  - 7-segment LCD
- **Random Addressing**
  - Stroke-mode CRT

Sequential Addressing (Raster Scan)

- Time is multiplexed
  - Signal exists in a time cell
- A pixel is displayed at a time
  - Single data line
- Rigid time sequence and relative spatial location of signal
  - Raster scan
- Data rate scales with number of pixels
- Duty cycle scales with number of pixels
- Horizontal sync coordinates lines
- Vertical sync coordinates frames
- Blanking signals (vertical & horizontal) so that retraces are invisible





Scan Lines

Retrace Lines

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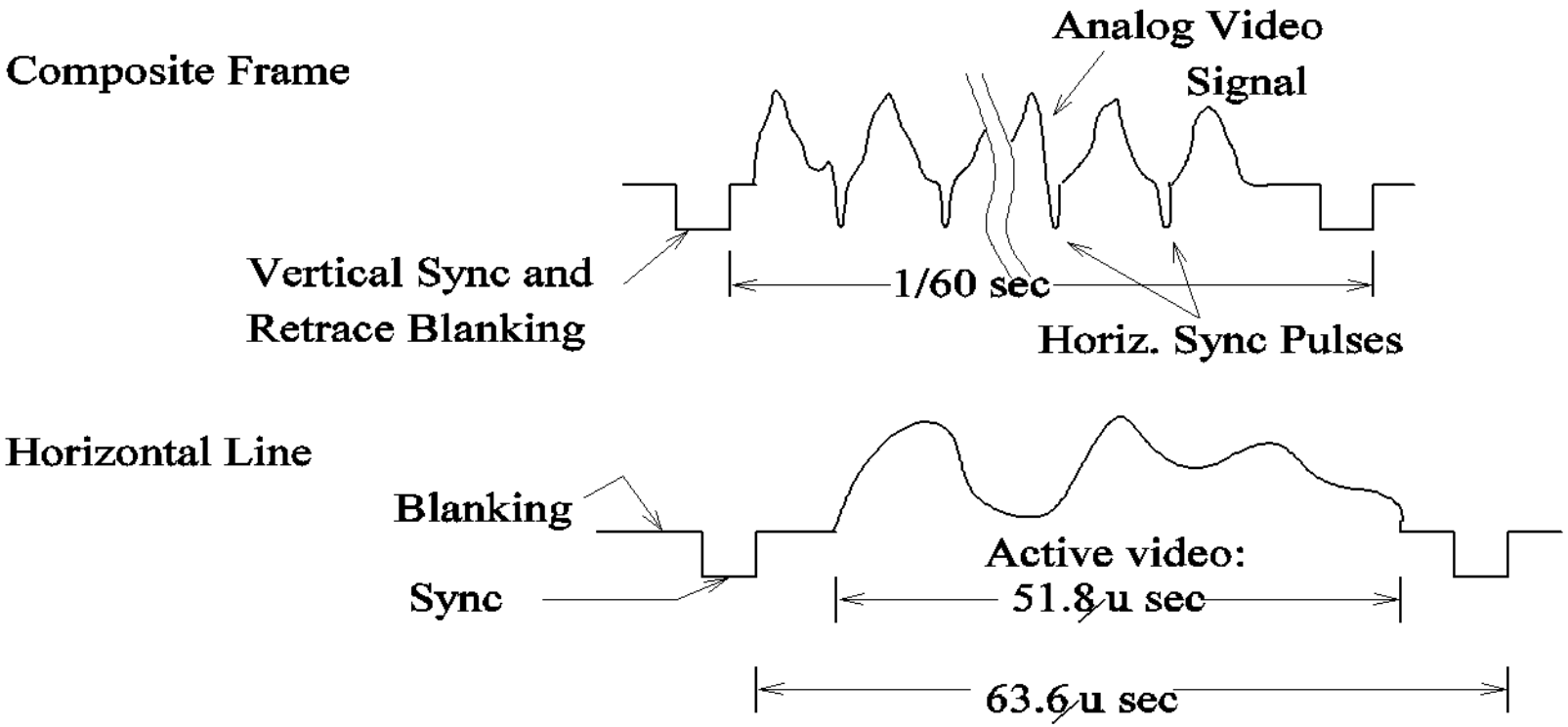
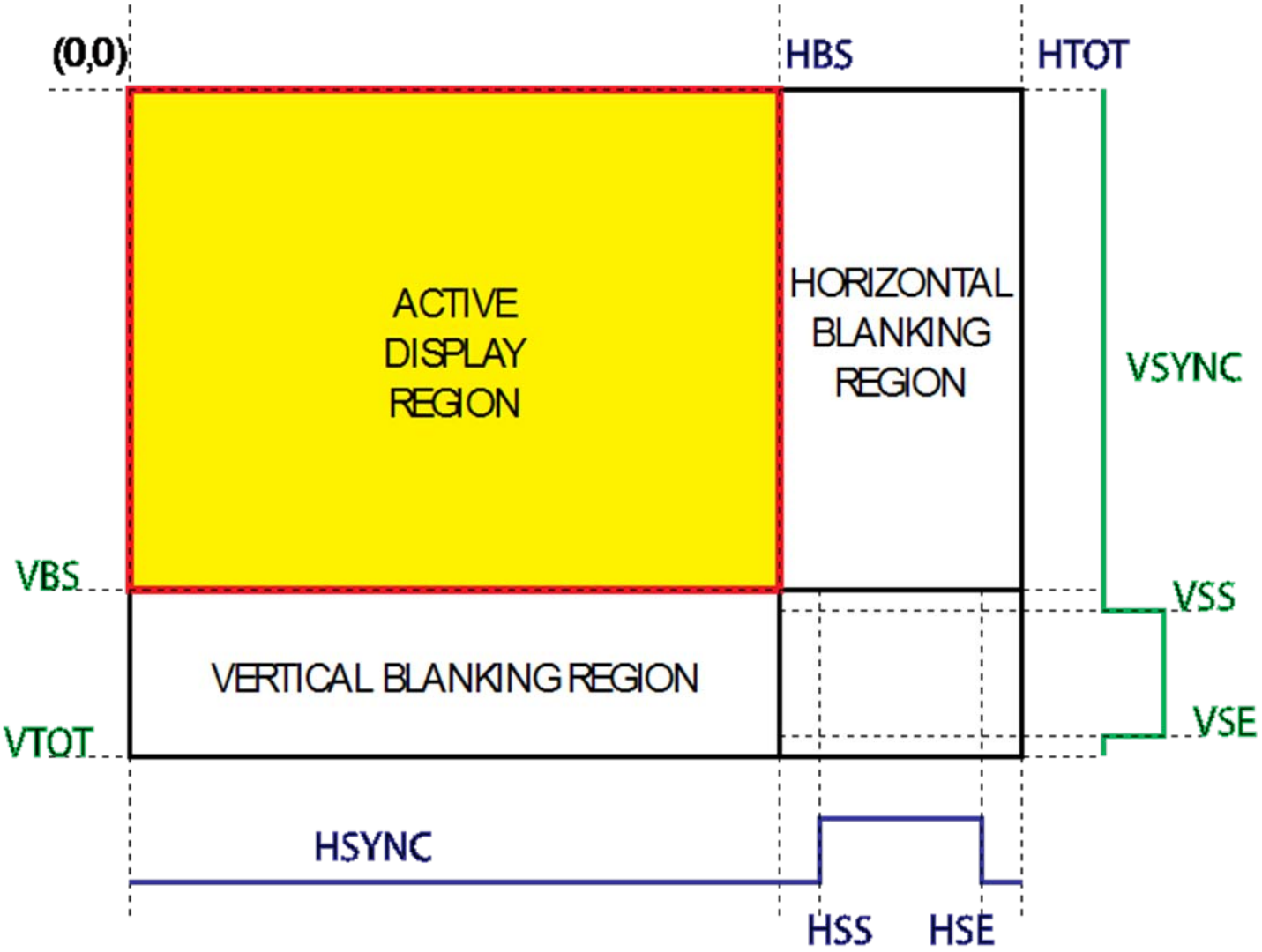
Composite Frames

- The 'frame' is a single picture (snapshot).
  - It is made up of many lines.
  - Each frame has a synchronizing pulse (vertical sync).
  - Each line has a synchronizing pulse (horizontal sync).
  - Brightness is represented by a positive voltage.
  - Horizontal and Vertical intervals both have blanking so that retraces are not seen (invisible).



Slide by Professor Don Troxel

Display Timing Generator Parameters

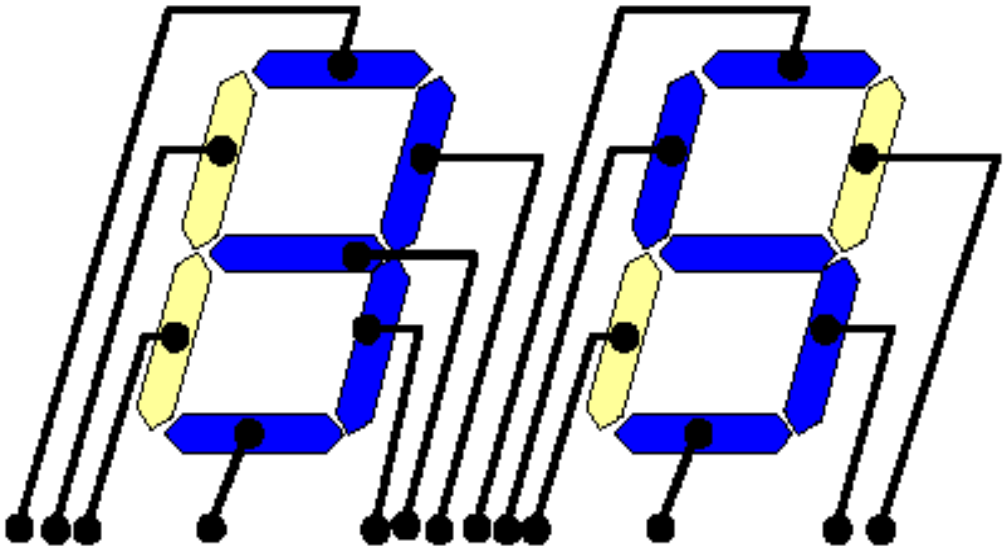


HTOT = Horizontal Total
HBS = Horizontal Blanking Start
HSS = Horizontal Sync Start
HSE = Horizontal Sync End

VTOT = Vertical Total
VBS = Vertical Blanking Start
VSS = Vertical Sync Start
VSE = Vertical Sync End

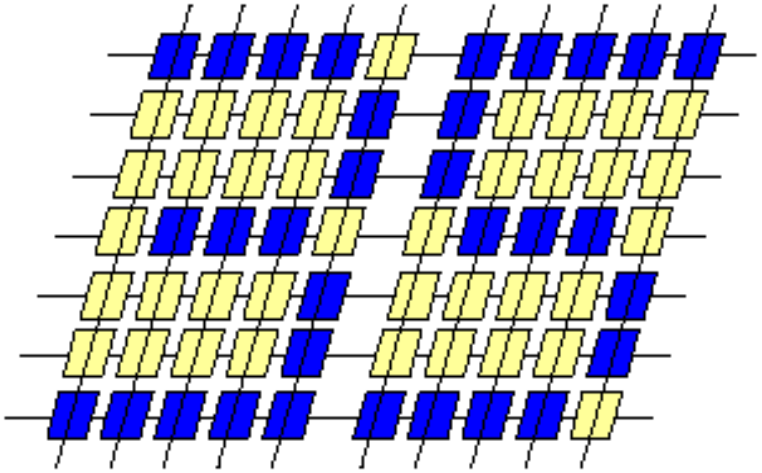
Direct vs. Matrix Addressing

Direct Driving



Segment Display
(7-segment)

Multiplex Driving

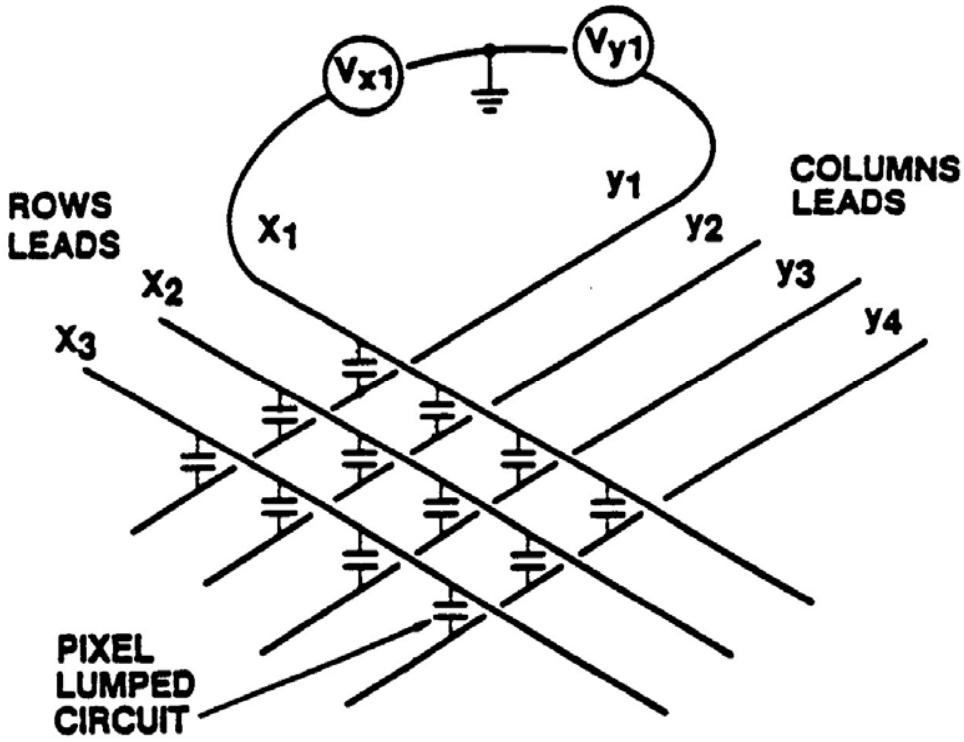


Matrix Display
(dot-matrix)

Kim, SID 2001

Matrix Addressing

- Time multiplexed
- Row at a time scanning
  - A column displayed during the time assigned to a row
- For a N rows by M columns display
  - M + N electrodes are required
- Row scanning rate scales with number of rows
- Data rate scales with number of pixels
- Duty cycle scales with number of rows



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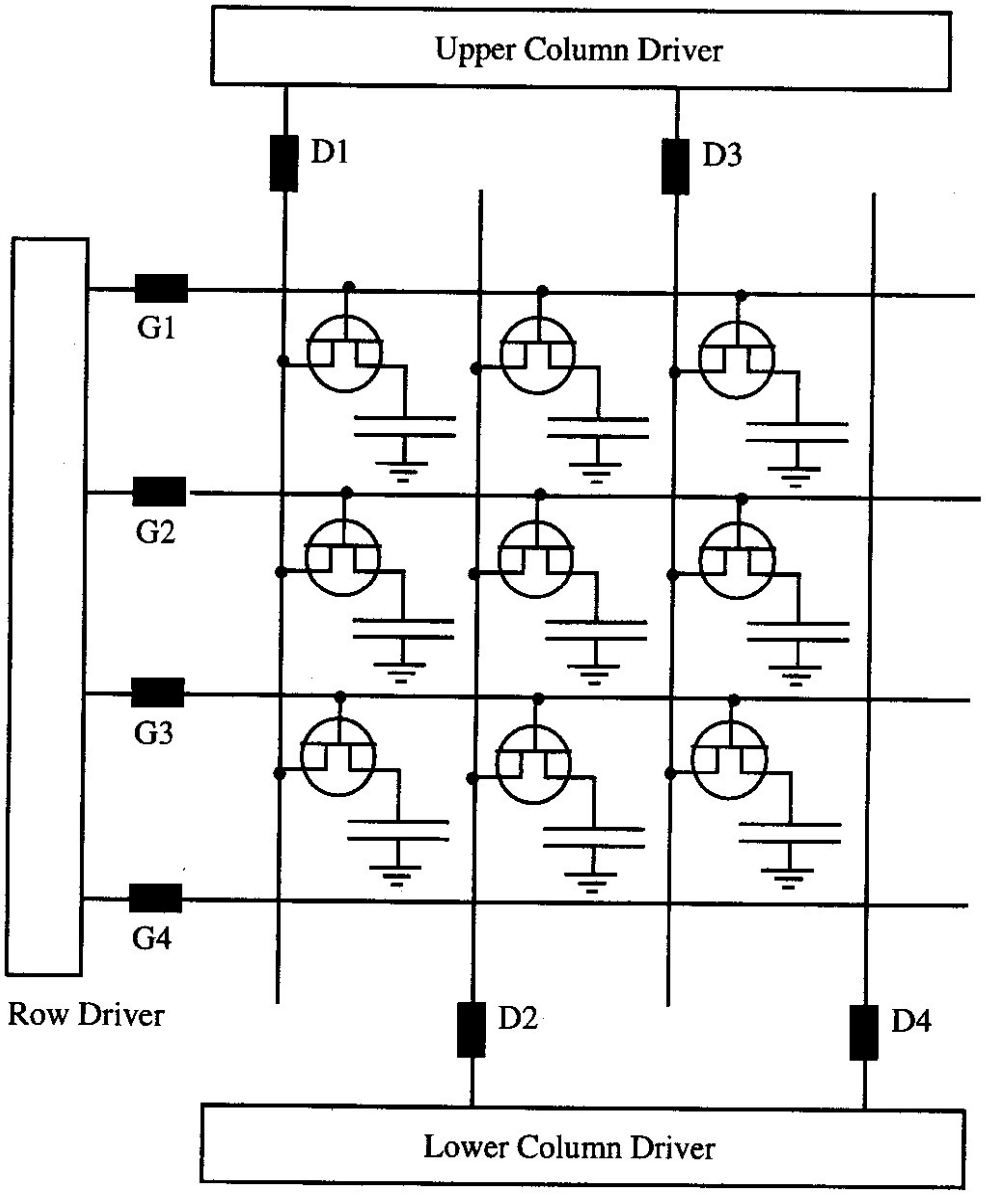
Active Matrix Addressing

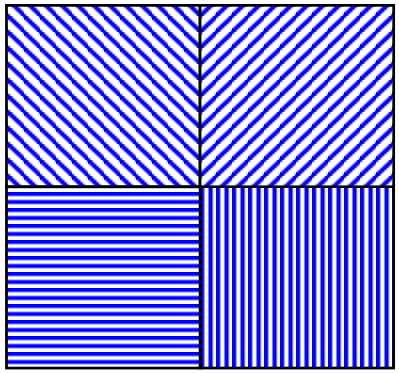


- Introduce non linear device that improves the selection.
- Storage of data values on capacitor so that pixel duty cycle is 100%
- Improve brightness of display by a factor of N (# of rows) over passive matrix drive
- Display element could be LC, EL, OLED, FED etc

Yeh & Gu

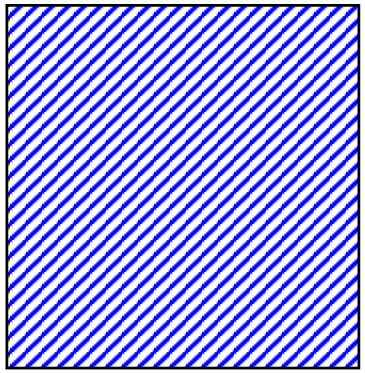
Grey Shades Generation Techniques

Spatial Modulation



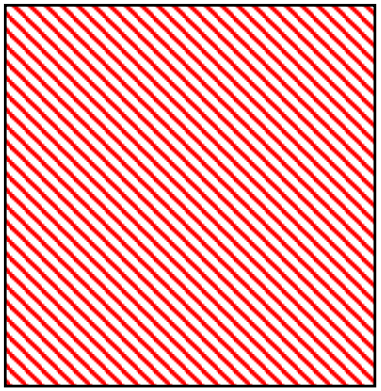
Individually selectable Areas per pixel area per dwell time

Frame Modulation



Reduced intensity by skipping frames per pixel area

Amplitude Modulation

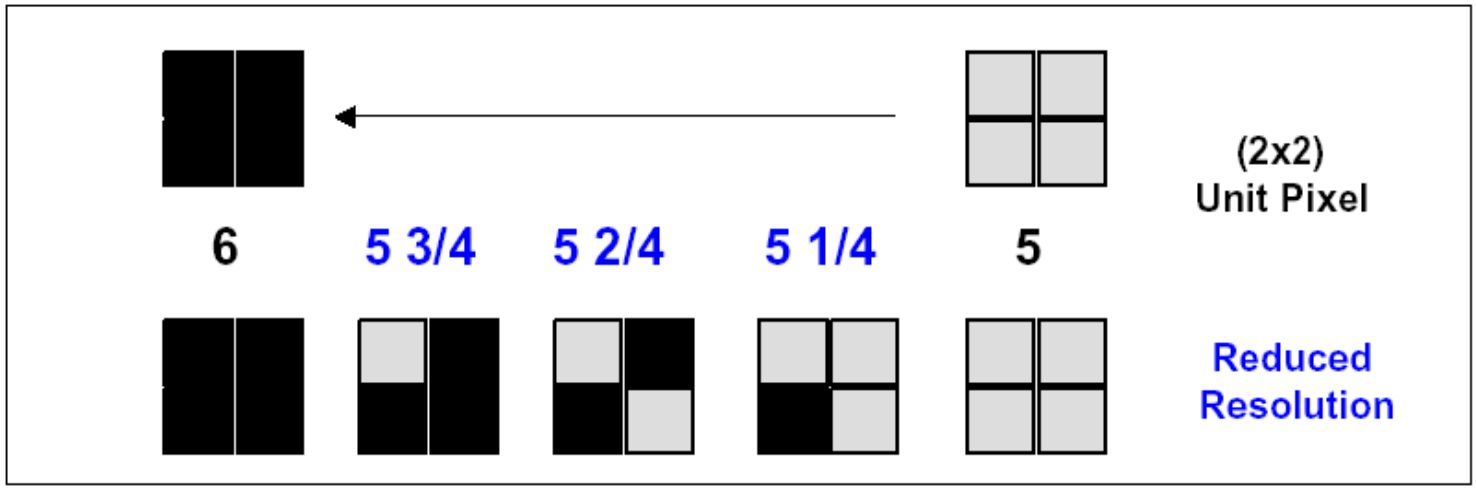


Analog intensity at full dwell time per pixel

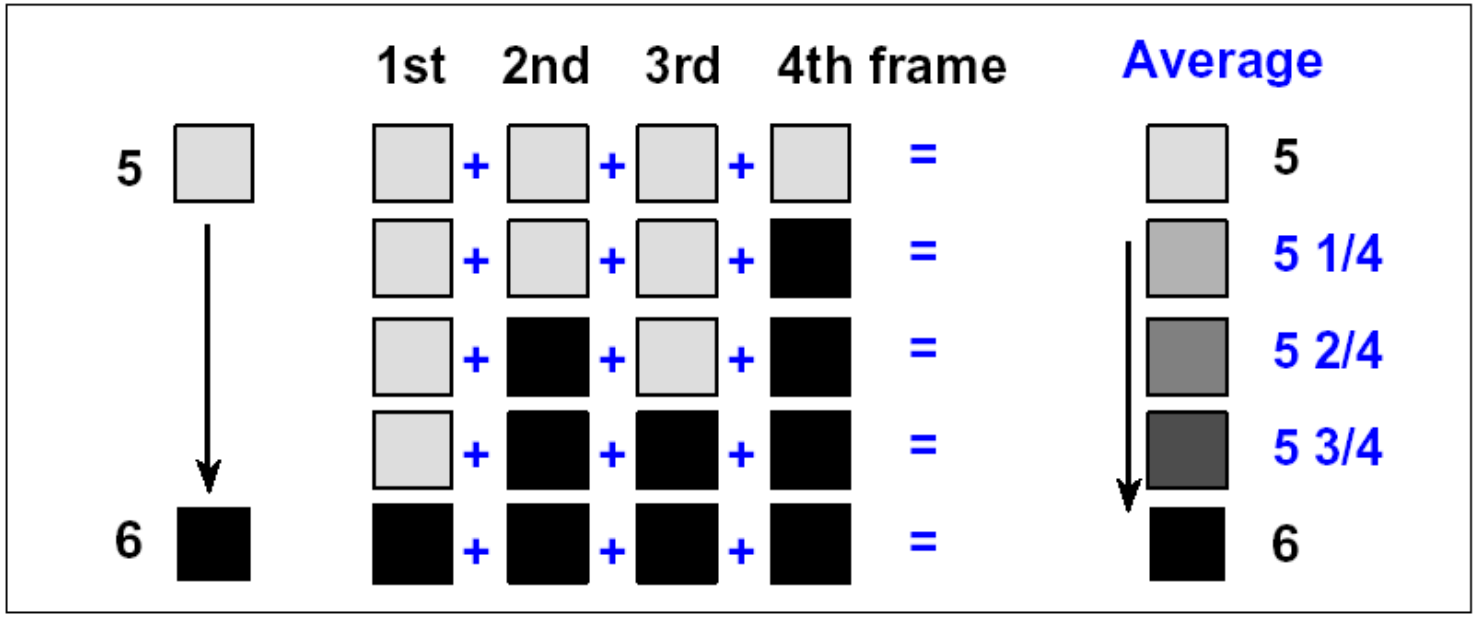
Grey Scale Generation

(Spatial Modulation / Frame Rate Control)

Dithering



Frame Rate Control (FRC)



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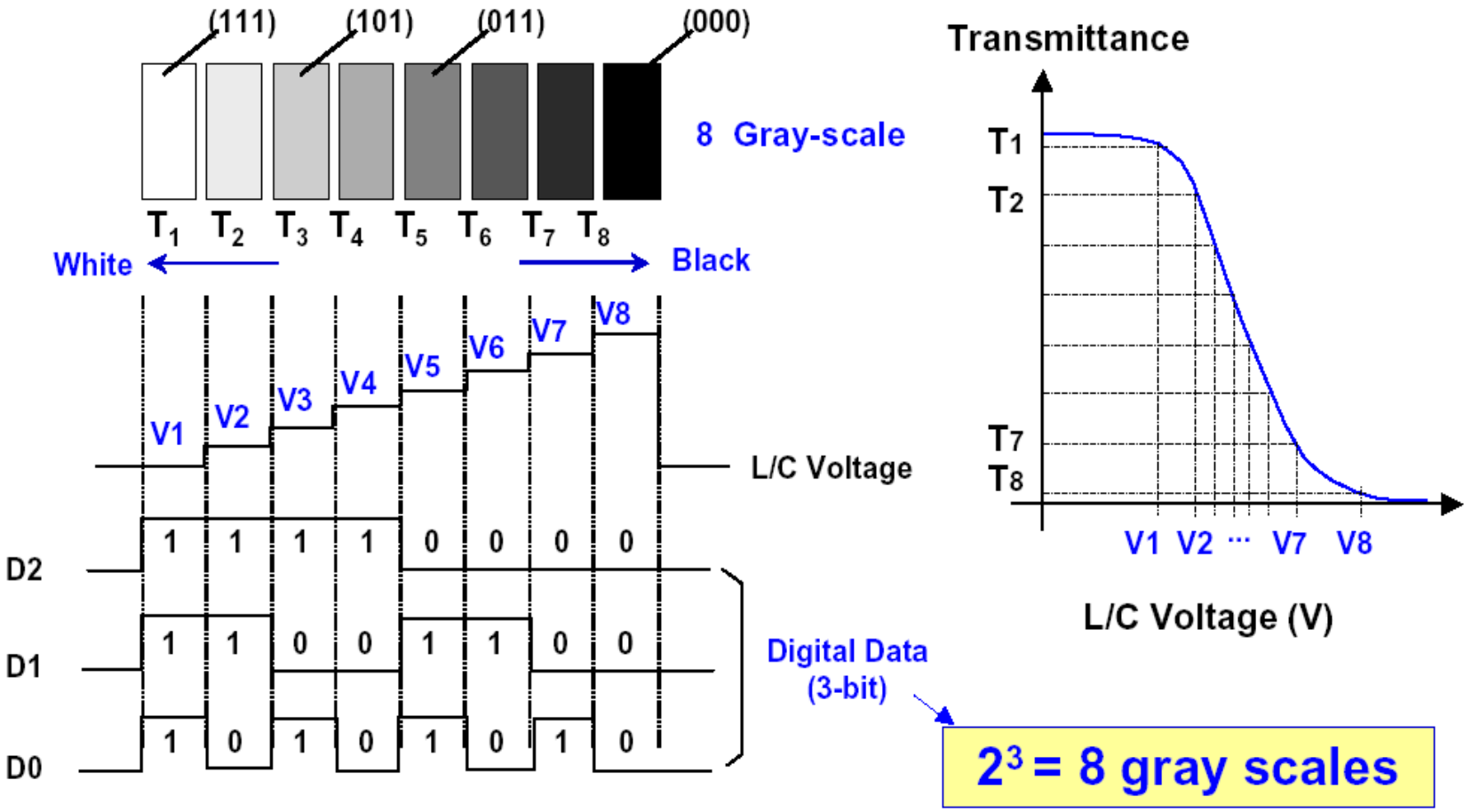
Grey Scale Generation
(Amplitude Modulation)



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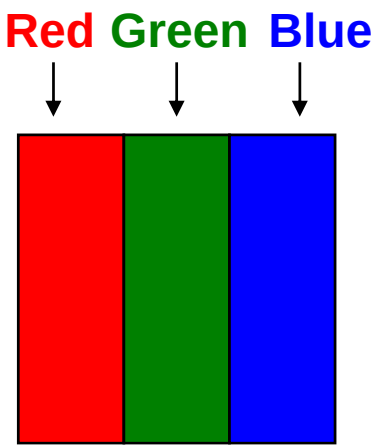
Color Generation Techniques

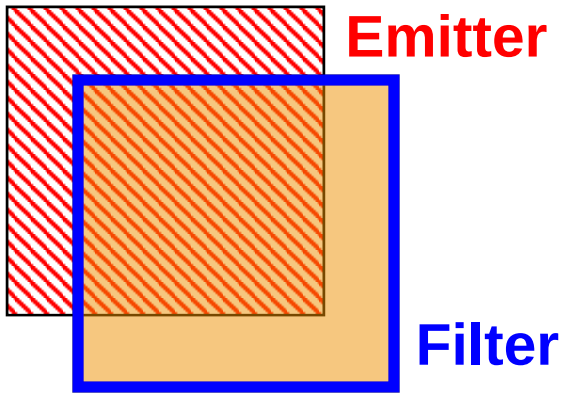
Spatial Color



Three selectable color areas per pixel area per dwell time at three times intensity

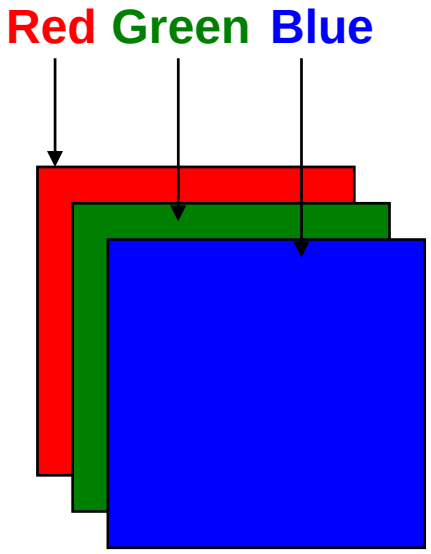
Sequential Color

One broadband emitter per pixel area addressed three times per dwell time at three times the intensity.



Electronic filter changed three times per dwell time.

Coincident Color

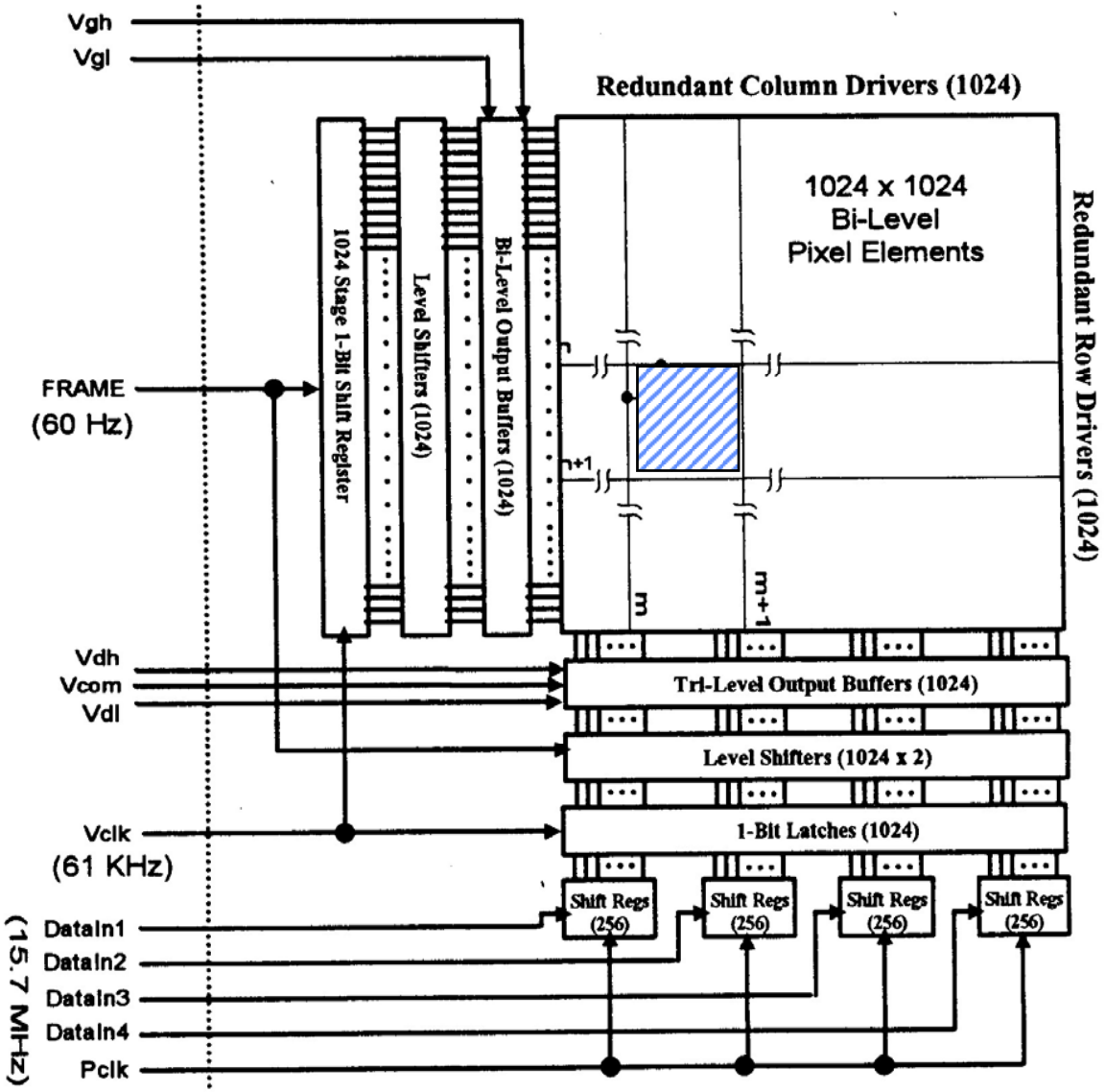


Three selectable transparent color areas per pixel area per dwell time at one times intensity

- Dwell time is allotted for each pixel operation
- Pixel area is total area allotted for spatial information

Driver Circuits

Row Driver Circuits

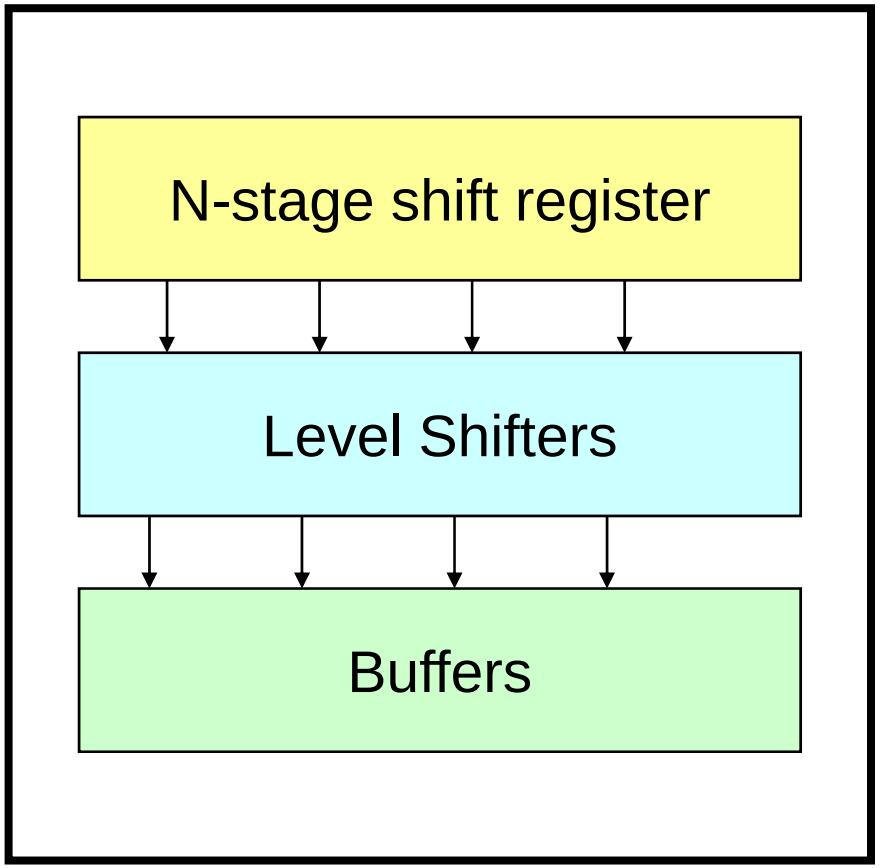


Display Pixel Array

Column Driver Circuits

Row Driver Circuits

- **Shift Registers**
  - N stage shift registers
  - Static vs Dynamic
- **Level shifters**
  - Match outside signal to signal on display
- **Output buffers**
  - Typically bi-level



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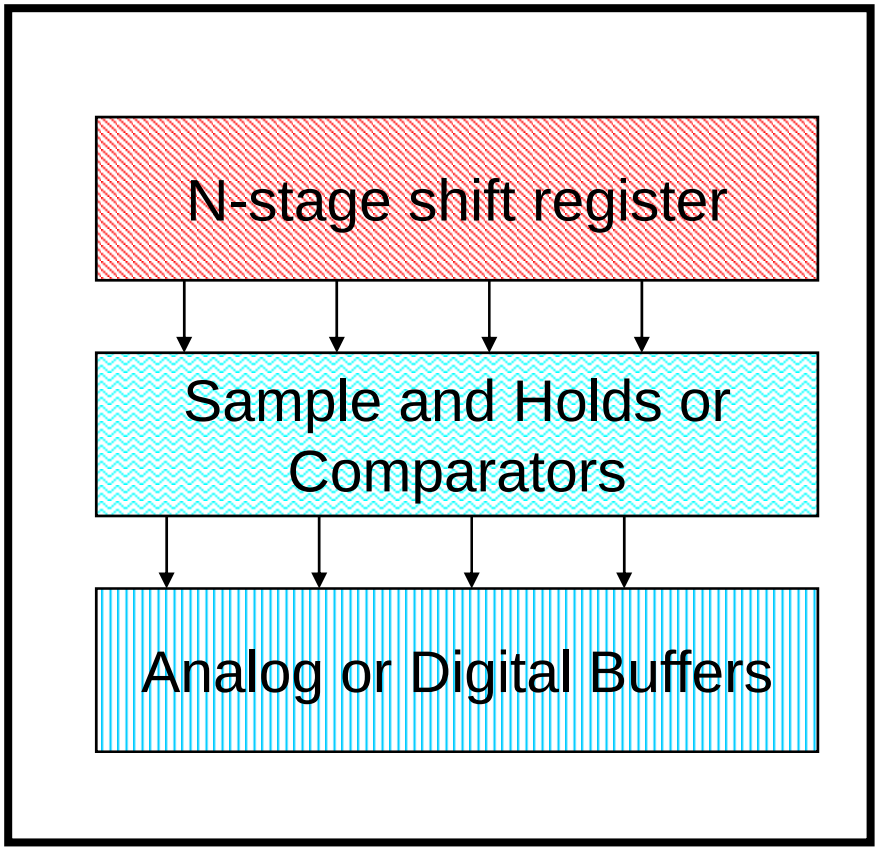
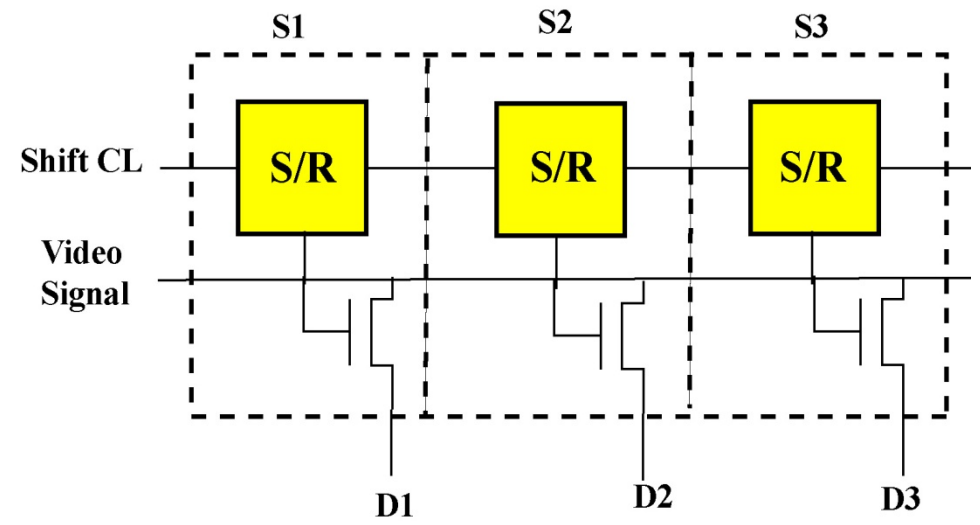


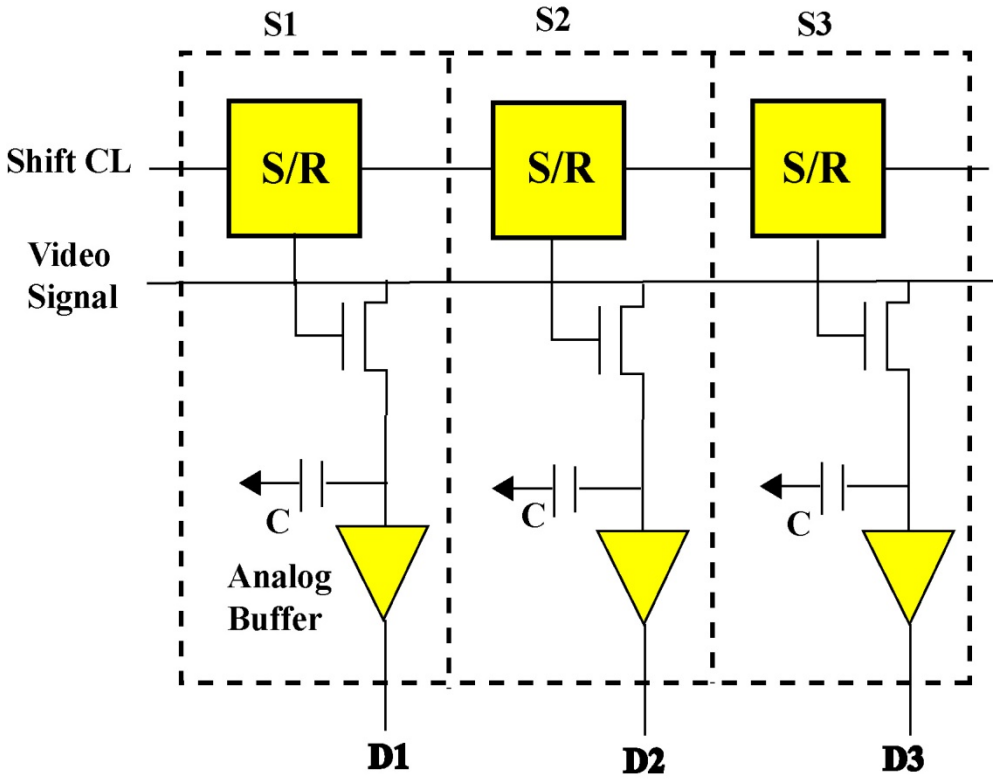
Analog Data Driver

Point at a time



Shift Registers

Line at a time



Shift Registers

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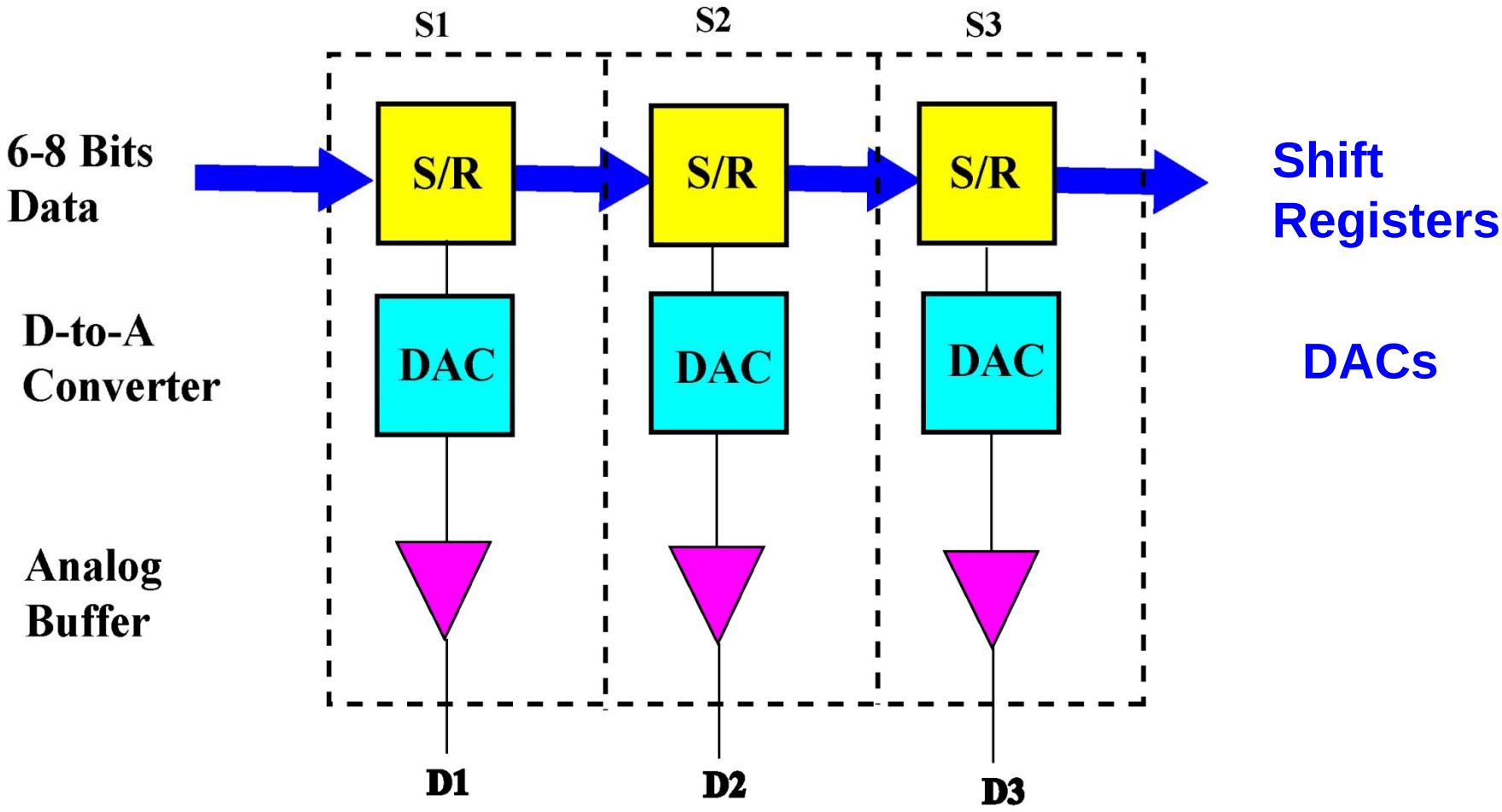
Digital Data Drivers



Morozumi, SID 00 Seminar Notes

Summary of Today's Lecture

- **Overview Flat Panel Display Devices**
  - How do Displays Work?
  - Emissive Displays (CRTs, FEDs, OLEDs, PDs)
  - Light Valve Displays (AMLCDs, DMDs, EPDs)

- **Display Drivers**
  - Addressing Schemes (Sequential, Direct, Matrix, Random)
  - Display Timing Generator
  - Gray Scale (Spatial, Frame, Amplitude)
  - Color Schemes (Spatial, Sequential, Coincident)

Emissive Displays

- Displays that generate photons when an electrical signal is applied between the terminals
- Energy causes excitation followed by relaxation
  - Hole + Electron recombination
  - Exciton formation and annihilation
  - Relaxation of excited radicals in a plasma
- The different types of Luminescence differ mostly in the way the holes and electrons are generated
  - holes and electrons are generated by UV in a phosphor which then recombine and generate red, green or blue light —Photoluminescence or Phosphorescence
  - holes and electrons injected by pn junction or generated by impact ionization or excitation which then recombine and generate red, green or blue light —Electroluminescence
  - holes and electrons generated by electron beam which then recombine and generate red, green or blue light — Cathodoluminescence
- Examples of Emissive Flat Panel Displays
  - Electroluminescence (Light Emitting Diode, Organic-Light Emitting Devices & In-organic ELectroluminescent Displays)
  - Cathodoluminescence (Cathode Ray Tube, Vacuum Florescent Display, Field Emission Display)
  - Photoluminescence (PLasma Displays)

Light Valve Displays

- Displays that "spatially and temporally" modulate ambient lighting or broad source of light and redirect to the eye.
- Display element spatially changes the intensity of plane wave of light using
  - Refraction
  - Reflection
  - Polarization change
- These displays are part of a broader class of devices called Spatial Light Modulators which in general operate though local
  - Amplitude change
  - Polarization change
  - Phase change
  - Intensity change
- Examples of Light Valve Displays
  - Liquid Crystal Displays (active & passive matrix)
  - Deformable Mirror Displays
  - Membrane Mirror Displays
  - Electrophoretic Displays (E-Ink)