# 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

***For more info take graduate course, 6.987 on flat panel displays***

**Tayo Akinwande**

# Applications of Flat-Panel Displays

## SMALL FORMAT

Medical Defibrillator

MP3 Player


Personal Digital Assistant


Car Navigation & Entertainment

## LARGE FORMAT

Courtesy of PixTech

Desktop Monitor (color)


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) |

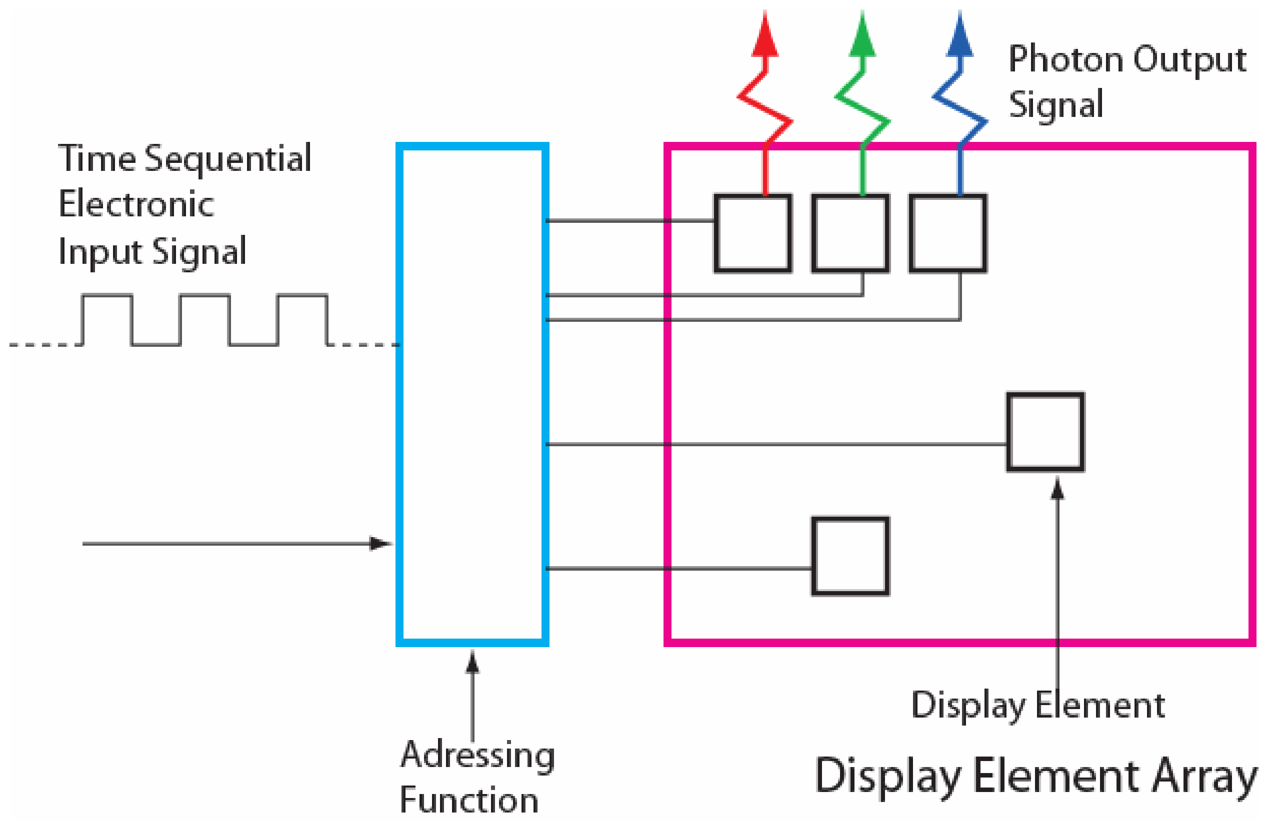
# Information Capacity of Displays

## (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*

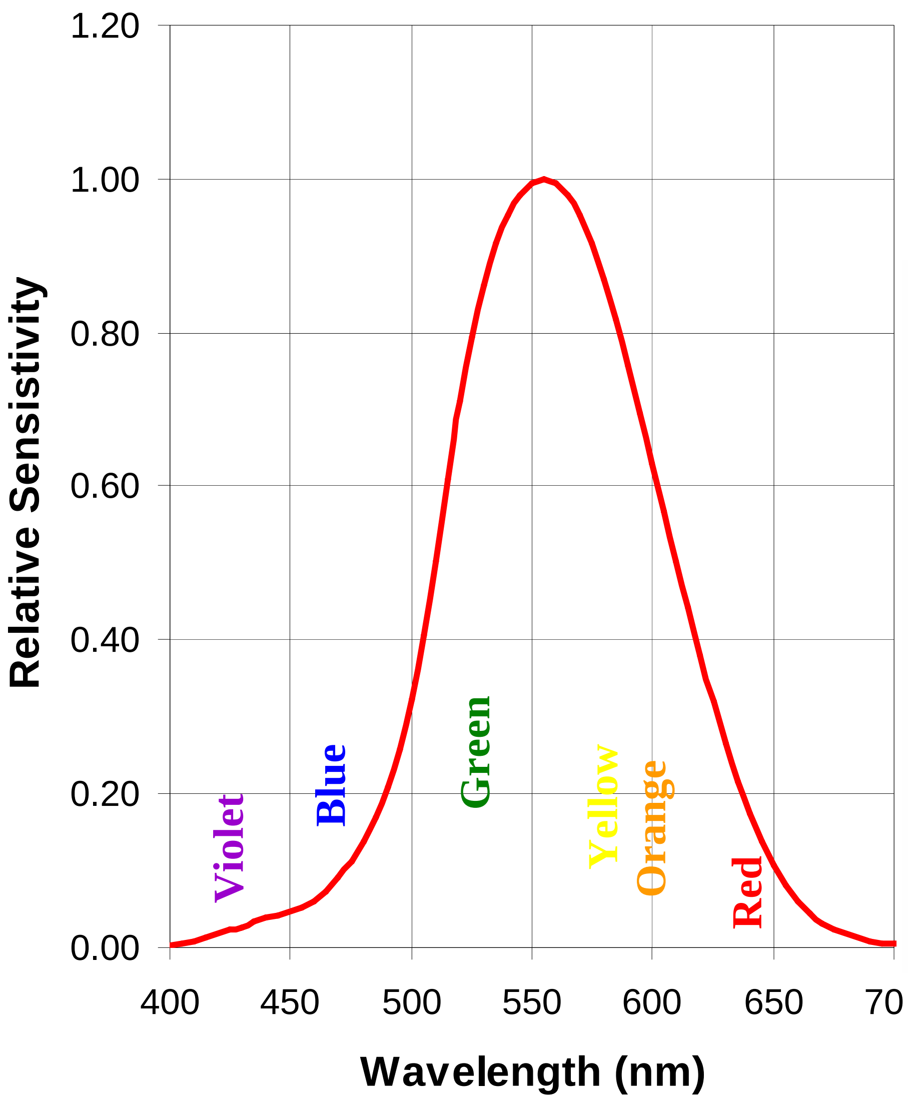
# How Do Displays Work?




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



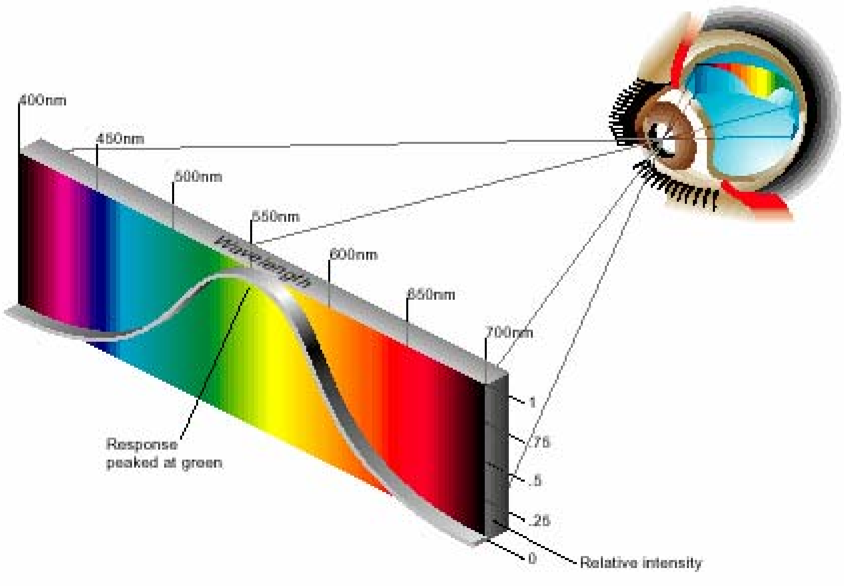




Figure 15. CIE Photopic Curve (Spectral Sensitivity of the Human Eye).

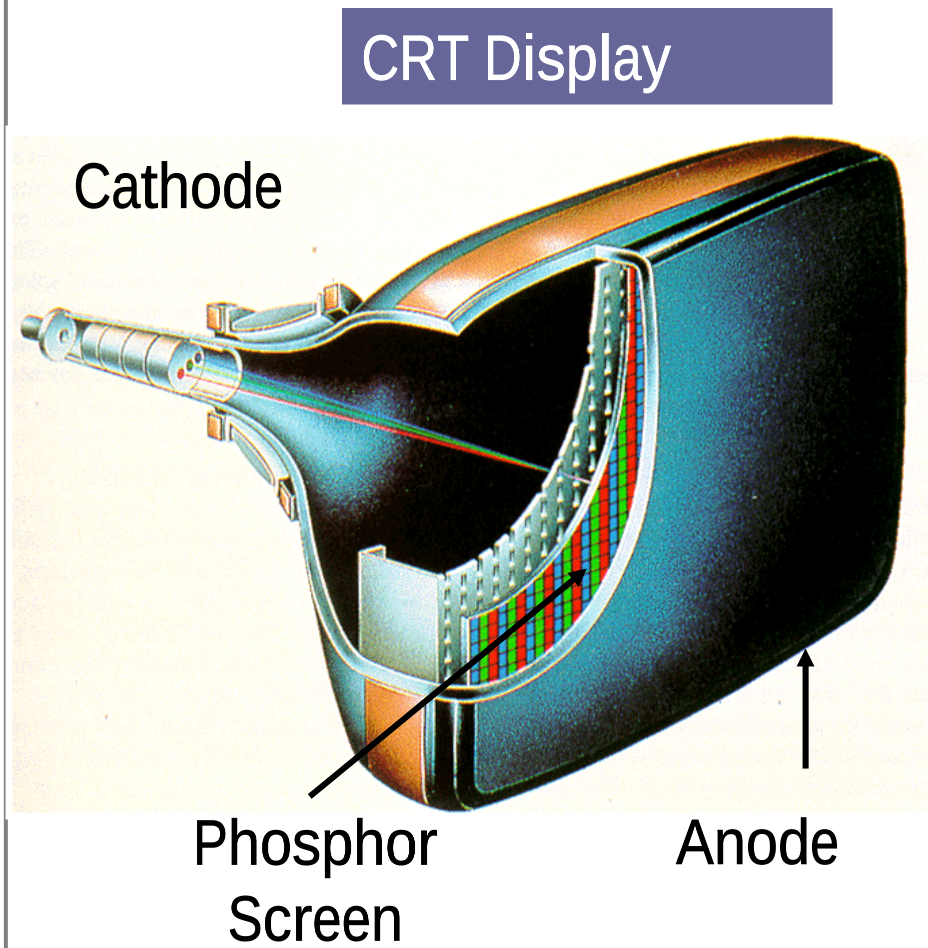
# Classifications of Displays by Technology

- 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)

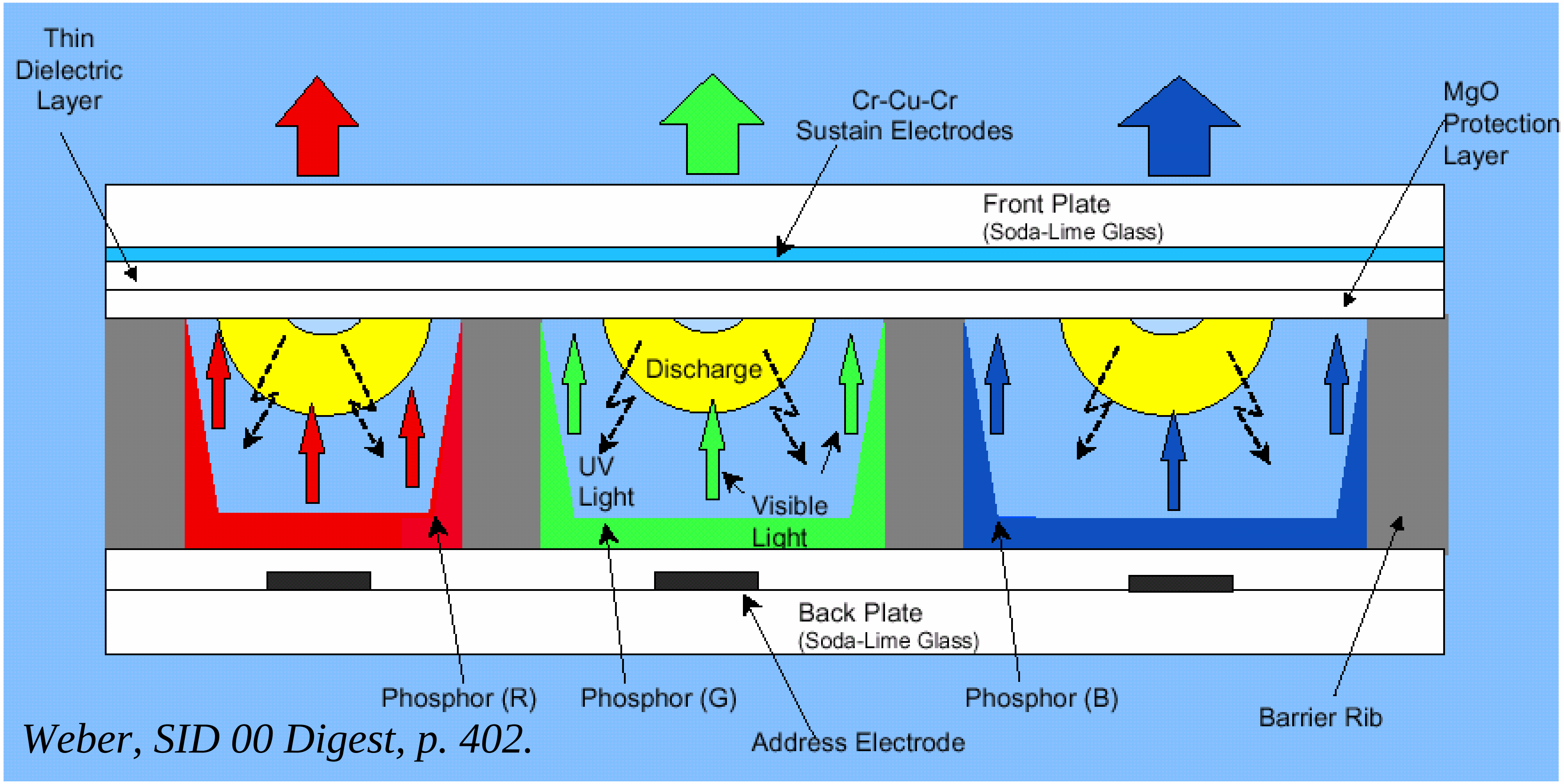
# Cathode Ray Tube




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

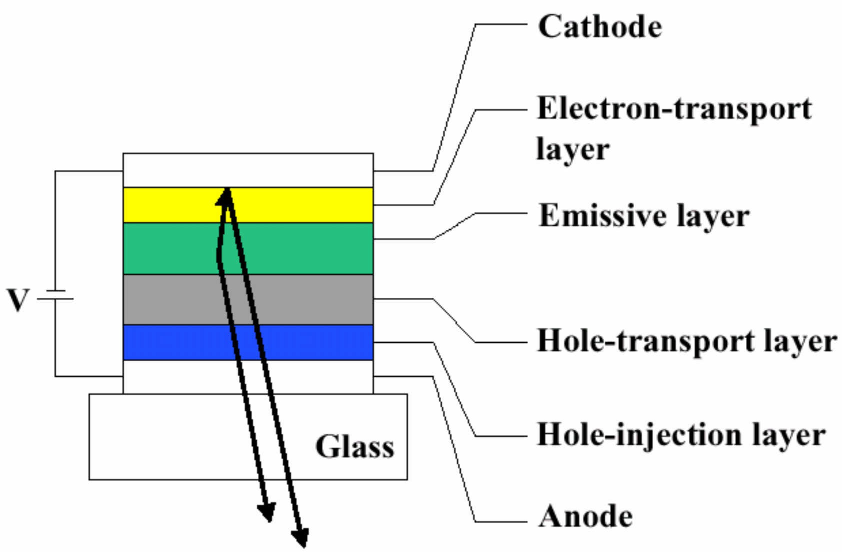



**Figure 1. A typical OLED multilayer device structure**

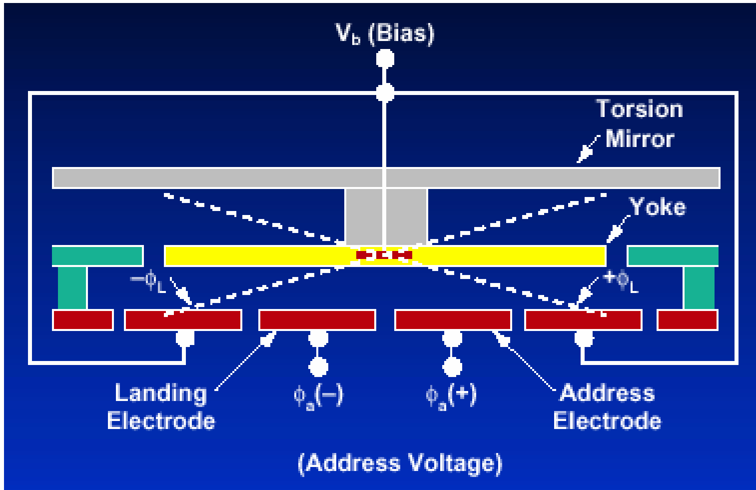
Rajeswaran et al., SID 00 Digest, p. 974

**17-inch Active Matrix OLED**

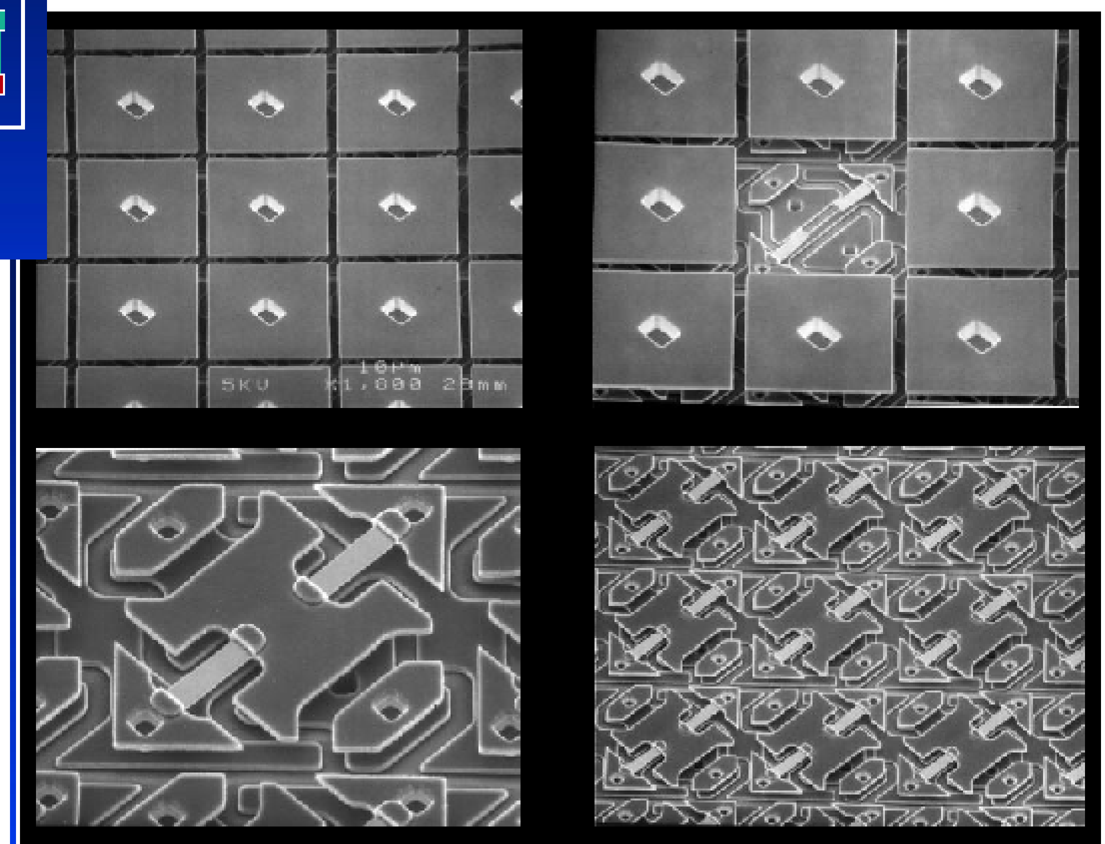
H.-K. Chung et al., SID 05 Digest, p. 956

**electroluminescence**

# Digital Mirror Device




Courtesy of Texas Instruments

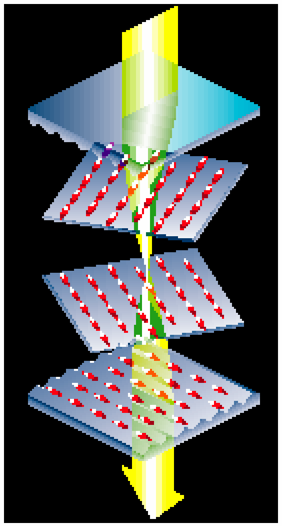


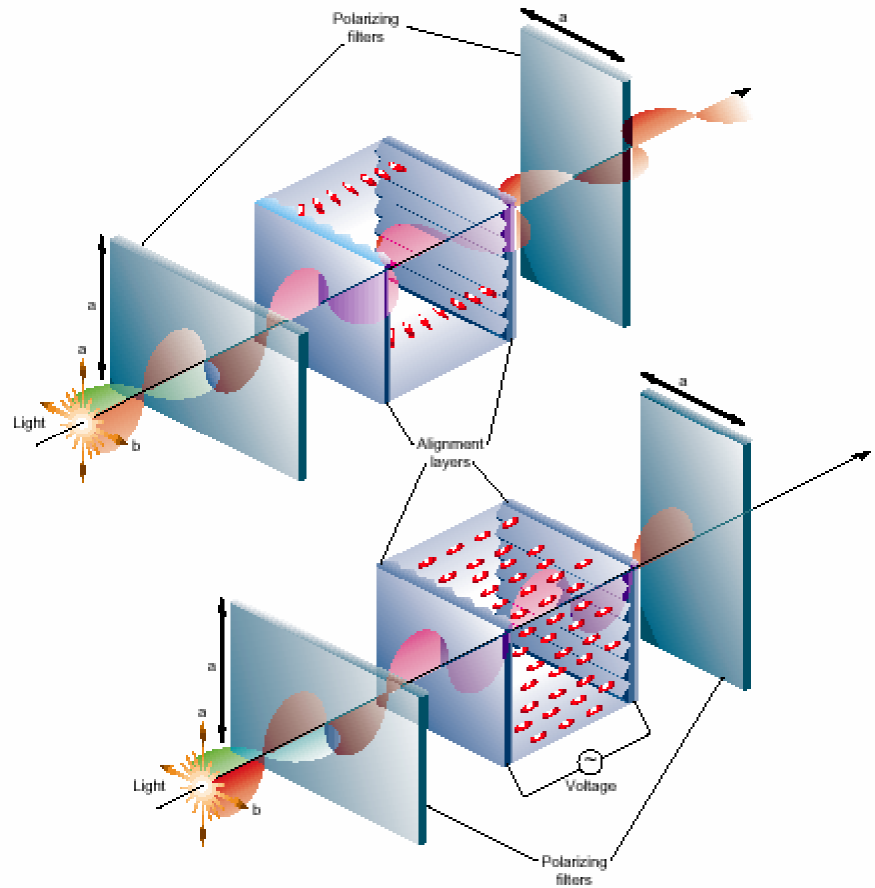
Applied voltage deflects
Mirror and hence direct light

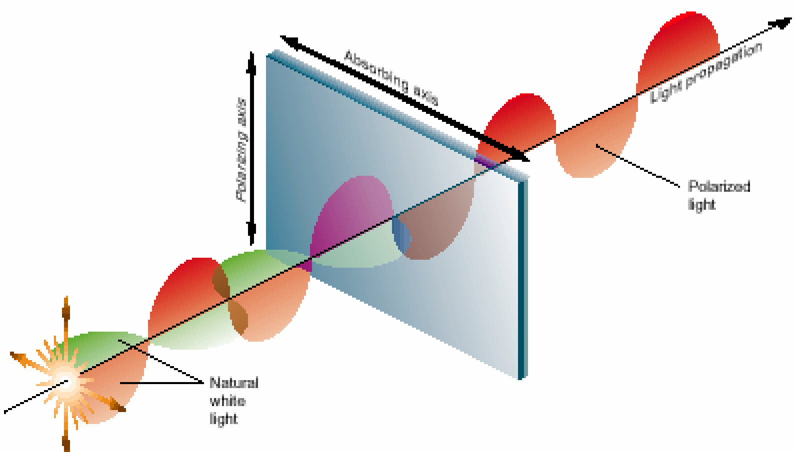
**Reflective Light Valves**

# Liquid Crystal Displays

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



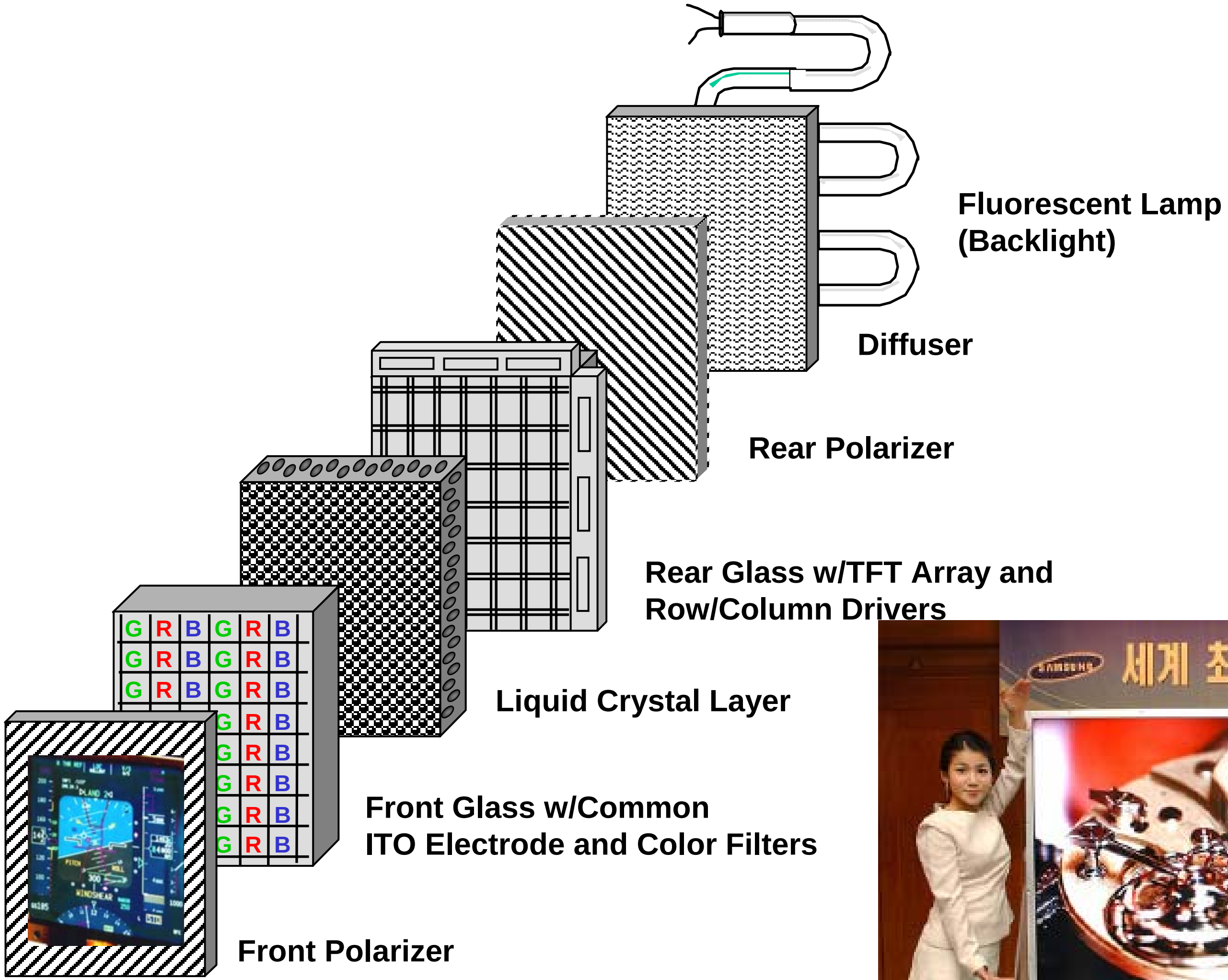



**Polarization Rotator**

Courtesy of Silicon Graphics

# TFT AMLCD




**82" TFT AMLCD**


**K. Sarma**

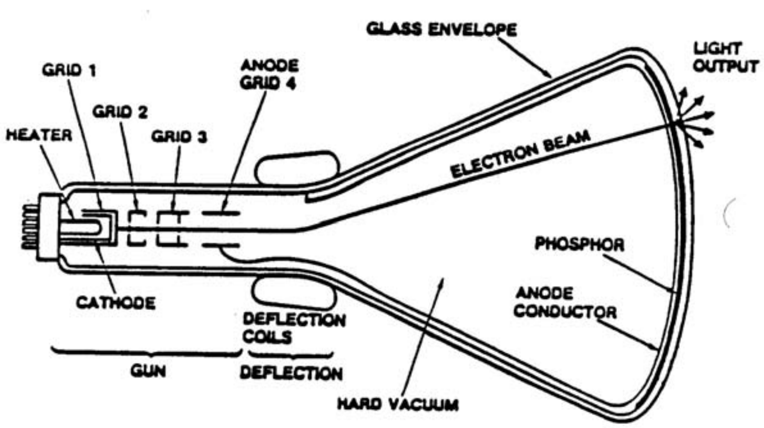
**SID 05**

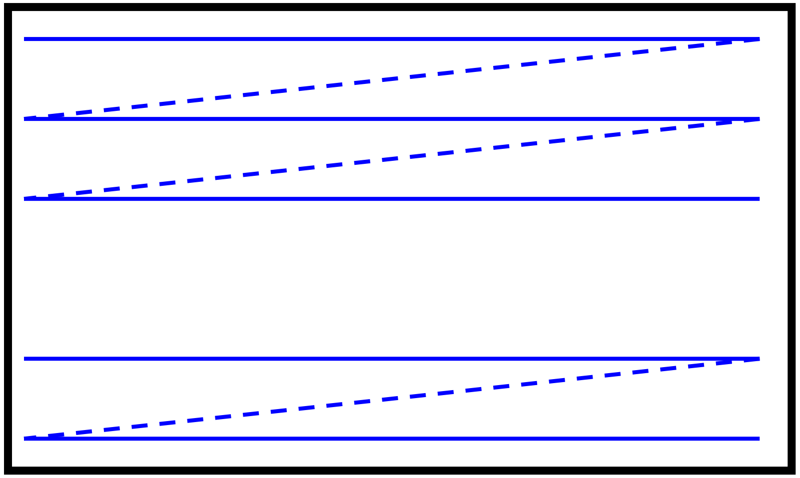
# Standard Display Addressing Modes

- 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



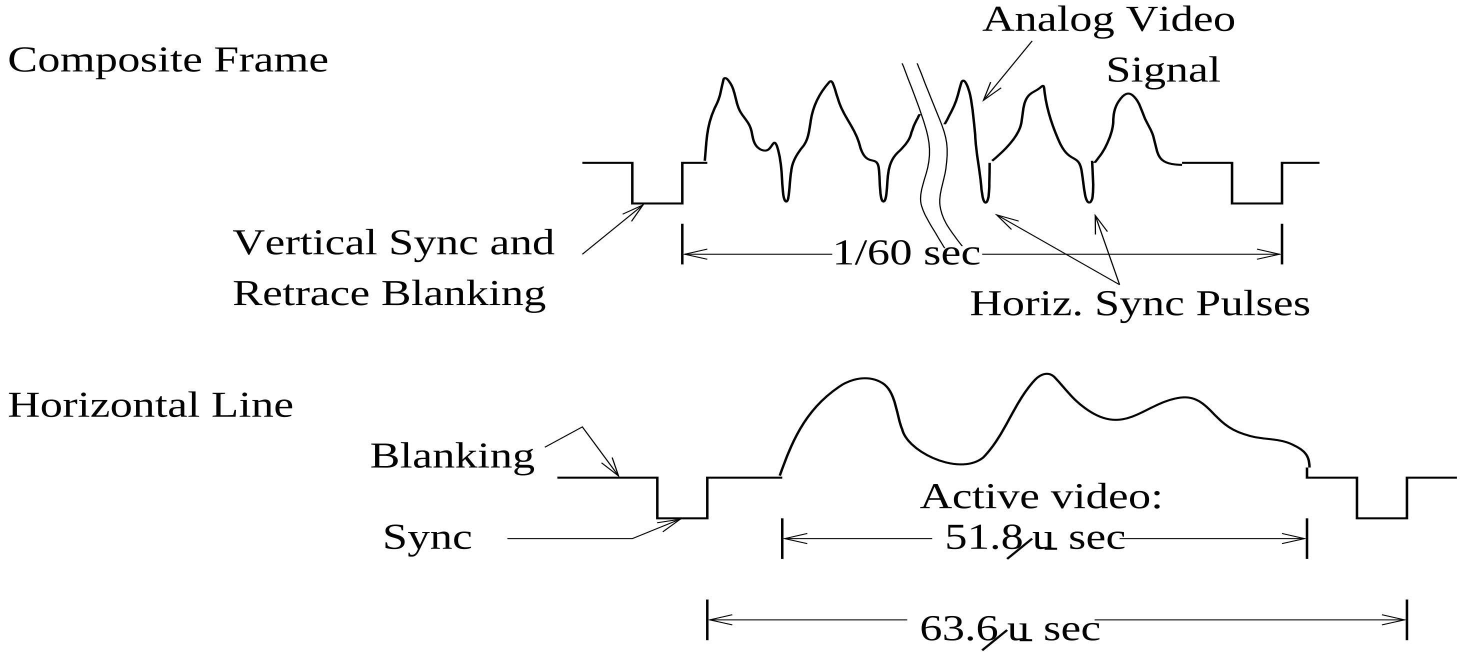
**Scan Lines**

**Retrace Lines**

**Tannas, SID 00 Applications Seminar**

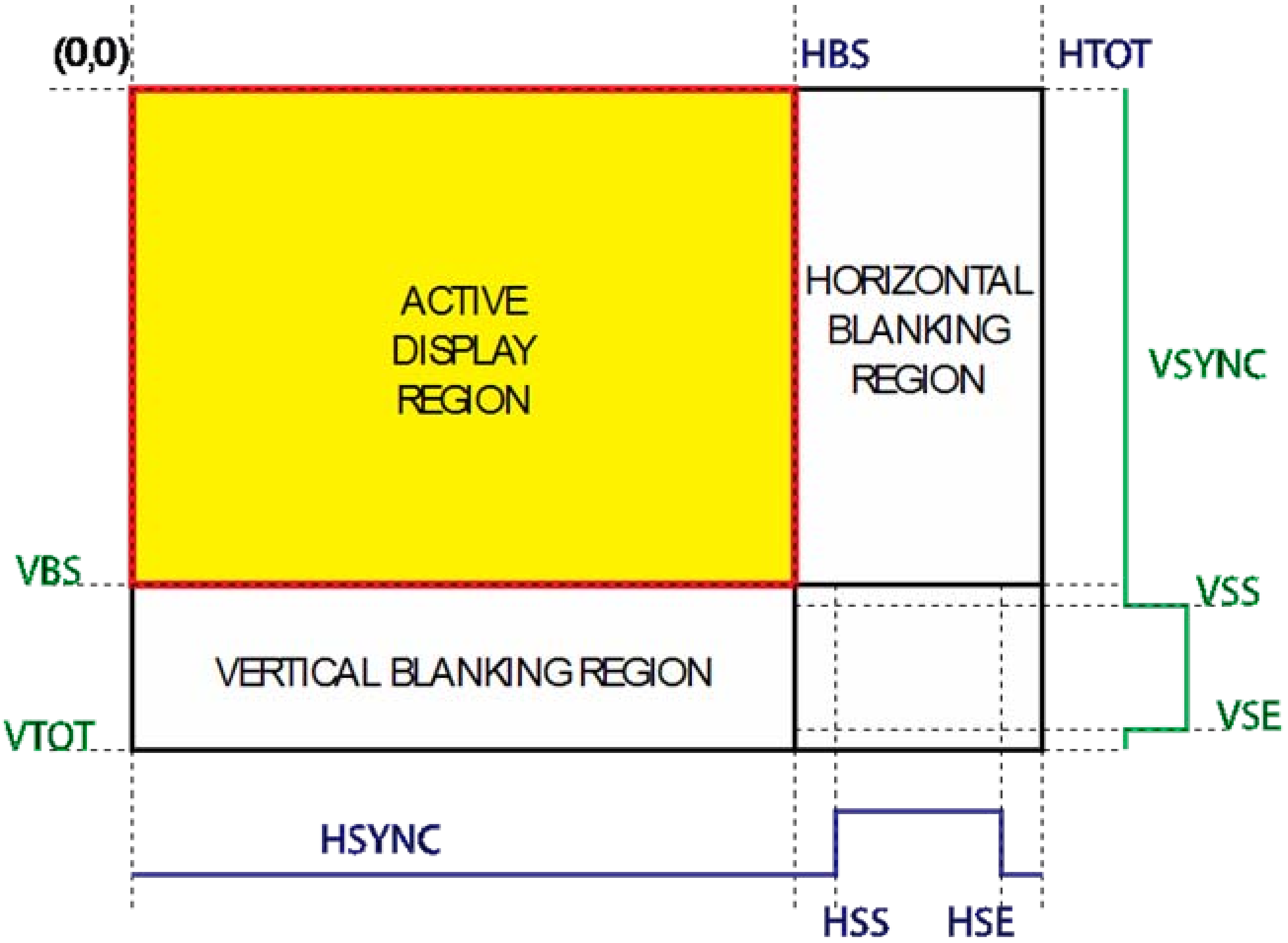
# Composite Frames

- 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**

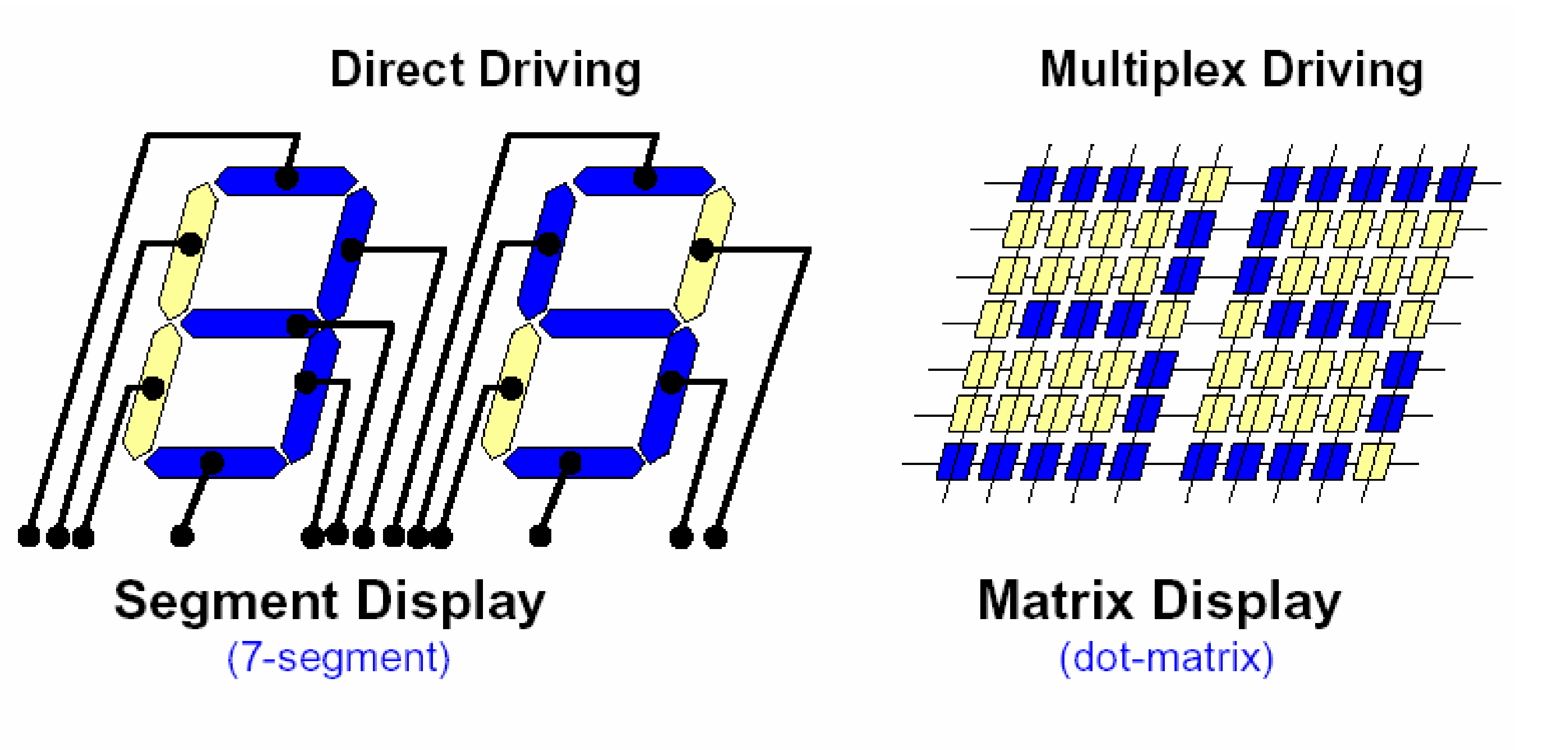
# Display Timing Generator Parameters




**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

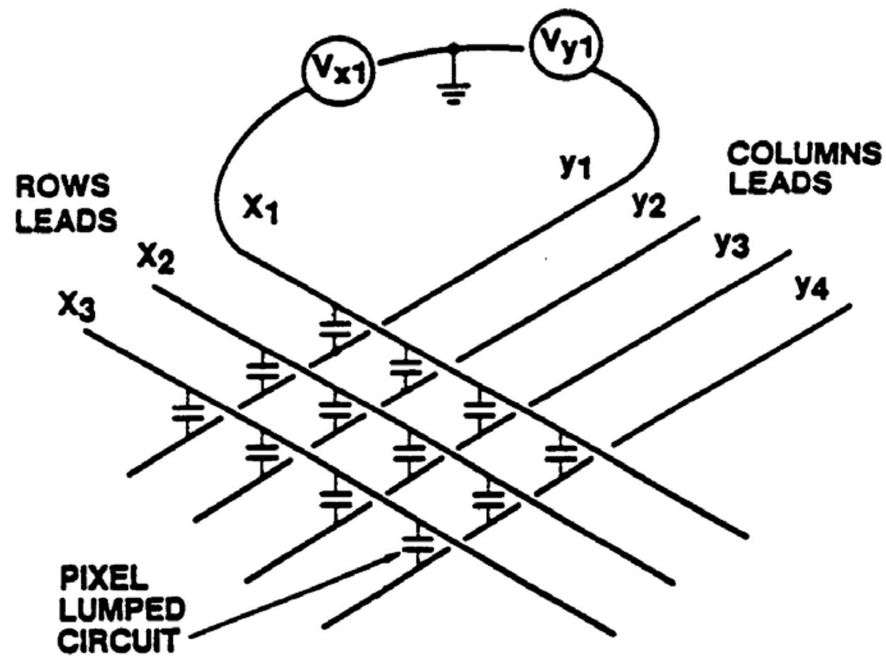
# Direct vs. Matrix Addressing




Kim, SID 2001

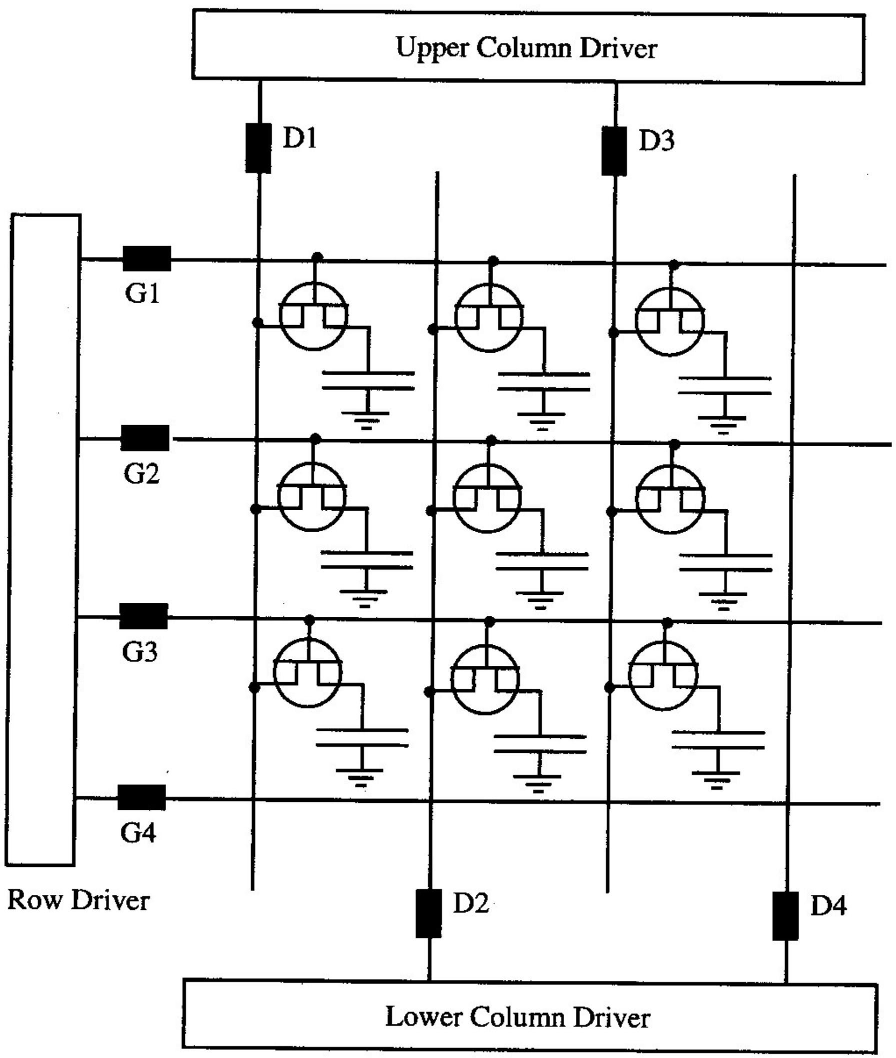
# Matrix Addressing

- 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




Tannas, SID 00 Applications Seminar

# Active Matrix Addressing

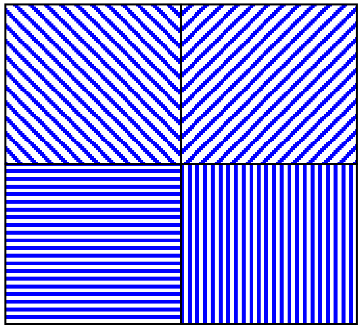



- Introduce non linear device that improves the selection.
- Storage of data values on capacitor so that pixel duty cycle is 100%
- Improve brightness of display by a factor of N (# of rows) over passive matrix drive
- Display element could be LC, EL, OLED, FED etc

**Yeh & Gu**

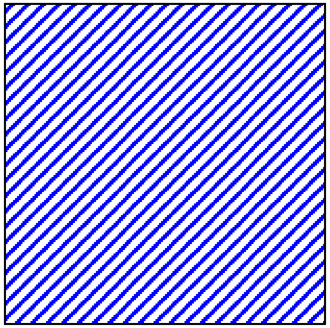
# Grey Shades Generation Techniques

**Spatial Modulation**



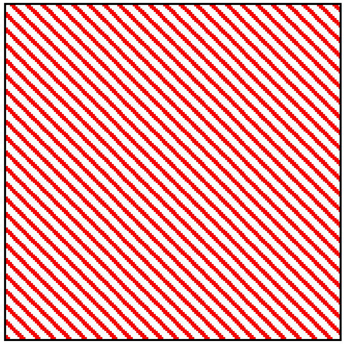
Individually selectable Areas per pixel area per dwell time

**Frame Modulation**



Reduced intensity by skipping frames per pixel area

**Amplitude Modulation**

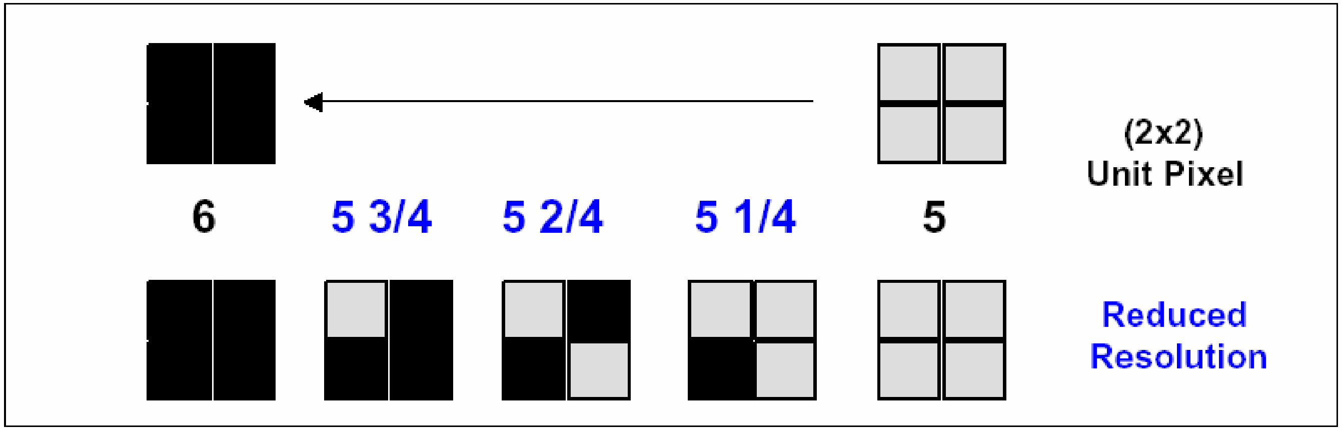


Analog intensity at full dwell time per pixel

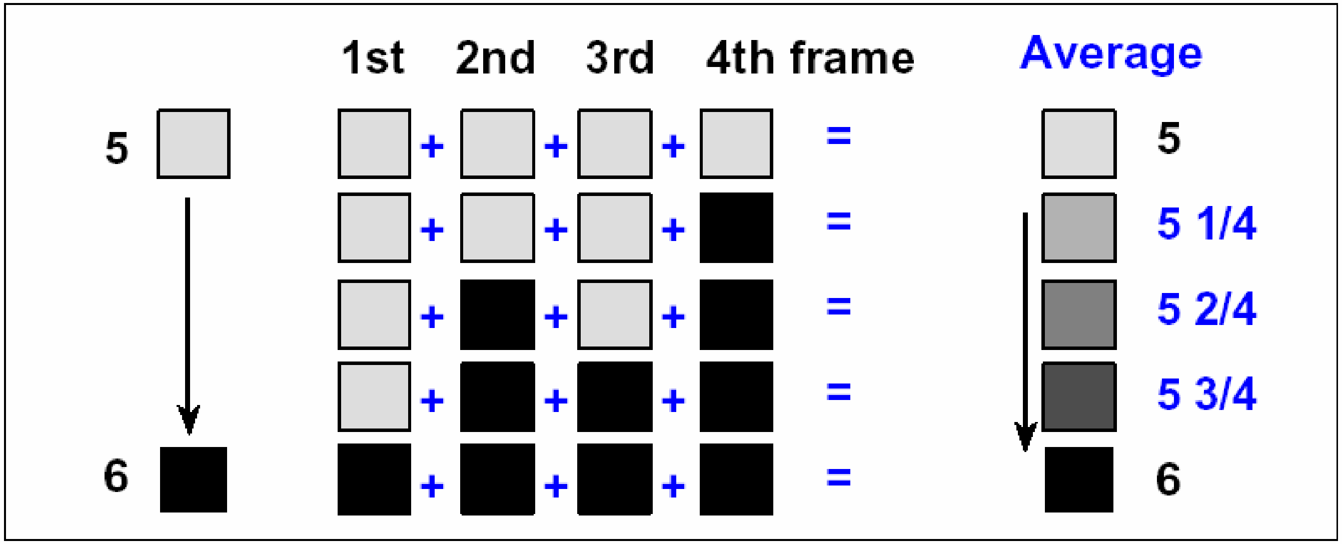
# Grey Scale Generation

## (Spatial Modulation / Frame Rate Control)

**Dithering**




**Frame Rate Control (FRC)**

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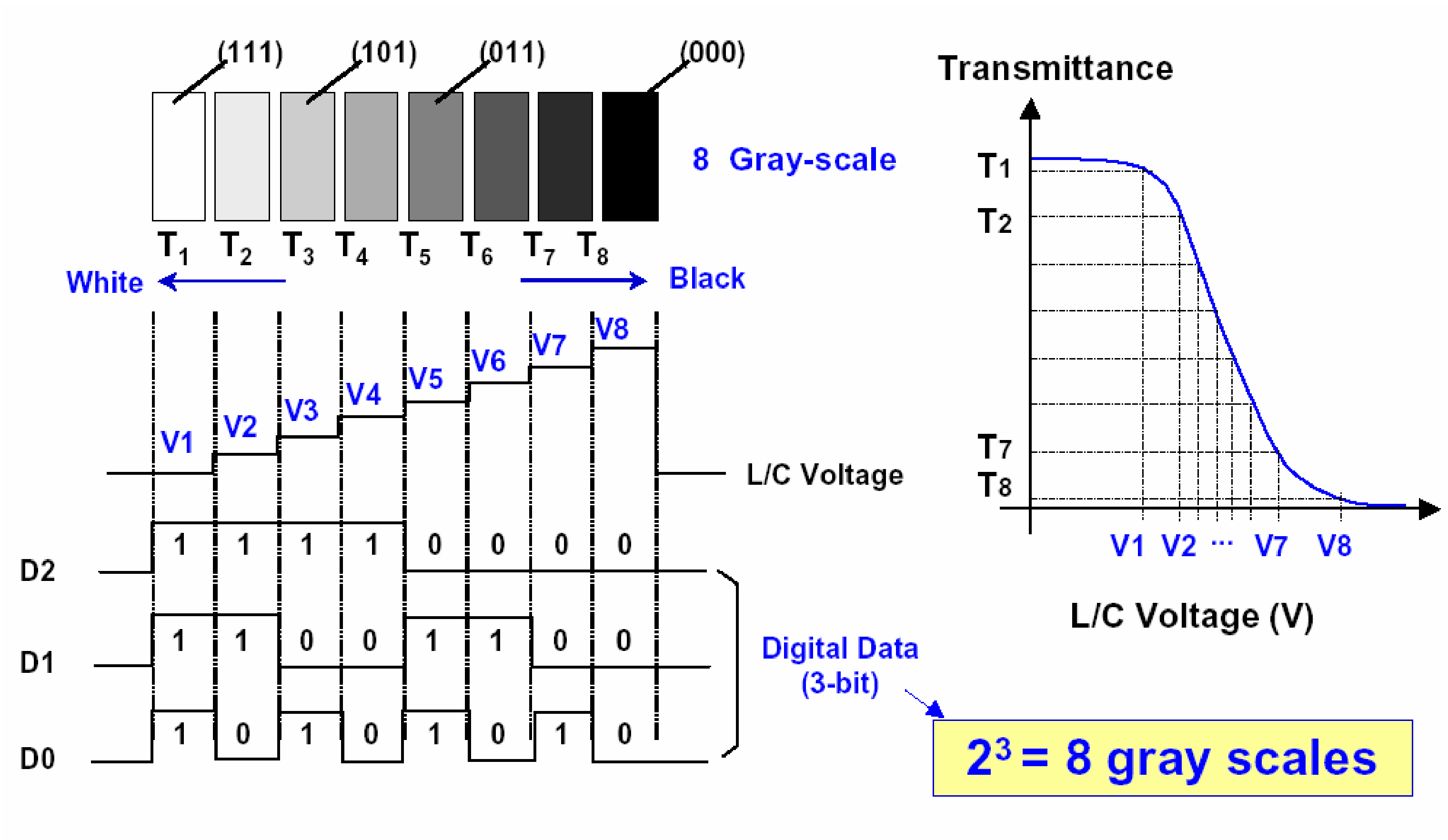
# Grey Scale Generation

## (Amplitude Modulation)

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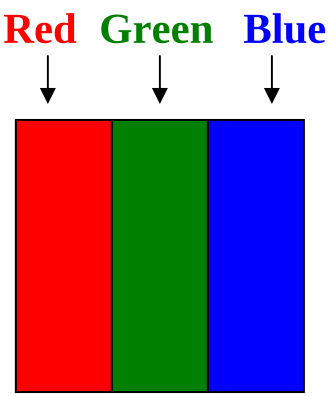
# Color Generation Techniques

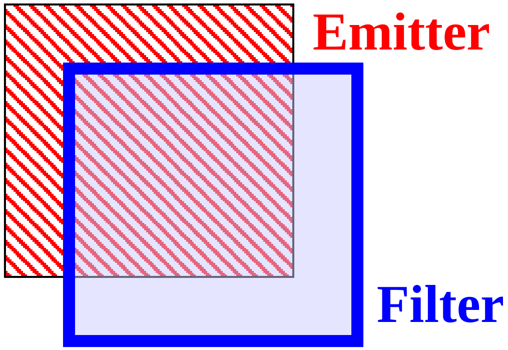
## Spatial Color




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

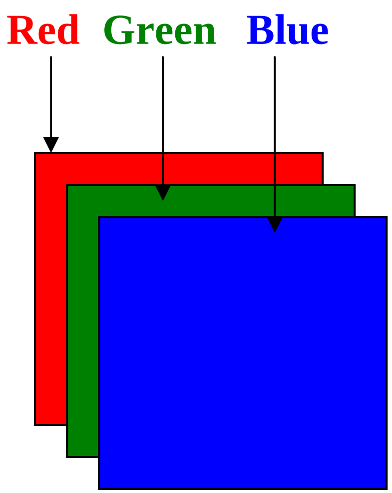
## Sequential Color

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

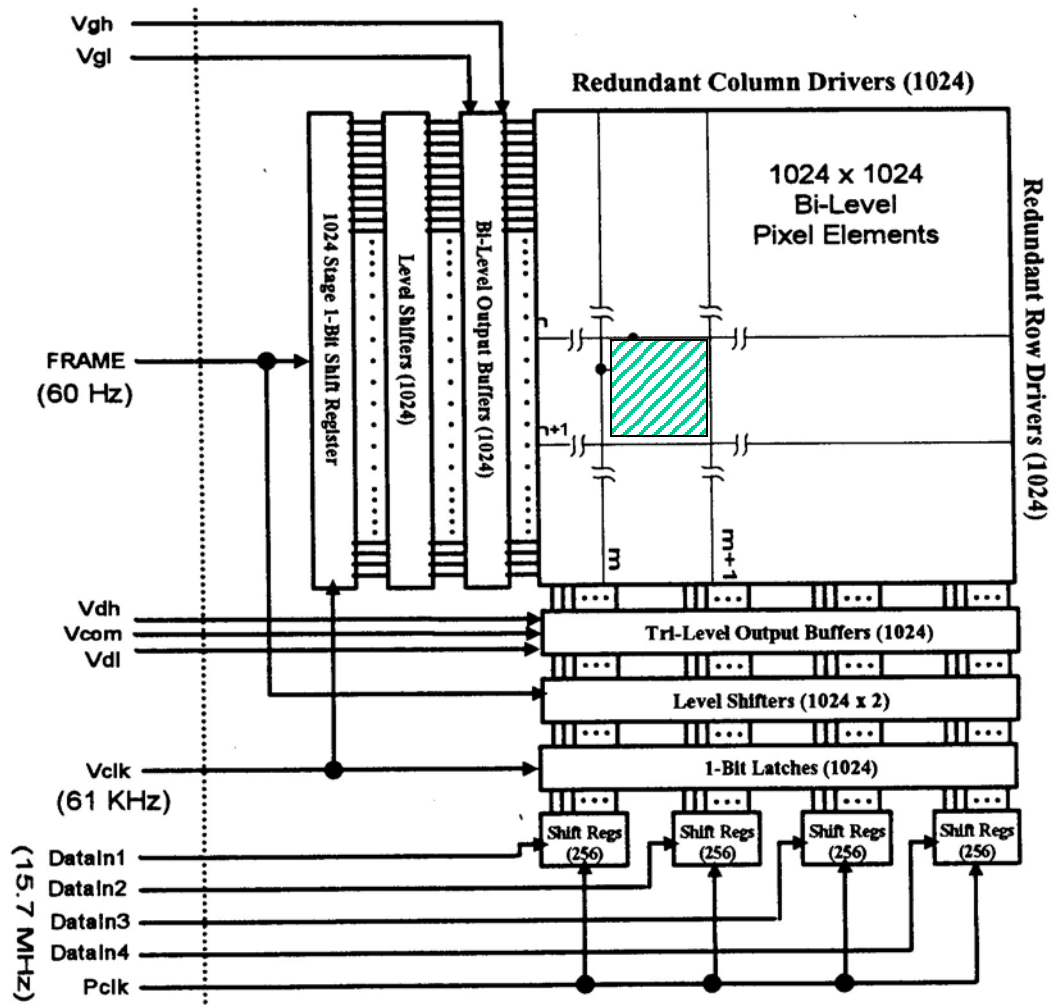



Three selectable transparent color areas per pixel area per dwell time at one times intensity

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

# Driver Circuits

Row Driver Circuits

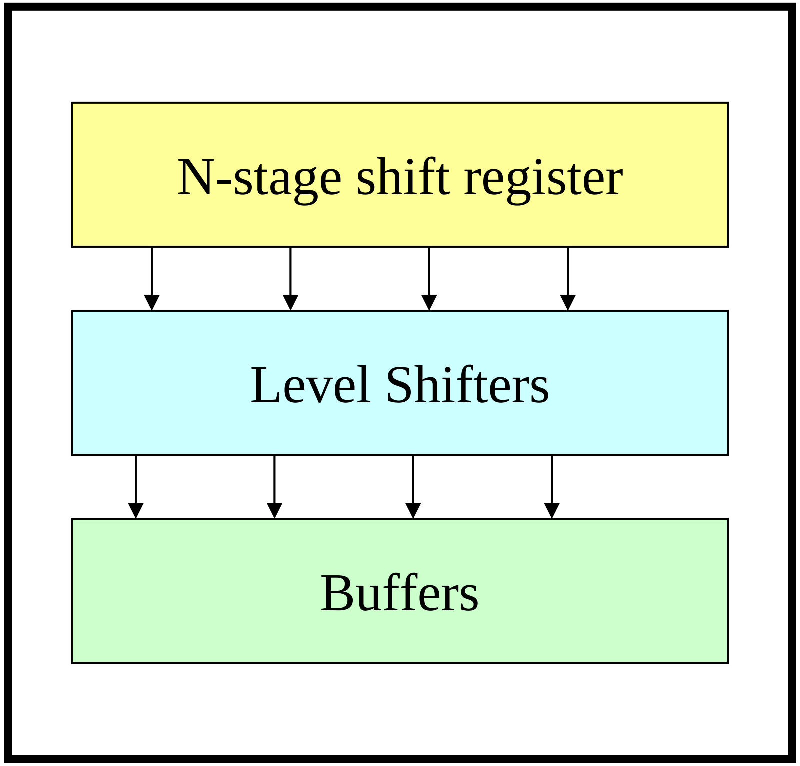



Display Pixel Array

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



# Column Driver Circuits

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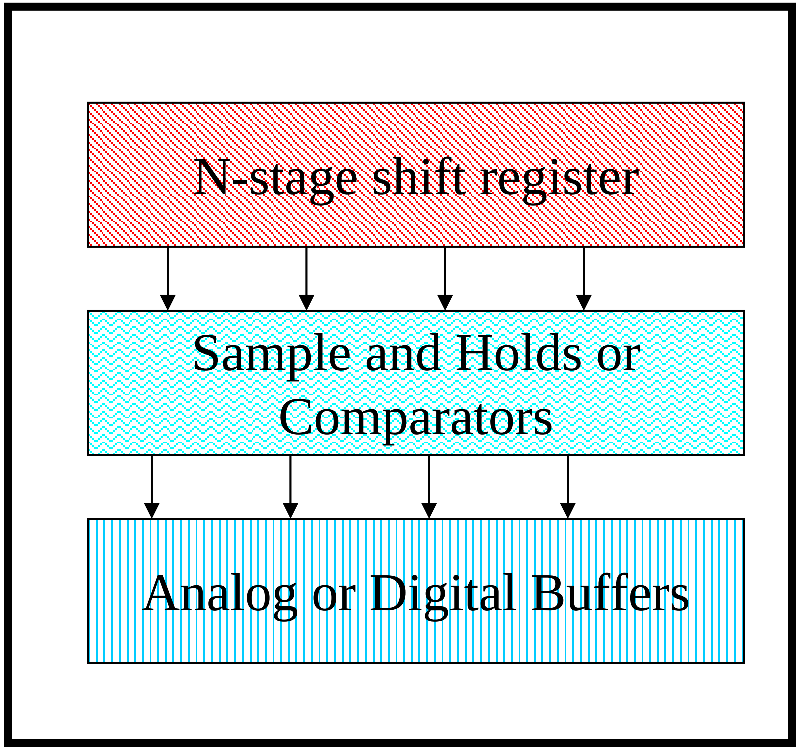
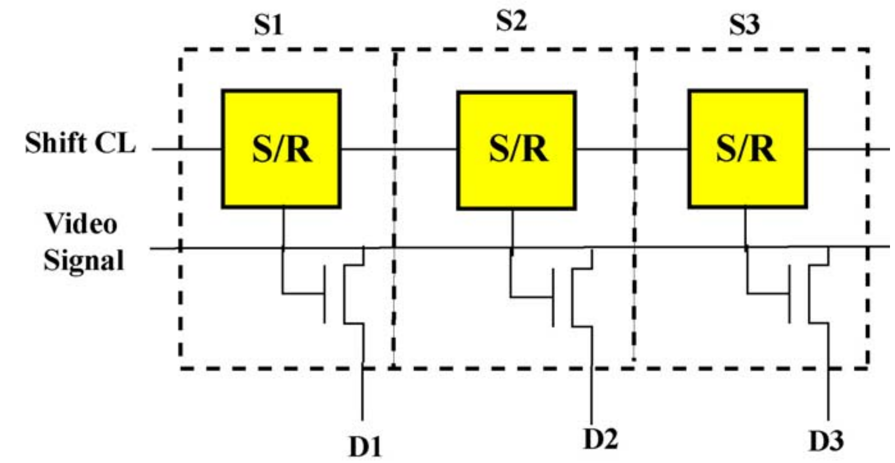


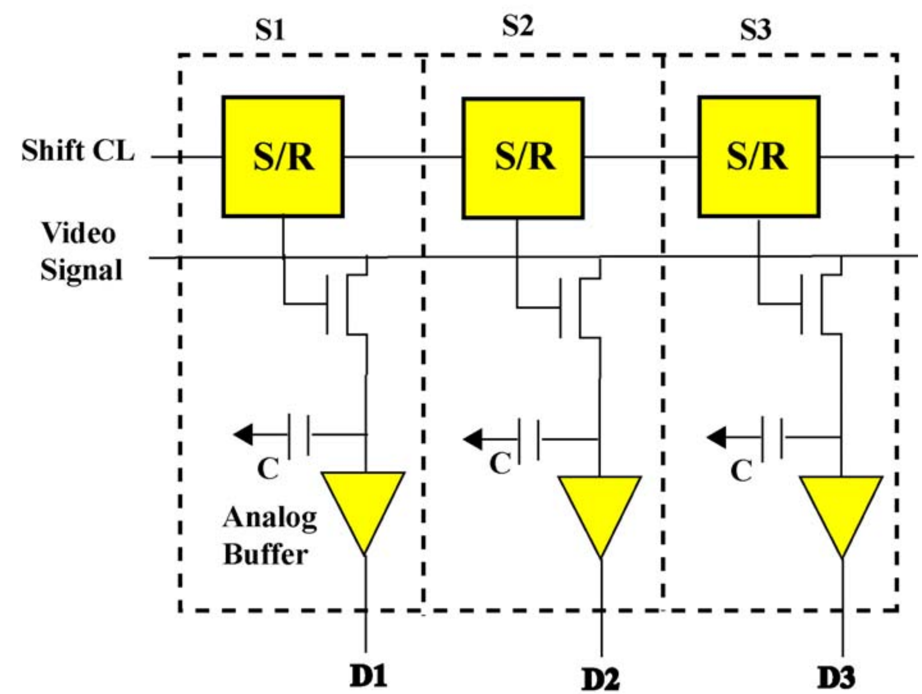
# Analog Data Driver

Point at a time




Shift
Registers

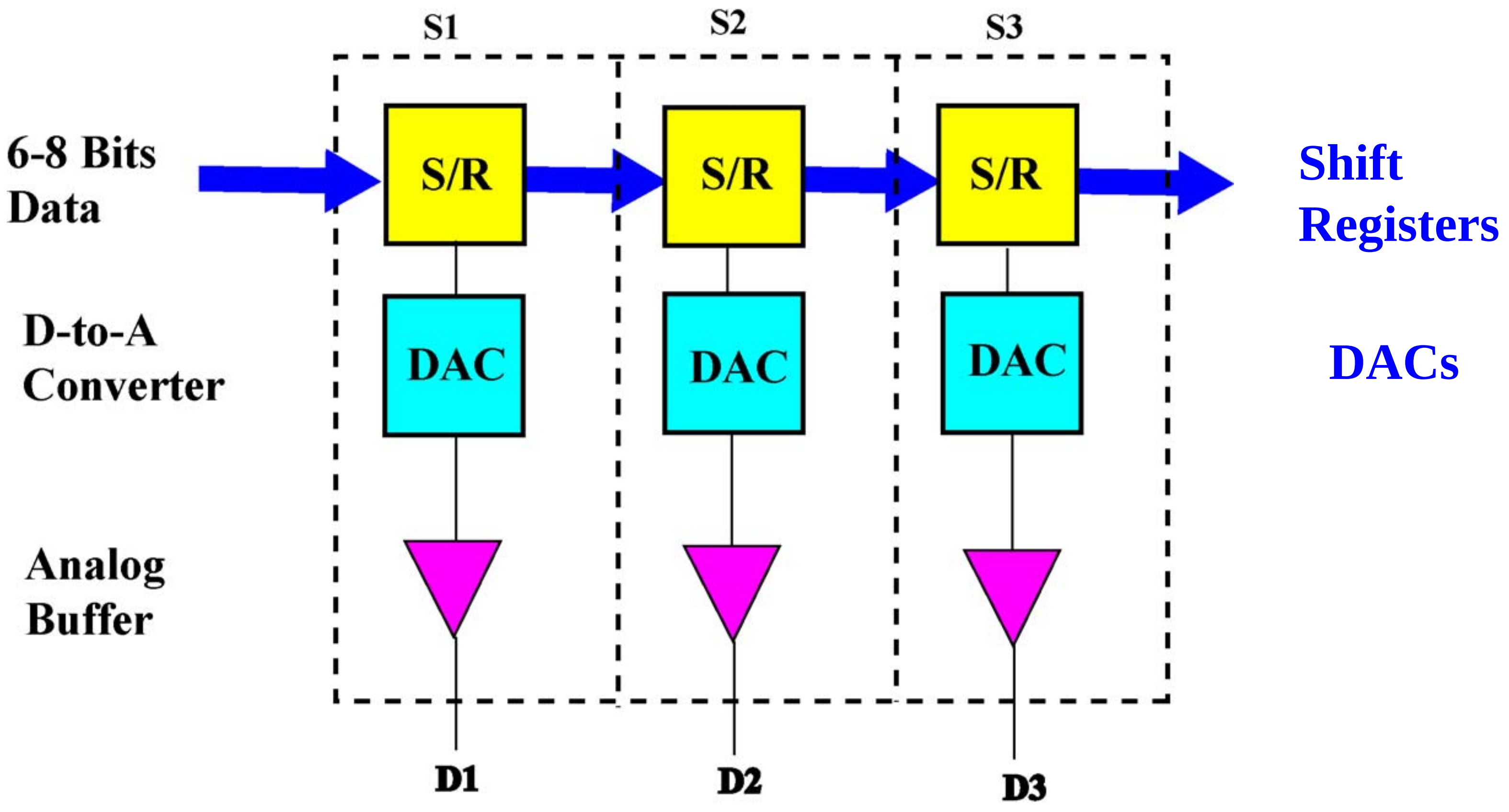
Line at a time




Shift
Registers

Morozumi, SID 00
Seminar Notes

# 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 (**L**ight **E**mitting **D**iode, **O**rganic-**L**ight **E**mitting **D**evices & In-organic **EL**ectroluminescent Displays)
  - Cathodoluminescence (**C**athode **R**ay **T**ube, **V**acuum **F**lorescent **D**isplay, **F**ield **E**mission **D**isplay)
  - Photoluminescence (**PL**asma **D**isplays)

# 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
  - **L**iquid **C**rystal **D**isplays (active & passive matrix)
  - **D**eformable **M**irror **D**isplays
  - **M**embrane **M**irror **D**isplays
  - **E**lectrophoretic **D**isplays (E-Ink)