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**

- Desktop Monitor (color)
- Large Screen Television (color)

Courtesy of PixTech
### Some Display Terminologies

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

### (Pixel Count)

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Pixel</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Graphic Array (VGA)</td>
<td>640 x 480 x RGB</td>
<td>4:3</td>
</tr>
<tr>
<td>Super Video Graphic Array (SVGA)</td>
<td>800 x 600 x RGB</td>
<td>4:3</td>
</tr>
<tr>
<td>eXtended Graphic Array (XGA)</td>
<td>1,024 x 768 x RGB</td>
<td>4:3</td>
</tr>
<tr>
<td>Super eXtended Graphic Array (SXGA)</td>
<td>1,280 x 1,024 RGB</td>
<td>5:4</td>
</tr>
<tr>
<td>Super eXtended Graphic Array plus (SXGA+)</td>
<td>1,400 x 1,080 x RGB</td>
<td>4:3</td>
</tr>
<tr>
<td>Ultra eXtended Graphic Array (UXGA)</td>
<td>1,600 x 1,200 x RGB</td>
<td>4:3</td>
</tr>
<tr>
<td>Quad eXtended Graphics Array (QXGA)</td>
<td>2048 x 1536 x RGB</td>
<td>4:3</td>
</tr>
<tr>
<td>Quad Super eXtended Graphics Array (QSXGA)</td>
<td>2560 x 2048 x RGB</td>
<td>4:3</td>
</tr>
</tbody>
</table>

*Display Devices, No. 21, Spring 2000, p. 41*
How Do Displays Work?

- Electronic display converts “**Time Sequential Electrical Signals**” into spatially and temporally configured light signal (**images**).
  - Electrical signals are appropriately routed to the various display elements (**similar to memory addressing**)
  - Display element (pixel) converts the routed electrical signal at its input into light of certain wavelength and intensity (**inverse of image capture**)
Human Eye—Spectral Response

![Human Eye Spectral Response Graph](image)

- **Wavelength (nm)**: 400, 450, 500, 550, 600, 650, 700
- **Relative Sensitivity**
  - Violet
  - Blue
  - Green
  - Yellow
  - Orange
  - Red

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

- Displays that **generate photons** when an electrical signal is applied between the terminals
- Energy causes excitation followed by excitation 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 & Inorganic 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 through 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)
Cathode Ray Tube

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).

Courtesy of PixTech
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
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
Digital Mirror Device

Applied voltage deflects Mirror and hence direct light

Courtesy of Texas Instruments
Liquid Crystal Displays

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

Courtesy of Silicon Graphics
TFT AMLCD

Fluorescent Lamp (Backlight)

Diffuser

Rear Polarizer

Rear Glass w/TFT Array and Row/Column Drivers

Liquid Crystal Layer

Front Glass w/Common ITO Electrode and Color Filters

Front Polarizer

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).

Composite Frame

Vertical Sync and Retrace Blanking

Horizontal Line

Blanking

Sync

Active video: 51.8μsec

63.6μsec

1/60 sec

Horiz. Sync Pulses

Analog Video Signal

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
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)

Kim, SID 2001
Grey Scale Generation
(Amplitude Modulation)

Kim, SID 2001
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.

**Coincident Color**

- Electronic filter changed three times per dwell time.

- 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
Column 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

Diagram:

1. N-stage shift register
2. Sample and Holds or Comparators
3. Analog or Digital Buffers
Analog Data Driver

**Point at a time**

**Line at a time**

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Morozumi, SID 00
Seminar Notes
Digital Data Drivers

6-8 Bits Data

D-to-A Converter

Analog Buffer

S1
S/R

S2
S/R

S3
S/R

D1
DAC

D2
DAC

D3
DAC

Shift Registers

DACs

Morozumi, SID 00 Seminar Notes