Applications 2 Displays

Complementary and Saturation

W: x = y = z = 0.33

Saturation:

Sat = \frac{WA}{WD}

Complementary:

C and B are on the opposite sides of W

δ C & B are Complementary colors

Color Gamut & NTSC Color Gamut

- NTSC Color Gamut

<table>
<thead>
<tr>
<th></th>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.67</td>
<td>0.33</td>
</tr>
<tr>
<td>G</td>
<td>0.21</td>
<td>0.71</td>
</tr>
<tr>
<td>B</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>W</td>
<td>0.310</td>
<td>0.316</td>
</tr>
</tbody>
</table>

Image Display and the Effect of Resolution

Spatial resolutions
210 x 250
105 x 125
70 x 83
52 x 62
42 x 50

Each image uses 256 different gray levels
Resolution Standards

Color Display

Challenges Performance

- Take an HDTV example:
  - 1920 x 1080 resolution
  - 24-bit per pixel
    (8-bit Red, Green and Blue values)
  - 30 progressive frames per second
- Bandwidth = 1920 x 1080 x 24 x 30 = 1.49Gbps

Demand

- HIGH RESOLUTION
- HIGH BRIGHTNESS
- LARGE VIEWING ANGLE
- HIGH WRITING SPEEDS
- LARGE COLOR GAMUT
- HIGH CONTRAST
- LESS WEIGHT AND SIZE
- LOW POWER CONSUMPTION
- LOW COST
Electronic Displays

- Projection
  - CRT
  - LCD
  - DMD
- Direct View
  - Cathode Ray Tube (CRT)
  - Flat Panel Display (FPD)
- Projection Displays
  - Front Projection
  - Rear Projection

Display Technology

- Cathode Ray Tube (CRT)
- Field Emission Display (FED)
- Plasma Display Panel (PDP)
- Liquid Crystal Display (LCD)
- Organic Light Emitting Diode (OLED)
- Projection Display

Flat Panel Displays

- Flexible Display
- LCD Monitor
- Rear Projection Display
- Front Projection TV & Display
- PDA
- HMD
- E-Book
- NRPG
- TFT Film
- OLED
- OLED DMD

High Information Content Displays

- High Resolution
- Low Power - High Efficiency
- Full Color
- Fast Response Time
- Wide Viewing Angle
- No Image Artifact
- Bright - Thin - Light - Small
- No EMI - Recyclable

CRT

- 100 YEAR OLD WORKHORSE
- CATHODOLUMINESCENT
- BEAM SCAN DEVICE
- LARGE VIEWING ANGLE
- HIGH BRIGHTNESS
- HIGH RESOLUTION
- GOOD COLOUR GAMUT
- BEST PERFORMANCE TO COST
- BULKY, HEAVY
- UNIMPLEMENTABLE IN LARGE SIZES
- OBSOLESCENCE
- STILL ENJOYS 70% MARKET
**CRT**

- Consists of:
  - electron gun
  - electron focusing lens
  - deflection plates/coils
  - electron beam
  - anode with phosphor coating
- Electrons "boil off" the heated cathode and shoot towards the anode.
- Electrons striking the phosphors create light through:
  - fluorescence (short life)
  - phosphorescence (10 to 60 use sec)
- Different phosphors have different colors:
  - red: europium yttrium vanadate
  - green: zinc cadmium sulfide
  - blue: zinc sulfide
- Persistence (as long as a few seconds)
  - Image must be refreshed to avoid flicker. Typically at least 60 Hz, though 72 Hz is easier on the eyes.

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**Color CRT**

- Many color monitors employ shadow mask technology. The variety depicted above uses **triads** of red, green, and blue phosphors at each pixel.
- Uses three electron guns, one per color shadow mask used to make each kind of phosphor only "visible" from one gun.
- These are also known as RGB monitors.

---

**Vector Scan vs. Raster Scan**

- Vector Scan
- Raster Scan
- Raster Lines

---

**Interlace vs. Progressive Scan**

**Interlace**

- First all odd lines scanned (1/60 sec) then all even lines (1/60 sec)
- Presenting a full picture (1/30 sec)

**Progressive**

- All lines scanned in single pass
- Presenting a full picture (1/60 sec)
FED

- MATRIX DISPLAY
- LARGE VIEWING ANGLE
- HIGH BRIGHTNESS, HIGH RESOLUTION
- EXCELLENT COLOUR GAMUT
- TECHNOLOGY NOT MATURE

FED - Technology Options

- Spinjet Type Emitters
  - Oldest, Expensive and Yield problems
- Carbon Nanotube Emitters (Max R&D funds)
  - Japanese funding lot of research for display application
  - Has problems with Short range uniformity
  - Potential of low cost printing for manufacture
- SED (Surface-Conduction Electron-Emitter Display)
  - Does not have emitting tips, uses electron tunneling
  - Being pursued by Toshiba - Canon (IPR bought from Candescent) for commercialization (50” prototype by 2005)

---

Field emission displays, electrons coming from millions of tiny microtips pass through gates and light up pixels on a screen.

This principle is similar to that of cathode-ray tubes in television sets. The difference: Instead of just one "gun" spraying electrons against the inside of the screens face, there are as many as 500 million of them (microtips).
Carbon Nanotube

- Superior mechanical strength
- Low weight
- Good heat conductance
- Ability to emit a cold electron at relatively low voltages due to high aspect ratios ($10^{-10}$ nm) and nanometer size tips ($1 - 50$ nm).

SED

- SED is one kind of FED (Field Emission Display)
- Based on the same light-emitting principle as the cathode-ray tube (CRT), the SED inherits the superior picture quality of the CRT but with improvements in sharpness and other characteristics.
- SED brings the image quality of the traditional cathode-ray tube (CRT) to flat panel displays.
- Delivering bright, high-resolution images offering high contrast, high gradation levels, fast responsiveness and low power consumption.

FED advantages

- Inherently high luminous efficiency
- No Response Time issues
- CRT-like Color Gamut
- Lower Power Consumption
  - Cold Cathode Emission
  - Distance between cathode and screen ~0.2-3 mm
- Flat Panel Technology
  - Matrix Addressed ~ No DY
- Capital investment for manufacturing VLS TV with printable CNT FEDs ~ 1/10th of LCD
- Cost advantage over LCD could be 40%

<table>
<thead>
<tr>
<th>Technology</th>
<th>Luminous Efficiency (Lm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRT (at 30KV)</td>
<td>3</td>
</tr>
<tr>
<td>PDP</td>
<td>0.8</td>
</tr>
<tr>
<td>LCD</td>
<td>3</td>
</tr>
<tr>
<td>OLED / PLED</td>
<td>5</td>
</tr>
<tr>
<td>FED at 8 KV</td>
<td>7</td>
</tr>
</tbody>
</table>
LEDs
- From watches to indicator lights to spelights to large billboards.
- Best Sunlight readable emissive display technology.
- Blue only recently available.
- Efficient - possible future use in lighting applications, for projection displays, and for backlights.
- More work needed on low-cost arrays and “active” addressing.

Liquid Crystal

Cholesteryl benzoate

F. Reinitzer, Monatsh. Chem. 1888, 9, 421

Liquid Crystal

An息香酸膽固醇酯

Cholesteryl benzoate

| Solid | 145°C | 膽固醇液晶相 | 175°C | 液相 |

Reinitzer, Monatsh. Chem. 1888, 9, 421

Isotropic

Nematic

Crystal

LCD
- Most mature flat panel technology
- Major share of PDP market
- Poor intrinsic viewing angle
- Requires backlight
- Inefficient
- Slow
- Effects by Temperature and sunlight

Cholesterylbenzoate

Reinitzer, Monatsh. Chem. 1888, 9, 421
There are many modes operation
- TN 90 deg twist
- STN 270 deg twist
- IPS in plane switching
- Patterned vertical alignment
- MVA multi-domain vertical alignment
Twisted Nematic LCD

In-Plane Switching Mode

Narrow View Angle on the TN Mode

Asymmetric viewing

Inufficient view angle

In-Plane Switching Mode
Patterned Vertical Alignment

- PVA - Developed by Samsung Electronics
- LC alignment optimized for wide viewing angles (typically 150° H/V)
- Improved contrast
- High brightness

Multi-domain VA
Control of LC molecule movement by deformed E-field

Dielectric ribs

PM LCD and AM LCD

Passive Matrix
Active Matrix

TFT-LCD
CCFL Backlight and Color Filter

- CCFL (cold cathode fluorescent light)

- Color Filter

LCD with RGB LED Backlight

- LCD with RGB LED Backlight

Reduced Motion Artifacts

- Without Brightness or Lifetime Penalty

Backlight Constant-On

Backlight Blinking with Fast-Switching
Reflective LCD

- Reflective LCD

<table>
<thead>
<tr>
<th>Glass</th>
<th>Liquid Crystal</th>
<th>Reflective Panel</th>
</tr>
</thead>
</table>

Liquid Crystal

LCD Pros and Cons

- Sandwich of multiple layers
- Thin Film Transistor – RGB
- Fluorescent backlight

Pros
- Portable
- Bright vivid colors
- Longer lifespan – 30,000 hours
- Increase technology = more panels per glass substrate
- Low power consumption

Cons
- Slow response time of panel
- Lower contrast than PDP

PDP

- Large Displays >32"
- High Resolution
- High Brightness
- Good Contrast
- Good Color gamut
- Large viewing angle
- High Speed
- Presently High Cost

Samsung 102” PDP

The World’s Largest Plasma TV
Plasma

- Gas
- Plasma
- North light
- Gas
- Plasma
- UV
- Discharge

PDP

- Gas-filled (xenon and neon) sub-pixels coated with red, green, and blue phosphors
- Voltage applied by electrode
- Exciting the gas to stimulate the phosphors to emit color light beams

PDP Rib Structure (Simple)

- Waffle-like pixel structure for higher light output
- Improves luminous efficiency
- Black levels higher
- Viewing angles the same as conventional ribs
- More complex to manufacture than ribs
PDP Pros and Cons

- 2 glass panels, layer of electrodes and pixels
- Gas plasma emits UV light - phosphors to glow RGB

Pros
- Wide viewing angle
- Large screen size
- More cost effective than large LCD
- Higher contrast than LCD
- More natural colors

Cons
- Screen burn
- Limited lifespan ~ 15,000 hours
- High power consumption

OLED

- Most promising technology
- Already in small sizes
- No inherent size limit
- Conformal displays
- Large viewing angle
- High resolution
- High Speed
- Good color gamut
- Lifetime issues to be solved
- Great threat to LCD 2008?
OLED advantages

- Color Gamut comparable to CRT, with potential to get better – Striking visual appeal
- Thinner – No backlight
- Less Expensive than LCD due to lesser components
  - White + Color Filter route takes away some of this advantage
- Potential for printing in manufacturing.
- Flexible and Conformal Displays

Advantage of Using AMOLED Panel

- wider viewing angle

Transparent OLED

Flexible OLED

Source: UDC

Source: Covion
**OLED Roadblocks**

- **Materials**
  - Small molecule lifetimes still not OK for TV applications, although robust for mobile phones
  - Polymers struggling with material stability
- **Manufacturing**
  - UHV process not easily scalable to larger Mother Glass. Currently, manufacturing restricted to 370 x 470mm
  - Printing (Polymers) still in R&D stage
- **Active Matrix Back plane**
  - Incompatible with the existing a:Si technology
  - LTPS technology (considered suitable for current driven devices) suffers from uniformity problems and restricted to displays < 8"
Each mirror can rotate in one of two directions:
+ 10 degrees or -10 degrees.

+10 degrees is ON state.
-10 degrees is OFF state.

DMD

http://www.dlp.com/dlp_technology/default.asp

Digital Grayscale control

(Note: for clarity, only central column is addressed and no light source is shown)

DMD  Projection Lens

Video Field Time

(Sensations of Gray Shades
By Viewer’s Eye)

(4-Bit Example)

http://www.christiedigital.com/projection101/technologyMovies/DLPcolorWheel.asp

Projection Display

- LCD (Liquid Crystal Display)
  - 3 panels (RGB), Transmissive display
  - 32 Megapixels
- DLP (Digital Light Processing)
  - Digital Micro mirror Device
- LCOS (Liquid Crystal On Silicon)
  - Reflective LCD
  - Higher resolutions and brightness
- Pros
  - Cost effective solution for large screen sizes
  - Side Shot 2™
  - High Pixel Density
- Cons
  - Limited viewing angle
  - Fan noise
### DISPLAY Technology

<table>
<thead>
<tr>
<th>Attribute</th>
<th>PMLCD</th>
<th>AMLCD</th>
<th>LCOS</th>
<th>PDP</th>
<th>FED</th>
<th>DLP</th>
<th>OLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>&lt; 15”</td>
<td>&lt; 15”</td>
<td>&lt; 1”</td>
<td>&gt; 30”</td>
<td>&lt; 15”</td>
<td>&gt; 6”</td>
<td>No limit</td>
</tr>
<tr>
<td>Brightness (nits)</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 500</td>
<td>&lt; 500</td>
<td>&lt; 500</td>
<td>&gt; 10000</td>
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<td>Resolution Medium</td>
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<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Large</td>
</tr>
<tr>
<td>Inherent VA</td>
<td>Small</td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
<td>Large</td>
<td>Large</td>
<td>Large</td>
</tr>
<tr>
<td>Efficiency (lm/w)</td>
<td>6</td>
<td>6</td>
<td>-</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>Color gamut</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Maint &amp; cost</td>
<td>Medium</td>
<td>V. High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Cost</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>&lt; 1</td>
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<td>Market presence</td>
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<td>Established</td>
<td>Entering</td>
<td>?</td>
<td>Established</td>
<td>In 2 years</td>
<td></td>
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</tbody>
</table>

### Future Technologies

- New light emitting display technologies
  - FED
  - Organic LED
  - Radical new emission phenomena
- Need to concentrate on:
  - Full color
  - Low power
  - Low voltage
- The possibilities are endless

### Reflective – Gyronic
(as digital electronic paper)