A Pixel Consists of Approximately $2 \frac{2}{3}$ Triads
A Pixel Consists of Approximately 2 2/3 Triads
Important Properties of Liquid Crystals

- Crystals are transparent
- Can alter the orientation of polarized light passing through them
- Polarization properties can be changed by applying electrical field
- Switching can be done fast
Polarization of Liquid Crystal

Scientific American, November 1997
Liquid Crystal Color Display
LCD Advantages & Disadvantages

- Can have high resolution and very flat glass panels are now being produced relatively cheaply.
- Although currently the most popular display device, what is wrong with this technology?

It throws away too much energy (watts) one-half due to polarization plus a large percent due to light which doesn’t pass through the liquid crystals.
Plasma Display: Advantages & Disadvantages

• The advantage is that they can have high brightness (at the expense of watts). Thus can be used in brightly lit areas.

• The difficulty with plasma displays is that the cell size (pixel) is large relative to a liquid crystal. Thus for a given resolution, the screens must be large.
DMD Structure

Digital Micromirror Device (DMD™)
A True Microelectromechanical System
DMD™ Optical Switching Principle

Pixel Image

+10°

Projection Lens

-10°

Flat

Light From Illuminator

20°

20°

40°

Pixel Mirror

-10° +10°
DMD™ Switching Example (1 On)

- Projection Screen
- Light Source
- Projection Lens
- Light Absorber
- 3 DMD Micromirrors

(Actual Top View)
DMD™ Grayscale Projection
Pulsewidth Modulation

Reset and Parallel Update

Word

Number of LSB Times

<table>
<thead>
<tr>
<th>Word</th>
<th>MSB (1000)</th>
<th>(0100)</th>
<th>(0010)</th>
<th>LSB (0001)</th>
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<tr>
<td></td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>1</td>
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</table>

\[ 2^3 + 2^2 + 2^1 + 2^0 = 1 + 2 + 4 + 8 = 15 \text{ LSB Times} \]

Field Time = 1 + 2 + 4 + 8 = 15 LSB Times

(4-Bit, 16 Gray-Level Example)
How Grayscale is Created

DMD™ Binary Pulsewidth Modulation

Input

(1111)
(1001)
(0100)
(0010)
(0001)
(0000)

Video Field Time

(Sensations of Gray Shade®
By Viewer’s Eye)

4-Bit, 16 Gray-Level Example
3-Chip DLP Optical System

- Lamp & Reflector
- Condenser Lens
- DMD3 (B)
- TIR Prism
- DMD2 (G)
- Projection Lens
- Color-Splitting/Color-Combining Prisms
- DMD1 (R)
DLP Projection System
Digital Micromirror Devices (DMD)

• Pioneered by Texas Instruments. The research on these micromechanical (MEMs) devices started in 1977.

• The first digital light valve projection systems (DLPs) had mirrors measuring 17 microns per side. At 1280 x 1028 resolution (HDTV) this resulted in a rather large chip in 1996.

• Today this technology is used in almost all digital theaters and some home televisions.

• Most theaters now use DLP with 4K resolution (4096 x 2160)
Christie CP4230 Digital Cinema Projector

- 4K DLP
- Screen size up to 105ft (32m)
- 4096 x 2160 resolution
- 2100:1 contrast
Cost of HDTV Displays

Note: Each year the cross over points keep moving to the right.
Modifications to Existing Technology

• The quest for size
Stonybrook’s Reality Deck
Stony Brook’s Reality Deck
Modifications to Existing Technology

- The quest for size
- The quest for brightness
Visual Adaptation

- Luminance (log cd/m²):
  - display ranges from -6 to 8.
  - Starlight: -6 to -4
  - Moonlight: -4 to -2
  - Indoor lighting: -2 to 0
  - Sunlight: 0 to 8

- Range of illumination:
  - Scotopic: Low luminance
  - Mesopic: Moderate luminance
  - Photopic: High luminance

- Visual characteristics:
  - Scotopic:
    - Poor contrast
    - No color
    - Low acuity
  - Mesopic:
    - Good contrast
    - Good color
    - High acuity
  - Photopic:
    - Very high contrast
    - Excellent color
    - Very high acuity
Sunnybrook Display Technology

High resolution colour LCD

High Dynamic Range Display

Low resolution Individually Modulated LED array
Modifications to Existing Technology

• The quest for size
• The quest for brightness
• The quest for energy reduction
How E-Paper Works

GYRICON BEADS

LIGHT STATE

DARK STATE

E INK MICROCAPSULES

LIGHT STATE

DARK STATE

ELECTRODE

NEGATIVELY CHARGED

POSTIVELY CHARGED

Electronic ink is a straightforward fusion of chemistry, physics and electronics to create this new material.
Flexible Tablet-Sized Display From L.G. Philips LCD and E Ink Corporation

http://www.eink.com/
Kindle 2
End