# High Dynamic Range Displays

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## The Demise of the CRT

<table>
<thead>
<tr>
<th>What was good:</th>
<th>LCD corollary:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large viewing angle</td>
<td>Challenge</td>
</tr>
<tr>
<td>High contrast</td>
<td>Challenge</td>
</tr>
<tr>
<td>Consistent EO transfer function</td>
<td>Requires standard</td>
</tr>
<tr>
<td>Good motion rendition</td>
<td>Improving</td>
</tr>
<tr>
<td>50+ years of experience</td>
<td>5 years of experience</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What was bad:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor ambient contrast</td>
<td>Good ambient contrast</td>
</tr>
<tr>
<td>Low light output capability</td>
<td>High light output</td>
</tr>
<tr>
<td>Short life span</td>
<td>Long life span</td>
</tr>
<tr>
<td>Spot size MTF roll-off</td>
<td>High MTF fixed pixel</td>
</tr>
</tbody>
</table>

*These differences are what get us in trouble today*
Our World and the Human Visual System

Display Technology – Conventional Display

- Cold cathode fluorescents (CCFL) provide LCD backlight
- Light spread evenly and does not vary with image content
- Image control is purely in the LCD panel, not the backlight, and is limited to 8-bit signal to Red, Green, and Blue colour channels
Display Technology – HDR Display

- LCD backlight is provided by an array of LED’s
- Each LED is controlled with 8 bit (255 step) signal
  - Brightness is adjusted to level demanded by source image
- LCD panel provides additional 8 bits of brightness control
- LED and LCD panel combine optically to deliver 16 bit performance
- LED’s provide greater brightness while saving power

Blur Correction Algorithm – Image Processing

HDR Image | LED array | LCD with correction | Output image
HDR Display Technology – Veiling Luminance

Receive Image
Drive LED

Divide Image by LED light field to obtain LCD values

Output Luminance is the product of LED light field and LCD transmission (modest error)
HDR Display Technology – Veiling Luminance

The impact on the human visual system of bright objects on nearby dark areas can be calculated.

\[ P(\alpha) = \eta \delta(\alpha) + \frac{c}{\Pi(\alpha)} \]

HDR Display Technology – Veiling Luminance

Veiling Luminance masks imperfection.
HDR Display Technology

- Dual Modulation
- High/Low Resolution and Correction
- Veiling Luminance

Calibration Techniques

- Factory calibration for luminance uniformity
  - Primarily affected by LED manufacturing differences
  - Stored reference model
- Active internal calibration during use
  - Primarily affected by LED differential aging
  - Comparison to stored reference model
- Manual calibration with external instrument
  - Set white point
  - Emulate another display
**Factory Calibration**

**Luminance Uniformity Results**

Uncalibrated 46” HDR display showing medium grey image

Calibrated 46” HDR display showing medium grey image

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**Internal Calibration**

**Software Correction for dim LEDs (extreme case)**
Internal Calibration
Luminance Uniformity before and after software correction

Lifetime Testing Process
50mm diameter Integrating Sphere for LED lifetime test
HDR Display luminance characterization
HDR Display luminance characterization

% Transmission of LCD Color Filters (Normalized to Peak Transmission @ 668nm for Red)
Test of actual RGB LEDs showing Gamut larger than SMPTE “P3”
HDR Display Technology – Summary

- Dual Modulation
- High/Low Resolution and Correction
- Veiling Luminance