Flat Panel Displays: Advanced Technology Trends

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- **Sr. Engineering Manager, Display BU**
  - North American Apps Engineering manager
  - 15+ years engineering experience with NEC LCD Displays.
  - Design demonstration computers and display housings for field demo program. Circuit design & board layout of display interfaces. Mechanical design of equipment housings.
  - Work directly with NLT Technologies Japan to solve technical issues and help define future products.
  - De-bug customer applications and provide design guidance.

- **Over 25 years experience in the electronics industry**
  - Research & development at Cincinnati Microwave (founders of ESCORT radar detectors)
    - Opened a branch office in Sydney Australia
  - Founded US design and manufacturing company – Creative Circuits
Renesas Technology & Solution Portfolio
Display Module Solutions
Sophisticated solutions  Sustainable support

LED Backlight LCDs
- Low power consumption
- Long life LEDs
- Thin profile and light weight design
- Replaceable LED light source unit

Enhanced View TFT (EVT)
- Suited for a variety of ambient-light environments
- Proprietary transflective LCD technologies
  - Reflective-Enhanced View TFT (R-EVT)
  - Transmissive-Enhanced View TFT (T-EVT)

Wide Format LCDs
- More data on a single screen
- 16:9 aspect ratio

Super-Fine TFT (SFT)
- High luminance and wide color gamut
- Superior image quality
- Ultra-wide viewing angles

Industrial Mobile Displays
- Robust feature sets
- Long-term product support
- Amorphous silicon (A-Si) displays
- Low-temperature polysilicon (LTPS) displays

Emerging Technologies
- 2D/3D displays
- On-cell touch
- PCAP touch
You, yes you.

The one with the really Big Brain.

You know who you are.
‘Enabling The Smart Society’

■ Challenge:
  ● As the technology driving today’s smart society evolves the man-to-machine interface remains one of the most critical components. Understanding and selecting the right display with the right capabilities for your product is key.

■ Solution:
  ● This course is an overview of today’s display technologies with a look into the future. No longer simple viewing devices they bring a new range of user enhancements in the form of touch sensor, 3 dimensional imaging, low power and color accuracy. Knowing display technology trends will form the ideas for new products and it will give you a really BIG BRAIN!
Agenda

- New Display Technologies
  - Projected Capacitive (PCAP)
  - On-Cell Touch Technology
  - Louver Displays
  - Autostereoscopic Displays
- SFT - Wide Viewing Angle Technology
- Advancements in TFT Driver Integration
- LED Performance Update
- ColorXCell
- Interface Update
New Display Technologies
R&D Technology Tree

Future

Function Enhancement
- 3D CAD
- 3D Medical
- Automotive
  - Dual-View
- POS/ATM
- Mobile
  - On-cell Touch Panel
- HxDP 3D
  - Stereoscopic Image
  - Simple structure
  - Excellent picture quality

Present
- Mobile
- Mobile
- POS/ATM
- Automotive
  - Dual-View
- 3D CAD
- 3D Medical

Application Enhancement
- Wearable
- Ecology
- E Book
- Mobile
- Mobile
- Mobile
- Consumer
- a-Si Gate Driver
  - Low cost, Slim
- Field Sequential
  - No CF, Low cost, High NTSC, Low power consumption
- Color e-Paper
  - Low Power
- Flexible displays
New Technologies

- **Industrial Touch Panel Solutions**
  - ✔️ *PCAP* with Air Gap or Optical Bonding  ➔ Good outdoor visibility
  - ✔️ *On-cell*  ➔ Future technology for thinner LCD

- **Louver integration**
  - ✔️ New type of Louver, In Backlight  ➔ Improved front viewing while maintaining security.
  - ✔️ Works Well With Touch Panel  ➔ Easy Value-Add produced by NLT factory

- **3D (HxDP Technologies)**
  - ✔️ 3D Enhances machine command and control.
  - ✔️ Medical 3D diagnostic images
Projected Capacitive (PCAP)
Touch Panel Categories

- Resistive type
- Capacitive type
  - Surface Capacitive
  - Projected Capacitive
- Optical type
- SAW type
- Digitizer

* NLT’s Original On-Cell
* NLT developed touch sensor + driver board
Projected-capacitive touchscreens have no moving parts. The only thing between the LCD and the user is ITO and glass, which have near 100% optical clarity.
PCAP Positional Measurement

- As a finger or other conductive object approaches the screen, it creates a capacitor between the sensors and the finger.
- One common measuring technique known as Capacitive Sensing using a Sigma-Delta Modulator (CSD) involves rapidly charging the capacitor and measuring the discharge time through a bleed resistor.
PCAP Structure

Mutual Capacitance PCAP Screen

- Protective Anti-reflective Coating
- Sensing Lines
- Insulating Material
- Driving Lines
- Protective Cover
- Bonding Layer
- Driving Lines
- Sensing Lines
- Glass Substrate
- LCD Display Layers

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*Not to scale*
PCAP Summary

**Advantages**
- Multi-touch/Gesture
- Long life
- Good Durability

**Disadvantages**
- Higher costs
- Gloved operation tradeoff
- Custom design
- Many wires
PCAP Options
Standard Air Gap

Air Gap

Thickness: LCD plus 1mm for PCAP
Standard Air Gap with Surface Treatment

Air Gap w/ Surface Options

Thickness: LCD plus 1mm for PCAP plus <0.2mm
1. AFP - Clear, Hardness 3
2. AFP – AG, Hardness 3
3. AR – Hardness 2
Cover Panel Type

Cover panel bonded with OCA

Cover panel

Thickness: LCD plus 2 to 4mm
OCA – Optically clear adhesives
Cover Panel Type with Surface Options

Cover panel w/Surface Options

Thickness: LCD plus 1mm for PCAP plus <0.2mm
1. AFP - Clear, Hardness 3
2. AFP – AG, Hardness 3
3. AR – Hardness 2
Optically Bonded

Optical Bond

Thickness: LCD plus ~ 1mm
Optically Bonded
Surface treatment for Optical Bonding

Optical Bond w/Surface Options

Thickness: LCD plus ~ 1.2mm
1. AFP - Clear, Hardness 3
2. AFP – AG, Hardness 3
3. AR – Hardness 2
Tough Style Panel

**Optical Bond w/Cover**

Thickness: LCD *plus* ~ 2mm to 4mm
Optically Bonded

Cover panel bonded with OCA
Surface Treatment for Cover Panel

Optical Bond/Cover /Surface Options

Thickness: LCD plus ~ 1.2mm
1. AFP - Clear, Hardness 3
2. AFP – AG, Hardness 3
3. AR – Hardness 2
On-Cell Touch Technology
On-Cell Touch Panel LCD

**Features**
- High image-quality
- Light weight & Thin
- Reduction in assembly process

**Applications**
- Industrial: ATM, KIOSK, etc.
- Consumer: Note PC, Media Player, etc.

Image quality comparison

Conventional  On-Cell
Louver Products

Features
• Focused privacy with good visibility
• Less moire
• Works with touch panel

Applications
• Industrial: ATM, In-flight, KIOSK, etc.
• Consumer: Note PC, Media Player, etc.

Louver placed on backlight side

LCD Panel

Louver
Optical Profile Old vs. New Louver

- **Conventional Type Louver**
- **New Type Louver**

**Brightness**

- Wider bright Area $\rightarrow$ Easy to watch!
- @±20 degree Same light profile

- Same light blocking effect

Horizontal Viewing Angle

-50 -30 -10 0 10 30 50
Optical Profile of Old vs. New Louver

1. Conventional Type Louver
2. New Type Louver

Wider bright Area → Easy to watch!
Autostereoscopic 3D
Conventional vs. NLT 3D Technology

Conventional Design

HDDP* Panel Design

* Horizontally Double-Density Pixels

Lenticular Lens

Conventional needs 2x pixels for 3D while HDDP is same

Pixel pitch is the same for 2D
2D and 3D Simultaneous Images

- 2D and 3D images can be displayed at the same time by changing the input image data => Easy to **mix** 2D and 3D images
6-View Imaging
Multi-View 3D with HxDP Structure

- Actual pixel density is *x times* that of vertical
- Viewer sees native resolution 3D image clearly at many angles

**HDDP Sub-Pixel Structure**

**HxDP Sub-Pixel Structure**

*HxDP: Horizontally x times-Density Pixels*
HxDP Advantage

- **Perfect 2D Images** – Same data is clear from all viewing angles
- **2D and 3D images** - Can be displayed simultaneously

![Diagram showing 2D and 3D images comparison]

- **2D Image**
  - Same Data
  - No "Jagged" 2D Character

- **Multi-view 3D Object** (=2D resolution)
  - View1 Data
  - View2 Data

- **3D Image (2v)**

- **3D Image (6v)**
  - V1
  - V2
  - V3
  - V4
  - V5
  - V6

- **HxDP (e.g. x=6)**
SFT - Wide Viewing Angle Technology
High Aperture Ratio SFT

- New cell structure
- Improved transmissivity
- Same or better than TN
- Applicable to 15” or smaller
  (Larger high resolution panels need different structure)
Development of High Contrast & Brightness

**Improved Contrast**

- Darker black by reducing light leakage
  - High contrast LC material
  - High contrast color filters
  - Optimized cell structure

**Improved Luminance**

- Higher aperture ratio
  - Slimmer wiring
  - Larger aperture area

Conventional pixel

New Pixel

3M color LCD display with LED backlight
Contrast ratio target 1400:1
Luminance 800 nits
Advancements in TFT Driver Integration
Conventional TAB Details

Conventional TAB assemblies
Chip-On-Film (COF) Details

COF TFT Gate Driver

COF TFT Source Driver
Chip-On-Glass (COG) Details

- COG TFT Gate Driver
- COG TFT Source Driver
- Flex-to-Glass Table Bonding Area
LED Performance Update
CCFL vs LED B/L (Long Life) Power Comparison

35% - 50% Lower Power Than CCFL

Note: Comparison of B/L unit only, Power of CCFL does not include Inverter Loss.
## Competitive Comparison – 10.4” VGA

### Longer Life with Lower Power !!!

<table>
<thead>
<tr>
<th>Item</th>
<th>NLT</th>
<th>Company &quot;A&quot;</th>
<th>Company &quot;B&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminance</td>
<td>450cd/m²</td>
<td>450cd/m²</td>
<td>450cd/m²</td>
</tr>
<tr>
<td>Thickness</td>
<td>10.5mm</td>
<td>8.0mm</td>
<td>12.5mm</td>
</tr>
<tr>
<td>Weight</td>
<td>475g</td>
<td>390g</td>
<td>580g</td>
</tr>
<tr>
<td>Power Consumption (B/L Only)</td>
<td><strong>2.7W</strong></td>
<td><em>(4.4W)</em></td>
<td><strong>3.7W</strong></td>
</tr>
<tr>
<td>Life Time</td>
<td><strong>70,000H</strong></td>
<td>50,000H</td>
<td>50,000H</td>
</tr>
<tr>
<td>Room Temp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Temp.</td>
<td><strong>60,000H</strong></td>
<td></td>
<td>50,000H</td>
</tr>
</tbody>
</table>

- Ratings based on stand alone LED device
### Competitive Power Comparison

#### NLT Displays are Lower Power !!!

<table>
<thead>
<tr>
<th>Compare with other vendor</th>
<th>Power Consumption [W]</th>
<th>Module Luminance [cd/m²]</th>
<th>Forward Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.4”</td>
<td>B</td>
<td>4.2</td>
<td>450</td>
</tr>
<tr>
<td></td>
<td>NLT</td>
<td>2.3</td>
<td>450</td>
</tr>
<tr>
<td>10.4”</td>
<td>B</td>
<td>6.6</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>NLT</td>
<td>3.0</td>
<td>500</td>
</tr>
<tr>
<td>12.1”</td>
<td>C</td>
<td>5.8</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>NLT</td>
<td>4.0</td>
<td>500</td>
</tr>
</tbody>
</table>

- *Power is determined by same luminance*
Luminance Life Time CCFL vs. LED

Greatly Improved Lifetimes with Long Life LEDs

21.3type Life Time Estimation (CCFL-BL vs LED-BL) \( (t_a=25°C) \)

- **CCFL Backlight**
- **LED Backlight**

Luminance (a.u.) vs. Time (hrs.)
LED Color Shift vs. Time

- Color shift is less than CCFL
- LEDs shift in the blue direction from their original value
- Most color shift is caused by the degradation of the LED reflector

LED LCD Color shift $\Delta x$ (Ta=25°C)

<table>
<thead>
<tr>
<th>Time [H]</th>
<th>$\Delta x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.020</td>
</tr>
<tr>
<td>10</td>
<td>-0.010</td>
</tr>
<tr>
<td>100</td>
<td>0.000</td>
</tr>
<tr>
<td>1,000</td>
<td>0.010</td>
</tr>
<tr>
<td>10,000</td>
<td>0.020</td>
</tr>
<tr>
<td>100,000</td>
<td>0.030</td>
</tr>
</tbody>
</table>

LED LCD Color shift $\Delta y$ (Ta=25°C)

<table>
<thead>
<tr>
<th>Time [H]</th>
<th>$\Delta y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.0200</td>
</tr>
<tr>
<td>10</td>
<td>-0.0100</td>
</tr>
<tr>
<td>100</td>
<td>0.0000</td>
</tr>
<tr>
<td>1,000</td>
<td>0.0100</td>
</tr>
<tr>
<td>10,000</td>
<td>0.0200</td>
</tr>
<tr>
<td>100,000</td>
<td>0.0300</td>
</tr>
</tbody>
</table>
CCFL Color Shift vs. Time

- CCFLs shift in the yellow from their original value.
- Color shift in CCFLs is due to changes in the phosphor and the degradation of the optical parts due to ultra-violet exposure.

CCFL-LCD Color shift \( \Delta x \) (Ta=25\(^\circ\)C)

CCFL-LCD Color shift \( \Delta y \) (Ta=25\(^\circ\)C)
ColorXCell
What is ColorXCell?

- ColorXCell is a proprietary hard coded algorithm integrated into the LCD module’s timing controller ASIC that corrects color without sacrificing performance.

- Original source images seen LCD displays tend to look muted. ColorXCell enhanced displays correct by pushing the panel’s color points out to their original color saturation levels.
Color Conversion Comparison

**Low color gamut LCD**

Original picture source  
Displayed picture  
Tinted color

**Color Conversion LCD**

Original picture source  
Embedded in T-con  
LCD Display

ColorXcell

- Color hue
- Vividness
- Brightness

High Color Reproduced
Conventional LCDs alter the original source image color reproduction.
**Color Conversion Effect**

**Conventional LCD**

- Single color trajectory
- Blackbody trajectory
- NTSC
- AdobeRGB
- sRGB
- LCD color area
- Skin
- Lip
- Empty
- Greenery
- Kiwi

**Color Conversion LCD**

- Single color trajectory
- Blackbody trajectory
- NTSC
- AdobeRGB
- sRGB
- LCD color area
- Skin
- Lip
- Empty
- Greenery
- Kiwi

**Color tinted**
Color plots move closer to white

**Original vividness reproduced**
Color plots are back near original points
Color Gamut vs. Transmissivity

- To increase color performance, highly saturated color filters are used which *reduce* transmissivity
- **ColorXCell** technology:
  - Reproduces truer color than competitive solutions
  - Using standard low color gamut color filters keeps transmissivity high reducing power required for the backlights
### ColorXCell Part Numbers

<table>
<thead>
<tr>
<th>Size</th>
<th>Resolution</th>
<th>Part Number</th>
<th>ColorXCell</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5”</td>
<td>VGA</td>
<td>NL6448BC20-30/30C/30D/30F</td>
<td></td>
</tr>
<tr>
<td>8.4”</td>
<td>SVGA</td>
<td>NL8060BC21-11/11C/11D/11F</td>
<td></td>
</tr>
<tr>
<td>10.4”</td>
<td>SVGA</td>
<td>NL8060BC26-35/35C/35D/35F</td>
<td></td>
</tr>
<tr>
<td>10.6”</td>
<td>WXGA</td>
<td>NL12876AC18-03/03D</td>
<td></td>
</tr>
<tr>
<td>12.1”</td>
<td>WXGA</td>
<td>NL12880BC20-05/05D</td>
<td></td>
</tr>
<tr>
<td>Under Development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.3”</td>
<td>XGA</td>
<td>NL10276BC26-32D</td>
<td></td>
</tr>
</tbody>
</table>

Standard industrial LCD’s have some color or tint variance from the source image.

NLT’s ColorXcell enables images be reproduced that are comparable in color intensity to the original video source.

Vivid images without increasing power consumption.
Interface Update
Common Interfaces

There are many video interface standards but only a few are used by the display manufacturers:

- Parallel RGB
- LVDS
- MIPI
- CPU direct

Honorable mention

- DVI
- HDMI
- DisplayPort
- Thunderbolt
MIPI Alliance

- **MIPI – Mobile Industry Processor Interface**
  - An alliance of industry leaders that set hardware and software standards for interfacing in mobile devices.
  - Non-profit organization - Began 2004
  - Board members include Intel, Nokia, Samsung, STMicroelectronics, Toshiba & Texas Instruments.
MIPI – Display Interface Specifications

- **Display Serial Interface (DSI)** – CLK & Data differential pair
  - Uses D-PHY “physical” serial interface
  - Defines high-speed serial interface between display and host processor
  - Builds on the DPI-2 and DCS specifications

- **Display Command Set (DCS)** – Common command set for controlling DSI, DPI, DBI

- **Display Pixel Interface (DPI-2)** – conventional parallel RGB

- **Display Bus Interface (DBI-2)** – Host processor bus direct
  - Type A – M68 compatible interface
  - Type B – i80 compatible interface
  - Type C – Serial interface
## MIPI Interface Comparison

<table>
<thead>
<tr>
<th>Spec</th>
<th>DSI</th>
<th>DBI</th>
<th>DPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential CLK &amp; data signal pairs. Depending on the amount of data, can increase from 1 to 4 (lane) data pairs. H/W support required. Differential signal level is less than ±70mV.</td>
<td>Same as CPU I/F CMOS signal Asynchronous communication</td>
<td>Same as RGB I/F CMOS signal Synchronous communication</td>
<td></td>
</tr>
<tr>
<td><strong>CLK</strong></td>
<td>~ 500MHz (specification is 1.3GHz, for practical purposes as described above)</td>
<td>~ 40MHz (Flux law on the transmission quality FPC)</td>
<td>~ 40MHz (Flux law on the transmission quality FPC)</td>
</tr>
<tr>
<td><strong>Transfer rate</strong></td>
<td>~ 500Mbps / lane 2Gbps_max (4 lane)</td>
<td>~960Mbps (24bit parallel)</td>
<td>~960Mbps (24bit parallel)</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>~ HD (4-lane)</td>
<td>~SVGA</td>
<td>~SVGA</td>
</tr>
<tr>
<td><strong>Number of wires required</strong> (Only for display data transfer)</td>
<td>4〜10</td>
<td>28 (24bit parallel)</td>
<td>28 (24bit parallel)</td>
</tr>
</tbody>
</table>
Interface Trend

qHD
540 x 960
MoVI3(FaltLink3G)
RGB
mipi-DSI(DPI)
mipi-DSI(DBI)

wVGA
480 x 864
MoVI3(FaltLink3G)
MDDI 1.0 -> MDDI 1.2
RGB
BUS
mipi-DSI(DPI)
mipi-DSI(DBI)

nHD
360 x 640
MoVI3(FaltLink3G)
BUS
mipi-DSI(DPI)
mipi-DSI(DBI)

HVGA
320 x 480
MoVI3(FaltLink3G)
MDDI 1.0 -> 1.2
RGB
BUS
mipi-DSI(DPI)
mipi-DSI(DBI)

wQVGA
240 x 432
MoVI3(FaltLink3G)
MDDI 1.0
RGB
BUS
mipi-DSI(DPI)
mipi-DSI(DBI)

QVGA
240 x 320
MoVI3(FaltLink3G)
MDDI 1.0
RGB
BUS
mipi-DSI(DPI)
mipi-DSI(DBI)
The Goods and Not-So-Goods of MIPI

- MIPI standardizes the I/F for mobile and tablet products
- Supports high resolution
- Slim FPC I/F due to the reduction of signal conductors

- Pay $10,000 per year to the MIPI Alliance for the logo
DVI – Digital Visual Interface

- Video display interface developed by Digital Display Working Group – 1999

- Types:
  - DVI-D – digital only
  - DVI-A – analog only
  - DVI-I – digital and analog

- PanelLink TMDS signaling by Silicon Image
HDMI – High-Definition Multimedia Interface

- Digital display interface developed by HDMI consortium - 2003
- Compatible with DVI
- Royalty !!
DisplayPort

- Digital display interface developed by VESA - 2006
- Designed to replace VGA, LVDS, DVI
- Supports much of the same functionality as HDMI. Expected to compliment not replace it.

**Versions:**
- mDP – mini DisplayPort
- eDP – embeded DisplayPort
- DDM – Direct drive monitor
- iDP – internal DisplayPort
- PDMI – Portable display media interface

**Royalty free!!**
Thunderbolt

- Interface for connecting peripherals to a PC
- Developed by Intel - 2009
- Uses mini DisplayPort connector
‘Enabling The Smart Society’

Challenge:

- As the technology driving today’s smart society evolves the man-to-machine interface will remain a critical component. New high performance integrated displays will enhance the user experience.

Solution:

- This course is an overview of today’s display technologies with a look into the future. No longer simple viewing devices they bring a new range of user enhancements in the form of touch sensor, 3 dimensional imaging, low power and color accuracy. Knowing display technology trends will form the ideas for new products and it will give you a really BIG BRAIN!

Feeling smarter already?
Questions?
Please Provide Your Feedback...

- Please utilize the ‘Guidebook’ application to leave feedback

- Ask me for the paper feedback form for you to use...