Implementing Automotive Displays with SerDes Daisy Chaining & Local Dimming Backlight Architecture

Logan Cummins
Systems Engineering & Marketing – Automotive Infotainment
The automotive display market is continuing to evolve; the number of displays inside vehicles is drastically increasing while auto makers are looking to differentiate their customers’ experiences through improving picture quality and display performance. This session will provide an introduction to the infotainment cockpit architecture, daisy-chaining display technology, and increasing picture quality through local dimming backlight architecture. A demonstration of the SerDes daisy chaining and local dimming will also be demonstrated.

Training level: Intermediate

What you’ll learn:
In this presentation you’ll learn about the market trends, typical customer design challenges, and what types of designs TI has for local dimming and daisy chaining displays.

Questions/Dialog: Muted call, submit questions or comment via chat.
Outline

• Automotive display trends
• Infotainment display architecture
• IVI SerDes & daisy-chaining
• Local dimming backlight architecture
• System implementation
  • Reference design
  • Demo videos and explanation
  • Future Work
• Wrap-Up
• Questions
Automotive Display Market: Global Shipments

**Automotive Display 2019-2024 CAGR: 6.86%**

Average ~1.66 displays per vehicle in 2022 based on 89M vehicle shipments

Average ~2 displays per vehicle in 2027 based on 104M vehicle shipments

Data pulled from Stategy Analytics MetrixLive: Infotainment & Telematics
Evolution of Automotive Display

Yesterday

- 720p
- 480p
- 240p

+ 480p/1080p

Cluster

PM LCD

LCD-VA/TN/IPS

a-Si TFT

LTPS LCD

Today

- ~2k/1080p
- 720p

+ 480p/720p

Cluster/HUD

Tomorrow

- 4K
- 2K

+ 720p/1080p

+ 720p/1080p

Head Unit

Cluster/HUD

RSE

Mini-LED

OLED

Segment Display

Local Dimming

Micro-LED

Texas Instruments
Re-architecting the cockpit

- 1080P AR HUD
- 2K Full display cluster
- 2K Passenger display
- 3K Center stack display
- Automotive head unit / cock-pit
FPD-Link IV Daisy Chain Architectures

Daisy-chained displays

Point-to-point connection

Content duplication

Different content & same resolution

Different content & resolution

Des

Ser

SoC

Des

Ser

SoC

Des

Ser

SoC

Des

Ser

SoC

Des

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SoC
Features & Benefits

Transmission of video, bidirectional control (I²C, SPI), GPIO, and power over twisted pair or coaxial cable assemblies

FPD-Link → eDP/DP deserializer
- Supports Display Port1.4b HBR3/HBR2/HBR/RBR up to 8.1 Gbps/lane
- 2 x eDP/DP main link with selectable 1, 2 or 4 lanes each

Daisy-chaining and Splitter configurations
Video networking supported by:
- Super-frame, MST based networking capability for multiple display architectures
- Daisy-chaining support

Multi protocol compatibility
- Backwards compatibility with FPD-Link III serializers
- Backwards compatibility with FPD Link III deserializers

Diagnostic functions
- CRC and ECC support
- Embedded voltage and temperature sensors
Display Technology  LCD TFT Technology

- **Fundamentals**
  - Backlight illumination required
  - Liquid crystal layer blocks or passes-through the backlight per RGB sub-pixel to create each pixel

- **Limitations**
  - Liquid crystal can’t block 100% of light during dark pixel
    - Dark/black pixels still partially illuminate; never a deep, true black
    - Dim backlight based on image content
  - Transmissivity of all-layers is only 5-10%

- **Backlight types**
  - Direct-lit, locally dimmed (left)
  - Edge-lit, globally dimmed (right)

Source: Meko
Local Dimming Concept

- In Local Dimming backlight, LEDs under the LCD panel are divided into many small zones.
- The brightness of each zone is adjusted according to different display content.
- Automotive HMI – lots of black backgrounds

**Goals**
- Improve contrast ratio greater than ~1000:1 in traditional automotive displays
- “Darker blacks” and “brighter whites”
- Lower backlight power consumption
Local Dimming Architecture

<table>
<thead>
<tr>
<th></th>
<th>Global Dimming</th>
<th>Local Dimming</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCON</td>
<td>Process Video stream only</td>
<td>Process both Video stream and backlight control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>signal</td>
</tr>
<tr>
<td>LED Backlight Unit</td>
<td>Mostly edge-lit</td>
<td>Direct lit only. Each zone contains at least one LED</td>
</tr>
<tr>
<td>LED Driver</td>
<td>Channel current output global controlled</td>
<td>Channel current output individually controlled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Digital interface cascaded</td>
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</tbody>
</table>

System Board → Timing Controller (TCON) → LCD Panel

Video Stream → Timing Controller

LED Backlight Control Signal → LED Driver

Digital interface cascaded

SPI
**TLC6C5748-Q1**

48ch, 16bit PWM LED Driver with low headroom voltage and high output voltage

### Features

- 48 Outputs with 7bit DC for each output
- 16bit PWM Constant-Current with 7bit Brightness Control and 3bit Max Current Control for 31.9mA, no external RIREF resister
- IC Supply Voltage Range: 3.0 – 5.5V
- LED Breakdown Voltage: 11V
- Precise Constant Current Regulation:  
  - Channel-to-Channel: ± 2% (typ)  
  - Device-to-Device: ± 2% (typ)
- Low Headroom Voltage: 0.25V@19mA
- LED Open/Short Detection
- Over Temperature Detection
- Power Save Mode: 7uA consumption
- HTTSSOP-56 Package (DCA)  
  - 6.1 mm * 14 mm
- Operating Junction Temperature Range: -40 C to +125C

### Benefits

- Best to drive 48 LED zones with uniformity
- Chip-on-LED-board architecture
- Direct daisy chain interface with TCON controller
- Max 3 single-junction LEDs/ 1 dual-junction LED in series
- Reduces system power consumption
- Reduces system cost

### Applications

- Automotive Local Dimming Backlight
- Automotive Pixel Lamp
- Automotive RGB display

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![Diagram](image-url)
TLC6C5748-Q1 interface

SIN: Serial data input for the 769-bit common shift register.
SCLK: Serial data shift clock, SIN data is shifted to internal common register at the rising edge.
LAT: LAT is used to latch the data to GS register to display.
GSCLK: Reference clock for the grayscale (GS) PWM control for all outputs.

Whole data for one frame
Low for GS data, high for control data
Shift 769 bits data and input LAT pulse
**XTIDA-020036 384-Zone 12” Local Dimming Backlight Reference Design**

**Features**
- 384 zones & LEDs
  - 12x32 matrix; 1S1P
  - 0.9 cm pitch
- PCB Specifications
  - Direct driver on back of PCB
  - 2 layer PCB
- SPI control for 8x daisy-chain
- 8x 48-ch low-side LED drivers
- Compatible with local dimming TCONs
- LED Specifications
  - OSRAM Mini TOPLED White 120° SMD
  - Size: 2.3mm x 1.9mm (91mil x 75mil)
  - Single junction @ 3.05V forward voltage
  - 20mA per LED

**Benefits**
- Provides data-points and guidance on signal integrity and thermals
- Can be retrofit into 12.3” display panel for local dimming demo with LCD
- Demonstrates high zone count with 2-layer routing

**Tools & Resources**
- TIDA-020036 Folder
- Design Guide
- Design Files: Schematics, BOM, Gerbers, Software, etc.
- Device Datasheets:
  - TLC5955
  - SN74LVC2G17
  - LCW MVSG.EC-BXCX
XTIDA-020039/48 Local Dimming TCON, FPD-Link 4, & Power Reference Design

Features

• Local dimming zone dimming calculations
  • HX8880-D03
  • Up to 448 local dimming zones (36 max row/col)
• Controls XTIDA-020036 384-zone backlight design
• System power & SPI interface for LED driver control
  • Data
    • GSCLK, SCLK, Latch, MISO, MOSI
• Power
  • LED bias voltage: 3-7V
  • System Power: 3.3V
• Video Input Interface
  • XTIDA-020048
    • FPD-Link IV Deserializer DP output
  • XTIDA-020039
    • DP connector

Benefits

• Provide end-to-end demonstration of SerDes to local dimming signal path
• Evaluate TCON local dimming generation based on input video

*XTIDA-020039 doesn’t have FPD-Link, and instead used DP input
Automotive Display Demo SerDes Daisy Chaining & Local Dimming Backlight

- Off-Battery Buck
- Low Vin LDO
- Low Vin Buck
- Off-Battery Buck VLED
- USB2ANY MCU
- 98x Deserializer
- Local Dimming TCON, FPD-Link IV, & Power PCB XTIDA-020048
- Display Panel 1920x720p 12.3°
- Buffers
- TLC65748-Q1 x8
- VLED
- MOSI
- SCLK
- LATCH
- GSCLK
- MISO
- CLKS/Latch
- LED Driver & LED PCB XTIDA-020036
Demo Hardware Setup & Overview
2x Daisy Chain of 1920x720p 12.3” Display Panels Based on 983 Pattern Generation Output
Locally Dimming Demo

• Local dimming performance depends on:
  • **Zone count**
  • Native contrast ratio of the panel
  • LED/zone locality (bleed into neighboring zones)
  • Dimming algorithm
    • Spatial filtering, thresholds, aggressiveness
Module Height vs. Light Uniformity Comparison

- Uniformity depends on:
  - LED pitch
  - LED angles
  - Air gap
  - Diffuser films
  - Light guide & grids

- Potential improvements:
  - LEDs with wider radiation pattern
  - Stronger diffuser
  - More LEDs
  - Light guide/grid

![Diagram of LC Panel, Diffuser, Air Gap, Substrate/PCB, LED Light Spread, and Luminous Intensity](image)

X,Y distance from center of LED
Future Work & Resources

• Future Work
  – Continue to develop daisy chain and local dimming demo
    • Daisy chain
      – Showcase super-frame example from GPU
    • Local dimming
      – Optimize optical stack-up
      – Power and contrast comparison analysis

• Resources & Collateral
  – End Equipment Pages
    • Central Information Display
    • Cluster Display
  – Local Dimming Contributed Article
    • EEWorldOnline.com & PowerElectronicsTips.com
      – A better automotive display from pixel to picture with local dimming
      – Higher contrast, better resolution: Automotive display full-array local dimming

Stay tuned in with your local FAE for hardware updates and most recent collateral!
Wrap-Up

• Automotive display market is growing and experiencing new technology adoption

• Head-unit to cockpit transition brings opportunity for daisy-chaining architecture

• Automotive displays lagging in optical and visual performance.
  – Full-array local dimming can bridge gap between low-contrast LCD and OLED options
Questions?
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