DLP® for HUD and Adaptive Lighting

April 25th. 2019
DLP introduction –
A scalable, high quality digital imager

Traditional DLP Display markets…

Cinema Projection
(>15 years)

Standard Projection
(>15 years)

Pico Projection
(>5 years)

>50Mu shipped

DLP beyond projectors…

Industrial
Medical
Security
Instrumentation
Automotive
DLP automotive technology: overview

Optical MEMS (Micro Electro-Mechanical System) device
DLP® technology: automotive qualified

- Automotive qualified using industry standard testing
- Extended operating temperature -40 to 105 °C
- Hermetically sealed packaging
- PPAP documents available upon request
- In production and shipping in volume
DMD 100 Qualification

- DLP automotive qualified chipset released in April 2015
- DLP automotive completed and passed tier1 qualification requirements
- First OEM customer shipping production since 2Q17
- “DMD100” is derived from AEC-Q100 requirements with minor exceptions.
- Most commonly asked question: Is Shock/Vibration a concern?

<table>
<thead>
<tr>
<th>Test Category</th>
<th>Tests</th>
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<tbody>
<tr>
<td>Accelerated Environmental Stress</td>
<td>Unbiased HAST</td>
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<tr>
<td></td>
<td>Temperature Cycling</td>
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<td>Power and Temp Cycling</td>
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<td>High Temp Storage Life</td>
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<td>Low Temp Storage Life</td>
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<td></td>
<td>Resistance to UV</td>
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<tr>
<td>Life Tests</td>
<td>High Temp Operating Life</td>
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<tr>
<td>Package Assembly Integrity</td>
<td>Wire Bond Shear</td>
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<td></td>
<td>Wire Bond Pull</td>
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<tr>
<td>Cavity Package Integrity</td>
<td>Mechanical Shock</td>
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<tr>
<td></td>
<td>Vibration</td>
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<td></td>
<td>Fine/Gross Leak</td>
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<tr>
<td></td>
<td>Package Drop</td>
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<td></td>
<td>Die Pull</td>
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<td>Internal Water Vapor Analysis</td>
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<table>
<thead>
<tr>
<th>Tests</th>
<th>Conditions</th>
<th>Samples</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>Mechanical Shock</td>
<td>1500 g, 5 shocks</td>
<td>117</td>
<td>Pass</td>
</tr>
<tr>
<td>Vibration</td>
<td>20g</td>
<td>117</td>
<td>Pass</td>
</tr>
</tbody>
</table>
DLP automotive business model

DLP®

PGU Module Makers
(Tier2s)

System Integrators
(Tier1s)

OEM's

DMD Controller

DMD

DLP Projector
(Optics, mechanicals, DMD, and illumination)

Integration & Design Support

Roadmap Alignment & Technology Evaluation

TI's role

Chip Supplier

PGU Design Support
DLP Automotive Applications

**Interior Display**
- **Wide** field of view, up to 12°
- **Farther** virtual images, up to 20m
- **Efficient** non-polarized imager
- **Vivid** image quality across temp

**Exterior Lighting**
- **Glare-free** high beam
- **LASER** or **LED** illumination
- **Symbol** Projection
- **Fully** Programmable beam
Automotive qualified **chipsets**

**DLP3030-Q1 Chipset**
- 0.3” DMD (864 x 480 resolution)
- -40 to 105 °C operation
- 60Hz video refresh
- Supports up to 5000:1 dimming ratio
- RGB video interface

**DLP5530-Q1 Chipset**
- 0.55” DMD (1152 x 576 resolution)
- 3x mirror array area vs. DLP3030-Q1
- RGB or OpenLDI video interface
- On-chip:
  - Video memory + diagnostics
  - LED dimming controller
  - DMD power management
Head-up Display
HUD Geometry & Terminology: 12 x 3° FOV @ 2m VID

- **Virtual image distance (VID)**
- **Windshield**
- **Eyebox (130 x 60mm)**
- **User’s Field of View (FOV)**
- **Available volume for HUD optics**
HUD Geometry & Terminology

• Field of view
  – The angle subtended from the driver’s eye to the virtual image

• Virtual image
  – HUD image that appears to “float” at some focal distance in space

• Virtual Image Distance
  – The focal distance where the virtual image appears to reside

• Eyebox
  – The area in which the HUD virtual image is viewable by the driver
DLP HUD simplified block diagram

- **Optics**
  - Diffuser Screen
  - DMD
  - RGB LEDs

- **Electronics**
  - DMD Controller
  - Illumination control & drive
  - Power mgmt

- **Host Processor**
  - RGB video
  - Control

- **HUD optics**
- **DLP PGU**
**DLP technology brings new functionality to HUD**

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<tr>
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<th>Past</th>
<th>Present</th>
<th>Future HUDs</th>
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<tbody>
<tr>
<td><strong>Narrow FOV &lt;4°</strong></td>
<td>Redundant display VFD or TFT 1-2 Colors</td>
<td>Short VID Medium FOV 7-8° TFT Basic Colors</td>
<td>AR capable Long VID 2-20m Primary display Real-time processing High Brightness / Full color palette</td>
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<tr>
<td><strong>Medium FOV 7-8°</strong></td>
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<td></td>
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<tr>
<td><strong>Wide FOV &gt;10°</strong></td>
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Automakers and Tier-1 suppliers now have the ability to create dynamic HUD systems for today and for future AR, holographic films and waveguide displays.
True augmented reality functionality
Requires VID > 7.5m and FOV > 10°
HUD architectures

**TFT**

- Driver
- Windshield
- HUD Mirrors
- TFT

**DLP Technology**

- Driver
- Windshield
- HUD Mirrors
- Diffuser screen
- DLP Projection Engine
HUD architectures

TFT

Driver

Sunlight

HUD Mirrors

TFT

DLP Technology

Driver

Sunlight

HUD Mirrors

Diffuser screen

DLP Projection Engine
AR virtual image distances > 7m

The longer the VID, the greater the HUD magnification resulting in higher surface temperatures

<table>
<thead>
<tr>
<th>Spec</th>
<th>TFT</th>
<th>Diffuser</th>
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<tbody>
<tr>
<td>Max Operating Temp</td>
<td>95 to 105°C</td>
<td>150 °C</td>
</tr>
<tr>
<td>Sun Light Absorption (Visible Spectrum)</td>
<td>~ 95%</td>
<td>&lt; 1%</td>
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Sunlight study: temperature rise

TFT Panel Temperature rise is ~ 6x faster than the DLP Diffuser
(IR/UV solar irradiance filtered out)

DLP Technology Advantages:
- No performance derating
- No turn off over temp
- Improved reliability & lifetimes

Temp Increase @ 12m VID

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<th>TFT</th>
<th>Diffuser</th>
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<tr>
<td></td>
<td>+ 190°C</td>
<td>+ 34°C</td>
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Note: Off Axis sunlight is up to 3x worse peak irradiance and must be accounted for in thermal simulations.
DLP technology benefits in HUD applications:

- **Wide Field of View** (supports up to 16 x 8° FOV and eyebox size > 140 x 120mm)
- **True Augmented Reality** (up to 20m virtual image distance; withstands solar load)
- **Brightness @ Low Power** (4-6x efficient vs. TFT @ < ½ power; 15k cd/m² brightness)
- **Image quality does not derate over temp** (-40 to 105 °C)
- **Unpolarized** (HUD images are viewable with polarized sunglasses)
- **Color Saturation** (DLP technology is 125% NTSC color gamut)
- **Future Proof** (DLP technology works w/ waveguides, holographic films and lasers)
DLP technology: design-in support tools

E2E Support & Application Notes

Evaluation Modules

DLP3030-Q1 Optical Module (PGU)

DLP3030-Q1 Combiner HUD EVM

DLP3030-Q1 Electronics EVM
Adaptive Lighting
Illuminate the future of automotive

Vehicles are adopting more complex lighting systems – moving from static incandescent bulbs towards dynamic LED illumination and even adaptive driving beam technologies – to embrace more efficient and creative automotive lighting designs.
Flexibility to create custom, fully programmable headlight systems that reinvent how vehicles and drivers interact

Customizable beam pattern

Allows designers to create headlight systems that could allow drivers to keep high beams on while operating a vehicle in sub-par conditions through partially or fully dim individual pixels.
Flexibility to create custom, fully programmable headlight systems that reinvent how vehicles and drivers interact

Adaptive driving beam (ADB) solution

Allows automakers and Tier-1 suppliers to control every one of the more than one million pixels in each headlight to maximize brightness and minimize glaring for oncoming traffic or reflection from retroreflective traffic signs.
Only automotive technology on the market that is both fully programmable and offers the highest resolution available.

Transforms headlight systems into communication channels by projecting relevant information on the road that can enhance communication between drivers, pedestrians and other vehicles.

Programmable lighting technology
DLP® Technology in Digital Headlights

Benefits of DLP® Technology

<table>
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<tr>
<th>Feature</th>
<th>Design Benefit</th>
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<tbody>
<tr>
<td>Automotive qualified</td>
<td>First DLP Chipset engineered specifically for Automotive Applications</td>
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<tr>
<td>Highest Resolution</td>
<td>Delivers &gt;1.3M Pixels per Headlight for most versatile Projection – Enables Transition from Lighting to Communication (Car2X)</td>
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<tr>
<td>Fully programmable</td>
<td>Supports all Kinds of dynamic Adjustments, e.g. different geographic Regions, Leveling, Cut-off Lines / Kinks</td>
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<tr>
<td>Small Form Factor</td>
<td>Allows compact Optics supporting Minimum Projection Lens Height for stylish Vehicle Design</td>
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<tr>
<td>Light Source agnostic</td>
<td>Flexibility for Designers, allowing to select LED or Laser Illumination</td>
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High Resolution Smart Headlight

- **Glare-free** High Beam
- **LASER** or LED Illumination
- **Symbol** Projection
- **Fully** Programmable Beam
DLP5531Q1EVM - Headlight EVM

- Evaluation Module (EVM) for DLP553X-Q1 includes electronics serving the HUD and Headlight applications
- EVM is available for Purchase online and through Distribution
Thank You!
For more information, please visit our website at:
http://www.ti.com/dlp-chip/automotive/overview.html