



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...



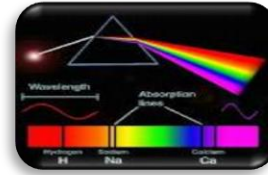
Industrial



Medical



Security

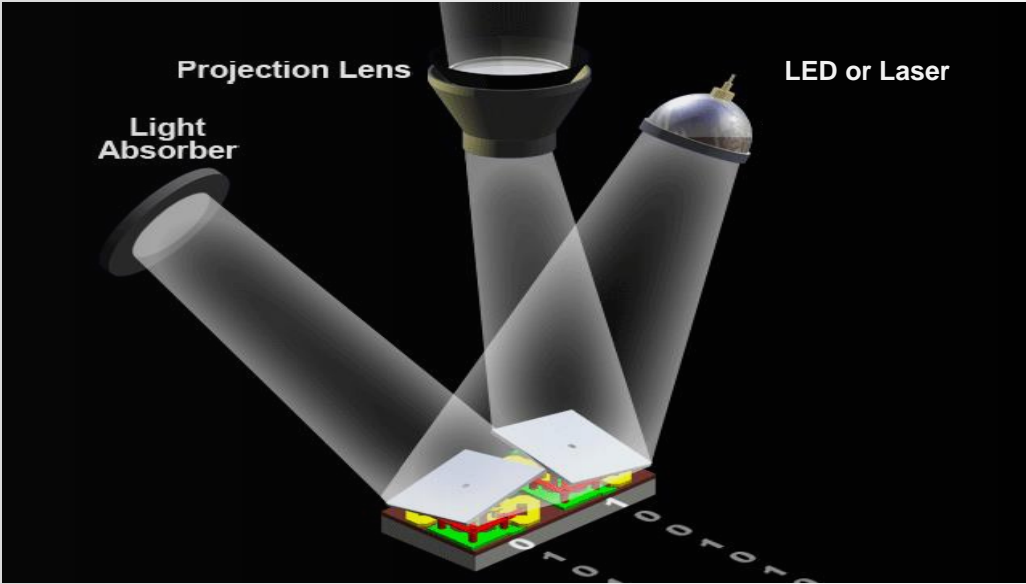
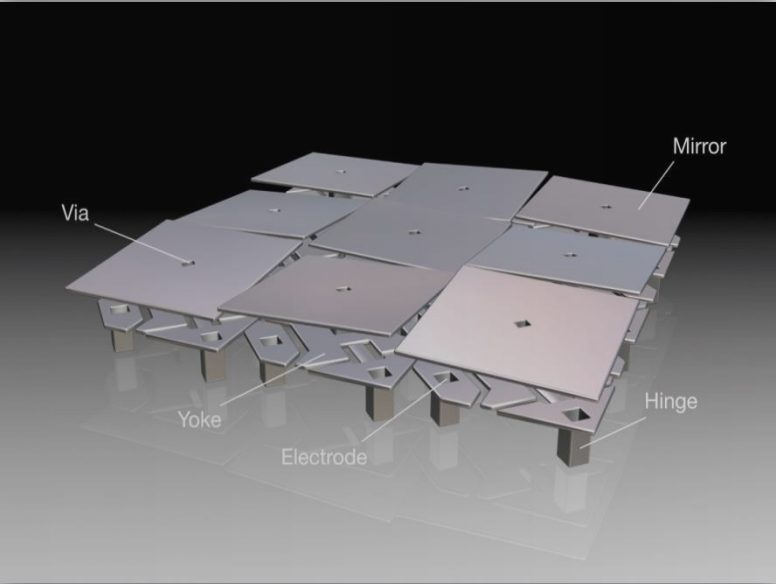


Instrumentation



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

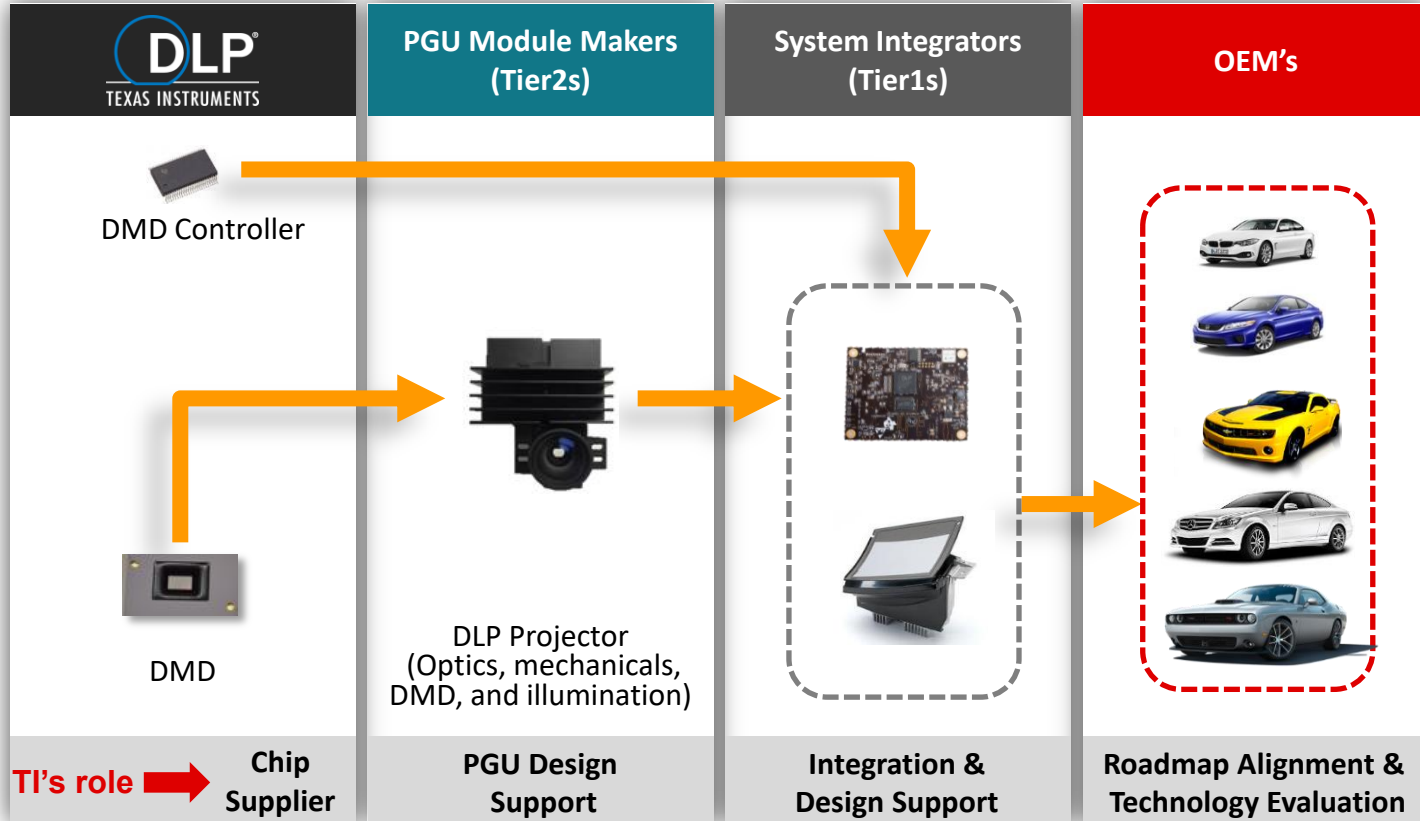
DMD 100 Qualification

- 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?

Test Category	Tests
Accelerated Environmental Stress	Unbiased HAST Temperature Cycling Power and Temp Cycling High Temp Storage Life Low Temp Storage Life Resistance to UV
Life Tests	High Temp Operating Life
Package Assembly Integrity	Wire Bond Shear Wire Bond Pull
Cavity Package Integrity	Mechanical Shock Vibration Acceleration Fine/Gross Leak Package Drop Die Pull Internal Water Vapor Analysis

Tests	Conditions	Samples	Result
Mechanical Shock	1500 g, 5 shocks	117	Pass
Vibration	20g	117	Pass

DLP automotive **business model**



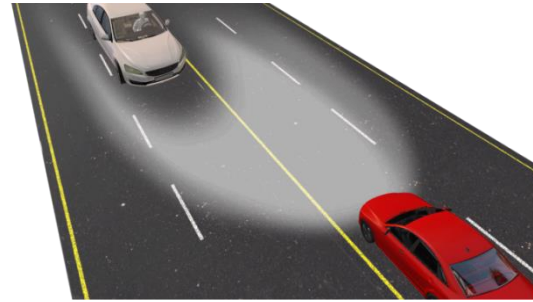
DLP Automotive Applications

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

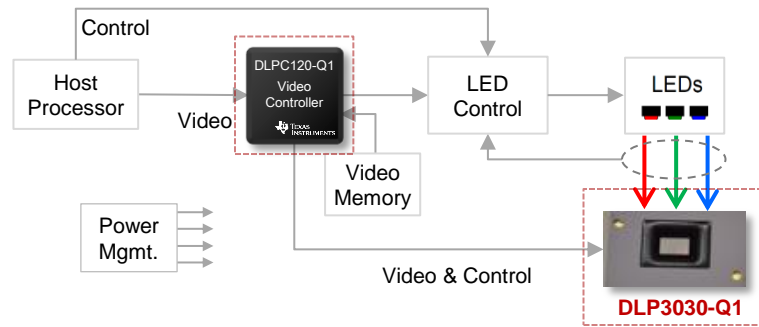


- **Glare-free** high beam
- **LASER** or LED illumination
- **Symbol** Projection
- **Fully** Programmable beam

Automotive qualified chipsets

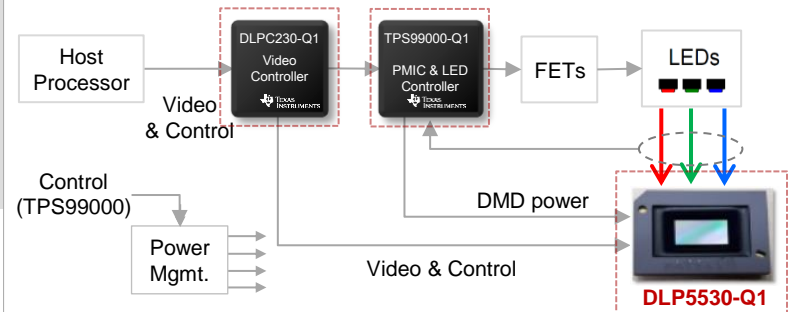
DLP3030-Q1 Chipset

- 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



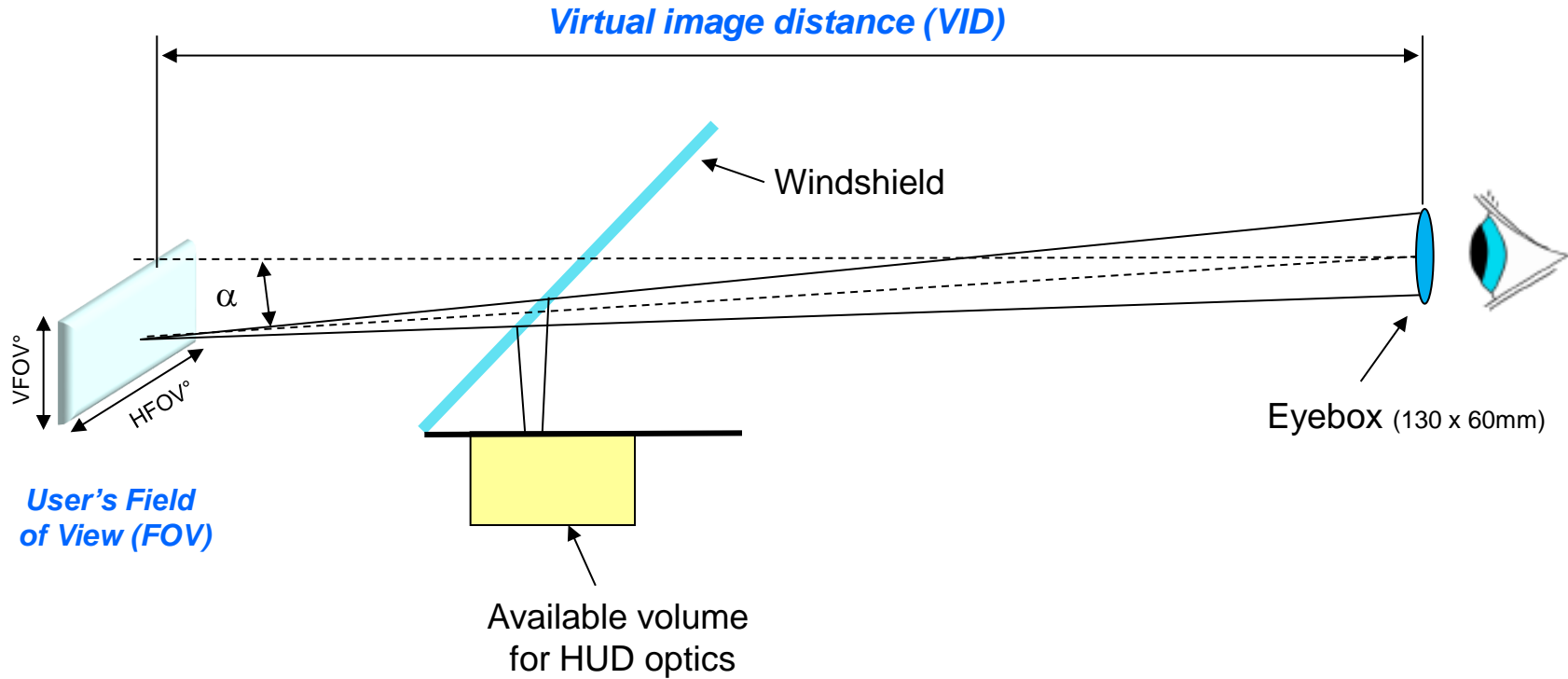
DLP5530-Q1 Chipset

- 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



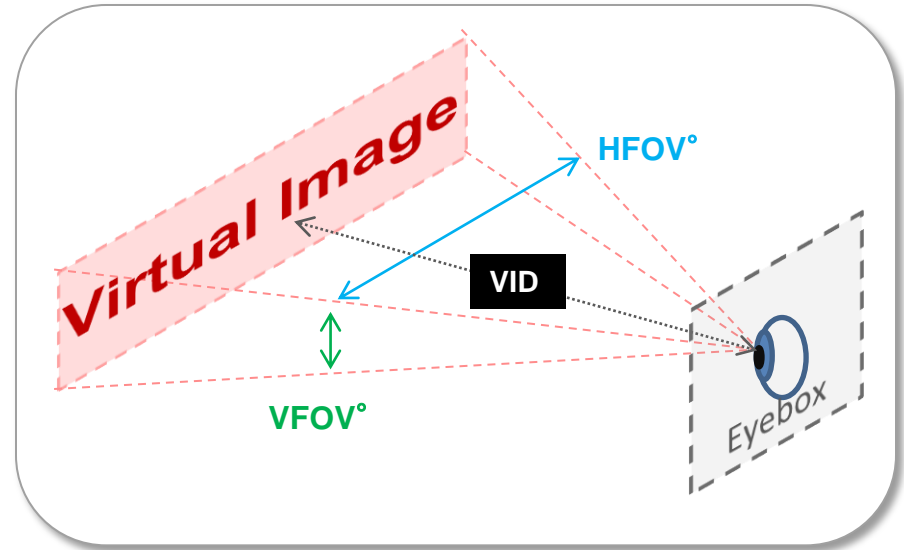
Head-up Display

HUD Geometry & Terminology: 12 x 3° FOV @ 2m VID

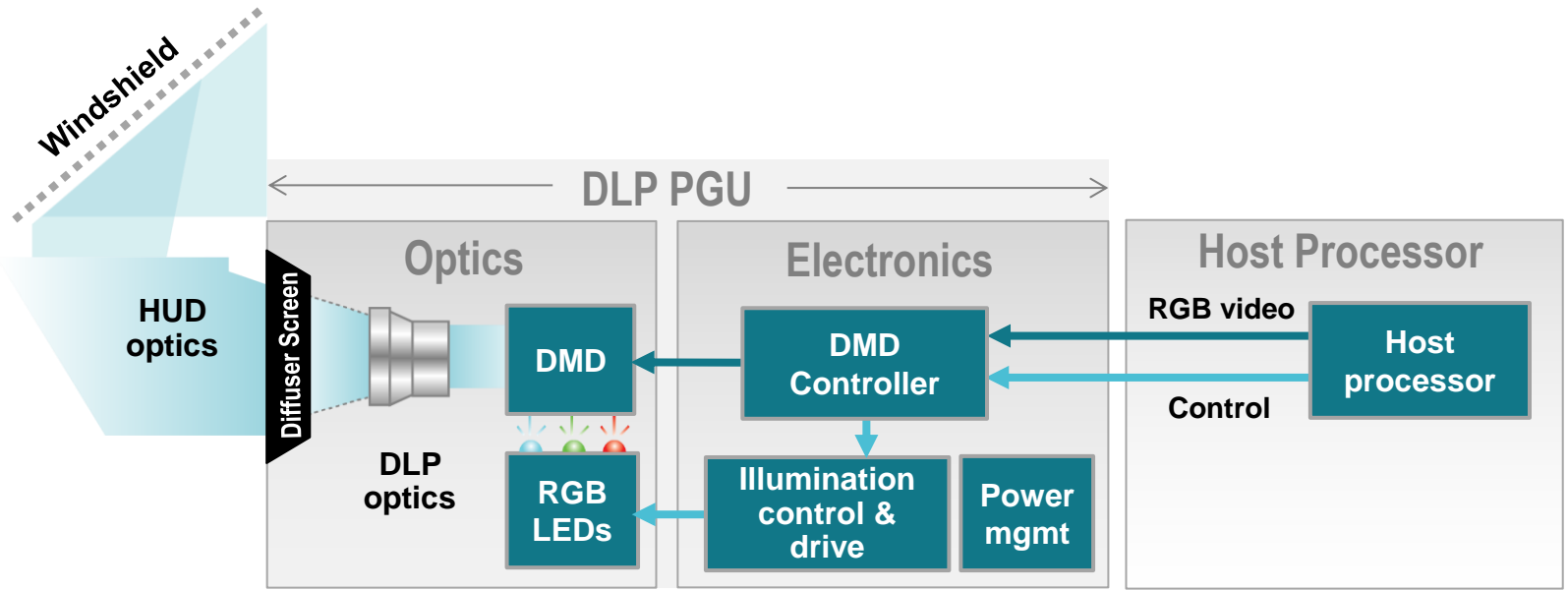


HUD Geometry & Terminology




- 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



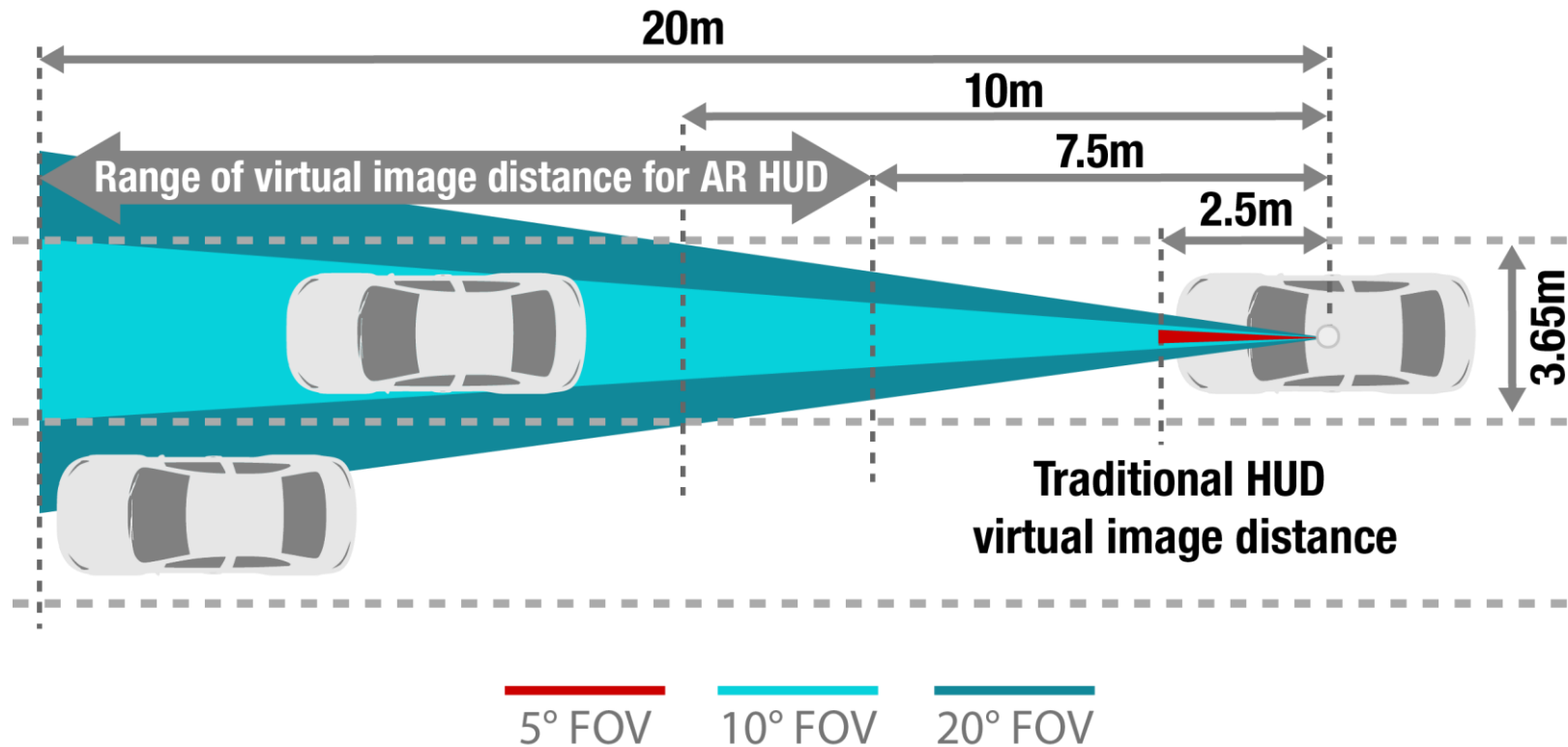
DLP technology brings new functionality to HUD

Past	Present	Future HUDs
		
Narrow FOV <math><4^{\circ}</math>	Medium FOV 7-8 $^{\circ}$	Wide FOV >10 $^{\circ}$
<u>Redundant</u> display	Short VID	AR capable
VFD or TFT	<u>Secondary</u> Info	Long VID 2-20m
1-2 Colors	TFT	<u>Primary</u> display
	Basic Colors	Real-time processing
		High Brightness / Full color palette

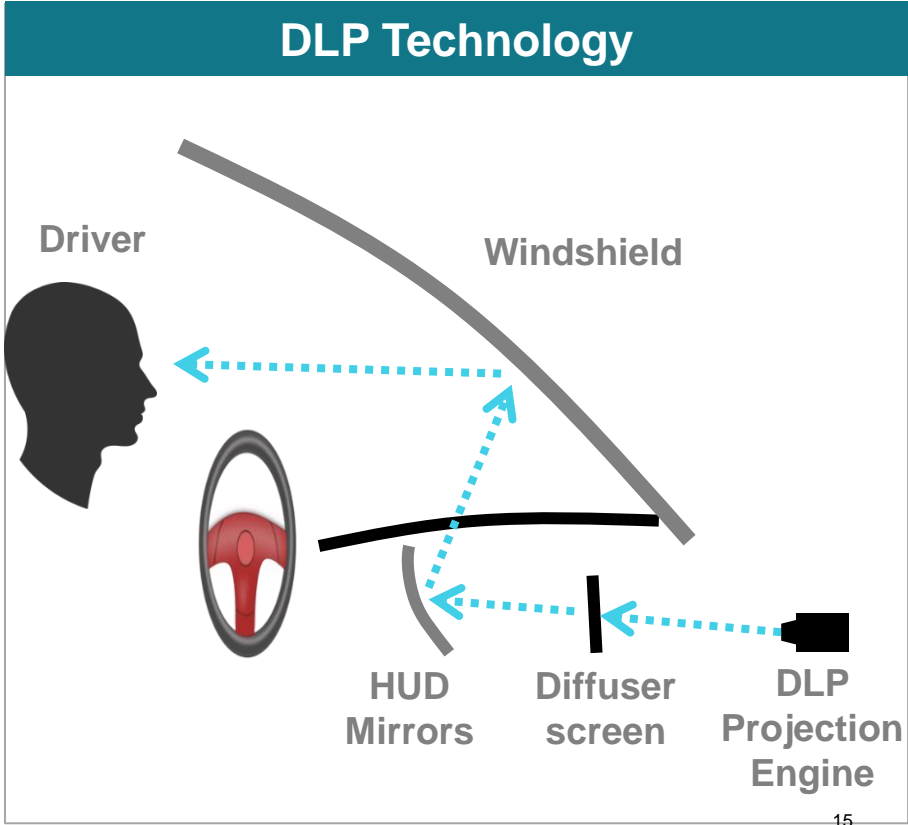
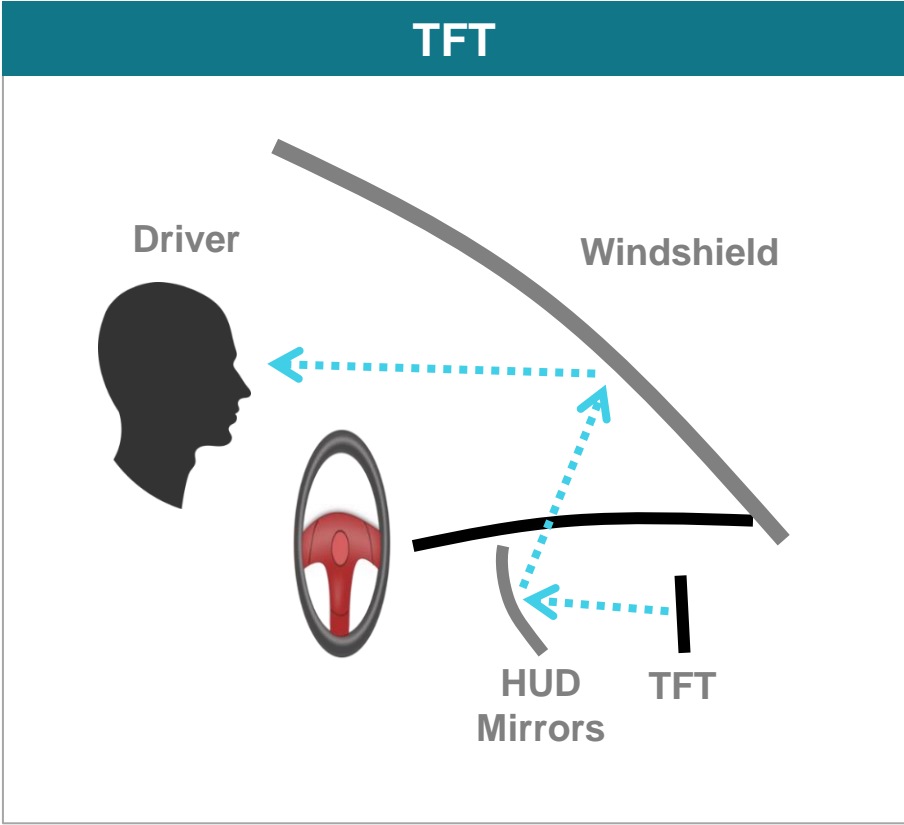
Automakers and Tier-1 suppliers now have the ability to create dynamic HUD systems for today and for future AR, holographic films and waveguide displays

True augmented reality functionality

Requires VID > 7.5m and FOV > 10°

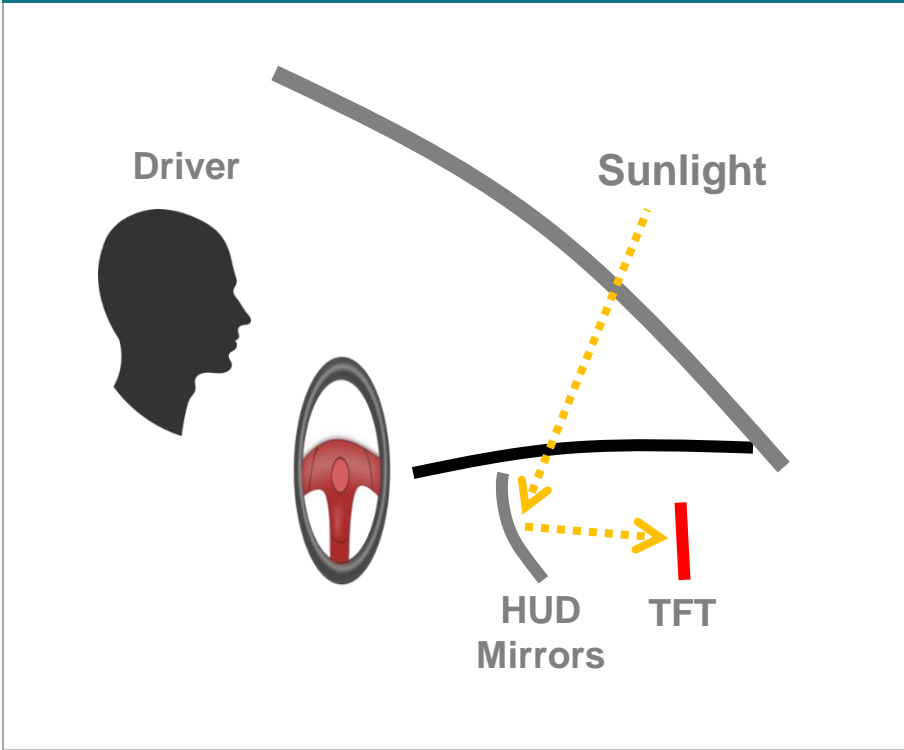


HUD architectures

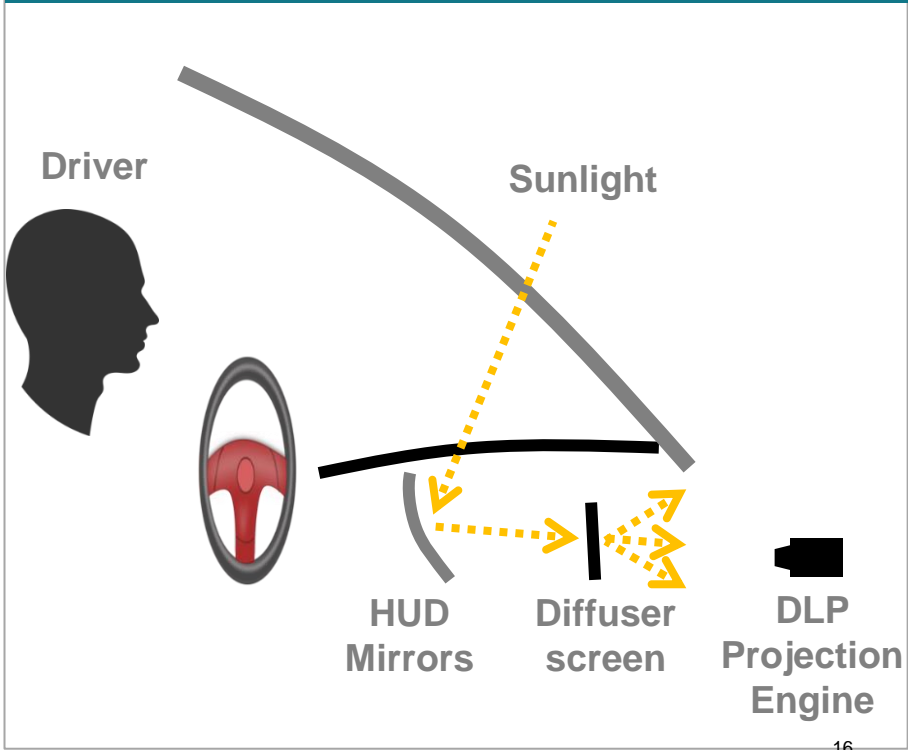


HUD architectures

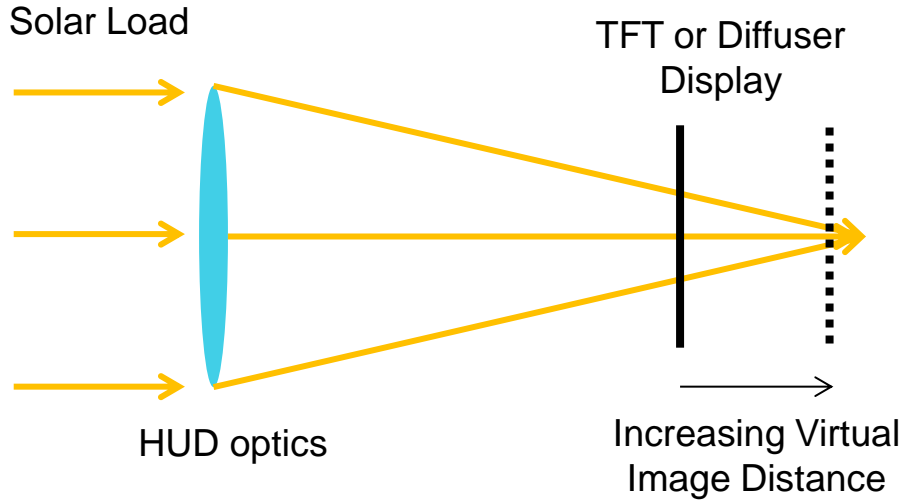
TFT



DLP Technology



AR virtual image distances > 7m

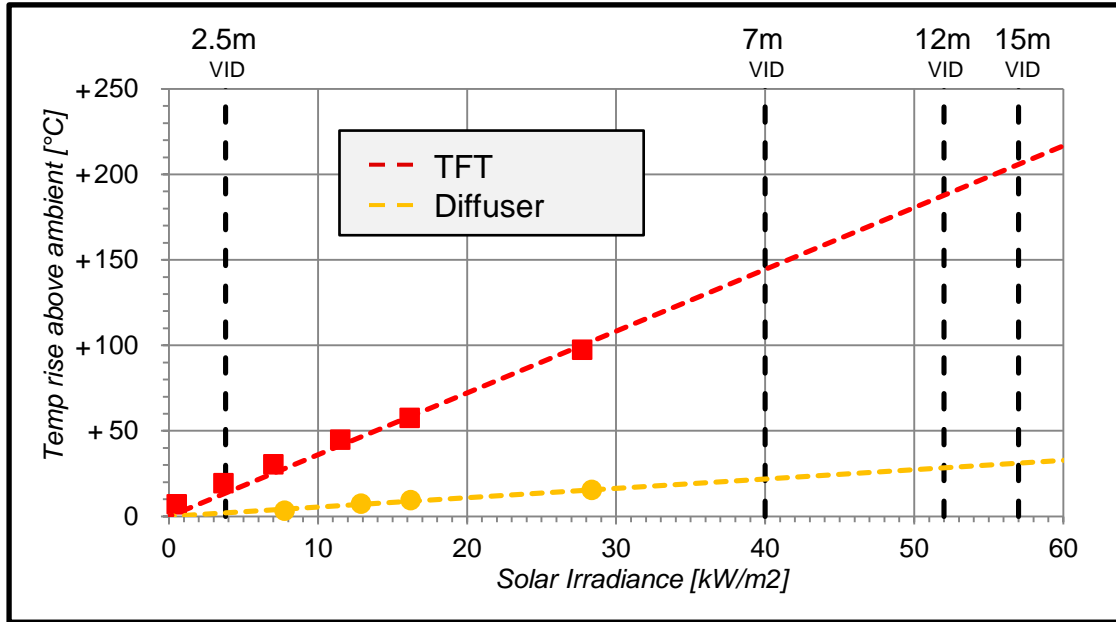


Spec	TFT	Diffuser
Max Operating Temp	95 to 105 °C	150 °C
Sun Light Absorption (Visible Spectrum)	~ 95%	< 1%

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

Sunlight study: temperature rise

Note: Off Axis sunlight is up to 3x worse peak irradiance and must be accounted for in thermal simulations



Temp Increase @ 12m VID

TFT	+ 190°C
Diffuser	+ 34°C

DLP Technology Advantages:

- No performance derating
- No turn off over temp
- Improved reliability & lifetimes

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

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)

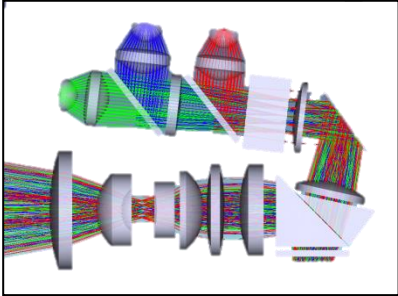
Future Proof (DLP technology works w/ waveguides, holographic films and lasers)

DLP technology: design-in support tools

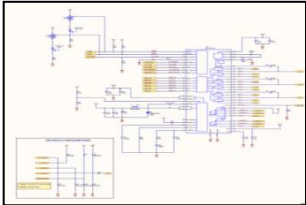
E2E Support & Application Notes



E2E Technical Support



Optical Reference Designs & Reviews



Design Reviews

DLP3030-Q1 RGB LED Driver and Control Circuit
Application Note

DLPC230 Programmer's Guide

Programmer's Guide

Piccolo Software Programmer's Guide for the DLPC120 ASIC

User's Guide



Application Notes & User Guides

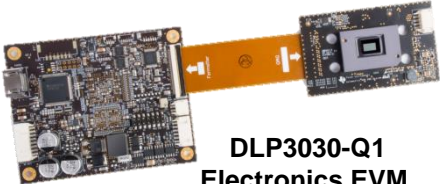
Evaluation Modules



DLP3030-Q1 Optical Module (PGU)



DLP3030-Q1 Combiner HUD EVM



DLP3030-Q1 Electronics EVM

Adaptive Lighting

Illuminate the future of automotive



TREND

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



**Programmable
lighting
technology**

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

DLP® Technology in Digital Headlights

High Resolution Smart Headlight



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

Benefits of DLP® Technology

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

DLP5531-Q1 Chipset Documentation

DLP® Automotive

Headlight Gen 2 - Documentation

Last Modified Date: 18-July-2018

Gen 2 DLP Chipset				
Device	Document	Drawing #	Revision	Date
DLP230-Q1 DMD Controller Chip	DLP230-Q1 Datasheet Product Folder	DLP5904	See Tl.com	See Tl.com
	DLP230-Q1 IBS Model	2515345	2.0	04/19/2018
	DLP230-Q1 BSDL File	2515347	B	06/11/2015
TPS9900-Q1 System Management and Illumination Controller	DLP5531-Q1 Programmer's Guide (Headlight)	DLP0408	C	06/29/2018
	TPS9900-Q1 Datasheet Product Folder	DLP5939	See Tl.com	See Tl.com
DLP5531-Q1 DMD	TPS9900-Q1 IBS Model	2515478	1.0	12/02/2015
	DLP5531-Q1 DMD Data Sheet Product Folder	DLP5075	See Tl.com	See Tl.com
	DLP5531-Q1 DMD IBS Model	2525344	1.0	02/16/2016
	DLP5531-Q1 DMD Mechanical ICD	2514853	C	11/09/2017
	DLP 5450 DMD and System Mounting Concepts Application Report	DLPAR15	See Tl.com	See Tl.com
Optical Reference Designs	DMD 3D-CAD (STEP format)			
	DMD Mechanical Mounting and Mating Connector Information (Consumer Version)			
Application Reports	2-LED and DLED Reference Design	*	A	02/02/2018
	Reliability Lifetime Estimates for DLP3030-Q1 and DLP5531-Q1 DMDs in Automotive Applications	DLPAR05	1.0	03/28/2018
DMD Optical Efficiency Application Report		DLPAR03	A	04/02/2018

System Reference Information				
Document	Drawing #	Revision	Date	
DLP5531-Q1 Electronics Evaluation Module (EVM) User's Guide	DLP0067	See Tl.com	See Tl.com	
DLP5531-Q1 Electronics EVM Formatter Board Design Files Zip	2515619C 2515619C 2515620C	C	3/27/2018	
DLP5531-Q1 Electronics EVM Driver Board Design Files Zip	2515624C 2515625C 2515626C	C	3/27/2018	

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DLPC230-Q1 for Light Control Applications

Programmer's Guide



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TPS9900-Q1 System Management and Illumination Controller

1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
 - Device Temperature Grade 2, -40°C to 125°C Ambient Operating Temperature
 - Device HBM ESD Classification Level 2
 - Device CDM ESD Classification Level C4
- Automotive System Management Device for Products:
 - Advanced Power Monitoring, Sequencing Protection Circuits
 - Two Die Temperature Monitors, MCU Ext Watchdog Timer, Clock Frequency Monitor
 - System Over-Brightness Detection
 - SPI Port With Parity, Checksum, and Password Register Protection
 - Second SPI Port for Independent System Monitoring
- On-Chip DMD Mirror Voltage Regulators
 - Generates +16 V, +8.5 V and -10 V DMD Control Voltages
- High Dynamic Range Dimming and Color Co-Enabling = 5000:1 Dimming Range With High Depth and White Color Balance:
 - Two Transimpedance Amplifiers (TIA) With Wide Dynamic Range Supporting Numerous Optical Designs
 - 12-bit ADC With up to 63 Time Sequence Samples per Frame
 - DAC and Comparator Functions for Color Pulse Control
 - FET Drivers for LED and Shunt Control

2 Applications

- Wide Field of View and Augmented Reality Head-Up Display (HUD) Systems
- Automotive Advanced Lighting Applications (Resolution Headlight)
- Adaptive Driving Beam (ADB)

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DLP230-Q1 Automotive DMD Controller

1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
 - Device Temperature Grade 2, -40°C to 105°C Ambient Operating Temperature
 - Device HBM ESD Classification Level 2
 - Device CDM ESD Classification Level C4B
- DMD Display Controller Supporting:
 - DLP5531-Q1 Automotive Interior Display Chipset
 - DLP5531-Q1 Automotive Exterior Lighting Chipset
- On-Chip Diagnostic and Self-Test Capability
 - Bezel Adjustment up to 45° Vertical Image Position and ±10% Horizontal Reducing the Need for Mechanical Alignment (HUD)
 - Support for Focus Coupling or Quasidoping to Allow Low Resolution Video Input
 - Gamma Correction
- Embedded Processor With Error Correction (ECC)
 - On-Chip Diagnostic and Self-Test Capability
 - System Diagnostics Including Temperature Monitoring, Device Interface Monitoring, and Photodiode Monitoring
 - Integrated Management of Smooth Dimming
 - Configurable GPIO
- No External RAM Required, Internal SRAM for Image Processing
- 600-MHz Sub-LVDS DMD Interface for Low Power and Emission
- Spread Spectrum Clocking for Reduced EMI
- Video Input Interface
 - Single OpenLDI (FPD-Link I) Port up to 110 MHz
 - 24-bit RGB Parallel Interface up to 110 MHz
- Configurable Host Control Interface
 - Serial Peripheral Interface (SPI) 10 MHz
 - IC (400 kHz)
 - Host IRQ Signal to Provide Real-Time Feedback for Critical System Errors
- Interface to TPS9900-Q1 System Management and Illumination Controller

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DLP5531-Q1 0.55-inch 1.3 Megapixel DMD for Automotive Exterior Lighting

1 Features

- Qualified for Automotive Applications
 - 40°C to 105°C Operating DMD Array Temperature Range
- The DLP5531-Q1 Automotive Chipset Includes:
 - DLP5531-Q1 DMD
 - DLP230-Q1 DMD Controller
 - TPS9900-Q1 System Management and Illumination Controller
- 0.55-inch Diagonal Micromirror Array
 - 7.6-µm Micromirror Pitch
 - ±12° Micromirror Tilt Angle (Relative to Flat State)
 - Bottom Illumination for Optimal Efficiency and Optical Engine Size
- 1.3-Megapixel Array Configured in 2:1 Aspect Ratio Enabling High Resolution and Wide Aspect Ratio Automotive Applications
- Compatible With LED or Laser Illumination
- 600-MHz Sub-LVDS DMD Interface for Low Power and Emission
- 104-MHz DMD Refresh Rate Over Temperature Extremes
- Built-In Self Test of DMD Memory Cells

2 Applications

- High Resolution Headlight
- LIDAR Optical Filter

3 Description

The DLP5531-Q1 Automotive DMD, combined with the DLP230-Q1 DMD controller and TPS9900-Q1 system management and illumination controller, provides the capability to achieve high performance high resolution headlight systems. The 2:1 aspect ratio supports very wide aspect ratio designs, and the 1.3-megapixel resolution enables high resolution symbol projection and adaptive driving beam applications. The DLP5531-Q1 has more than 3 times the optical throughput of the preceding DLP3030-Q1 Automotive DMD enabling an even larger field of view and higher lumens output. The DLP5531-Q1 Automotive DMD micromirror array is configured for bottom illumination which enables highly efficient and more compact optical engine designs. The 5450 package has low thermal resistance to the DMD array to enable more efficient thermal solutions.

Device Information(1) (R)		
PART NUMBER	PACKAGE	BODY SIZE (MM)
DLP5531-Q1	FPW (149)	22.35 mm x 15.20 mm

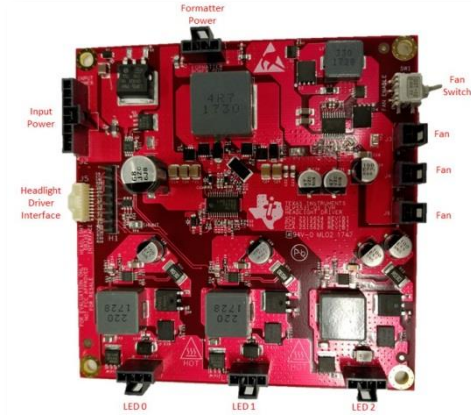
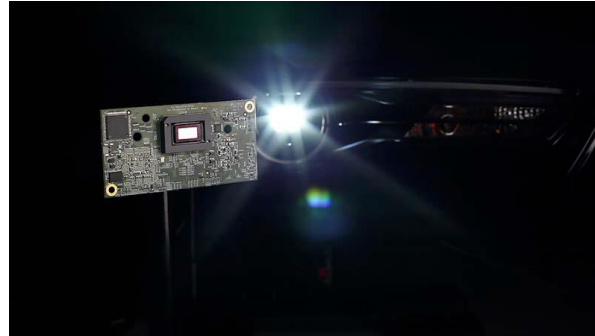
(1) For all available packages, see the orderable addendum at the end of the data sheet.
 (2) This catchword pertains to the specifications and application of this DMD in the headlight application. Please see the DLP5530-Q1 Datasheet (DLP5573) for head-up display specifications and application information.

DLP5531-Q1 DLP® Chipset System Block Diagram

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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



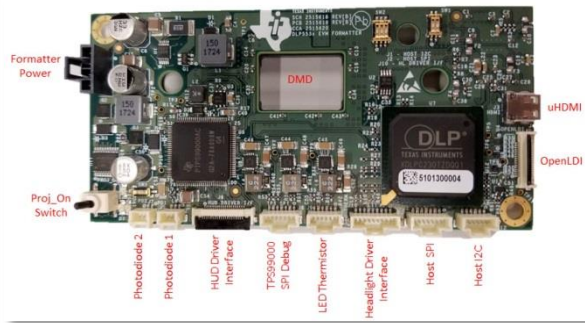
LED Driver Board



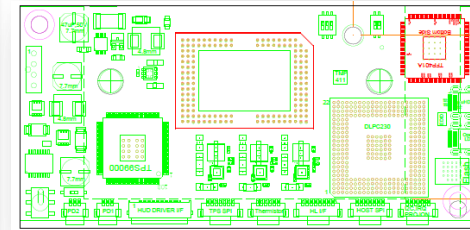
EVM Front Side with DMD mounted



EVM Accessories



EVM Back Side



Thank You!

For more information, please visit our website at:
<http://www.ti.com/dlp-chip/automotive/overview.html>