Optical Engine Reference Design for DLP3010 Digital Micromirror Device

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ABSTRACT

This application note provides a reference design for an optical engine. The design features TI's DLP3010 digital micromirror device (DMD), which utilizes the TI DLP® TRP pixel architecture to deliver high brightness and low power consumption. Design options for optical engines are discussed.

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1 Scope

This document provides a brief overview of a reference optical engine design for TI's DLP3010 DMD. It summarizes specifications and key design parameters of the optical engine. Optical engines using DLP® Pico™ technology with DLP3010 are well suited for integrating high quality display capability into ultra-compact products, such as smartphones, tablets, and near-eye displays; and portable applications such as mobile smart TV and digital signage.

This reference design is solely intended to assist designers who are developing systems that use the DLP3010 DMD. The performance and results listed in these documents are based on the design simulation tool Zemax. The actual performance of the end product will depend on the final design and manufacturing processes.

2 Applicable Documents

The following TI documents contain additional information required for design of an optical engine incorporating the DLP3010 DMD.

1. DLP3010 Datasheet
2. Geometric Optics for DLP Application Report
3. DLP3010 Optical Engine Design Files

3 DLP3010 Key Parameters

Table 1. DMD Specification

Features	Description
TI part number	DLP3010
Description	.3 720P DMD
Size	0.3 inch (7.93 mm) diagonal
Aspect ratio	16:9
Array size (pixels)	1280 (h) × 720 (v)
Pixel pitch	5.4 µm
Tilt angle of mirror	17° (TRP pixel architecture)
Illumination type	Side illumination
Package size	18.20 mm × 7.00 mm × 3.80 mm

4 Design Considerations

This section describes the TI DLP pixel architecture, which is a key factor when beginning an optical design. The design choices for various elements of the optical engine are also discussed.

4.1 DLP TRP Pixel Architecture

DLP TRP pixel architecture utilizes square pixels (Figure 1) and tilts by 17°. The mirror first tilts by 12° along the hinge then rolls by 12° to either ON or OFF position, resulting in a compound 17° angle. The TRP pixel architecture allows the DMD to be designed for side-illumination (illuminating the device from a direction parallel to the long-axis of the device) or for bottom-illumination (illuminating the device from a direction parallel to the short-axis of the device). Every DMD is designed for a specific illumination direction (side or bottom), which then determines the design of the window aperture. Refer to the datasheet for each specific DMD to determine the intended illumination direction. The recommended illumination angle is 34°, regardless of illumination direction, and the illumination cone angle is within ±17°. The f-number for the optical system is limited to f/1.7 maximum due to the flat state overlap. Side illumination enables thinner optical engine, while bottom illumination reduces the size of the prism in a telecentric optical design and also provides the potential for lower cost by reducing the size of the projection lens.

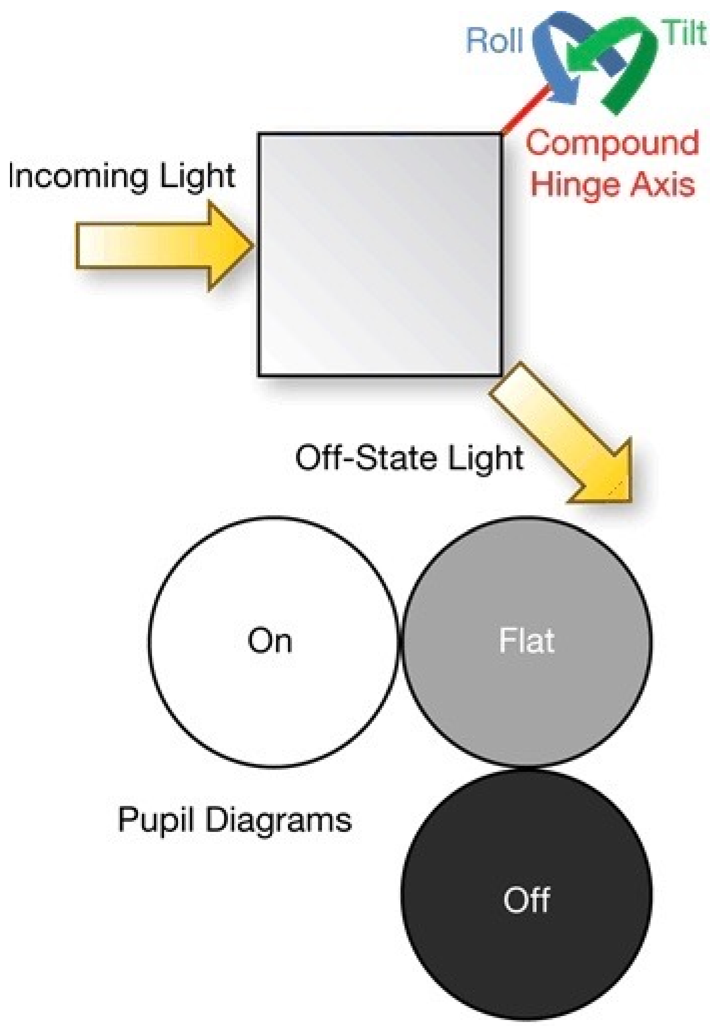

Figure 1. Side Illuminated TRP Pixel

4.2 Optical Design Options

Multiple components are used in an optical engine incorporating TI DLP technology. Figure 2 shows potential design options for these components. It also highlights the choices used in this reference design.

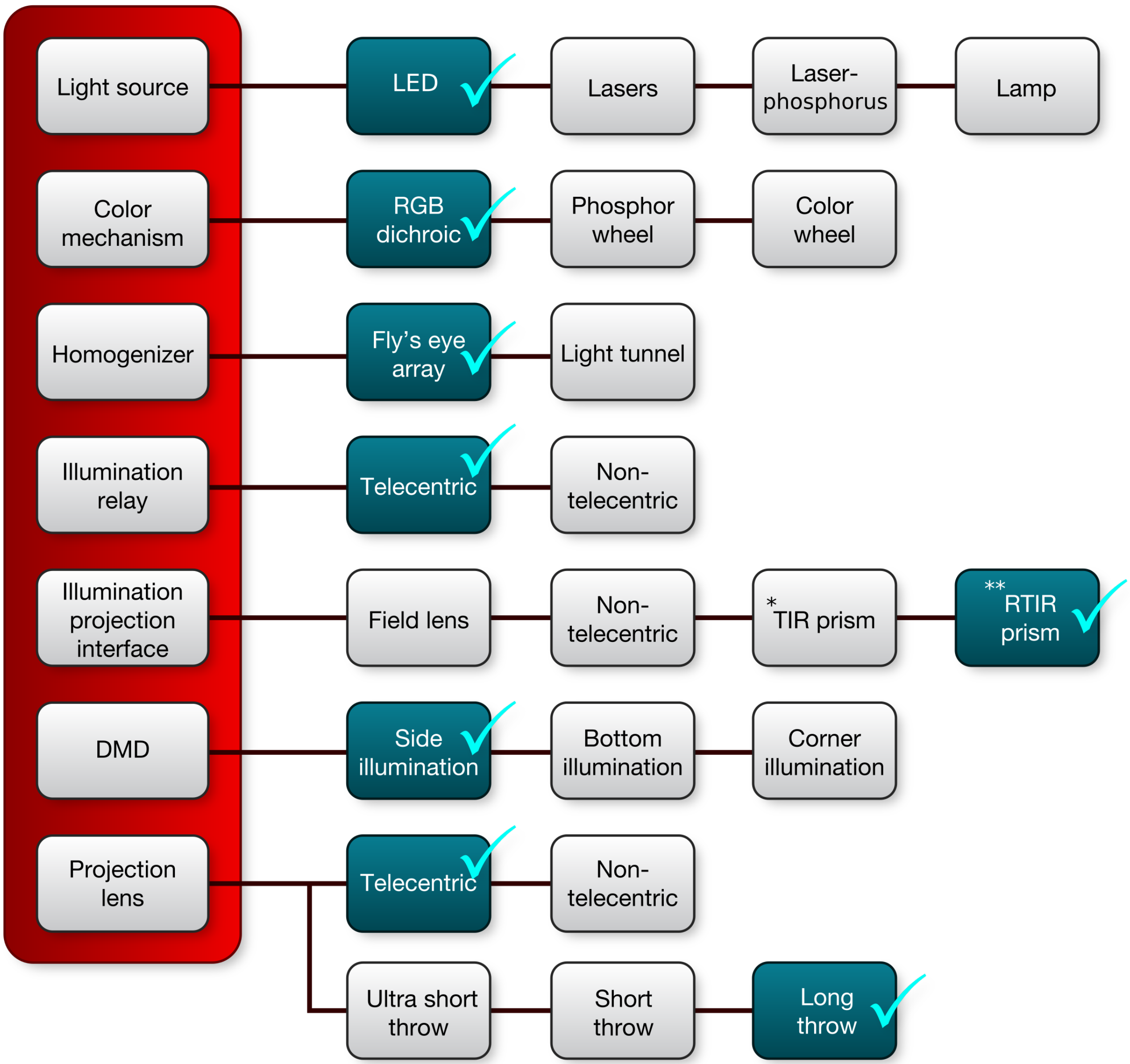

Figure 2. Optical Design Options

NOTE: The highlighted boxes with checks are options chosen in this design.

***TIR—** Total internal reflection

****RTIR—** Reverse TIR

4.3 Design Summary

Table 2 summarizes key attributes of this reference design:

Table 2. Design Summary

Specification	Description
Light source LED	Osram LE A Q8WP (1.5 × 1.2 mm) - Amber LE CG Q8WP (1.55 × 1.24 mm) - converted green LE B Q8WP (1.5 × 1.2 mm) - Blue
LED collection angle	80°
Dichroic	Three Channel Two dichroic
Homogenizer	Fly Eye Array
f/#	1.7
Geometric efficiency (ray tracing only)	R – 69.7% G – 68.6% B – 67.8%
Offset	100%
Contrast ratio (full on/full off)	Depends on final material used, design implementation, and manufacturing processes

5 Optical Layout

5.1 Optical System

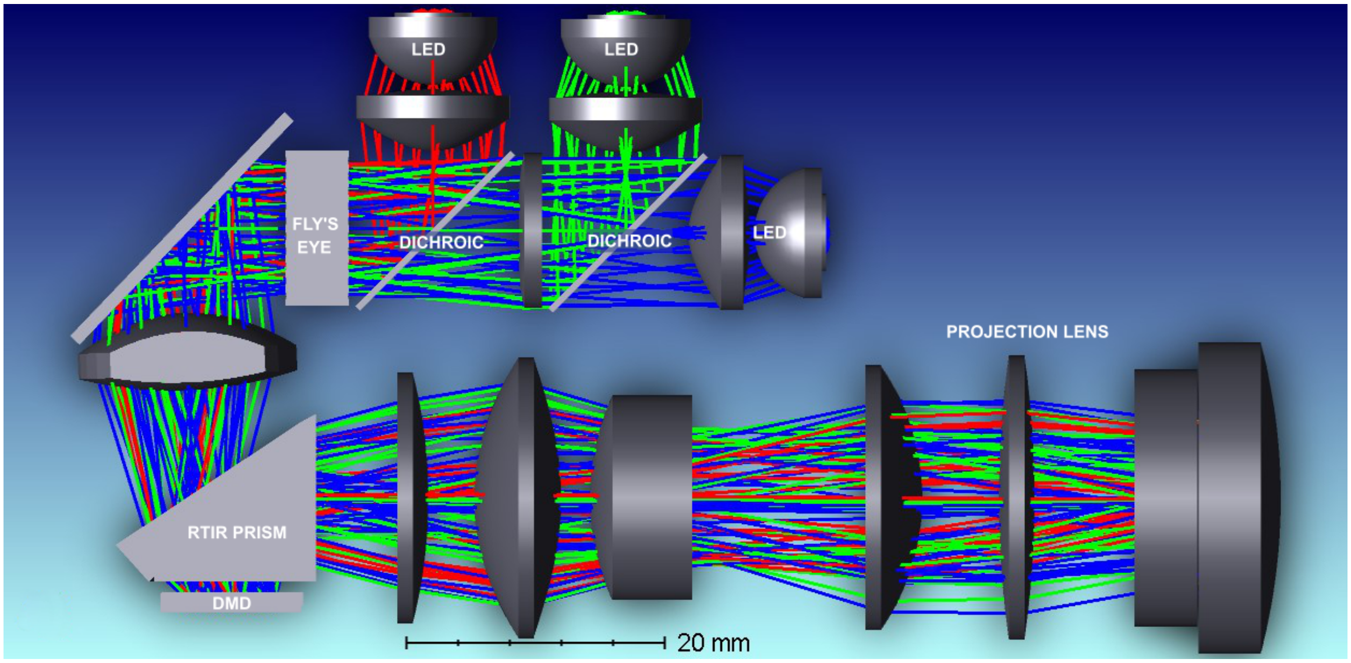

Figure 3. Optical System

5.2 Two Dimensional View

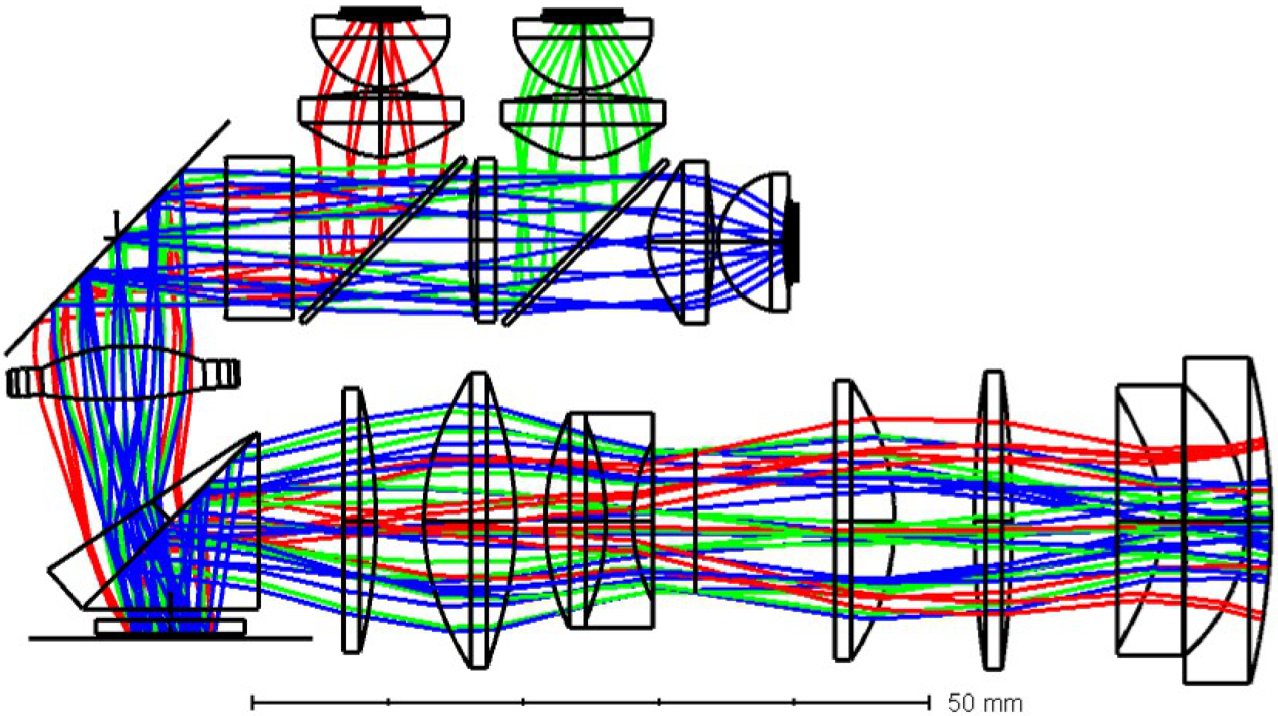

Figure 4. Optical Engine Top View

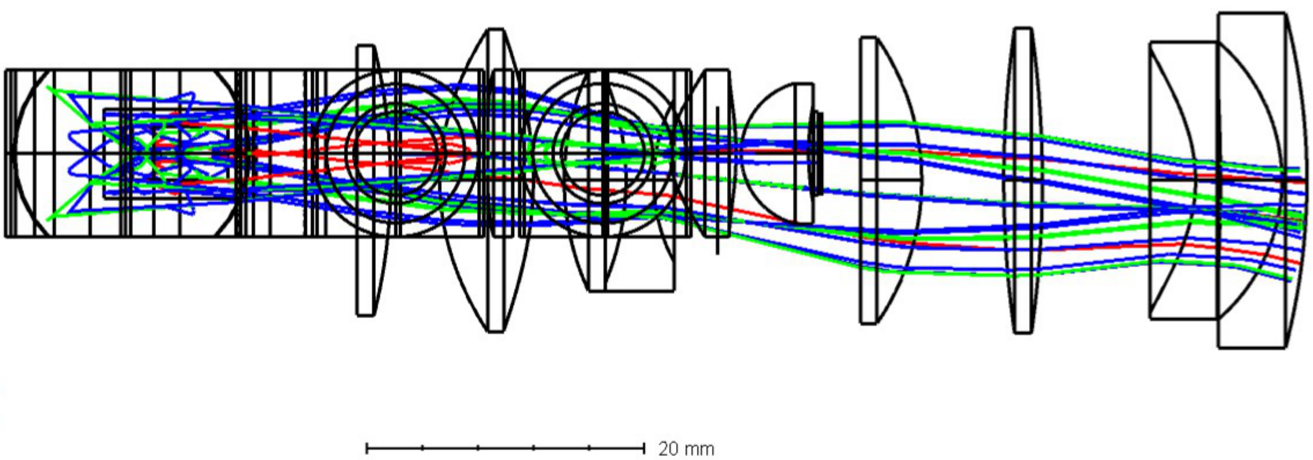

Figure 5. Optical Engine Side View

6 Estimated Brightness

This section shows the estimated optical efficiency and brightness based on design simulations. The actual efficiency will depend on the material used and the system design implementation.

6.1 Estimated Optical Engine Efficiency

The efficiency assumptions for optical elements used in Table 3 are representative of components used in a typical projection engine for consumer applications.

Table 3. Estimated Optical Engine Efficiency

Optical Element	Estimated Transmission Efficiency			Notes
	Red	Blue	Green	
Collimator lens	0.96	0.96	0.96	
Dichroic	0.92	0.90	0.90	Typical estimate
Fly's eye array	0.95	0.95	0.95	
RTIR prism	0.88	0.88	0.88	Estimate
DMD	0.68	0.68	0.68	Standard value
Projection lens	0.90	0.90	0.90	
Total optics transmission estimate	45.2%	44.2%	44.2%	
Geometric efficiency	69.7%	67.8%	68.6%	Zemax - Ray tracing
Estimated optical engine efficiency	**31.5%**	**30.0%**	**30.3%**	

6.2 Estimated Brightness (Lumens)

Table 4. Brightness at 1-W LED Power

	Red	Blue	Green	Notes
LED	LE A Q8WP	LE B Q8WP	LE CG Q8WP	Reference LED data sheet
Current (mA)	375	375	375	LED manufacturer's data sheet
Forward voltage (V)	2.0	2.8	2.8	LED manufactrurer's data sheet
Luminous flux	43	25	150	Mid bin LEDs; 40°C junction temperature
Duty cycle	30%	20%	50%	
Available flux	13	5	75	
Optical engine efficiency	31.5%	30.0%	30.3%	
Total flux	**28** lumens at **1.0** W[(1)] Total LED power			

(1) Sum of LED current x forward voltage × duty cycle for each LED.

Table 5. Maximum Brightness

	Red	Blue	Green	Notes
LED	LE A Q8WP	LE B Q8WP	LE CG Q8WP	Reference LED data sheet
Current (mA)	6000	6000	6000	
Forward voltage (V)	3.3	3.4	3.4	Corrected for high temperature
Luminous flux	333	225	1676	Flux derated for high temperature (90°C)
Duty cycle	30%	20%	50%	
Available flux	100	45	838	
Optical engine efficiency	31.5%	30.0%	30.3%	
Total flux	**299** lumens at **20.0** W[(1)] Total LED power			

(1) Sum of LED current × forward voltage × duty cycle for each LED.

7 Optical Engine Specification

Table 6 lists expected performance obtained from design simulation tools. Actual performance may vary from this and will depend upon materials used and manufacturing processes.

Table 6. Optical Engine Specification

Features	Description
Maximum brightness	Up to 299 lumens at 20 watts
Efficiency	Up to 28 lumens/watt
Image quality	
• Contrast ratio (full on/full off)	Depends on optical engine design and management of stray, flat-state and off-state light inside the engine
• Modulation Transfer Function (MTF)	50% at 93 lp/mm (designed)
• Uniformity	>70%
System	
• Dimension (optical system only) Does not include mechanical housing and heat sink	94 mm (L) × 50 mm (W) × 25 mm (H)
• Throw ratio	1.4
• Offset	100%

Please download "DLP3010 Optical Engine Design Files" from http://www.ti.com/lsds/ti/dlp/video-and-data-display/documents.page.

8 Design Variations

The projection lens is designed for high performance and large tolerances to ease fabrication. Further trade-offs can be made to achieve smaller application sizes. For example, the projection lens could be designed to have the same height as the illumination optics.

For applications like near-eye displays where a very small form factor and low power consumption are critical, brightness of up to 10 lumens is usually adequate. The design shown in this Application Report can further be reduced in size by using a device containing red, green and blue LEDs in a single package, which eliminates the need for dichroic optics. The optical component placement could be matched to the form factor of the end product, for example, by unfolding the light path and using an additional optical element to make an in-line layout.

9 Summary

The DLP3010 DMD enables a highly optimized and purpose built display solution for a wide range of applications including smartphones, tablets, digital cameras, mobile accessories, interactive surface computing, digital signage, aftermarket head-up displays and near-eye displays. The reference design shown in this Application Report is targeted for a compact projection engine with up to 300 lumens in brightness. This class of optical engines is best suited for a small hand-held battery-operated product.

Variations of this basic optical architecture are possible for applications like wearables or higher-end projectors.

10 Get Started

To get started with DLP Pico technology, we recommend the following actions:

- Learn more about DLP Pico technology.
  - Read the Getting Started with TI DLP® Display Technology application report.
  - Browse DLP products and applications.
  - Experiment with the DLP throw ratio and brightness calculator.
- Download TI Designs reference designs to speed product development, including schematics, layout files, bill of materials, and test reports.
  - Portable, Low Power HD Projection Display using DLP Technology
- Evaluate DLP Pico technology with an easy to use evaluation module (EVM).
- Find optical modules and design support.
  - Buy production ready modules from a worldwide optical supplier.
  - Contact optical module manufacturers to help accelerate product development and speed time to market.
  - Contact DLP design houses for custom solutions.
- Contact your local TI sales representative or TI distributor representative.
- Check out TI's E2E™ community to search for solutions, get help, share knowledge and solve problems with fellow engineers and TI experts.