

# **Optical Engine Reference Design for DLP3010 Digital Micromirror Device**

Zhongyan Sheng

## **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.

### **Contents**

1	Scope.....	2
2	Applicable Documents .....	2
3	DLP3010 Key Parameters.....	2
4	Design Considerations .....	3
5	Optical Layout .....	5
6	Estimated Brightness.....	7
7	Optical Engine Specification.....	8
8	Design Variations .....	8
9	Summary .....	9
10	Get Started .....	9

### **List of Figures**

1	Side Illuminated TRP Pixel .....	3
2	Optical Design Options .....	4
3	Optical System .....	5
4	Optical Engine Top View .....	6
5	Optical Engine Side View.....	6

### **List of Tables**

1	DMD Specification .....	2
2	Design Summary .....	5
3	Estimated Optical Engine Efficiency .....	7
4	Brightness at 1-W LED Power .....	7
5	Maximum Brightness .....	8
6	Optical Engine Specification.....	8

## 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**

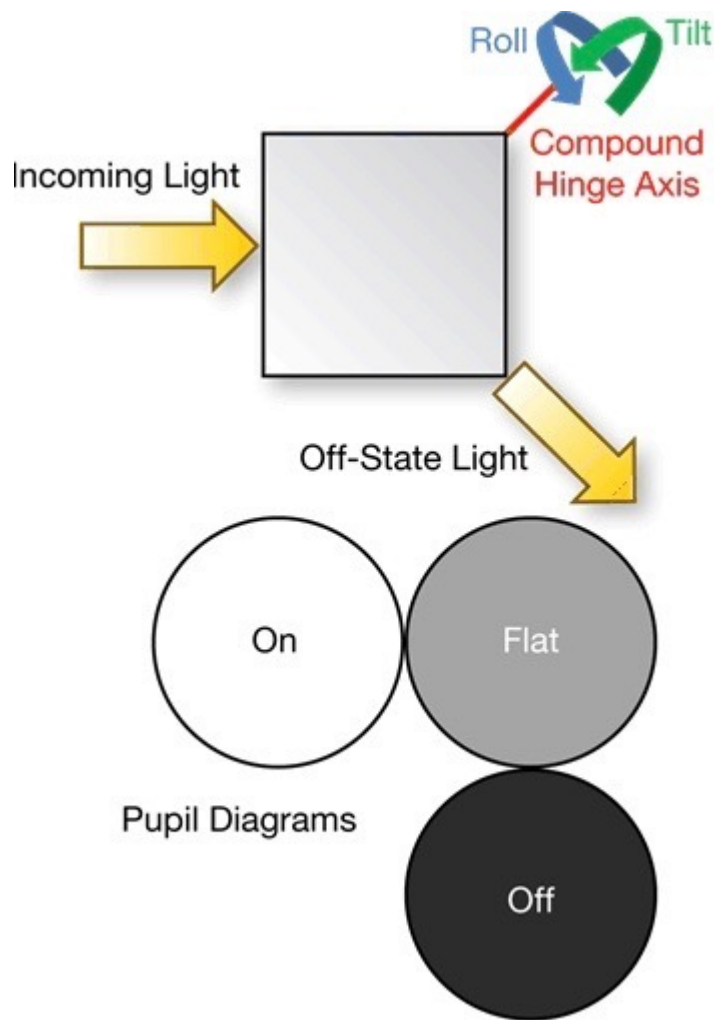
Features	Description
TI part number	DLP3010
Description	.3 720P DMD
Size	0.3 inch (7.93 mm) diagonal
Aspect ratio	16:9
Array size (pixels)	1280 (h) × 720 (v)
Pixel pitch	5.4 μm
Tilt angle of mirror	17° (TRP pixel architecture)
Illumination type	Side illumination
Package size	18.20 mm × 7.00 mm × 3.80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

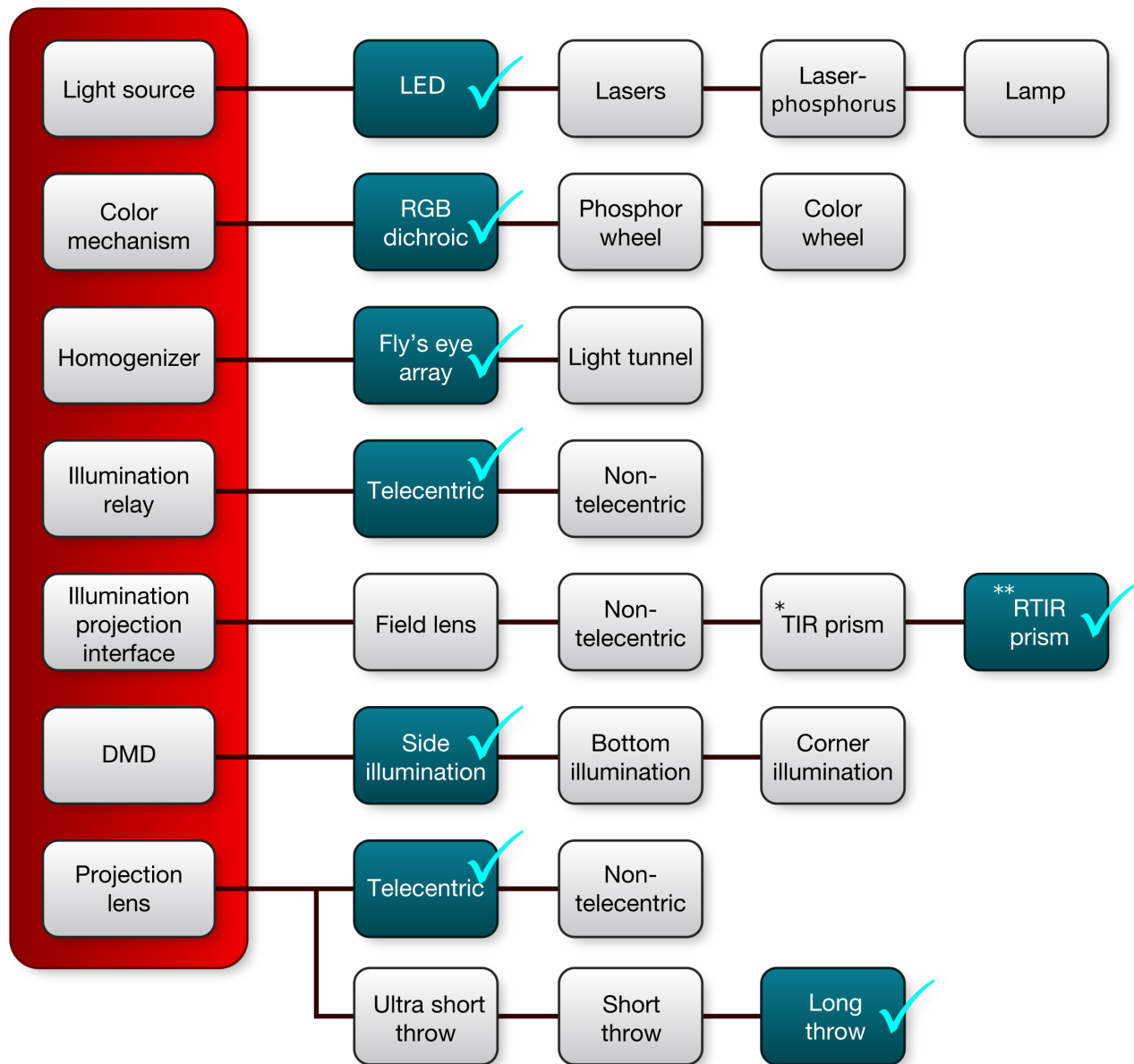


Figure 2. Optical Design Options

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

\*TIR— Total internal reflection

\*\*RTIR— Reverse TIR

### 4.3 Design Summary

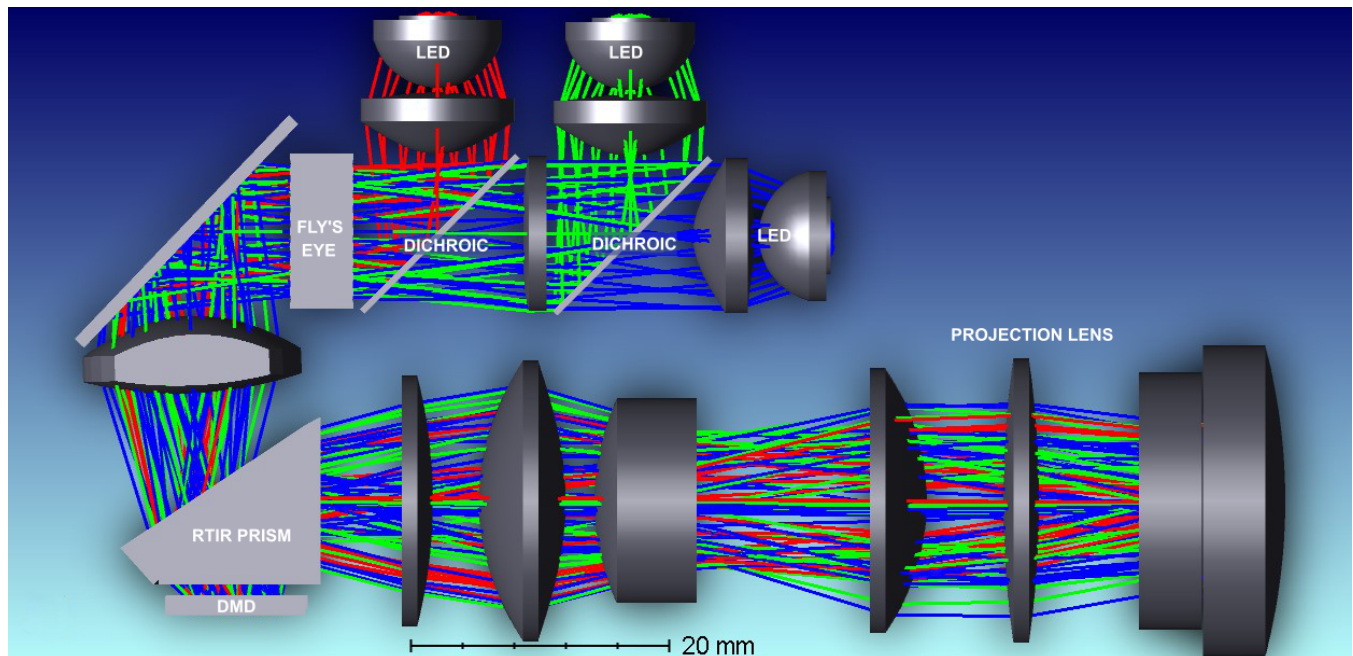
Table 2 summarizes key attributes of this reference design:

**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

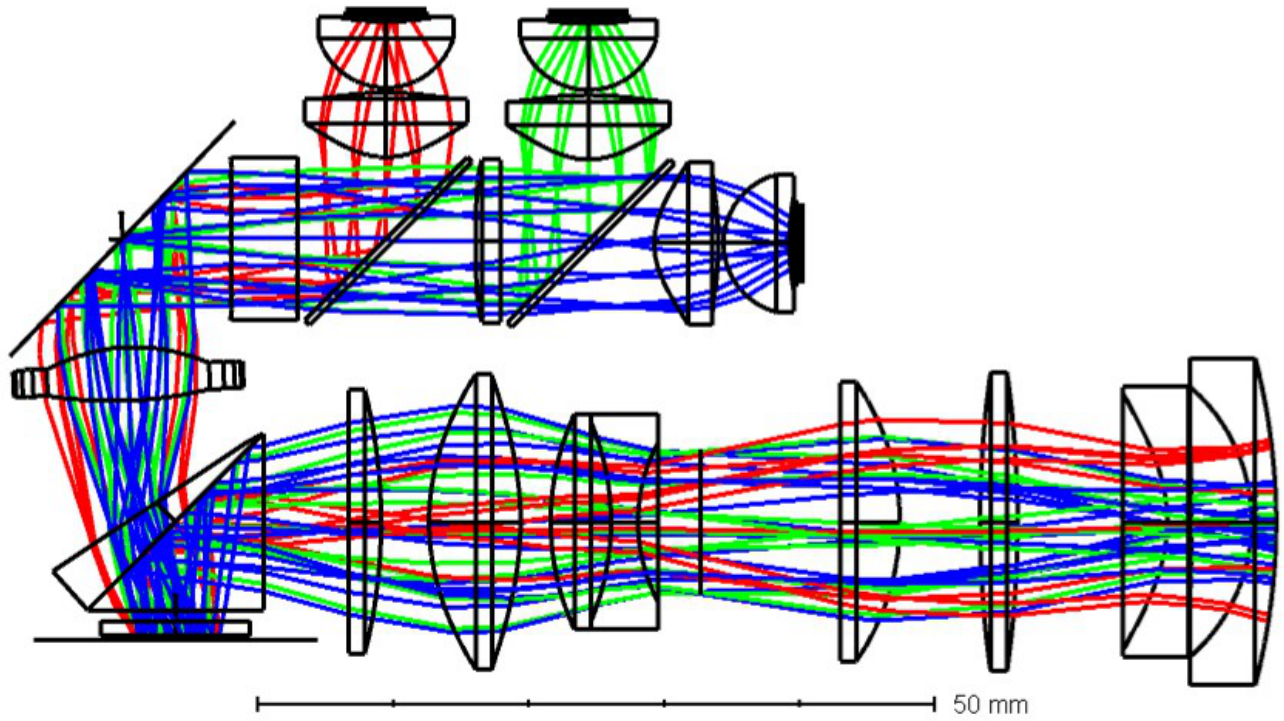
## 5 Optical Layout

### 5.1 Optical System

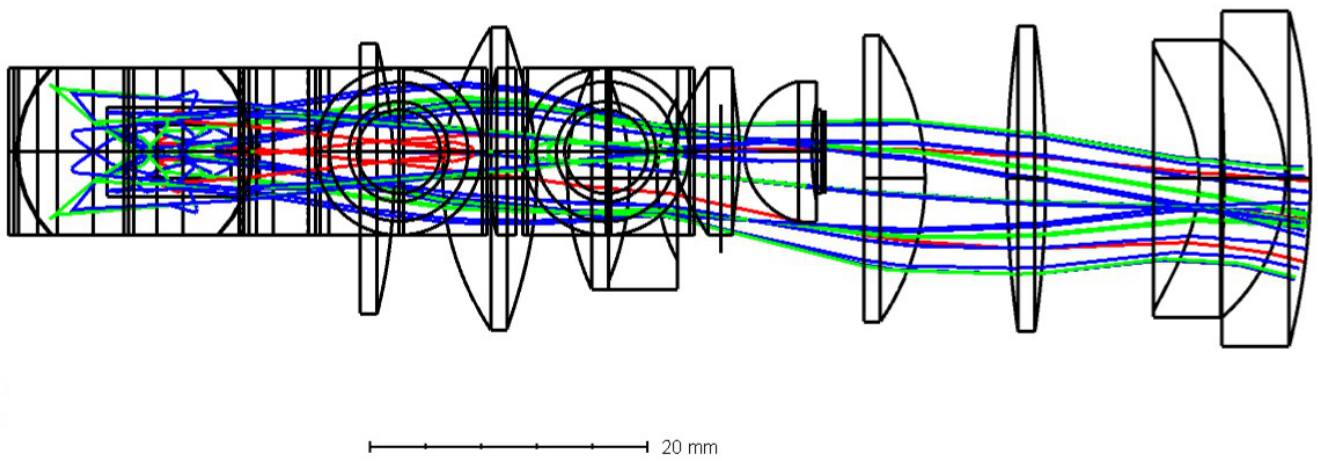


**Figure 3. Optical System**

**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	
<b>Total optics transmission estimate</b>	45.2%	44.2%	44.2%	
<b>Geometric efficiency</b>	69.7%	67.8%	68.6%	Zemax - Ray tracing
<b>Estimated optical engine efficiency</b>	<b>31.5%</b>	<b>30.0%</b>	<b>30.3%</b>	

### 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 manufacturer'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%	
<b>Total flux</b>	<b>28 lumens at 1.0 W<sup>(1)</sup> Total LED power</b>			

<sup>(1)</sup> Sum of LED current x forward voltage x 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%	
<b>Total flux</b>	<b>299 lumens at 20.0 W<sup>(1)</sup> Total LED power</b>			

<sup>(1)</sup> Sum of LED current x forward voltage x 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
<b>Maximum brightness</b>	Up to 299 lumens at 20 watts
<b>Efficiency</b>	Up to 28 lumens/watt
<b>Image quality</b>	
<ul style="list-style-type: none"> <li>Contrast ratio (full on/full off)</li> </ul>	Depends on optical engine design and management of stray, flat-state and off-state light inside the engine
<ul style="list-style-type: none"> <li>Modulation Transfer Function (MTF)</li> </ul>	50% at 93 lp/mm (designed)
<ul style="list-style-type: none"> <li>Uniformity</li> </ul>	>70%
<b>System</b>	
<ul style="list-style-type: none"> <li>Dimension (optical system only) Does not include mechanical housing and heat sink</li> </ul>	94 mm (L) x 50 mm (W) x 25 mm (H)
<ul style="list-style-type: none"> <li>Throw ratio</li> </ul>	1.4
<ul style="list-style-type: none"> <li>Offset</li> </ul>	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.

## IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>), [evaluation modules](#), and [samples](http://www.ti.com/sc/docs/sampterm.htm) (<http://www.ti.com/sc/docs/sampterm.htm>).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2017, Texas Instruments Incorporated