Getting Started With TI DLP® Display Technology

Application Report

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Scope

This document is a guide to getting started with DLP® technology for display applications. Multiple system components, including illumination and optics, as well as design considerations when developing display products using DLP chipsets are explained.

(1) Pico is a trademark of Texas Instruments.
(2) DLP is a registered trademark of Texas Instruments.

Introduction to Texas Instruments DLP Technology

2.1 Digital Micromirror Device (DMD)

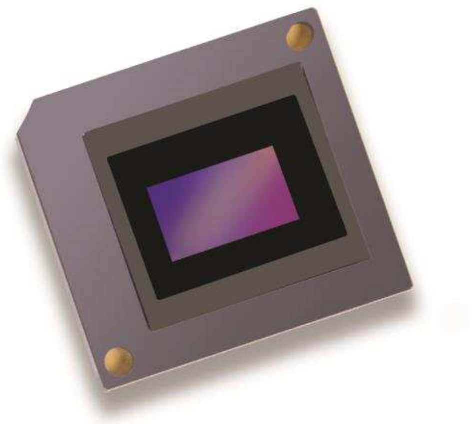

Figure 2-1. DLP® DMD

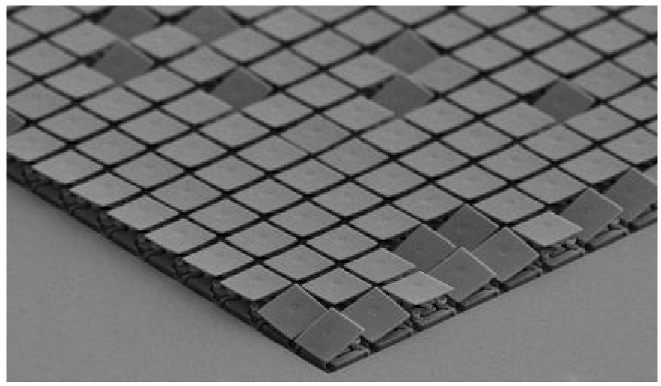

Figure 2-2. Close Up of DMD Micromirrors

Texas Instruments DLP technology is a micro-electro-mechanical systems (MEMS) technology that modulates light using a digital micromirror device (DMD). DMDs vary in resolution and size and can contain over 8 million micromirrors. Each micromirror (see Figure 2-2) of a DMD can represent either one or more pixels on the display and is independently controlled, synchronized with color sequential illumination, to create stunning images on virtually any surface. DLP technology enables a wide variety of display products worldwide, from tiny projection modules embedded in smartphones to high powered digital cinema projectors, and emerging display products such as near-eye display, head up display, projection mapping, and laser TV.

The most recent class of chipsets from Texas Instruments is based on a breakthrough micromirror technology, called the TRP pixel architecture. With a smaller pixel pitch of 5.4 μm and increased tilt angle of ±17 degrees, TRP chipsets enable higher resolution in a smaller form factor compared to our previous pixel architecture and enhanced image processing features while maintaining high optical efficiency.

2.2 Illumination

Display systems based on DMD technology require an illumination source to create a projected image. The technology can be used with virtually any light source including lamps, LEDs, lasers, and laser phosphors. Also, the DMD can steer a wide range of light wavelengths including visible, infrared, and ultraviolet wavelengths. Many traditional projectors still use lamps as an illumination source, however a significant market has developed for LED and laser phosphor illuminated systems. LEDs and laser phosphors provide a long life illumination source with instant on/off capabilities and enable a wide color gamut.

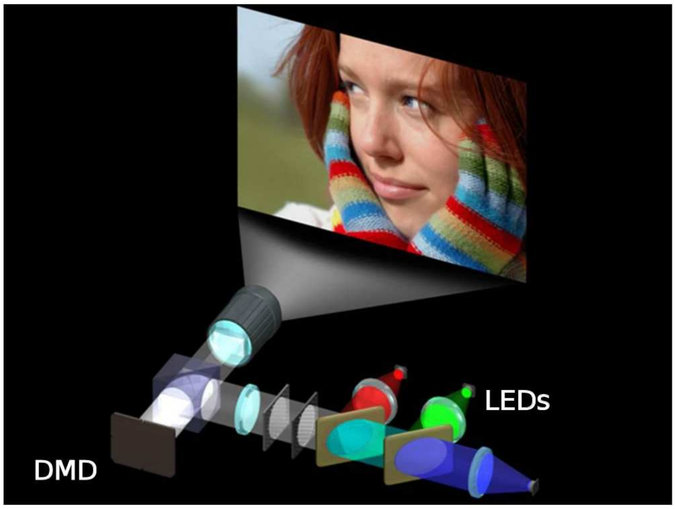

Figure 2-3. RGB LED Illumination

The illumination choice will depend on the application and system requirements. DLP product developers can work with optical module manufacturers to determine the best illumination source for their application. Refer to Chapter 6 for more information.

2.3 Optical Module

The DLP DMD, along with its associated electronics, an illumination source, optical elements, and necessary mechanical components are combined into a compact and rugged assembly known as an optical module or light engine. The optical module is the core display component of the system. Optical modules can be of various sizes depending on the application and requirements. In general, the higher the brightness, the larger the size of the optical module due to larger illumination sources, optics, DMD and thermal management in the form of heat sinks and fans.

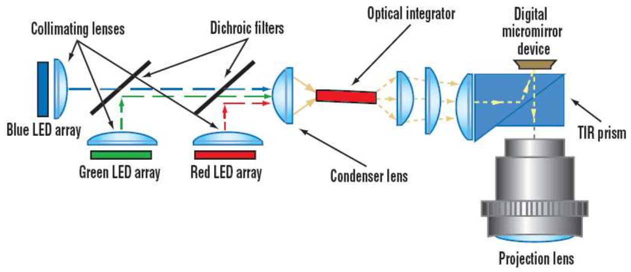

Figure 2-4. Simplified Diagram of an LED Optical Module

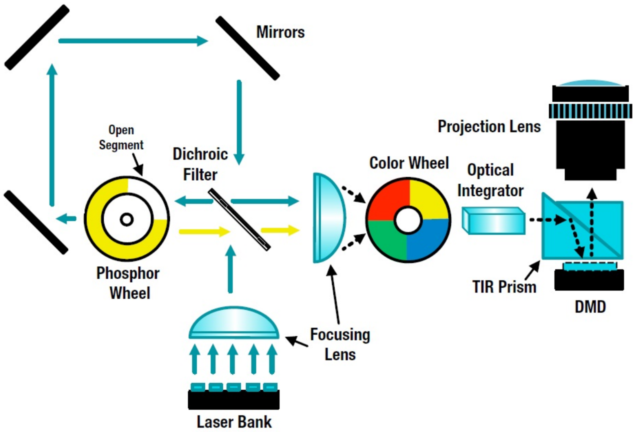

Figure 2-5. Simplified Diagram of a Laser Phosphor Optical Module

DLP optical modules of various designs, sizes, capabilities, and performance are available from a number of optical module manufacturers. The availability of existing optical modules accelerates the product development cycle of an end equipment producer because an appropriate DLP optical module can be utilized or adapted for use in the end product without requiring in-house expertise or resources. DLP design houses and some optical module manufacturers also have the ability to design and build custom optical modules for applications when required. Refer to Chapter 6 for more information.

Display System Overview Using DLP Technology

3.1 DLP Display Products

DLP display products are used in a wide range of traditional accessory projectors and emerging display equipment including embedded projectors in smartphones and tablets, interactive surface computing, screenless and laser TV, near-eye displays, digital signage, and projection mapping. DLP display technology contains two families of products, DLP Pico™ chipsets and DLP Standard chipsets. DLP Pico chips offer versatile display capability and can create images on virtually any surface from ultra-mobile devices. They are a good fit for any application requiring a display with high contrast, small size, and low power. DLP Standard chips enable amazing images for systems that require bright, high resolution, and large screen displays. Refer to Chapter 5 for more details describing the portfolio of DLP display chips.

3.2 Pico Display Application

DLP Pico technology offers an easy connection to the rest of the system (see Figure 3-1). The subsystem requires two primary connections: Power and data. Power must be supplied to the DLP PMIC chip. Digital video data (24-bit RGB) must be supplied to the DLP controller chip via a parallel interface. A front end media processor, which accepts external sources like HDMI and sends digital video data to the DLP controller, is commonly used. Alternatively, a product's host processor, such as in a smartphone or tablet, can also send digital video data to the DLP controller.

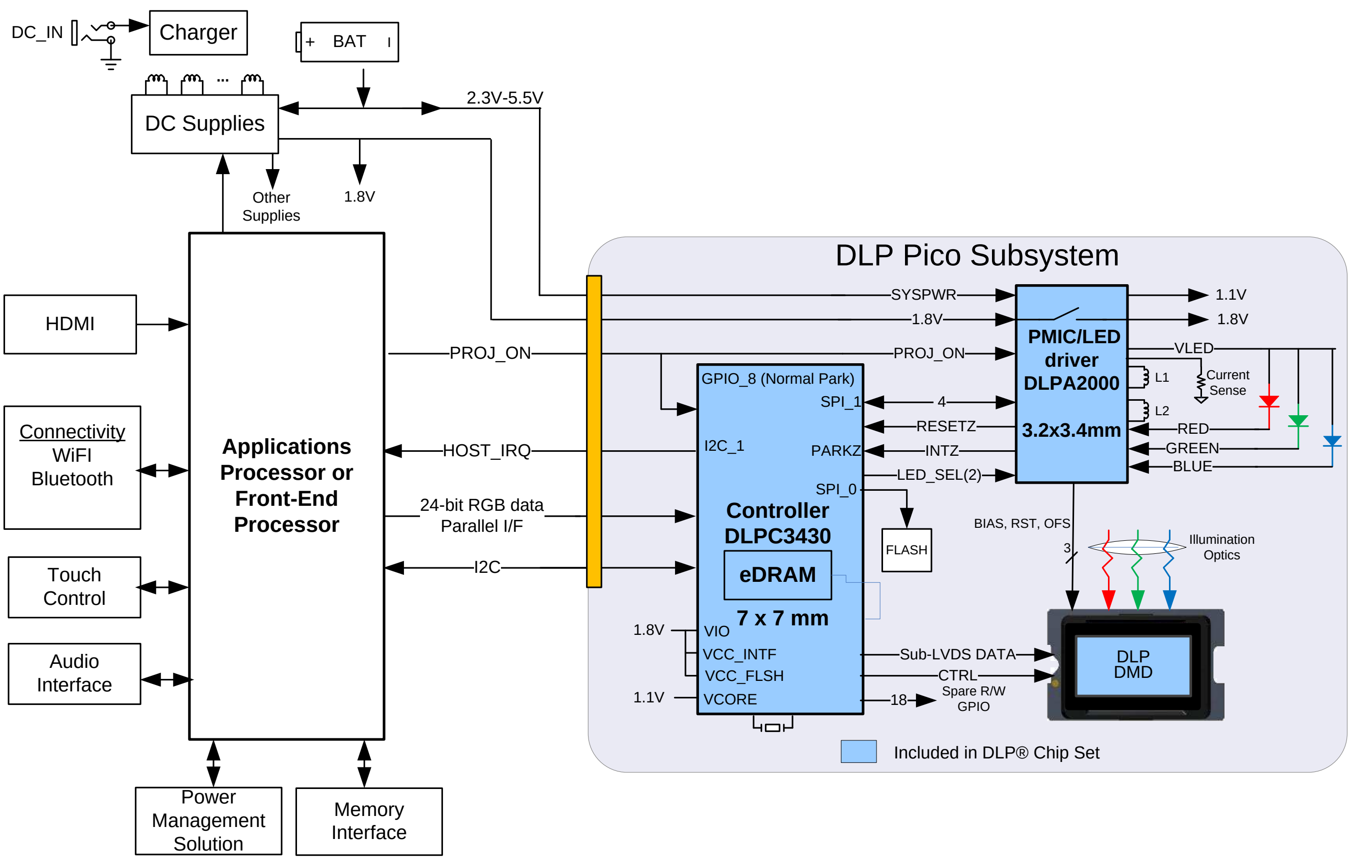

Figure 3-1. Block Diagram of a Typical DLP® Pico™ System

3.2.1 Electronics Size

DLP controller and PMIC chips that accompany the DLP Pico DMDs are very small (7 mm × 7 mm and 3.4 mm × 3.2 mm, respectively) enabling extremely compact display products. Figure 3-2 shows both sides of an example printed circuit board design (estimate only) with the DLPA2000 PMIC and DLPC3430 controller device, which drive a DLP2010 DMD.

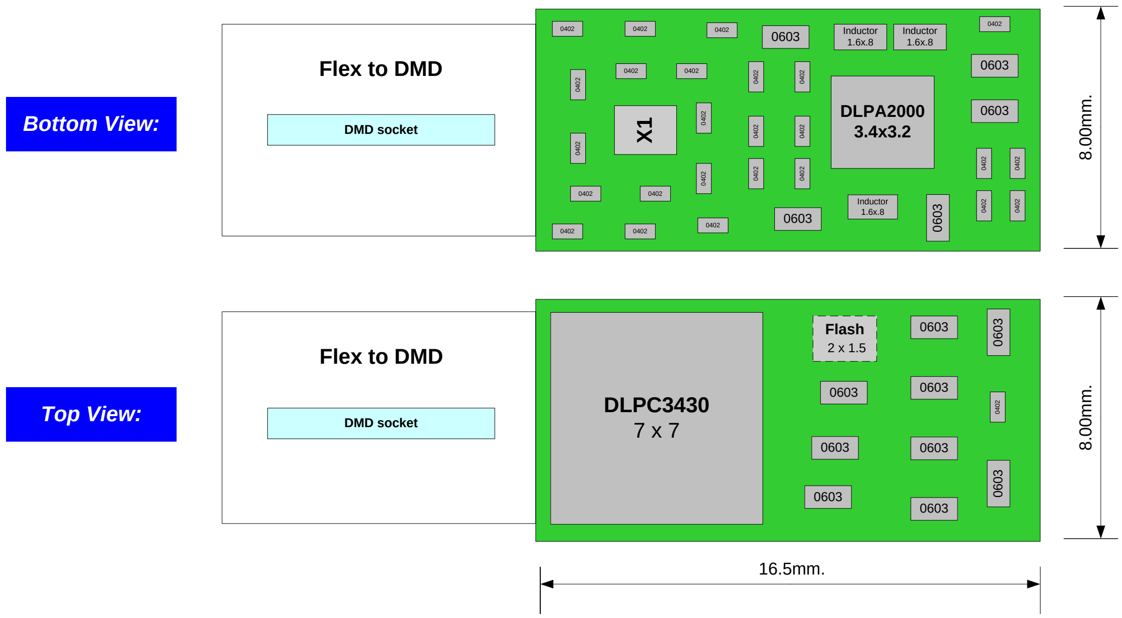

Figure 3-2. Example of a Small Board Design

3.2.1.1 Optical Module Interface

A DLP Pico optical module is connected to system electronics on a PCB mounted near the optical module. The DMD is connected to the DLP Pico controller via flex cable or board-to-board connector and the LEDs in the optical module are connected with wires to the PMIC/LED driver chip. System boards, fans, heat sinks, mechanical parts, switches, and other parts are assembled into a compact and robust final product around the optical module.

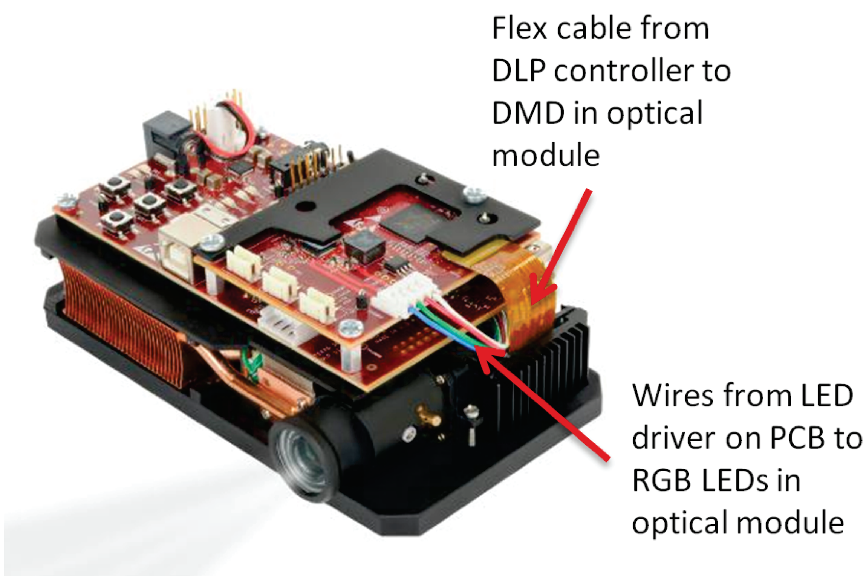

Figure 3-3. DLP® Pico™ Evaluation Module (EVM) With Optical Module and System Electronics

3.3 Standard Display Application

A system design using DLP Standard display chips has two main components: The formatter printed circuit board (PCB) and the DMD PCB (see Figure 3-4). The DMD PCB houses the DMD, the power supply circuitry for the DMD, and communication interfaces between the DLP controller and the DMD. The formatter board contains the electronics required to format the data and images to be displayed on the DMD.

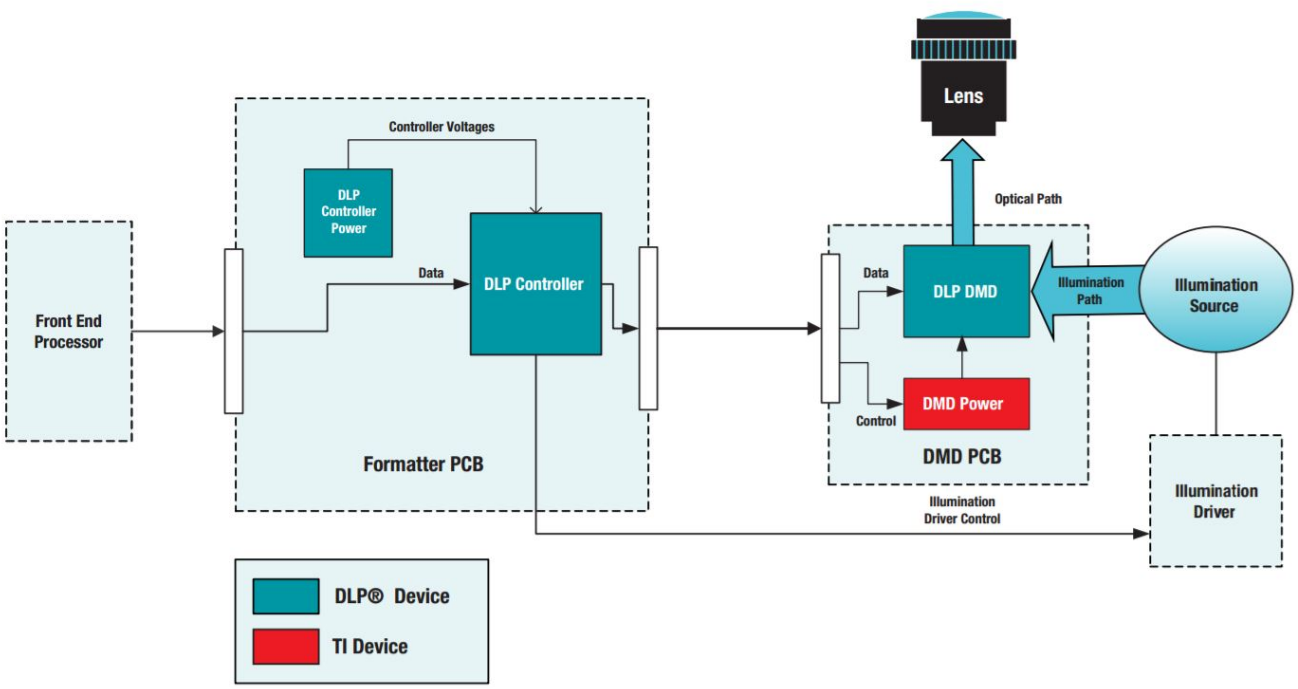

Figure 3-4. Block Diagram of a Typical 4K UHD DLP® Display System

3.4 DLP Controller

The DLP controller chip is the digital interface between the DMD and the rest of the system. The DLP controller takes digital input from front end digital receivers and drives the DMD over a high speed interface. The DLP controller also generates the necessary signals (data, protocols, timings) required to display images on the DMD. Some systems require dual controllers to format the incoming data before sending it to the DMD. The DMD and its appropriate controller are required to be used together in a system design to ensure reliable operation.

3.5 Power Management IC, LED Driver, and Motor Driver

DLP chipsets are comprised of a DMD, controller and sometimes a power management/LED driver chip. The power management IC (PMIC) and LED driver chip provide all of the voltage regulators required by the DMD and display controller. It also provides the driver functionality for the LEDs, other monitoring and protection functions, and dynamic LED control based on image color content. Integration of the power supply and LED driver circuitry in a small IC not only allows for small size electronics to be designed, but also reduces the product design cycle time.

A motor driver is also needed for systems that include a color wheel. This capability provides the color wheel motor drive control for lamp and laser illumination based applications as well as switching regulators and adjustable linear regulators for customer designed peripherals. It supports two peripherals by supplying three fan drivers and one 3-phase BEMF motor driver or controller for a color wheel.

3.6 Field Programmable Gate Array

Some display systems include a field programmable gate array (FPGA) between the front end interface and the DLP controller. The main function of the FPGA is to process high-resolution video into two successive sub-frames so that it can be displayed at the native DMD resolution. The FPGA is also required to split output video between the two display controllers required in some systems.

3.7 Complementary System Components

- **Front-end/Receiver Chips**

  For systems designed to accept an external display source, such as HDMI, a front-end chip (also known as a receiver chip) is required. A front end chip accepts the incoming data and converts it to the correct format to be sent to the controller or FPGA. Front-end chips vary in feature set depending on the application.

- **Applications Processor**

  Systems with an integrated applications processor, such as a smartphone or tablet, can drive the DLP display system directly if it can output the format required by the display controller.

- **Wireless**

  It is becoming more common for designers to integrate wireless connectivity into display systems so that content can be shown without running cables between equipment. For example, a smart projector or screenless TV may have a built in media processor and WiFi to enable wireless video streaming. If such a system is battery powered, it can enable a truly wireless display experience.

Display System Tradeoffs

4.1 Brightness vs. Power Consumption

In general, the brighter the projection module, the higher the power consumption (driven mainly by the illumination power). For embedded applications, a target power of 1 to 2 W is typical, while accessory projectors can range from a few watts to tens of watts. In the case of LED illumination sources, efficiency is typically not linear, meaning doubling the power to the LEDs results in less than double the brightness (see Figure 4-1). Finding the right balance of brightness and power consumption is important.

4.2 Brightness vs. Size

Optical modules can vary greatly in size from a few cubic centimeters in embedded smartphone or tablet applications to hundreds of cubic centimeters in high brightness accessory projectors. In general, projection modules with higher brightness capability are larger in size. A larger illumination source, optics, and DLP DMDs may be used in order to achieve a higher brightness. The power and heat generated by the illumination source increases as the brightness increases. Heat dissipation requirements add to the size if heatsinks or fans are necessary. The size of small, low power DLP Pico systems is driven mainly by the size of the optical module, while the size of larger, higher brightness DLP display systems is driven not only by the size of the optical module but also the size of the thermal solution (see Figure 4-1).

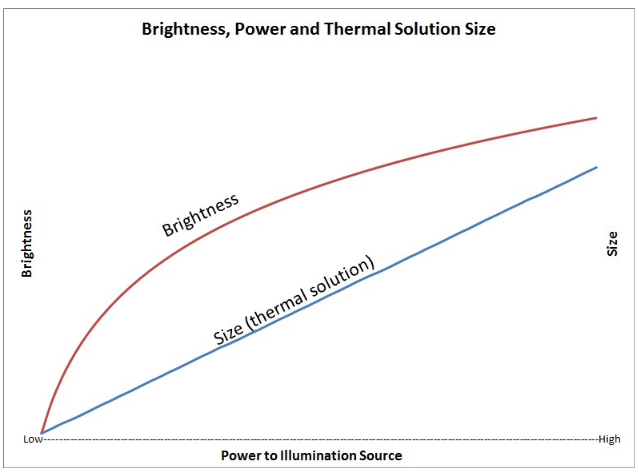

Figure 4-1. The Tradeoffs Between Brightness, Size, and Power Consumption

4.3 Throw Ratio vs. Size

In general, the shorter the throw ratio (see definition in Chapter 7), the larger the optical module due to larger optical components such as lenses and mirrors.

DLP Display Chipset Selection Guide

Choosing the right DLP chipset for your display application will depend on a number of requirements and tradeoffs. TI provides a wide range of chipsets across multiple resolutions from nHD to 4K UHD. See Table 5-1 to compare DLP chipsets.

Table 5-1. DLP® Display Technology Chipset Selection Guide

DLP® Pico™ DMD	Micromirror Array Diagonal (inch)	Display Resolution	Micromirror Pitch (µm)	Typical Brightness (Lumens)	Controller Part Number	Power Management /Illumination Driver Part Number
DLP2000	0.2	640x360	7.6	15-25	DLPC2607	DLPA1000
.24" VGA (1)	0.24	640x480	7.6	30-50	DLPC2607	
DLP3000 (.3" WVGA)	0.3	854x480	7.6	50-150	DLPC2607	
DLP4500 (.45" WXGA)	0.45	1280x800	5.4	150-750	DLPC6401	
DLP2010 (.2" WVGA)	0.2	854x480	5.4	50-100	DLPC3430 DLPC3435	DLPA2000 DLPA2005
DLP230GP (.23” qHD)	0.23	960x540	5.4	50-200	DLPC3432	DLPA2000 DLPA2005 DLPA3000
DLP230KP (.23” HD)	0.23	1280x720	5.4	50-200	DLPC3434	DLPA2000 DLPA2005 DLPA3000
DLP3010 (.3" 720p)	0.3	1280x720	5.4	100-300	DLPC3433 DLPC3438	DLPA2000 DLPA2005 DLPA3000
DLP3310 (.33" 1080p)	0.33	1920x1080	5.4	100-300	DLPC3437 (2x)	DLPA3000
DLP4710 (.47" 1080p)	0.47	1920x1080	5.4	300-1000	DLPC3439 (2x)	DLPA3000 DLPA3005
DLP Standard DMD						
.65" WXGA (1)	0.65	1280x800	7.6	1000-4000	DLPC4422	DLPA100
.65" 1080p (1)	0.65	1920×1080	7.6	1000-4000	DLPC4422	DLPA100
DLP660TE (.66" 4K UHD)	0.66	3840x2160	5.4	1000-5000	DLPC4422 (2x)	DLPA100

(1) Contact TI for more information on this device.

Resources to Get Started With DLP Technology for Display Applications

6.1 Resources to Get Started With DLP Technology for Display Applications

1. Learn more about DLP technology:
   - For DLP Pico chipsets:
     – Browse getting started resources
     – Learn about the variety of display applications which DLP technology enables
     – Browse DLP products and datasheets
     – Read other technical documents for video and data display
   - For DLP Standard chipsets:
     – Browse DLP products and datasheets
     – Learn about the variety of display applications which DLP technology enables
     – Read other technical documents for video and data display
2. Evaluate DLP display technology with an easy to use Pico evaluation module (EVM).
3. Download TI Designs reference designs to speed product development, including schematics, layout files, bill of materials, and test reports.
   - For DLP Pico chipsets:
     – DLP2010: Ultra Mobile, Ultra Low Power Display Reference Design using DLP Technology
     – DLP3010: Portable, Low Power HD Projection Display using DLP Technology
     – DLP4710: Portable, Low Power Full HD Projection Display using DLP® Technology
   - For DLP Standard chipsets:
     – DLP660TE: 4K UHD Display using DLP Technology
4. Browse TI's E2E community to search for solutions, ask for help, share knowledge and solve problems with fellow engineers and TI experts.
5. Find optical modules and design support.
   - For DLP Pico chipsets:
     – Buy small quantities of DLP Pico projection optical modules from a distributor
     – Contact optical module manufacturers for high volume, production-ready optical modules
     – Contact DLP design houses for custom DLP Pico display technology solutions
   - For DLP Standard chipsets:
     – Contact optical module manufacturers for high volume, production-ready optical modules
     – Contact DLP design houses for custom DLP Standard display technology solutions

Common Display and Projection Terminology

- **Offset**

  The DMD in many DLP projectors is offset to a position below the optical axis of the projection lens in order to shift the image above the horizontal plane. This is useful when the projector is placed on a table to avoid cutting off the bottom of the projected image. The offset also avoids the distortion of the image which would occur if the projector was simply tilted up.

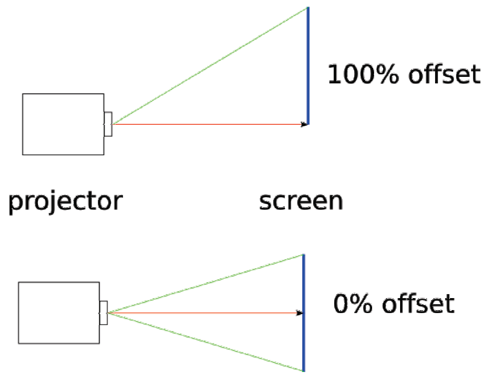

Figure 7-1. Effect of Offset

- **Throw ratio**

  In many projection applications, the placement of the projector with respect to the viewing screen is important. The throw ratio of the projector determines how far away the projector must be placed in order to achieve a certain screen size. The width of the projected image (W) with respect to the distance from the lens to the center of the screen (D) is the throw ratio (T).

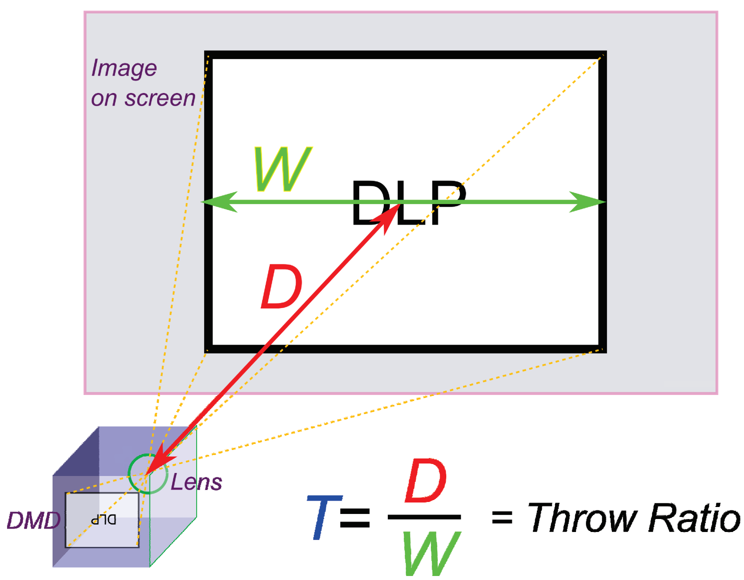

Figure 7-2. Throw Ratio

Rough definitions: Normal throw T>1; short throw 1>T>0.4; ultra short throw T<0.4.

- **F-number**

  The relative brightness of a projected image is a function of both the brightness of the illumination system and the aperture of the lens – that is, the width (D) of the lens opening with respect to the focal length (f) of the lens (determines the size of the projected image). This is expressed as a value called the F-number (N). N = f/D.
  The relative “brightness” (rb) of two lenses is a function of square of the inverse ratio of their f-numbers. rb= (N_2N_1)2. For example, a lens of N1=2 is 4x “brighter” than a lens of N2=4. f-number impacts the system as a tradeoff between brightness and volume (dimensions). Higher f-number (N=2.4) systems are thinner, but sacrifice brightness compared to a system with lower f-number (N=1.7).

- **Brightness**

  Brightness is a measure of how much light is perceived by the human eye in a given scene. This is a function of the amount of light (number of photons) and their spread across the color spectrum (photon energy), as well as the varying sensitivity of the human eye across the visible spectrum (most sensitive in the yellow-green region, less sensitive in the blue and red regions). The International System of Units (SI) identifies the lumen as the unit of measurement for brightness.

- **Lumens**

  A DLP projector will often be specified by the number of lumens it is capable of delivering in its projected image. The brightness (lumens) determines how large a screen the projector can create and still be viewable in a given ambient light environment. The greater the brightness, the bigger the displayed image can be made. End products utilizing DLP display technology can range from 20-30 lumens in smartphones and tablets to greater than 50,000 lumens in digital cinema projectors.

- **Resolution**

  The level of detail available in an image is determined by the number of pixels which make up the displayed image. In a DLP system, this is a function of the number of mirrors on the DMD which can represent one or more pixels of the displayed image. Resolution is the number of pixels that can be displayed. The level of detail displayed is not only dependent on the resolution of the projector system but it is also dependent on the resolution of the source content. If the resolution of the source content does not match the resolution of the projector system, the source content is mapped by the controller to make maximum usage of the resolution displayed. DLP display resolutions range from 640 × 360 (nHD) to 3840 × 2160 (4K UHD).

- **Keystone**

  When the optical axis of a projection system is not perpendicular to the imaging screen, the image will be geometrically distorted. One of these distortions, caused by the different distance to the screen top and bottom, is called keystone distortion. The resulting image will have a different width from top to bottom, giving the image the shape of an architectural keystone (used at the top of an arch). This distortion can be avoided by keeping the projection axis perpendicular to the screen. However, this is sometimes unavoidable. The keystone distortion can be corrected optically (very difficult, cost prohibitive, not adjustable) or by image processing means. DLP controllers provide keystone correction by re-mapping the input image to the DMD array in such a way as to produce a rectangular image at the screen. The keystone correction feature is commonly paired with an accelerometer in the system to automatically adjust the image as the projector is tilted up and down.

- **Front Projection / Rear Projection and Screens**

  A DLP display system uses an optical system to produce a real image of the pixel pattern displayed on the DMD. In order for the projected image to be seen by viewers, the light must be scattered off a surface co-located with the plane of image focus. This function is provided by a screen, which may be a specially optimized sheet of material, or simply a wall, floor, or countertop - any smooth, light colored surface can make a great image. In a front-projection system, the screen must be a reflective surface. A rear-projection system requires a translucent, dispersive screen. In both cases the viewer focuses their eyes on the screen in order to see the projected image. There are some display systems which work by producing a virtual image. For example, near eye displays and head-up displays create images that are only formed after the light travels through the eye onto the retina.

- **Contrast**

  The quality of a displayed image is greatly dependent on the distinction between the brightest and the darkest areas of the viewed image. This is quantified by the contrast ratio, which is the ratio of the brightest possible region of the image to the darkest possible region of the image. While the contrast ratio specification of a DLP system is based on system performance, the viewing experience can also be greatly impacted by ambient light. The more ambient light on the screen, the lower the viewable contrast of the image. Together, system contrast and ambient light determine the true viewable contrast of the image. Special attention must be given to the optical design, and quality of optics used in the optical module to maximize contrast.

- **Color Sequential Display**

  DLP DMDs are made up of micromirrors. They only reflect the light which illuminates them. So, how can a DMD chip reproduce full color images? The secret is in the way the human eye works. The human retina and brain synthesizes perceived color by means of a short-term time averaged differential response to the quantity of light impinging on the 3 types of retinal cones (red sensitive, green sensitive, blue sensitive). Since the eye continuously averages the light striking the retina over a period of about 1/50 second, it is possible to illuminate the eye sequentially at a sufficient rate with red, green, and blue images such that the viewer perceives the impression of full color images. This is achieved by a DLP optical module by sequentially turning the R, G, B light sources on and off such that there is, for example, a red image, followed by a green image, followed by a blue image.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from B Revision (August 2017) to C Revision	Page
• Added the DLP230GP (.23" qHD) and DLP230 KP (.23" HD) to the DLP Display Technology Chipset Selection Guide (Table 5-1)	12

Changes from A Revision (January 2017) to B Revision	Page
• Updated .2" nHD DMD to DLP2000 and added corresponding links in Table 5-1	12

Changes from Original (January 2015) to A Revision	Page
• Updated all images and sections	5

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