DLP® Technology for Near Eye Display

Application Report

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What is DLP® Pico™ Technology?

Texas Instruments' Digital Light Processing (DLP) technology is a micro-electro-mechanical systems (MEMS) technology that modulates light using a digital micromirror device (DMD). Each micromirror on a DMD represents a pixel on the screen and is independently modulated, in sync with color sequential illumination, to create stunning displays. DLP technology powers the displays of products worldwide, from digital cinema projectors to smartphones. In 2014, a new class of DLP Pico chipsets based on a breakthrough micromirror technology called DLP TRP (Figure 1-1) was launched.

With a smaller pixel pitch of 5.4 µm and increased tilt angle of 17 degrees, TI's DLP TRP chipsets have higher resolutions, lower power consumption, and enhanced image processing features while maintaining DLP technology's best in class optical efficiency. TI's TRP chipsets are a great fit for any display system that requires high resolution and high brightness at low power in a compact size.

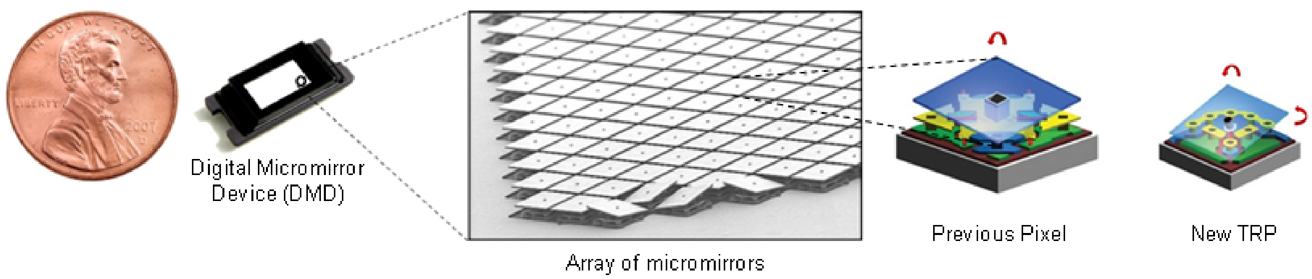


Figure 1-1. Texas Instruments DLP TRP Technology: Smaller, Brighter, Lower Power

What is Near Eye Display?

Near Eye Displays (NED), also known as head mounted displays (HMD) or wearable displays, create a virtual image in the field of view of one or both eyes. To the eye, the virtual image appears at a distance and appears much larger than the relatively small display panel and optics used to create the image. To better understand the type of experience that near eye displays can provide, let's look at another media: audio (Figure 2-1).

Figure 2-1. Evolution of Media from Large and Shared to Small and Personal

Traditional speakers are large, not easily portable, and create a shared listening experience. Headphones and earbuds, on the other end of the spectrum, are small, portable, and create a personal listening experience. Similarly, televisions and monitors are large, not easily portable, and create a shared viewing experience. Near eye displays are the headphones of the display world, creating small, portable, personal viewing experiences.

Near eye displays have several key advantages over traditional displays:

- Compact size, lightweight, portable
- Very low power
- Can be see-through

While a big screen TV is physically large, a near eye display can produce a virtual image that looks like a big screen TV from a small, wearable-sized package.

Near Eye Displays can be broadly placed in two categories: Immersive and See-Through (see Figure 2-2).

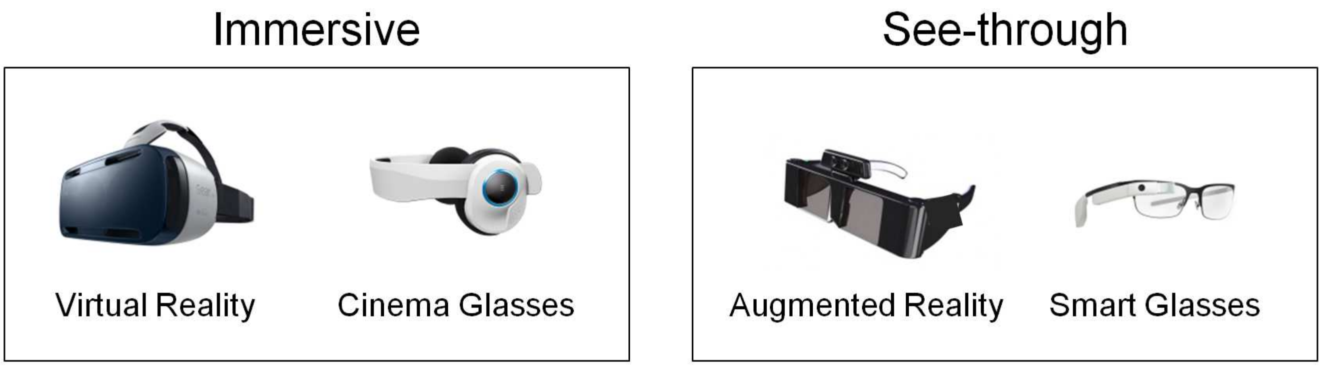


Figure 2-2. Two General Types of Near Eye Displays

Immersive near eye displays block a user's view of the real world and create a large field of view image, typically 30-60 degrees for cinema glasses and 90+ degrees for virtual reality displays. These products can act as a user's personal cinema or gaming environment.

See-through NEDs leave the user's view of the real world open and create either a transparent image or a very small opaque image that blocks only a small portion of the user's peripheral vision. The see-through category can be broken down into two applications: augmented reality and smart glasses. Augmented reality headsets typically have a 20 to 60 degree field of view and overlay information and graphics on top of the user's view of the real world. Smart Glasses, such as Google Glass, typically have a smaller field of view and a display at which the user glances periodically rather than looking through the display continuously.

NED's can be used in a variety of applications in both industrial and consumer markets:

Table 2-1. Near Eye Display Applications

	Industrial	Consumer
Augmented Reality/ See Through Display	• Warehouse Inventory Management • Equipment Repair and Assembly • Police/Firefighting/EMS	• AR Console Gaming • Smartphone/Tablet Accessory • Smart Glasses • Sports/Outdoor Activity Monitors
Virtual Reality/ Immersive Display	• Virtual Reality/ Immersive Display • VR Training Simulators • Remote Control Drone/Robot	• VR Gaming • 3D Console Gaming • Smartphone/Tablet Accessory • 3D Movies

Optical Considerations for NED Systems with DLP Technology

DLP technology is compatible with a variety of near eye display optical systems (Figure 3-1). In general, optical systems using DLP technology must include:

- An illumination system that includes a light source (typically RGB LEDs) and illumination optics to guide the light onto the DMD
- The DMD, which intelligently reflects the incoming light to create the image
- An optical system that collects the light reflected off the DMD and directs it into the eye

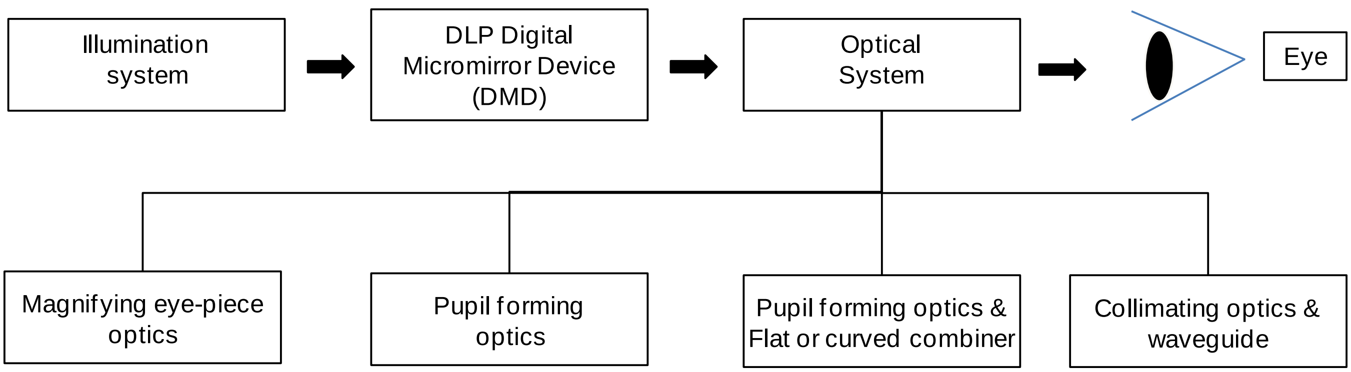


Figure 3-1. Optical System Overview

A common misconception about near eye display optics is that a small projector module shines an image on a semi-transparent surface (e.g. glasses lenses) to create the display. This is not feasible because the eye cannot focus on something that close. In fact, a near eye display optical system is quite different from a traditional projection system – rather than creating a real image on a surface, a near eye display forms a pupil and the human eye acts as the last element in the optical chain, converting the light from the pupil into an image on the retina.

Waveguide-based designs (Figure 3-2) are of particular interest because of their transparent display and pupil-expansion capabilities. A waveguide collects light at the input and relays it to the eye. It allows for the microdisplay, optics, and illumination to be located out of the way – for example, on the side of the head, leaving only a relatively small, light, transparent waveguide optical element in front of the eye.

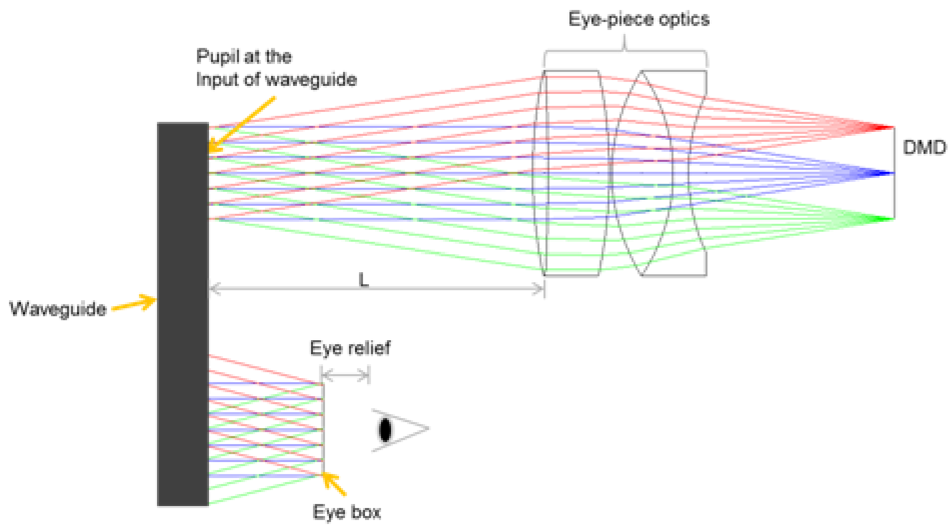


Figure 3-2. Basic Waveguide Optical System with DLP Technology (Illumination Optics Not Shown)

3.1 Tradeoffs in Optical Design

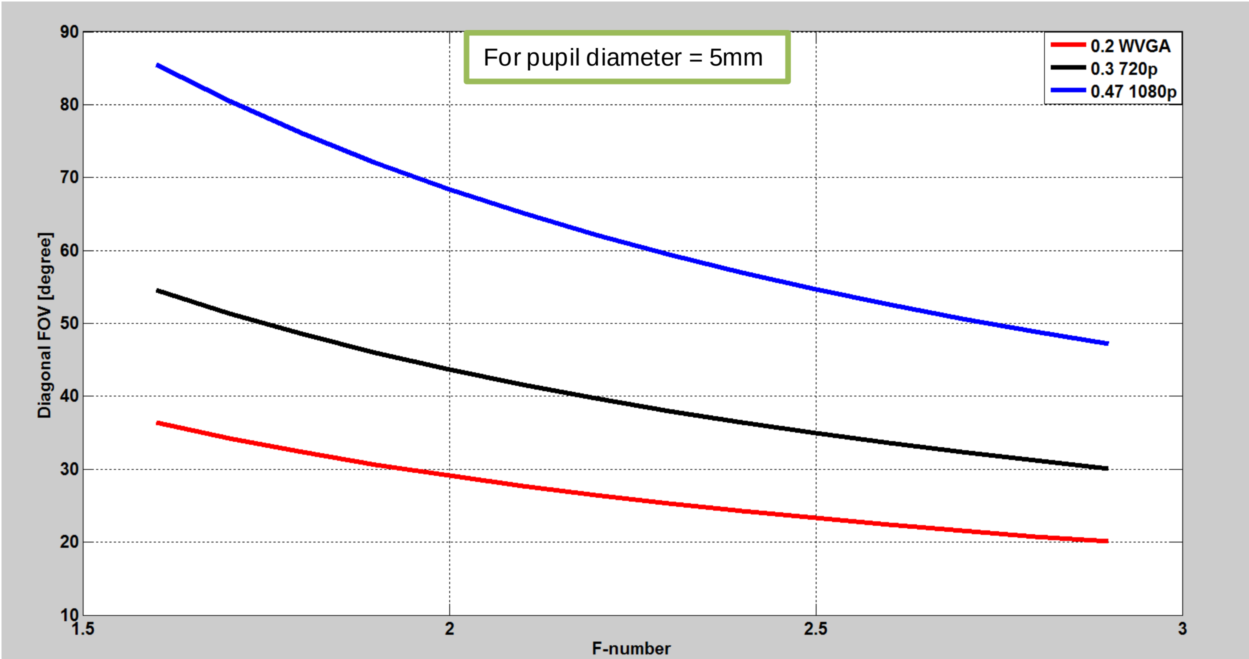
There are a number of tradeoffs to be made in the optical design of a near eye display system. Four key parameters are field of view, resolution, contrast, and system size.

There are three primary factors that control the field of view: DMD size, f-number of the optics, and pupil size at the input of the waveguide. Figure 3-3 shows the F-number vs. Diagonal field of view trade-off for a 5-mm pupil diameter for various DMD sizes. The key parameters are:

DMD size— Field of view and resolution requirements drive the required DMD diagonal size. A larger field of view will require a larger DMD, which in turn will increase the system size due to larger optics. While the size of a DLP optical module varies based on system requirements, it can be as small as a few cubic centimeters, including LEDs, the DMD, illumination optics, and pupil forming optics.

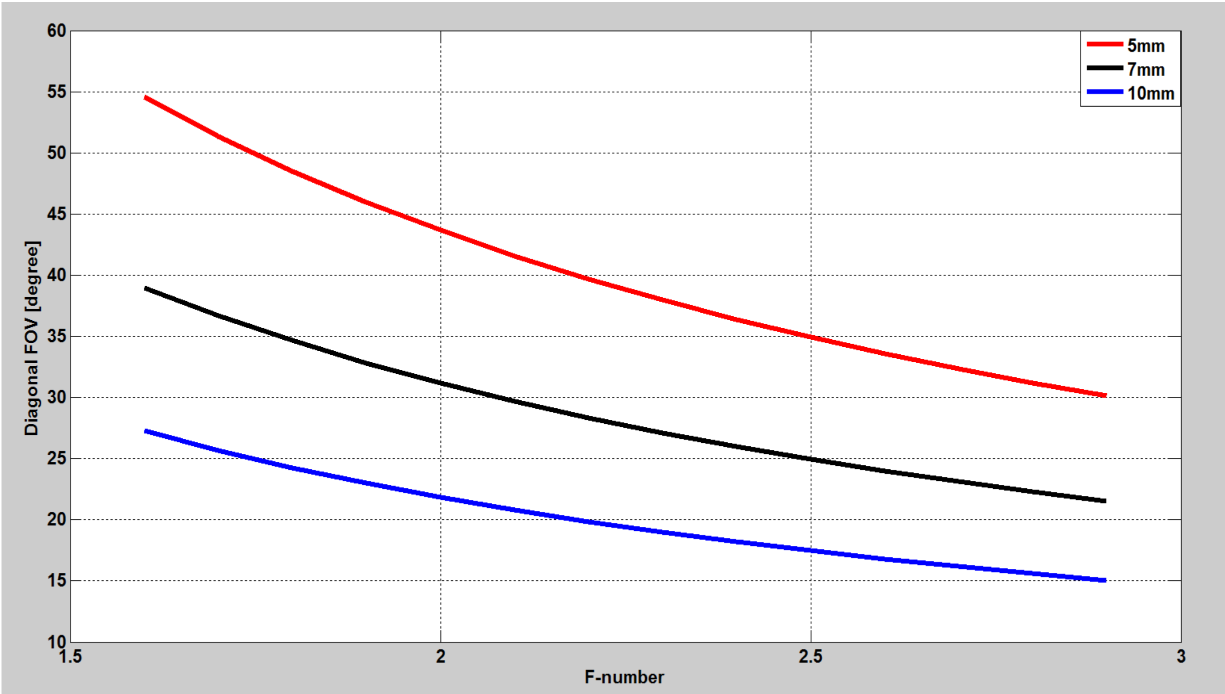
F-number of optical design— The F-number of an optical system describes the ratio of the lens' focal length to the diameter of the entrance pupil. In general, a lower F-number system enables a larger field of view and larger etendue. However, the tradeoff is an increase in the optics size. In addition, a lower F-number results in lower contrast. On the other hand, a larger F-number system yields higher contrast, reduced optical design complexity, and smaller optics size at the expense of field of view and etendue/brightness.

Pupil size at the input of the waveguide— Typically, a 5 mm pupil diameter is sufficient if a waveguide is used to expand the pupil and increase the size of eye box. A larger pupil size results in a smaller field of view for the same DMD diagonal (Figure 3-4).



Contrast increases as F-number increases ➔
Optical system size decreases as F-number increases ➔

Figure 3-3. The Relationship Between F-number and FoV for Various DMD Sizes



Contrast increases as F-number increases ➔
Optical system size decreases as F-number increases ➔

Figure 3-4. The Relationship Between F-number and FoV for a Variety of Pupil Diameters

3.2 How Illumination Orientation Impacts Optical Layout and Size

The DLP TRP architecture of the 5.4-µm pixel DMDs enables two possible illumination orientations: Side or bottom (Figure 3-6). These two options offer greater flexibility in the optical layout. For example, a longer but thinner layout using side illumination and a shorter but thicker layout using bottom illumination are shown in Figure 4-1. Several optical layouts are possible, for example box shape, thin, or L-shape depending on system requirements. For example, a thin, long optical module may be a good fit for a waveguide-based design for which the module is located on the side of the head, whereas a short, thick optical design may work well for reducing overall module volume. Each DMD is designed with a specific illumination direction required. Please see Table 5-1 for the illumination direction of each DMD.

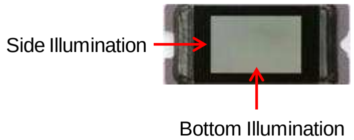


Figure 3-5. Flexible Illumination Orientation: Side or Bottom

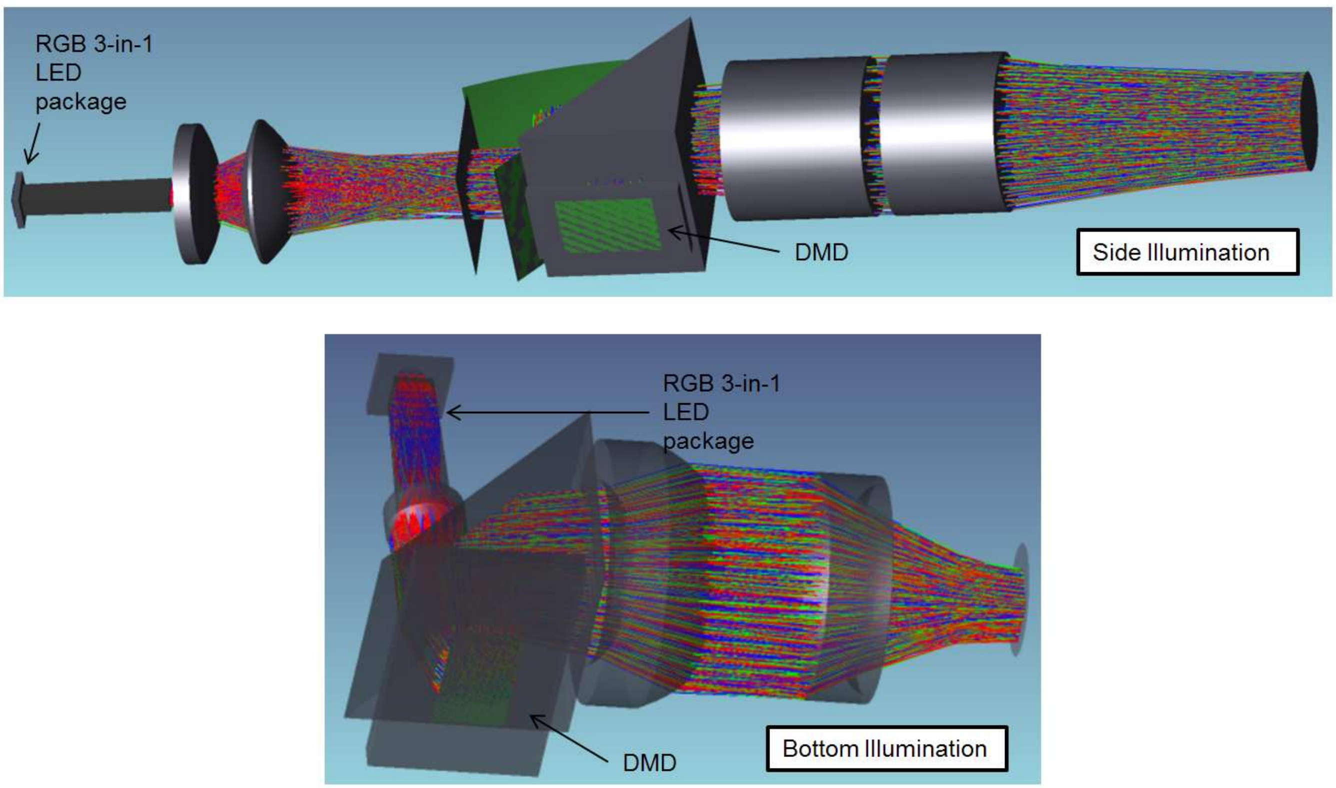


Figure 3-6. Example Optical Designs with Side and Bottom Illumination Orientations

System and Electronics Considerations for NED with DLP Technology

DLP Pico chipsets provide compact size and low power with a small, efficient controller and a PMIC/LED driver that enables an integrated, reliable system. The controllers are as small as 7 mm × 7mm, and the PMIC is as small as 3.4 mm × 3.2 mm (see Figure 4-1 for example board layout). The DMD and controller combine to draw a typical power consumption of between 150 mW to 300 mW, depending on the array size and resolution. A typical system block diagram for a Near Eye display application incorporating a DLP technology solution is shown in Figure 4-2.

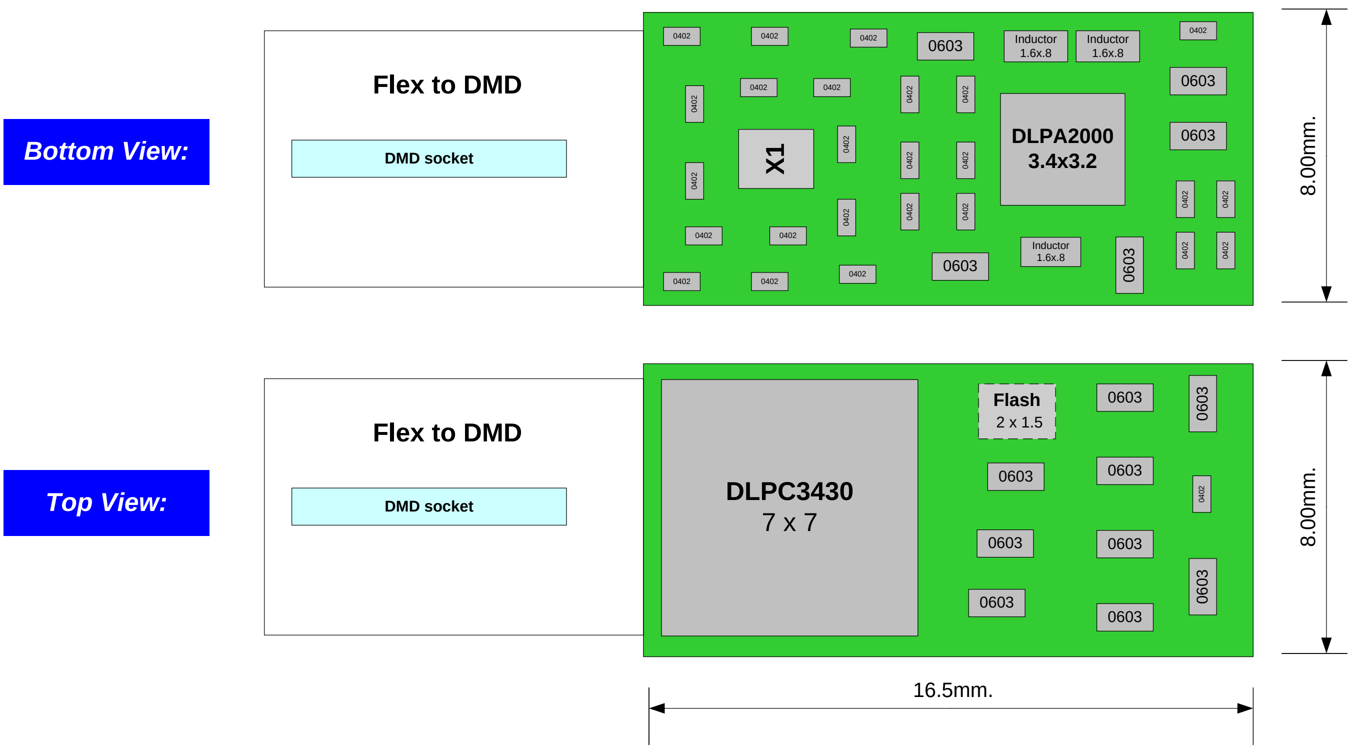


Figure 4-1. Example Small Board Design

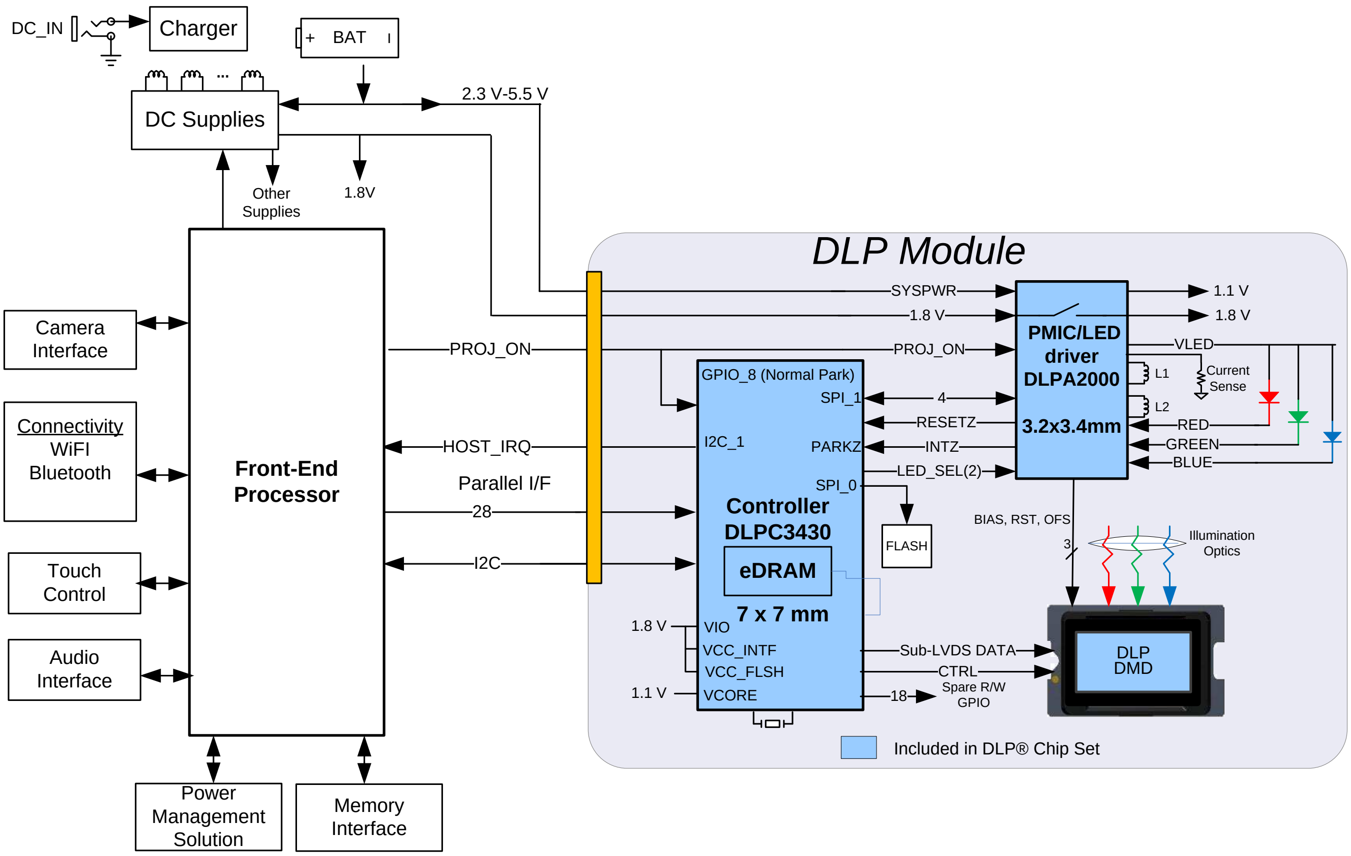


Figure 4-2. Example System Block Diagram

The DLP controller communicates with a front end processor via I^2C and receives 24-bit RGB video data via parallel interface. The front end processor controls power up/power down of the DLP system using the PROJ_ON signal. The PMIC/LED driver provides all the necessary power supplies for the controller and the DMD while the integrated LED driver provides configurable RGB LED current.

DLP Pico Chipset Portfolio for Near Eye Display

The following chipsets are well suited for near eye display:

Table 5-1. DLP Pico Chipset Portfolio for NED

	.2" nHD	.24" VGA	.3" WVGA	.2" WVGA	.3" 720p	.47" 1080p
Micromirror Array Diagonal	0.2"	0.24"	0.3"	0.21"	0.31"	0.47"
Resolution	640×360	640×480	854×480	854×480	1280×720	1920×1080
Pixel Pitch	7.6 µm	7.6 µm	7.6 µm	5.4 µm (TRP)	5.4 µm (TRP)	5.4 µm (TRP)
Pixel Orientation	Square	Diamond	Diamond	Square	Square	Square
Maximum FOV(1)	24°	29°	36°	34°	51°	86°
DMD Part #	DLP2000	TBD	DLP3000	DLP2010	DLP3010	DLP4710
Controller Part #	DLPC2607	DLPC2607	DLPC2607	DLPC3430	DLPC3433	DLPC3439
PMIC Part #	DLPA1000	N/A	N/A	DLPA2000	DLPA2000	DLPA3000
DLP IntelliBright™ Algorithms	No	No	No	Yes	Yes	Yes
DMD Illumination Direction	Corner	Side	Side	Side	Side	Bottom

(1) Assuming ideal optical design with 5mm pupil diameter and F/1.7 for TRP and F/2.5 for VSP DMD.

Why Choose DLP Technology for Near Eye Display?

There are several key advantages to using DLP technology in near eye display:

High optical efficiency — DLP technology offers very high optical efficiency. The microscopic aluminum micromirrors reflect the vast majority of incoming flight and can create a brighter near eye display with less illumination power.

Polarization agnostic — DLP technology can work with any light source including LEDs, lasers, laser-phosphor and lamp. In the case of a non-polarized source such as LED, a DLP-based solution yields high optical system efficiency because it does not have polarization conversion and recapture losses.

The advantage in optical efficiency makes DLP technology a particularly good fit for higher brightness near eye display applications, such as see-through, larger field of view applications. As brightness increases, DLP system power advantage increases (Figure 6-1).

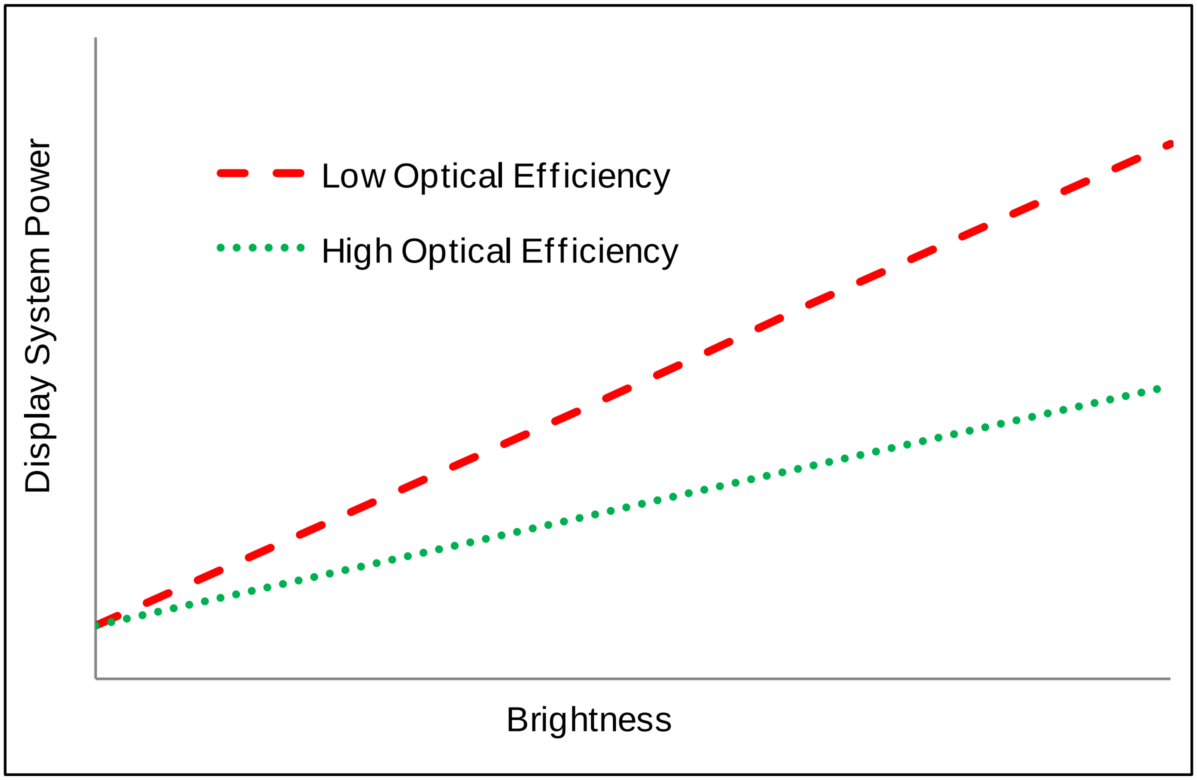


Figure 6-1. High Optical Efficiency Lowers System Power as Brightness Increases

High contrast — Depending on the optical design, DLP technology can enable contrast ratios over 2000:1, which creates deep blacks for immersive displays and highly transparent backgrounds for augmented reality displays (see Figure 6-2).

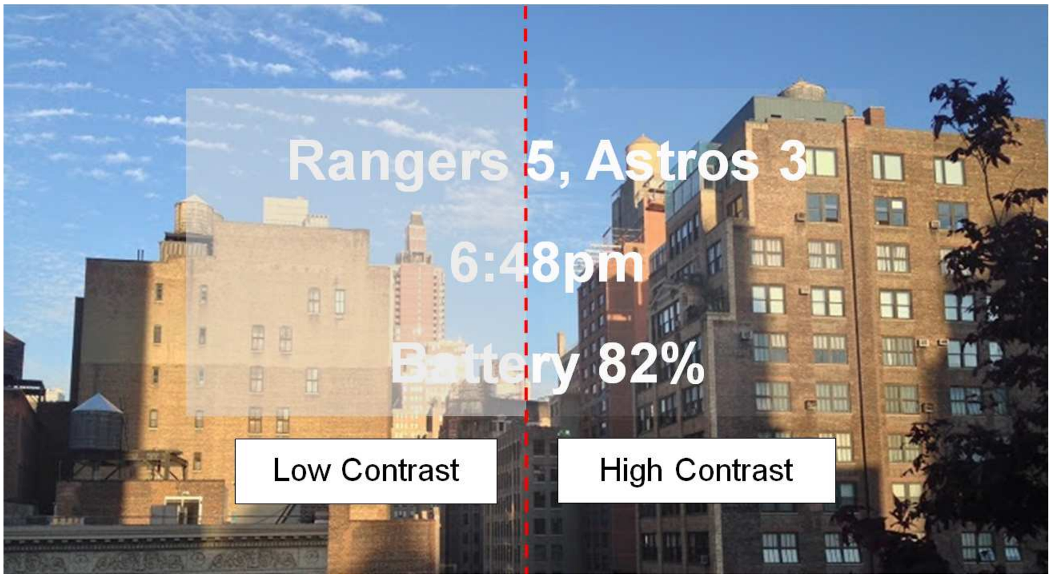


Figure 6-2. Low Contrast (Left) vs High Contrast (Right)

High speed — Low latency: DLP technology is one of the fastest display technologies in the world – each micromirror can flip thousands of times per second. This enables fast color refresh rates and low latency, which are of particular importance to near eye display applications.

In addition, TI's TRP chipsets have several additional features that make them particularly well suited for near eye display applications.

Higher resolution in a smaller form factor — TI's TRP is about 50% smaller in area than the previous DLP pixel technology, enabling 2x the pixels in the same array size. For example, a 0.3" array diagonal with TI's TRP enables 1280×720 pixels as compared to a 0.3" array diagonal of 854×480 pixels with the previous pixel technology.

Flexible illumination direction — TI's TRP technology enables DMDs designed with either side or bottom illumination direction. See Table 5-1 for the illumination direction of each TRP DMD.

Low power — TI's TRP chipsets were designed with power savings in mind. For example, TI's TRP 0.2" WVGA (854×480) chipset is about 50% lower power than the previous generation WVGA chipset, and the 0.3" 720p chipset is about 80% lower power than the previous generation 720p chipset.

Advanced image processing algorithms — DLP IntelliBright™ suite of algorithms performs two key functions: 1) Content Adaptive Illumination Control: Dynamically adjust each RGB LED to optimize power based on frame by frame content, 2) Local Area Brightness Boost: Intelligently boost darker regions of images depending on ambient lighting conditions. For more information, see the DLPC343x Software Programmer's Guide.

DLP technology is one of the most proven display technologies on the market. Tens of millions of DLP chips have been sold and DLP Cinema® is the technology of choice for nearly 90% of digital cinema screens worldwide. DLP chipsets for near eye display take the same core technology and transform it into a tiny display that creates a cinema quality image in just about any near eye display application.

Next Steps

If you have optical design expertise and want to design your own optical module

1. Learn more about DLP Video and Data Display chipsets with datasheets, reference designs, and more at www.ti.com/dlp
2. Purchase an EVM: www.ti.com/lsds/ti/dlp/video-and-data-display/tools.page
3. Check out TI's E2E community to search for solutions, get help, share knowledge and solve problems with fellow engineers and TI experts.e2e.ti.com/support/dlp__mems_micro-electro-mechanical_systems/default.aspx
4. Contact your local TI salesperson or TI distributor representative. www.ti.com/general/docs/contact.tsp
5. Work with a DLP Design Network partner with optical design, electronics, and software expertise. www.ti.com/lsds/ti/dlp/video-and-data-display/solutions-services.page

Revision History

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

Changes from Original (September 2014) to A Revision **Page**

- Updated DMD Part # and PMIC Part # for .2" nHD from TBD and N/A to DLP2000 and DLPA1000, respectively........ 13

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265