Application Report

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TI DLP® System Design: Brightness Requirements and Tradeoffs

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ABSTRACT

The objective of this application note is to help product developers who are new to DLP technology understand brightness and the related system tradeoffs.

Prior to reading this application note, it is recommended to read the Getting Started with TI DLP® Technology whitepaper to get a high level understanding of the technology and the applications it enables.

After reading this, check out the DLP Throw Ratio and Brightness Calculator to experiment with projection specifications.

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Trademarks

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1 Introduction

Brightness requirements are one of the key considerations to account for when designing any projection system.

The terms *projector brightness* and *image brightness* are used throughout this paper. Here is how they are defined for the sake of this paper:

- **Projector brightness** [1] is the amount of visible light emitted from a projector or projection system. It is measured in ANSI [2] lumens (lm) and is independent of image size. With TI DLP technology, it is possible to create projectors spanning a broad brightness range: From 30 lumens for projectors embedded into products like smartphones or tablets, to over 10,000 lumens for large venue projectors. Projection systems can include several different types of illumination sources including lamps, LEDs, and lasers. Factors that impact projector brightness include illumination source type (lamp, LED, or laser), illumination source output capability (radiant watts), illumination source input power (electrical), optical design, and the DLP active array area.
- **Image brightness** is a measure of the brightness of an image reflected off of a surface. It is measured in nits (candelas per square meter) and is proportional to lumens per square meter projected onto the surface. [3] For a fixed display area (image size), the more lumens a system can output, the higher the nits. Likewise, for a fixed number of lumens from the projection system, the smaller the display area, the higher the nits. Image brightness also depends on the projection surface; different surfaces have different reflective characteristics, but exploring the impact and trade-offs of surface characteristic is beyond the scope of this paper.

The term *projector* can often have limiting connotations. Classically, a projector is a system used only to display a video or image on a wall, and while this is still the case, projection systems can be utilized to display any form of visuals or infographics on virtually any display surface. These can be used for smart home displays, digital signage, laser TVs, and many other potential applications. DLP technology enables projection systems of many sizes for use in countless applications, in addition to supporting bright, vivid displays for classically defined projectors.

The two of the most frequently asked questions from customers who are new to TI DLP technology are: “How much brightness is needed for my application,” and “how bright can the projection system get?” In other words:

- What is the right brightness (in lumens) for my product, given the application and user environment?
- Given specific power size and cost requirements, what is the maximum brightness that my product can achieve?

The first question is often asked by product developers for whom image *quality* is the highest priority, whereas the second question is often asked by product developers who have certain technical constraints, most frequently power, size, and cost, which will ultimately constrain the maximum brightness of the projection system.

(1) Projector brightness is technically defined as luminous flux, which is the energy within the visible wavelengths radiated from a source per unit time. The SI unit of luminous flux is the lumen.

(2) ANSI (American National Standards Institute) lumens are measured by averaging the brightness of nine points across the projected image, thus taking into account differences in brightness uniformity across different projectors.

(3) Technically, for an arbitrary reflector (surface), Nits = (Lumens × Screen Gain) / ($\pi \times m^2$), but a discussion about screen gain is outside the scope of this application note. In this application note, it is being assumed that all reflective surfaces are Lambertian with a screen gain of 1 unless otherwise noted.

2 Determining the Right Brightness for Your Product

Answering the two most frequently asked questions proposed in Section 1 depends on the following variables:

- **Ambient lighting environment.** The ambient light level of the expected use-environment is a critical factor to consider. For example, with the same projection system, the perceived brightness of a 50-inch (diagonal) image in a well-lit office may be similar to a 100-inch image in a dark room.
- **Screen size required.** For every 2x increase in the image diagonal (e.g. 20 inch to 40 inch), projector brightness (lumens) needs to increase by 4x (e.g. 50 lumens to 200 lumens) in order to maintain constant image brightness (nits).
- **Video content type.** The *brighter* the image content (technically, the higher the average picture level) or the more *colorful* the image content (technically, the more saturated the colors are), the fewer lumens or nits needed to create an image that appears *bright*.
- **Projection surface.** For the purpose of this application note, a non-glossy, white surface is assumed. For applications requiring a different type of surface, such as a patterned or colored surface, more nits may be required.

Ultimately, necessary *brightness* is a subjective assessment. This paper will focus specifically on how a projection system's brightness requirement is impacted by ambient light level and screen size.

3 The Impact of Ambient Light Level

Ambient light levels vary significantly across different use environments. Consider for example the ambient light level of a movie theater compared to that of a typical office environment. Because the ambient light level in a movie theater is both well controlled and very low, the cinema industry standard for image brightness is relatively low (~50 nits).

Based upon empirical testing by TI, the estimated minimum image brightness for different ambient light environments is summarized in Table 1.

Table 1. Ambient Lighting and Estimated Minimum Image Brightness in Nits

	Ambient Lighting Environment				
	Dark Room	**Dim Room**	**Lit Room**	**Bright Room**	**Outdoors**
Example environment	A room at night with all lights turned off	A room with soft lighting at night	A well-lit office conference room with no daylight (Home Theater)	Well-lit room with windows and indirect daylight (TV)	Indirect sunlight
Suggested image brightness	50 nits	100 nits	200 nits	300-400 nits	600+ nits

4 The Impact of Screen Size

Figure 1 provides suggested projection brightness (lumens) as a function of diagonal image size and image brightness (nits) levels from Table 1. Additionally, Figure 1 references the DLP chip class (categorized by the diagonal of the DLP chip micromirror array, called a digital micromirror device or DMD, measured in inches) associated with each brightness level. You can learn more about the DLP product portfolio here.

Image Diagonal (inches)	Suggested Projection Brightness (lumens)					
140+	1000	2000	4000	6100	8200	12200
120	750	1500	3000	4500	6000	9000
100	500	1000	2000	3100	4100	6200
80	300	700	1300	2000	2700	4000
70	250	500	1000	1500	2000	3000
60	200	400	750	1100	1500	2200
50	150	250	500	800	1000	1500
40	100	150	300	500	700	1000
30	50	100	200	300	400	550
20	20	50	100	125	150	250
10	5	10	20	30	40	60
Image Brightness (nits)	50	100	200	300	400	600

DMD Diagonal	Typical Brightness Range (lumens)
0.9" Class	Up to 10000
0.6" Class	Up to 5000
0.4" Class	Up to 4000
0.3" Class	Up to 350
0.2" Class	Up to 150

Figure 1. Suggested Projection Brightness for a Combination of Image Sizes and Image Brightness Levels

These calculations [4] assume a projection surface with a reflectivity of 80%. When projecting onto a non-ideal surface, the actual lumens desired may be different than those shown above. A typical white wall has a reflectivity of 80% but colored paints can reduce this number. High gain screens are designed to increase reflection in a particular viewing direction and can be used to increase image brightness without increasing projection brightness.

(4) Over time these levels have the potential to increase as new light sources and DMD technology are introduced to the market.

5 Trade-offs Associated with Brightness

How bright can a DLP projection system get? The short answer is *very bright*. One of the core advantages of DLP technology is its high optical efficiency, enabling bright projection systems with low power consumption and compact size. If limitations on size and power are not a factor, you can create displays with over 10,000 lumens like the ones used at major sporting events during player introductions or halftime shows.

However, for this paper, the scope of the question will be limited to *"What is the maximum brightness of a DLP projection solution for my size and power requirements?"* The answer is “it depends” – there are tradeoffs that can be made at a system design level which depend upon the product design priorities. To make a brighter projection solution, it is necessary to also increase one of (or a combination of) these variables:

Table 2. Key Projection System Variables and Impacts

Variable	Contribution	Limitation
Illumination source output capability	Amount of light that can be generated	Source and DMD etendue [5]
Optics size	Amount of light that can be collected	Size and cost
DMD chip size	Amount of light that can be reflected	Size and cost
Illumination source drive power	Illumination source brightness level	Thermal limit and cost of power design
Illumination thermal solution	Amount of heat dissipated from the illumination source	Size and cost

For a production-ready optical engine, the first three variables in Table 2 will be constant.

The last two variables in Table 2 (illumination source drive power and the illumination thermal solution) can vary depending on the design requirements of the final product. For example, a given optical module can achieve different brightness outputs depending on the current supplied to the LEDs or lasers. Lamps have a fixed power input and output, but can often be switched for higher power bulbs.

DLP technology is flexible and can be used with any illumination source. There are three main types of illumination typically used in DLP projection systems: lamp, LED, and laser. Lamp sources offer a cost effective solution; LED and laser sources offer high efficiency, solid state illumination. Lamp illumination is often used in classroom, conference room, and home theater projectors. LED illumination is often found in small, battery powered projection systems. Laser illumination is used to reduce size and increase brightness of products ranging from portable displays to high brightness, large venue projections.

For LEDs and lasers, increasing the input power to the illumination source will cause them to output more light, but also causes more heat to be generated by the illumination system. This necessitates a more efficient thermal system to keep the illumination sources at their recommended operating temperatures. Therefore, as brightness increases, so does the illumination device temperature, which in turn drives an increase in the complexity of the illumination thermal system. It is worth noting that higher illumination source output will also result in a higher heat load on the DMD. Therefore, at some point, the size of the DMD thermal solution may need to be increased as well.

Additionally, it is important to keep in mind that as the power to the illumination source increases, so does brightness, but at a decreasing rate, resulting in increased heat generation. Although illumination power and brightness varies for different illumination types, all illumination sources will have an optimal brightness range in which they can operate with maximum efficiency. The thermal management solution must be carefully designed to remove the necessary heat from the system while minimizing the impact to the product’s size and cost.

[5] Etendue is a measure of the geometric extent of the light source approximated by the area of the source multiplied by the solid angle of the light emission. Optimum light throughput is usually obtained when the etendue of the source and the DMD are equal where the DMD solid angle is determined by the micromirror tilt angle.

6 Other Considerations

While brightness, power consumption, and size are typically the most dominant system requirements, there are two additional performance parameters that product developers should consider when designing a DLP projection system: optical engine contrast ratio and projection lens throw ratio.

The contrast ratio of a projection engine impacts the perceived quality of the projected image. The higher the contrast ratio, the greater the difference between the light and dark areas of the image (see Figure 2). High contrast results in deep blacks and vivid looking colors.

There are two methods of measuring a systems contrast ratio: Full-On and Full-Off (FOFO) Contrast and ANSI Contrast. FOFO Contrast is essentially a measurement of the display panels inherent contrast ratio, whereas ANSI Contrast is essentially a measurement of the projection optics contrast ratio. DLP technology can enable contrast ratios of over 2,000:1, depending on the projection optics design.

Figure 2. Simulated Images of High Contrast (Above) and Low Contrast (Below)

Projection lens throw ratio relates the size of the projection image to the distance from the projection system to the projection surface, and is defined as D/W, where D is the distance from the projection lens to the projection surface, and W is the width of the projected image. This is illustrated in Figure 3.

While throw ratio does not impact projector brightness (lumens), it does impact image brightness (nits) from a given projection distance. Two projectors of the same *projector brightness* (lumens) but with different throw ratios will create different size images when placed the same distance from the viewing surface. Since the different throw ratios result in different image sizes, the *image brightness* levels (nits) will also be different. The projector with the shorter throw ratio will create a bigger image, and thus a dimmer image because the light (lumens) is be spread out over a larger area. Conversely, the projector with the longer throw ratio will create a smaller (and therefore brighter) image. Throw ratio should be considered based on the use case of the final product, whether the projection system will be close to the image or far away from it.

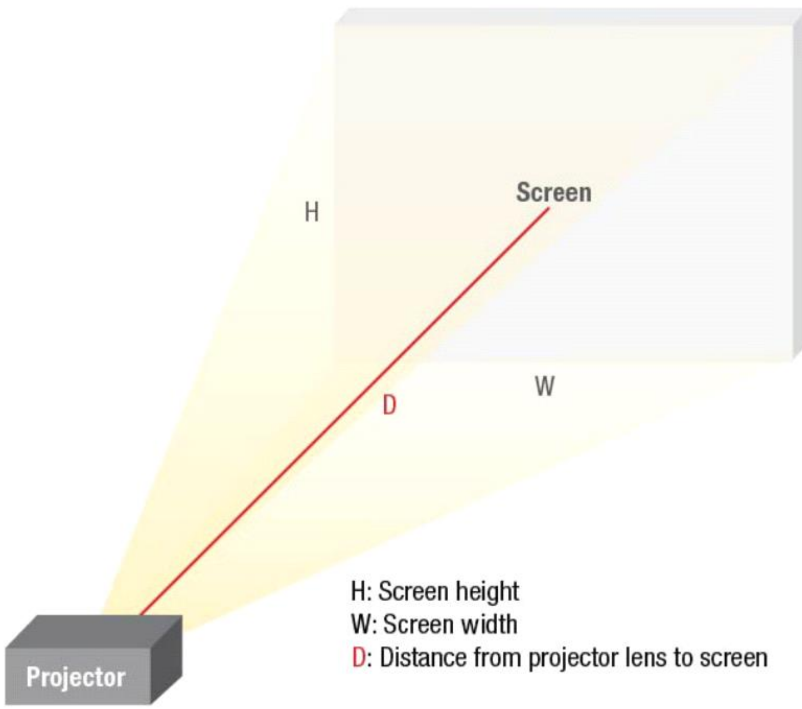

Figure 3. Projection Throw Ratio

7 Conclusion and Getting Started

DLP technology enables a wide range of brightness capabilities. Designers can influence the brightness capability of their DLP projection solution by balancing the product requirements of power consumption, product size, and illumination source selection.

It is important to remember that the brightness requirement of a display is highly dependent on the ambient light level in the target environment, desired image size, and the image content (video versus graphics).

Taken together, these insights can help determine an optimal DLP projection design for a given product. Furthermore, the high optical efficiency and high contrast capability of DLP technology can enable bright and vivid images, even for products with size or power consumption limitations.

Table 3. Recommended Chipset Portfolio

Target Brightness Range	Key System Requirements	Recommended DLP Chipset Portfolio
Up to 1,500 lumens	Smaller size, lower power	DLP Pico Display
Up to 10,000 lumens	Higher brightness	DLP Standard Display

DLP Pico chipsets are the smallest, lowest power display chips offered by TI DLP Products. They are a good fit for applications like wearable displays, tablets, smart home displays, after-market head-up displays, and more. DLP Standard chipsets are larger and therefore enable higher brightness levels. They are a good fit for applications such as education and office projectors, large format digital signage, and laser TVs.

7.1 Steps to Learn More About DLP Technology

1. Learn more about DLP display technology:
   - Browse getting started resources
   - Learn about the variety of applications which DLP display technology enables
   - Browse products and datasheets
   - Read other technical documents for video and data display
2. Evaluate DLP Pico technology with an easy to use evaluation module (EVM).
3. Download reference designs to speed product development, including schematics, layout files, bill of materials, and test reports.
   - For DLP Pico display technology:
     – 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 display technology:
     – DLP660TE: 4K Ultra High Definition (UHD) Display using DLP Technology
     – DLP470NE: 1080p Laser TV Reference Design
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 display technology:
     – 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 display technology:
     – Contact optical module manufacturers for high volume, production-ready optical modules
     – Contact DLP design networks for custom DLP Standard display technology solutions

Revision History

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