# An Introduction to the Digital Light Processing (DLP™) Technology

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## Introduction

Digital Light Processing (DLP™) is a revolutionary new way to project and display information. Based on the Digital Micromirror Device (DMD™) developed by Texas Instruments, DLP creates the final link to display digital visual information. DLP technology is being provided as subsystems or "engines" to market leaders in the consumer, business, and professional segments of the projection display industry. In the same way the compact disc revolutionized the audio industry, DLP will revolutionize video projection.

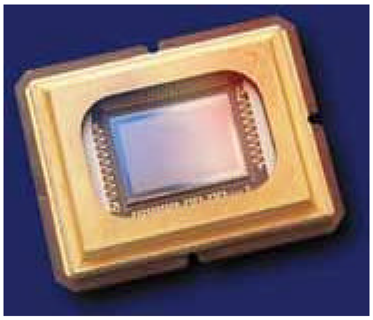
DLP has three key advantages over existing projection technologies. The inherent digital nature of DLP enables noise-free, precise image quality with digital gray scale and color reproduction. Its digital nature also positions DLP to be the final link in the digital video infrastructure. DLP is more efficient than competing transmissive liquid crystal display (LCD) technology because it is based on the reflective DMD and does not require polarized light. Finally, close spacing of the micromirrors causes video images to be projected as seamless pictures with higher perceived resolution. For movie projection, a computer slide presentation, or an interactive, multi-person, worldwide collaboration—DLP is the only choice for digital visual communications, today and in the future.

## Digital Light Processing: How It Works

In the same way a central processing unit (CPU) is the heart of a computer, a DMD is the cornerstone of DLP. One-, two-, and three-chip DLP systems have been built to serve different markets. A DLP-based projector system includes memory and signal processing to support a fully digital approach. Other elements of a DLP projector include a light source, a color filter system, a cooling system, and illumination and projection optics.

A DMD can be described simply as a semiconductor light switch. Thousands of tiny, square, 16 x 16Êmm mirrors, fabricated on hinges atop a static random access memory (SRAM) make up a DMD (**Figure 1**). Each mirror is capable of switching a pixel of light. The hinges allow the mirrors to tilt between two states, +10 degrees for "on" or -10 degrees for "off." When the mirrors are not operating, they sit in a "parked" state at 0 degrees.

**Figure 1**



An 848 x 600 Digital Micromirror Device. The central, reflective portion of the device consists of 508,800 tiny, tiltable mirrors. A glass window seals and protects the mirrors.

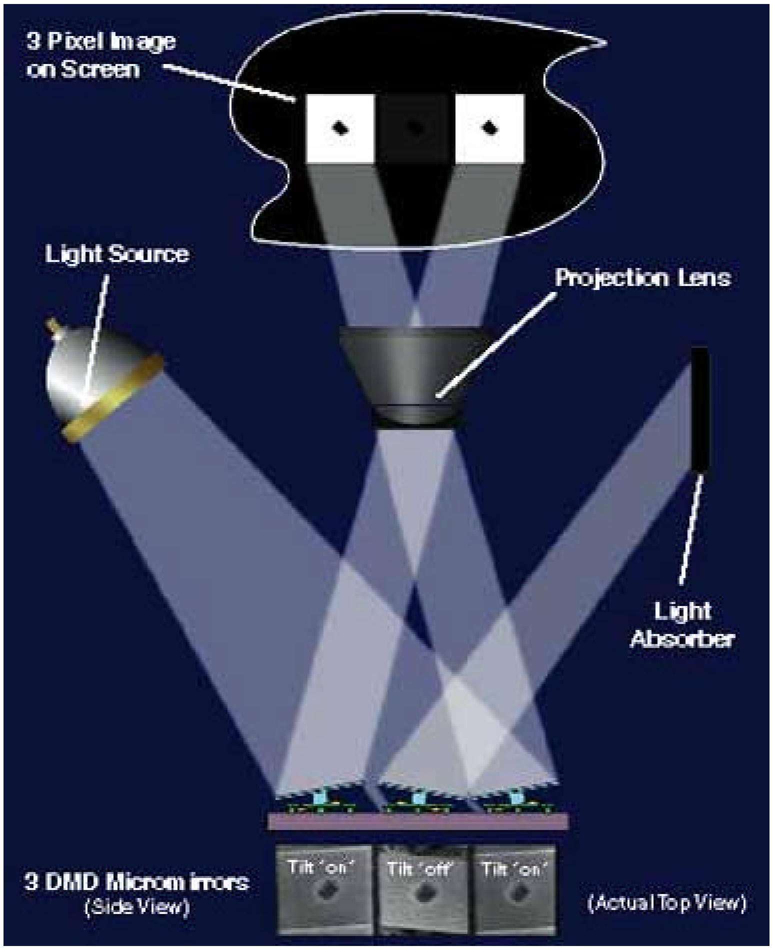
Depending on the application, a DLP system will accept either a digital or an analog signal. Analog signals are converted to digital in the DLP's or the original equipment manufacturer's (OEM's) front-end processing. Any interlaced video signal is converted to an entire picture frame video signal through interpolative processing. From here, the signal goes through DLP video processing and becomes progressive red, green, and blue (RGB) data. The progressive RGB data are then formatted into entire binary bit planes of data.

Once the video or graphic signal is in a digital format, it is sent to the DMD. Each pixel of information is mapped directly to its own mirror in a 1:1 ratio, giving exact, digital control. If the signal is 640 x 480 pixels, the central 640 x 480 mirrors on the device will be active. The other mirrors outside of this area will simply be turned to the off position.

By electrically addressing the memory cell below each mirror with the binary bit plane signal, each mirror on the DMD array is electrostatically tilted to the on or off positions. The technique that determines how long each mirror tilts in either direction is called pulsewidth modulation (PWM). The mirrors are capable of switching on and off more than 1000 times a second. This rapid speed allows digital gray scale and color reproduction.

At this point, DLP becomes a simple optical system. After passing through condensing optics and a color filter system, the light from the projection lamp is directed at the DMD. When the mirrors are in the on position, they reflect light through the projection lens and onto the screen to form a digital, square-pixel projected image (**Figure 2**).

**Figure 2**



Three mirrors efficiently reflect light to project a digital image. Incoming light hits the three mirror pixels. The two outer mirrors that are turned on reflect the light through the projection lens and onto the screen. These two "on" mirrors produce square, white pixel images. The central mirror is tilted to the "off" position. This mirror reflects light away from the projection lens to a light absorber so no light reaches the screen at that particular pixel, producing a square, dark pixel image. In the same way, the remaining 508,797 mirror pixels reflect light to the screen or away from it. By using a color filter system and by varying the amount of time each of the 508,800 DMD mirror pixels is on, a full-color, digital picture is projected onto the screen.

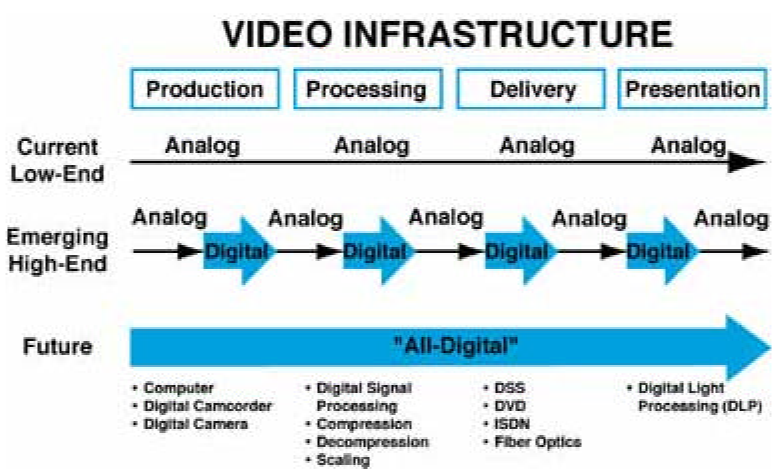
**The Digital Advantage**

The audio world started the trend toward digital technology well over a decade ago. Recently, an abundance of new digital video technology has been introduced to the entertainment and communications markets. The digital satellite system (DSS) quickly became the fastest selling consumer electronics product of all time, selling record numbers of units in its first year of introduction. Sony, JVC, and Panasonic have all recently introduced digital camcorders.

Epson, Kodak, and Apple are a few of the companies that now have digital cameras on the market. The digital versatile disc (DVD), a widely anticipated new storage medium, will feature full-length films with better than laser disc video quality by placing up to 17 gigabytes of information on a single disc.

Today we have the ability to capture, edit, broadcast, and receive digital information, only to have it converted to an analog signal just before it is displayed. DLP has the ability to complete the final link to a digital video infrastructure as well as to provide a platform on which to develop a digital visual communications environment. Each time a signal is converted from digital to analog (D/A) or analog to digital (A/D), signal noise enters the data path. Fewer conversions translates to lower noise and leads to lower cost as the number of A/D and D/A converters decreases. DLP offers a scalable projection solution for displaying a digital signal, thus completing an all-digital infrastructure (**Figure 3**).

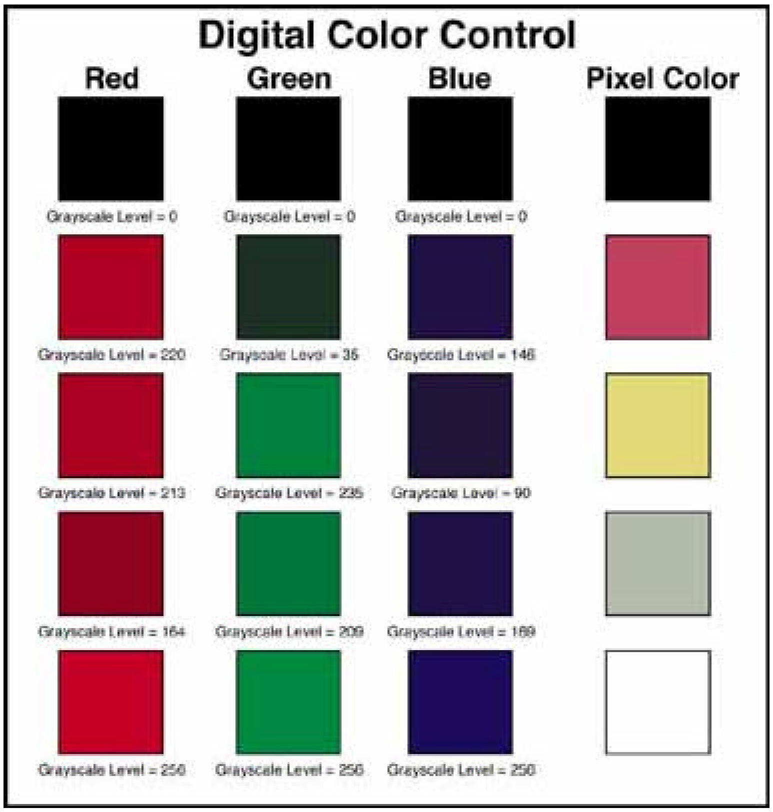
**Figure 3**




The video infrastructure. DLP offers the final link to a complete digital video infrastructure.

Another digital advantage is DLPâs accurate reproduction of gray scale and color levels. And because each video or graphics frame is generated by a digital, 8- to 10-bits-per-color gray scale, the exact digital picture can be recreated time and time again. For example, an 8-bits-per-color gray scale gives 256 different shades of each of the primary colors, which allows for $256^3$, or 16.7 million, different color combinations that can be digitally created (**Figure 4**).

**Figure 4**




DLP can generate digital gray scale and color levels. Assuming 8 bits per color, 16.7 million digitally created color combinations are possible. Above are several combinations of different gray scale levels for each of the primary colors and the resultant digitally created pixel colors.

**The Reflective Advantage**

Because the DMD is a reflective device, it has a light efficiency of greater than 60%, making DLP systems more efficient than LCD projection displays. This efficiency is the product of reflectivity, fill factor, diffraction efficiency, and actual mirror "on" time.

LCDs are polarization-dependent, so one of the polarized light components is not used. This means that 50% of the lamp light never even gets to the LCD because it is filtered out by a polarizer. Other light is blocked by the transistors, gate, and source lines in the LCD cell. In addition to these light losses, the liquid crystal material itself absorbs a portion of the light. The result is that only a small amount of the incident light is transmitted through the LCD panel and onto the screen. Recently, LCDs have experienced advances in apertures and light transmission, but their performance is still limited because of their dependence on polarized light.

**Seamless Picture Advantage**

The square mirrors on DMDs are 16 µm², separated by 1 µm gaps, giving a fill factor of up to 90%. In other words, 90% of the pixel/mirror area can actively reflect light to create a projected image. Pixel size and gap uniformity are maintained over the entire array and are independent of resolution. LCDs have, at best, a 70% fill factor. The higher DMD fill factor gives a higher perceived resolution, and this, combined with the progressive scanning, creates a projected image that is much more natural and lifelike than conventional projection displays (**Figure 5**), (**Figure6a**), (**Figure6b**).

**Figure 5**

Photograph used to demonstrate the DLP advantage. This digitized photograph of a parrot was used to demonstrate the seamless, filmlike DLP picture advantage detailed in Figures 6a and b.

A leading video graphics adapter (VGA) LCD projector was used to project the image of the parrot shown in **Figure 5**. In **Figure 6a**, the pixelated, screen-door effect common to LCD projectors can be easily seen.

The same image of the parrot was projected using a DLP projector and is displayed in **Figure 6b**. Because of the high fill factor of DLP, the screen-door effect is gone. What is seen is a digitally projected image made up of square pixels of information. With DLP, the human eye sees more visual information and perceives higher resolution, although, as demonstrated, the actual resolution shown in both projected images is the same. As the photographs illustrate, DLP offers compellingly superior picture quality.

**Figure 6a & 6b**

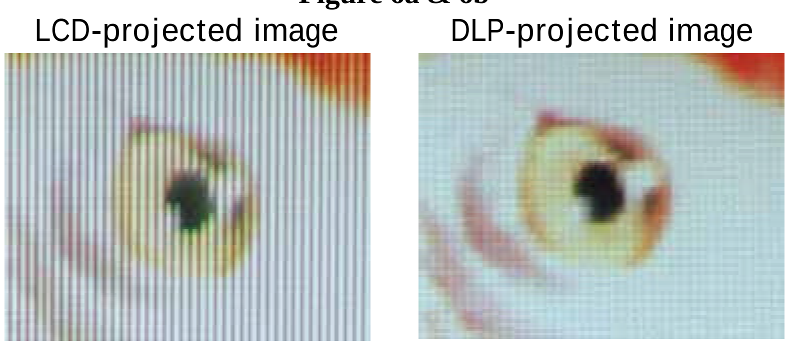



Figure 6. Actual closeup photographs of both (a) an LCD-projected image and (b) a DLP-projected image. A three-panel polysilicon VGA resolution LCD projector (a) and a one-chip VGA resolution DLP projector (b) both project the photograph of the parrot shown in Figure 5. Both the LCD and DLP photos were taken under the same conditions, with each projector being optimized for focus, brightness, and color. Note the high level of pixelation in the LCD image in contrast to the seamless DLP image. DLP offers superior picture quality because the DMD mirror pixels are separated by only 1 µ thus eliminating pixelation.

## Reliability

DLP systems have successfully completed a series of regulatory, environmental, and operational tests. Standard components with proven reliability were chosen to construct the digital electronics used to drive the DMD. No significant reliability degradation has been identified with either the illumination or projection optics. Most of the reliability concerns are focused on the DMD because it relies on moving hinge structures. To test hinge failure, approximately 100 different DMDs were subjected to a simulated 1 year operational period. Some devices have been tested for more than 1 trillion cycles, equivalent to 20 years of operation. Inspection of the devices after these tests showed no broken hinges on any of the devices. Hinge failure is not a factor in DMD reliability.

The DMD has passed all standard semiconductor qualification tests. It has also passed a barrage of tests meant to simulate actual DMD environmental operating conditions, including thermal shock, temperature cycling, moisture resistance, mechanical shock, vibration, and acceleration testing. Based on thousands of hours of life and environmental testing, the DMD and DLP systems exhibit inherent reliability.

## Conclusion

Simply put, DLP is an optical system driven by digital electronics. The digital electronics and optics converge at the DMD. Using a video or graphics input signal, DLP creates a digitally projected image with unprecedented picture quality.

DLP has three key advantages over existing projection technologies. The digital nature of DLP enables digital gray scale and color reproduction and also positions DLP to be the final link in the digital video infrastructure. Because it is based on the reflective DMD, DLP is more efficient than competing transmissive LCD technologies. Finally, DLP has the ability to create seamless, filmlike images. DLP makes images look better. You've heard the digital revolution, now see it with Digital Light Processing.

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