LED TV: Technology Overview and the DLP® Advantage

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Abstract

This white paper will discuss Light Emitting Diode (LED) technology and its impact on television applications. It will highlight the advantages and challenges for these applications and will explore the specific advantages that LED technology has for DLP® product applications.

Introduction

The LED has become a pivotal illumination technology with a wide variety of applications. Since their initial invention, LEDs have been used in many diverse applications such as watches, calculators, remote controls, indicator lights, and backlights for many common gadgets and household devices. The technology is advancing at a rapid pace and new applications continue to emerge as the brightness and efficiency of LEDs increase.

LED History

From the early 1900s, scientists have been discovering ways to generate light from various materials. In 1907, Henry Joseph Round discovered that light could be generated from a sample of Silicon Carbide (SiC). For the next 50 years, scientists continued to discover the light emitting properties that exist with some compounds. In the 1950s, studies around the properties of Gallium Arsenide (GaAs) paved the way for the first official LED discoveries that soon followed.[1]

LED research began in the early 1960's, primarily at Bell Labs, Hewlett Packard (HP), IBM, Monsanto, and RCA. Gallium-Aresenide-Phosphide (GaAsP) provided the basis for the first commercially available red LEDs in 1968 by HP and Monsanto. In the early 1970s, the use of LEDs exploded with new applications such as calculators and watches by companies like Texas Instruments (TI), HP, and Sinclair. Other applications such as indicator lights and alphanumeric displays soon became the mainstream use for LEDs and continued to be so for many years.[2]

LED Technology Background

As the name implies, an LED is a diode that emits light. The diode is the most basic semiconductor whose purpose is to conduct electrical current with some form of controlled variability. The diode in its simplest form is comprised of poor conducting materials that have been modified (or "doped") to increase the amount of free electrons that are available. High electron materials (referred to as N-type materials) are combined with low electron materials (referred to as P-type materials) to form a junction for these free electrons to flow. This junction is often referred to as the PN junction.

An LED is a PN junction diode semiconductor that emits photons when voltage is applied. This process of photon emission is called injection electroluminescence and occurs when electrons move from the N-type material to fill the lower energy holes that exist in the P-type material. When the high energy electrons fall into these holes, they lose some of their energy which results in the generation of photons. The materials used for the P-type and N-type layers along with the size of the gap between them determine the wavelength and overall energy level of the light that is produced.

Many materials have been developed for manufacturing LEDs. Aluminum-Gallium-Arsenide (AlGaAs), Aluminum-Indium-Gallium-Phosphide (AlInGaP), and Indium-Gallium-Nitride (InGaN) are commonly used for present LED architectures. "AlInGaP" is typically used for Red and Yellow dies while "InGaN" is used for Blue and Green. These materials efficiently produce photons that have wavelengths in the visible spectrum. These materials in combination with new manufacturing architectures have enabled the production of very bright LEDs that are beginning to find their way into general lighting and automotive applications. Some architectures have begun utilizing additional phosphor compounds to generate white light and are now beginning to compete with common incandescent and fluorescent lighting - with much lower power and much longer lifetimes.

The worldwide production of LEDs has risen to about 4 billion units per month. Manufacturing in Taiwan, Japan, and the U.S. comprises the most significant volumes with Taiwan leading with about one half of that volume overall. Much of the manufacturing involves the packaging of the LED die with a limited number of manufacturers creating the actual LED die material. Figure 1 illustrates the market size for low brightness and high brightness LEDs as a function of the total LED market.[3]

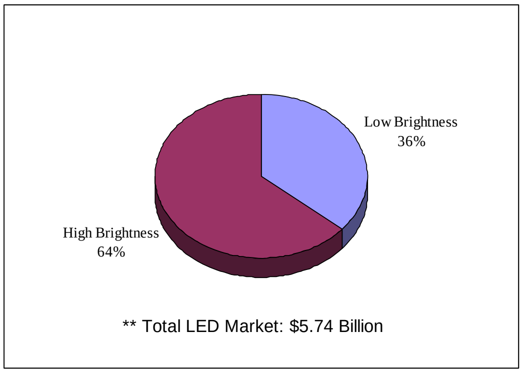

Figure 1 - LED Market Segments

LED Technology Breakthroughs

Recent innovations in the manufacturing of the die material and packaging have resulted in ultra high brightness capabilities. The use of new materials for the substrate have allowed for improved thermal conductivity which allows for higher power consumption and net light output. This increase in light output has enabled new applications for LEDs such as automotive lighting, traffic signals, and more recently, television displays. An example of these new structures is illustrated in Figure 2.

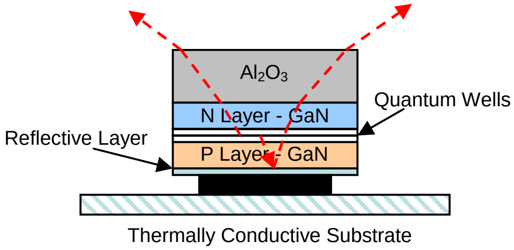

Figure 2 - Basic LED Structure

Significant improvements in the production of Aluminum-Indium-Gallium-Phosphide (AlInGaP) and Indium-Gallium-Nitride structures have allowed for improved brightness in green and blue specifically. Additional colors such as amber and cyan are also being developed at a rapid pace. These improvements enable system designs that can produce better color fidelity at near equivalent brightness to common lamp-based technologies with longer lifetimes. Additional performance enhancements include system level features like instant on, no mercury, no color refresh artifacts, dynamically adjustable brightness, and improved color gamuts. Figure 3 illustrates the gamut area for LED illumination as compared to the common reference standard (Rec. 709).

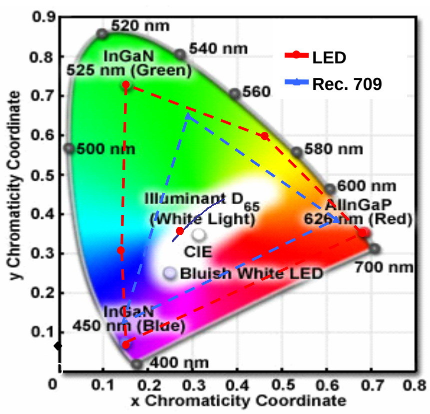

Figure 3 – LED Color Gamut

LED illumination provides a much larger color gamut (as much as 40% or more than the HDTV color standard [Rec. 709]), providing more accurate color fidelity. These performance attributes can be quite appealing for television applications where long life and excellent color fidelity are required. As LEDs continue to advance, their impact on television applications could be significant. Figure 4 illustrates the evolution of LEDs and their potential brightness efficiency in the coming years.[4]

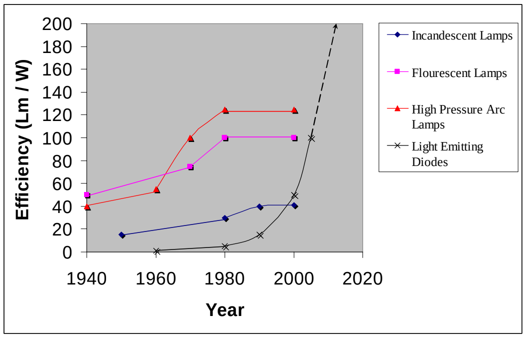

Figure 4 – Lighting Technology Evolution

LED Technology Challenges

Controlling the thermal stability of the LED die is critical to the performance and stability of LED illumination and reliability. The LED architecture inherently produces light from all sides and surfaces of the PN structure in a lambertian distribution (uniform distribution into a 180 degree hemisphere). While this might seem efficient, most of this light is actually absorbed into adjacent die, the mounting substrate, or other surfaces of the LED assembly. This absorption results in an increased thermal loading of the entire LED assembly. This heat must be addressed to obtain maximum light output and reliability. Additionally, for applications that require imaging of the light energy to a small display device (e.g. DLP® HDTV), any light that is emitted outside of the system etendue is not useable and only adds to the heat and overall power loading. Controlling this absorption, shaping the light to match the system etendue, and maximizing the thermal efficiency to extract heat from the die are all critical to increasing the light output and usability of the LEDs.

For traditional applications, LEDs are commonly driven in CW (continuous wave – 100% duty cycle) mode. For high brightness applications, however, this is not as desirable. Since the average temperature of the PN junction determines both the light output and lifetime of the LED, it is often more efficient to drive the LEDs with a smaller duty cycle. With a smaller duty cycle, the LEDs can potentially be driven to higher current loads to increase the overall light output while maintaining a lower average temperature of the PN junction. The challenge with this, however, is that the driver circuitry must be able to generate fast switching waveforms, switching large currents in as short a time as only a few microseconds. This certainly presents some challenges for the design of the LED power driver. But, solutions have already been developed with performance that easily meets these requirements.

Another challenge that results from higher thermal loading is that of color shift. As the PN junction changes temperature, the output wavelength of the light can shift by as much as 10nm or more. This color shift obviously impacts the color point for that color, but also impacts the white point for the system since each of the colors are mixed to create white. Fundamentally, to stabilize this color shift, the LEDs must either be run at a lower power or maintain extreme thermal stability. However, with the implementation of some form of system feedback and proper power control algorithms, the stability of the white could be preserved while maintaining high brightness efficiency.

DLP® TV with LED Illumination

TI has developed a DLP® HDTV system to take advantage of LED illumination with brightness performance that is nearly equivalent to lamp based systems. By utilizing the latest generation of high brightness LEDs and implementing a unique feedback system, it is now possible for DLP® HDTV designs to enjoy the benefits of LED illumination. Figure 5 illustrates the basic optical configuration of this system.

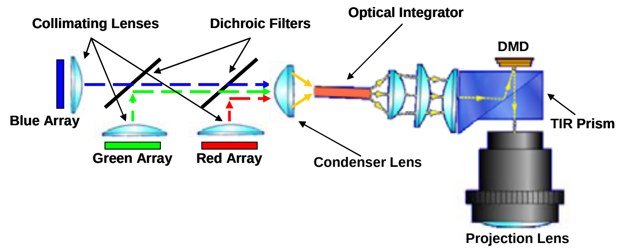

Figure 5 – DLP® HDTV LED Optical Architecture

Utilizing a unique feedback algorithm, TI has demonstrated that any color shift variations that affect the white point can be controlled to a tolerance beyond what the eye can detect.

The current DLP® products implementation with LED technology utilizes a TI DSP component to process system information in real time, offering superior stability over a wide range of operating temperatures while maximizing brightness and reliability.

DLP® Products Performance Advantages

The rapid switching capabilities of LED technology match perfectly with the fast switching properties of DLP® technology. By taking advantage of the high speed capabilities of the DMD and LEDs, it is now possible to utilize color refresh rates that are much higher than what exists with today's designs. It is also possible to randomize the color order. Ultimately, images can be created with higher bit depth, better motion fidelity, and higher brightness. By increasing the switching frequency of the LEDs, it is possible to drive them with increased power while minimizing the thermal loading of the PN junction. These fast switching capabilities of

DLP® technology take advantage of the new LED colors that are becoming available, providing much more flexibility for multiple color configurations using a single DMD device. With a DLP® system, the LEDs do not require polarization, reflecting the light precisely off of the DMD mirror surface. The light is used efficiently, only when it is needed. This maximizes brightness and system efficiency while reducing heat. The net result is a lower system cost with higher brightness and larger color gamuts that far exceed those possible by traditional systems utilizing other common illumination sources.

Conclusion

As LED technology developments continue to improve brightness and reliability, LED illumination may become more of a mainstream light source for many future applications. Future developments will be able to take further advantage of the fast LED switching time to improve video performance, enhance contrast without opto-mechanical components, and create adjustable color gamuts that far exceed the possibilities of traditional illumination sources. New products will soon benefit from these fundamental capabilities providing new, unique designs that offer instant on, better colors, and overall better picture using the speed of DLP® micromirror arrays. With the advantages of LED and DLP® technologies working together, it is expected that DLP® HDTVs will provide even better performance with better reliability far exceeding any existing DLP® HDTV product.

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