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Challenges in the design of a RGB LED display for indoor applications

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Abstract

LED is the dominant technology used in full-color outdoor display panels. However, until recently, there has not been wide spread usage of this technology for similar indoor applications because of the availability of other competing technologies. This paper examines some of the design considerations and trade-off's facing the designer of indoor LED-based display signs. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

It is not uncommon to drive through the major cities in the world and come upon one or more full color display screens. Invariably these brilliant screens, showing moving or still pictures with vivid colors, are made up of red, blue and green light emitting diodes (LED's). Much rapid growth has been made in the installations of full color video LED's display screens since their early appearance in 1995. The worldwide market for these displays in 1999 is estimated to be US$ 297 million, with growth of 128% over previous year in North America and Europe [1]. The quick acceptance of LED technology over current display technologies such as incandescent lamp and flat display tube can be attributed to the availability of ultra-bright green and blue LED's based on indium gallium nitride technology to complement previously available ultra-bright red color LED's. The strengths of LED technology are high visibility, sunlight viewable, long operation life, high reliability and resistance to the environments, lower power consumption, lower weight and thin profile, full range of power, wide range of color spectrum, flexibility in design.

By 1999, LED technology was firmly established with its proven low cost of ownership as there was no major competing technology for the outdoor full color display market. It is a different story for the indoor full color video display market. See Fig. 1 for an example of an indoor LED display screen.

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In the indoor display market, there are a number of competing technologies, which provide similar or acceptable performance, and cost is often the deciding factor. The indoor environment requires the LED screen to have higher resolution (more LED's per unit area) and wider viewing angle because of shorter viewing distance; lower screen brightness but higher color uniformity; reduced protection against the elements and less supporting structure. The requirements and their impact on cost are summarized in Table 1.

2. Design implementation

2.1. Integrated display modules

Early designs of full color LED screens utilized discrete LED lamps and connected by wire harnesses to the drive electronics. A better design is to mount the LED's and drive electronics on an integrated module resulting in a more robust package and also eliminates the problem of transporting high frequency high amplitude currents over cable connections. Field maintenance is facilitated by the replacement of an entire module resulting in higher uptime. A modular display module, which can be stacked in *X*, and *Y* directions will also allow easy system integration. Fig. 2 is an example of such a display module.

2.2. Use of multiplex drive

Multiplex drive is preferred to direct drive in electronic displays with many pixel elements, primarily because of cost. A 16 × 16 multiplexed matrix is shown in Fig. 3. Main

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Fig. 1. Photo of an indoor full color LED display screen (courtesy of Lighthouse Technologies).

advantages are reduced driver elements, reduced inter-connections and simplicity of circuit board layout, especially for smaller pitch, less than 10 mm, displays. In some cases, there may be some gain in brightness with peak current at low duty cycle [2].

There are some drawbacks to the use of high ratio multiplexing circuitry in LED displays, namely, early degradation if peak current and duty cycle exceeds manufacturer's ratings and the high switching currents may cause electromagnetic interference (EMI) which may necessitate precautionary measures.

Table 1
Requirements of outdoor versus indoor LED displays

Features	Outdoor	Indoor	Cost impact
Viewing distance	>20 m	<25 m	
Pixel pitch (mm)	10–50	4–10	+
Brightness (cd/m^2)	>5000	500–1500	−
Viewing angle	120°	>120°	/
Installation structure	Heavy duty	Light	−
Weather proofing	High	Minimal	−
Competing technologies	None	LCD/CRT video wall, projection, plasma	

2.3. Reduced LED chip size

The cost of an LED chip increases with chip size. As the emitting surface is reduced, the light output of a LED chip also drops. Ultra-bright indium gallium nitride (InGaN) green and blue LED's are usually fabricated on either sapphire or silicon carbide (SiC) substrates. The former, being electrically insulating, requires that the chip is designed with both anode and cathode contacts being mounted on the top surface of the chip, resulting in a net reduction of top surface emitting area and also necessitating the placement of two wire bonds on the top surface for chip-on-board (COB) display construction. SiC substrates are electrically conductive and allow the conventional top and bottom contacts with just one wire bond connection required.

2.4. Serial interface

Digital video data is usually loaded onto a LED display via three data pipes, one for each color. Each data pipe can consist of a parallel or serial data pipe. The parallel interface allows gray scale data to be loaded in parallel. A high-speed serial interface can achieve the same gray scale capability and offers cost savings in the onboard electronics and reduced number of inter-connections (Fig. 4).

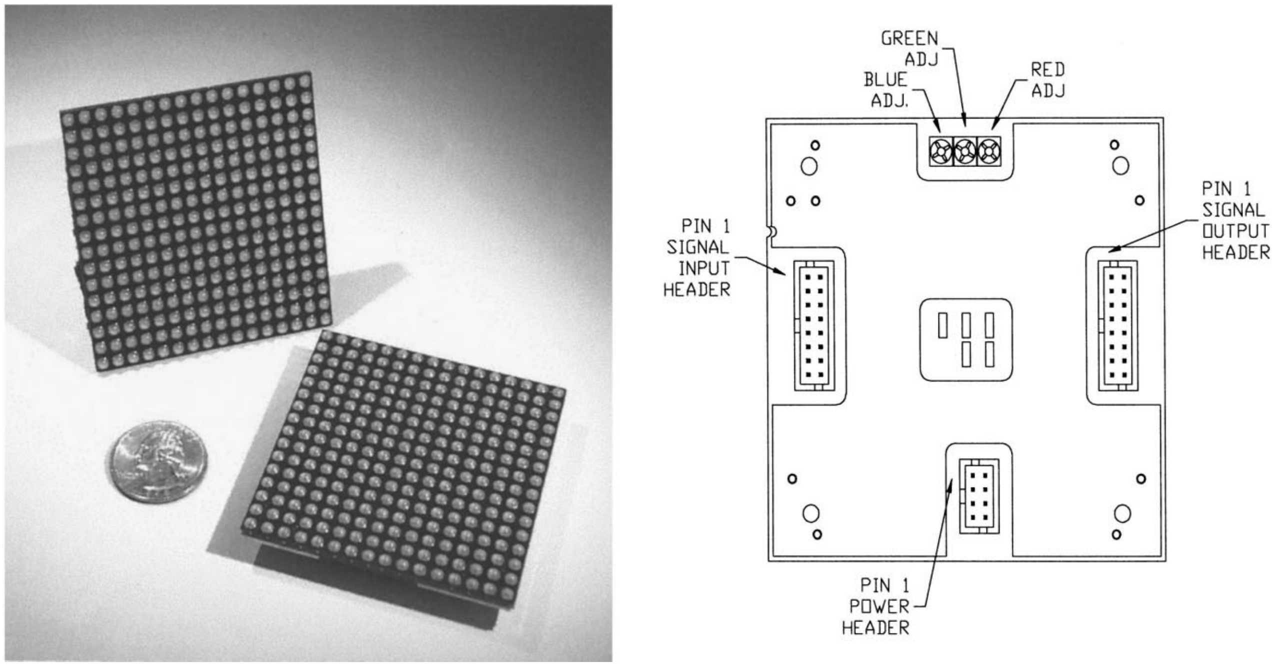

Fig. 2. Photo and back view sketch of a 4 mm, 16 × 16 LED display module.

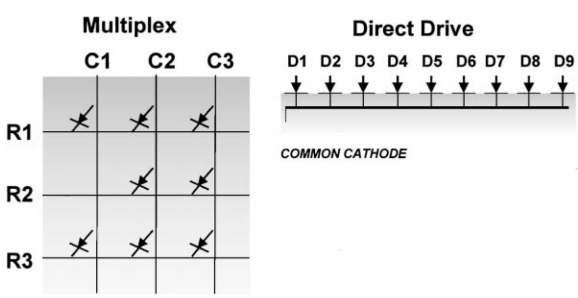

Fig. 3. Multiplex vs. direct drive.

The current design loads video data via a number of high-speed serial pipes. Each pipe services eight rows per color of each display. There are two pipes of three serial inputs for red, green and blue information for the Osram IG4M1616 display module with a 16 × 16 matrix. Refer to Fig. 5 for a inter-connection block diagram of the display module. Modules are then cascaded to form the horizontal block of a screen. The number of pipes will be determined by the height of the screen. The eight rows can be addressed sequentially or in random fashion. With advanced video processing, high quality video can be achieved.

2.5. High color uniformity

In the indoor environment with a lower ambient light level, the human eye is more sensitive to color and brightness variations. Traditionally the color uniformity of LED display screens are controlled by the pre-sorting or ''binning'' LED lamps to narrow ranges of brightness and hue. This can be costly and present logistics difficulty. For the Osram IG4M1616 display module, a ''chip-on-board'' technique is used. LED chips are picked from adjacent locations

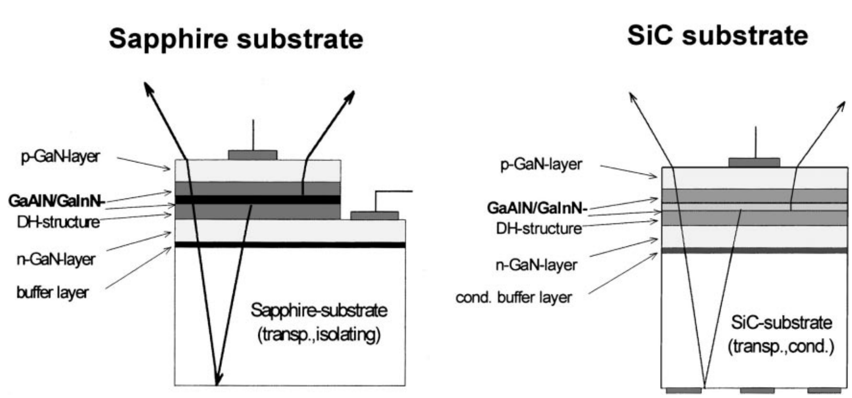

Fig. 4. LED's with sapphire and SiC substrates.

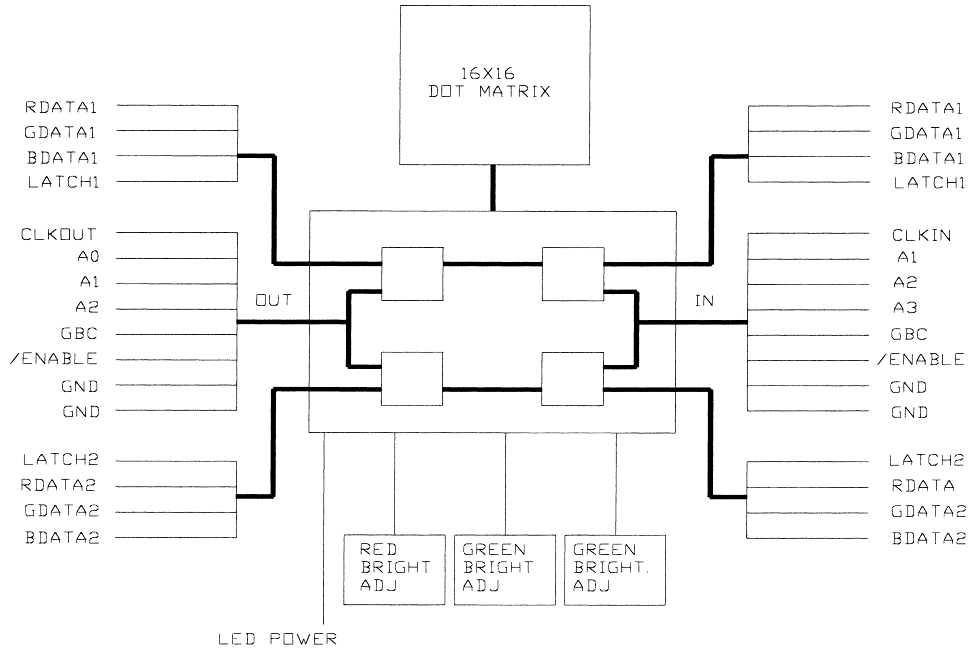

Fig. 5. Inter-connection block diagram of Osram IG4M1616 RGB display module.

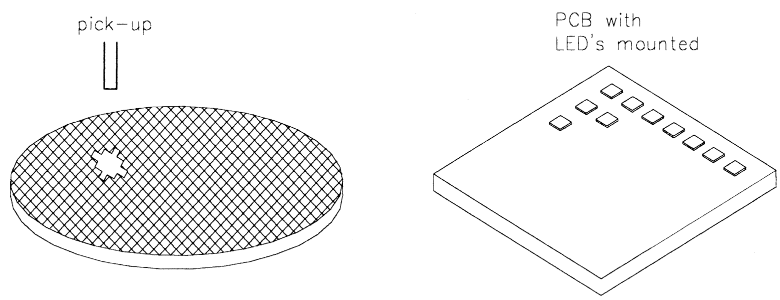

Fig. 6. LED matching through chip-on-board pick and place.

of a wafer matrix and placed on the same module substrate by automatic pick and place machinery (refer to Fig. 6). This method guarantees a high degree of brightness and color matching within each module. Module-to-module brightness variation can be normalized by the use of resistor or digital trim pots.

It is also possible to store, either electronically or through software, a map of the brightness and hue of each LED and provide the necessary compensation to the display image. This technique raises the complexity and cost of the system.

2.6. Wide viewing angle

Typical 12 power radiation angles of LED lamps used for display applications are about 120° in the horizontal direction. For indoor applications, it is desirable to have a lager radiation angle in order to catch a larger portion of the audience. The Osram IG4M1616 display module utilizes a clear lens "printed" or formed directly on the printed board substrate. This lens system allows a wide viewing angle of over 160°, tight grouping of the three color LED's for color mixing and a cost effective package (refer to Fig. 7).

2.7. Low cost video interface

Fig. 8 shows the block diagram of a simple low cost video interface board that was developed as a reference design and to demonstrate the video capability of the IG4M1616 display module. Fig. 8 is a photo of the video interface board. It is based on a frame capture design utilizing a Samsung KS0127 video decode chip to process analog video signals. For digital video system, the decoder chip can be eliminated and digital video signals can be fed to the frame buffer memory.

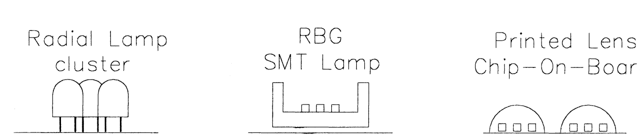

Fig. 7. Printed epoxy lens for wide viewing angle.

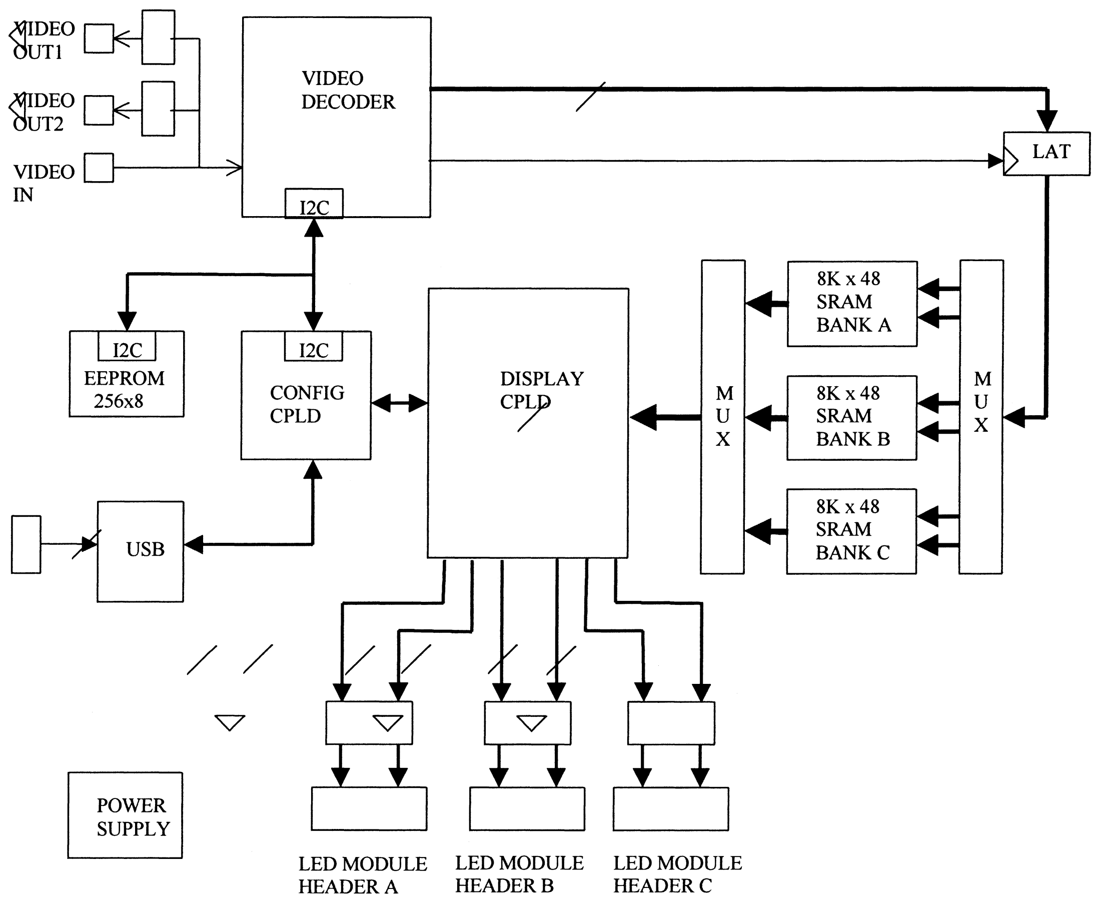

Fig. 8. Block diagram of a video interface board.

2.8. Modular design

The IG4M1616 is the smallest, at 4 mm pitch, in a family of display modules. Larger sizes, 6, 8, 10 mm, in the family are being developed and all share a common interface and connectors. The same drive electronics are used to provide manufacturing and end-use flexibility.

3. Summary

As the production of ultra-bright LED gets up the learning curve due to demand from other growth areas, e.g. backlight lamps for cellular phone and automotive applications, the lower costs of the LED's will allow full color LED display screens to meet the market price points for indoor applications. We can expect to see similar growth rate for the indoor full color LED display market.

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