



Comparison of LCD and LED Display Technology for QSR Drive-Thru Order Confirmation Applications

Introduction

Drive-thru Order Confirmation Systems (OCS) available on the market today are comprised of two distinctly different display technologies; Liquid Crystal Display (LCD) and Light Emitting Diode (LED). There are benefits and shortcomings of each technology as it pertains to outdoor environments where the displays are subject to direct sunlight across a wide range of temperature and humidity conditions. As part of Delphi's ongoing Research and Development program, we continuously evaluate the latest display technologies available in the market. New technologies are incorporated into our products only if they meet our stringent criterion for reliability, maturity, cost effectiveness, long-term support, and added value for our customers. This white paper provides a perspective on the differences, benefits and shortcomings of both LCD and LED technologies as a display medium for Drive-thru OCS applications.

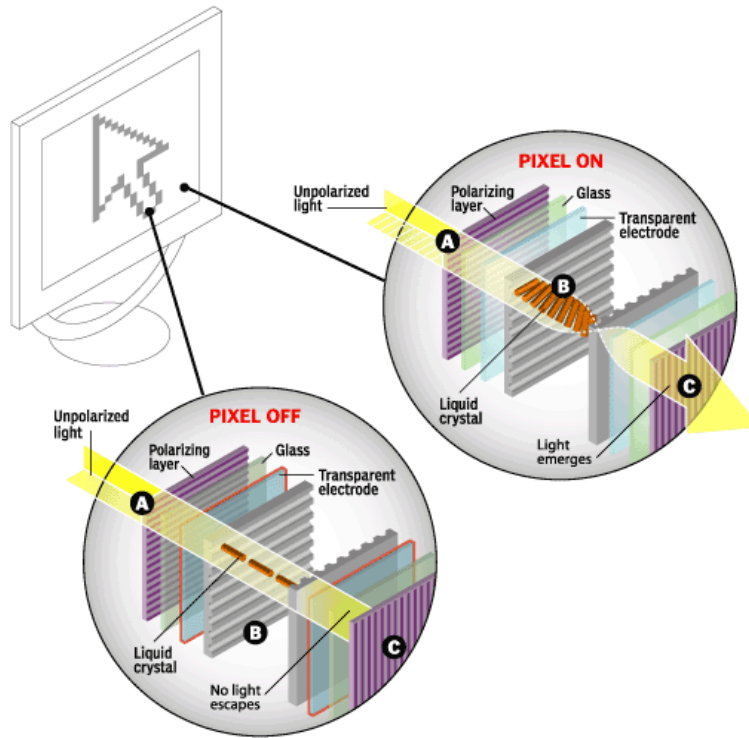


Figure 1 - LED vs. LCD OCS Screens

LCD Overview

LCD displays consists primarily of two sheets of polarized glass plates with a thin layer of liquid crystal solution sandwiched between them. The type of liquid crystals used in LCD panels have very specific properties that enable them to serve as effective 'shutters' that open and close to block or let light through in response to an electric current. The current through the liquid crystals is controlled by a voltage applied between the glass plates via transparent electrodes that form a grid, with rows on one side of the panel and columns on the other.

As the electric current passes through these liquid crystals, they untwist to varying degrees, depending on the voltage applied. This untwisting effect will change the polarization of the light passing through the LCD panel. As the polarization changes in response to the applied voltage across the glass plates, more or less light is able to pass through the polarized filter on the face of the LCD. Intersecting grid points represent picture elements (pixels).



Courtesy PC Magazine

Figure 2 – Inside an LCD

In a color LCD panel, each pixel is made up of three liquid crystal cells. Each of those three cells contains a red, green, or blue filter. Light passing through the filtered cells creates the colors seen on the LCD.

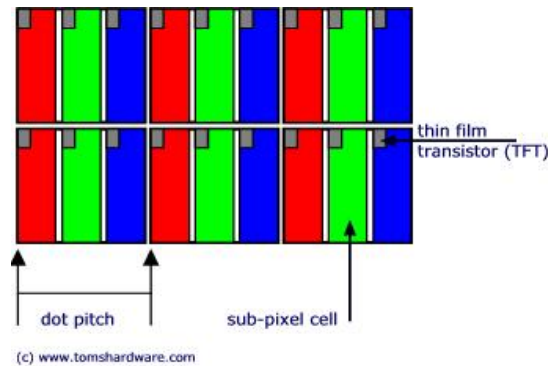


Figure 3 - LCD Color Pixels

LED Overview

LEDs differ from traditional light sources in the way they produce light. In an incandescent lamp, a tungsten filament is heated by electric current until it glows or emits light. In a fluorescent lamp, an electric arc excites mercury atoms, which emit ultraviolet (UV) radiation. After striking the phosphor

coating on the inside of glass tubes, the UV radiation is converted and emitted as visible light.

A light emitting diode, in contrast, is made from a chip of semiconducting material in a way that when connected to a power source, current flows in one direction but not the other. When current flows through the diode, energy is released in the form of a photon (light). The specific wavelength or color emitted by the LED depends on the materials used to make the diode.

Red LEDs are based on aluminum gallium arsenide (AlGaAs). Blue LEDs are made from indium gallium nitride (InGaN) and green from aluminum gallium phosphide (AlGaP). "White" light is created by combining the light from red, green, and blue (RGB) LEDs or by coating a blue LED with yellow phosphor. OCS displays in use today utilize red LEDs.

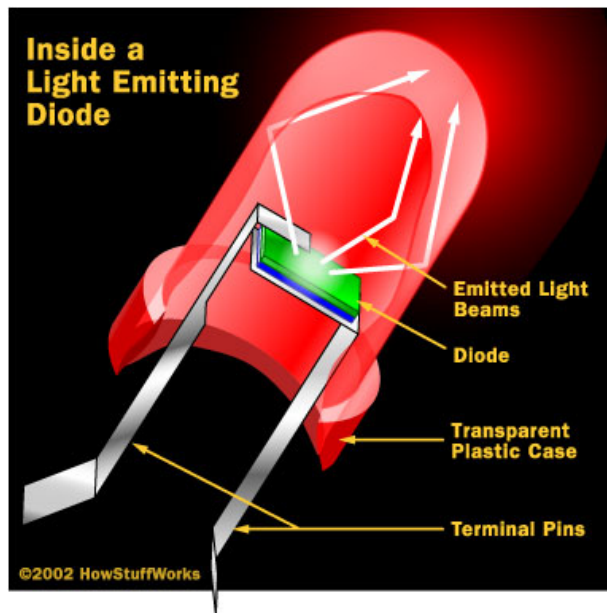


Figure 4 – Inside an LED

To make a readable display from LEDs, they are arranged in a matrix as shown below. The matrix is configured with sufficient number of LEDs to allow alpha-numeric characters to be formed by illuminating specific patterns.



Figure 5 - LED Matrix

The matrices are typically arranged end-to-end to form rows that can be used to display lines of text as shown below.



Figure 6 - Typical LED Display

Comparison of LCD vs. LED Technology

Both LCD and LED technology have been deployed for drive-thru OCS applications since the early 1990s. Each technology has its own strengths and weaknesses as outlined in the table below.

| | LED | LCD (high bright) |
|--------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------------------------|
| Reliability | 20,000 hours typical | 50,000 hours typical |
| Wide Temperature Operation | Good | Good |
| Sunlight Readability | Moderate | Good |
| Pixel pitch (pixels / inch) | 0.20" (5) typical | 0.011" (85) – 15" LCD |
| Number of Colors | 1 Color – Red typical | 16 Million Colors |
| Graphic Display Capability | None | Full Color Graphic Capable |
| International Characters | No | Yes |
| Flexibility of Display Layout | None. Fixed at a limited number of rows and columns of characters. | Total Flexibility. Fonts are configurable and can be scaled in real time. |
| Cost | Low | Moderate |

Reliability – LCD reliability is limited primarily by the backlight technology utilized. Delphi’s LCDs utilize high-bright cold cathode fluorescent (CCLF) bulbs, which have an expected life time of over 50,000 hours. This is measured as the average (mean) time to half-brightness or MTTH. LEDs can have a MTTH of up to 100,000 hours if operated in room temperature (25°C) conditions. However, in drive-thru OCS applications where the display is subject to heat from direct sun exposure, the internal temperatures within the display can reach 60°C. This elevated temperature dramatically reduces the longevity of LEDs to approximately 20,000 hours.

Wide Temperature Operation – When OCS technology was first developed in the late 1990s, the temperature performance of LCDs at that time were limited. The limitation was due to the temperature at which the LCD fluid would reach its isotropic or “clearing point” (point where the

crystals in the fluid no longer respond to electrical current) -- typically about 70°C. When LCD fluid reaches its clearing point, a black spot appears on the display -- typically when exposed to direct sunlight. This condition is further exacerbated when heat-producing high-bright backlights are employed. Over the past decade, several advances have been made in industrial grade LCD technology resulting in clearing points of over 100°C. By utilizing industrial grade LCDs in combination with heat blocking filters, the operating temperature of the LCD can be significantly extended. LEDs in contrast have wider temperature operating limits; however their brightness and expected lifetime falls off significantly with heat. Red LEDs, utilized in OCS products on the market today perform worst, falling off to 40% of brightness at 100°C.

Pixel Pitch – Due to the relatively large size of individual LEDs, they inherently have far fewer pixels per inch than LCDs (17:1 ratio of LCD pixels to LED pixels for the same size display area). Accordingly, they are not optimal for displaying pictures, international language characters or complex figures when viewed at close range as with OCS applications. This was not a limitation during the initial designs of LED based OCS products in the 1990s because the content displayed at that time was limited to English alpha numeric characters.

Number of Colors – As mentioned above, red LEDs are typically used in OCS equipment in the field today. A single color limits the amount of information that can be conveyed to the customer. Additionally, red is not the optimum color for high contrast readability in direct sunlight. In contrast, color LCDs can display over 16 million colors and achieve brightness and contrast ratios to be easily viewed in direct sunlight.

Graphic Display Capability – By their very nature, LCDs are graphical display devices. However, LEDs (as used in OCS equipment today) are limited to displaying simple alpha numeric characters and have no graphic display capability.

International Characters – Delphi's LCD-based OCS can display multi-byte characters to support all international language fonts. On the other hand, LEDs used in OCS equipment today cannot support complex multi-byte international language character fonts due to their inherent limitation in resolution.

Flexibility of Display Layout – OCS LED displays are arranged as a fixed number of rows and columns of fixed size characters, allowing no flexibility in the layout of the display. LCDs, being graphical devices by their very nature, have total flexibility of display layout limited only by the software that drives them.

Cost – Due to the simplicity of the design of LED based OCS displays, they are typically lower cost than LCD based OCS displays. However, recent advances in technology have reduced the cost gap significantly.



Conclusion

When OCS technology was first adopted in the early 1990s, the intended purpose was limited to order confirmation via simple text displays. As the sophistication of drive-thru operations have increased over the past two decades, requirements driven by both operations and marketing have necessitated the utilization of high resolution color LCD displays. Recent advances in LCD technology have made it possible to produce robust and reliable products for outdoor applications. As OCS technology continues to evolve from its origin as strictly an order confirmation device to a powerful marketing tool, the necessity for full color graphic display capability will become a requirement. Until the time when LEDs can be made sufficiently small to produce small format, high resolution color displays suitable for use in drive-thru OCS applications, LCDs will remain the technology of choice.

For further information on Delphi's LCD based OCS products, please contact Delphi (sales@delphidisplay.com) with any questions or visit us on the web at: www.DelphiDisplay.com