

Comparison of LCD Backlight Technology for Outdoor Applications

Introduction

A key component in the deployment of Liquid Crystal Display (LCD) technology for outdoor applications is the integration of a high bright backlight (or light source) behind the LCD glass. There are several different LCD backlight technologies being employed in the outdoor digital signage market today; Cold Cathode Fluorescent Lamp (CCFL), External Electrode Fluorescent Lamp (EEFL), Hot Cathode Fluorescent Lamp (HCFL), Light Emitting Diode (LED), and Flat Fluorescent Lamp (FFL). There are advantages and disadvantages for each technology as it pertains to outdoor environments where displays are typically subject to direct sunlight across a wide range of temperature and humidity conditions. In order to perform well in these environments, the backlight must meet certain minimum criteria for outdoor use that include brightness, reliability, efficiency, thermal packaging, and color reproduction. In LCD panels, the majority of power consumption in the product comes from the backlight source. With today's energy costs skyrocketing, the efficiency and longevity of the backlight plays a critical role in the cost of operation, and ultimately in the total cost of ownership. This white paper provides a comparison of the current backlight technologies available today for outdoor display applications and provides insight into Delphi's long term backlight technology development roadmap.

CCFL Overview

By far, the most commonly used LCD backlight technology employed today is CCFL with an estimated market share of 93.5% of the LCD-TV market in 2008¹. CCFL backlights have very good performance properties which include: good luminous intensity, high density (compact and light weight), good color reproduction/uniformity, vibration/impact resistance, durability, quick start at low temperature, long lifetime and high efficiency. Because of their wide adoption and deep market penetration, CCFL is a very mature lighting solution which results in an associated cost that is low when compared to other less-mature backlight technologies.

A CCFL lamp is constructed from a sealed glass tube with an electrode on each end. The inside surface of the tube is coated with a phosphor material and filled with inert gases such as argon (Ar) and neon (Ne) mixed with a slight amount (approx. 4mg Hg per lamp) of mercury vapor (Hg). When a high voltage is applied to the electrodes, the gas is ionized allowing the electrical current to flow. When ionized, the gas emits ultraviolet light that is converted to visible light as it strikes the phosphor coating on the inside surface of the bulb. The color of the visible light depends on the type of the gas and phosphor used. The figure below depicts the construction of the CCFL bulb.

¹ DisplaySearch Q2'07 Backlight Lamp and Backlight Report

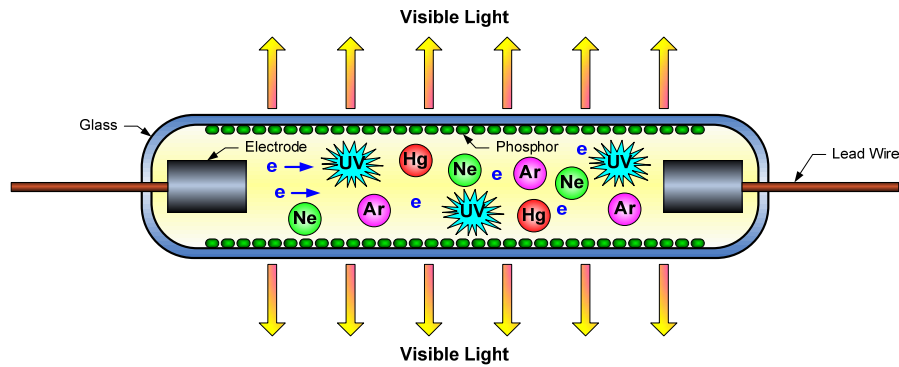


Figure 1 - CCFL Construction

In a CCFL backlight, multiple bulbs are arranged in an array as shown in the figure below. A reflector is oriented behind the bulbs to direct the light out the front of the LCD. A diffuser is installed in front of the bulbs to spread out the light evenly across the LCD panel.

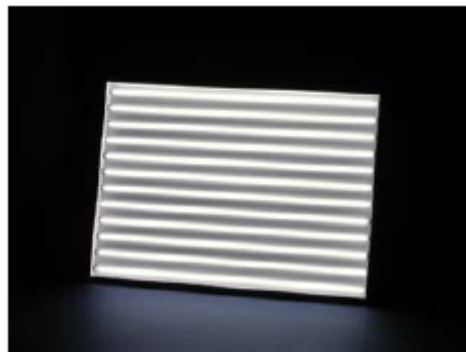


Figure 2 - Typical CCFL Backlight

EEFL Overview

A second available backlight construction sometimes employed by manufacturers is EEFL technology, which differs from CCFL in the way the electrodes are oriented on the outside of the lamp. As there are no electrodes within the lamp, no wires need pass through the glass tube, eliminating the requirement for a glass-to-metal seal, the chief advantage being a reduction in gas leakage problems. EEFL also contains less mercury (<4mg Hg per lamp). The principle gas discharge technology however is the same as with CCFL, with the technical properties being defined by the external electrodes. Claimed advantages of the EEFL include high efficiency and brightness, less heat generated, less deterioration of the phosphors that heat causes, as well as the elimination of the electrode deterioration caused by ion bombardment -- enhancing the longevity of the EEFL. Illumination stability and brightness efficiency is also claimed to be good. The figure below depicts the construction of the EEFL bulb.

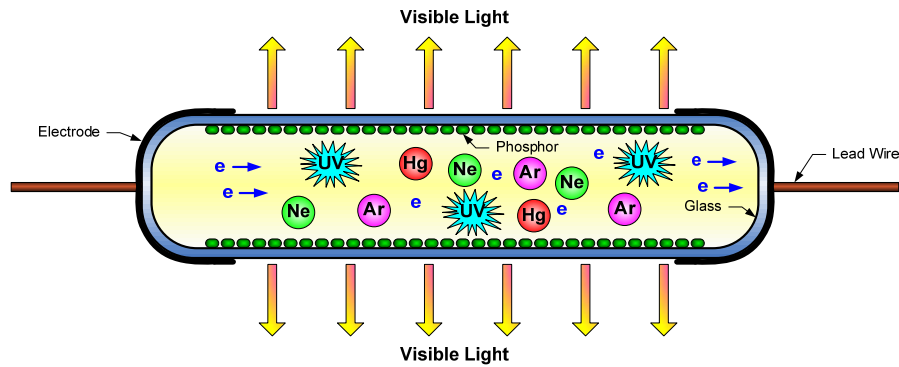


Figure 3 - EEFL Construction

EEFL is a relatively new development in fluorescent lamp technology, and as such is not prevalent in many current display products today. However, many LCD manufacturers are introducing large format displays (32" or larger) that are employing EEFL backlights. This suggests that this technology will continue to gain share in the large format LCD segment. Additionally, many manufacturers believe that this may be the next generation of LCD backlight technology.

HCFL Overview

HCFL technology utilizes internal filaments that must be heated by an external current prior to lighting by a ballast device, similar to the common fluorescent light used in the home. In this device, a gaseous mixture flows between two tungsten electrodes or filaments. This backlight technology is typically used in very large format LCDs where long bulbs are required to illuminate the entire surface of the LCD. The figure below depicts the construction of the HCFL bulb.

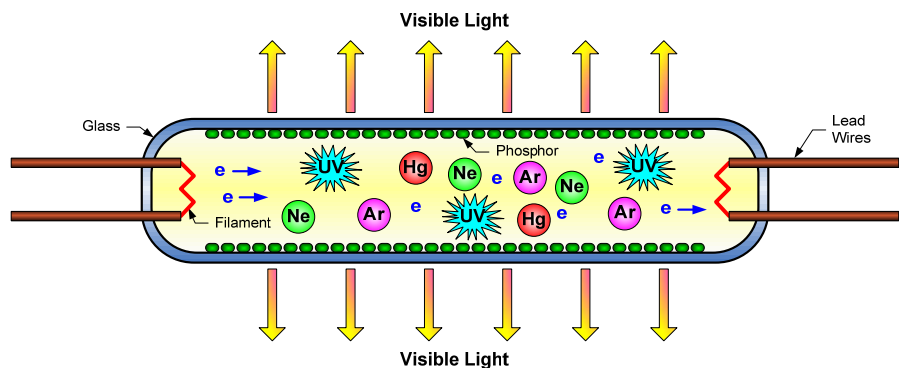


Figure 4 - HCFL Construction

LED Overview

LEDs are the fastest growing backlight technology on the market today. They provide many benefits as a backlight source for LCDs including reasonably good efficiency, a wider range of color reproduction, enhanced contrast ratio (due to the option of arbitrarily scaling/dimming individual display areas), low voltage operation, mercury-free construction, good thermal dissipation properties and high luminance.

Many manufacturers have designed very large LCD-TV products utilizing red, green and blue (RGB) LEDs for the backlight and have achieved good performance. However, RGB LED backlights demand color mixing technology in order to overcome unevenness of luminance. Color mixing has significantly improved with an increased understanding of the design and function of direct backlight concept. Today, RGB LED clusters (usually 1x red, 2x green, and 1x blue) are grouped in matrices with some space provided between clusters to facilitate good color mixing and to minimize the need for design of thermal radiation structures. Another critical factor to consider in LED backlight design is the need for control of system temperature, as this is essential in order to avoid color shift, which is another challenge in LED backlight systems. Many new backlights are being designed utilizing white LED technology.

An LED is a semiconductor device that creates light using solid-state electronics. A diode is composed of a layer of electron rich material separated by a layer of electron deficient material which forms a junction. Power applied to this junction excites the electrons in the electron rich material leading to photon emission and the creation of light. Depending on the chemical composition of the semiconductor layers, the color of light emission will vary.

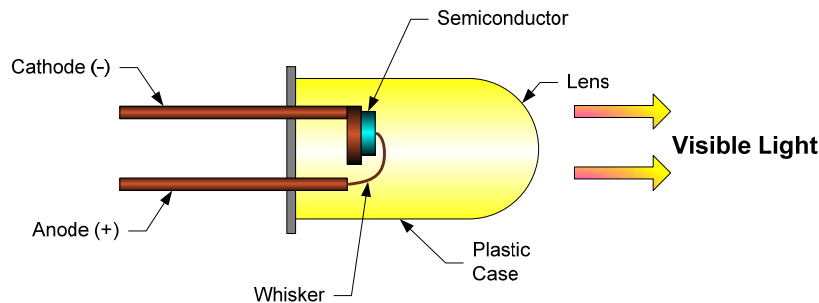


Figure 5 - LED Construction

For outdoor applications, high bright backlights are constructed as a matrix of LEDs covered by a set of filters to diffuse and balance the light across the entire surface of the LCD. A typical LED backlight matrix is shown in the figure below.



Figure 6 – Typical LED Matrix Backlight

FFL Overview

FFL is another backlight technology that entered the market in the early 2000's. Its primary benefits are touted as being a long operating lifetime coupled with a mercury-free construction. The FFL is a thin, flat, rectangular lighting source that has the appearance of being an adaptation of the EEFL. According to Taiwanese Delta-Optoelectronics Inc., the first company that commercialized FFL, the backlights have longer lifetimes (100,000 hours) and better color reproduction and light uniformity compared to the typical CCLF. The FFL is sufficiently thin and large to cover the entire display area, requiring one FFL for a large LCD vs. multiple CCFLs for the same panel. While these attributes would seem to make FFL a desirable technology to employ, there remain some serious shortcomings with the technology that must be considered. FFLs are approximately 50% as efficient as CCFLs, and thus require considerably more power to deliver the same measured brightness. In outdoor applications where sunlight readability is essential, the backlight must produce sufficient brightness to provide 1,500 cd/m² (nits) of luminosity through the front of the LCD. In order to produce this level of luminosity, the FFL may require over twice the power consumption as a CCFL backlight, making it a less economical alternative.

FFLs produce light using a pulsed dielectric barrier discharge process. The electrodes are arranged on the back surface of the FFL fixture, phosphors coat the front and back, while the xenon gas plasma (Xe) occupies the space between. A voltage is applied to the electrodes, which excites Xe atoms in the gas chamber and enables the formation of excited Xe² molecules. UV radiation is produced in the process which is converted to visible light by the phosphors. The flat construction permits the backlight source to be spread across the entire display area. A reflective coating is also used on the back surface to maximize reflected light out the front of the assembly. The figure below depicts the construction of the FFL bulb.

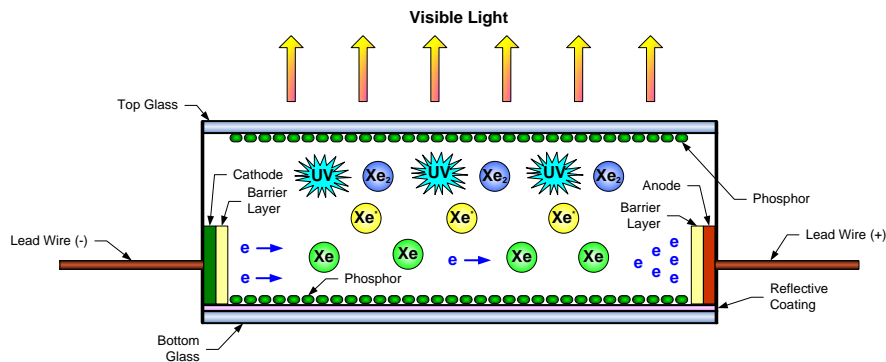


Figure 7 - FFL Construction

In order to improve even light distribution across the surface of the backlight, some designs have incorporated multiple conical spacers as shown in the figure below. Multiple design challenges remain to make this a viable mainstream backlight technology. They include improved efficiency, reduced power consumption and lower manufacturing costs. Research available on this technology

suggests that there has been no significant development since 2006, bringing into question the long term viability of FFL as a LCD backlight solution.



Figure 8 – Typical FFL Backlight

Technology Comparison

The data in the following table was compiled from many industry sources including written publications, online information, interviews with manufacturers and industry experts. The data presented is for comparative purposes only and should be used as such. Delphi does not guarantee the accuracy of all information presented here.

	CCFL	LED	FFL	EEFL	HCFL
Typical Hi-Bright LCD Luminance (cd/m²)	1500	1000	1000	1500	N/A
Typical Efficiency (lm/W)	80	60	30	80	65
Average Cost	1x	2x – 2.5x	1.5x	0.9x	1.25x
MTTH (hours)	60K	50K-60K	100K ²	60K-70K	60K
Color Reproduction (% of NTSC Spec.)	72% - 80%	100%	80%	72%	92%
Mercury / Unit	~4 mg	0 mg	0 mg	<4 mg	>5 mg
Power Consumption	Low	Medium	High	Low	Medium
Heat Produced	Moderate	Moderate	High	Low	Moderate
Gas Composition	Hg, Ar, Ne	None	Xe,Ar,Ne	Hg,Ar,Ne	Hg,Ar,Ne
Energy Required for Sunlight Readability	100%	125%	147%	100%	125%
Operating Temperature (°C)	-34 ~ +75	-30 ~ +80	-30 ~ +85	N/A	N/A

Figure 9 –Backlight Technology Comparison

Industry demand forecast for the LCD TV market is shown in the figure below. Based on this information compiled in 2008, it appears that CCFL/EEFL/HCFL backlight technology will dominate the LCD industry through 2011, with less than 10% share being taken by LED technology. FFL showed continued declines in market share from 2006 to 2007 with almost no share in 2008 and beyond.

² While 100,000 hours is the stated MTTH by the manufacturer, we have found no test data to support this claim. The only data found, shows testing to 10,000-20,000 hours and theoretical extrapolation to 100,000 hours.

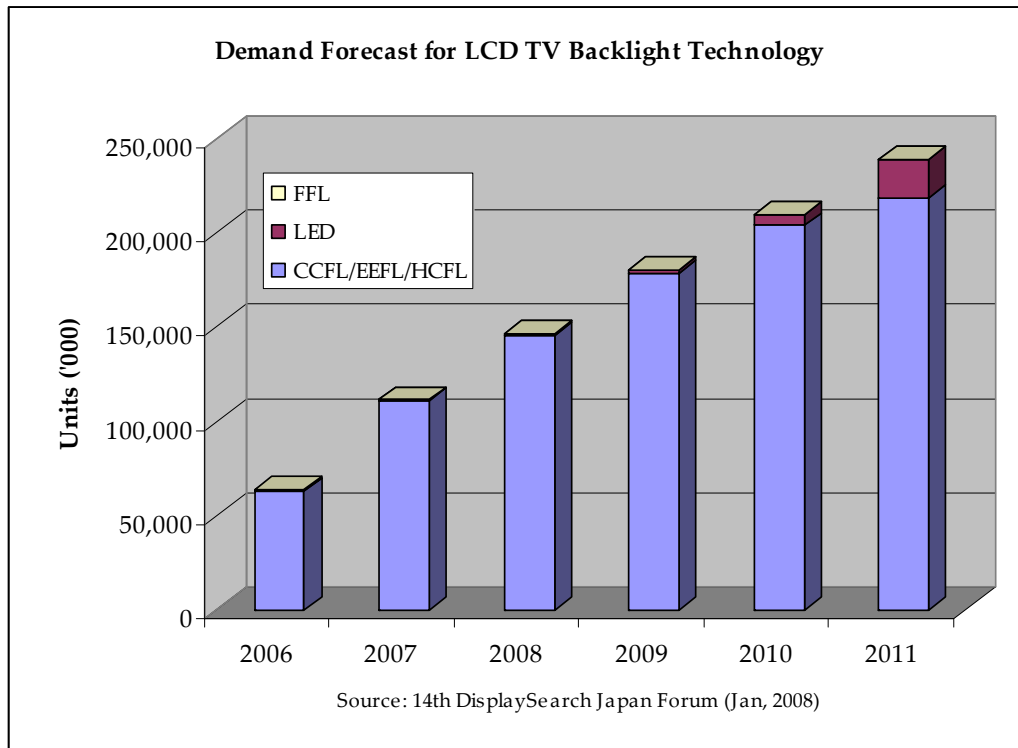


Figure 10 – LCD TV Backlight Demand Forecast

Conclusion

Backlight technology will play a critical role in the development of the LCD market going forward. As more importance is placed on picture quality, lifetime, and power consumption, the technologies that provide benefits in these areas will win out in the long run. Today, the vast majority of LCD-TVs utilize CCFL backlights. Accordingly, CCFL will continue to play an important role in the foreseeable future due to its good efficiency and price-to-performance ratio. The two emerging backlight technologies that are being embraced by the industry are EEFL and LED. EEFL offers improved power efficiency, though much work remains to solve the mercury issue. LED backlights have the most promising market and environmental improvement potential in the mid- to long-term future. LEDs offer a number of distinct advantages over CCFL and HCFL including better power efficiency, mercury-free operation, and flexible dimming capability. Virtually all major LCD manufacturers have LED backlight solutions on their product roadmaps today, driven by increasing reliability and declining costs. Conversely, in spite of its claimed long-life and mercury-free operation, it does not appear that FFL technology is being developed in any significant fashion over the past two years, likely due to its poor efficiency and relatively high power consumption.

Delphi continuously evaluates the latest backlight technologies and future trends as part of its ongoing Research and Development program. When new technologies reach a level of maturity where they meet our strict criterion for reliability, maturity, cost effectiveness, long-term support, and added value for our customers, we incorporate them into our next



generation products. Delphi's backlight technology roadmap is focused on two key backlight technologies for our future outdoor LCD products; Advanced CCFL and LED. Advanced CCFLs will have reduced power consumption and longer life operation, approaching 100K hours MTTH. Additionally, mercury-free CCFLs are being developed to address the environmental concerns with mercury. Based on our knowledge of the industry, Delphi believes that LED backlights will be the dominant backlight technology for outdoor applications over the next decade, specifically in small to mid-size LCDs. As a result, we are integrating this technology into our next generation of outdoor digital signage products, with first product release planned in Q4 of 2008.

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