



One Step Ahead in Display Innovations – Always!

**POWER EFFICIENCY
BRILLIANCE:
FULL ARRAY LOCAL
DIMMING
over EDGE-LIT LCDs**

WHITEPAPER

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By Lincoln Technology Solutions

INTRODUCTION

The advancement of liquid crystal display (LCD) backlighting technologies has brought major improvements in visual quality and power efficiency. Among these, Full Array Local Dimming (FALD) and Edge-Lit backlighting are the two leading approaches used in modern LCD displays. While both aim to enhance contrast and reduce energy consumption, they differ significantly in structure, performance, and cost. Edge-Lit LCDs place light emitting diodes (LEDs) along the edges of the display panel on one, two, or all four sides. A light guide plate (LGP) distributes the light uniformly across the screen. FALD, on the other hand, utilizes an array of LEDs directly behind the LCD panel and an individual LED or group of LEDs defines a zone. These LEDs can be independently controlled in zones, allowing precise dimming and illumination where needed.

UNDERSTANDING BACKLIGHT TECHNOLOGIES

Edge-Lit LCDs

Edge-lit LCDs are generally less power-efficient for high dynamic range (HDR) content due to their limited control over localized lighting. To achieve sufficient brightness in certain areas, the backlight must be driven at higher average power levels, even when large portions of the screen display dark content. As a result, energy is wasted illuminating areas that do not contribute meaningfully to the image brightness. Bright and dark regions receive nearly the same amount of light. This is particularly evident in scenes with mixed brightness levels, for which full power is needed.

Full Array Local Dimming (FALD)

FALD places an array of LEDs directly behind the LCD panel. These are divided into zones, and each zone is capable of individual brightness adjustment. This precise control enhances both contrast and power efficiency. FALD requires more hardware and control algorithms but yields superior performance.

FALD dramatically improves power efficiency by illuminating only the parts of the display that need it. With hundreds or even thousands of independently controlled zones (or even individual LEDs), FALD dynamically adjusts brightness of each independent zone in real-time. A simple downscaling FALD algorithm can compute in an inexpensive field programmable gate array (FPGA). The algorithm buffers data line-by-line until the final pixel row of a designated LED zone is reached. Then, the total grayscale value of each zone in the row is calculated during horizontal blanking. By performing the calculation at the end of each row in this manner, frame buffers and computational time at the end of the frame aren't required. This method prevents latency between

the backlight and video stream. Figure 1 shows an edge-lit versus FALD panel arrangement comparison.

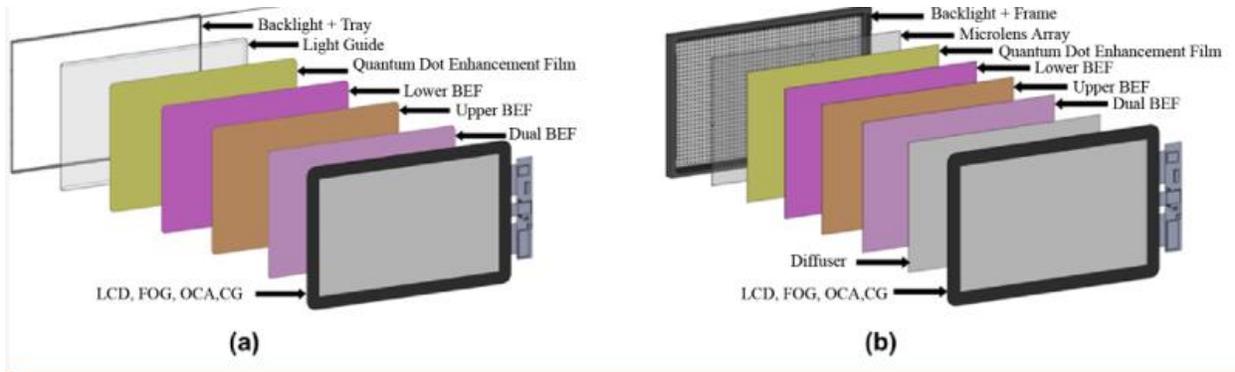


Figure 1. LCD display stack, (a) edge lit and (b) FALD typical film arrangement.

LTS BENCHMARK: LCD255 – 7” FALD MINI-LED DISPLAY

Key Specs:

- **Size:** 7”
- **Backlight:** Mini-LED in Chip Scale Package
- **Local Dimming Zones:** 273
- **Brightness:** 3000 NIT
- **LED Type:** Chip Scale Packaging (CSP)
- **Use Cases:** medical imaging, drone controllers, rugged displays, battery powered displays

Performance Analysis

Lincoln Technology Solutions (LTS) has multiple custom solutions for FALD backlights using mini-LEDs in chip scale packaged (CSP) and Light-on-Board (LOB) formats. LOB is also sometimes referred to as Chip-on-Board (COB). LED size varies from dual-die 2835, chip scale package (CSP) to light on board LOB package (mini-LED). There are different options in LED packaging for use, depending on form factors, optical, and electrical requirements.

Our latest LCD255 7” FALD has 273 zones with 1092 chip scale package LEDs and delivers 3000 nits across the entire screen. This design is optimized optically for maximum light outcoupling. While exact numbers vary among different backlight sizes or LCD panels, studies show that our LCD255 FALD backlighting realizes power savings when APL is under 85% compared to edge-lit systems. This efficiency comes from reduced average backlight power due to dimming unlit

zones. Secondary benefits include lower thermal output, reducing the need for cooling and power savings because of more consistent use of power aligned with human visual perception (we perceive contrast more than raw luminance). Our LCD255 pushes the boundaries of power efficiency, with significant power savings compared to an equivalent edge-lit display, as demonstrated in Figure 2.

Figure 2 shows average pixel luminance (APL) vs power (W) data. Average pixel luminance (APL) is the average illumination level of pixels on display, taking all pixels into account. For instance, a display showing a 50% Gray image (RGB 127, 127, 127) which covers the entire screen will have a 50% APL, and a display showing a completely white image (RGB 255, 255, 255) which covers the entire screen will have a 100% APL. Note, both test images will have an open pixel ratio (OPR) of 100% since every pixel is on. An evenly distributed checkerboard would have OPR of 50%. LCD255 FALD shows lower power consumption up to 85% APL vs edge lit LCD.

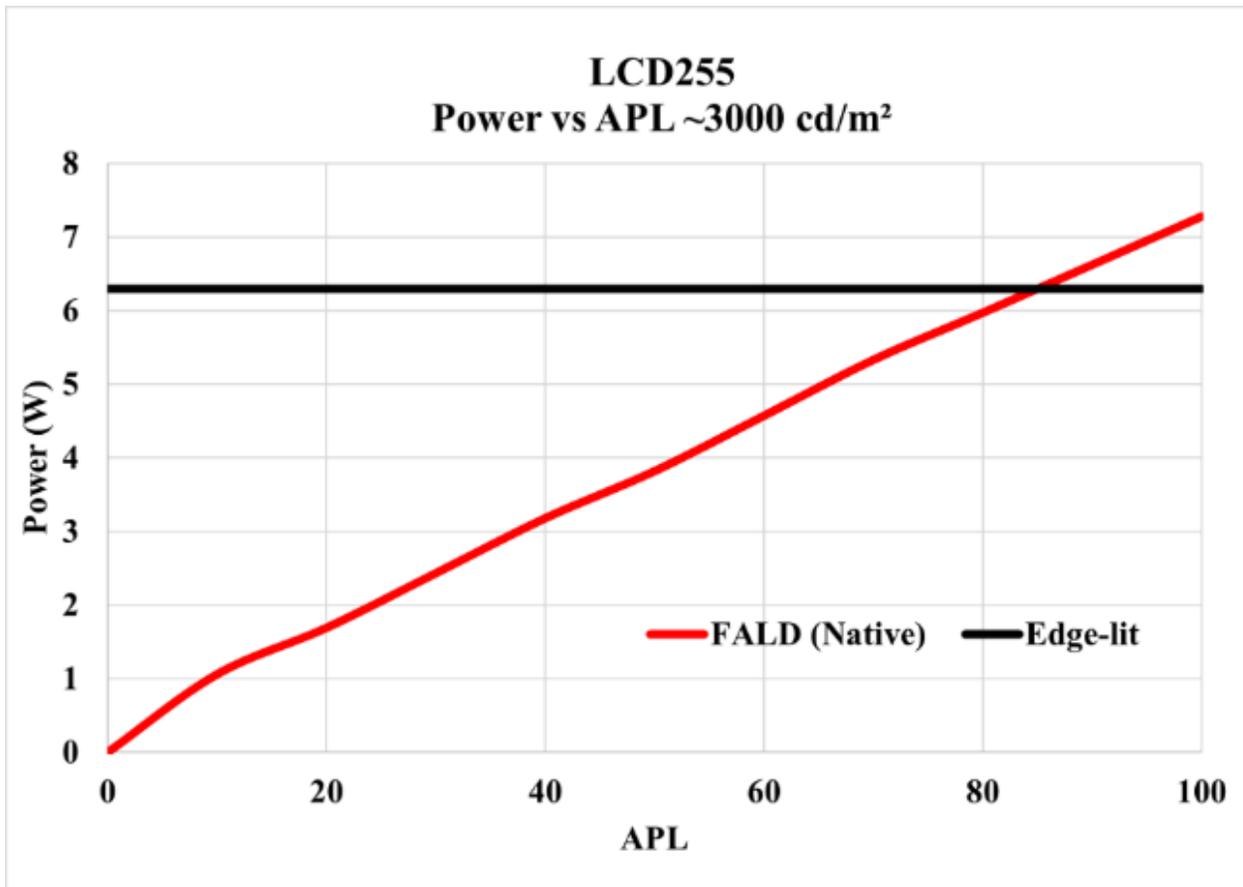
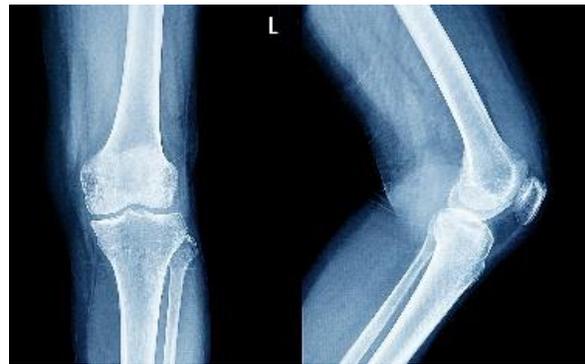


Figure 2: Average pixel luminance (APL) for LCD255 (FALD) versus an edge-lit panel with the same LCD cell and the same displayed content.

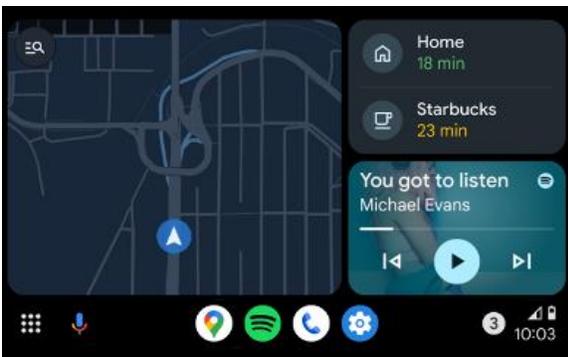
Table 1: Example graphics with APL%.



18% APL



47% APL



20% APL



36% APL

Table 1 shows a variety of images with different APL levels to better illustrate power savings from different types of content. In one example, the two colorful birds have an OPR of 85% but since the pixels are illuminated at different levels it results in an APL of 36%. This yields 55% power savings compared to the equivalent edge-lit panel.

LCD255 stands out as superior technology over the same size Edge-Lit LCD in terms of **power efficiency**, **contrast performance**, and **HDR capabilities**. By enabling intelligent illumination only where needed, FALD saves energy and enhances viewing quality.

Scalability and Cost Considerations

While the initial hardware can be more costly, especially due to the number of LEDs and complexity, techniques like **multiplexing** help make FALD more affordable and scalable. As demand grows for energy-efficient, high-performance displays in TVs, monitors, automotive displays, and portable devices, FALD with optimized cost structures is poised to become a mainstream backlight technology.

USE CASES AND APPLICATIONS

FALD displays from LTS are ideal for:

- **Medical monitors** with DICOM-grade calibration
- **Drone and avionics controllers** exposed to sunlight
- **Broadcast monitors** with high color accuracy needs
- **Industrial and rugged environments** requiring HDR and efficiency

CONCLUSION

FALD display technology, especially when powered by mini-LED and intelligent zone control, delivers superior power efficiency, contrast, and user experience over edge-lit alternatives. LTS's LCD255 panel exemplifies how design innovation meets practical performance needs. As the demand for energy-efficient, HDR-ready displays grows, FALD is poised to become the preferred backlight technology across industries.

ABOUT AUTHORS

Nilesh earned his Bachelor's and Master's in Electronics from RTM Nagpur University and completed a PhD in Semiconductor Physics at Kyung Hee University, South Korea. He conducted postdoctoral research at North Carolina State University before working with startups, semiconductor companies, and Meta, where he contributed to AR display technologies, including the Orion AR glasses prototype.

At Lincoln Technology Solutions, he is focusing on innovating advanced display technologies for medical, drones, avionics, automotive, consumer electronics, and agriculture.



Dr. Nilesh Barange
Staff Display Engineer, PhD

Jacob graduated from North Carolina State University with a dual Bachelor of Science degree in both Electrical and Computer Engineering, as well as a minor in Business Management. In 2013, Jacob co-founded Lincoln Technology Solutions, with David Lincoln, our CEO, with a deep passion of bringing creativity to life through electronic-based products, while not settling for “good enough,” pushing the limits of what technology can do and delivering many industry firsts.

While innovating fascinating display projects in various industries, Jacob cherishes travelling around the world to visit clients, and oversee our factories in China, Thailand, and Malaysia.



Jacob Kimbrell
CTO & Co-Founder

ABOUT LINCOLN TECHNOLOGY SOLUTIONS

We are display Innovators!

As a leading custom display manufacturer, we deliver cutting-edge LCD & OLED solutions that power next-generation displays across broadcast, in-flight entertainment, medical, drone controllers, industrial, automotive, agriculture, and more. We specialize in taking on challenging designs that require high-bright, enhanced color uniformity and high contrast applications.

From pioneering ultra-high brightness local-dimming backlights showcased in award-winning broadcast monitors at NAB 2019, to launching the first OLEDs in in-flight entertainment, and developing a panoramic head-up display featured in BMW's iVision Dee concept car at CES 2023, our display breakthroughs continue to capture the attention of forward-thinking innovators worldwide.

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