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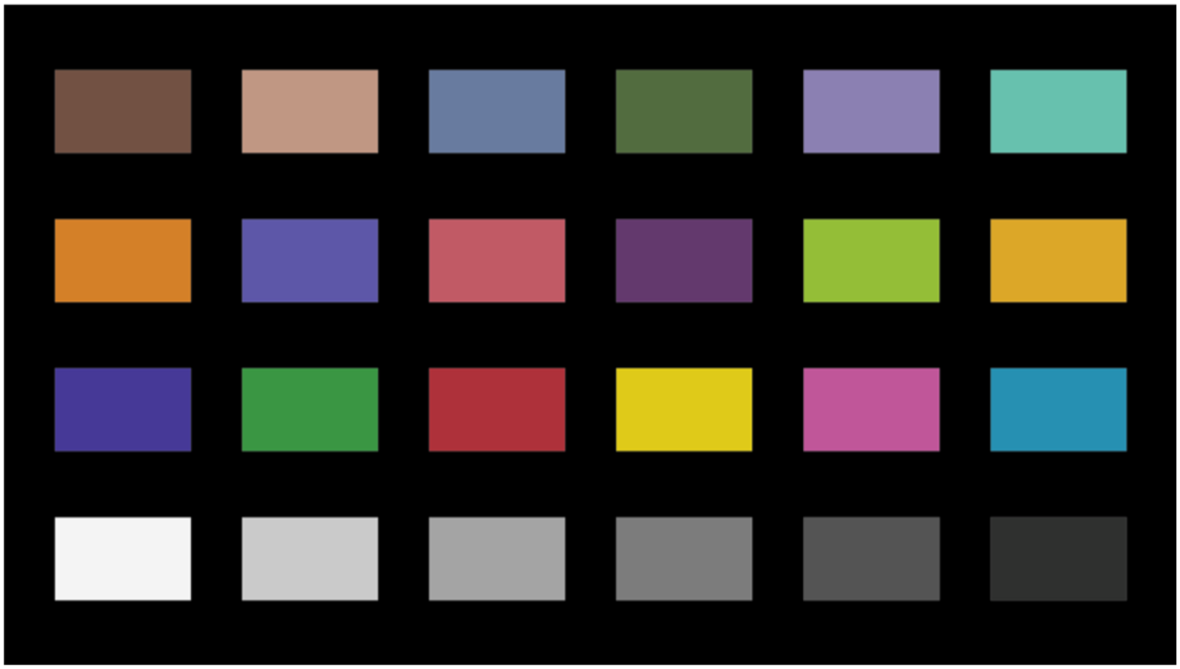
WHITEPAPER



ADVANCING OLED LONGEVITY AND UNIFORMITY

How Digital De-Burn-In Compensation reduces OLED burn-in using pixel-level data modeling validated by 3000-hour test results

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INTRODUCTION

OLEDs are renowned for their excellent picture quality, but their long-term performance can be affected by permanent image retention, commonly known as burn-in. Burn-in is a permanent phenomenon and presents as noticeable luminance and color differences between pixel areas that are stressed differently, based on image content. Burn-in occurs when a static image is displayed on a screen for an extended period, causing localized activated pixels to degrade more quickly than the rest of the active area. Over time, differences in degradation of pixels activated on static images versus normal global degradation of pixels becomes more obvious.

To establish specifications, Delta E (CIEDE2000 standard for noticeable difference) is applied assuming that a 3-5% luminance delta between adjacent pixels represents the threshold of noticeable change after 3000 hours. Fortunately, several techniques and methods are available to mitigate and even reverse burn-in effects. This paper provides an overview of compensation algorithms for De-burn-in (DBI) and outlines best practices for OLED display management.

BURN-IN COMPENSATION

In the display field, there are three main types of de-burn-in compensation: digital de-burn-in compensation, current/voltage sensing compensation, and optical compensation. Each method has distinct advantages and disadvantages for display applications:

(1) Digital de-burn-in (DBI) compensation: Utilizes a data accumulation method to estimate individual pixel stress through video or image input data calculation. This technology is widely used in display applications due to its cost efficiency and minimal panel space requirements. The compensation data is stored in a Look-Up Table (LUT) and is updated over time.

(2) Current or voltage sensing compensation: This method offers a highly accurate and reliable solution for real-time compensation of luminance variation, providing high accuracy and reliability. It effectively addresses dynamic luminance variation across panels, regardless of the degree of variation. However, it requires extra sensing circuitry space within the pixel array, leading to increased panel complexity and higher manufacturing costs.

(3) Optical compensation: This technique uses a high-resolution camera to capture luminance and compensate for burn-in. It can achieve high accuracy regardless of display size. However, it requires a dedicated camera system and does not support real-time burn-in compensation, as the camera inspection system is not integrated into the display/monitor.

Lincoln Technology Solutions (LTS) OLED panels use digital De-burn-in (DBI) compensation. The industry standard burn-in test method is to collect luminance data while displaying a static image of the Macbeth pattern, as shown in Figure 1(a). Luminance measurements are taken within and outside of the region of interest (ROI) during initial testing and at specified intervals up to 3000 hours, as illustrated in Figure 1(b).

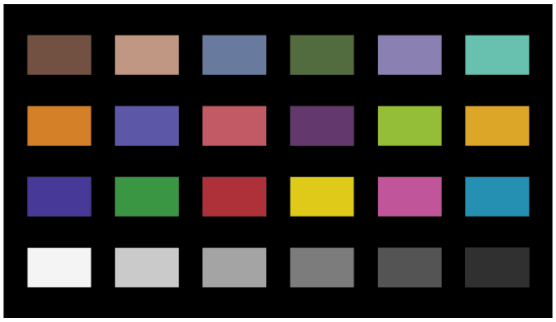

Figure 1: (a) Macbeth pattern used for DBI testing

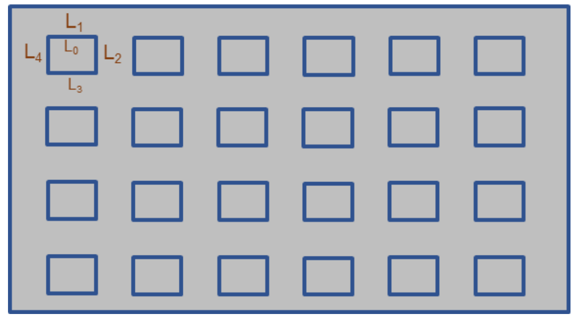

Figure 1: (b) Luminance measurements taken within and outside the region of interest (ROI)

Burn-In Collection and Compensation

1. Data collection: Begins by recording the initial luminance at the ROI. The Macbeth pattern is displayed for a specified time interval, followed by a 50% gray screen to measure luminance. This process is repeated over a 3000-hour period, with luminance measurements taken at defined intervals. The resulting decay curves are collected and fitted using the model $L(t) = L(0) * \exp\left(-\left({}^{t}/_{\eta}\right)^{m}\right)$

2. Coefficient determination: Attenuation coefficients η and m are extracted from the decay curves to establish a predictive model for the relationship.

3. Brightness compensation: Apply the DBI compensation formula to adjust luminance based on the actual panel brightness. The steps involved in the DBI compensation process are illustrated in Figure 2.

4. Delta Luminance Calculation: Delta luminance is calculated using the following formula:

$$dL = \max\left(abs(L_N - L_0)/L_0 * 100\right); N = 1,2,3,4.$$

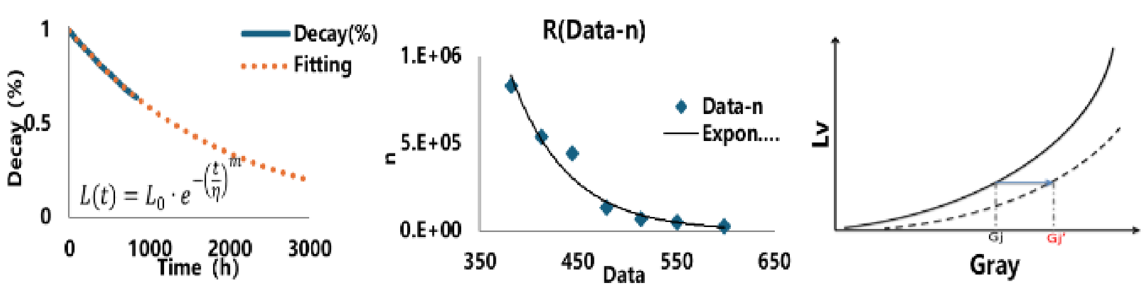

Figure 2: Measurement and curve fitting

Luminance decay between pixels at specific intervals is represented by metrics such as LT_{50} or T_{50}, which indicates the time it takes for luminance to decay 50%. Similarly, T_{70}, T_{95}, and T_{97} correspond to 30%, 5% and 3% luminance decay respectively. Among these, T_{95} and T_{97} are particularly important as a 3-5% change in luminance is near the human eye's perception threshold and is often used to assess the likelihood of visible image burn-in.

Decay Compensation:
After collecting data for 3000 hours and identifying the decay curve, LTS applies a burn-in compensation algorithm as illustrated in Figure 3.

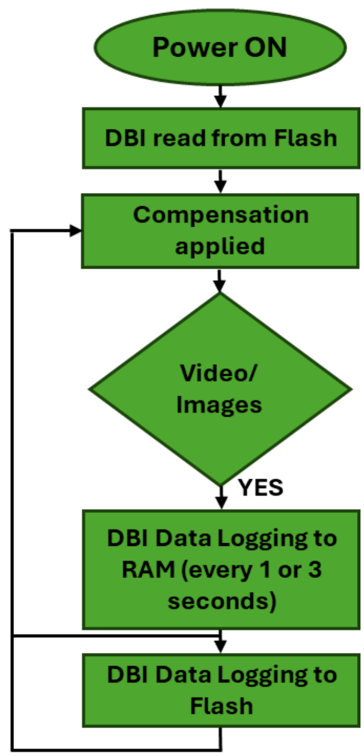

Figure 3: Flow chart of burn-in compensation process

Once the panel is switched ON, it reads DBI data from the look-up table (LUT) and applies the appropriate compensation. After running video/image content for 1 to 3 seconds, the panel logs DBI data in RAM. Every 20 minutes this data is written into Flash memory for future use.

The effect of compensation on the test panel is shown in Figure 4. This panel is currently undergoing testing, with results shown for up to 3000 hours running at 400 nits. Running panels at max brightness can cause burn-in to occur even faster. As the data indicates, color degrades at varying rates and the DBI algorithm attempts to correct for these variations. White point shift can also occur in OLEDs after burn-in; however, our panels maintain consistent white point color coordinates as shown in Figure 5. We are continuously collaborating with our industry partners to refine and optimize the DBI algorithm to improve accuracy and performance.

Figure 4 represents data from panels that were operated at a constant 400 nits during testing, however in real world conditions panels are not running at max brightness all the time and may vary based on content. To test real world content/situations, we used IEC 62087-2:2021 test video, solid RGB colors and standard images used in broadcast industry running on panels under test. The data collection procedure is like the panels with the Macbeth pattern, but running standard images and video, not static full brightness patterns. The result is shown in Figure 6, and interestingly at 3000 hours the delta luminance of all colors is ~1.5 %.

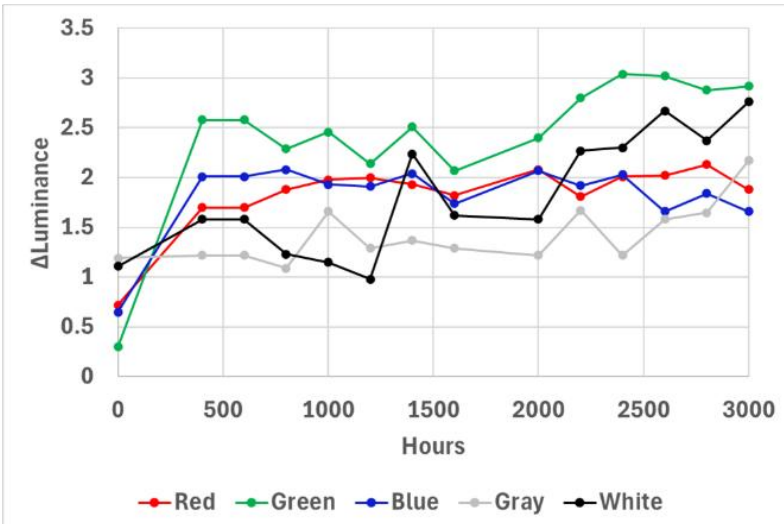

Figure 4: DBI algorithm performance on an OLED panel for 3000 hours of operation

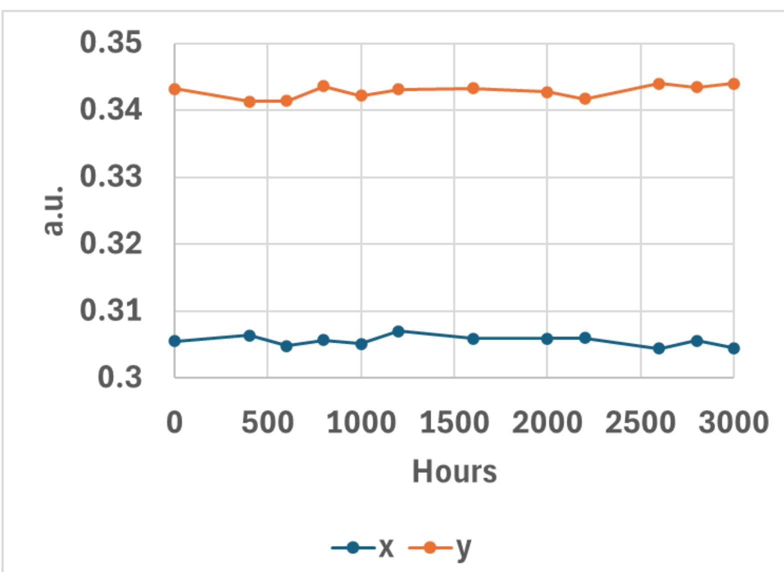

Figure 5: White point color coordinates for same panel

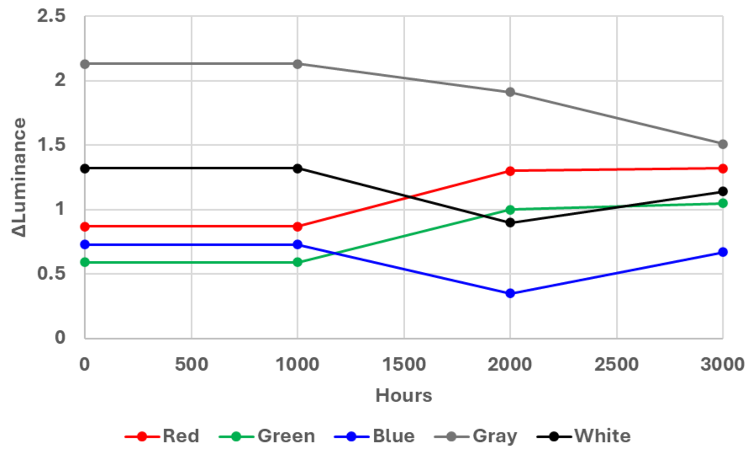

Figure 6: Delta luminance vs. hours for OLED panel tested under real world conditions

CONCLUSION

The latest De-Burn-In methods have drastically improved the burn-in performance of OLED displays. At LTS, we are constantly striving to push the boundaries of image quality and product lifetime, so we will continue to work with our industry partners to further enhance our DBI algorithms. As this paper has described, LTS OLEDs achieve a luminance delta of less than 3.5% over the course of a 3000-hour burn-in test using extreme conditions. Test scenarios more closely aligned with real-world conditions result in less than 1.5% delta luminance.

In parallel, several techniques exist to mitigate burn-in issues at the module level, including pixel shifting, luminance reduction, and the use of screensavers. OLED technology continues to evolve, driven by advances in material science, device stack design, and improvements in optical and electrical properties. For example, tandem OLED structures theoretically reduce current density by half, which can double the operational lifetime compared to single-junction OLEDs. LTS will continue to introduce new OLED technology into the market for high quality displays.

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

Jesse Henrikson joined Lincoln Technology Solutions in 2022, bringing with him a diverse engineering background shaped by his work in Minnesota and Texas, and early roots on a farm in North Dakota. He holds both a Bachelor and Master of Science in Mechanical Engineering from the University of North Dakota.

Jesse is driven by the opportunity to collaborate with talented, highly motivated teams focused on building world-class display technology. He values LTS's agility and its ability to respond quickly to customer needs while consistently delivering exceptional results.

Jesse Henrikson
VP of Engineering

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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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https://lincolntechsolutions.com/

sales@lincolntechsolutions.com

1-844-463-6587