ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika

ISSN(p): 2338-8323 | ISSN(e): 2459-9638 | Vol. 14 | No. 1 | Halaman 42 – 56
DOI : http://dx.doi.org/10.26760/elkomika.v14i1.42 January 2026

Experimental Comparison of DALI and 0–10V LED Dimming Systems for Smart Lighting

Article History:
Received
9 December 2025
Revised
12 January 2026
Accepted
14 January 2026

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ABSTRAK

Studi ini membandingkan kinerja dimming DALI dan 0–10 V menggunakan tiga driver LED komersial pada delapan tingkat dimming. Pengujian meliputi konsumsi daya, iluminansi, serta stabilitas kedip. Hasilnya menunjukkan bahwa DALI mampu menjaga kurva dimming tetap linier hingga level rendah seperti 10%, 5%, dan 1%, dengan kedip yang konsisten berada pada zona Tanpa Risiko. Konsumsi daya saat 0% juga rendah, sehingga cocok untuk aplikasi yang memerlukan dimming dalam dan kenyamanan visual stabil. Sebaliknya, sistem 0–10 V bekerja cukup baik pada level tinggi dan sedikit lebih efisien pada daya rendah, namun performanya turun drastis di bawah 30%. Pada 10%, iluminansi hampir mendekati nol dan tingkat kedip memasuki zona Risiko Tinggi. DALI lebih ideal untuk pencahayaan pintar dengan transisi halus, sedangkan 0–10 V lebih sesuai untuk instalasi dasar.

Kata kunci: *DALI, 0-10V, LED Dimming, Smart Lighting, Driver LED*

ABSTRACT

This study compares the dimming performance of DALI and 0–10 V using three commercial LED drivers at eight dimming levels. The testing included power consumption, illuminance, and flicker stability. The results showed that DALI was able to maintain a linear dimming curve down to low levels such as 10%, 5%, and 1%, with consistent flicker within the No Risk zone. Power consumption at 0% was also low, making it suitable for applications requiring deep dimming and stable visual comfort. Conversely, the 0–10 V system performed quite well at high levels and was slightly more efficient at low power, but its performance dropped drastically below 30%. At 10%, the illuminance was almost zero and the flicker level entered the High Risk zone. Overall, DALI is more ideal for smart lighting with smooth transitions, while 0–10 V is more suitable for basic installations.

Keywords: *DALI, 0-10V, LED Dimming, Smart Lighting, Driver LED*

1. INTRODUCTION

Lighting is one of the most important components in a human life. Lighting can certainly help with all activities anywhere especially in building **(wu et al., 2016)**. However, electricity consumption for lighting is often overlooked by some institutions. This sometimes results in electricity usage exceeding estimated costs. Recent research indicates that inadequate power management in street lighting can result in budget misallocation of up to 40%. **(Cacciatore et al., 2017).** Similar research has also been conducted in the UAE and proven that energy can be saved by up to 55% **(Takruri et al., 2023).** In addition to energy consumption, the choice of lighting will also affect the surrounding environment, as it will indirectly have an unnoticed impact on the environment. Therefore, choosing the right lighting must go hand in hand with being environmentally friendly **(Sinha et al., 2017).**

LED technology has also demonstrated strong efficiency advantages beyond building lighting. For example LED as a more efficient option for motorcycle main headlamps, indicating that LEDs can provide adequate illumination with lower power demand than conventional lamps. This broader evidence supports the role of LED-based systems as a key enabler for energy-saving lighting solutions across sectors **(Simatupang et al., 2022).**

Based on that explanation LED is powerful. So one solution to reduce energy consumption without compromising visual comfort is the use of dimming systems. Dimming allows light levels to be adjusted based on occupancy, daylight availability, or task requirements, which can significantly reduce energy use while extending the lifespan of lighting components **(Kshirsagar et al., 2025) (Hadikusuma & Santoso, 2025).** This research will focused two common dimming control methods are widely used: 0–10 V and DALI (Digital Addressable Lighting Interface). The 0–10 V method operates using an analog voltage signal to control brightness but often shows variations due to signal tolerance and driver differences **(Moonsindustries, 2025).** In contrast, DALI communicates digitally and supports features such as device addressing, grouping, scene control, and status feedback, making it more suitable for automation and smart building applications **(Adam, 2019)**.

Digital Addressable Lighting Interface (DALI) is an advanced building lighting control solution that is more accurate and flexible than conventional analog systems **(Sinha et al., 2017)**. **(Hosseini & Heiranipour, 2024)**. Unlike 0–10 V dimming, which controls lighting by changing voltage levels and relies on analog system control, DALI uses digital commands, enabling individual control, scene programming, system feedback, and grouping that surpasses analog systems in overall system control. DALI is thus integrated into smart and energy-efficient modern buildings that utilize adaptive lighting systems crucial for energy management and comfort . Several studies on adaptive lighting systems confirm the superior dimming consistency and system interoperability of DALI across various systems with the enhanced DALI-2 interoperability standards and certification **(Wade et al., n.d., 2019).** The operational energy consumption of commercial building systems is positively influenced by the use of DALI controls, which is also where timely DALI controls and smart scheduling controls and automation are present **(Kshirsagar et al., 2025)**. Although DALI is reliable, system control and device compatibility (e.g., commercial drivers and lighting fixtures) can pose problems. The interoperability, precision, and control of the DALI system make it efficient in building automation systems, and therefore it is widely adopted and explored in system engineering and construction as a key component of smart building lighting **(Lin & Chen, 2023).**

One of the first methods used to control light levels in commercial and industrial environments was the 0-10 V dimming method. As the name suggests, this system is connected to control light levels using a 0 to 10 volt control signal, where 0 volts is minimum light and 10 volts is maximum light. This is one of the last systems used because of its easy installation and its ability to work with various lighting systems, such as LED drivers and fluorescent lamps **(Waghale & Poplawski, 2023).** However, digital systems tend to be more advanced. Standardization is a major issue; one of the more common problems seen with different dimming curves and flickering visible at low dimming levels is with manufacturers. Wu et al. described this issue as varying performance, and it is a frequently cited limitation of this method **(Wu et al., 2020)**.

Several large studies recommend that electrical installations in large smart buildings requiring extensive adjustable controls and system-level feedback should avoid the 0–10 V protocol due to its shortcomings and consider DALI instead **(Takruri et al., 2023).** However, it can be suggested that in scenarios where a building is undergoing conservation cleaning and a complete system replacement is not an option, 0–10 V dimming controls can be configured to provide good dimming and energy savings **(Maheswaran, 2024)**. This low market entry complexity, reasonable pricing, and therefore widespread market adoption make the 0-10 V control method still the main benchmark in the comparative assessment of contemporary modern lighting control methods.

This condition becomes increasingly important as Indonesia pushes forward with national initiatives such as the *Gerakan 100 Smart City* launched by the Ministry of Communication and Informatics and the long term national vision Indonesia Emas 2045, which emphasizes digital transformation, energy efficiency, and intelligent infrastructure **(Kementerian Bappenas, 2020) (Kementrian Kominfo, 2021)**. Reliable and predictable lighting control performance is one of the foundational components in future smart buildings and smart city ecosystems. Therefore, this research aims to provide a practical, test-based comparison of both dimming systems using several commercial LED drivers, offering a more objective technical reference for selecting the most suitable lighting-control technology to support Indonesia's smart city development.

To clarify the contribution of this work, Table 1 summarizes the research gap, objectives, and the novelty offered by this study.

Table 1. Summary of research gap, objective, and novelty

Research gap / problem	Objective	Novelty (this study)
Limited test-based, side-by-side evidence comparing DALI and 0-10 V across multiple commercial LED drivers.	Compare power consumption and illuminance at eight dimming levels (100% to 0%) using three drivers per protocol.	Controlled experiment with identical dimming steps and comparable driver types to produce an objective, comparable dataset.
Deep-dimming (<10%) behavior and minimum usable level are often unclear in practical installations.	Assess dimming-curve behavior and minimum usable output at 10%, 5%, 1%, and 0% for each protocol-driver combination.	Identifies stable operating range versus abrupt cut-off, supporting protocol selection for applications requiring deep dimming.
Flicker behavior is rarely analyzed together with energy and light output in the same DALI vs 0-10 V comparison.	Measure flicker behavior across dimming levels and relate it to power and illuminance changes.	Links flicker interpretation with energy/output results to form practical guidance for smart lighting (DALI) vs basic installations (0-10 V).

2. RESEARCH METHOD

The purpose of this research is to test and compare the performances of two of the most used dimming systems and their interaction with three brands of commercially available LED drivers for each of the systems using the experimental method. In order to ensure balance, the experiment was conducted in makeshift, controlled, consistent test site environments that minimize unaccounted for measurement changers. Preparation and installation of test site fixtures, wiring to the site dimming protocol, communication verification between the site controller and drivers, and measurement are steps in the test process. Each fixture was assessed at several dimming levels from 0% to 100%, to record the changes in light output, power used, responsiveness of the dimming, and the device activity as control signals changed.

During each test stage, measurements were systematically recorded using calibrated tools to capture illuminance, electrical power, and visual dimming characteristics such as smoothness of transition, minimum achievable dimming level, and potential flicker occurrence. Additional observational notes were taken to document response delays, signal irregularities, or inconsistencies among different brands of drivers. All procedures were repeated using identical steps for every unit to maintain experimental fairness and reliability of comparison. The collected data was then organized in a structured format to support further analysis, interpretation, and performance benchmarking between the two dimming systems. This experimental approach was selected to produce practical, real-world reference findings supported by an integrated lighting control system without the need for additional external software intervention. For clarity regarding the overall workflow of this study, the general experimental research process is illustrated in the flowchart provided in Figure 1 & 2.

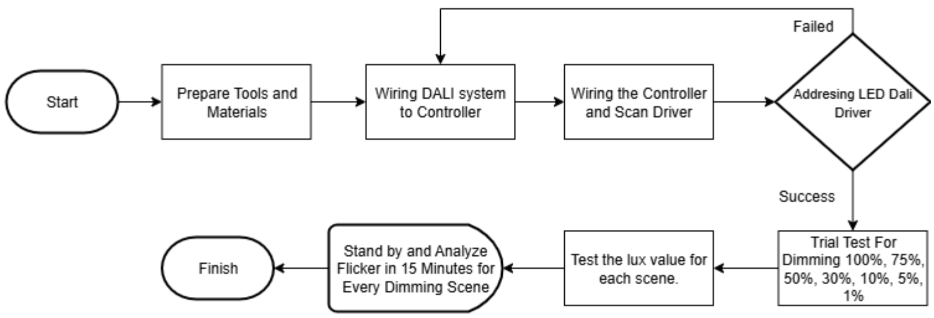

Figure 1. DALI Experimental Flowchart

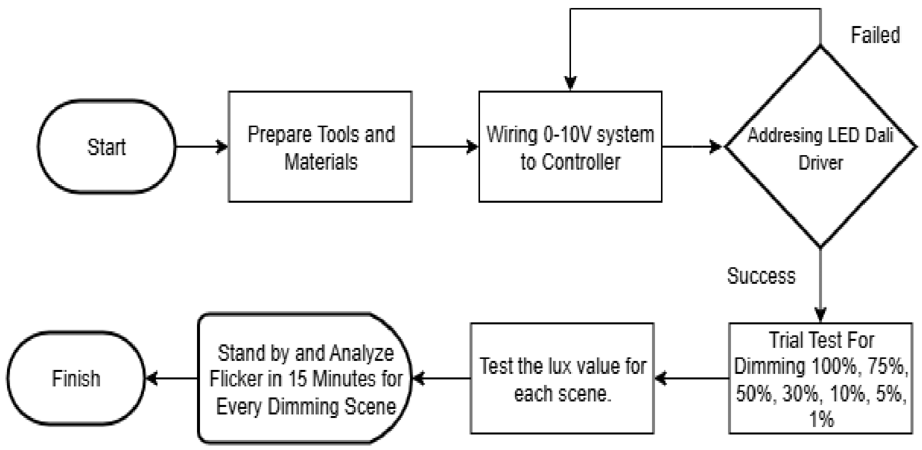

Figure 2. 0-10V Experimental Flowchart

2.1 Prepare Tools Material

The first thing done in this study was to prepare the materials. In preparing the materials here, I used 3 different driver brands, each with a DALI and 0-10V dimming system, so there are a total of 6 drivers. There are also DALI and 0-10V controllers, 1 piece each, to control the drivers' dimming. After that we prepared 6 lamps of the same type that will be tested as the output of the system. For more detailed information about the test materials used.

Table 2. List LED Driver

No	Type Driver	Control Type	Output Type	Current Range	Voltage Range
1	Ltech SE-30-200-800-W1D	DALI	Constant Current (CC)	200-800 mA	9-42V
2	Euchips EUP20D-1HMC	DALI	Constant Current (CC)	350/500/550/700 mA (Selectable)	18-42V
3	BOKE BK-DCL010S-AHA0700ADN	DALI	Constant Current (CC)	200-700 mA	9-43V
4	Ltech SE-30-200-800-W1A	0-10V	Constant Current (CC)	200-800 mA	9-42V
5	Euchips EUP20A-1HMC	0-10V	Constant Current (CC)	350/500/550/700 mA (Selectable)	18-42V
6	BOKE BK-DRL015S-AHA0700AMN	0-10V	Constant Current (CC)	200-700 mA	9-43V

Table 3. LED Lamp Technical Specification

Parameter	Value
Brand & Model	Venezina R6238 COB LED
Power Rating	15W
Output Current	350–700 mA *(depending on driver)*
Operating Voltage	18–42 VDC *(constant-current dependent*
Collerate Colour Temperature (CCT)	3500 K
Colour Rendering Index (CRI)	80

Table 4. Controller Specification Used in Testing

Parameter	Philips Dynalite DDBC120-DALI	Philips Dynalite DDBC1200
Control Protocol	DALI-2	0-10V
Output Channels	1 DALI Bus Output	12 Independent Channels
Control Output Current	Max 250 mA	50-100 mA per channel
Max Driver Capacity	64 DALI Driver	Up to 80 Driver (Broadcast)
Power Supply Input	100–240 VAC	100–277 VAC

The three tables summarize the hardware used in the dimming performance study. Table 1 lists the six LED drivers tested, consisting of three DALI and three 0–10 V models, all operating in constant-current mode with similar current and voltage ranges, ensuring fair comparison between the two control protocols. Table 2 provides the technical specifications of the LED lamp used as the load during testing, a 15 W Venezina R6238 COB LED with a voltage range of 18–42 VDC, a selectable output current of 350–700 mA depending on the driver, a CCT of 3500 K, and a CRI of 80, making it suitable for evaluating dimming behavior and color stability.

Table 3 describes the controllers used: the Philips Dynalite DDBC120-DALI for DALI-2 communication and the DDBC1200 for 0–10 V control, each having different output capacities and channel configurations, ensuring proper and standardized control of the respective driver groups during all measurement scenarios.

2.2 Wiring System

Before proceeding to testing, all devices were assembled into a complete working system to ensure proper functionality and compatibility between the controllers, drivers, and luminaires. The installation process began by powering the control units and arranging the wiring paths according to each dimming protocol's requirements. The first configuration was the DALI setup using the Dynalite DDBC120-DALI controller. DALI bus operates with a two wire digital communication line and does not require polarity, the connection from the controller to each LED driver was made following the standards. Once the wiring was completed, the controller was powered and checked to confirm that all connected drivers were detected and able to respond to basic dimming commands. The DALI Wiring Diagram and Wiring diagram of the experimental setup shown in figure 2 and figure 3, respectively.

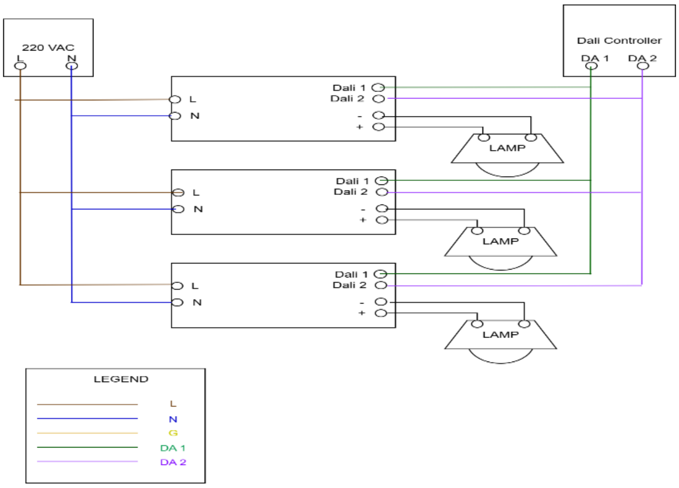

Figure 3. DALI Wiring Diagram

Figure 4. DALI Wiring

The wiring diagram shows a typical setup for connecting several LED drivers to a single DALI controller. Each driver receives a 220 VAC supply through the L and N lines, which are distributed in parallel to all units. The DALI communication pair, labeled DA1 and DA2, is also wired in parallel and shared by all drivers, since the DALI bus is designed for multi-drop communication. From each driver, the DC output terminals (+ and –) are connected directly to the lamp it powers. This means every lamp has its own driver, but all drivers are controlled together through the same DALI bus. The layout makes it clear that only two low-voltage wires are needed for control, without polarity, and the power wiring stays completely separate from the signal wiring. This is the standard way DALI networks are installed: one controller, one bus, and multiple drivers connected in parallel.

After verifying the DALI configuration and collecting the DALI data, the installation will continue with the 0–10 V system using the Dynalite DDBC1200 controller. Unlike DALI, the 0–10 V protocol relies on an analog control signal, meaning polarity must be observed when connecting the control wires to the driver terminals. The dimming signal wires were connected first, followed by the lamp power supply wiring, since the 0–10 V line only carries a reference control signal rather than load power. Cable routing, length, and termination quality were inspected to prevent voltage drop, noise interference, or instability in dimming response.

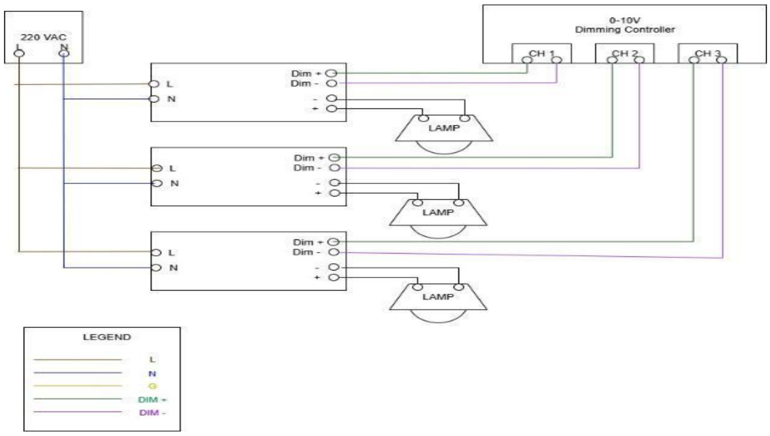

Figure 5. 0-10V Wiring Diagram

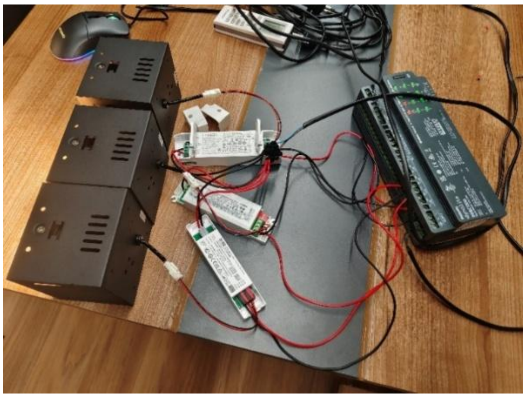

Figure 6. 0-10V Wiring

This wiring shows how the three LED drivers are connected to a 0–10 V dimming controller. The power side is straightforward: all drivers share the same 220 VAC supply, so the L and N lines are distributed in parallel to each driver. The dimming part uses a different approach from DALI. Each driver has its own Dim+ and Dim– terminals, and these are connected to separate channels on the controller CH1, CH2, and CH3. Because 0–10 V is an analog signal, every channel sends a specific voltage to its driver, which is why each lamp gets its own pair of dimming wires. When the controller outputs around 10 V, the lamp goes to full brightness, and as the voltage drops, the light level follows it. The diagram simply shows this one-to-one wiring style: one channel, one driver, one lamp.

2.3 Configuration Controller and Driver

After the wiring stage was completed, the controllers and drivers were configured so that each system could operate as intended under its dimming protocol. The configuration process started with the DALI setup using the Dynalite DDBC120-DALI controller. The controller was powered and placed into standard operating mode, then a device discovery was performed to detect and assign addresses to the connected drivers. This step ensured that each driver was recognized individually on the DALI network instead of being treated as a single broadcast line. No presets, automation rules, or advanced settings were activated at this point to keep the testing environment neutral. Once the DALI system was confirmed to be functioning correctly, the configuration continued with the Dynalite DDBC1200 for the 0–10 V setup. Since this controller supports different operating modes, it was set specifically to provide analog dimming output. All dimming curves and response settings were left at factory defaults so the evaluation would reflect the natural behavior of the protocol and the drivers, not tuning preferences. Each connected driver was then checked to make sure the 0–10 V signal translated smoothly to brightness changes without flicker or unexpected steps. With both systems responding as expected, the configuration was considered complete. No calibration or optimization was applied, and the system was left in a clean baseline state to maintain fairness before moving into the testing phase described in the next section.

2.4 Data Collection

Data collection in this study was carried out after the wiring and configuration stages were confirmed stable. The goal of the data collection process was to record how each driver responded to dimming commands under the DALI and 0–10 V protocols. The measurement procedure followed a structured sequence where each sample was tested individually under the same conditions to maintain consistency. The dimming level was adjusted in steps from 0% to 100%, and at every interval the light output and electrical parameters were recorded. A lux meter was used to measure illumination levels, while a wattmeter or power monitoring device was used to record voltage, current, and any changes at the driver output. Each reading was taken only when the system reached a stable state, meaning there was no visible flicker or noticeable delay in response.

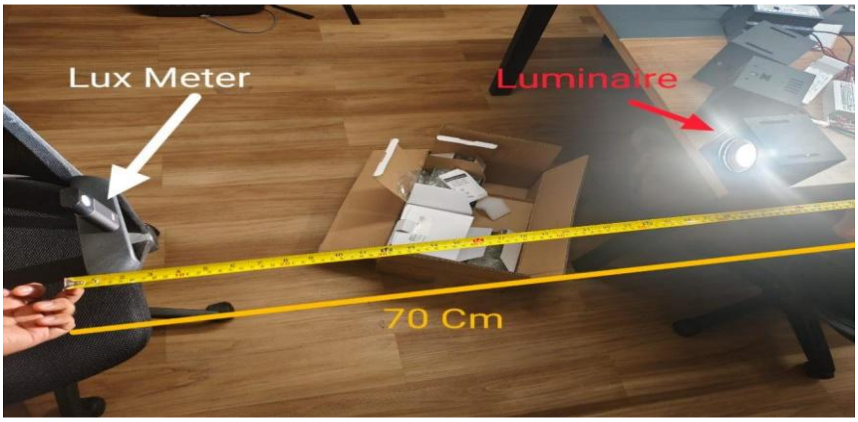

Figure 7. Lux level measurement method

During the data collection process, no external automation, delay compensation, or calibration was applied. The intention was to capture the raw behavior of each dimming protocol and driver combination. All measurements were recorded in a structured table format to simplify comparison, and repeated only when readings appeared inconsistent or abnormal. Once all six driver samples had been tested under both dimming systems, the collected data was reviewed and organized for analysis, which is presented in the next section.

3. RESULTS AND DISCUSSION

3.1 Power Consumption

The aim of the power-consumption test is to see how each dimming protocol (DALI & 0-10 V) and each driver behaves in terms of efficiency and responsiveness to varying intensities. We try using 8 measuring points dimming levels (100%, 75%, 50%, 30%, 10%, 5%, 1%, and 0%) were used. The results describe how all systems have a pattern of decline. However, the rate and consistencies of dropping differ from other drivers. Especially, at mid to low levels, switches and drivers were used to power.

Overall, the 0-10 V systems power drawn has ranges of less at low levels of omissions, supportive of the argument that during dimmed use, or on standby settings, the systems perform more efficiently than DALI. DALI displays elimination and more levels of mid stability in range levels and power of standby at 0%. Focusing on the substantial patterns of decline to fuel emissions shows the straightforward impacts of considering energy conservation over consistent performance. Table 4 and table 5 shown the power consumption of the DALI Driver and 0-10 V Drivers, respectively. And this result are illustrated in Figures 6 and 7, respectively. results

To make easier understand the result, please look at table and figure below it.

Table 5. Power Consumption DALI Driver

Dimming Level (%)	Ltech SE-30-200-800-W1D (W)	Euchips EUP20D-1HMC (W)	BOKE BK-DCL010S-AHA0700ADN (W)	All DALI Driver
100%	14,5	14,8	14,8	44,1
75%	11	11,2	11,2	33,4
50%	7,4	8,3	7,7	23,4
30%	4,4	5,3	5,3	15
10%	2	2,3	2	6,3
5%	1,4	1,7	1,1	4,2
1%	0,8	0,8	0,8	2,4
0%	0,4	0,4	0,4	1,2

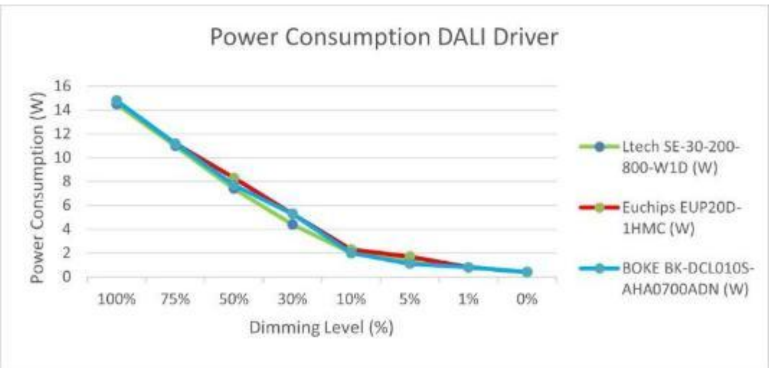

Figure 6. Graphic Power Consumption DALI Driver

Table 6. Power Consumption 0-10V Driver

Dimming Level (%)	Ltech SE-30-200-800-W1A (W)	Euchips EUP20A-1HMC (W)	BOKE BK-DRL015S-AHA0700AMN (W)	All 0-10V Driver
100%	14,8	14,8	14,8	44,4
75%	11	13	11,2	35,2
50%	7,4	9,5	7,4	24,3
30%	4,3	5,6	4,4	14,3
10%	1	1,1	1,1	3,2
5%	0,8	0,8	0,8	2,4
1%	0,7	0,7	0,7	2,1
0%	0,4	0,4	0,4	1,2

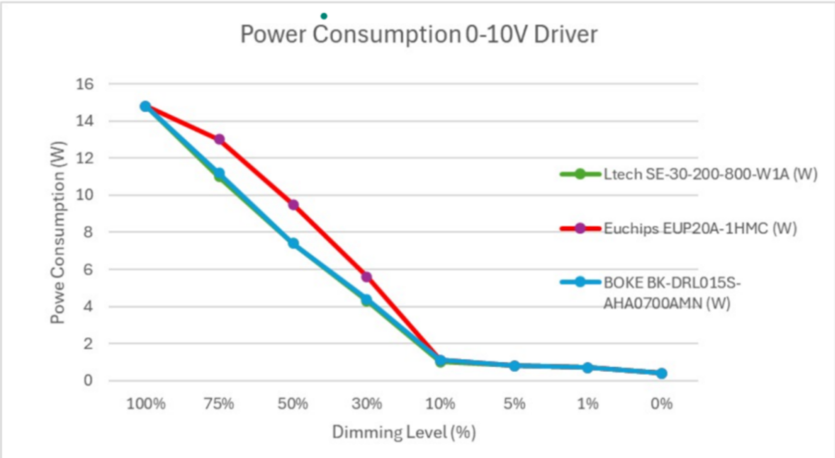

Figure 7. Graphic Power Consumption 0-10V

Both charts show how the drivers use power at different dimming levels, and the pattern between the two systems is quite different. In the DALI graph, the three drivers follow a steady and predictable decline as the dimming level goes down, and even at very low settings 10%, 5%, or 1% they still draw a small but controlled amount of power. This is why the curve stays smooth all the way to 0%, where a little standby power remains. On the other hand, the 0–10 V drivers drop much faster. They still match the expected values at high levels, but once the dimming goes below roughly 30%, the power falls almost straight to zero. By 10% and below, the drivers are basically consuming only standby power. From the two graphs, it’s clear that DALI keeps the light output stable at low levels, while 0–10 V tends to fade out completely much earlier.

3.2 Illuminance Performance

The measurement of illuminance offers a profound differentiating characteristic of the two dimmers, especially when consumers are near to low-dimmed output values. As for the DALI, all three drivers are able to reduce the light output in a phased and linear manner, and as such, the dimming values are set to decrease. From 7088 lux average light output during the 100% setting, the light output is reduced in graduated tiers with light stepping to 75%, to 50% and then to 30% with no jumps in the light output. Most impressive is that DALI is able to output light, albeit small, but measurable light even down to 10%, and 5% light output, and 1%. At these output levels, DALI outputs a controlled and smooth dimming function down to the lower limit of its set dimming range and outputs 830 lux, 388 lux, and 61 lux.

Table 7. Lux Measurement DALI Driver

Dimming Level (%)	Ltech SE-30-200-800-W1D (Lux)	Euchips EUP20D-1HMC (Lux)	BOKE BK-DCL010S-AHA0700ADN (Lux)	Average Lux
100%	6843	7473	6948	7088,0
75%	5329	5761	5509	5533,0
50%	3675	4134	3943	3917,3
30%	2124	2631	2850	2535,0
10%	678	941	871	830,0
5%	328	422	414	388,0
1%	57	60	66	61,0
0%	0	0	0	0

Table 8. Lux Measurement 0-10 Driver

Dimming Level (%)	Ltech SE-30-200-800-W1A (Lux)	Euchips EUP20A-1HMC (Lux)	BOKE BK-DRL015S-AHA0700AMN (Lux)	Average Lux
100%	7184	7347	7595	7375,3
75%	5783	6490	6025	6099,3
50%	3994	4807	3953	4251,3
30%	2048	2775	2148	2323,7
10%	24	38	42	34,7
5%	1	0	0	0,3
1%	0	0	0	0,0
0%	0	0	0	0

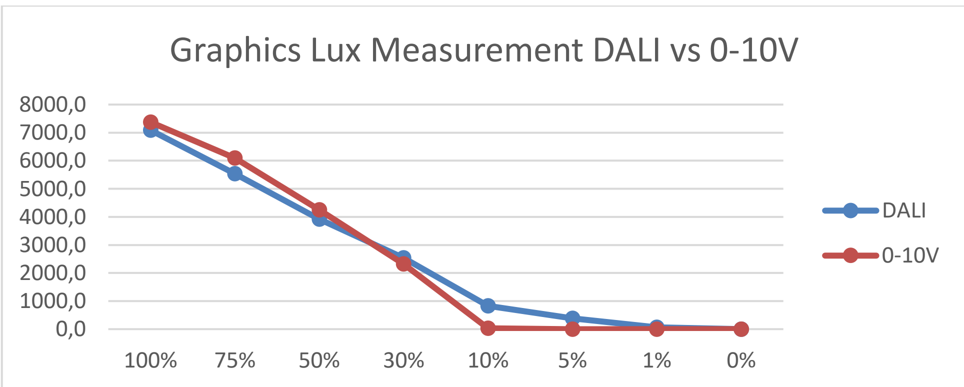

Figure 8. Graphics Lux Measurement DALI vs 0-10V

From this data, we see findings differ by dimming protocol. The 0-10 V protocol responds similar but with very different behavior. The drivers output strong consistent levels of illuminance at higher levels, e.g., 100% at 7375 lux and 75% at 6099 lux. However, once we reach a dimming level of 30% behavior changes. At 10% we only have an average of 35 lux being output. At dimming levels of 5% and 1% the output is near zero. Thus, the 0–10 V does seem to have a cut off behavior at low dimming levels (although a very low cut-off level) unlike the DALI which has a very slow decline. In this way correlates to 0-10 V system and low level illumination as well as the way it moves to darkness once dipming is low enough.

In all, this indicates a very different implimentation of function and with DALI being the system with more usable levels. 0-10 V does produce a higher output at the upper dimming levels but is less usable at the low dimming levels. In the tables and graphs to follow, we present the full illuminance values of each driver to more clearly demonstrate the DALI values against its 0-10 V counterparts.

3.3 Flicker Behavior of Dimming System

In this experiment flicker for 100%, 50%, and 10% brightness levels to understand how each dimming plan responds to different light output levels.

Figure 9. Photometric Flickers DALI

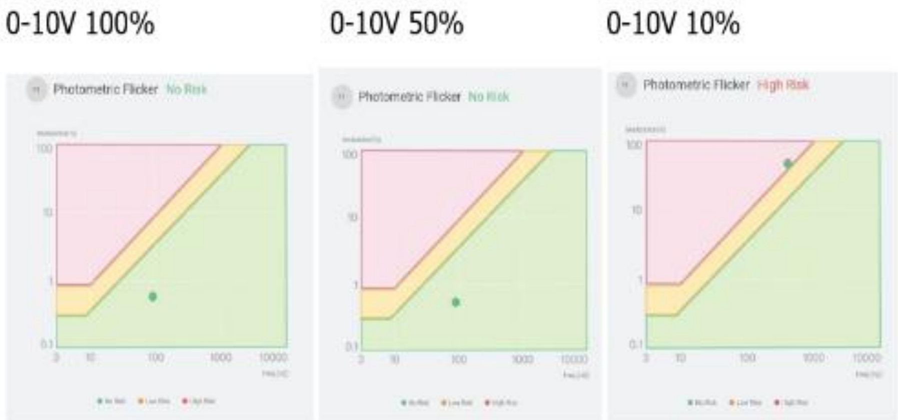

Figure 10. Photometric Flickers 0-10V

Based on figure 9 and figure 10 DALI measures light output and flicker to low levels for all dimming ranges. Even at 10%, where many systems show instability, the measured point is still a safe zone. This indicates that DALI has good control of light output and low flicker across the entire dimming range. The system with 0-10V output shows a different pattern than the previous ones. At 100% and 50%, the flicker measurement falls into the No Risk zone, just like with DALI. However, at 10%, the behavior is different, as the modulation that is measured jumps into the High Risk zone. This means that with 0-10V, there is less output stability and there are likely greater problems with the control signal being analog and how the driver interprets minute changes to the voltage at the very bottom of the dimming curve. Moving from a flicker safe to a flicker high risk zone right at 10% is consistent with the previous 0-10V where there was also lot of light and also a considerable drop in output illuminance. Overall, the results suggest that DALI produces low flicker at any dimming level, which means it is better for tasks where steady light is needed for a long time. On the other hand 0-10V is safe at mid and high level range but at lower dimming levels it is unstable, which is problematic in places where flicker sensitivity is high. The following plots show flicker behavior for both systems at the dimming levels of interest.

4. CONCLUSION

The two dimming systems show different traits when their power use, illuminated output, and flicker rate are considered together. The DALI system is the most homogeneous across all three parameters. Its power consumption is smooth and predictable. Also, the system holds steady at every dimming level, and while there is a small amount of standby power, it remains stable. DALI illuminance can maintain usable lumens at very low dimming levels (10%, 5%, and 1%), indicating a true dimming curve rather than an abrupt cutoff. Furthermore, DALI flicker is in the No Risk zone at all tested levels, confirming that the protocol provides stable and visually comfortable lumens, even at deep dimming levels. The 0–10 V system exhibits a distinctive pattern. It is more efficient at higher power settings and produces better illuminance at high and mid-range settings. However, it becomes unstable at certain dimming levels. In this section, dimming levels below 30% result in an illuminance cap of 10%, and instability becomes evident in the flicker results as the system transitions to the high-risk section with low dimming levels. This shows that this analog protocol is more affected by low voltages and the instability associated with deep dimming. So DALI is clearly more appropriate for modern smart lighting systems that require smooth dimming, reduced flicker, and consistent light quality across the range, including near-zero outputs.

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