Vol 58, No 2—June 2024

ANALOG DEVICES | ADI Analog Dialogue™

LED Matrix Manager Empowers High Density Automotive Intelligent and Safe Front Light System

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Abstract

The LED matrix manager provides original equipment manufacturers (OEMs) with an advanced front light system that enhances safety and distinguishes their brand. It offers seamless integration, high performance coupled with safety features, and effectively reduces electromagnetic interference (EMI). Additionally, it incorporates a built-in logarithmic fade-in/fade-out function, low $R_{DS(ON)}$, and slew rate control for optimal operation. This article will discuss how the LED matrix manager can be used to elevate the intelligence of automotive front light system designs.

Introduction

The increasing adoption of intelligent front light systems is primarily driven by safety and the desire for unique brand identities. These systems are growing at a rate of 8.3% annually.[1] They feature glare-free high beams, LED, and matrix lighting, which together form adaptive driving beam (ADB) systems. These ADB systems eliminate the risk of blinding oncoming traffic. To further enhance safety and comfort for drivers, automotive OEMs are incorporating additional adaptive lighting functions (AFS) like cornering light and dynamic curve light.

The LED matrix manager plays a crucial role by efficiently managing current for matrix and pixel lighting. It typically controls LED voltage (up to 65 V) using 6 to 12 integrated switches, simplifying design and saving time. Its integrated MOSFET, rated between 5 V and 14 V, has a low on-resistance $R_{DS(ON)}$, allowing it to handle LED currents up to 2 A.

Additionally, the LED matrix manager offers an optimal pulse-width modulation (PWM) dimming setup with exceptional performance. This includes smooth transitions between PWM dimming states and the option for internal or external clock control for PWM dimming.

The rapid advancements in the dimming performance of the LED matrix manager are contributing significantly to increased safety, improved driving experiences, and enhanced brand identities.

Advantages of LED Headlights

Currently, automobiles use halogen, xenon, or LED lamps for their front lights. Xenon lamps were common in higher end vehicles for a while, but now LED lamps are becoming more popular. It's likely that LED lamps will soon be the most common choice.

The differences among these lamps are summarized in Table 1. LED lamps are brighter than halogen, but not as bright as xenon. Xenon lamps can be too dazzling at night. Typically, halogen lamps use only 20% of their power for light, while LED lamps use 80%.[2] Even though LED lamps cost more initially, their long lifespan and energy efficiency can save money in the long run. They are also smaller, giving carmakers more design freedom for headlights.

Table 1. Comparison between Halogen Lamp, Xenon Lamp, and LED Lamp

	Halogen Lamp	Xenon Lamp	LED Lamp
Brightness	Low	High	Medium
Energy Efficiency	Low	Medium	High
Lifespan	Short	Medium	Very long
Size	Large	Large	Small
Price	Low	Medium	High

LED Exterior Front Light System Overview

A front light system as shown in Figure 1 includes a microcontroller, voltage sources, current sources, and LED lamps. The microcontroller, referred to as the LED module (LM), is situated outside of the lamps. It's commonly known as the LED control module (LCM). The LCM often employs the CAN bus to communicate and monitor the status of the LM, including features like animation and brightness. Inside the LCM, buck-boost topologies are frequently used as LED drivers, allowing them to accommodate different LM configurations, such as 6 or 12 LEDs in a single LM. In Figure 1, the LED driver within the LCM comprises both voltage and current sources. Typically, the voltage sources adjust the battery voltage to a higher level, determined by the number of LEDs, while the current sources deliver a consistent current to the LM and lower the boosted voltage.

The automotive exterior front lighting system has several lighting functions, including a low beam headlamp (LB), high beam headlamp (HB), daytime running light (DRL), front position lamp (PL), and turn indicator. Depending on the specific lighting functions, the LM is set up with varying numbers and colors of LEDs. This means the LCM must provide the appropriate current source to regulate brightness. To save costs, manufacturers might integrate two or more lighting functions into a single LM, like combining daytime running light and front position light.

The LED matrix managers, such as the MAX25608, are used to control LEDs individually with different dimming scenarios, such as welcome functions and a wiping indicator. The LED matrix managers consists of multiple switches that can be independently programmed to bypass the LEDs across each of the switches in the string. Each switch can be turned fully on, fully off, or dimmed with or without fade-transition mode. The dim frequency is set by an internal oscillator or set to an external clock source.

Smart Lighting Function: ADB

The ADB systems are a smart HB control system that can adaptively adjust the beam pattern based on driving conditions. The full high beam can be distracting to oncoming drivers and pedestrians. The adaptive capabilities of an ADB system can automatically turn the bright lights off or partially beam to avoid dazzling drivers and pedestrians. Based on different headlight resolution requirements, the LM of an ADB system would consist of four or more LED matrix managers to control four or more LED zones. With an LED matrix manager, ADB systems can be easily implemented and LEDs in an ADB system can be dimmed individually.

Fault Detection and Protection of LED Matrix Manager

Detecting if LEDs are open or shorted is vital for safety. A system with safety features reduces the impact of potential failures. Checking for open or shorted LEDs in the headlight system helps catch any issues that might occur. The LED matrix manager naturally provides protection against short circuits and open circuits. The MAX25608 keeps track of any faults related to open or short circuits. The open-LED fault is triggered when the voltage between the individual LED switch drain node (Figure 2) and the switch source node exceeds the open threshold and is reported in the status register. As shown in Figure 3, the voltage cross switch is 4.88 V, which triggers an LED open fault, when open threshold is set to 4.66 V. A short LED fault is triggered when the voltage between the switch drain node and the switch source node is below the short threshold for an open switch condition and is reported in the status register. Figure 4 provides an example, whereby the voltage cross switch is 2.4 V, which triggers an LED short fault when the short threshold is set to 1.4 V.

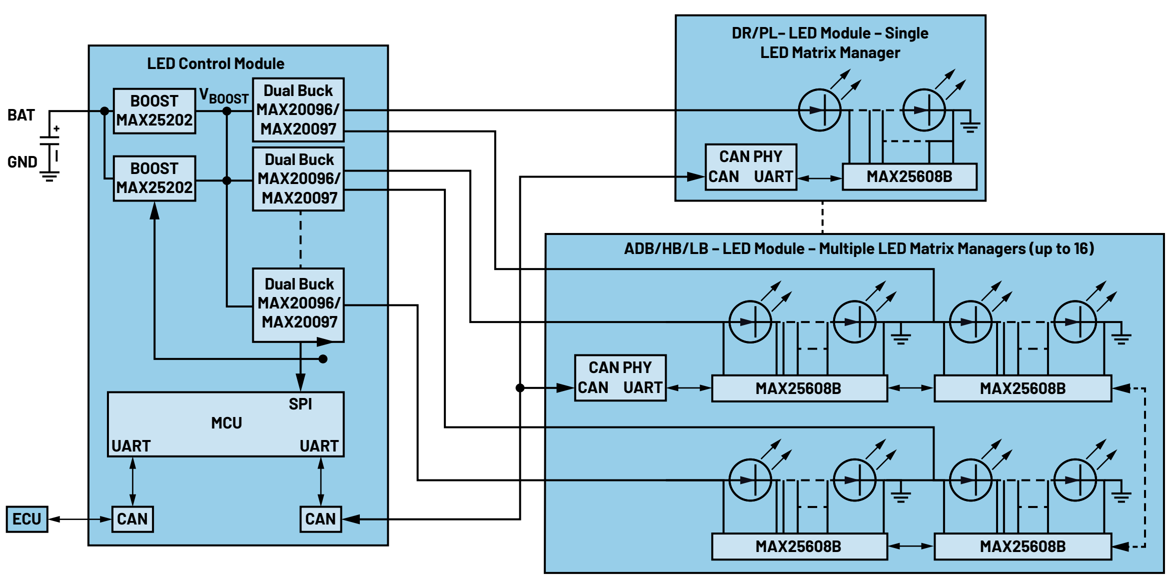

Figure 1. An LED front light system

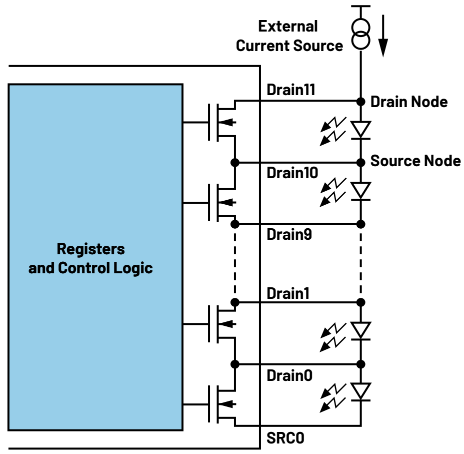

Figure 2. LED fault detection.

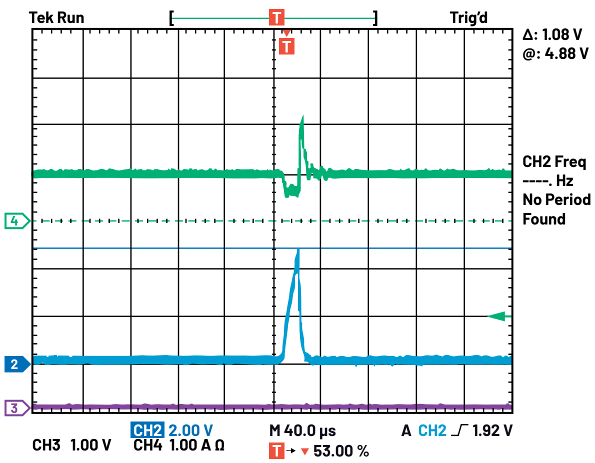

Figure 3. The MAX25608 LED open detection (Channel 2: Drain voltage; Channel 3: FLTB; Channel 4: LED current).

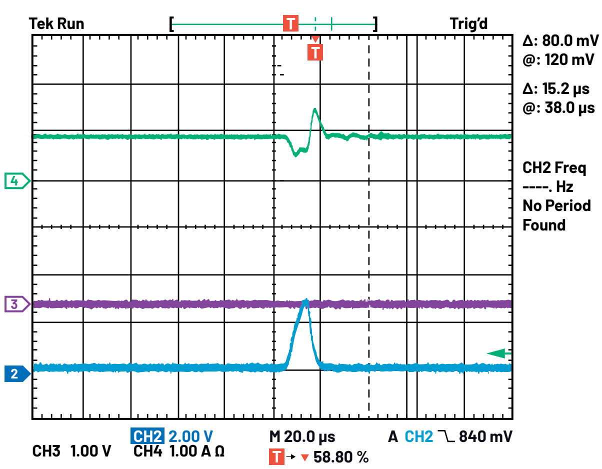

Figure 4. The MAX25608 LED short detection (Channel 2: Drain voltage; Channel 3: FLTB; Channel 4: LED current).

Safe UART Communication Protocol

ADI's MAX25608 provides multidrop universal asynchronous receiver-transmitter (UART) communications between the microcontroller and up to 16 MAX25608 devices. The write and read command examples are shown in figures 5 and 6. To ensure data security, the read/write transactions are protected using a 3-bit cyclic redundancy check (CRC) on the packet. If the microcontroller transmits a data packet with an incorrect CRC, the MAX25608 does not reply and discards the attempted communication.

In the event of lost communication, the UART watchdog feature of the MAX25608 sets the switches into a preconfigured state. When a microcontroller communication line is inactive for more than the set time, the fault indicator is on, and the LEDs enter a preconfigured state if the UART watchdog is enabled. As shown in Figure 7, the UART watchdog timer is set to 500 ms. After a UART receiver signal is inactive for 480 ms, the LEDs are turned off since the preconfigured state is off.

Figure 5. An example of a write command.

Figure 6. An example of a read command.

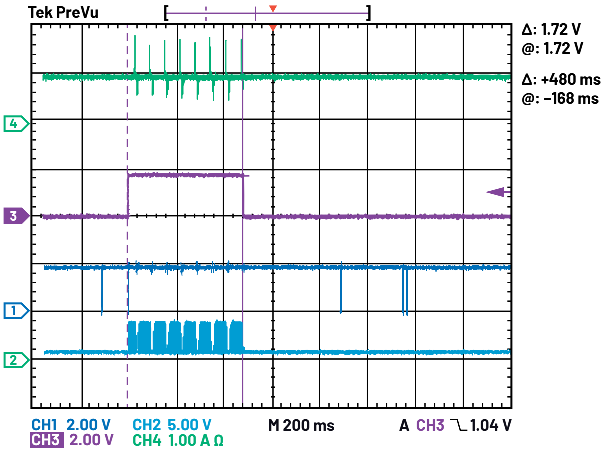

Figure 7. The MAX25608 UART watchdog function (Channel 1: UART receiver; Channel 2: Drain voltage; Channel 3: FLTB; Channel 4: LED current).

Performance of the LED Matrix Manager

ADI's MAX25608 offers advanced integration, high performance and safety, flexibility, and EMI mitigation functionality such as the following:

- Integration: Provides built-in logarithmic fade-in/fade-out capability that simplifies LED programmability and reduces taxation on system bus lines.
- High performance and safety: Features advanced fault protection and management for open, short, and open-trace LED detection. Low $R_{DS(ON)}$ safely enables high LED current.
- Flexibility: Supports multiple ICs to manage large LED pixel counts; allows designers to configure LED groups, such as 1 string × 12 series switches, and 2 strings × 6 series switches.
- EMI mitigation: Slew-rate control reduces EMI and noise.

Performance metrics such as thermal and EMI performance can easily be evaluated. As shown in Figure 8, the matrix manager is driven by the MAX25601 boost buck LED driver with all switches closed on the matrix manager and provide a 1.5 A output to 12 LEDs. Under a room temperature environment, only a 30.4°C temperature rise is captured.

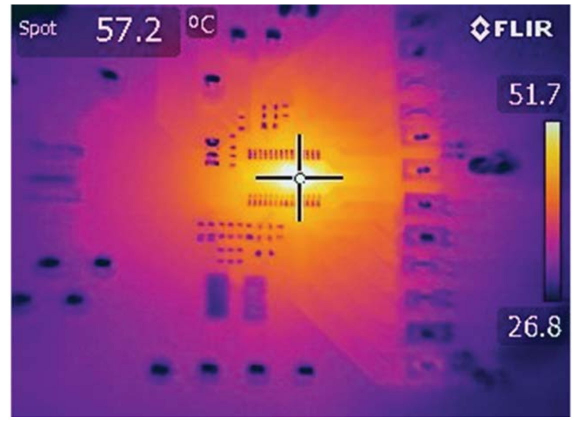

Figure 8. The MAX25608 thermal camera capture under 1.5 A condition.

Under the same test environment of a 1 A output to 12 LEDs, EMI results show no spikes due to the MAX25608's proprietary charge pump design as shown in Figure 9.

The MAX25608 is driven by the MAX25600 H-bridge LED driver with two LEDs at each channel. A 4.7 µF output cap and a filter (1 µH + 0.1 µF) are added to the MAX25600. The current spike is measured while dimming, as shown in Figure 10.

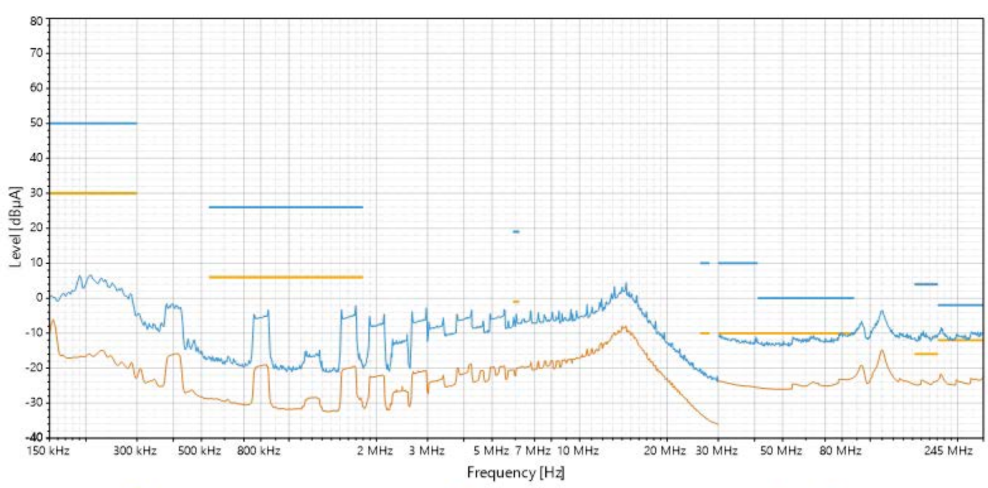

Figure 9. A conducted EMI of the MAX25608.

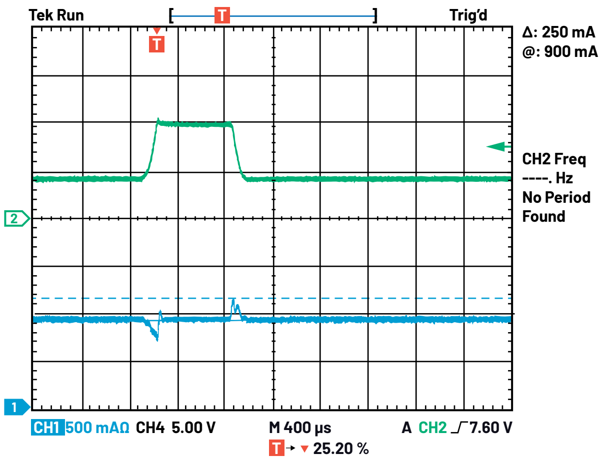

Figure 10. Current spikes during dimming.

Conclusion

As the trend of vehicle electrification and intelligence is growing fast, the lighting system has become an increasingly important feature in present and future vehicle designs. The lighting system is characterized by flexibility, efficiency, reliability, and more personalized and artistic effects. ADB and AFS are considered advanced safety features. In these designs, an accurate, efficient, and reliable LED manager for the LED matrix is required.

References

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[2] "LED vs Halogen Bulbs." DISPLAYS2GO, August 2023.

About the Author

Jason Bai is an application engineer at Analog Devices and is responsible for support and application of automotive power products. Jason joined Maxim Integrated (now part of Analog Devices) in 2020 and holds a master's degree in electrical engineering from Miami University (Ohio).

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