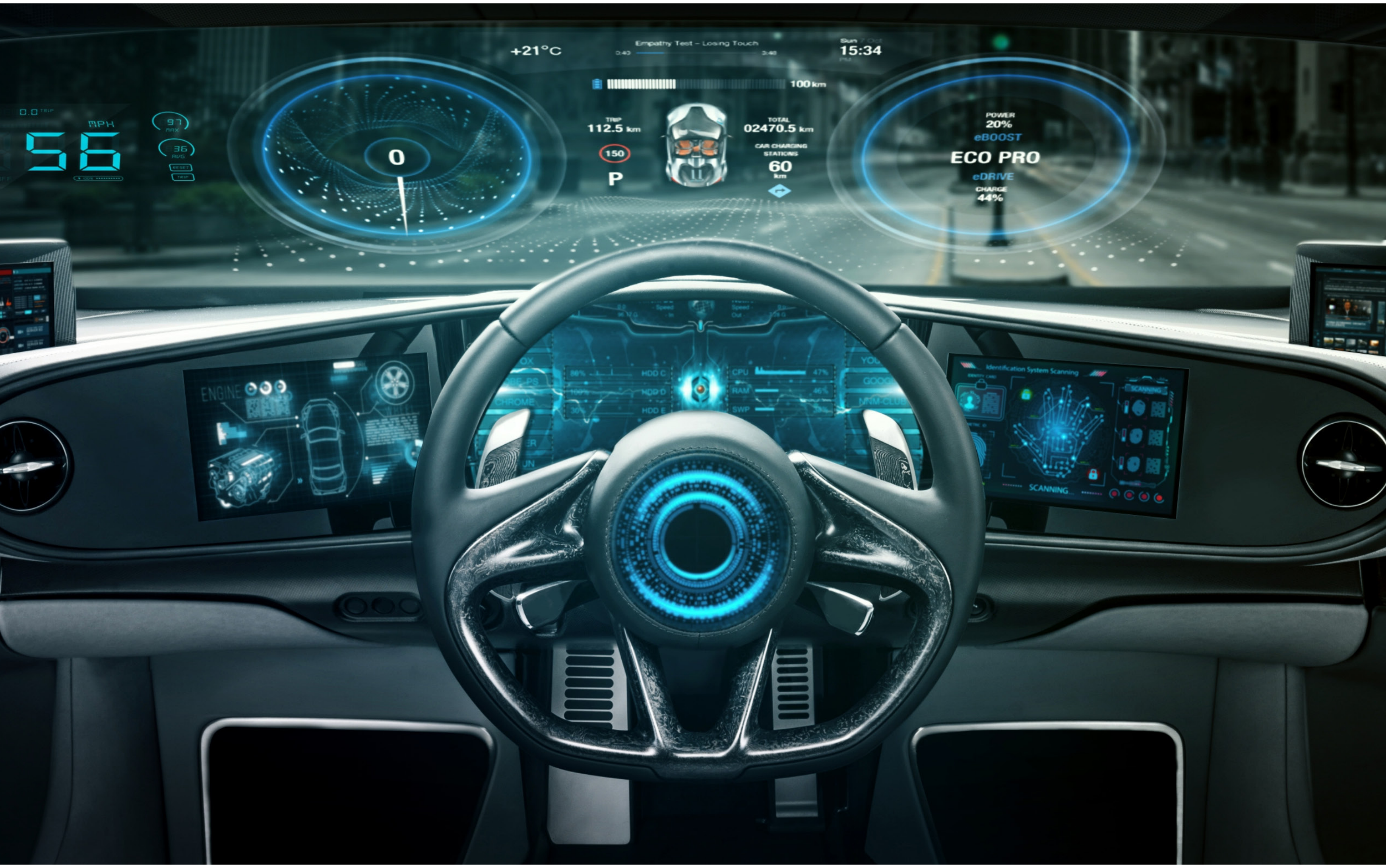
LED DRIVER FOR AUTOMOTIVE DISPLAY APPLICATIONS

Solution Guide



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INTRODUCTION

In today's entertainment and information-centered world, displays play a bigger role in customers' minds when selecting a vehicle. Thus, automotive displays have been integrated in applications such as Instrument Clusters, Central Information Displays, Heads Up Display, Mirror Replacements, Rear-Seat Entertainment Displays, and many more, with a total of up to 12 displays per car. People also want home entertainment or phone or tablet display quality experience inside the car. Thus, bigger, wider, higher resolution and crisper displays are needed.

Figure 1. Automotive Cockpit with Displays

There are many types of display technology, ranging from Thin Film Transistor (TFT) Liquid Crystal Displays (LCD), OLED and MicroLED technology. TFT LCD technology offers a bright and reliable display at a reasonable cost, which is the commonly used display in cars.

Compared to consumer displays, Automotive displays have more requirements. The electronics must be robust enough to not only withstand a harsh automotive environment (cold/hot crank, load-dump, start/stop), but also incorporate additional diagnostics required to meet ASIL (Automotive Safety Integrity Level) safety standards, have low electromagnetic interference (EMI) to reduce interference with multiple RF receivers in the vehicle, and be small enough to fit additional electronics within the same space. In addition, local dimming using normal LED or mini-LED is being used to offer customers crisper and high contrast display.

In this solution guide, we will be showing various display needs in automotive applications, and how Maxim LED driver products can meet these criteria.

Figure 2. Multiple Display Sizes

MARKET NEEDS

In the following sections, we will discuss seven key needs that Display hardware designers face when designing an LED Driver for TFT-LCD Display

Systems:

1. **Bigger and Higher Resolution Display**
2. **Lower Input Voltage**
3. **Functional Safety**
4. **Higher Contrast Display**
5. **Higher Dimming Ratio**
6. **Passing CISPR 25 EMI Standard**
7. **Lower Overall Solution Cost**

NEED 1 – BIGGER AND HIGHER RESOLUTION DISPLAY

With the merging of instrument cluster and CID, the trend is to have bigger, wider displays, or even a pillar-to-pillar display to cover the whole cockpit. Since the display is an essential part of the cockpit, a lot of important content is being shown on the display, which means higher resolution is needed. 4k or even 8k resolution is within reach in the near future. Bigger panels mean more LEDs and higher resolution means higher pixel counts and less light output, which also means more LEDs. More LEDs means that more LED channels are needed without stacking too many LEDs in one string to avoid low boost efficiency and high temperature issues.

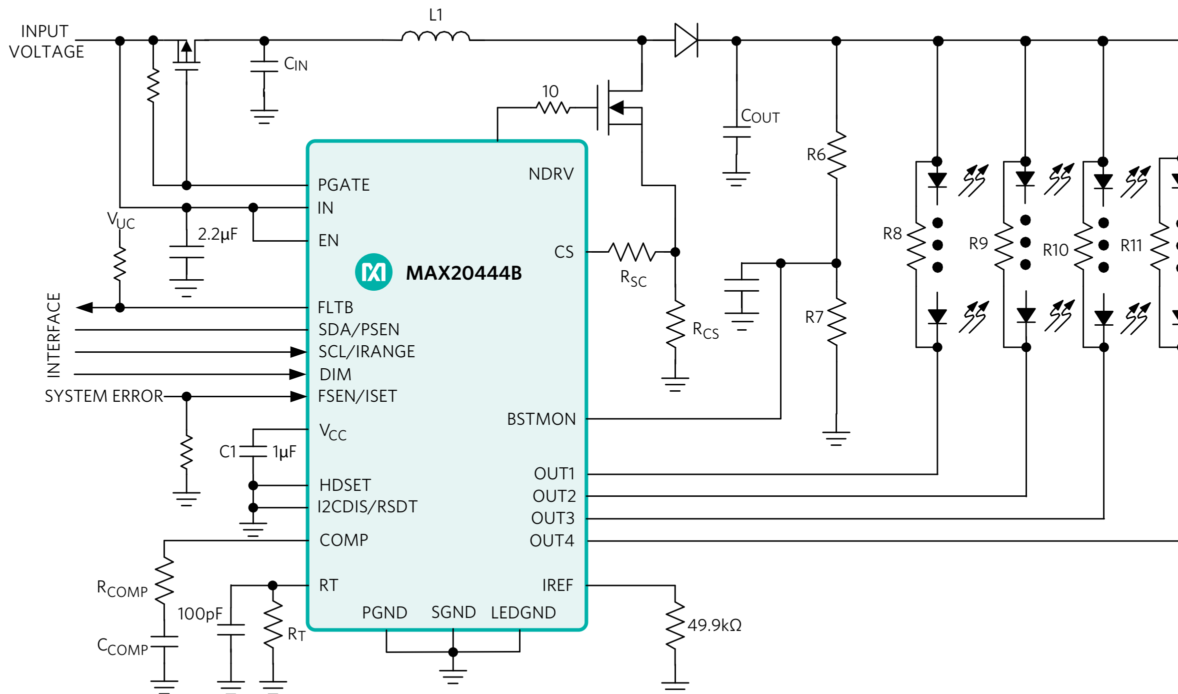

Figure 3. MAX20444B 4ch LED Driver

Maxim offers 4 strings, **MAX20444B** (**Figure 3**) and 6 strings **MAX20446B**/**C** (**Figure 4**) LED drivers without boost FET integrated solutions and also **MAX25512** (**Figure 5**) with integrated boost FET solution. In addition, Maxim offers combo solutions like **MAX25530** (**Figure 6**) which means integrating LED driver and TFT bias into one chip to offer cost competitive and size compelling solution.

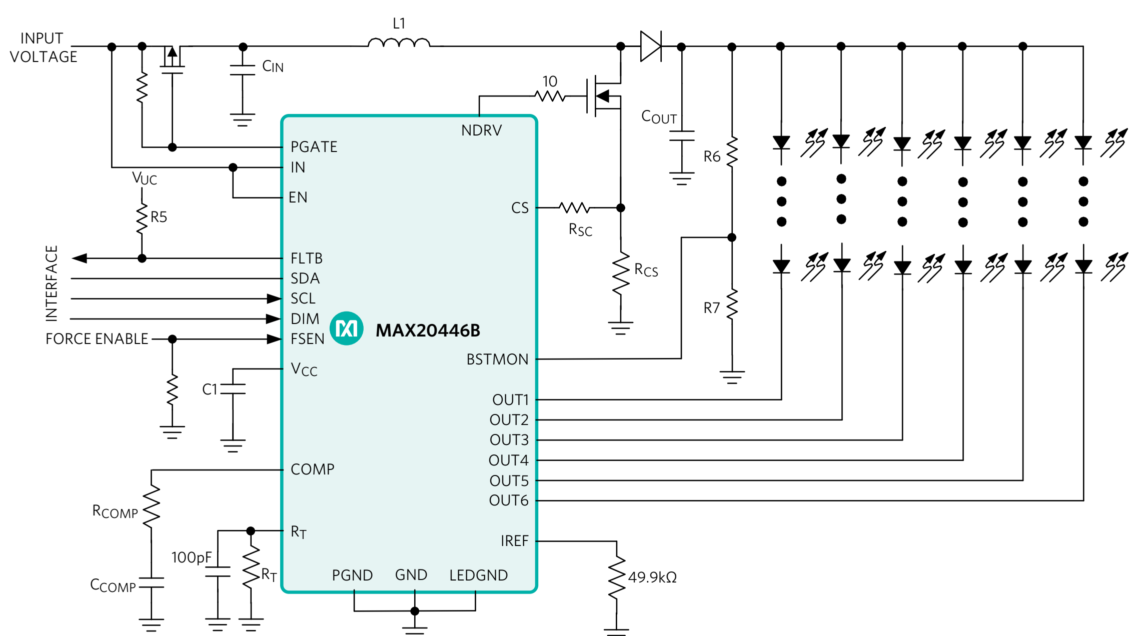

Figure 4. MAX20446B 6ch LED Driver

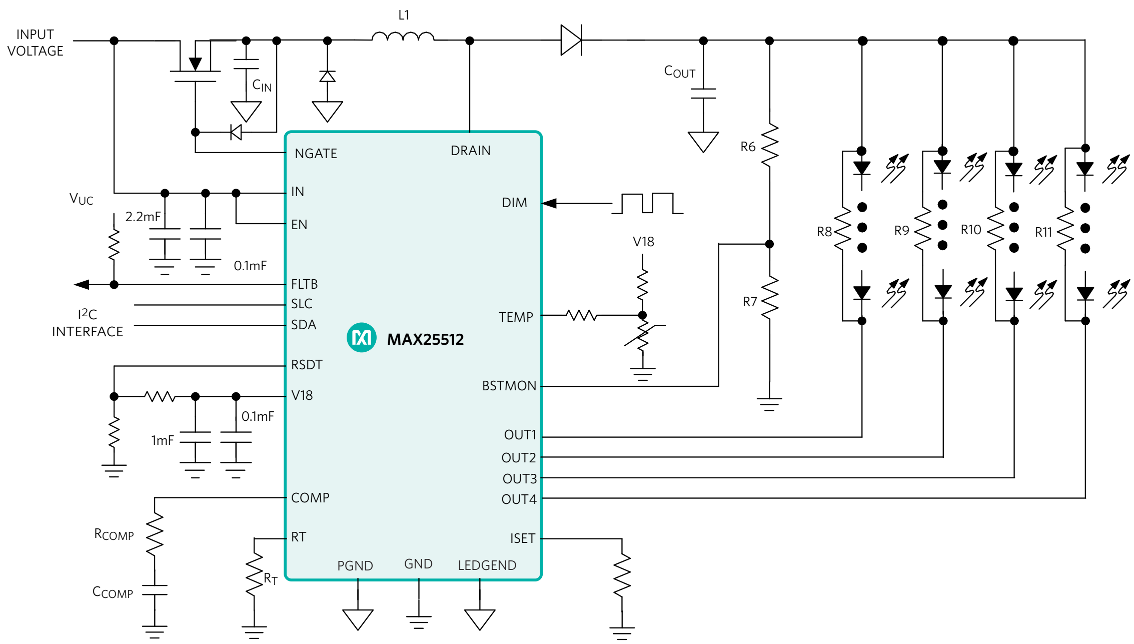

Figure 5. MAX25512 4ch LED Driver with Integrated FET

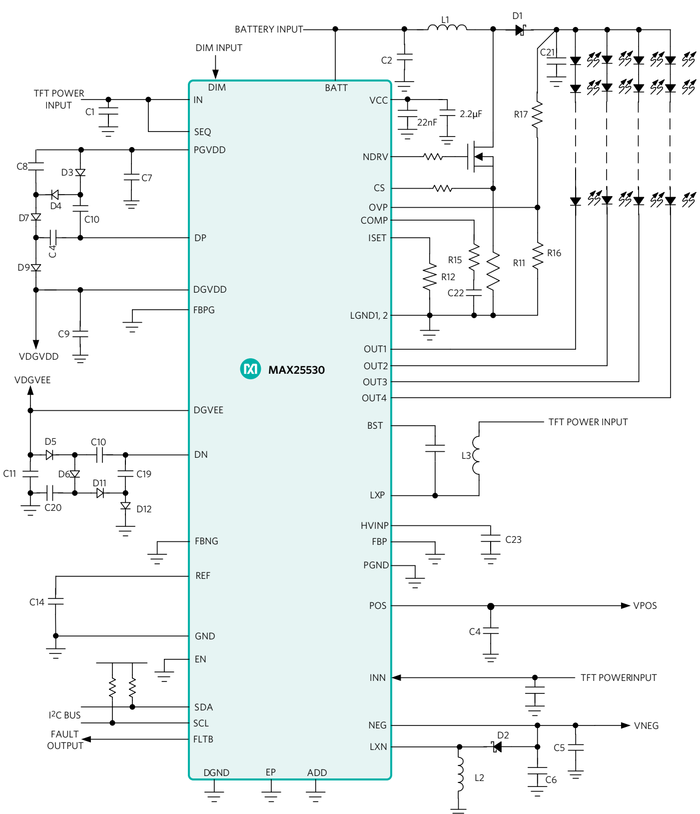

Figure 6. MAX25530 4ch LED Driver with TFT Bias

NEED 2 – LOWER INPUT VOLTAGE

When you enter your car, the display is already on to welcome you. When you start the engine in cold weather, Vin may go down to 3V during cold crank as shown in **Figure 7**. However, display still needs to be on or not blinking during cold crank to give the best user experience. One can put a pre-boost in front of the LED driver, however, it will increase cost and lower efficiency. An alternate way is to ensure the LED driver can handle this low voltage. Maxim offers MAX25014 and MAX25024 which can handle as low as $2.5V_{IN}$ after starting up, while MAX25510/1/2 can handle as low as $3V_{IN}$ after starting up with no external charge pump or extra power supply.

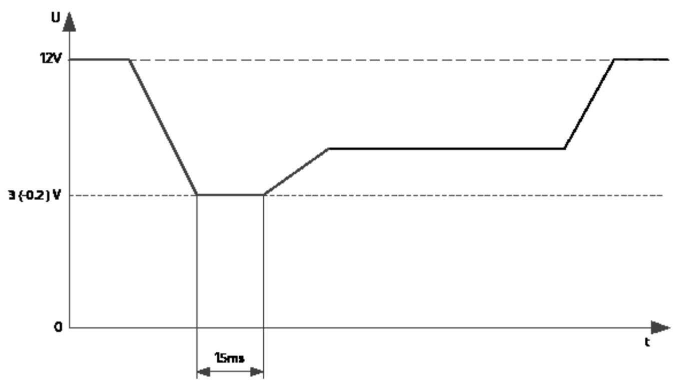

Figure 7. Cold Crank Battery Voltage Profile

NEED 3 – FUNCTIONAL SAFETY

With display-based instrument clusters getting more and more popular and the merging between instrument cluster and CID (Center Infotainment Display), functional safety for display is becoming more and more important.

ISO 26262, an international standard, dictates the functional safety of automotive electronic/electrical systems. An integral part of this standard is the Automotive Safety Integrity Level (ASIL), which classifies the inherent safety risk in an automotive system.

ASIL D mandates the most safety-critical process and testing, based on severity (of injuries), exposure (probability), and controllability. Automotive displays generally fall under the parameters of ASIL B. Specifically, within the instrument cluster display, there are a few blocks that should meet ASIL B criteria. Two of these blocks are the thin film transistor (TFT) bias for power management and the light-emitting diode (LED) backlighting driver. The TFT bias is typically comprised of AVDD and NAVDD voltages for the TFT source driver, VGON and VGOFF voltages for the TFT gate driver and, in some cases, VCOM voltage for the liquid-crystal display (LCD) backplane. **MAX25222** is the world's first TFT Bias with ASIL B certified. **MAX25024**, a 4 channel, I^2C LED Driver, is the world's first LED Driver with ASIL B certified as shown in **Figure 8**.

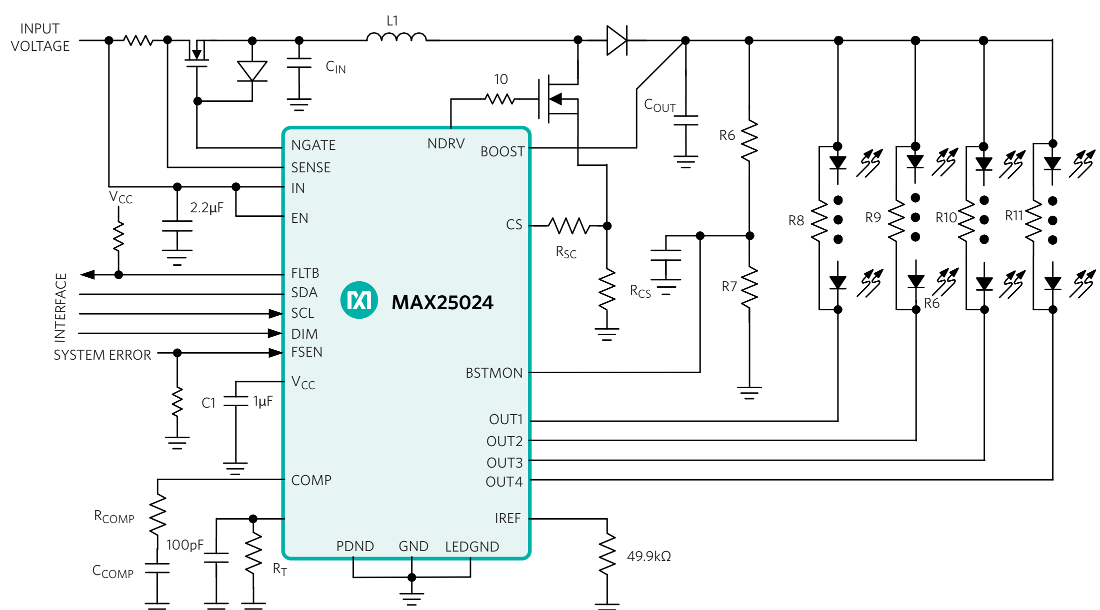

Figure 8. MAX25024 4ch LED Driver with ASIL B

An LED driver that meets ASIL B criteria would need to have these features:

- I²C (the data signal and the clock signal) and fault pin for performing setting adjustments and diagnostics on each rail
- Open or short LED per-string detection
- Output voltage measurement
- LED current measurement per string
- Internal resistors with fixed output or adjustable output through I²C
- Open enable
- A redundant reference to monitor the output

NEED 4 – HIGHER CONTRAST DISPLAY

LED is using Pulse-width modulation (PWM) duty cycle to dim the light of the LEDs, high duty means more light coming out of LEDs. One shortcoming of traditional LCD displays has been the use of edge-lit backlights. The backlight LEDs are located along the edges of the panel, the LEDs cannot be completely turned off because PWM of all the LEDs is set globally. This will make the display not truly black but dark gray. This is very annoying especially at night and will cause fatigue.

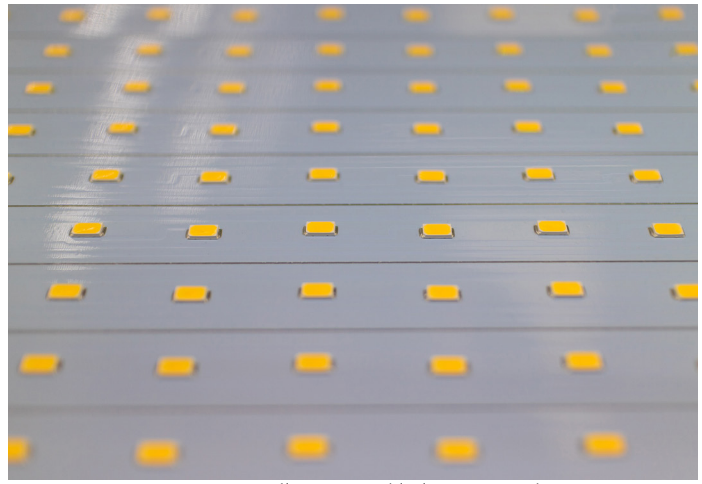

Figure 9. Full Array Backlight LED Panel

New LCD displays solve the problem by reengineering the backlight, from edge-lit to full-array LEDs, as shown in **Figure 9**. Now the LEDs are put at the back of the display and can be individually controlled from full luminosity to full darkness. With local dimming, deeper blacks and more impressive contrast in the picture are obtained. **MAX21610** is Maxim's first-generation local dimming LED Driver. It can drive up to 16 channels, each with 100mA. It can support up to 10 devices in single SPI daisy chain mode. **Figure 10** shows two MAX21610 in daisy chain mode connecting with the front-end DC/DC converter.

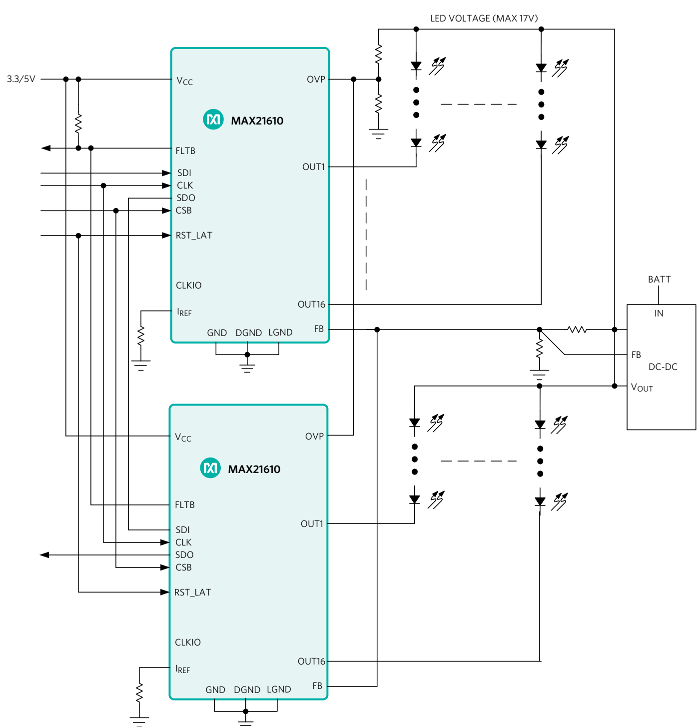

Figure 10. Full Array Backlight LED Panel

NEED 5 – HIGHER DIMMING RATIO

With the increasing demand of HDR (High Dynamic Range) display, and HUD (Heads Up Display) for automotive applications, one will need to support an over 20,000:1 dimming ratio. One of the critical specs is minimum pulse width which will need to be at 250ns at a PWM frequency of 200Hz, to achieve a 20,000:1 dimming ratio. One of the ways to improve dimming ratio is to use hybrid dimming. Hybrid dimming is to use analog dimming at high brightness and use PWM or digital dimming at mid to low brightness. Figure 11 is showing hybrid dimming at 25% of threshold. **MAX20444**, **MAX20446**, **MAX25014**/**24** and **MAX25510**/**11**/**12** all have hybrid dimming feature and with minimum pulse width of at most 500ns. By using hybrid dimming as shown in **Figure 11**, one can easily achieve 40,000:1 dimming ratio.

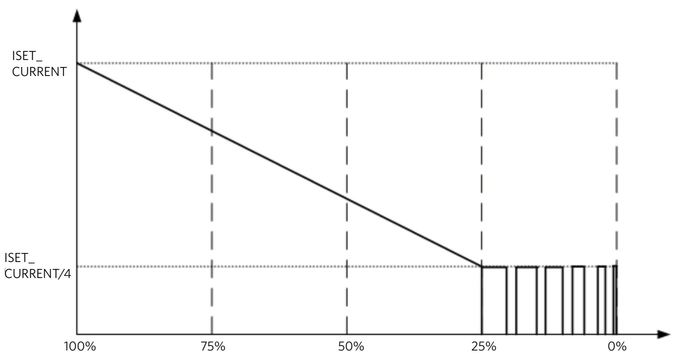

Figure 11. Hybrid Dimming

NEED 6 – PASSING CISPR 25 EMI STANDARD

With the quantity of infotainment electronics increasing, there are now more risks for interfering with communication and broadcast electronics. Because of these risks, the automotive industry has several electromagnetic compatibility (EMC) requirements so that these electronics do not emit too much electromagnetic interference (EMI). Integrating EMI mitigation features within the IC solution itself saves customers on BOM cost without adding chokes, snubber circuitry, and other filtering. Mitigation techniques are spread spectrum, variable switching frequencies from 400kHz to 2.2MHz setting, synchronizing to external clock, and hybrid dimming.

Spread Spectrum is a technique in which the information signal bandwidth is extended from narrowband to wideband. The purpose of this technique is to distribute spectral power density across a wider range of frequencies so that the resulting power associated with the signal is lower and less likely to interfere with narrowband communication signals. Hybrid dimming can significantly reduce the peak power at high brightness. MAX20444, MAX20446, MAX25014/24, **MAX20069**, MAX25510/11/12, MAX21610, MAX25530 utilize the above-mentioned techniques to help mitigate EMI problems.

NEED 7 – LOWER OVERALL SOLUTION COST

While adding the latest features to the modern vehicle increases its appeal, there is a limit to how much the consumer will spend in each market segment. Therefore, it is critical for the Original Equipment Manufacturer (OEM) to appropriately allocate their costs. This responsibility is passed down from the OEMs to their Tier 1 suppliers who continue to pass it to their providers. Therefore, the solution cost for a given feature set is tightly monitored and this monitoring starts with the Bill of Materials (BOM).

A designer can minimize BOM cost by reducing the number of essential components needed to make a solution work, for instance, less output capacitors, less filtering for EMI, using input NMOS instead of PMOS for input protection, eliminating boost FET or current sense with devices that already have them integrated, and eliminating charge pumps and using smaller inductor sizes. MAX20444B (Figure 3) and MAX20446B/C (Figure 4) LED drivers use less output capacitors than competitors. MAX25512 (Figure 5) integrates the boost FET and current sense with the highest efficiency and can use NMOS instead of PMOS for input protection. MAX25024 can support inputs down to 2.5V without an external charge pump, the same as MAX25512 which can support down to 3V. In addition, MAX25530 (Figure 6) integrates TFT Bias and LED Driver into one chip to offer a cost-competitive and size-compelling solution.

SUMMARY

The surge of display integration in the modern car requires modern solutions. Maxim Integrated offers a strong portfolio of LED Driver for automotive display applications. Each product is designed to work with a wide range of display panels and can be configured for multi-solution platforms to help customers save time and efforts.

In this design guide, we discussed the seven key needs for modern automotive display: Bigger and Higher Resolution Display, Lower Input Voltage, Functional Safety, Higher Contrast Display, Higher Dimming Ratio, Passing CISPR 25 EMI Standard and Lower Overall Solution Cost.

In each case, Maxim provided the best products that market has to offer.

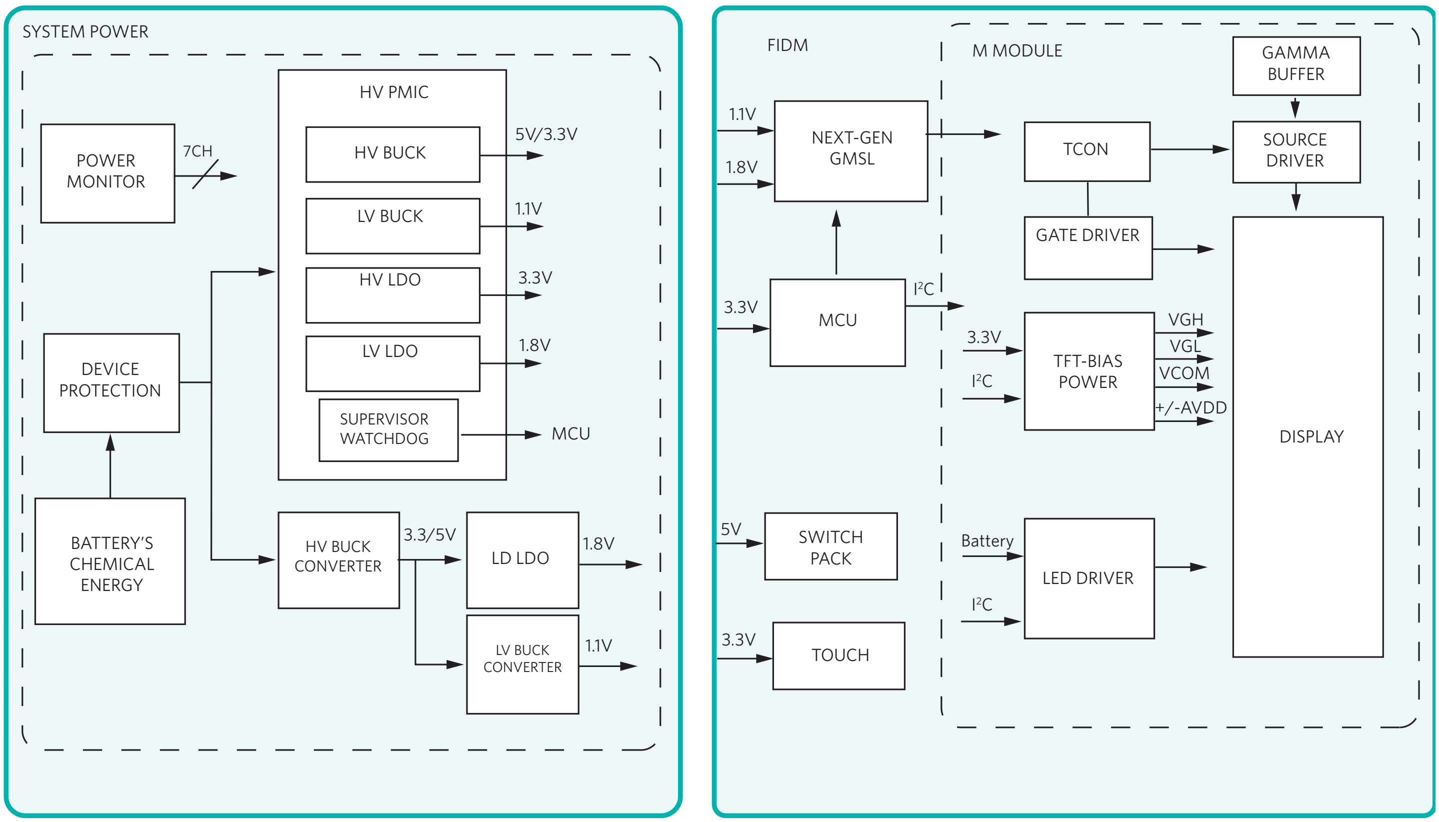

Figure 12. Automotive Display Block Diagram

Below is a summary of Maxim's Automotive LED Driver Product Solutions. See the Product Selector Table to compare product specifications.

Product Solutions

Applications	Product	Function
CID	**MAX16813B**	Automotive 4-Channel, 150mA per Channel LED Driver
	MAX20444B	Automotive 4-Channel, 130mA per channel LED Driver with Hybrid Dimming and I^2C/stand alone with full diagnostics
	MAX20446C	Automotive 6-Channel, 130mA per channel LED Driver with Hybrid Dimming and stand alone with full diagnostics
	MAX25014	Automotive low voltage 2.5V, 4-Channel, 150mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics
	MAX25510	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming with 4.5A current limit
	MAX25511	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming with 5.5A current limit
	MAX25512	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics
	MAX25530	Automotive 4-Channel, 150mA per Channel LED Driver and 4 channel TFT Bias with I^2C
Instrumental Cluster Display	**MAX25024**	Automotive low voltage 2.5V, 4-Channel, 150mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics and ASIL B
	MAX20446B	Automotive 6-Channel, 130mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics
	MAX25512	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics
	MAX25530	Automotive 4-Channel, 150mA per Channel LED Driver and 4 channel TFT Bias with I^2C
HUD	**MAX25024**	Automotive low voltage 2.5V, 4-Channel, 150mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics and ASIL B
	MAX20446B	Automotive 6-Channel, 130mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics

Product Solutions (Continued)

Applications	Product	Function
Rear Seat Infotainment Display	**MAX25510**	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming with 4.5A current limit
	MAX25511	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming with 5.5A current limit
	MAX20446C	Automotive 6-Channel, 130mA per channel LED Driver with Hybrid Dimming and stand alone with full diagnostics
E-Mirror	**MAX25510**	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming with 4.5A current limit
Side Mirror Replacement	**MAX25024**	Automotive low voltage 2.5V, 4-Channel, 150mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics and ASIL B
	MAX25512	Automotive low voltage 3V, 4-Channel, 120mA per channel LED Driver with Hybrid Dimming and I^2C with full diagnostics
Local Dimming Display	**MAX21610**	Automotive 16ch SPI LED Driver with PWM individually, phase shift and diagnostics

LED Driver Product Selector Table

Part Number	V_{IN} Range	Channel	Current	Controller Converter	Hybrid Dimming	Phase Shift	Front Protection	PWM Dimming Individually	I^2C/SPI Stand Alone
MAX16813B	4.5V-36V	4	150mA	Controller	No	No	PMOS	No	Stand alone
MAX20444B	4.5V-36V	4	130mA	Controller	Yes	Yes	PMOS	Yes	I^2C/ Stand alone
MAX20446B	4.5V-36V	6	130mA	Controller	Yes	Yes	PMOS	Yes	I^2C
MAX20446C	4.5V-36V	6	130mA	Controller	Yes	Yes	PMOS	Yes	Stand alone
MAX25014	2.5V-36V	4	150mA	Controller	Yes	Yes	NMOS	Yes	I^2C
MAX25510	3V-36V	4	120mA	Converter	Yes	Yes	NMOS	No	Stand alone
MAX25511	3V-36V	4	120mA	Converter	Yes	Yes	NMOS	No	Stand alone
MAX25512	3V-36V	4	120mA	Converter	Yes	Yes	NMOS	No	I^2C
MAX25530	4.5V-36V	4	150mA	Controller	No	Yes	PMOS	No	I^2C Stand alone
MAX21610	2.5V-5.5V	16	100mA	-	No	Yes	-	Yes	SPI

Related Resources

White Paper

How Automotive Displays Can Comply with Functional Safety Requirements

Application Note

Why Functional Safety is Important for Automotive Displays

Design Solutions

Back to Black with Backlight Local Dimming

Highly Integrated LED Driver Design for Automotive Displays

Videos

MAX25512 How to Design Video

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