Improve Matrix Lighting with the Next Generation of LED Controllers and Switches

Introduction

Modern automotive matrix lighting often utilizes strings and matrices of LEDs, requiring an increasing number of integrated circuits to control them. New designs must usually pack more electronics in the same or a smaller space.

To meet time-to-market constraints and provide for efficient use of design resources, it is imperative that LED modules designed for a given complex light pattern be easily reconfigured for a new pattern.

The space challenge clearly requires more integration of the LED controller building blocks, while the reconfiguration for faster time-to-market requires the ability to communicate with the LED controller IC.

In this article, we will show how to pack more functionality in a smaller PCB space while adding flexibility to automotive matrix lighting.

Figure 1. Automotive LED Headlight

Typical Highly Integrated Solution

Integrating two controllers into a single IC is a good first step in the direction of up-integration. Figure 2 shows a typical dual-channel automotive lighting implementation which uses non-synchronous rectification. Unfortunately, in high-current applications, the use of non-synchronous rectification, and the selection of p-channel transistors and Schottky diodes, leads to significant power inefficiencies. This is discussed in detail in a related article.

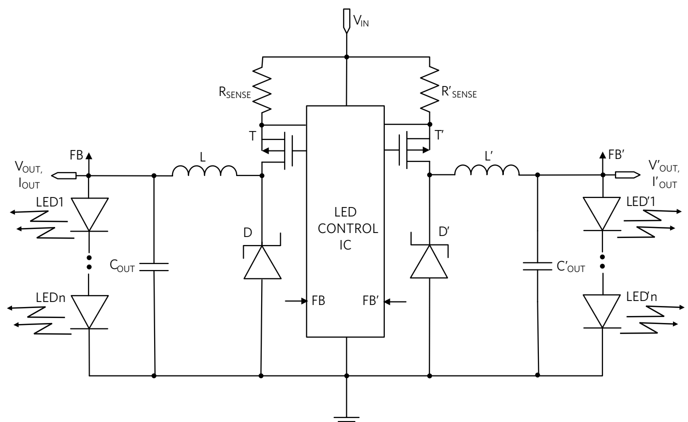

Figure 2. Typical Dual Controller Non-Synchronous Rectification Solution

In one possible non-synchronous implementation, n-channel transistors are used on the high-side instead of p-channel transistors in an attempt to recover some efficiency points. However, this solution requires huge n-channel MOSFETs to compensate for the lossy Schottky diodes on the low side. The dual controller may also be housed in a bulky TSSOP package, further adding to the solution footprint. Figure 3 shows a typical n-channel, non-synchronous rectification solution that occupies a board area of 264mm^2.

The Synchronous Rectification Advantage

As an example, for a 48V input and 12V output, the buck converter works with a duty cycle of about 25%. This means that the high-side transistor (T in Figure 2) conducts only 25% of the time. The external rectifier diode (D) conducts the remaining 75% of the time, which accounts for most of the power dissipation. On the other hand, if we utilize a synchronous architecture the diode is replaced with a low-side MOSFET that acts as a synchronous rectifier. We can trade off the high drop across the diode with the low drop across the MOSFET transistor's on-resistance, $R_{DS(ON)}$. The MOSFET conduction loss can easily be one order of magnitude smaller than the Schottky power loss at full load! Clearly, the logical way to minimize power dissipation is to use synchronous rectification.

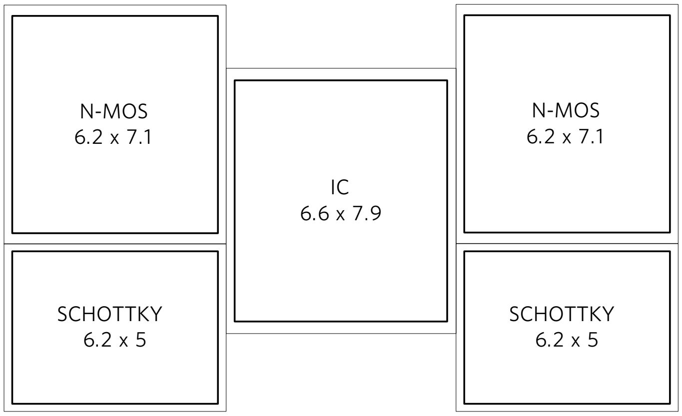

Figure 3. Non-Synchronous Rectification Solution Footprint (264mm²)

A Synchronous High-Power Dual-Buck LED Driver Solution

The synchronous, all n-channel, buck LED controller with serial-to-parallel (SPI) interface in Figure 4, integrates two channels in a single IC, reducing the solution footprint and the BOM. Two out-of-phase channels smooth out the input current, spreading out its energy and resulting in lower RMS current and lower EMI emissions. With a lower RMS current, smaller and less expensive input capacitors can be used. A high, well-controlled switching frequency, outside the AM frequency band, reduces radio frequency interference and meets EMI standards. Fast transient response prevents output voltage and current fluctuations consequent to instantaneous variation of the diode string length in high-ratio dimming applications. The device is ideal for matrix lighting and LED driver module (LDM) platforms.

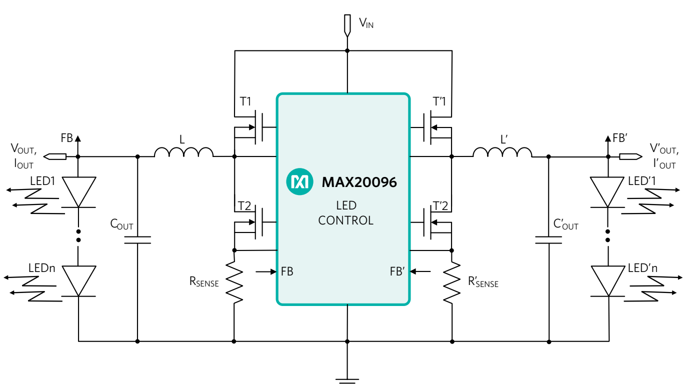

Figure 4. Synchronous High-Power Dual-Buck LED Controller

The utilization of an advanced silicon process allows the entire dual controller function to be packaged in a small package. Elimination of the Schottky diode greatly reduces power losses in high current applications, while allowing the use of smaller discrete MOSFETs (Figure 5).

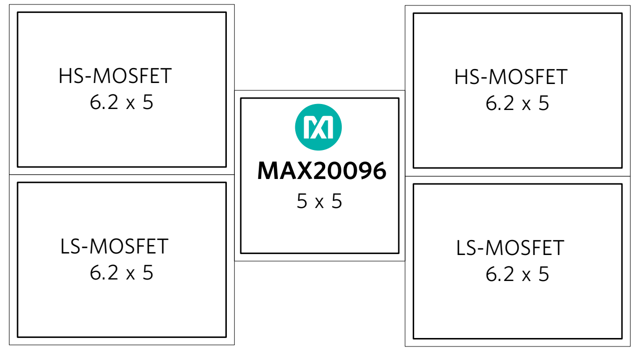

Figure 5. Synchronous Rectification Solution Footprint (149mm²)

With synchronous rectification, the net solution size goes down from 264mm² to 149mm², a 43% reduction. Further system integration can be obtained by using dual MOSFET devices (HS- and LS-MOSFET integrated in a single package).

High Efficiency

Figure 6 shows the efficiency of the LED driver. Two synchronous rectification MOSFET transistors (HS 107mΩ, LS 58mΩ), in a small LFPACK56 package, provide high efficiency over a wide range of load currents.

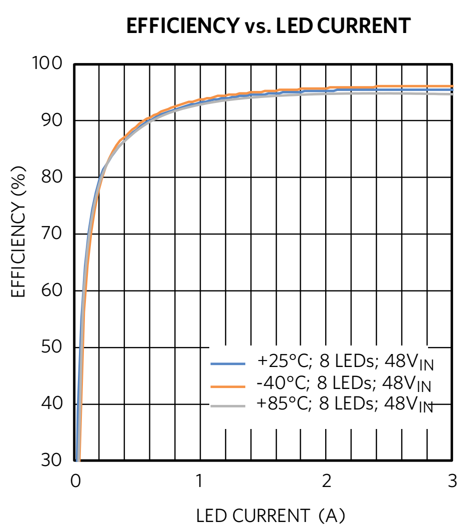

Figure 6. LED Driver Solution Efficiency vs. Load Current

Serial Peripheral Interface

The SPI interface (MAX20096 only) allows flexibility and reuse of the LED lighting module since it is compatible with standard microcontrollers (µCs) from a variety of manufacturers. Dimming of the LED lights can be performed through SPI. Fault conditions, output currents/voltages on both channels and the junction temperature can be read back through the SPI interface. With a fail-safe mode—if SPI communication is cut—the device can still operate in analog mode.

12-Matrix Switch Manager

The 12-matrix switch manager (Figure 7) can be implemented by the MAX20092. This IC features a serial peripheral interface (SPI) for serial communication. The MAX20092 is a slave device that uses SPI to communicate with an external microcontroller (µC), which is the master device. Each of the 12 switches 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 PWM frequency is set by an internal oscillator or set to an external clock source. The IC features open-LED protection as well as open- and short-LED fault reporting through the SPI. The MAX20092 is available in a 32-pin (5mm x 5mm) side-wettable TQFN (SWTQFN) package with a thermally enhanced exposed pad.

The boost converter in Figure 7 can be implemented with the MAX16990/MAX16992 36V, 2.5MHz automotive boost/SEPIC controllers.

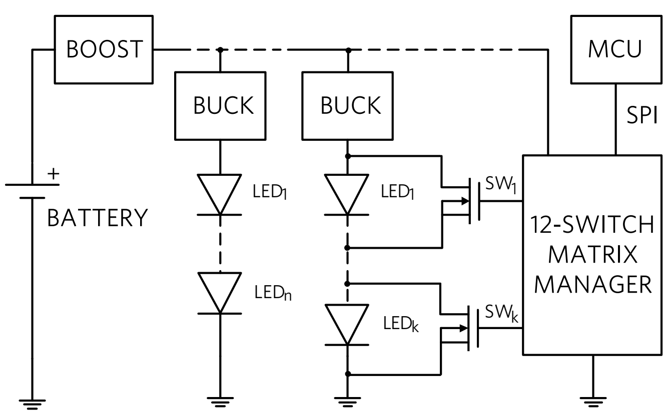

Figure 7. LED Driver Solution With 12-Switch Matrix Manager

Conclusion

In this article, we showed how to pack more functionality in a smaller PCB space while adding flexibility to the next generation of LED controllers for automotive matrix lighting. The MAX20096 synchronous, n-channel, buck LED controller integrates two out-of-phase channels in a single IC reducing the BOM and PCB space occupancy. It also enables higher flexibility and reuse via its SPI interface. The simpler MAX20097 addresses applications that do not require SPI communication. With MAX20092 12 switches can be independently programmed to bypass the LEDs across each of the switches in the string for fine lighting control.

Glossary

BOM: Bill of materials

LED: Light-emitting diode

RMS: Root-mean-square

SPI: Serial peripheral interface

Learn more:

MAX20092 12-Switch Matrix Manager for Automotive Lighting

MAX20096 Dual-Channel Synchronous Buck, High-Brightness LED Controller with SPI Interface

MAX20097 Dual-Channel Synchronous Buck, High-Brightness LED Controller with Fault Flag

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