Redefining the Future of In-Cabin Lighting

Dynamic Multi-Color Lighting Supports a Differentiated and Enhanced User Experience

A whitepaper by Vincent Wang, EVP Asia Sales & Marketing

Light Emitting Diodes (LEDs) are an extremely versatile light source that offer numerous benefits over more traditional lighting sources such as incandescent or halogen. They have a long operational life and are highly efficient, converting more electrical energy to light, while producing very little heat. Also, LEDs are physically smaller and can be controlled or dimmed, allowing flexibility for vehicle user experience (UX) designers to use them in tight spaces and create innovative lighting experiences.

As a result, LEDs are being adopted rapidly for a wide range of interior and exterior automotive applications, contributing both to safety features and improving the overall in-cabin environment and user experience. Externally, one of the primary uses is in vehicle headlights. Increasingly, arrays of LEDs are being deployed in headlamps, improving light intensity and allowing for beam steering which can be controlled/directed in almost limitless ways, while consuming less power than traditional incandescent bulbs. This brings enormous benefits for road safety, such as shaping the beam to avoid the line of sight of oncoming drivers, ‘steering’ the beam to illuminate the direction of travel and the oncoming environment when taking corners, and ensuring as much coverage as possible without dazzling other road users.

Inside the vehicle, LED adoption is contributing to the overall enhancement of the in-cabin experience with a new generation of multi-color, high-power, and high-luminance products from a variety of manufacturers. The high brightness of these next-generation LEDs enables more applications and provides additional opportunities for designers to further differentiate their products. For example, by combining these LEDs with advanced LED drivers and lossy light-guides, very appealing, eye-catching, and mood-lifting interior lighting effects can be achieved. In other cases, these LEDs simply allow for increasing the amount of light output while maintaining or reducing scarce mounting space.

Driving the LEDs

As the focus on vehicle lighting continues to grow, the need for smart lighting control systems enabled by advanced semiconductor technologies is also on the rise.

There are two primary approaches to driving LEDs – either a linear LED driver or a DC-DC switch-mode supply (generally a buck converter). In both cases, managing the thermal performance of the system is important – especially within the typically cramped environments of in-cabin applications. While the LED itself does not generate huge amounts of heat, the driver stage can be a significant source of unwanted thermals. Often, the current to the LED is reduced to bring thermal levels to an acceptable state, thereby incurring a reduction in potential brightness. If this is not done, then thermal protection mechanisms will trip, shutting the system down. In general, the goal of any thermal management is to ensure constant and consistent brightness over the operating temperature range – typically -40°C to +50°C ambient temperature.

Electromagnetic Interface (EMI) is a further concern. On the one hand, non-lighting system-generated EMI could impact the lighting system, causing it to behave in an erratic way - such as flashing, reduced or intermittent brightness or color shifts - that distracts the driver. On the other hand, if the lighting circuitry is operating at unacceptable levels of EMI, this could impact nearby electronics, including safety-related systems.

While thermal management and EMI are clearly important, many other factors affect lighting performance. The physical size of the PCB on which the lighting solution is built plays an important role along with the method of construction and layout – including the number of layers and the weight (thickness) of the copper. Heatsinking and the ambient environment have a significant effect on overall thermal dissipation as does the surface area of the copper, use of thermal vias, available airflow, and operating ambient temperature.

Improving/increasing any or all of these attributes will allow for increased light output, assuming everything else remains constant.

Integrating LED Lighting Solutions into a Single IC

Using discrete components to deliver a buck solution requires a controller, LED driver, battery conditioning circuit, and a communication interface. With more components comes increased development time as multiple design iterations are needed to optimize the circuitry into the smallest form factor. In addition, more potential points of failure can impact reliability, while more connections make designing for EMC compliance more challenging. These factors – plus the demand to simplify manufacturing complexity and reduce inventory count – are driving the development of new, highly integrated LED driver semiconductors.

The iND83211 is the latest generation of indie's highly integrated circuits (ICs) that offer the performance demanded by next-generation automotive lighting designs while simplifying design and minimizing component count. This IC is designed to drive LEDs efficiently and consistently at their maximum luminous output without exceeding safe operating conditions and with minimal external components.

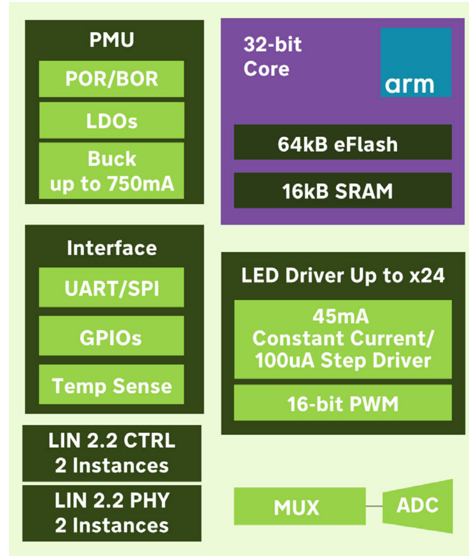

Figure 1: Block diagram of the iND83211 System-on-Chip

The iND83211 (Figure 1) features an integrated 32-bit Arm® Cortex® M0 processor, 64kB of Flash memory, and 16kB of SRAM. Unique to this IC is a built-in power management unit (PMU) that implements a step-down buck converter and two on-chip voltage regulators. This PMU is the key to creating a small form factor, high-power, flexible power management system capable of driving 24 LEDs or eight RGB channels.

The integrated step-down buck converter makes the iND83211 an ideal choice for enabling high-power LEDs. The device can deliver the maximum constant current while maintaining low-power dissipation to minimize the LED's junction temperature (a key contributor to decreased operating life and performance) all while meeting the stringent thermal requirements for these types of applications.

Driver Comparison: Linear vs Buck

The linear driver approach is acceptable when low-power LEDs are being driven but, as power increases, so too do losses. In a 12V system, for example, the fact that the LEDs only require approximately 3V, significantly increases losses as the remaining 9V contributes to heat dissipation in the linear voltage converter – thereby wasting a significant amount of energy.

In this comparison, we are referencing indie's iND83211 LED driver IC, operating at 85% efficiency and a 5V nominal output adjusted down to 4.5V (while keeping the current constant). By comparison, a buck converter uses switching techniques to efficiently convert the battery voltage to a level much closer to that required by the LEDs.

This approach generates much less heat and is suitable for both low- and high-power LEDs. As shown in Figure 2, the buck converter LED driver is contrasted against a linear LED driver, with all three LEDs controlled independently. As the supply voltage increases, the benefit of the buck converter also increased due to the optimized power savings.

Based on the scenario outlined in Figure 2, the buck converter design requires a Vbatt total power of 2.35W, while the linear design needs 5.4W. The buck converter is clearly a better solution in this example, with considerably less power dissipation (over 2x more efficient). In fact, the buck solution can typically deliver several times the brightness with similar thermal performance. This advantage becomes even more important if the application requires the use of a small PCB to fit in a tight or confined spaces.

As mentioned previously, the buck converter delivers up to 750mA supporting high-current LEDs, which require more than 200mA per RGB channel. A 5V nominal output can be adjusted down to 3.3V, while keeping the current constant. In addition, any of the 24 channels can be connected in parallel to increase the current-sinking capabilities. The current for each channel can also be configured in the firmware to distribute loads optimally and minimize thermal impact.

A further advantage of the iND83211 (Figure 3) is that by driving fewer LEDs at higher currents, it can be used to create compact and efficient LED 'light pipes' that transport light from an LED source to wherever it is needed – a feature that is becoming increasingly popular in newer vehicles as it enables innovative, engaging and immersive lighting effects within the complex contours of the dashboard and cabin's physical structure. And because the IC can withstand a 40V load dump from the car battery, it can be connected directly to the automotive supply, further minimizing the need for additional components. Indeed, in using the iND83211, it is possible to realize a complete single-chip solution just by adding reverse battery protection and components for the EMI circuit and ESD on LIN.

Reference Designs

To enable automotive OEMs and Tier 1 manufacturers to accelerate and de-risk next-generation lighting applications, indie has

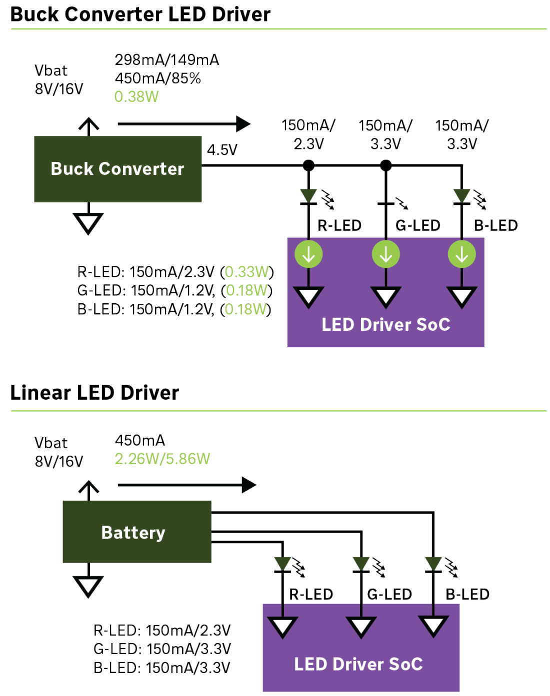

Figure 2. Power dissipation buck converter vs linear LED drivers

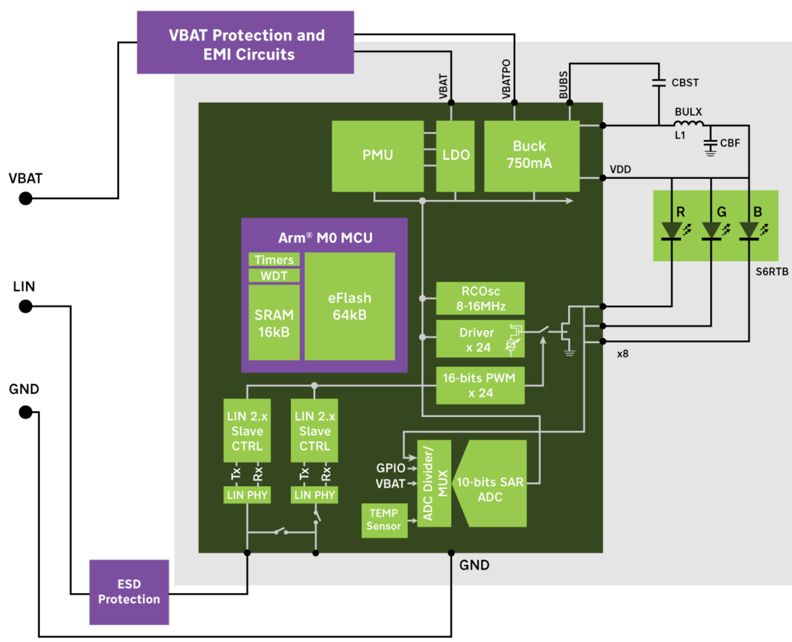

Figure 3: iND83211 is a single-chip solution for high-power LED applications

developed a series of reference solutions (Figure 4) that are based on the company's lighting ICs and offered together with the associated development tools needed to evaluate system performance in real-life deployment scenarios representative of OEM-compliant solutions.

These reference designs help to demonstrate the improved color mixing, reduction in hot spots, and up to five-fold increase in light output of indie's solutions, while minimizing board footprint, power consumption and thermal limitations.

The automotive-grade reference design for the iND83211, for example, is a fully functional module provided in a mechanical package comparable to a final production solution (Figure 5). It features a single high-power RGB LED, controlled via LIN and color compensation to ensure that the color remains constant, even as temperature changes.

The module, which is designed to meet OEM EMI requirements, uses automotive-grade components and follows automotive design rules for manufacturability. Advanced testing of the reference design demonstrates good thermal performance and compliance with FMC1278 for radiated EMI. The iND83211 module has been tested with lightguides (Figure 6), and among the applications for which it is already being considered is for electric vehicle (EV) charger port lighting where an existing design encountered thermal limits that restricted LED current to 30mA total, resulting in a very poor lighting capability. At the same time, the design was challenged by color mixing issues, which necessitated optics improvements.

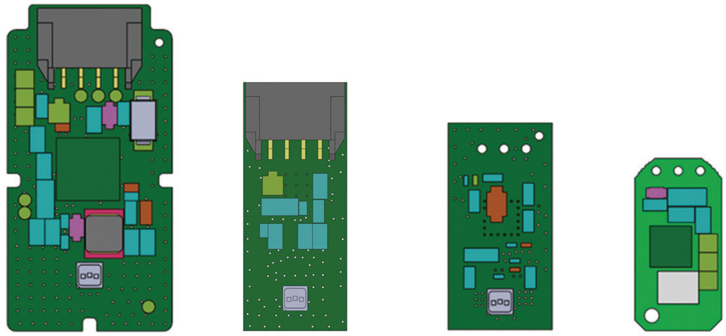

Figure 4: indie Semiconductor solutions for various LED currents

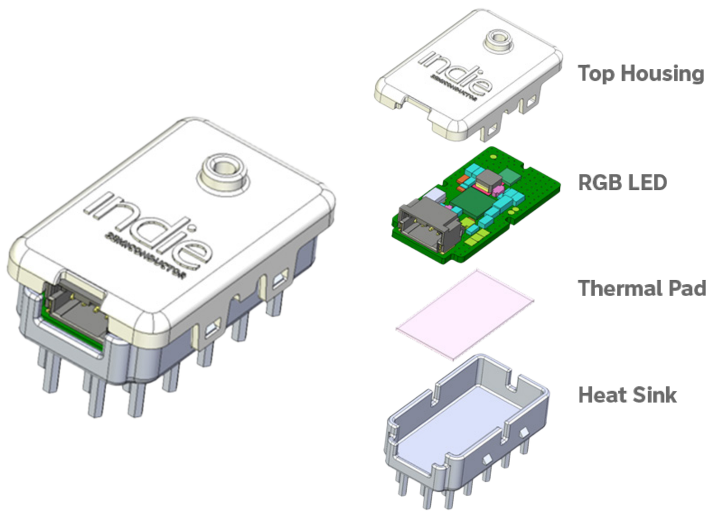

Figure 5: Exploded view of the iND83211 reference design

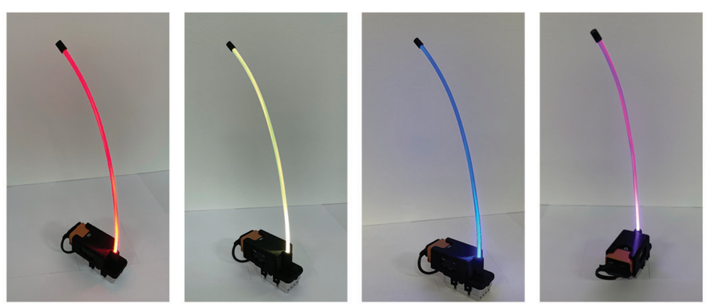

Figure 6. Examples of modules with attached lightguide.

Conclusion

The interior and exterior lighting of today's vehicles is rapidly evolving. With advanced dynamic lighting, it is possible to improve visibility and make it easier for drivers to see and be seen, which can help reduce the risk of accidents. Innovative lighting can also improve the comfort of the driver and occupants, creating an atmosphere suited to the context of the journey, style preference of the vehicle owner, or the mood. indie's solutions are designed to address this growing demand for innovative and power-efficient LED lighting.

For more information, please visit us at www.indiesemi.com.