

Semiconductors for automotive lighting solutions

Original equipment manufacturers are implementing modern automotive lighting use cases. This article introduces semiconductor technologies from Texas Instruments (TI) impacting headlight, rear light, and other lighting systems.



Automotive lighting applications include dynamic and static headlights (low beam, high beam, turn indicators, etc.), rear lights, as well as interior light systems. Adaptive headlight systems (see Figure 1) adjusting the beam shape are available on cars in Europe, but yet forbidden in the USA. The systems use high-powered LEDs (light-emitting diodes) as a light source. The LEDs require high-powered drivers to regulate current and to achieve the required brightness. Switching LED drivers must be implemented as dual-stage power-processing topologies.

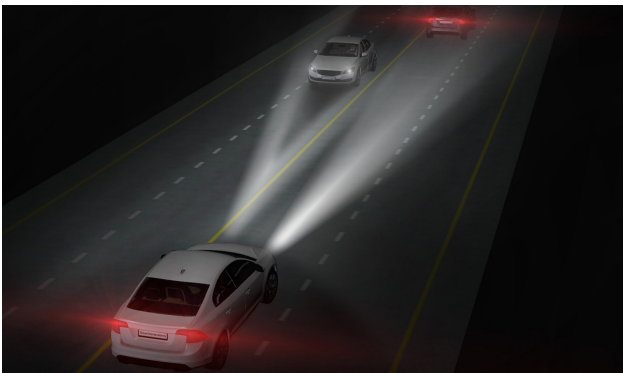


Figure 1: Adaptive headlights adjust the beam shape and illuminate the entire field of view while avoiding glare from oncoming traffic. (Source: Texas Instruments)

Headlight ECU reference design

The headlight ECU implements a two-stage boost controller of multiple buck LED drivers that support four channels to an LED matrix manager. The system overview is shown in Figure 2. The TPS92682-Q1 boost controller is set in voltage regulation mode capable of 130-W output power. The boost output drives two TPS92520-Q1 dual-channel synchronous buck LED drivers. This makes a total of four buck channels with a 120-W total output. The synchronous buck channels manage pixel-controlled loads using the TPS92662 LED matrix manager devices. The LED matrix-manager ICs (integrated circuits) are responsible for adjusting the headlight beam shape (see Figure 1). They control the intensity of each pixel to generate different beam patterns and to illuminate the entire field of view while avoiding glare from oncoming traffic.

The MSP432E401Y micro-controller enables the headlight ECU with two CAN interfaces. The micro-controller communicates with the in-vehicle CAN networks. It controls the TPS92682-Q1 and the two TPS92520-Q1 devices via SPI (serial peripheral interface). It also communicates with the lighting matrix module using UART (universal asynchronous receiver transmitter) communications via the TCAN1042 CAN transceiver. ▶

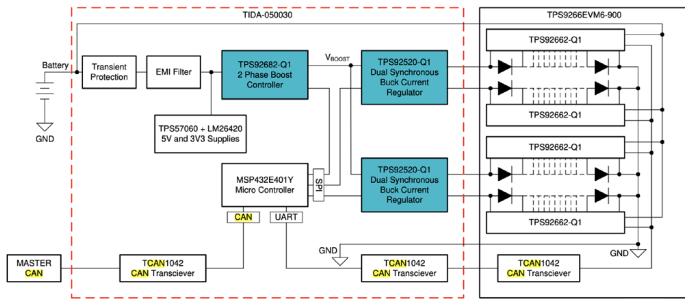


Figure 2: Automotive headlight ECU reference design (Source: Texas Instruments)

The system can operate at voltages from 9 V_{DC} to 24 V_{DC} with a derate down to 6 V_{DC}. It also operates during cold crank and load dump conditions when the battery voltage varies. A two-stage ECU is needed due to the dynamic nature of a matrix load. Here, the LED current regulation is done by a low-output capacitor topology such as a buck at the second stage. The wide input voltage variability of an automotive battery system requires to boost the first stage to ensure a consistent input voltage for the buck second stage.

Further headlight options

Headlights based on TI's DLP technology enable beam shape adjustment as well as symbol projection. Symbols can be made visible to the drivers as well as to other road participants. For example, the lane marking uses headlights to draw the planned driving path on the road. This can help drivers to navigate within hazardous driving conditions. This marking helps also the others to see where the vehicle will be traveling. Company's DLP5531-Q1 chipset for headlight such applications is already used on the road.



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CAN FD light protocol

CAN in Automation (CiA) members started to develop the CAN FD light master/slave protocol based on CAN FD. It is intended for simple sensor and actuator communication. A typical example are the modern LED lamps in passenger cars.

The CAN FD master node synchronizes the slave nodes with hundreds of LEDs. The slave nodes transmit CAN-FD data frames only on request of the master. This avoids the implementation of high-performance and costly oscillators. The implementation of the CAN FD slave nodes is also simplified, because there is no arbitration needed. It is intended to run such networks with one bit-rate. Therefore, the bit-rate is limited to 1 Mbit/s, which is fast enough for such applications. Only the CAN FD data frames with 11-bit CAN-identifier are used for the communication. Error and overload frames are not supported at all. Nevertheless, data fields of up to 64 byte are possible.

The CiA Special Interest Group (SIG) named "CAN FD light" works on the intended specification. Fred Rennig from ST Microelectronics chairs the group, which comprises about 20 experts from different companies.



Figure 3: Rear lighting that spans across the length of a vehicle (Source: Texas Instruments)

Using the headlight leveling technology, the beam lights the road regardless of the road inclination or vehicle's acceleration (deceleration). Pointing the headlight to the road enhances visibility while driving in the night. Bipolar stepper motors are typically used to control headlight leveling. The DRV8889-Q1 stepper motor driver integrates a power stage to drive the motor, as well as a stall detection capability.

TI's CAN transceivers (e.g. TCAN1044-Q1), and CAN-capable system-basis chips (e.g. TCAN4550-Q1) are the provided options for automotive lighting applications.

Animated rear lights

LED-based rear lights (e.g. brake lights, turn indicators) can also include animation or personalized lighting messages. A static LED driver module enables lights operation at low battery voltages and lowers the high battery voltages to optimize the thermal management of the second-stage LED drivers. TI's TPS929120-Q1 12-channel LED driver for animated lighting uses company's Flexwire (UART) interface to enable individual pixel control. Thus, high-LED-count systems can dim independently. The unit can also provide a CAN interface. A diagnostic and a fail-safe mode ensure LED lamps reliability. The chip offers off-board support, which is suitable for rear lighting implementations spanning across the entire vehicle length. (see Figure 3).

Another example is the swiping turn, where the turn indicator LEDs light up in sequence instead of all at once. Rear lights can also be used to display welcome messages for drivers or message alerts for drivers behind the car.

Additional lighting functions

Inside the cabin an array of LEDs can be adopted to display personal messages (e.g. welcome messages) or to adapt the light beam to shine at a specific location. The TLC6C5724-Q1 is a 24-channel red-green-blue LED driver that independently controls each channel, which is critical for zoning applications.

The original intention of ground projection (puddle lights) was to illuminate the vicinity of the vehicle to help drivers to navigate entering. The next generation of

puddle lights will enable dynamic ground projection. This feature can communicate information to drivers before they enter their cars, alert those around the car, or provide a branding opportunity for automakers. Cars with static puddle lights that project a static symbol such as a logo are already available.

There is a need to develop systems displaying ride-sharing-related messages. Additionally, the trend toward autonomous vehicles demands methods for cars to communicate with other vehicles and pedestrians. For example, such messages can be displayed on a car window. TI's DLP technology can project information on windows when the car is stopped and keep the windows clear when the car is being driven. The technology can also display billboard advertisements on the window. ◀

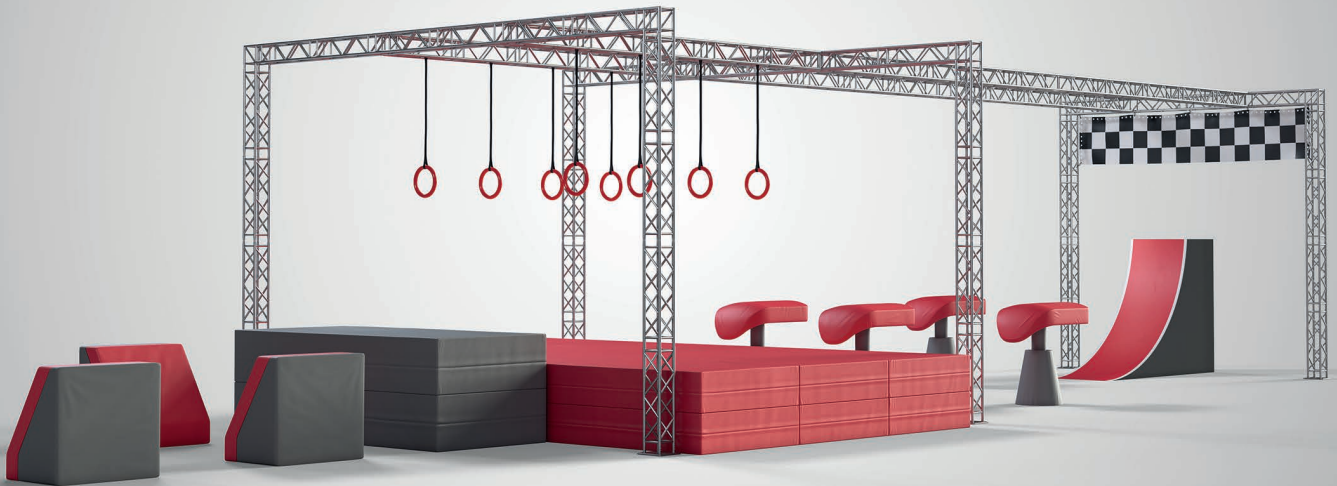


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