



System Solution Guide - Preview

# Advanced Front and Rear LED Lighting



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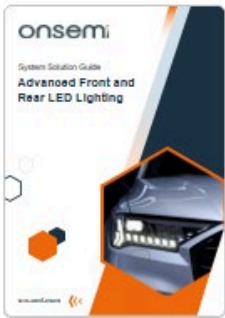
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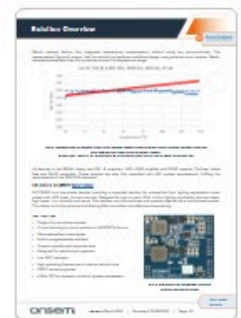
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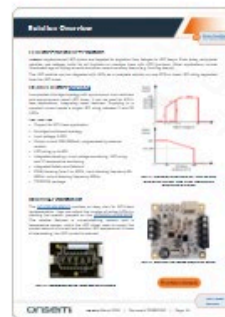
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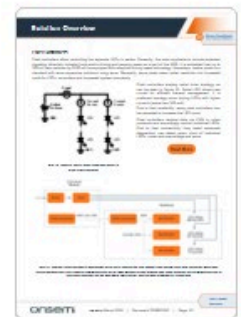
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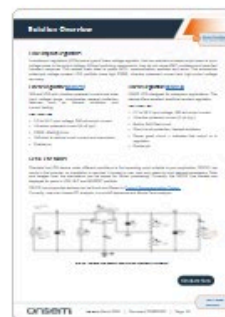
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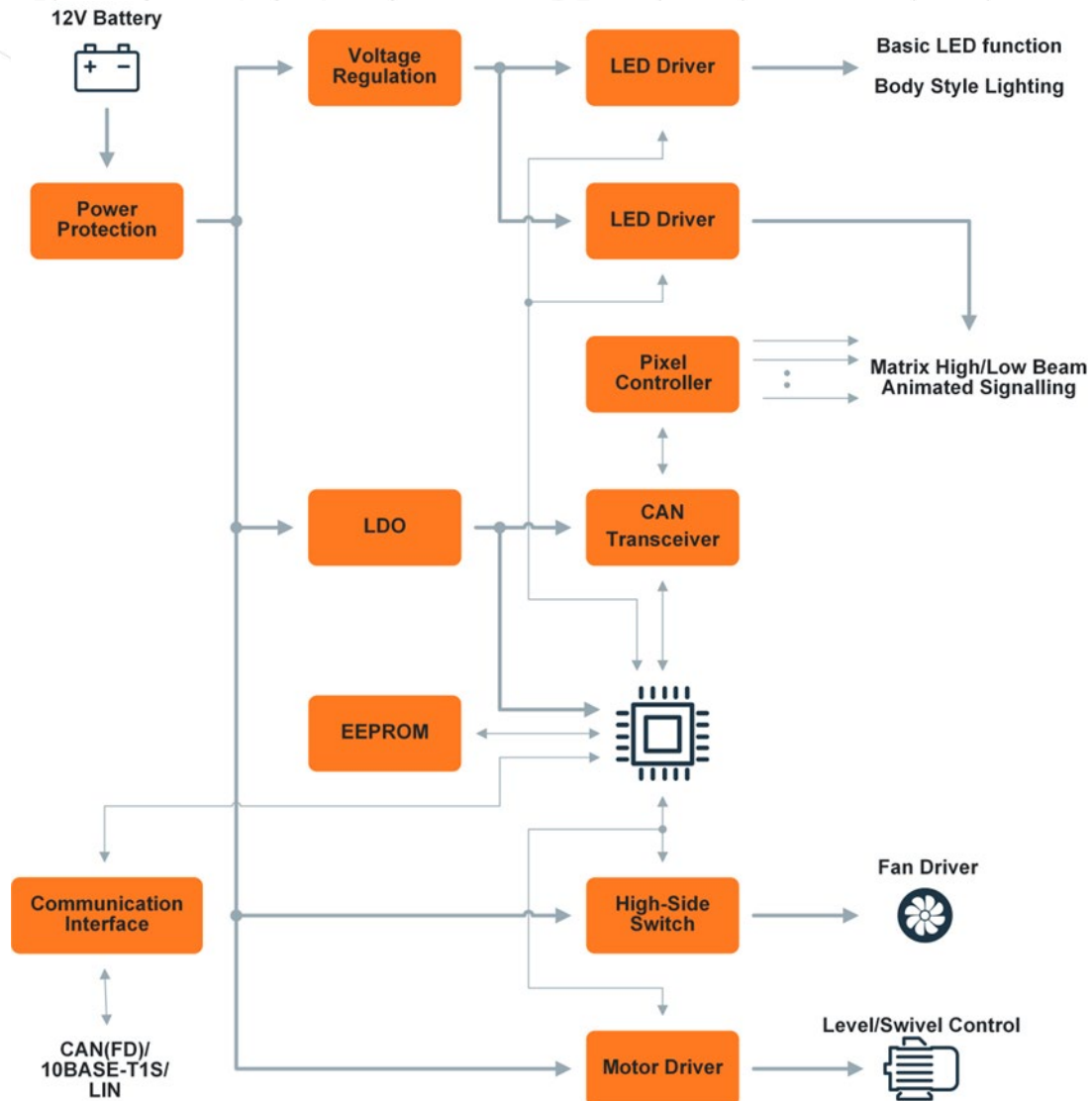
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# Block Diagram

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## Front LED Lighting Top Level Topology

Block diagram below represents automotive advanced front lighting solution recommended by onsemi. Both basic LED function and more advanced and ever more popular matrix function are offered. In addition to main functions which are controlled by LED drivers, onsemi offers other important components for low voltage power conversion, fan control, headlamp leveling and swivel control, CAN and LIN transceivers and more.



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## Front Lamp Architecture

LED driver solutions need to adhere to the strict automotive regulations and be able to pass ESD and EMC testing. With increasing complexity, more and more logic parts are required, compared to the traditional halogen headlamps, which could be powered directly by battery voltage. On the other hand, LEDs need to be supplied by a current source, and with correct operational voltage, otherwise they can be easily damaged.

Front lamp architecture (figure 3) usually uses two-stage topology to achieve the best stability and efficiency. The input battery voltage is first converted into higher, stable DC voltage (usually 40-60V) using a voltage boost converter. Then, the current to the LED strings is supplied by buck LED drivers. The boost converter is slow but it provides more stability and can act as an input filter. On the other hand, buck regulator reacts fast so offers the best LED current regulation. This architecture allows all functions in the lamp to have common voltage source, and each function can have separate current source with diagnostic features. This topology is stable over wide range of load conditions and is more efficient compared to having separate solution for every light function. EMC issues can be also solved more easily.

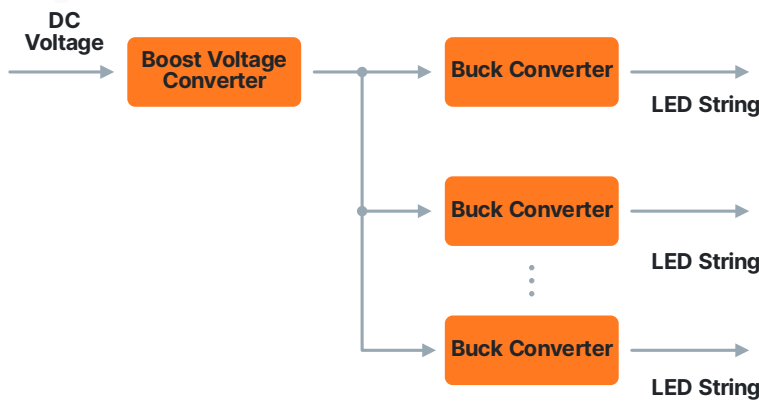


Fig.3: Two stage topology with multiple cascaded buck converters and one boost voltage converter

Sometimes multiple functions are provided by one LED string (e.g. DRL and position light) and each requires different brightness. This is done by PWM (pulse width modulation) dimming. Directly changing the LED current also slightly shifts the LED color. Large changes and fluctuations in LED current can shift color outside legal specifications (UN ECE R48 and FMVSS 108).

What is more, the PWM frequency needs to be high enough to avoid LED flicker – above 200 Hz. Modern LED drivers also offer many diagnostic features which improve safety. Vehicle can notify driver about failure and limit drives with unsafe vehicle.

## onsemi Gen4+ LED Driver Family

Generation 4+ intelligent LED drivers are targeting Front lighting LED driver modules for legacy domain architecture as well as the emerging zonal architecture for software defined vehicles (SDV) using 10BASE-T1S ethernet standard. These state-of-the-art devices meet major market requirements for Automotive LED lighting. See their comparison with competition in table 2.

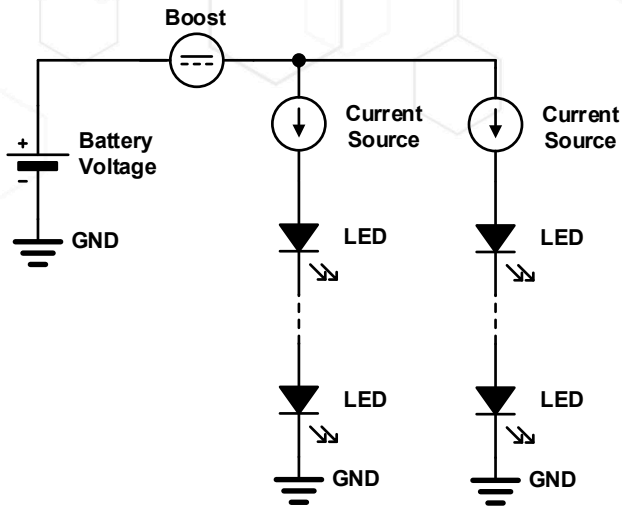
Top or bottom side exposed pad offers free selection of cooling strategy and in the case of top side exposed pad component side is directly shielded by a heatsink. Advanced device diagnostics including ASIL B in compliance with ISO26262 on device level and full LED string diagnostics. Furthermore, the devices boast secured SPI communication at up to 4 MHz and stand-alone mode with auto-recovery option.

Tab.2: Comparison of major market requirements for LED drivers of onsemi Gen4+ family with competition

Property	onsemi Gen4+	Comp A	Comp B
Internal synchronous rectification FET	Yes	Yes	Yes
Switching frequency up to 2MHz	Yes	Yes	Yes
Adjustable current up to 1.5A with 10-bit res	Yes	No	No
Operating voltage up to 70V input and 2V-60V output	Yes	No	No
Integrated shunt	Yes	No	No
Residual output-voltage in OFF-state < 1V, output-leakage-current < 1µA	Yes	No	No
Enable/disable and PWM via µC (On/Off)	Yes	Yes	Yes

## Pixel Controllers

Pixel controllers allow controlling the separate LEDs in series. Presently, the main applications include animated signaling (direction indicator) and matrix driving and passing beam as a part of the ADB. It is estimated that up to 38% of new vehicles by 2030 will be equipped with adaptive driving beam technology. Nowadays, twelve pixels is a standard with more expensive solutions using more. Generally, more pixels mean better resolution but increased costs for LEDs, controllers and increased system complexity.



Pixel controllers employ serial drive topology as can be seen in figure 12. Serial LED drivers are crucial for efficient thermal management. It is preferred topology when driving LEDs with higher currents (more than 200 mA).

Due to their scalability, many pixel controllers can be cascaded to increase the LED count.

Pixel controllers receive data via CAN or other protocols and accordingly control individual LEDs. Due to their connectivity, they boast advanced diagnostics, can detect open, short of individual LEDs, under and overvoltage and more.

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Fig.16: Typical serial drive topology used in Pixel architectures

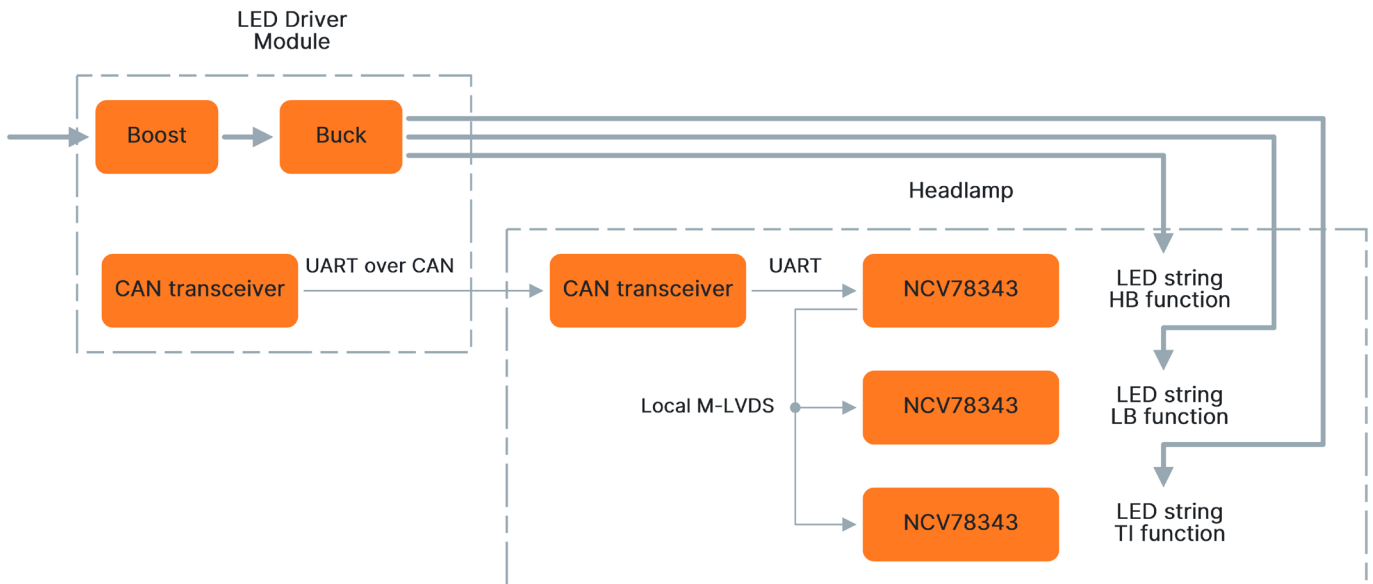


Fig.18: Typical architecture of headlamp with pixel controlled low beam, high beam and turn indicator functions using NCV78343, first device communicates with LED Module using UART and then bridges the communication to the other devices using M-LVDS (multipoint low voltage differential signaling)

# Frequently Asked Questions (FAQ)

## What are the main advantages of LED lighting in automotive front and rear lamps?

- 1 LED lighting offers high efficiency, lower power consumption, long operational lifetime (often exceeding 10,000 hours), and exceptional design flexibility. Compared to halogen and HID lamps, LEDs enable advanced safety functions, improved reliability, reduced maintenance, and distinctive lighting signatures for vehicle differentiation.

## How does Adaptive Driving Beam (ADB) technology improve nighttime driving safety?

- 2 Adaptive Driving Beam (ADB) dynamically controls individual LED segments to maintain maximum road illumination while preventing glare for oncoming traffic. By selectively dimming or switching off specific light segments based on camera input, ADB enhances visibility, reduces driver fatigue, and improves overall road safety without mechanical components.

## Why are LED drivers critical in automotive lighting systems?

- 3 LED drivers provide precise current regulation, voltage control, diagnostics, and safety functions required by automotive LEDs. Unlike traditional bulbs, LEDs are sensitive to overcurrent and temperature, making intelligent LED drivers critical for system reliability, efficiency, EMC compliance, and functional safety in automotive lighting.

## How does zonal E/E architecture impact automotive lighting design and cost?

- 4 Zonal architecture groups electronic control units by physical vehicle zones rather than by function. This reduces wiring complexity, weight, and cost while improving scalability. Automotive lighting systems benefit by integrating more easily with Ethernet-based communication such as 10BASE-T1S in software-defined vehicles.

## Why is 10BASE-T1S Ethernet important for next-generation automotive lighting?

- 5 10BASE-T1S enables reliable, low-power Ethernet communication over a single twisted pair in multi-drop topologies. For lighting systems, it supports higher data rates, improved cybersecurity, simplified gateways, and seamless integration into zonal controller and software-defined vehicle architectures.




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