Automotive LED Headlamp With A Laser Channel Provides Versatile and Flexible Solution

Multi phase driver IC enables flexible topology for headlamp LCU design

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Abstract

With the global drive for more intelligent automotive lighting systems and energy consumption, automotive lighting is an area that has room for innovation and improvement. Automotive Solid State Lighting (ASSL) systems implement multiple groups of load today, this load includes LED,OLED, laser diode etc., whereas engineers are looking for a more flexible platforms that can combine these loads more efficiently.

A good use case for this is the LED headlamp with a laser channel. The light control unit (LCU) drives both the laser channel and the Daytime Running Lamp (DRL) channels simultaneously with one boost voltage. This is not very efficient and incurs heat dissipation for the laser channel, since the boost voltage that drives the laser channel is higher than voltage needed because it share a common voltage with the DRL.

This article will look at how this issue can be solved using NXP's ASSL driver IC which provides two independent voltages that can be controlled individually via a SPI interface. With two use cases and a system level efficiency versus Laser channel efficiency comparison, it is very easy to see the improvement of this innovated structure.

Background

Automotive headlamps have evolved quickly since LED and laser diode technologies were introduced a few years ago. LED lamps with a laser channel, usually equipped with Adaptive Front Lighting System (AFS) features or matrix beams, are becoming more and more popular with OEMs. This is not just because they save energy, but also because they are glare free and extend the light range. LED headlamps with a laser channel are developing particularly quickly in Europe supported by major OEMs such as BMW, Audi and LED suppliers like OSRAM. According to headlight sources, the market share trend forecasted in Driving Vision News 2014, the LED and Laser headlamp will ramp up fast from 2020 moving to about 18% market share by 2025.

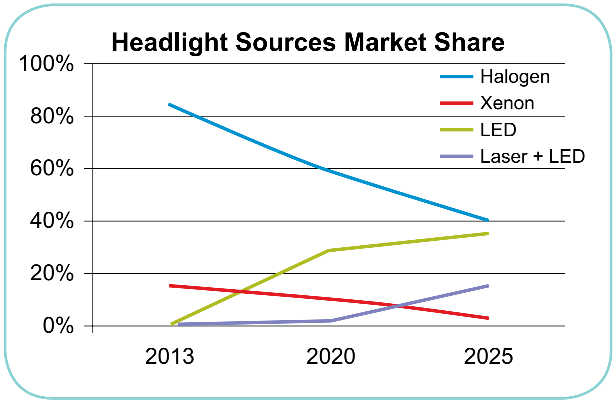

Fig. 1 headlight market share

1. Lighting Control Unit

The LCU is the key component for a LED headlamp with laser, its functions include laser-based lighting, AFS, dynamic levelling or matrix-type functions. A typical implementation is shown below in Fig 2.

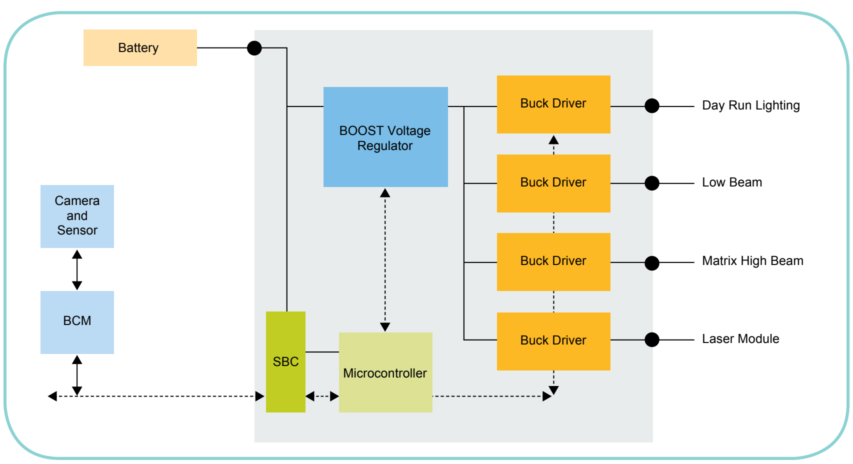

Fig. 2 Typical LCU implementation

The driver module usually contains a microcontroller (MCU) and transceivers that communicate to the Body Control Module (BCM). The MCU controls the drive IC via the SPI interface; commands from the BCM or the LCU sense traffic conditions by analyzing signals from cameras or sensors. In power electronics architecture, a two-stage topology is often used. This employs a boost voltage regulator and independent buck channels to drive the LEDs or laser diodes for the different lighting functions.

2. Power stage design

As shown in Fig 2, this two stage topology allows a stable voltage source over a wide range of conditions, such as load-dump and cold-crank incidents, while still responding to a dynamic load in each stage. This feature is critical in matrix or full LED headlight design, where selecting external components for different buck channels may prove counterproductive. For example, buck channels driving DRL have a relatively low output current of 0.2-1 A, but a high voltage: so the MOSFET drain-source voltage (VDS) and diode reverse leakage current are important. However, buck channels driving laser channels have a higher output current of >1 A but a low VF: so the MOSFET drain-source on-state Resistance (Rdson), inductor DC Resistance (DCR) and diode forward voltages are more important. It would clearly be a struggle for one boost voltage to drive all these channels. With this solution, it is possible to have two boost voltages or even one boost voltage and one SEPIC voltage with one controller IC. The benefit is comes from the powerful digital regulation loop. Two use cases are shown below and show clearly the improvement on system efficiency and Laser channel efficiency.

* Use case 1: Let's have a look at a design example of a 60 W LCU with three load groups: 54 V/ 540 mA DRL, 16 V/ 0.5 A fog lamp, 8 V/ 2 A laser module as shown in Fig 3.

  - Solution 1 is to design a 63 V boost for all three groups of Buck. It is easier to design MOSFET and inductor by using two phases of boost in parallel to drive 60 W.
  - Solution 2 is to design a 63 V boost 1 for DRL, another 35 V boost 2 for the fog lamp and laser module.

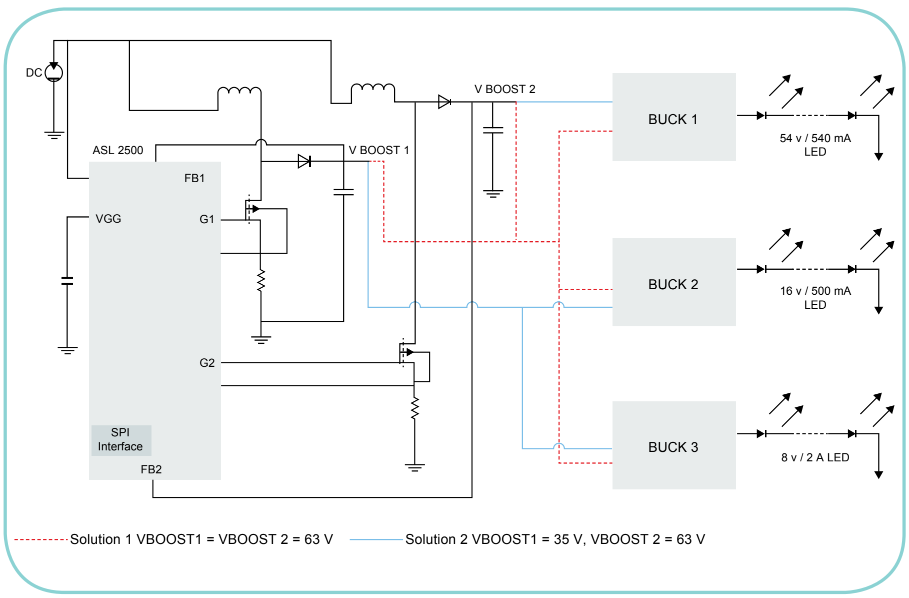

Fig. 3 Diagram of solution 1 and solution 2

We use ASL2500 as a control IC for the solutions shown in Fig. 3. The ASL2500 includes two independent, internal control loops (Fig 4), and are considered virtual phase logic 1 and virtual phase logic 2. Two physical phase boost gate drivers can be connected to an internal virtual phase by programming different phase allocation registers using SPI, without needing additional components to determine assignments. The boost gate drivers can drive one common output voltage together, or two separated output voltages.

	Vin	Iin	Vbuck1	Iout1	Vbuck2	Iout2
Solution 1	12	5.17	53.4	0.537	14.72	0.553
Solution 2	12	4.98	53.4	0.538	14.72	0.54

Table 1: Test results from use case 1

In table 1, we see that the evaluation results show that solution 2 has a 3% system efficiency improvement over solution 1: equivalent to a 1.8 W heat dissipation saving for a 60 W LCU design. Considering the compact size of the LCU, this is significant for simplifying thermal design.

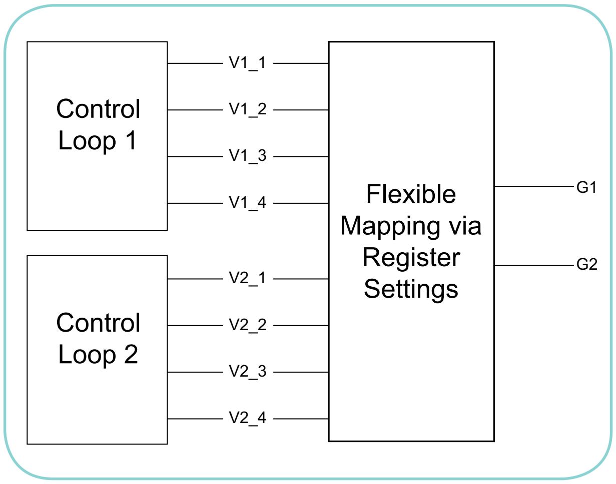

Fig. 4 ASL2500 control logic

* Use case 2: This example uses a 60 W LCU with three load groups: 52 V/ 320 mA DRL, 15 V/ 0.55 mA fog lamp, 8 V/ 3 A laser module as shown in Fig 4.

- Solution 3 is to design a 63 V boost for DRL 52V/320mA and Fog lamp 15V/0.55mA, 9.5V SEPIC for Laser module 8V/3A
- Solution 1 is to design a 63 V boost for all three groups of Buck. It is easier to design MOSFET and inductor by using two phases of boost in parallel to drive 60 W.

Solution 3 is an attractive option if the laser channel output current is 3 A or even higher current- 6 A. The ASL2500 registers include a rich choice of loop compensation parameters (Kp,Ki) and frequency is set from 125 K-700 KHz by SPI. This means it can be configured to SEPIC converter for some typical load conditions as well. In this example, the SEPIC converter can drive the laser diode as it allows higher or lower battery voltage than its output voltage. And, in terms of efficiency, the SEPIC output voltage is just a few volts above the load at 8 V. In boost topology, a typical output voltage is higher than the maximum battery voltage: it could be set to 35 V for example. This optimizes the buck channel duty cycle so that power loss in buck freewheel diode is minimized. Buck 3 as seen in figure 5 efficiency is therefore close to sync buck which topology uses a low-side MOSFET to replace the freewheel diode. Buck3 works in a high duty cycle, with the freewheel diode (D1) turned off most of time.

For example: driving 2 LEDs at 3 A with a 63 V voltage for buck as in solution 1, the diode has as 88% duty cycle for the diode

3 A * 0.7 V * 0.88 = 1.89 W

Using a 9.5 V voltage for buck as in solution 3, the diode has a duty cycle of 19%

3 A * 0.7 V * 0.19 = 0.4 W

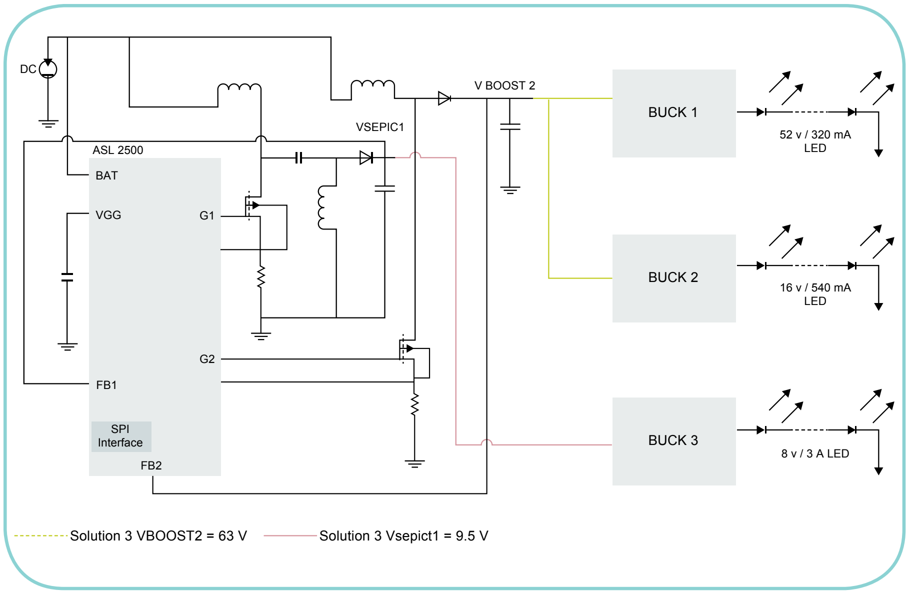

Fig. 5 Diagram of solution 3

With SEPIC as the first stage in Fig 5 a 40 V or even 30 V MOFSET with lower gate charge and "ON" resistance can be used. With a 30 V schottky barrier rectifier, both the VF and reverse leakage current are lower than its 60 V or 100 V counterpart. For the buck inductor, AC loss and DC loss is smaller. What's more, the cost and size of buck 3 are minimized.

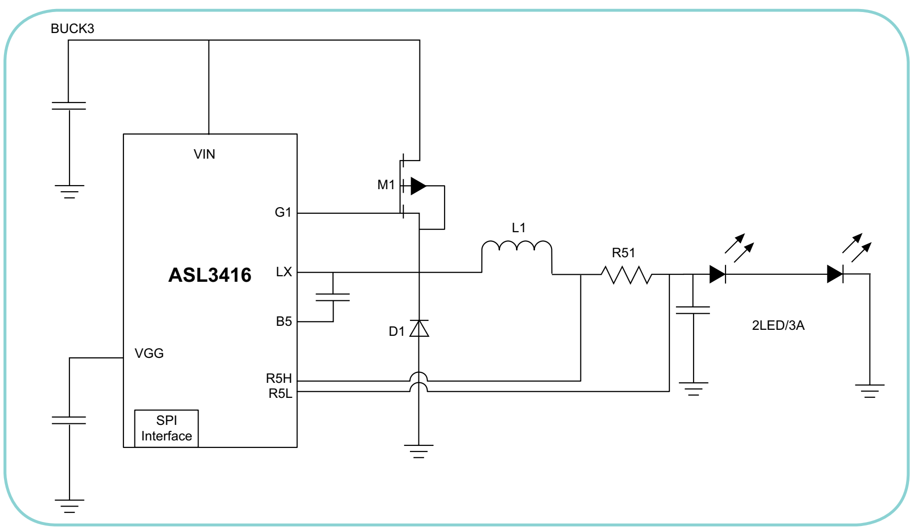

Fig. 6 Buck3 typical schematic

If we look at buck 3 in more detail, we can see what happens when there are changes made at the component level. Figure 6 shows a typical schematic for buck 3 and table 2 below outlines the results of changes at the component level, specifically the reduction in Rdson and gate charge, lower VF and reverse leakage current and less DCR and AC loss with SEPIC as the first stage. This clearly demonstrates the increased efficiency of the solution. In fact, table 3 below shows the efficiency improvement of buck 3 from a 60 V input voltage versus a 9.5 V input voltage. The results in table 3 are tested while only buck3 is in operation, the results in table 4 are tested while first stage and all bucks are in operation.

Part	Boost as first stage	SEPIC as first stage	Notes
M1	80 mΩ/80 V,9.9 nC	40 mΩ/40 V,4.5 nC	Rdson and gate charge is smaller
D1	4 A/80 V	5 A/30 V	Both VF and reverse leakage current are lower
L1	68 uH	10 uH	Both DCR and AC loss are smaller
	12 mm*12 mm*10 mm	7.3 mm*6.8 mm*3 mm	Inductor size is only 35% of solution 1

Table 2: component changes in buck 3

Input voltage	Input current	Output voltage	Output current	efficiency
60 V	0.46	7.71	2.991	0.8355
9.5 V	2.63	7.71	3.011	0.9291
				Delta:9.36%

Table 3: efficiency improvement of buck 3

In the system efficiency comparison table 4, solution 1 is now driving 3 A load in buck 3. We can see efficiency decreases about 3% compared to driving 2 A in buck 3 as we saw previously in use case 1. This demonstrates that the typical single boost voltage is not the best choice for the 3 A laser channel example in use case 2. Solution 3 provides a 1.65% efficiency from a total system point of view.

	Vin	Iin	Vbuck1	Iout1	Vbuck2	Iout2	Vbuck3	Iout3	Efficiency
Solution1	12	5.14	52	0.324	14.73	0.547	7.86	3.08	0.7963
Solution3	12	4.90	52.3	0.316	14.75	0.545	7.92	3.01	0.8128
Delta									1.65%

Table 4: test results from use case 2

Summary

At the outset of this paper, we discussed how automotive headlamps are transitioning to LED lamps with laser features or matrix beams. The reasons for this are threefold: they save energy, they are glare free and they extend the light range. As this paper has outlined, NXP's LED drivers combine a deep understanding of LCU design and IC knowledge with world-class automotive A-BCD mixed signal HV technology. This is essential for developing flexible platforms that can combine loads efficiently and deliver on the promise of LED lighting.

For more information, please visit NXP's website **http://www.nxp.com/products/automotive-products/power-management/lighting-driver-and-controller-ics:LIGHTING-DRIVER-CNTRLLR-AUTO** and contact local support.

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