

One LED Driver Is All You Need for Automotive LED Headlight Clusters

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Low beam headlights, high beam headlights, daytime running lights and signal lights are often fashioned together in a single unit or cluster, allowing designers to produce distinctive automotive front end looks. LED lighting has found its way into these clusters, distinguishing the high end faces of today's luxury vehicles; but LEDs offer more than just good looks. They have a number of technical advantages over competing lighting technologies—notably improved efficiency, robustness and lifetime. Despite these advantages, automobile lighting designers are challenged by the cost of replacing traditional lamps with LEDs.

A significant portion of the cost LED lighting is driven by the costs of the LEDs themselves, thermal management assemblies (such as finned metal heat sinks) and robust LED driver circuits. Traditionally, each LED beam or light type would require its own LED driver PCB. Costs and complexity can be significantly reduced if a single driver is

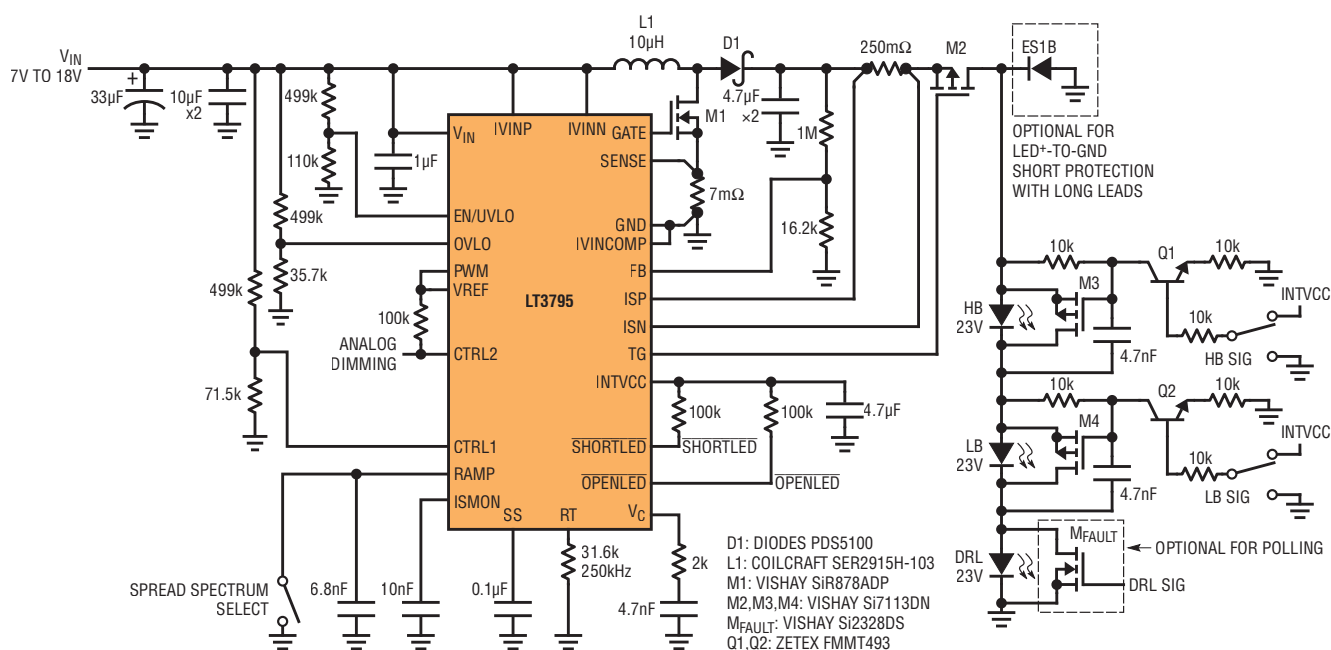
used to drive multiple LED strings (in series) within the lighting cluster.

A comprehensive, multi-LED-string driver must support the high voltages and high currents required by high power LED strings. It must also deftly handle the on/off transitions of some LED strings while others remain on and unaffected. In an automotive environment, it should accommodate wide ranging input and

output voltages, of the battery at the input and the LED strings at its output. Automotive environments also demand that the driver feature low EMI and open and short-circuit fault protection.

The LT3795 and LT3952 automotive LED drivers satisfy these requirements when used in boost and (patent-pending) boost-buck topologies. These LED drivers can operate in high voltage boost (step-up)

Figure 1. LT3795 70W (70V 1A) automotive boost LED driver drives daytime running lights, low beam, and high beam strings in series with 95% efficiency.



The LT3795 and LT3952 automotive LED drivers can operate in high voltage boost (step-up) and boost-buck (step-up and step-down) topologies—driving series-stacked LED strings directly from a wide automotive battery voltage range.

and boost-buck (step-up and step-down) topologies. They support large stacks of LED strings, accept a wide battery voltage range and can gracefully transition the number of ON LEDs in the output. They both feature spread spectrum frequency modulation for reduced EMI and short and open LED protection.

BOOST LED DRIVER FOR LOW BEAM, HIGH BEAM, AND DAYTIME RUNNING LIGHT

The total voltage of a low beam, high beam and daytime running light headlight cluster can be about 70V when driven with 1A LEDs. The 100V+ LT3795 single channel LED driver can drive 70W of LEDs directly from a standard 9V–16V automotive input—all three lights in the cluster can be driven in series.

The combination driver circuit in Figure 1 shows how the LT3795 single channel LED driver can be used to power 1A through the daytime running light, low beam and high beam headlights in a boost topology. This allows the low and high beam lights to be turned on and off—daytime running lights are always on.

As the low and high beams are turned on and off, their LED strings are added to and subtracted from the daytime running light strings by high current MOSFET switches M3 and M4. These switches act as shorting-out devices. When the MOSFET is on, it shorts out its corresponding beam, turning it off; when the MOSFET is off, the beam runs with 1A current. This easy-to-implement design is robust and saves significant space, requiring no extra controllers.

Switching an entire 23V beam string of LEDs (such as low beam) on and off creates a 23V transient on the output. It is important that on and off transitions are not instantaneous. In this design, Q1 and Q2 control the MOSFET on and off transitions to prevent large spikes of LED string current, which would otherwise result as energy that is taken up or released by the output cap. Instantaneously switching M3 and M4 would drop the LED current temporarily to zero, causing a visible blink

in the low beam lights, or it could induce a high current spike, up to 3A, that would stress even the most robust LED string.

Figure 2 shows the controlled switching of M3 and M4, transitioning the LED current and output voltage over ~500μs. The shorting-out driver for M3 and M4 works at a rate at which the output capacitor and the converter can handle slow transients with less than 20% deviation in output current over a very short

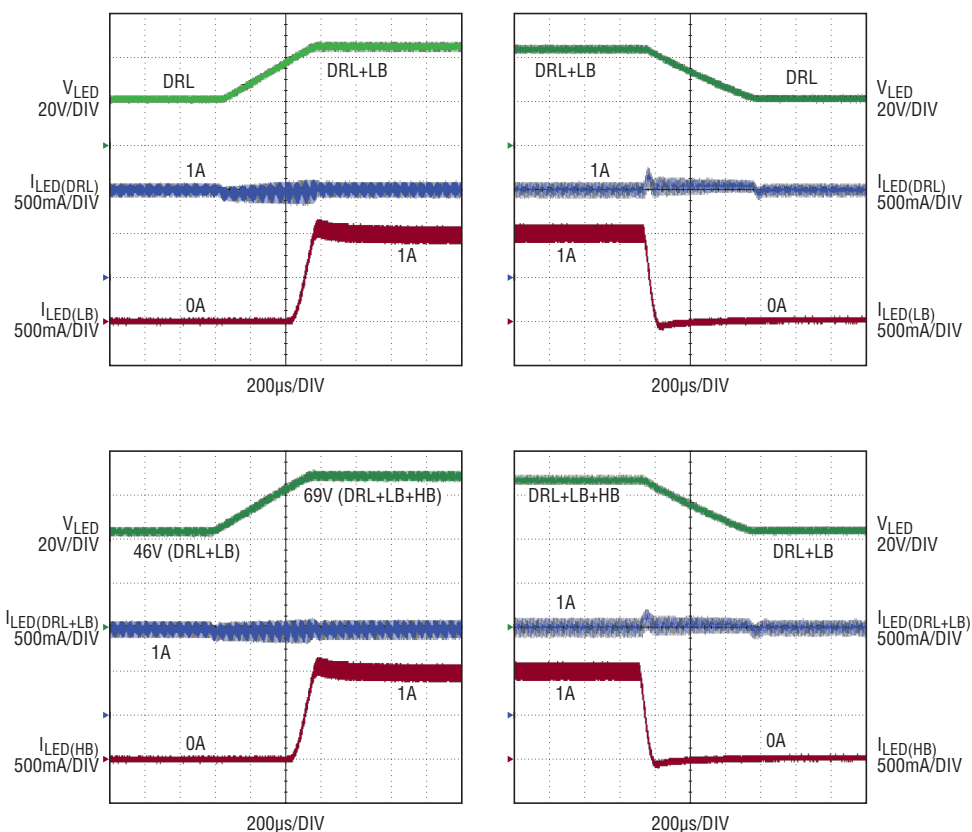


Figure 2. All cluster LED strings are driven in series by one IC channel, but no running string is significantly affected by turning on (or off) other strings—constant brightness is maintained even as low beam and high beam strings are turned on and off. Transitions are controlled by slowly switching on or off LED beams with shorting-out MOSFETs, preventing current spikes on other, unchanged strings.

In the combination driver circuit, the LT3795 single channel LED driver can be used to power 1A through the daytime running light, low beam and high beam headlights in a boost topology. This allows the low and high beam lights to be turned on and off—daytime running lights are always on.

time. There is no perceivable blinking or flicker in the low beam or other running lights when a string is added to or subtracted from the always-on running lights.

The LT3795 boost LED driver circuit in Figure 1 has 91% and 95% efficiency when only daytime running lights are on, and when all beams are on, respectively. It has short-circuit and open LED protection. With good layout and sufficient copper area for the discrete power components, the highest temperature rise component of this 70W boost driver can be kept under 40°C without additional heat sinks or airflow. EMI filters, a GATE drive resistor and spread spectrum frequency modulation can be used for reduced EMI.

BOOST-BUCK LED DRIVER FOR DAYTIME RUNNING LIGHT AND SIGNAL LIGHT COMBO

Some vehicles use LED lighting for daytime running lights and signal lights, but not for high or low beams. Daytime running lights are designed in a variety of different configurations, from long strings of LEDs with relatively low current to short strings with high current. An IC that can support

both step-up and step-down conversion can power a combination daytime running light and sometimes-on trim light or amber signal light. Using an IC that can seamlessly handle transitions of stacked-string voltages in a step-up and step-down topology allows designers to focus on light aesthetics and functionality, without

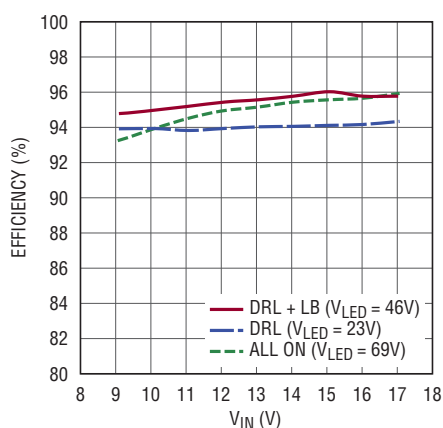


Figure 3. Efficiencies of various light combinations are between 94% and 96%.

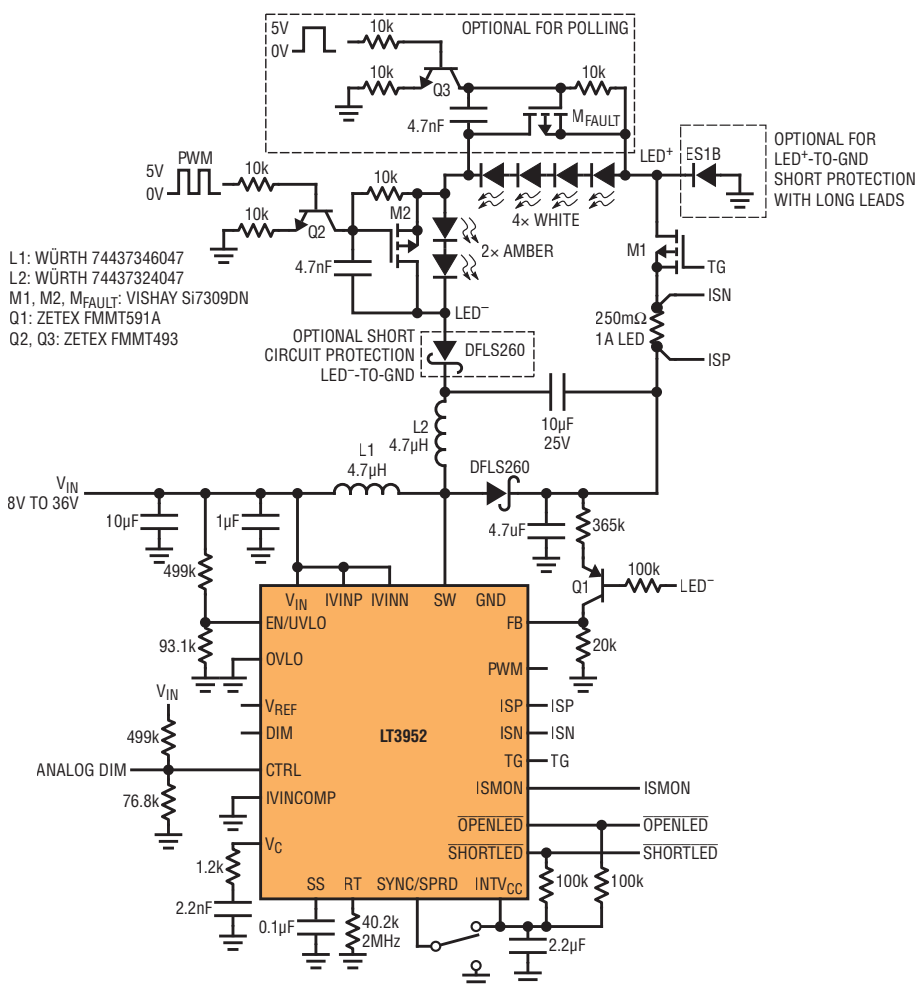


Figure 4. This 18W (18V, 1A) automotive boost-buck LED driver runs daytime running lights and amber signal lights at different brightness levels. 2MHz switching frequency keeps EMI above and outside the AM band.

In automotive environments, it is important that a failure of one lamp function not impede operation of other LEDs. The LT3952 and LT3952 include fault detection and reporting features that enable a system controller to turn on operational LEDs, even when other strings in the series are faulty.

worrying about the driver. Dimming can be thrown into the mix with little effort.

The (patent-pending) boost-buck LT3952 LED driver in Figure 4 regulates 1A through a compact daytime running light and a series amber signal or trim light. The 2-LED amber light can be blinked or PWM-dimmed via the M2 shorting-out MOSFET without affecting the brightness of the constantly running daytime running light.

The result is a single, compact 1A boost-buck LED driver whose output drives a visibly steady daytime running light of 2–4 LEDs, and a blinking signal light and/or variably dimmed trim light.

LED current transients are minimized by the controlled switching of MOSFET M2—which turns on to short out the amber light and turns off to enable the amber light. Figure 5 shows PWM dimming of the amber light operates at

120Hz for flicker-free 10:1 dimming without affecting the brightness of the daytime running light. Similarly, it can be blinked on and off at 1Hz—say 10%-dimmed “off” (or other) to 100% “on” to act as a turn signal light.

The new boost-buck LED driver topology allows the input voltage and output voltage ranges to cross over each other, simplifying design by reducing the need for pre-regulation.

Figure 5. PWM dimming amber signal lights at 10:1 (and up to 20:1) at 120Hz does not affect the LED string current of the daytime running lights.

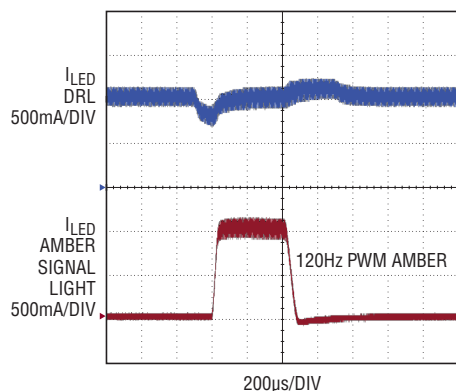
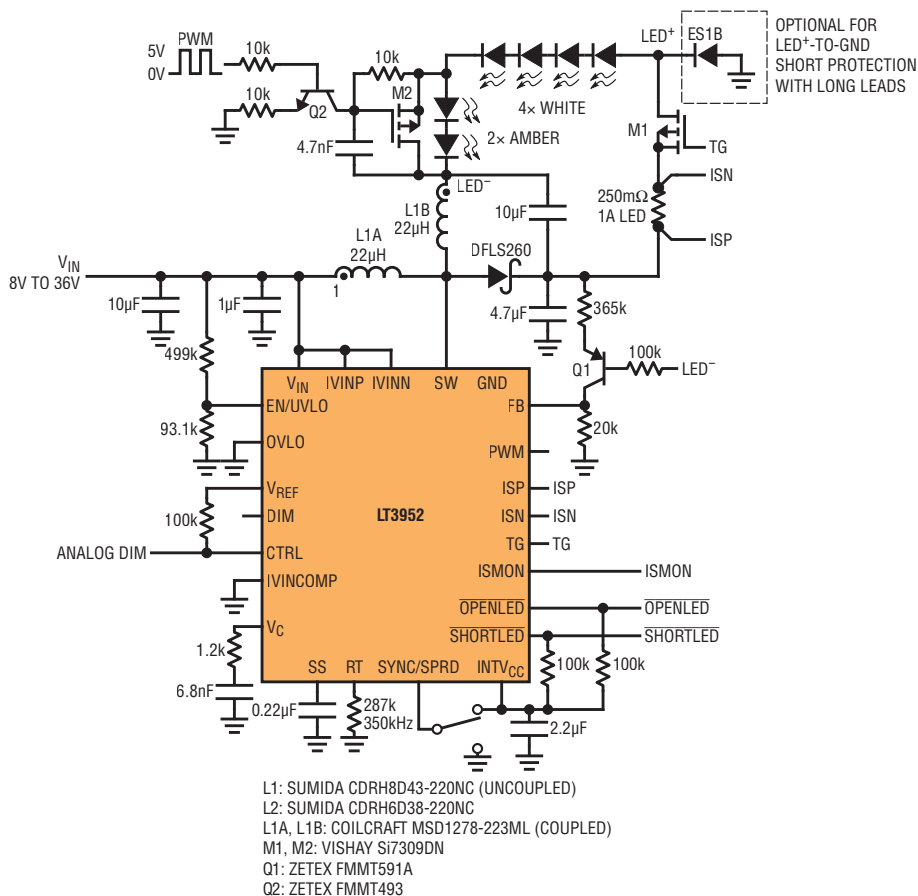


Figure 6. Similar automotive boost-buck LED driver to Figure 4, but this one uses a switching frequency of 350kHz for improved efficiency.



The converter is short-circuit and open LED protected. An optional low V_F diode in the LED^- path provides LED^- -to-GND protection in addition to the LED^+ -to-GND protection from the TG MOSFET (M1) and LT3952 overcurrent detection. The boost-buck topology has both low input and low output ripple for very low EMI, which is reduced even further with spread spectrum frequency modulation.

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To improve efficiency, the converter can be operated at a switching frequency of 350kHz (Figure 6). Efficiencies of the two options are compared in Figure 7. Note that the 2MHz solution has the advantages of a reduced size inductor, and EMI above and outside of the AM band. At either 350kHz or 2MHz, uncoupled inductors can be used in place of the single, coupled inductor in the boost-buck topology.

SHORT AND OPEN POLLING

In automotive environments, it is important that a failure of one lamp function does not impede operation of other LEDs. The LT3795 and LT3952 include fault detection and reporting features that enable a system controller to turn on operational LEDs, even when other strings in the series are faulty.

Using the fault flags and an additional, optional diagnostic switch (M_{FAULT}), the system computer can poll the LED beams by turning them on and off to determine which one has an open. The system controller can run the remaining non-faulty LED beams while the faulty beam is shorted out. The faulty string can be re-pollled, and brought online as soon as it is healthy again. Both the LT3795 and LT3952 circuits handle short and open circuits, so shorting and opening strings poses no potential harm for the circuits.

Additional voltage readings and short-circuit detections can be put in place to turn off strings that have been shorted, or to report shorted segments that require servicing. The LED driver circuits maintain functionality and reliability even when one of the LED strings has been damaged.

CONCLUSION

Combination automotive LED lights can be driven from a single-channel LED driver to save cost and space. High power and high voltage strings can be stacked in a boost topology, or various brightness or lower voltage strings can be turned on and off in the new, boost-buck topology. Using a single driver for several strings saves cost and complexity while retaining aesthetic benefits.

The LT3795 and LT3952 are powerful and flexible LED driver ICs that can be used for combination headlight cluster LED strings. They feature high voltage, high current, spread spectrum frequency modulation, and short-circuit and open LED protection. ■

Figure 7. Comparison of efficiency of 350kHz boost-buck solution (Figure 6) and 2MHz solution (Figure 4).

