

Single 2 MHz Buck-Boost Controller Drives Entire LED Headlight Cluster, Meets CISPR 25 Class 5 EMI

By **Keith Szolusha**

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Automobile LED headlight clusters combine high and low beams, daytime running lights, and sometimes signal and clearance lights into a single headlight cluster. The components of the cluster can have vastly different driver requirements, including voltage and current requirements, topologies, power levels, or unique dimming functions. Meeting this range of requirements usually means employing separate driver solutions. Using multiple drivers not only complicates BOMs and production, it can make it difficult to meet EMI standards. Each additional driver adds its high frequency signals to the EMI mix, complicating EMI qualification, troubleshooting, and mitigation.

Although the headlight cluster for each automobile make and model may be outfitted with a creative variety of LED currents and voltages, they commonly top out at 30 W total. With that in mind, there should be a number of drivers that satisfy the power and feature requirements of every string in the cluster. There are not. Such a driver needs to take the relatively wide battery voltage range and, using a buck-boost topology, convert to the wide variety of string voltages. It needs to be small and versatile to fit easily into the space constraints of the cluster, and it must produce little EMI to minimize R&D efforts and eliminate the need for costly metal-shielded EMI cases. It should also be efficient. The Power by Linear™ **LT8391A** 2 MHz buck-boost controller is unique in satisfying all of these requirements, making it possible to drive the entire headlight cluster, and more, with a single controller.

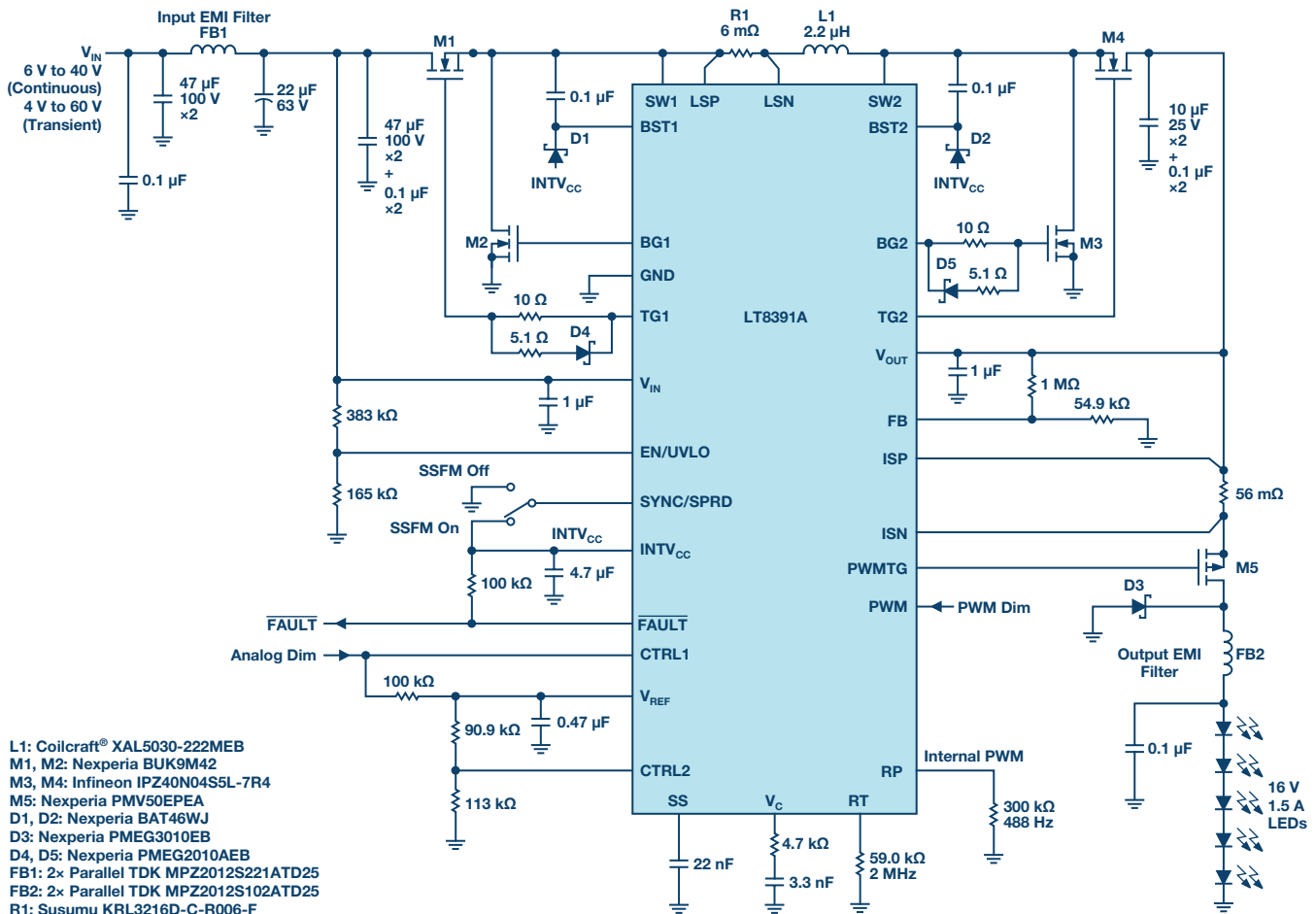


Figure 1. LT8391A 2 MHz 16 V, 1.5 A automotive buck-boost LED driver passes CISPR 25 Class 5 EMI.

LT8391A 2 MHz Synchronous Controller with Low EMI

The LT8391A is the first of its kind—a 2 MHz buck-boost controller for LED current regulation. The very high 2 MHz switching speed enables the use of a single, small inductor and small overall solution size for high power LED applications. Unlike monolithic converters, whose power switches are contained within the IC package, controllers such as the LT8391A can drive external power switches with much higher peak currents, such as 10 A. Such peak currents would burn up the small IC packages of typical integrated converters. In contrast, a controller with external 3 mm × 3 mm synchronous MOSFETs can deliver much higher power. These MOSFETs can be arranged in tight quarters with hot-loop capacitors for very low EMI. The unique peak switch current sense amplifier architecture places the sense resistor next to the power inductor, which is outside of the critical input and output hot loops—reducing EMI. Optional spread spectrum frequency modulation (SSFM) further reduces the controller's EMI.

The 2 MHz LT8391A 16 V, 1.5 A (24 W) buck-boost LED driver in Figure 1 boasts as high as 93% efficiency with EMI filters and gate resistors, as shown in Figure 2. Efficiency is 1% to 2% higher with the optional EMI components removed. With small 3 mm × 3 mm MOSFETs and a single high power inductor, the temperature rise for this converter is low, even at 24 W. At 12 V input, no component rises more than 25°C above room temperature. At 6 V input, the hottest component rises less than 50°C with a standard 4-layer PCB and no heat sink or airflow. It continues to run at full 24 W load in the face of input transients down to 4.3 V; or reduced load current via analog or PWM dimming when the input drops for long periods. The 8 A to 10 A sense resistor makes this high power at low V_{in} possible.

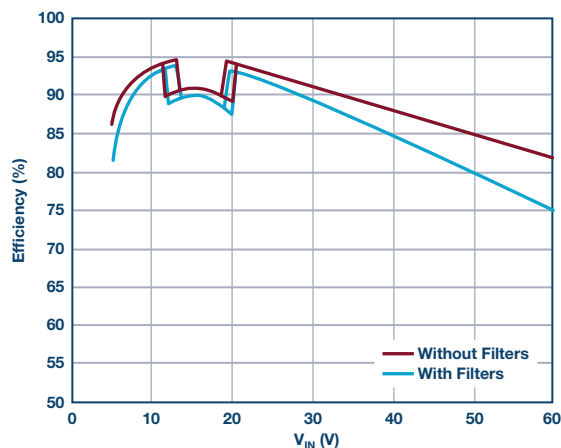


Figure 2. Efficiency of LED driver solution in Figure 1. Measurements made using 16 V, 1.5 A, demonstration circuit DC2575A LED driver with and without optional EMI components.

The LT8391A includes the latest PWM dimming features and open LED fault protection. This synchronous buck-boost regulates current through a string of LEDs with a voltage that may or may not lie within the input voltage range, such as a 9 V to 16 V car battery or a truck battery (18 V to 32 V). It can run down to 4.0 V cold crank input and can withstand up to 60 V input transients. The LT8391A provides up to 2000:1 PWM dimming ratio at 120 Hz and can use its internal PWM dimming generator for up to 128:1 accurate dimming ratio without the need for an externally supplied PWM clock.

CISPR 25 EMI for Automotive Applications

The 2 MHz LT8391A LED driver in Figure 1 is designed for automotive headlights. It uses AEC-Q100 components and meets CISPR 25 Class 5 radiated EMI standards. Spread spectrum frequency modulation (SSFM) reduces EMI and also runs flicker-free simultaneously with PWM dimming. Its small size is highlighted by its small inductor and especially small input and output EMI filters. Large LC filters are not needed for 2 MHz converters and only small ferrite beads are used for high frequency EMI reduction.

Automotive EMI requirements are not easily met by high power converters. High power switches and inductors placed on large PCBs next to large capacitors can create undesirable hot loops, especially when a large sense resistor is included. The unique LT8391A buck-boost architecture removes the sense resistor from both the buck and boost switch-pair hot loops, enabling low EMI.

Figure 3 and Figure 4 show the measured EMI of the 24 W LED driver of Figure 1. Despite this controller's 2 MHz operating frequency and 24 W of power, this buck-boost passes CISPR 25 Class 5 radiated and conducted EMI. Class 5 is the most stringent requirement and the goal of most automotive EMI testing. Converters that cannot pass Class 5 EMI either get designed out of automotive circuits or must be encased in large metallic EMI shields. Even if the bulkiness of the shield does not create assembly issues, adding them is costly.

Buck-Boost for Multibeam Applications

LED headlight clusters can be both innovative and artistically creative. High beams and low beams can be wrapped up with nifty and distinctive daytime running lights (DRLs). Because the daytime running lights are only needed when high and low beams are off, a single LED driver can be used to power either the high and low beam LEDs or the daytime running lights. This only works if the LED driver has a flexible input-to-output ratio and can both step-up and step-down the input-to-output voltage. A buck-boost design satisfies this requirement.

The multibeam LT8391A buck-boost LED driver in Figure 5 can drive LED string voltages ranging from 3 V to 34 V. This enables it to drive both a low beam string and create a high beam by adding LEDs to the low beam string. The same driver switches over and drives a higher voltage, yet lower current, DRL. Switching from low beam-only LEDs to a low/high beam combo string generates no spike on the output voltage or LED current, as shown in Figure 6a. The LT8391A can smoothly transition between boost, 4-switch buck-boost, and buck regions of operation. Changing from a small number of LEDs to a high number of LEDs without an LED spike can be challenging for a converter, but this multibeam circuit does this with ease. Switching back from high and low beams to just low beams is also very clean, without any harmful LED spikes, as shown in Figure 6b.

The same is true when switching to and from the DRL string. Figure 6c demonstrates how the low beam is turned off and the DRL is smoothly connected to the output capacitor. Even the LED current is changed from 1 A (high and low beams) to 700 mA (8 LED DRL) without any issues. Other trim or signal LEDs can be added in as well, and the DRL can be blinked as a signal light. Figure 6d shows how the DRL can be PWM dimmed with the internally set PWM generator and then switched over smoothly to low beams when darkness falls.

Automotive environments require robust solutions in the face of short-circuits and open LEDs. Short- and open-circuit conditions are safely handled by the multibeam solution shown in Figure 6 and reported via the converter's fault flag.

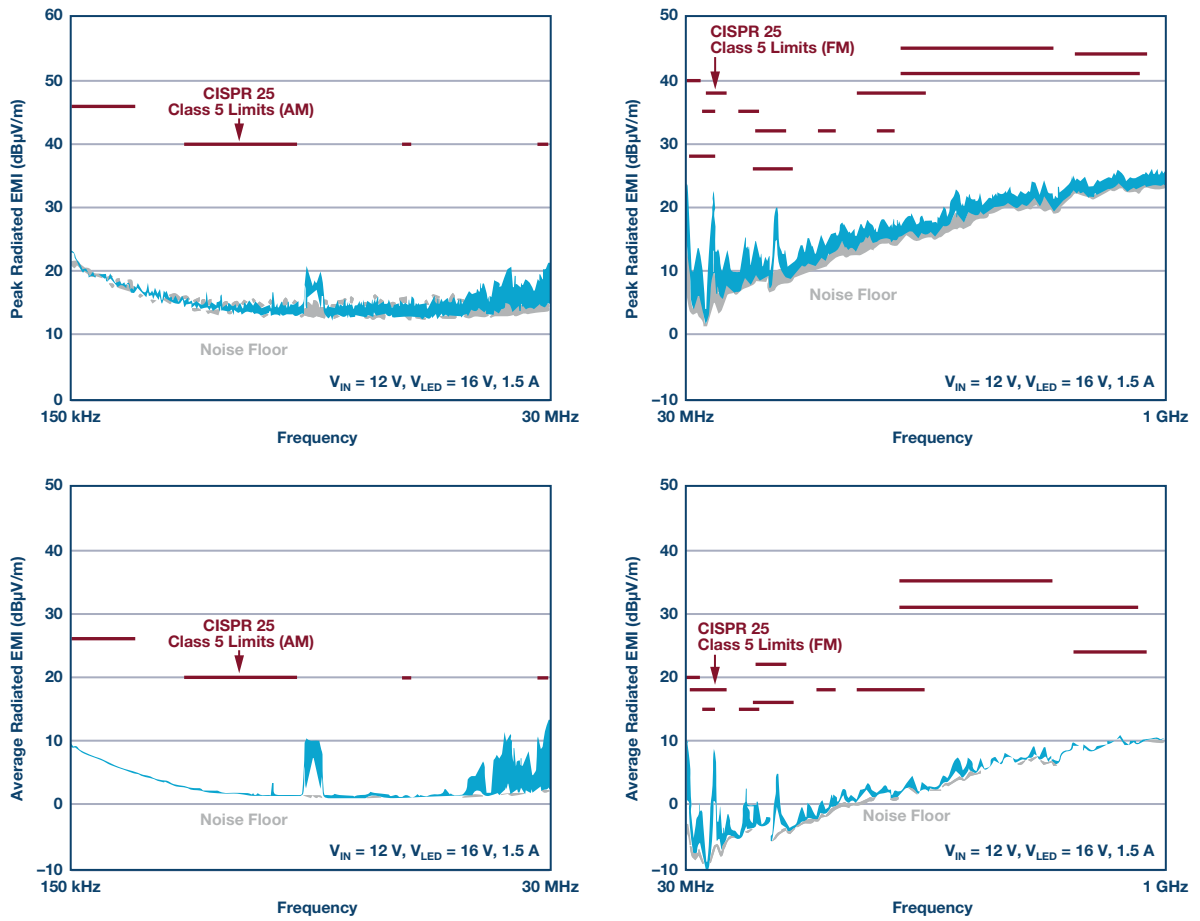


Figure 3. LT8391A demonstration circuit DC2575A passes CISPR 25 Class 5 automotive radiated EMI.

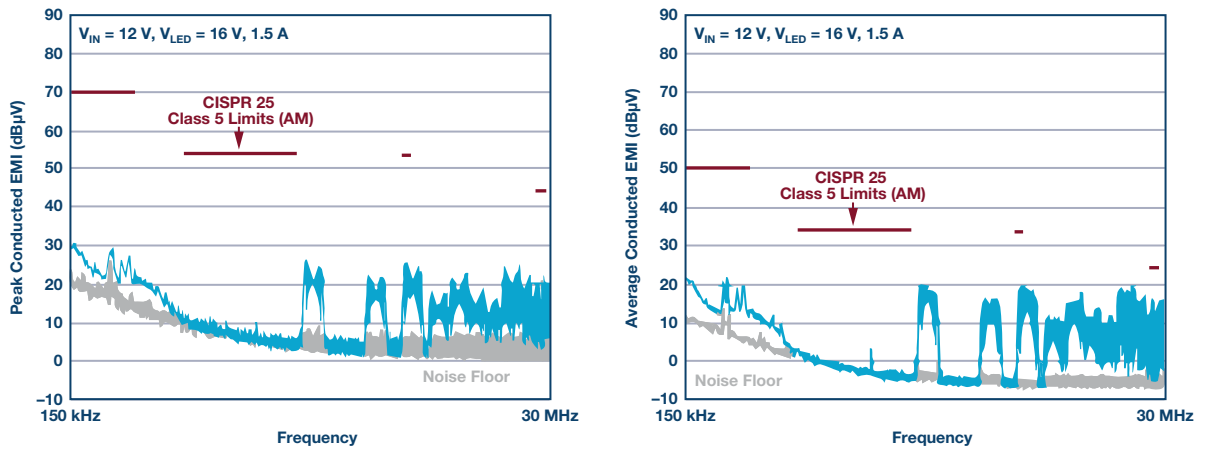


Figure 4. LT8391A demonstration circuit DC2575A passes CISPR 25 Class 5 automotive conducted EMI.

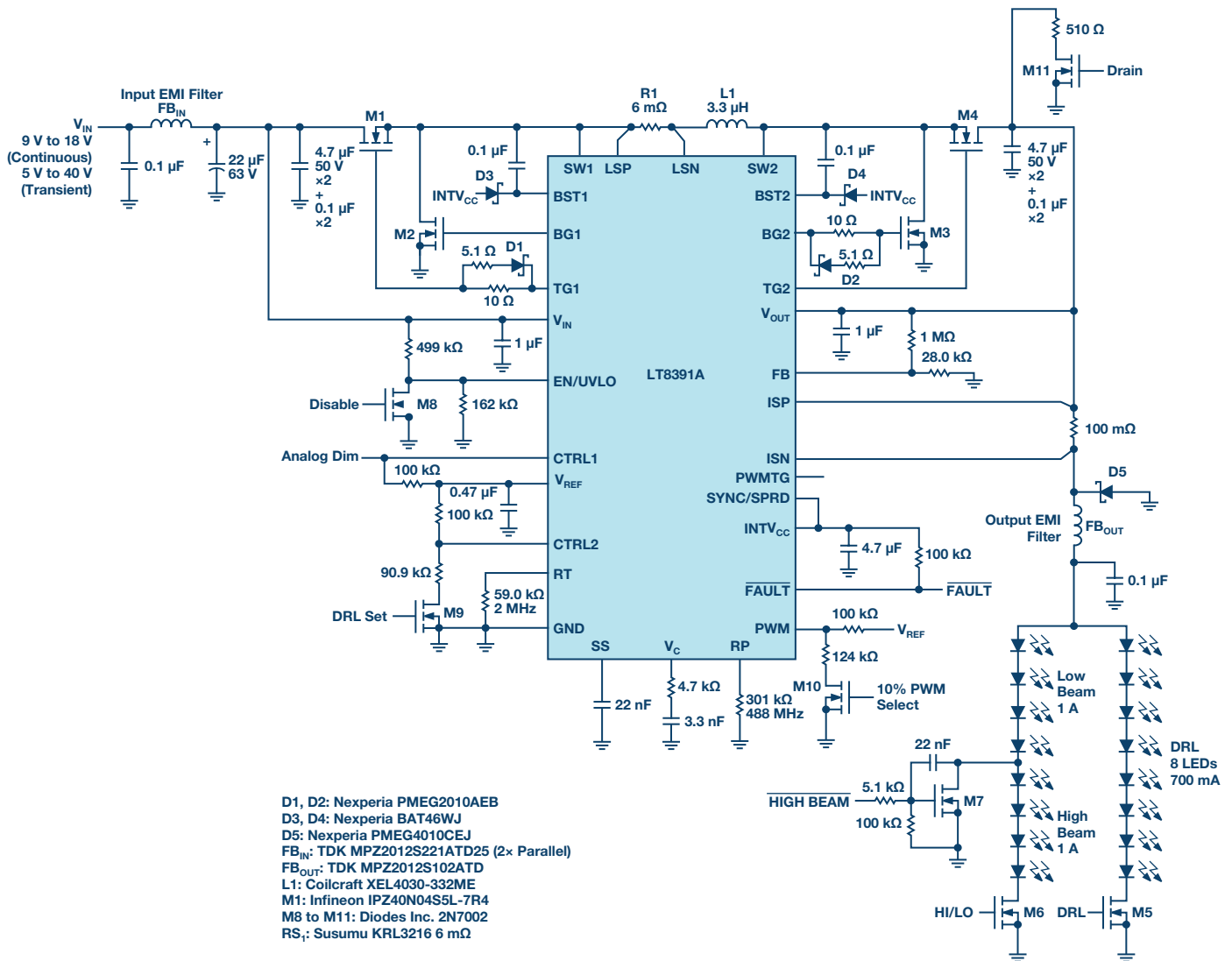


Figure 5. LT8391A multibeam LED headlight cluster solution for low, high, and DRL lights.

FE and QFN Packages Fit Tight Spots

The LT8391A is available in a 4 mm × 5 mm, 28-lead QFN to meet small size requirements and a 28-lead TSSOP FE package for automotive designs. Both packages have thermally enhanced GND pads for power dissipation of the internal INTVCC LDO from higher voltages.

The internal LDO INTVCC regulator of these converters can handle driving four synchronous MOSFETs at 2 MHz with about 15 nC gate charge. The small size of the LT8391A FE 2 MHz 16 V, 1.5 A demonstration circuit (DC2575A, based on the design of Figure 1) is shown in Figure 7. Only a single 5 mm × 5 mm inductor is necessary for this high power, versatile application.

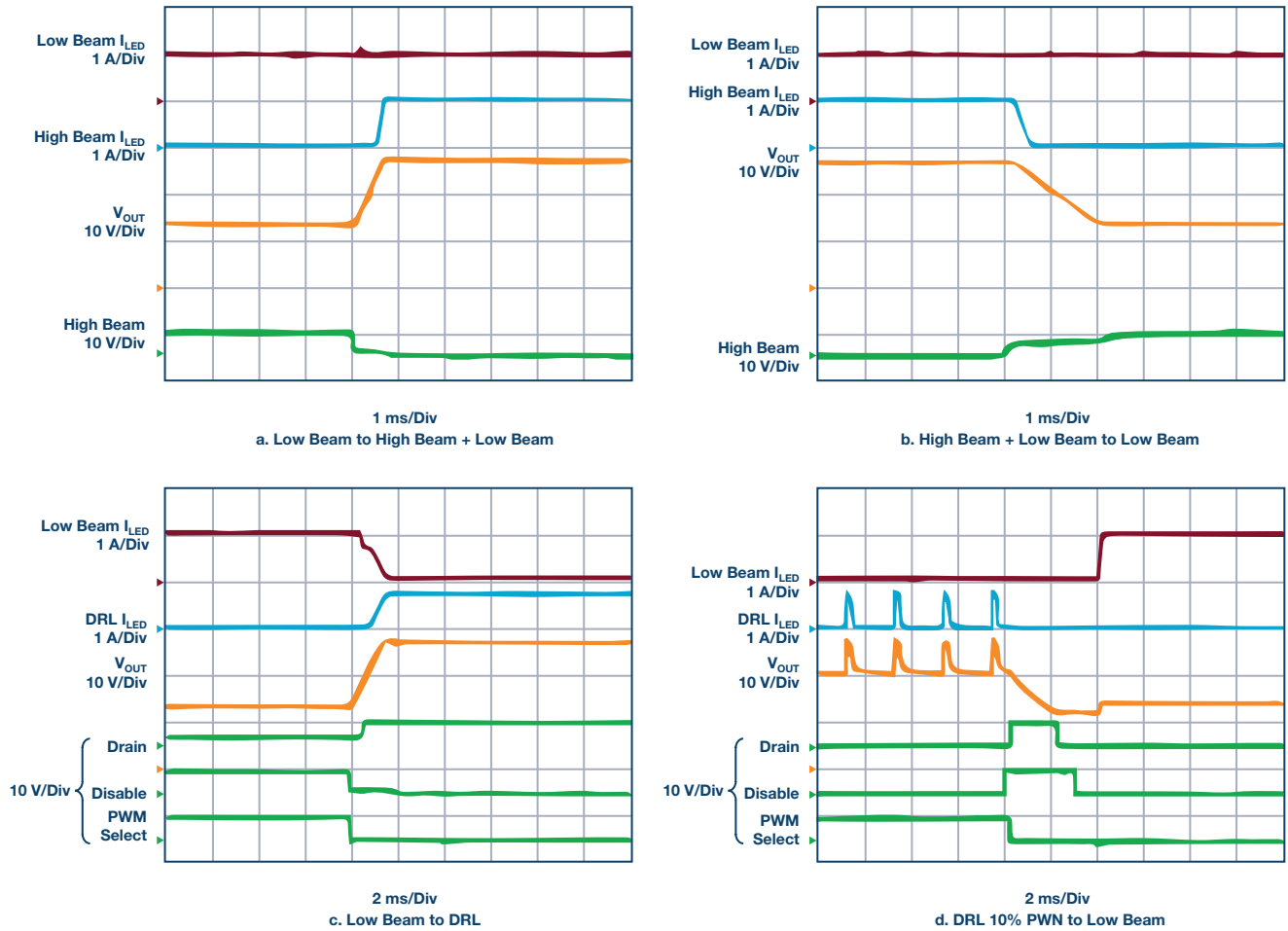


Figure 6. Waveforms show smooth switchover between high and low, low, and DRL LED strings for the LT8391A multibeam application in Figure 5.

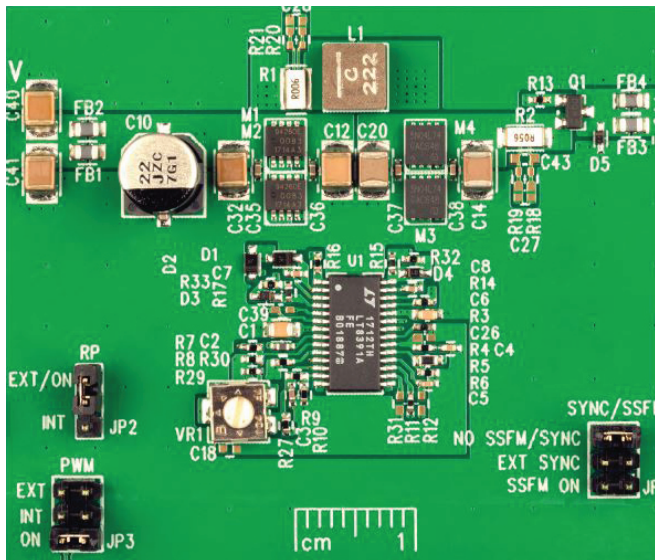


Figure 7. Compact solution: 2 MHz demonstration circuit DC2575A, featuring LT8391A, drives 16 V LEDs at 1.5 A.

Conclusion

The LT8391A 2 MHz, 60 V buck-boost LED driver controller powers LED strings in automotive headlights. Its features include its low EMI 4-switch architecture and spread spectrum frequency modulation for meeting CISPR 25 Class 5 EMI requirements. The unique, high switching frequency allows it to operate above the AM band, requiring very little EMI filtering. Its small size and versatility enable use in headlight cluster LED strings of a variety of voltages and currents.

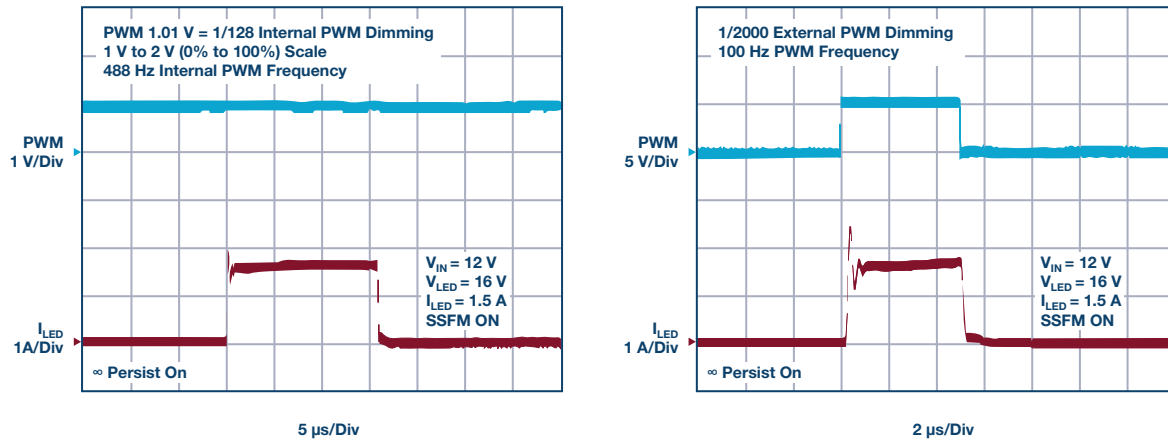


Figure 8. PWM dimming using internal and external PWM options; 1% and 0.05%, respectively.

Table 1. High power, High Efficiency Synchronous Buck-Boost Controllers for Automotive Power Solutions

	LT8390	LT8390A	LT8391	LT8391A
Voltage Regulator	x	x	x	
LED Driver			x	x
Automotive Input/Output Ranges to 60 V	x	x	150 kHz to 650 kHz	x
Switching Frequency	150 kHz to 650 kHz	600 kHz to 2 MHz	x	600 kHz to 2 MHz
Optimized Hot Loop Layout for Low EMI	x	x	x	x
Spread Spectrum Frequency Modulation for Low EMI	x	x	450 W+	x
Output Power	450 W+	50 W+	4 mm × 5 mm, 28-lead QFN, 28-lead TSSOP FE	50 W+
Package	4 mm × 5 mm, 28-lead QFN, 28-lead TSSOP FE	4 mm × 5 mm, 28-lead QFN, 28-lead TSSOP FE		4 mm × 5 mm, 28-lead QFN, 28-lead TSSOP FE

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