Designing Automotive LCD Panel Backlight Applications

LEDs are increasingly used as backlight for LCD panels in automotive applications. But under power line surges, electronic modules for automotive applications may suffer from an input voltage of 5 to 7 times higher than nominal. The surge voltage is clamped by external devices like TVS, while the clamped voltage is customer dependent. Electronic engineers always aim at designing electronic modules which can work with a wide input voltage range so that one single design can meet different requirements specified by different customers. This article introduces an LED driver consisting of a boost converter and a 2-channel linear current regulator. **LK Wong, TK Man, Texas Instruments, USA**

DC power in vehicles is provided by a power line which connects all electronic modules powered by the line, a battery, and an alternator driven by the engine of the vehicle. For typical 12 V or 24 V systems, a variation of ±30% in the power line voltage is normally seen. Therefore all electronic modules in automotive applications should take care of such input voltage variation. But during power line surges, the power line voltage rises tremendously. The ISO7637-2 defined pulses 2a and 5a and described some causes of surges (see Table 1). Pulse 2a considers a surge due to sudden interruption of currents in an electronic module powered by the line and the inductances of the wiring harness. Pulse 5a considers a surge due to a load dump transient occurring in the event of a discharged battery being disconnected while the alternator is generating charging current with other loads remaining on the alternator circuit at this moment.

A typical power line voltage profile describing the above surges is shown in Figure 1. It can be seen that the highest power line voltage can be 5 to 7 times of the nominal voltage. Although the duration of surges is not long, only 0.05 ms for pulse 2a and a few hundred milliseconds for pulse 5a, electronic modules connected directly to the power line may be damaged by such a high surge voltage. A common practice is to add an external component like a transient voltage suppressor (TVS) to clamp the peak power line voltage during power line surges. The value of the clamped voltage is customer dependent. However, designers of electronic modules always aim at application circuits which can work with a wide input voltage range so that one single design can suit for different requirements specified by different customers.

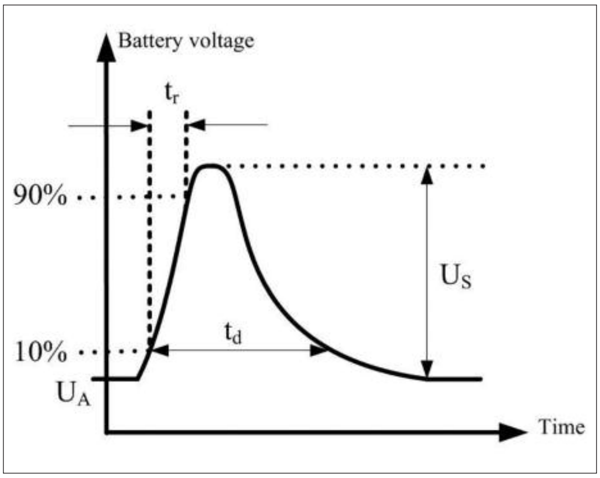

Figure 1: Profile of the power line voltage under surge

LED driver for automotive backlight application

LEDs are increasingly used as backlight for LCD panels in automotive applications because of the fast response time, high contrast ratio, and low power consumption of LEDs. LEDs are in general connecting in series to form a LED string (multiple LED strings can be used for large panels) so that one current regulator can regulate the current of many LEDs. The required driving voltage of a LED string is usually higher than the power line voltage (of 12 V or 24 V systems). In order to step up the power line voltage to drive the LED strings, a boost converter is normally used. A popular architecture of such step-up type LED driver consists of a boost converter and a multi-channel linear current regulator which drives multiple LED strings (as shown in Figure 2). The boost converter consists of an inductor L_1, a switch Q_1, a boost diode D_1 and an output capacitor C_{OUT}.

The input and output voltages are v_{IN} and v_{OUT} respectively. The LED strings 1 to n connects from v_{OUT} to the multi-channel linear current regulator and their forward voltage are represented by V_{LED1} to V_{LEDn}. The current of each LED string is regulated by linear current regulators 1 to n

Pulse	2a		5a
	12V system	24V system	12V system
U_A	13.5V	27V	13.5V
U_S	37V-50V		65V-87V
t_d	0.05ms		40ms-400ms
t_r	9,5µs – 10µs		5ms-10ms

Table 1: Parameters of ISO7637-2 pulses 2a and 5a

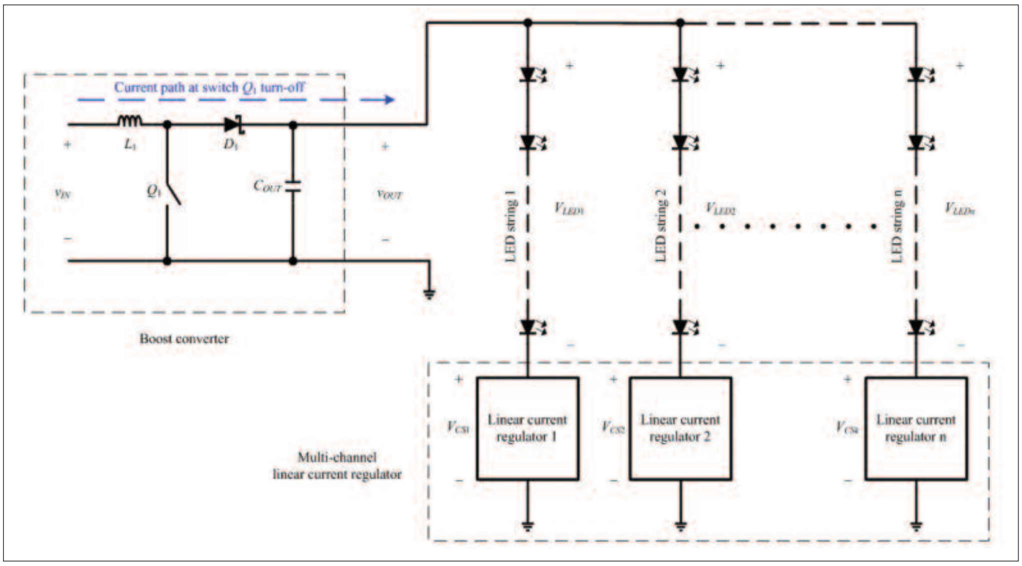

Figure 2: LED driver with a boost converter and a multi-channel linear current regulator

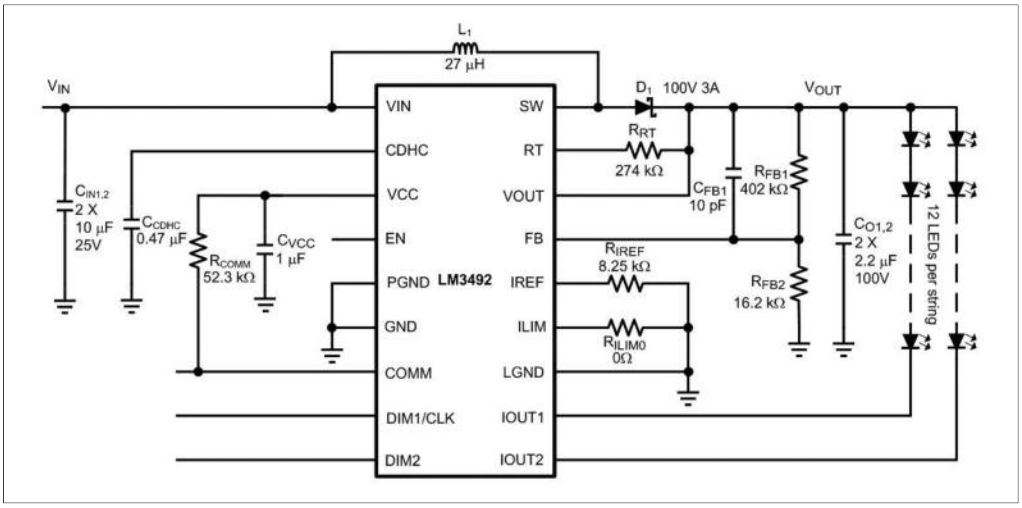

Figure 3: Schematic of the LM3492 LED driver for automotive LCD panel backlight

embedded in the multi-channel linear current regulator, and V_{CS1} to V_{CSn} represent the voltage drop on each linear current regulator.

Boost converter under power line surges

Under normal operation, v_{OUT} is regulated to a value which can fully turn on the LED strings and at the same time keep V_{CS1} to V_{CSn} to the minimum. For example, the forward voltage of an LED string (V_{LED1} to V_{LEDn}) with 12 LEDs in series is 38 V, and v_{OUT} can be 39 V if the typical voltage of V_{CS1} to V_{CSn} is 1 V. For 12 V or 24 V systems, v_{OUT} is therefore higher than v_{IN}. But under power line surge, when v_{IN} rise significantly, an abnormal condition that v_{IN} higher than v_{OUT} occurs. A direct response of the boost converter is to stop operation, i.e. to stop the switching of Q_1, and Q_1 stays turned-off. However, the boost diode D_1 is forward biased in this case, the inductor L_1 acts as a short circuit, and consequently a current path still exists (as shown in Figure 2). Hence, v_{OUT} approximately equals $v_{IN,PEAK}$, where $v_{IN,PEAK}$ is the clamped peak power line voltage under surges (depends on the external TVS). It is required that the maximum voltage of the boost controller IC and the drain voltage of the switch Q_1 (either external switch or switch integrated in the IC) should be higher than $v_{IN,PEAK}$. Otherwise, components may be damaged under surges.

An alternative approach to protect the boost converter is to insert a switch between the power line and the boost converter such that the switch turns off if surges detected. The major drawback of this approach is that the LEDs powered by the boost converter must turn off under surges. Therefore this alternative approach is not suitable for a design which is required to meet class A or B of the ISO Failure Mode Severity Classification (all functions of an electronic module perform as designed during and after exposure to interference for class A, and may go beyond the specified tolerance for class B).

Linear current regulator under power line surges

Under power line surges, v_{OUT} can rise to $v_{IN,PEAK}$. But the forward voltage of each LED string (V_{LED1} to V_{LEDn}) remains the same because the LED current, which is still regulated by the linear current regulator, is not affected. As a result, V_{CS1} to V_{CSn} increase significantly. For example, let V_{LED1} and V_{CS1} be 38 V and 1 V respectively under normal operation. If $v_{IN,PEAK}$ is 48 V under surges, V_{CS1} can be 10 V, which is 10 times more than normal. Since the current passing through the linear current regulators remains the same, a sudden increase of V_{CS1} to V_{CSn} drastically increases the power loss; If $v_{IN,PEAK}$ is larger, or V_{LED1} to V_{LEDn} is smaller, V_{CS1} to V_{CSn} is even larger. This increases the power loss of the linear current regulators and damaging may occur. A good design of the linear current regulator should be capable of reducing the regulated current in order to limit the power loss under surges.

Proposed circuit and measured results

A LED driver employing a boost converter and a 2-channel linear current regulator using the LM3492 from Texas Instruments is introduced in Figure 3. The circuit drives two LED strings, each of which consists of

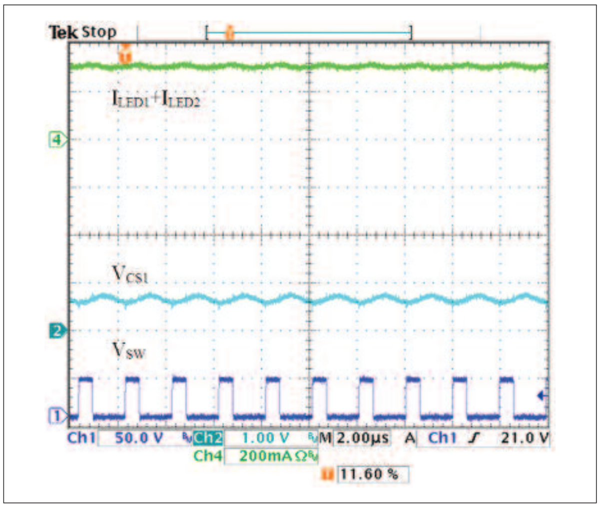

Figure 4: **Waveforms of the LM3492 under a nominal input voltage of 12 V**

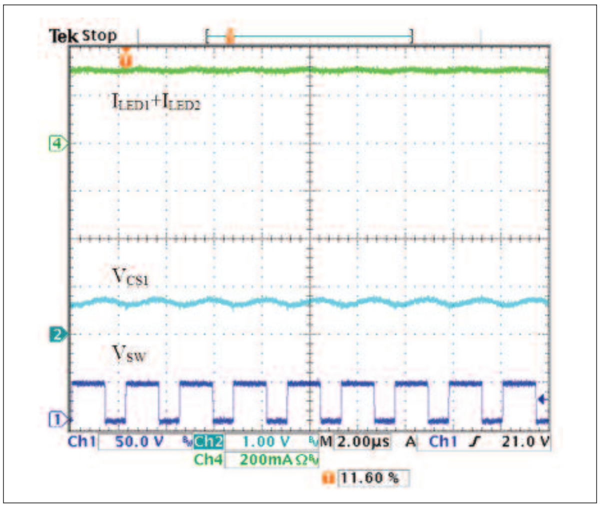

Figure 5: **Waveforms of the LM3492 under a nominal input voltage of 24 V**

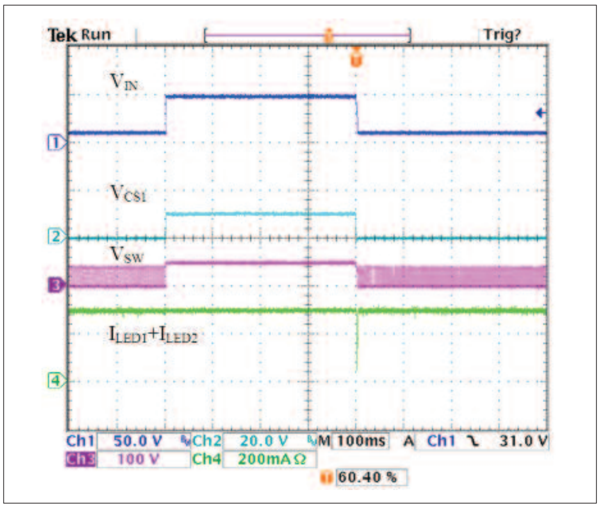

Figure 6: **Waveforms of the LM3492 under a 50 V surge at a nominal input voltage of 12 V**

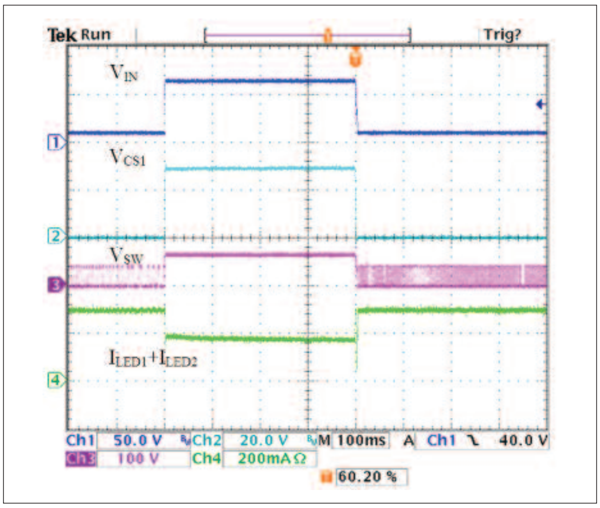

Figure 7: **Waveforms of the LM3492 under a 65 V surge at a nominal input voltage of 12 V**

12 LEDs running at 150 mA, with a nominal LED string forward voltage of 38 V. Figures 4 and 5 show the steady state waveforms of the voltages of the SW, IOUT1 (i.e. V_{CS1}, the voltage drop of the linear current regulator 1) pins of the LM3492 and the total LED current $I_{LED1}+I_{LED2}$ under normal input voltages of 12 V and 24 V respectively. It can be seen that V_{CS1} is below 1 V. Under surges with $V_{IN,PEAK}$ of 50 V (Figure 6), the boost converter stops operation (no switching is seen in the V_{SW} waveform). The total LED current remains unchanged, but V_{CS1} rises to about 9 V, meaning that the power loss is 9 times larger. When V_{IN} drops from the peak to the nominal, the boost converter is usually not turned on fast enough so that a small dip in the LED current is seen. If $V_{IN,PEAK}$ is increased to 65 V (Figure 7), V_{CS1} further rises to 27 V, but the total LED current is reduced to around 200 mA (i.e. 100 mA for each channel instead of 150 mA) by the internal over-power protection circuit in order to protect the linear current regulator.

Conclusion

LEDs are increasingly used as backlight for LCD panels in automotive applications. But under power line surges, electronic modules for automotive applications may suffer from an input voltage of 5 to 7 times higher than nominal. By applying a LED driver consisting of a boost converter and a 2-channel linear current regulator using the LM3492, the LED strings can still operate under surges, showing that the design can meet class A and B of the ISO Failure Mode Severity Classification. Waveforms of the introduced circuit under normal operation and surges are shown.