Over voltage management with TLD5190QU/QV

How to safely design the over voltage limit

About this document

Scope and purpose

TLD5190QU/QV is a 4 switches buck boost controller specially designed for LED application in the harsh automotive environment. Due to his synchronous topology, it perfectly fits for high power demanding application where the overall efficiency of the system has impacts on PCB size and heat sink.

The device can work as pure buck, buck boost and even pure boost mode, depending on the output voltage and input voltage. The transition between modes are seamless.

In case of high output current with low inductor, low output capacitor and with output voltage lower than input voltage, if a load current persists during overvoltage event, repetitive overvoltage triggering may occur with a frequency higher than switching activity. This prevents inductor current regulation and the output current may even increase.

This document explains how to properly design the over voltage limit in way to avoid this condition

Intended audience

This document is indented for hardware designer that want to efficiently use the over voltage protection with TLD5190QU/QV in buck or buck boost mode with high output current.

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1 System overview

For automotive application, LED manufacturers are developing and proposing in the market high power LED with extremely high current. Just as an example, OSLON Boost HX KW CULPM1.TG can be driven up to 6.6 A producing more than 2000 lm. Having a lot of light available on single point source enables to have simpler optic and also modern design for the headlamp.

With a small string with only two or even one LED, designer have to select buck or buck boost converters because they have to cover all the load and input voltage scenario. The requirement of current higher than 5 A forces the choice of synchronous topology and for this application, the TLD5190QU/QV perfect fits. Moreover, high current of LED string introduces some limitations on maximum inductor value, because, the higher saturation current, the lower the inductor value available on the market.

A preferred solution is then depicted on Figure 1

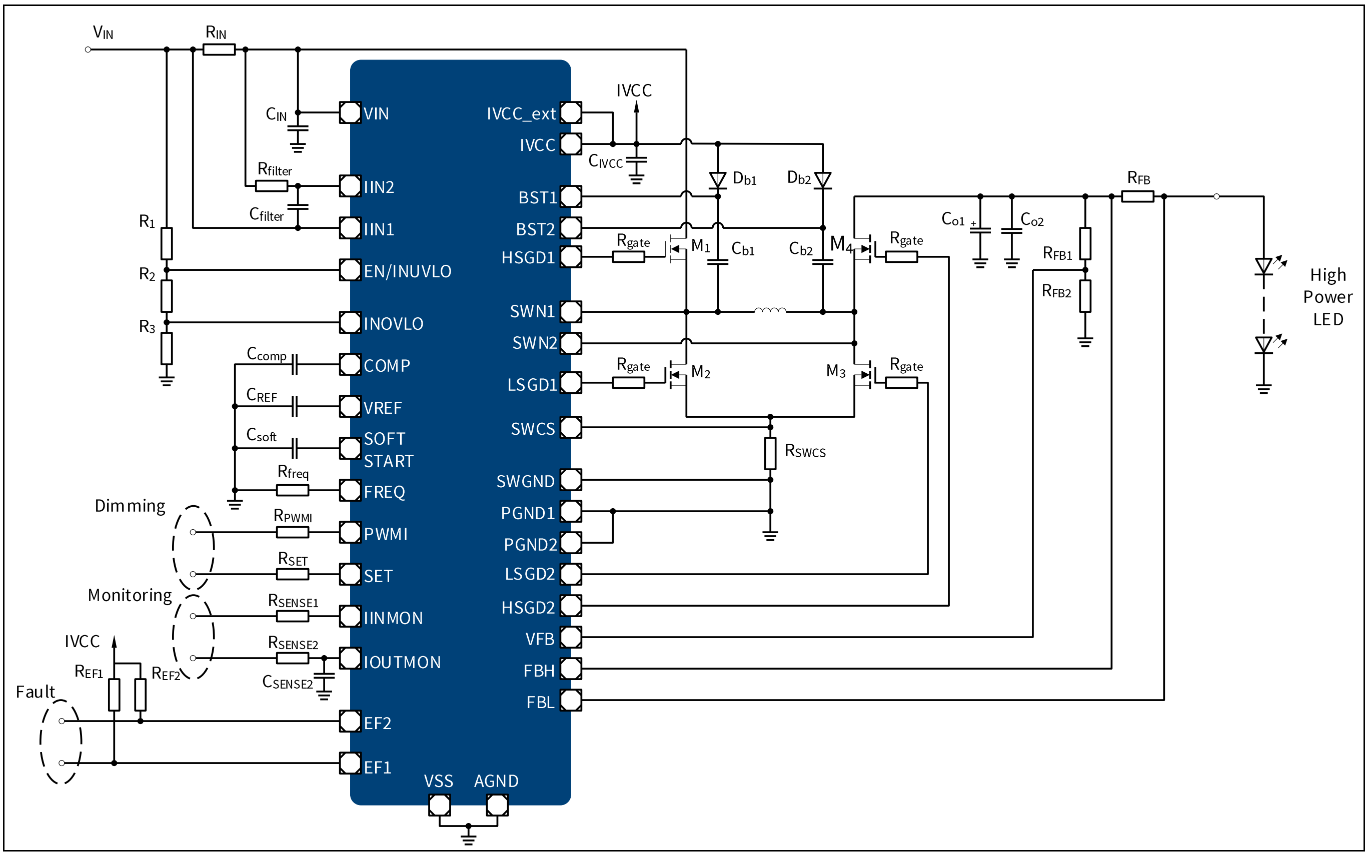

Figure 1 **Typical application with TLD5190QU/QV as current regulator**

2 Behavior during over voltage

Aging of LEDs usually produces a positive shift of forward voltage. If the forward voltage of the LED string hits the overvoltage protection threshold, then an over voltage event occurs even with output current at load side (LED not open).

With TLD5190QU/QV, an over voltage event is triggered when the voltage on voltage feedback pin VFB reaches the VFB over voltage feedback threshold (V_{VFB_OVTH}). Once its voltage touches the threshold, the device starts protection mechanism and goes through the following phases:

1. Phase 1: The device enters in over voltage fault state. The two high side MOSFETs will be turned off and the two low side MOSFETs will be turned on. Therefore the current path from the inductor into the output capacitance will be immediately stopped and the inductor current circulates through the low side MOSFETs. Also error flag EF2 toggles to low state in order to indicate the error state.
2. Phase 2: The device exits overvoltage conditions when the voltage on VFB pin decreases by the output over voltage feedback hysteresis ($V_{VGB\_OVTH,HYS}$) value. Then the device re-starts with one full cycle of HSGD1 and HSGD2 high; error flag EF2 returns to high state.
3. Phase 3: The device continuous in normal mode regulating the output current

There is the risk that in special application cases TLD5190QU/QV cannot reach phase 3 and permanently goes from phase 2 back to phase 1. This may be the case for applications where the output voltage can raise and drop very fast (e.g. when having high output currents, small output capacitors and low inductor value). Then special care has to be taken when designing overvoltage protection. In such cases overvoltage re-occur in phase 2 when the both high side gate drivers turn on and the inductor current is still on a high level and thereby output voltage shoots up to the overvoltage threshold again. That means that the TDL5190QU/QV can not enter phase 3 and therefore can not regulate the current. Thus overcurrent may occur.

This phenomena can be checked by monitoring the switching frequency of left side of H-bridge: the frequency triggered by overvoltage could be higher than the desired switching frequency of the DC/DC. This is also reflected on EF2 activity.

Behavior during over voltage

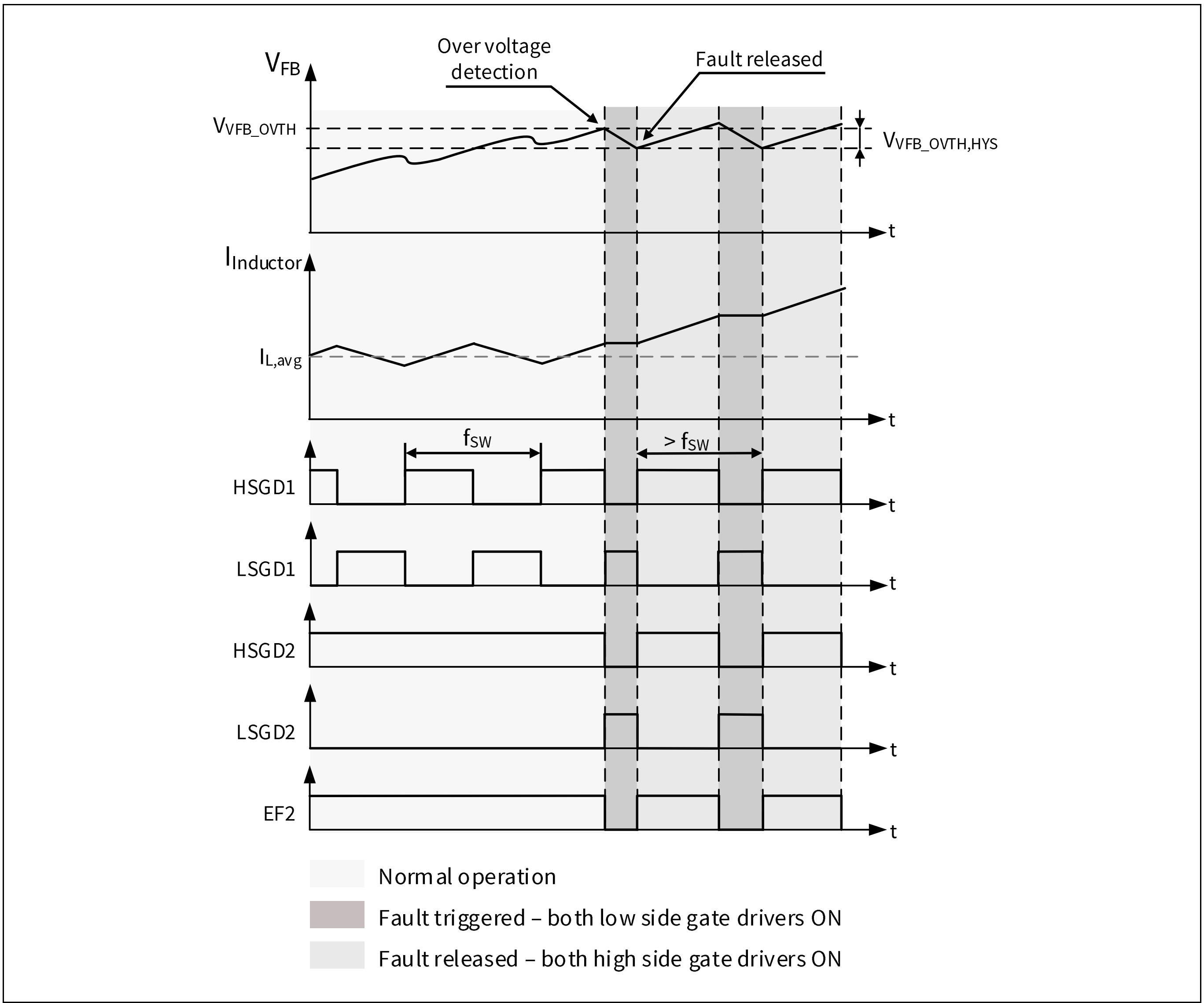

Figure 2 **Re-triggering of over voltage in buck mode**

3 The right system design of over voltage threshold

As reported in Section 2, if the over voltage threshold is reached, a hysteretic behavior could be triggered, losing the control of the inductor current.

A proper sizing of inductor and output capacitor are an efficient countermeasure if during the phase 2 the over voltage threshold is not re-triggered. This means the TLD5190QU/QV is able to keep the regulation of the inductor current. As a final result, the hysteretic behavior of the system has a frequency lower than the switching frequency of the device. As a design hints, the two points to be highlighted are:

- Having higher output capacitor allows to have longer duration time of phase 1
- Having higher inductor impacts on having lower voltage increase during high side ON time (phase 2).

In this case, the system performs the over voltage detection as depicted in Figure 3.

During the phase 1 state, the inductor current remains quite stable because it recirculate through low side MOSFETs (same behavior reported in Section 1), but when the device restarts with high side ON time (phase 2), the big inductor keeps the current more stable and the voltage do not touch the over voltage threshold. After that, the control loop is able to keep the regulation, changing the duty cycle of the left side of the bridge.

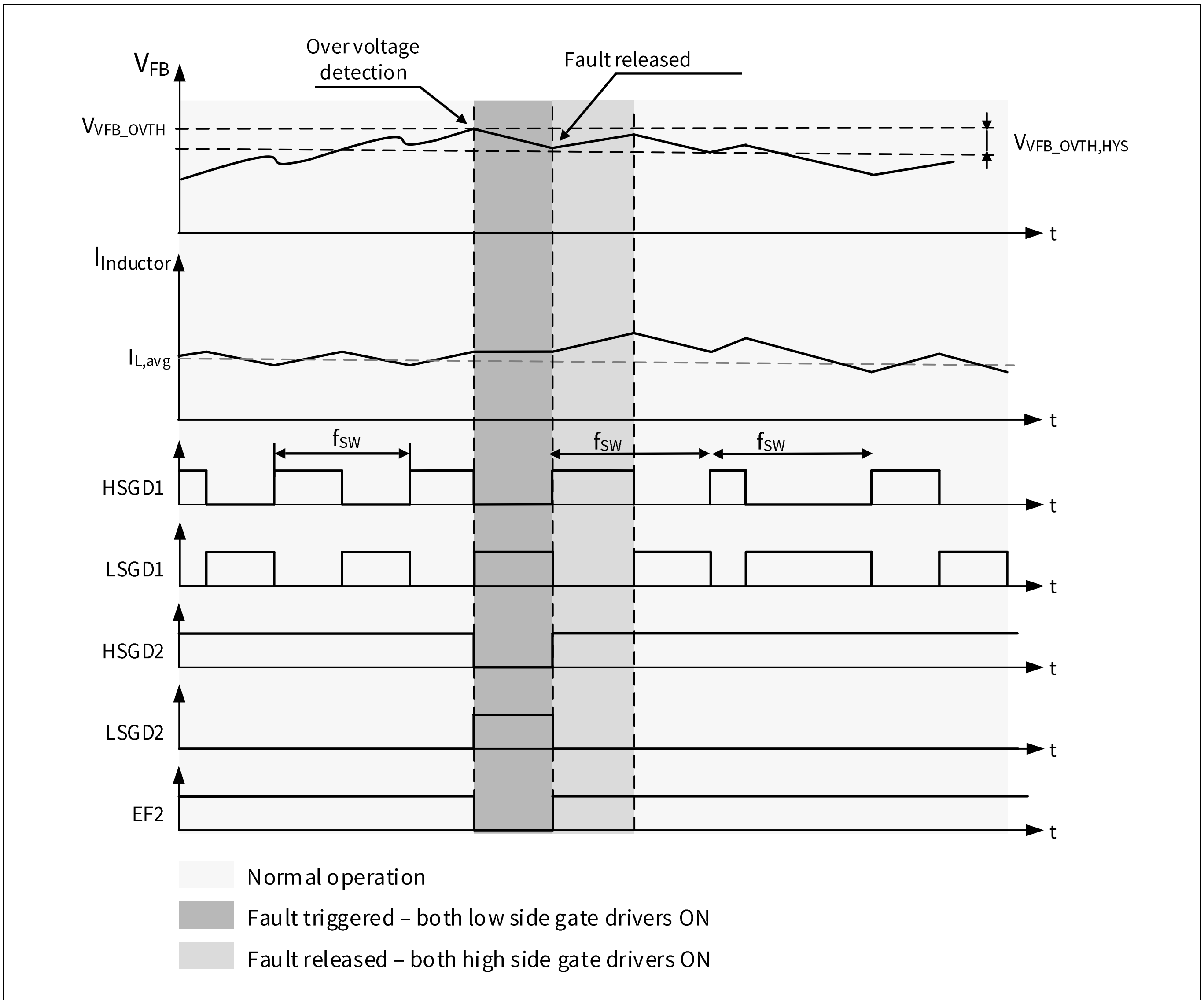

Figure 3 Over voltage behavior with increased inductor and output capacitor

The right system design of over voltage threshold

Sometime this design approach is not feasible, mainly because inductors with high saturation current are available only with low inductance value. Then, another way to avoid a continuous retriggering of over voltage event is to move the over voltage threshold above the maximum input voltage available.

As depicted in Figure 4, if the over voltage threshold is above the input voltage, during phase 2, the inductor current is discharged because with both high side gate driver in ON state the voltage across the inductor is negative ($V_{OUT} > V_{IN}$). Having the overvoltage higher than input voltage forces the DC/DC to work in boost mode when the fault is released.

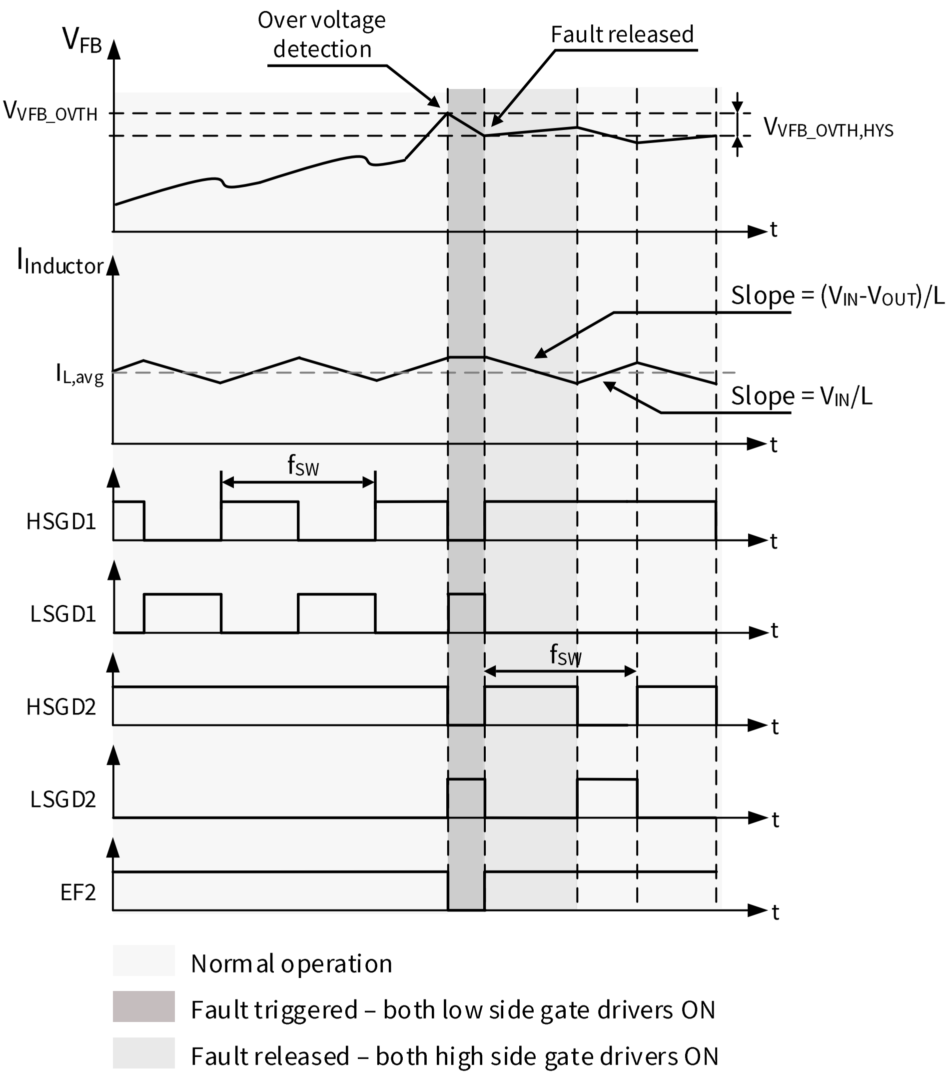

Figure 4 Behavior with over voltage threshold higher than input voltage

4 Conclusion

Over voltage threshold can be triggered due to aging of LED junction or due to increased resistance of the path (aging of contacts). If this protection is triggered in boost mode, the TLD5190QU/QV is able to keep the current under control. Special care has to be taken if the protection is triggered in special cases (e.g. when having high output currents, small output capacitors and low inductor value).

There are mainly two ways to avoid to trigger the hysteretic behavior: one is to use higher inductor and larger output capacitor, another way is to move the over voltage threshold above the maximum input voltage.

The first solution proposed can be used mainly if the output current is quite low, while the second solution works without limitation.

Revision history

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1.00	2020-02-12	First release

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