

# Improved Automotive Short Circuit Reliability Through Adjustable Current Limiting

Alec Forbes, Power Switches



Many automotive systems provide power distribution from a central ECU to common loads like lighting, heating, or cameras, and any automotive system that distributes power to these off-board load must be able to survive cable short-circuits to the car chassis. The high side switch is responsible for protecting the output during these fault cases, however, traditional high side switches attempt a universal protection scheme with a much higher than necessary current limit. This means protection cannot be guaranteed in all cases, leading directly to requirements for higher cost and complexity safeguards to guarantee robustness during soft short circuit events.

In contrast, TI High Side Switches integrate an adjustable current limit ( $I_{LIM}$ ) to offer improved protection against short circuit events. By guaranteeing a quick response, transient currents and supply droop are minimized, allowing automotive manufacturers to maintain high reliability and simplify system design.



Figure 1. Short Circuit Event

When a short circuit occurs, a low impedance current path is created that can draw hundreds of amps from the car battery through the high side switch. When this transient current passes through a high side switch, the internal  $I_{LIM}$  registers an overcurrent event and shuts off the switch, preventing current flow.

However, in an attempt to enable universal usage, traditional high side switches implement a fixed current limit that is often up to 10 times higher than the max load current. Meanwhile, to enable higher reliability regardless of the load type, TI high side switches integrate an adjustable  $I_{LIM}$  that enables a system to be optimally designed for specific loads. Table 1 shows the comparison between TI's  $I_{LIM}$  and traditional high side switch's  $I_{LIM}$ .

Table 1. High Side Switch  $I_{LIM}$  Characteristics

On Resistance	Maximum DC Current	Typical Fixed $I_{LIM}$	TI Adjustable $I_{LIM}$
8 m $\Omega$	12 A	90 A	Down to 6.4 A
16 m $\Omega$	8 A	60 A	Down to 4.4 A
50 m $\Omega$	4 A	30 A	Down to 1.6 A
100 m $\Omega$	3 A	25 A	Down to 0.5 A

With a fixed  $I_{LIM}$ , it's impossible to design a system to fit specific application and load requirements and as a consequence short-circuit reliability suffers. The TI adjustable  $I_{LIM}$  functionality enables the system to be designed to be ideal for any given load, simplifying protection against short-circuit events without sacrificing reliability or adding cost.

## Benefits of a Lower Current Limit

Lets look at an example of an ECU using the TI TPS2HB08-Q1 8 m $\Omega$  high side to drive a 10 A load in a seat heater application. The system includes an input cable with a 50 m $\Omega$  and an output cable with a 80 m $\Omega$  resistance.

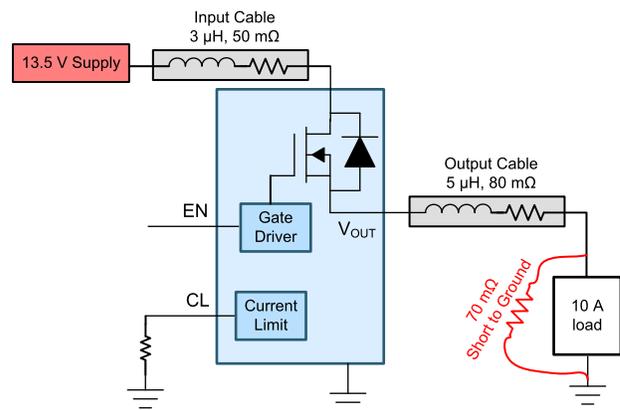


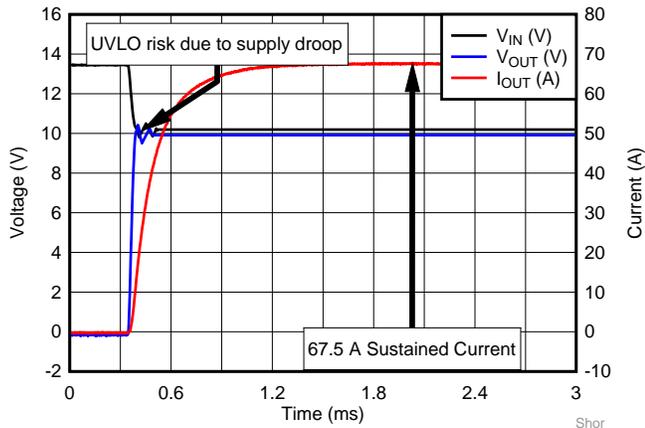
Figure 2. Short Circuit Event

Since most shorts occur through elements like long cables or corrosion there is almost always series impedance that must be included in the short-circuit analysis. This means that while the output current will rise to unsafe levels, it is still ultimately limited by series impedance. In this example, in addition to the cables we assume a 70 m $\Omega$  short-circuit resistance.

The next two sections will examine the impact of the  $I_{LIM}$  setpoint on the system behavior during this type of short circuit event.

### Short Circuit Detection with a Fixed $I_{LIM}$

The short-circuit event will cause the output current to increase until reaching a steady state; with a 13.5 V output through 200 m $\Omega$ , this will be 67.5 A, well above the operating max current of 10 A. A high side switch with a fixed internal  $I_{LIM}$  of 90 A will not register an overcurrent event, as  $I_{LOAD}$  is still below the device fixed  $I_{LIM}$ . This behavior is shown in Figure 3



**Figure 3. Short Circuit Waveform (Fixed High  $I_{LIM}$ )**

The waveform shows that the system will provide a constant 67.5 A until a system element shuts down the output. Two events can trigger this shutdown:

- The device can hit thermal shutdown due to overheating from the current
- A secondary method of fault detection can trigger an overcurrent interrupt such as current monitoring

Both methods will expose the system to extremely high transient current that can cause damage if the system is not designed to handle them.

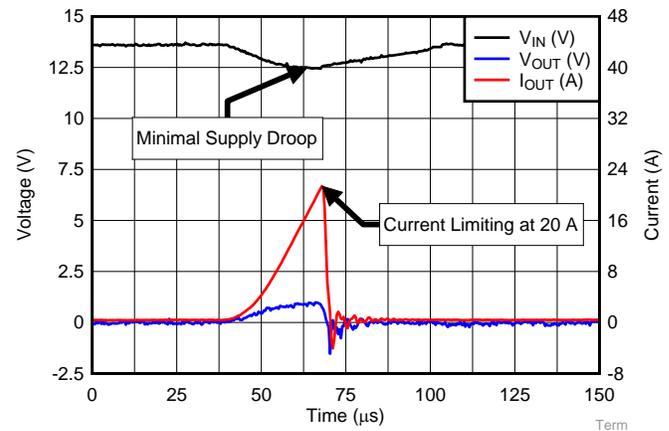
In case the system relies on thermal shutdown, a typical 8 m $\Omega$  high side switch will sustain current for 10-20 milliseconds before shutting down. Managing this transient current flow directly leads to higher cost and complexity systems - cabling, copper traces, connectors, supplies, and system IC's must all be rated to handle 10-20 ms of 67.5 A current flow.

In case the system relies on a monitoring scheme, the designer must introduce an additional fault detection method either through introducing additional IC's or adding additional monitoring from existing MCU's. Regardless, quickly registering this short circuit event requires additional system complexity and cost.

In addition to the transient current, during the event the upstream supply will significantly droop. The input and output cables create a voltage divider that will pull  $V_{IN}$  down from 13.5 V to 10.1 V. This means that any other IC's using the same supply input will see a large supply droop and have a risk of triggering UVLO, shutting down the entire system.

### Short Circuit Detection with an Adjustable $I_{LIM}$

In contrast, using the TPS2HB08-Q1, the system can be simplified without sacrificing reliability. Because the  $I_{LIM}$  threshold can be set at 20 A, this short will immediately trigger an overcurrent event and the TPS2HB08-Q1 will prevent current flow within a few microseconds, without the need for any external protection or increased margins on other system components. This behavior is shown in Figure 4.



**Figure 4. Short Circuit Waveform (Adjustable  $I_{LIM}$ )**

Instead of a large transient current and extended supply droop, we see only a very short current transient and a short supply droop that will minimally impact the system.

### Conclusion

Traditional high side switches cannot reliably protect against all types of short circuits in automotive environments, leading to the risk of high transient currents and supply drop out. In contrast, TI high side switches integrate an adjustable current limit to enable more robust short circuit protection. By designing the output current limit to a specific load requirement, the overall system reliability is increased without adding any cost or complexity.

**Table 2. Device Recommendations**

Device	Channel Count	$R_{ON}$ (m $\Omega$ )	$I_{LIM}$ Range (A)
<a href="#">TPS2HB08-Q1</a>	2	8	6.4 A - 70 A
<a href="#">TPS2HB16-Q1</a>	2	16	4.4 A - 49 A
<a href="#">TPS2HB35-Q1</a>	2	35	2 A - 30 A
<a href="#">TPS2HB50-Q1</a>	2	50	1.6 A - 22 A
<a href="#">TPS1H100-Q1</a>	1	100	0.5 A - 7 A
<a href="#">TPS4H160-Q1</a>	4	160	0.25 A - 8 A
<a href="#">TPS1H200-Q1</a>	1	200	0.25 A - 1.5 A

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