Easy Automotive Power Supplies: Compact Regulator Produces Dual Outputs as Low as 0.8V from 3.6V–36V and is Unfazed by 60V Transients

by Peter J. Andrews

Introduction

The LT3509 dual channel step-down regulator operates over an impressively vast supply range of 3.6V to more than 36V, but its real distinguishing feature is its ability to handily protect both itself and downstream components from transient input voltages up to 60V. It accomplishes this by entering a safe shutdown mode when the supply exceeds 38V, such as load dump events in automotive electrical systems.

In a vehicle electrical system, overvoltage transients can occur when heavy loads are switched because the rapid change in current across the wiring inductance induces a high voltage. These transients are usually short in duration, from several microseconds to several milliseconds. Longer duration voltage surges can happen when the battery is disconnected and the alternator and its regulator must respond to reduce the energizing field in the rotor. This can take several hundred milliseconds, enough time to damage electronic components and subsystems.

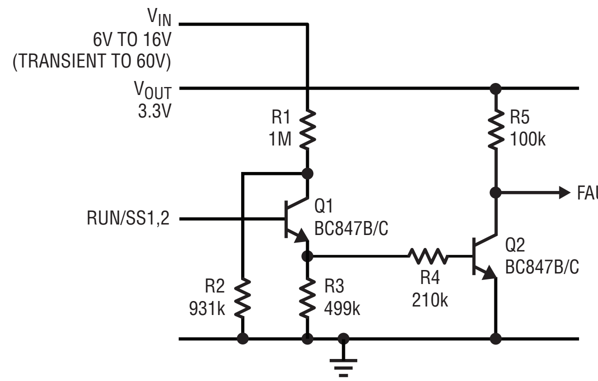

Figure 1. LT3509 RUN/SS to FAULT signal interface

The LT3509 protects itself and downstream systems from transient overvoltage events by shutting down for the duration of the event. For non-critical systems, that is all the protection that is needed, as long as power is restored relatively quickly. For critical systems that require full functionality during a transient event, a supercapacitor ride-through circuit can continue to provide hold-up power (see Linear Technology Design Note 450 or the cover article from the September 2008 issue of *Linear Technology* magazine). This article shows a circuit that allows powered systems to ride-through transients without requiring a reset.

A Little About the LT3509

The LT3509 integrates popular high voltage features into a compact dual supply solution for a wide range of applications. Each of two channels can produce up to 0.7A at an output voltage as low as 0.8V to within a

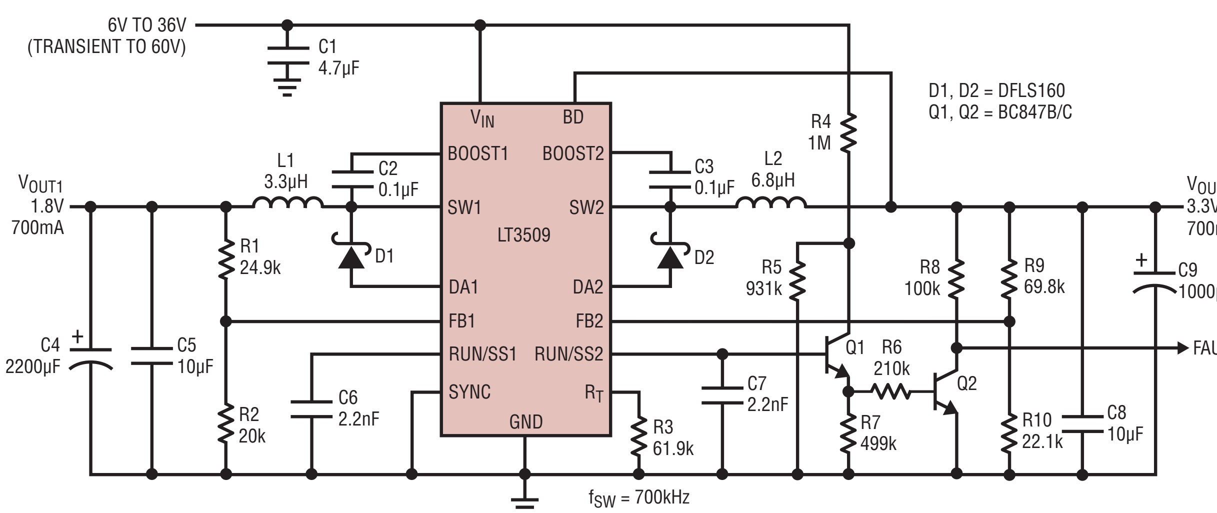

Figure 2. 12V auto battery to 3.3V and 1.8V with hold-up capacitors and FAULT indicator

half a volt of the input supply. It has integrated BOOST diodes and internal compensation to minimize the component count and the required board area. Robust short-circuit protection is also provided using catch diode current sensing. The ride-through feature is particularly useful in automotive applications, as is the wide operating frequency range of 300kHz to 2.2MHz and the ability to synchronize to an external reference clock. The switching frequency can be chosen or externally driven to meet stringent EMI requirements.

Riding Through Supply Transients

One way to reduce the ride-through energy storage requirements is to provide a FAULT signal to the powered systems so that that they can enter a low power state for the duration of the event. For example a microcontroller could enter a HALT state, digital circuitry could stop or reduce the clock frequency, displays could be blanked and audio circuits muted. This reduces the power draw to a minimum so that the output voltages can be maintained with relatively small electrolytic capacitors.

The LT3509 itself does not provide a dedicated logic signal to indicate that an overvoltage event has occurred but it is possible to detect the event by monitoring the RUN/SS pins. These pins are pulled low by an internal device whenever an overvoltage condition exists, but as they were not intended to drive logic directly a small interface circuit is required as shown in Figure 1. The RUN/SS pins are pulled up to approximately 3.0V by an internal 1µA pull-up in normal operation and are pulled to about 0.6V during a fault condition. This circuit has a switching threshold of around 1.4V and draws very little input current. The circuit operates at a very low current and the transistors were carefully selected—generic types may not give satisfactory performance. Q1's collector must be supplied from V_{IN} with a resistor divider as shown. If connected to V_{OUT}, the collector base junction will be forward biased at power-up and thus preventing the LT3509 from starting up. The resistor divider keeps the collector-emitter voltage of Q1 below its breakdown voltage.

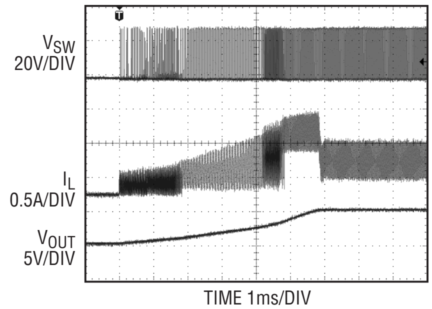

Figure 3. Soft-start waveforms

Automotive Accessory Supply 3.3V and 1.8V with Ride-Through Capability

The schematic in Figure 2 shows a typical application for a dual supply system requiring 3.3V and 1.8V rails, such as a radio or satellite navigation system. The goal is to maintain support for a ride-through capability described in the introduction where the output voltage is maintained just long enough for the powered circuitry to enter a low current state. The key features are that it includes the fault indication circuit of Figure 1 and the standard 10µF ceramic output capacitors C5 and C8 are augmented with 1000µF electrolytic capacitors C4 and C9. The ceramic capacitors should still be used to control high frequency ripple as they have much lower ESR than the electrolytic types.

The operating frequency is kept low to ensure that the 1.8V channel operates in fixed frequency mode at the normal operating voltage. The output capacitors have to support the output voltage while the regulator shuts off due to an overvoltage ride-through event. They must also supply the full load current for the time taken from the start of the overvoltage event until the load is put in a powered down state. The delay time from the overvoltage condition until the fault signal is asserted is dependent on the capacitor value on the RUN/SS pin. With the component values in the example circuit this is approximately 40µs. To this must be added any time for the powered circuit to shut down. The voltage droop during this time can be calculated from $\Delta V = I \bullet t/C$. So for 700mA, 40µs and 1000µF gives $\Delta V = 0.7A \bullet 40\mu s/1000\mu F = 28mV$.

Once the powered circuits have shut down, the droop rate depends on the residual current draw and the duration of the transient event. In an ideal case the system power should reduce to a few µA in which case the dominant current draw will be from the feedback divider, which in the example circuit takes around 37µA. Using the same equation, for a 400ms event, the droop during the transient is: $\Delta V = 40\mu A \bullet 0.4s/1000\mu F = 16mV$. Clearly the biggest droop occurs during the initial loss of power.

One last thing to consider is what happens when the transient is finished and normal operation resumes. The FAULT signal de-asserts as soon as the RUN/SS pin rises above the threshold, but the regulator is not able to deliver full current until the RUN/SS pin reaches approximately 2V. It may be necessary to create a small delay,

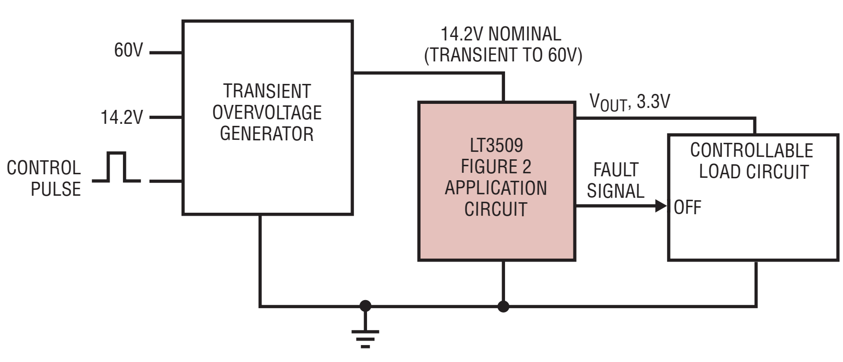

Figure 4. Test and demonstration set-up

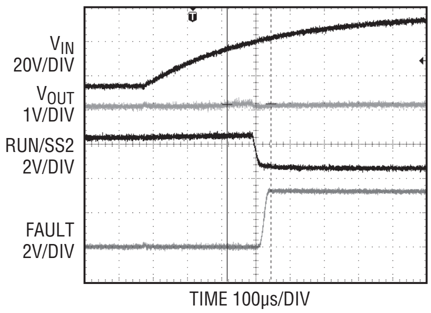

Figure 5. Transition to ride-through mode

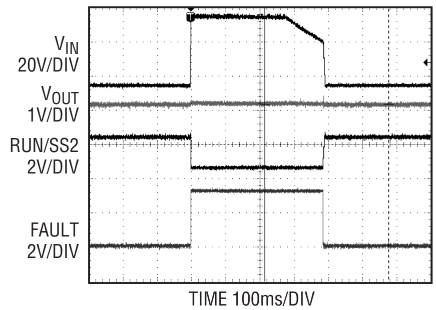

Figure 6. Complete ride-through event

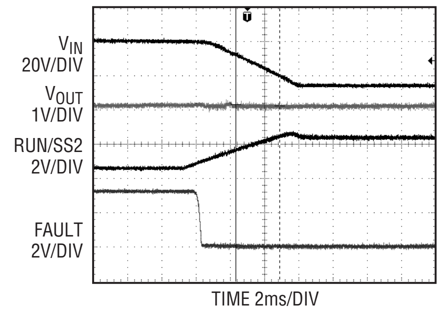

Figure 7. End of ride-through event

by software perhaps, from the time FAULT goes away until full current is demanded.

The LT3509 prevents inrush currents at start-up with a current limiting soft-start feature, which allows the available output current to ramp up slowly. Both the peak current limit and the valley current limit (the one sensed through the catch diodes) are controlled by the voltage on the RUN/SS pins, so as capacitors C6 and C7 charge up, the output current slowly increases to its normal maximum value. An example of the soft-start characteristic is shown in Figure 3.

Demonstration and Test Results

The ride-through performance the application of Figure 1 is tested using the setup shown in Figure 4. A switched supply produces either a normal input or an overvoltage transient. The output is connected to an active load circuit with ON/OFF controlled by the FAULT signal. Figure 5 shows the start of the overvoltage event on a fast time base to show the step that occurs as the regulator shuts off, but before the load is reduced. Figure 6 shows the entire 400ms transient and the droop that happens when there is no output but also very little load. Figure 7 shows the end of the event on an expanded timescale.

Conclusion

Overvoltage transients are a fact of life in automobile and industrial power systems. The LT3509, combined with a small, low cost capacitor, can be used to both protect components from overvoltage transients and allow the downstream systems to ride through the event without having to completely reset. It is possible to ride through an overvoltage transient of even several hundred milliseconds, provided a brief interruption of service can be tolerated.

LTC4265, continued from page 29

is applied. That is, the DC/DC converter continues to operate through the power transition. But the transition from auxiliary power to PoE power (when the auxiliary is removed) is not seamless since a PSE must redetect the PD before applying power.

Guidelines for Pairing the LTC4265 with a DC/DC Converter

The LTC4265 can be paired with just about any DC/DC converter, but two are particularly well suited to Type-2 Power over Ethernet Applications: the LT3825 flyback controller and LT1952 forward controller. Forward and flyback converters satisfy the electronic isolation requirement in the IEEE 802.3af and IEEE 802.3at specifications. In addition to the topology requirements, the LT3825 and LT1952 controllers are selected based on their ability to tolerate the wide PoE line voltage range, which varies from 36V to 57V.

As PoE power levels increase, the Schottky diode typically placed at the output of the secondary winding becomes an efficiency drain as it dissipates more power with increased output current. In addition, the output diode requires a considerably large heat sink and board area to displace the heat.

For these reasons, many power-hungry PDs are better served by synchronous DC/DC topologies, where the output diode is replaced with an active switch synchronized to the operation of the controller. Both the LT3825 and LT1952 include built-in synchronous drivers, enabling the use of an active switch.

Figure 5 shows the LTC4265 paired with an LT1952 in a self-driven synchronous forward power supply configuration. Figure 6 shows the LTC4265 paired with a LT3825. This is a synchronous flyback power supply configuration with no optoisolator feedback. The LT3825 may also be configured for a forward topology.

These are not the only DC/DC converter solutions that work well with the LTC4265. The LTC4265 can be easily applied in applications that already have a DC/DC converter.

Conclusion

The LTC4265 PD interface provides the features required in a PD interface to operate under the IEEE 802.3at standard with minimum component count. Since all of the features (signature resistance, UVLO, OVLO, inrush current, and thermal protection) are built in, little is needed around its low profile 4mm × 3mm DFN package to create a complete PoE Type-2 interface. Simply pair it with a PoE-ready DC/DC converter by hooking up the Type-2 and power good indicator pins, and a high power PD is ready to go. Add to this the ability to handle auxiliary power, and the LTC4265 proves a versatile PoE+ tool.