Automotive Surge Suppression Devices Can Be Replaced with High Voltage IC

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Background

Truck, automotive and heavy equipment environments are very demanding for any type of power conversion devices. Wide operating voltage ranges, coupled with large transients and wide temperature excursions, combine to make reliable and robust electronic system design challenging. Further, some applications require installation of power conversion devices under the hood, so 150°C operating capability is needed. At the same time, the number of electronic components is increasing, space requirements are shrinking, making high efficiency and high input surge voltage ride-through even more critical.

Whether it's a load dump, cold crank or high temperature under the hood, automotive onboard power supplies need to be designed to operate reliably under all of these conditions. Under normal steady state conditions, a 12V battery system only varies from about 9V to 18V and a 24V system varies about 21V to 36V. However**,** during a load dump transient, voltages in excess of 120V can be generated for hundreds of milliseconds. A load-dump occurs when the alternator is charging the vehicle's battery and an electrical open-circuit causes a momentary disconnection of the battery from the alternator – a very common phenomena. Until the voltage regulator can respond**,** the full alternator charging current is applied directly to the automotive power bus**,** raising its voltage to potentially dangerous levels. Such a transient could be caused through a physical disconnection and could also result from a faulty connection in the battery cable or corrosion at the battery terminals.

Other physical factors in vehicular design are also a concern. In particular there are long power supply lines that feed from the power distribution box in the engine compartment to the distant corners of the vehicle. The average automobile has approximately 1 mile of copper wire, compared to just 150 feet in 1948. Because of the inductive characteristics of long leads, there are even higher transient levels than those that occur during a load dump. The governing specification for tail light electronics is that they must be able to withstand transients of +100V. This can be a challenge for IC-based electronics such as LED tail light regulators.

Moreover, there are several electronic systems that require continuous power even when the vehicle's motor is not running, such as remote keyless entry, GPS and security systems. It is essential for these types of "always-on" systems to have a DC/DC converter with low quiescent current in order to maximize the battery run time when in sleep mode. Under such circumstances, the regulator runs in normal continuous switching mode until the output current drops below a predetermined threshold of around 30mA to 50mA. Below this level, the switching regulator must go into lower quiescent current operation in order to reduce the current draw, thereby reducing the power drawn from the battery, which in turn extends its run time.

Critical systems must survive, and must also function seamlessly through such transients without interruption. Until now, most vehicles have used a passive protection network consisting of a low-pass LC filter and a transient voltage suppression array to clamp the peak voltage excursions of the power bus. However, a recently released high input voltage DC/DC step-down controller can operate through these high voltage surges and protect downstream components without the need of additional surge suppression devices.

A New IC Solution

The LTC3895 is non-isolated synchronous step-down switching regulator controller that drives all N-channel MOSFET power stages. Its 4V to 140V (150V abs max) input voltage range is designed to operate from a high input voltage source or from an input that has high voltage surges, eliminating the need for external surge suppression devices. The LTC3895 continues to operate at up to 100% duty cycle during input voltage dips down to 4V, making it well suited for automotive, truck and heavy equipment applications.

The output voltage can be set from 0.8V to 60V, with output currents up to 20 amps and efficiencies as high as 96%. This part draws only 40µA in sleep mode with the output voltage in regulation, ideal for always-on systems. An internal charge pump allows for 100% duty cycle operation in dropout, a useful feature for surge stopping applications and when powered from a battery during discharge. The LTC3895's powerful 1Ω N-channel MOSFET gate drivers can be adjusted from 5V to 10V to enable the use of logic- or standard-level MOSFETs to maximize efficiency. To prevent high on-chip power dissipation in high input voltage applications, the LTC3895 includes an NDRV pin, which drives the gate of an optional external N-channel MOSFET acting as a low dropout linear regulator to supply IC power. The EXTVCC pin permits the LTC3895 to be powered from the output of the switching regulator or other available source, reducing power dissipation and improving efficiency.

The LTC3895 operates with a selectable fixed frequency between 50kHz and 900kHz and is synchronizable to an external clock from 75kHz to 850kHz. The user can select from forced continuous operation, pulse skipping or low ripple Burst Mode® operation during light loads. Its current mode architecture provides easy loop compensation, fast transient response and excellent line regulation. Current sensing is accomplished by measuring the voltage drop across the output inductor (DCR) for highest efficiency or by using an optional sense resistor. A low 80ns minimum on-time allows for high step-down ratios at high switching frequency. Current foldback limits MOSFET heat dissipation during overload conditions. Additional features include a fixed 5V or 3.3V output option, integrated bootstrap diode, a power good output signal, adjustable input overvoltage lockout and soft start. The LTC3895 is available in a TSSOP-38 thermally enhanced package with several pins removed for high voltage spacing. Two operating junction temperature grades are available with extended and industrial versions from –40 to 125°C and a high temp automotive version from –40°C to 150°C.

The schematic shown in Figure 1 produces a 12V output from a 7V to 140V input voltage range. When the input voltage is below 12V, the output voltage will follow the input voltage since it would be running at 100% duty cycle with the top MOSFET on continuously. This feature is possible due to the LTC3895's onboard charge pump.

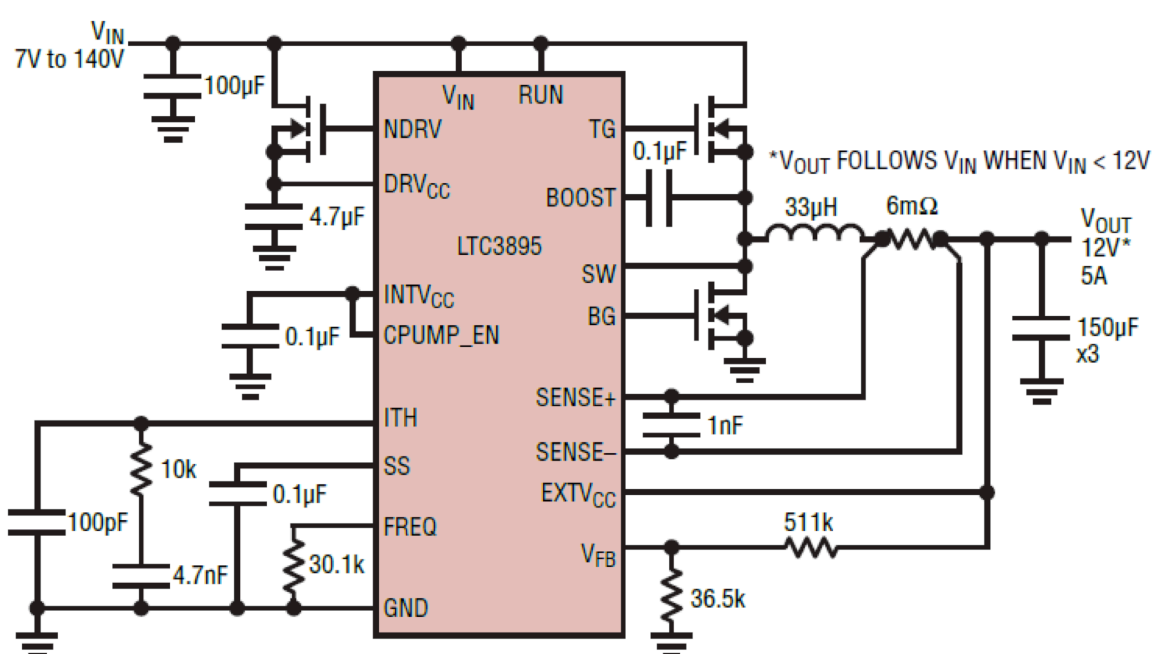

Figure 1 –Schematic showing the LTC3895 producing a 12V output from a 7V to 140V input

Burst Mode Operation

The LTC3895 can be enabled to enter high efficiency Burst Mode operation, constant frequency pulse skipping, or forced continuous conduction mode at low load currents. When configured for Burst Mode operation and during a light load condition, the converter will burst out a few pulses to maintain the charge voltage on the output capacitor. It then turns off the converter and goes into sleep mode with most of its internal circuits shut down. The output capacitor supplies the load current and when the voltage across the output capacitor drops to a programmed level, the converter starts back up, delivering more current to replenish the charge voltage. The action of shutting down and turning off most of its internal circuits significantly reduces quiescent current, thereby helping to extend the battery run-time in always-on systems when in standby mode.

Switching Surge Stopper

In addition to its use as a high voltage step-down DC/DC controller that can ride through high voltage surges, the LTC3895 can be designed for high efficiency switching surge stopper only applications. For example, when the input voltage is from a car with a 12V lead-acid battery the output voltage can be set to 12V. For that configuration, normal operation is in "dropout" with the top MOSFET is on continuously. The LTC3895 will then only switch during start-up or in response to either an input overvoltage or output short-circuit condition. If the time spent switching exceeds the time programmed by the OVLO pin, the LTC3895 will shut down to protect itself from overheating. This time spent switching can be programmed from a few milliseconds to up to several seconds before it shuts down.

MOSFET Drivers and Efficiency

The LTC3895 has powerful 1.1Ω onboard N-channel MOSFET gate drivers that minimize transition times and switching losses. The gate drive voltage can be programmed from 5V to 10V, allowing the use of logic- or standard-level N-channel MOSFETs to maximize efficiency. Due to the high drive current available, multiple MOSFETs in parallel can be driven for higher current applications.

The LTC3895 efficiency curves in Figure 2 are representative of the Figure 1 schematic with a 24V or 48V input voltage. As shown, the 8.5V output produces very high efficiency at up to 98%. The 3.3V is also over 90% efficient. In addition, this design is still over 75% efficient for each output with a 1mA load, due to its Burst Mode operation.

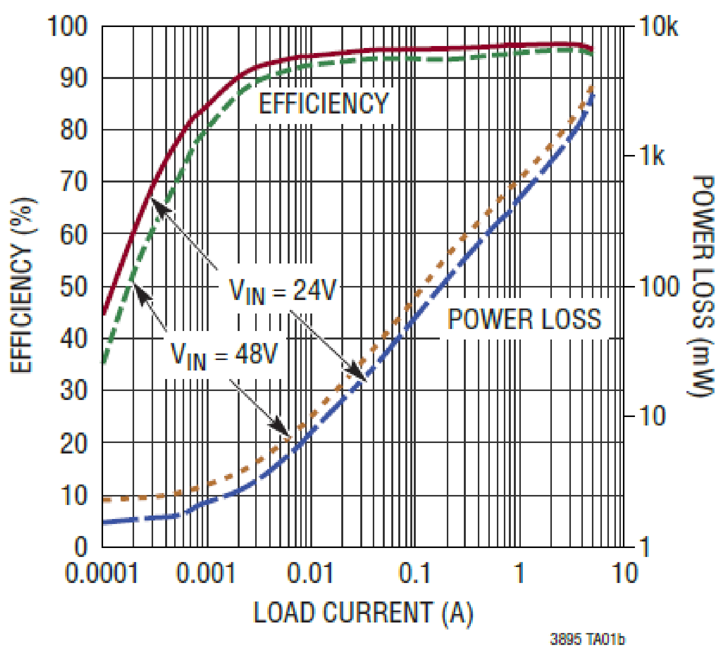

Figure 2 - LTC3895 Efficiency curves for a 12V output from a 24 or 48V input

Fast Transient Response

The LTC3895 uses a fast 25MHz bandwidth op amp for output voltage feedback. The high bandwidth of the amplifier, along with high switching frequencies and low value inductor, allow for a very high gain crossover frequency. This enables optimization of the compensation network for a very fast load transient response. Figure 3 illustrates the transient response of a 2A step load on a 12V output with a less than 100mV deviation from nominal and a 200µs recovery time.

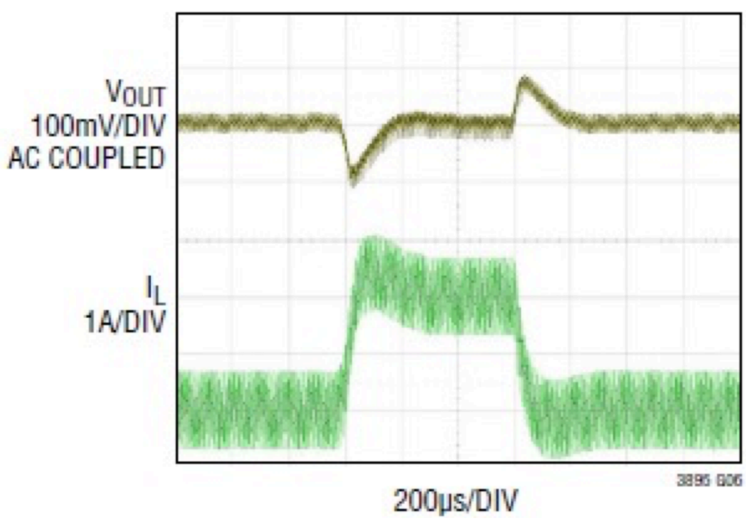

Figure 3 - LTC3895 transient response for a 2A step-load for a 12V output

Conclusion

The LTC3895 brings a new level of performance for safe and efficient operation in demanding high voltage transient environments such as those commonly found in automotive DC/DC converters. The powerful adjustable gate drive voltage provides the flexibility of driving logic- or standard-level MOSFETS. Its low quiescent current preserves battery energy during sleep mode, allowing for increased battery run-time, a very useful feature in “always-on” systems. The 150V maximum input voltage rating, fast transient and high temp grades make the LTC3895 an excellent choice for truck, heavy equipment, rail and automotive applications, where high voltage transients are commonplace.