

Powering Infotainment Devices in Automotive Start/Stop Systems

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Background

Automakers continue to tout stop/start systems that help save fuel. As its name implies, a stop/start system shuts off the engine instead of letting it idle at a stop, and then it rapidly restarts the engine once you need to drive away. If you do a lot of stop-and-go driving, you're reducing emissions and saving fuel by not idling the engine for extended periods of time. The concept is simple. As an example, if you're stopped at a red light or train crossing, you don't need the engine to be running; if the engine isn't running, you're not wasting any energy. As a result, the reduction in fuel consumption can be as much as 8% in city traffic compared to a car without such a system.

Driving comfort and safety are not compromised by an auto start/stop function, since it is not activated until the engine has reached an ideal running temperature. The same applies if the air conditioner has not yet brought the cabin to the desired temperature, if the battery is not adequately charged, or if the driver moves the steering wheel.

The auto start/stop function is coordinated by a central control unit that monitors data from all relevant sensors, including the starter motor and the alternator. If necessary for comfort or safety, the control unit will automatically restart the engine—for example, if the vehicle begins to roll, the battery charge falls too low, or condensation forms on the windshield. Furthermore, most systems recognize the difference between a temporary stop and the end of the trip. It will not restart the engine if a driver's seat belt is undone, or if the door or trunk is open. If desired, the auto start/stop function can be completely deactivated with the press of a button (for now, at least).

However, when the engine restarts and there is an infotainment system turned on or another electronic device requiring greater than 5 V, there is a possibility that the 12 V battery can dip to below 5 V, causing these systems to reset. Some navigation and infotainment systems operate from a 5 V and higher input voltage. When the input voltage dips to below 5 V during an engine restart, these systems will reset when the dc-to-dc converter only has the capability to step down the input voltage. Obviously, it is not acceptable to have a music player or the navigation system reset when the car restarts.

Solution

Analog Devices recently introduced a triple output dc-to-dc controller, the Power by Linear® LTC7815, that combines a boost controller and two step-down controllers in a single package. The high efficiency synchronous boost feeds the two downstream synchronous step-down converters, avoiding an output voltage dropout when the car battery voltage droops—a very useful feature in automotive start/stop systems. In addition, when the input voltage from the car battery is higher than its programmed boost output voltage, the boost controller runs at 100% duty cycle and simply passes the input voltage directly to the step-down converters, minimizing power loss.

Figure 1 shows an LTC7815 schematic with the boost converter supplying 10 volts to the step-down converters. In addition to powering the two step-down converters, which produce 5 V/7 A and 3.3 V/10 A, respectively, the boost converter can be used as a third output that can provide an additional 2 A. This circuit maintains 2.1 MHz operation at up to 28 V_{IN} and skips cycles above 28 V.

The LTC7815 operates from an input voltage of 4.5 V to 38 V during startup and maintains operation down to 2.5 V after startup. The synchronous boost converter can produce output voltages up to 60 V and can run with the synchronous switch fully on to pass through the input voltage when it is high enough to maximize efficiency. The two step-down converters can produce output voltages from 0.8 V to 24 V, with the entire system achieving efficiency as high as 95%. Its low 45 ns minimum on-time enables high step-down conversions while switching at 2 MHz, thus avoiding critical noise-sensitive frequency bands such as AM radio and allowing for smaller external components.

The LTC7815 can be configured for Burst Mode® operation, which reduces quiescent current to 28 µA per channel (38 µA when all three channels are on) while regulating the output voltage at no load, a useful feature for preserving battery run times in always-on systems. The powerful 1.1 Ω on-board all N-channel MOSFET gate drivers minimize switching losses and provide output current of more than 10 amps per channel, limited only by external components. Furthermore, the output current for each converter is sensed by monitoring the voltage drop across the inductor (DCR) or by using a separate sense resistor. The LTC7815's constant frequency current-mode architecture enables a selectable frequency from 320 kHz to 2.25 MHz or it can be synchronized to an external clock over the same range.

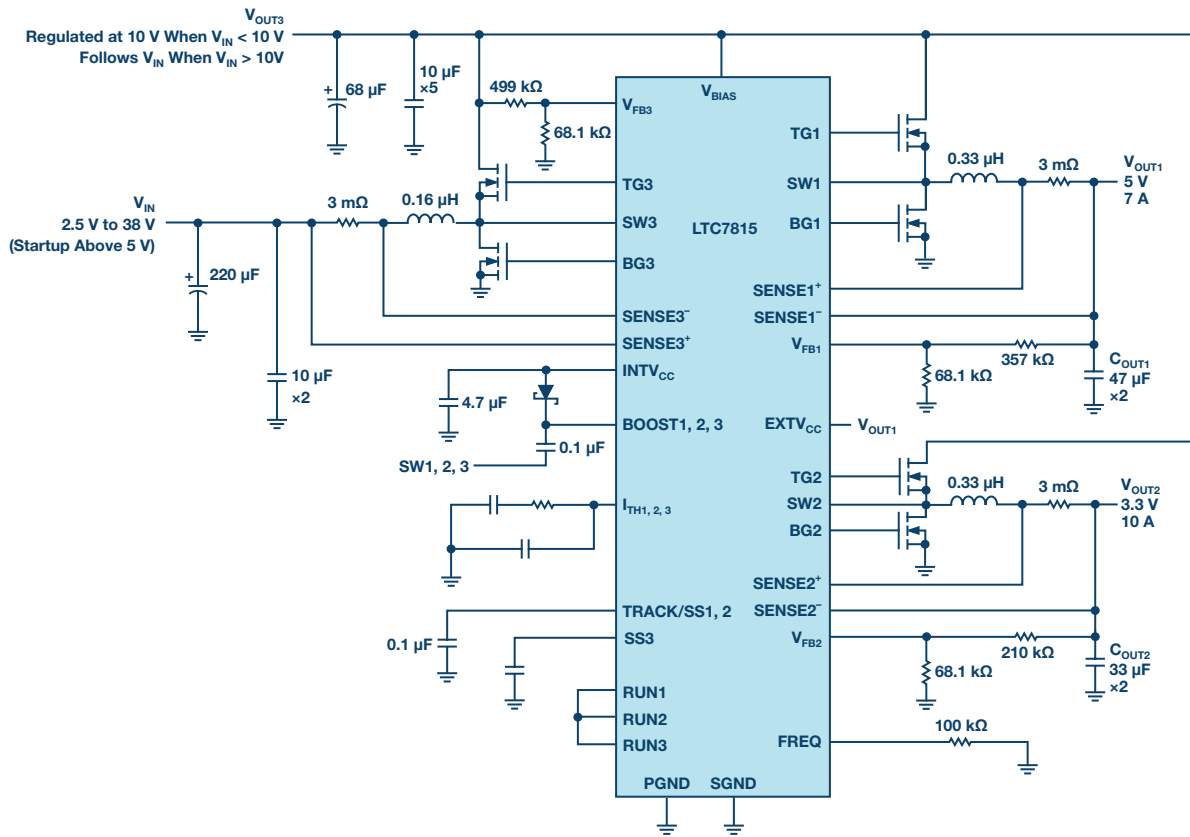


Figure 1. LTC7815 start/stop application schematic operating at 2.1 MHz.

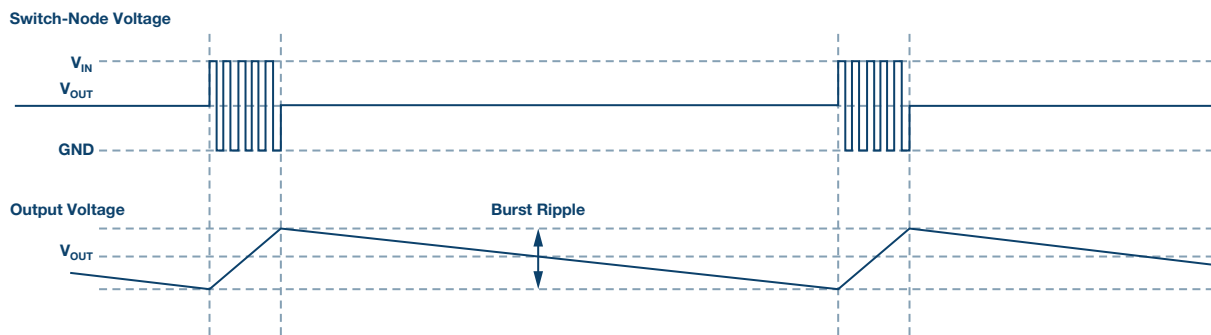


Figure 2. Burst Mode operation voltage diagram for the LTC7815.

Extending Battery Run Times

Any battery-powered system that requires an always-on power bus while the rest of the system is turned off must conserve battery energy. This state is commonly referred to as sleep, standby, or idle mode and requires these systems to have very low quiescent current. The need for low quiescent current to conserve battery energy is especially important in automotive applications that can have several electrical circuits such as telematics, CD/DVD players, remote keyless entry, and multiple always-on bus lines. The collective current consumption of these systems during standby mode needs to be as low as possible and the pressure continues to mount for battery energy conservation as cars become more dependent on electronic systems for their operation.

The LTC7815 draws a mere 28 μA when in sleep mode with the boost converter and one of the buck converters on. With all three channels on and in sleep mode, the LTC7815 draws only 20 μA , which significantly extends battery run times when in idle mode. This is done by configuring the part

to enter high efficiency Burst Mode operation, where the LTC7815 delivers short bursts of current to the output capacitor followed by a sleep period where the output power is delivered to the load by the output capacitor only. Figure 2 shows the conceptual timing diagram of how this works.

In sleep mode, much of the internal circuitry is turned off except for the critical circuitry needed to respond quickly. When the output voltage drops enough, the sleep signal is activated and the controller resumes normal Burst Mode operation by switching on the top external MOSFET. Alternatively, there are instances when the user will want to operate in forced continuous or constant frequency pulse skipping mode at light load currents. Both modes are easily configurable and have a higher quiescent current.

Efficiency/Solution Size

The efficiency for the 5V output as referenced in the Figure 1 schematic is about 90% as shown in Figure 3. A 3% to 4% higher efficiency can be attained if the operating frequency is reduced from 2.1 MHz to 300 kHz.

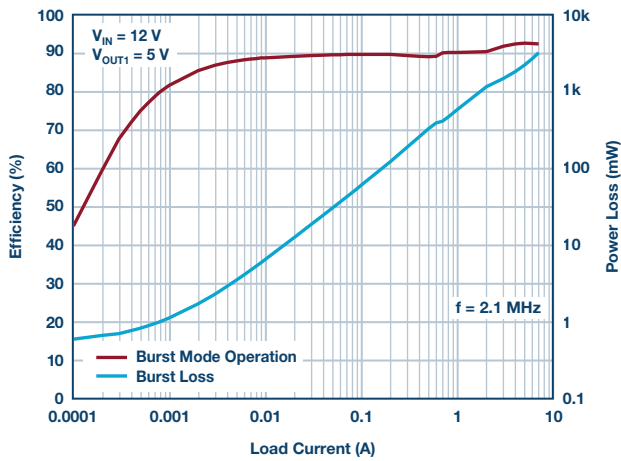


Figure 3. LTC7815 efficiency vs. load current for different converter sections.

Figure 4 shows the demo board for the LTC7815 (schematic shown in Figure 1) with the tallest part at 48 mm high.

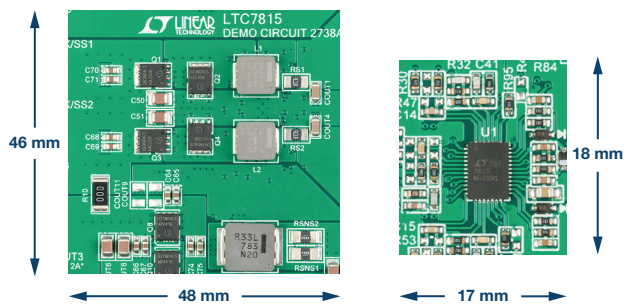


Figure 4. Size and layout of LTC7815 demo board top and bottom sides.

Protection Features

The LTC7815 can be configured to sense the output current by using DCR (inductor resistance) or a sense resistor. The choice between the two current sensing schemes is largely a trade-off between cost, power dissipation, and accuracy. DCR sensing is becoming popular because it saves expensive current sensing resistors and is more power efficient, especially in high current applications. The sense resistor, however, is a more accurate way of sensing current.

On-board comparators monitor the buck output voltages and signal an overvoltage condition when the output is greater than 10% of its nominal value. When this condition is sensed, the top MOSFET is turned off and the bottom MOSFET is turned on until the overvoltage condition is cleared. The bottom MOSFET remains on continuously for as long as the overvoltage condition persists. If the output voltage returns to a safe level, normal operation automatically resumes.

At higher temperatures, or in cases where the internal power dissipation causes excessive self heating on-chip, the overtemperature shutdown circuitry will shut down the LTC7815. When the junction temperature exceeds approximately 170°C, the overtemperature circuitry disables the on-board bias LDO, causing the bias supply to drop to 0 V and effectively shutting down the entire LTC7815 in an orderly manner. Once the junction temperature drops back to approximately 155°C, the LDO turns back on.

Conclusion

Automotive start/stop systems allow for fuel savings that will continue to evolve over the next several years. Care must be taken with regards to powering on-board infotainment and navigation systems that need up to, or can exceed 5 V. These systems can reset when the car battery voltage droops to less than 5 V with an engine restart. The LTC7815 provides a solution by boosting the battery voltage to a safe operating level. This, combined with two step-down controllers, makes it ideal for powering many automotive electronic devices in cars that have a start/stop system.

Bruce Haug [bruce.haug@analog.com] received his B.S.E.E. from San Jose State University in 1980. He joined Linear Technology (now a part of Analog Devices) as a product marketing engineer in April 2006. Bruce's past experience includes stints at Cherokee International, Digital Power, and Ford Aerospace. He is an avid sports participant.



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