Innovative Power Solutions for Transportation Systems

By Tony Armstrong
Director of Product Marketing

Linear Technology Corporation

tarmstrong@linear.com

Transportation System Needs

Transportation systems can have input voltage ranges up to 14V (single battery automotive), 28V (dual battery trucks, busses, airplanes), or higher, and require one or more low voltage rails for digital systems. As a result, designs of such systems need to know how they can step down from high input voltages simply, efficiently and reliably. Figure 1 below shows how the input voltage in an automotive environment can vary depending on its operating conditions which can vary from load dump to cold crank, and even reverse battery hook-ups.

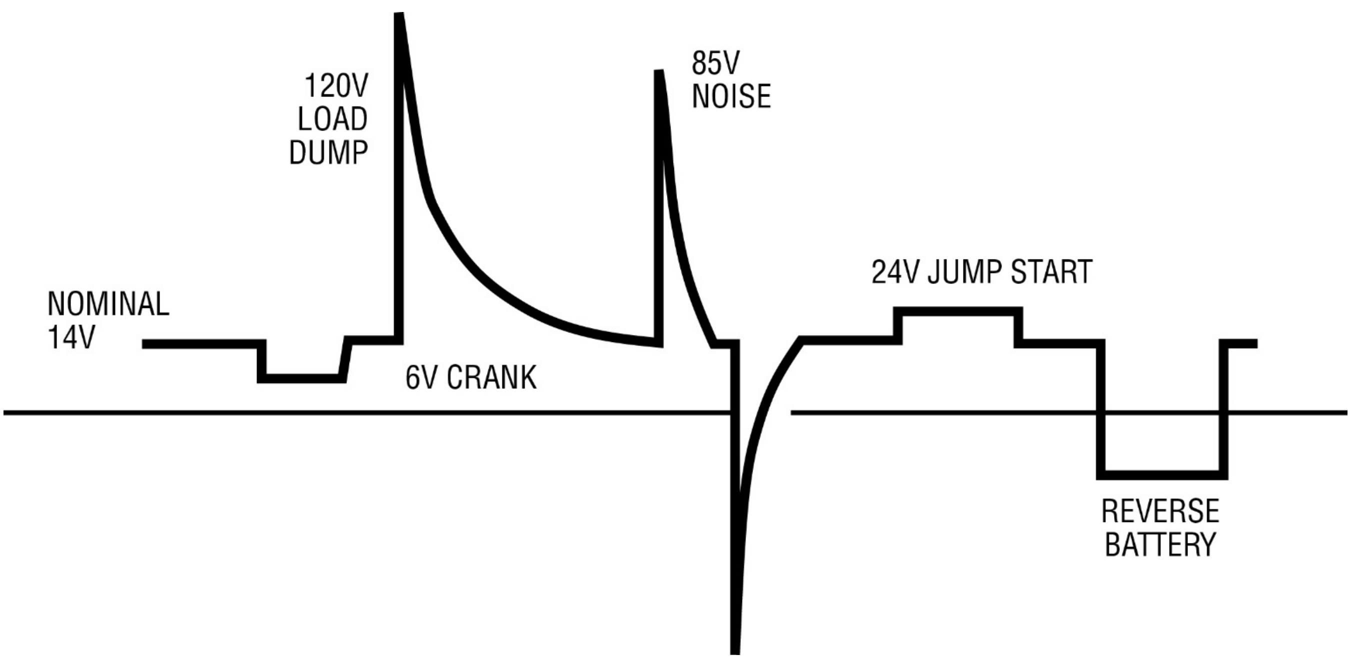


Figure 1. Typical Automotive Transients

When an application requires very high efficiency of power conversion in order to minimize the heat generated from the power lost during the conversion process, a switching regulator solution can help. Switching regulators can be monolithic in nature with MOSFETs integrated on chip – in either a synchronous or non-synchronous configuration. Or, they can consist of a switching controller that can drive external MOSFETs in single or multiple stage topology (multiphase) to deliver power levels from 10s of Amps up to 100s of Amps. As a result of this broad power range, Linear Technology offers an extensive array of switching regulator solutions enabling the user to select the most applicable device based on the specific design criteria necessary for the end system. Accordingly, our switching regulators have very board input voltage ranges, from 5V up to 150V, and output power levels from 100s of mille-amperes to as greater than 1,000A.

An example of this capability is the LTC3895 – a 150V input capable synchronous step-down converter that can be configured for multiphase operation, as shown in Figure2.

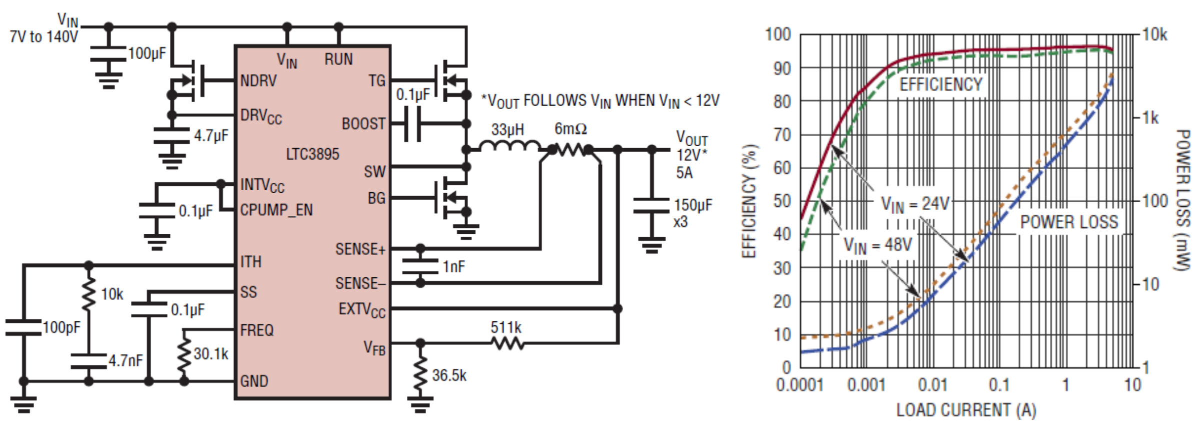


Figure 2. LTC3895 Schematic & Efficiency vs. Power Loss Curve

A commonly asked question in any transportation environment is: "how can I have a high step-down ratio and a compact solution footprint without impacting functional performance and conversion efficacy?" Until recently, there had not existed a solution that could deliver on all key performance matrixes without having some level of compromise. However, with the introduction of Linear's LT86xx family of monolithic 2MHz plus synchronous step-down converters, all the necessary performance aspects can be delivered at once.

A good example of this capability is the LT8609, a 2A, 42V input synchronous step-down switching regulator. A unique synchronous rectification topology delivers 93% efficiency while switching at 2MHz enabling designers to avoid critical noise-sensitive frequency bands, such as AM radio, while providing a highly compact solution footprint. Burst Mode®operation keeps quiescent current under 2.5µA in no-load standby conditions, making it well suited for always-on systems. The LT8609's 3.0V to 42V input voltage range makes it ideal for automotive applications which must regulate through cold-crank and stop-start scenarios with minimum input voltages as low as 3.0V and load dump transients in excess of 40V. Its internal 3.5A switches can deliver up to 2A of continuous output current with peak load currents of 3A. The schematic and corresponding efficiency curve for 2MHz switching are shown in Figure 3 below.

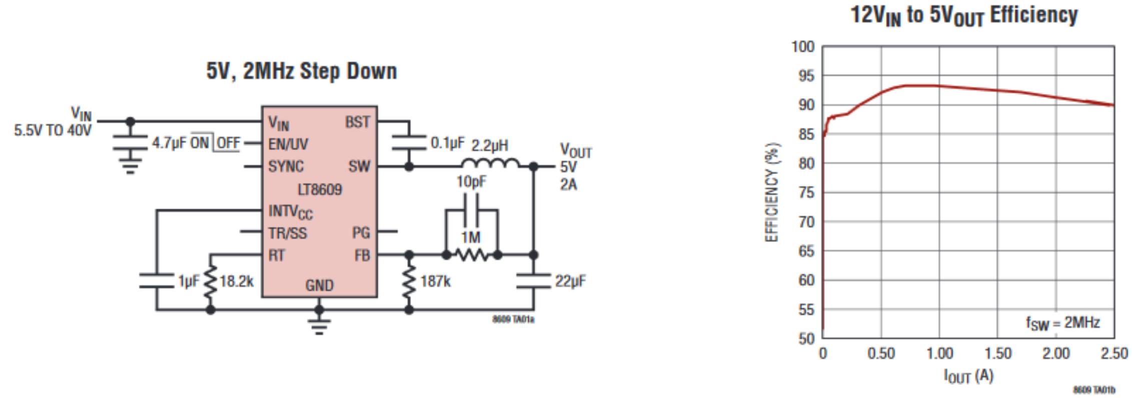


Figure 3. LT8609 Schematic & Efficiency Curve

Many transportation systems have a wide input voltage range due to the cold crank and load dump conditions commonly found in single or double battery vehicles. And, to complicate matters further, the desired output voltage can straddle this wind input voltage range. Thus, a system designer is faced with the complex problem of having to design a solution that allows for a fixed output regardless of whether the input voltage is above, below, or equal to the output voltage.

A common approach to solving this problem is to employ a SEPIC topology converter. However, this is a complicated design requiring two inductors and is usually not very space or conversion efficient. As a result, Linear has designed an extensive family of 4-switch Buck-Boost controllers that not only simplified the design, but are both space and conversion efficient, with power losses in the 5 to 7% range (depending on the input to output voltage range). The LT8705 shown in Figure 4 is an example of a 4V to 80V input capable Buck-Boost controller, delivering a fixed 12V output that is commonly found in vehicular environments.

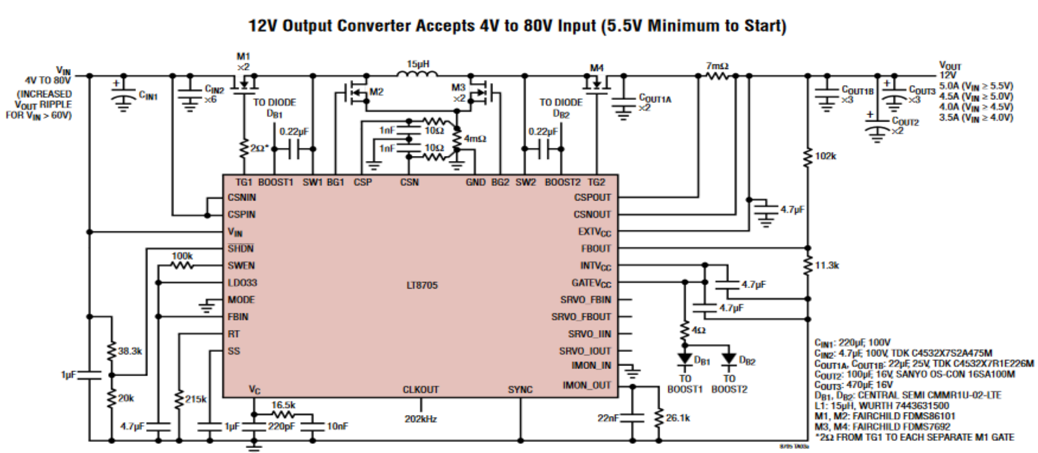


Figure 4. LT8705 Detailed Schematic for a Fixed 12V Output from a 4V to 80V Input

An alternative approach to dealing with an automotive cold crank condition is to employ a Boost converter, followed by a buck converter. In this topology, the output of the boost converter from a single battery is set to a few volts above the battery's nominal voltage, and then, it is stepped down with a buck converter to the desired operating voltage required by the downstream electronics. Although it requires two converters, Linear has developed a device that combines both a boost controller and buck controller that can be either used independently, or in boost-buck follower. The LTC7813 illustrates how this is done in Figure 5.

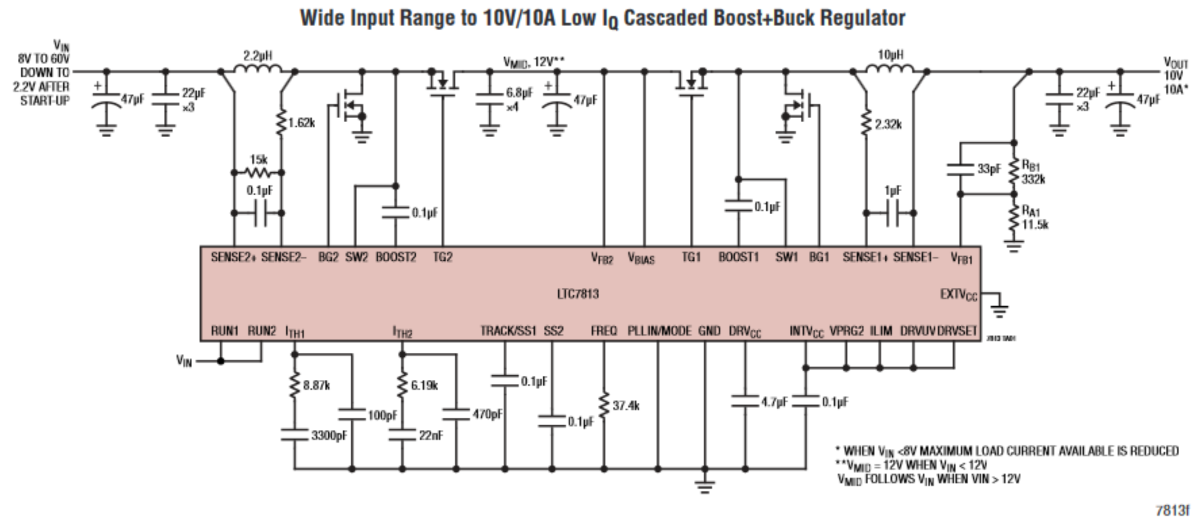


Figure 5. LTC7813 Schematic Is a Dingle IC with a Cascaded Boost & Buck Regulator

Low Noise Power Management

Electromagnetic Radiation (EMR), Electromagnetic Interference (EMI) and Electromagnetic Compliance (EMC) are terms that pertain to energy from electrically charged particles and the associated magnetic fields that can potentially interfere with circuit performance and signal transmissions. With the proliferation of wireless communications, the plethora of communication devices, and the growing number of communication methods using more and more of the frequency spectrum (with some bands overlapping), electromagnetic interference is a fact of life. To mitigate the effects, many governmental agencies and regulatory organizations have set limits on the amount of radiation that can be emitted by communications devices, equipment and instruments.

Thus, it is clear that low radiated emissions are a key requirement for many automotive and transportation customers. So how can system designers meet the stringent requirements of the automotive CISPR 25, Class 5 (shown in Figure 6) while still maintaining high efficiency and small solution size?

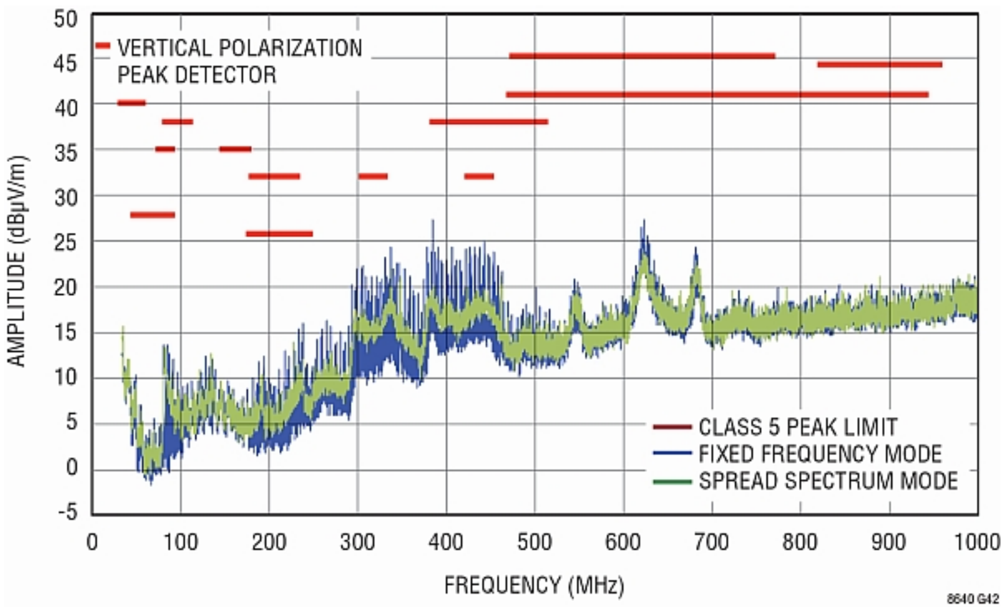


Figure 6a. Radiated Emissions of the LT814 Are Easily below the CISPR25, Class 5 Limits

Well, one answer might be to use Linear's Silent Switcher® family. An example is the LT8614 – a 42V input, 4A output, monolithic step-down converter that can switch at greater than 2MHz switching frequency with 94% conversion efficiency and can meet a step-down ratio of 16V input to 1.8V output due to is low 30ns minimum on-time. Furthermore, due to its patented Silent Switcher technology, it can exceed both CISPR 25 and CISPR 22 Class B emissions requirements as shown in Figure 7.

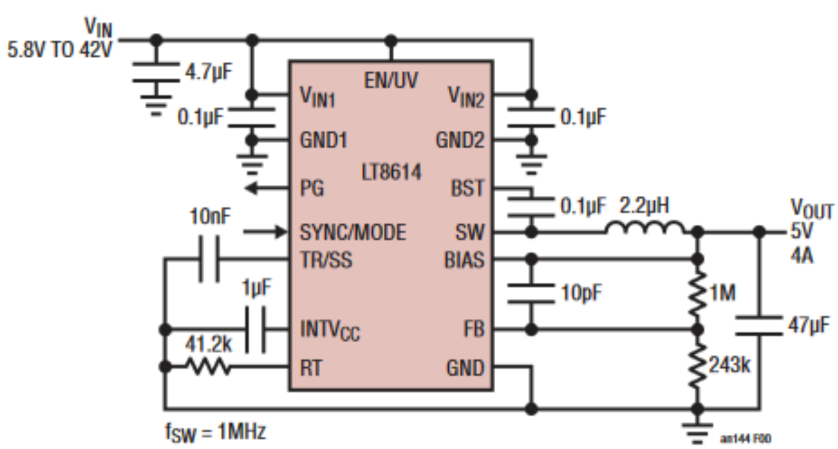
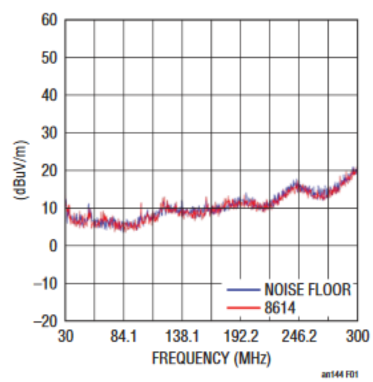
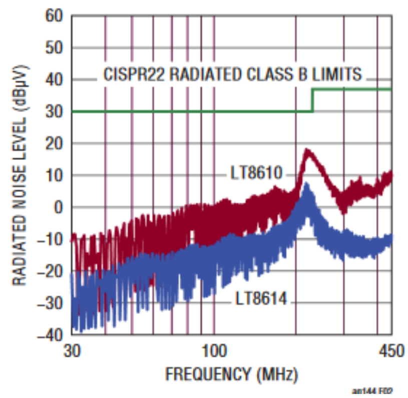


Figure 6b. LT8614 with Silent Switcher Technology





Figures 7a/b. Graphs Illustrating How the LT8614 Meets CISPR 22 & CISPR 25.

Low Quiescent Current Is Also a Key Requirement

There are many applications in transportation electronic systems that require continuous power even when the vehicle is parked, such as remote keyless entry, security and even personal infotainment systems, which usually incorporate navigation, GPS location and e-call functionality. Maybe it is hard to understand why these systems have to remain on even when the car is not moving, but the GPS aspect of this system has to be "always-on" for emergency and security purposes. This is a necessary requirement so that rudimentary control can be employed by an external operated when needed.

A key requirement for these applications is low quiescent current to extend battery life. Linear Technology has been producing switching regulators with standby quiescent current less than 10µA since 2010 – some of our newer products recently released take this figure below 2µA. As a result, these products are well positioned to be adopted in many automotive electronics systems.

Conclusion

Linear Technology offers a wide array of products that meet all of the demands for switching regulators with a set of attributes that makes them ideal for a plethora of transportations systems. These include the following:

- Wide input voltage ranges: 2.xV to 150V
- Low quiescent current in standby mode: typically less than 10µA
- Minimal output noise and low EMI/EMC emissions
- Extended temperature ranges: guaranteed 150°C ambient and junction temperature operation
- High efficiency: up to 97% at full load and as high as 80% under light load conditions
- Low thermal resistance packages: as low as 10°C/W (θjc)
- High switching frequency operation with high step-down ratios: up to 4MHz
- High current densities: up to 5A of continuous output current from 3mm x 5mm MSOP package
- Industry leading FIT rates: typically less than 0.2