Automotive Electronic Systems Drive the Demand for Multi-Channel Synchronous Buck Converters

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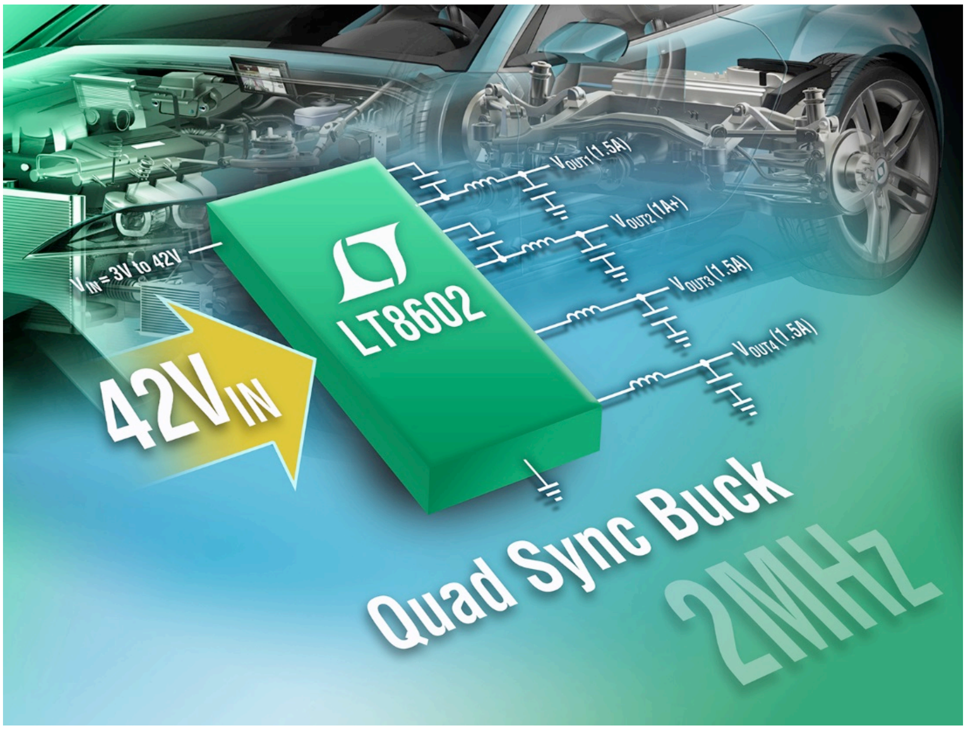

Introduction

As automobiles continue to add a higher density of electronic systems to enhance safety, comfort, efficiency and performance, it is not surprising that they require both smaller and higher performance power conversion solutions. These new multi-channel power management solutions need to deliver up to four independent power rails usually to power V_{CORE}, $V_{I/O}$, V_{MEM} required for microprocessors and generally a fourth 5V rail to power a CAN transceiver. According to Strategy Analytics, "The demand for enabling semiconductor devices is expected to grow at a compound average annual growth rate (CAGR) of five percent over the next seven years, with the total market worth over $41 billion by 2021, compared to $30 billion in 2014." They also identified that demand for microcontroller and power semiconductors will drive over 40 percent of revenues.

Strategy Analytics provides a very quantitative description of forecasting the growth of electronics content in automobiles, but more interesting is the prevalent role that power ICs play in this growth. These new power ICs must provide:

1) Multiple voltage rails from a single power management IC
2) Robust performance across a wide range of voltages, including cold-crank and stop-start scenarios from <4V to load dump transients in excess of 36V
3) Outputs ranging from 5V down to less than 1V
4) Ultralow electromagnetic interference (EMI) emissions
5) The highest efficiency possible to both minimize thermal issues and optimize battery run-time
6) Ultralow quiescent current (<10uA per channel) to enable always-on systems such as security, environmental control and infotainment systems to stay engaged without draining the vehicles battery when its engine (alternator) is not running.
7) The smallest solution footprints, often requiring multiple voltage rails to minimize space required for power conversion circuits
8) Switching frequencies of 2MHz or greater to keep the switching noise out of the AM Radio band and to keep solution footprints very small

The goal of the increased performance levels of power ICs is to allow the design of increasingly numerous and complex and electronic systems found within automobiles. Specific applications which are fueling the growth for electronic content in cars are found in every aspect of the vehicle. For example, new safety systems including lane monitoring, adaptive safety control, automatic turning and dimming headlights. Infotainment systems (telematics) which continue to evolve and pack more functionality into an already tight space must support an ever growing number of cloud based applications. Advanced engine management systems with the implementation of stop/start systems, electronically controlled transmissions and engine control. Drive train and chassis management aimed at simultaneously improving performance, safety and comfort. A few years ago these systems were only found in "high-end" luxury cars but now they are commonplace in automobiles from every manufacturer, further accelerating the automotive power IC growth.

Smaller Power Conversion Circuits

There are a few ways to make power conversion circuits smaller. In general, the largest components in a circuit is not the power IC, but the external inductor and capacitors. By increasing the switching frequency of the power IC from 400kHz to 2MHz, the size of these externals can be dramatically reduced. However, in order to do this effectively, the power IC must be capable of delivering high efficiency at these higher frequencies, which historically has not been feasible. Nevertheless, using new process and design techniques, synchronous power ICs have recently been developed that can deliver efficiencies in excess of 90% while switching at 2MHz. The high efficiency operation minimizes power loss, eliminating the need for heat sinks. It also has the added benefit of keeping switching noise out of the AM frequency band which is critical in many noise sensitive electronic systems.

Another way to make power conversion circuits dramatically smaller, is to use a multi-output converters in lieu of multiple single devices, when several unique output voltage rails are required. For example when powering a microprocessor, most designs require three independent outputs to power V_{CORE}, $V_{I/O}$, V_{MEM} required for microprocessors and a fourth 5V rail to power a CAN transceiver which enables the microprocessor to communicate with the rest of the system electronics. Because a properly designed quad converter IC is only moderately larger than an equivalent single converter whereas its solution footprint can be less than half the size of four separate single converters. This size improvement is especially compelling when comparing a quad output regulator using a switching frequency of 2MHz versus four singles which run at 500KHz. Additionally, quad output converters are designed to minimize unwanted cross-talk between the channels, whereas crosstalk between four adjacent single converters can be problematic, unless they are all synchronized to a common clock. Adding an external clock and synchronization adds both size, complexity and cost to the circuit.

Low EMI Operation

Because the automotive electrical environment is inherently noisy, with many applications being susceptible to electromagnetic interference (EMI), it is imperative that switching regulators don't exacerbate these EMI concerns. Because a switching regulator is typically the first active component on the input power bus line, and regardless of downstream converters, it significantly impacts overall converter EMI performance. So minimizing EMI is imperative. Historically, the solution was to use an EMI shielding box, but this adds significant cost and size to the solution footprint while complicating thermal management, testing and manufacturability. Another potential solution within the power management IC is to slow down the switching edges of the internal MOSFETs. However, this has the undesired effect of reducing the efficiency and increasing the minimum on-time which compromises the IC's ability to deliver low duty cycles at switching frequencies at, or above, 2MHz. As both high efficiency and small solution footprints are desired, this isn't a viable solution. Fortunately, some recent power IC designs have been introduced to enable fast switching frequencies, high efficiency operation and low minimum on-times concurrently. These designs can offer low EMI emissions even with 2MHz switching frequencies and over 90% efficiency. These performance levels are accomplished with no additional components or shielding, offering a significant breakthrough in switching regulator design.

A New Alternative

Linear Technology's LT8602 is a 42V volt input capable, high efficiency, quad output monolithic synchronous step-down switching regulator. Its 3V to 42V input voltage range make it ideal for automotive applications which must regulate through cold-crank and stop-start scenarios with minimum input voltages as low as 3V and load dump transients in excess of 40V. As can be seen in figure 1, its quad channel design combines two high voltage 2.5A and 1.5A channels with two lower voltage 1.8A channels to deliver four independent outputs delivering voltages as low as 0.8V enabling it to drive the lowest voltage microprocessor cores currently available. Its synchronous rectification topology delivers up to 94% efficiency while Burst Mode® operation keeps quiescent current under 30µA (all channels on) in no-load standby conditions making it ideal for always-on systems.

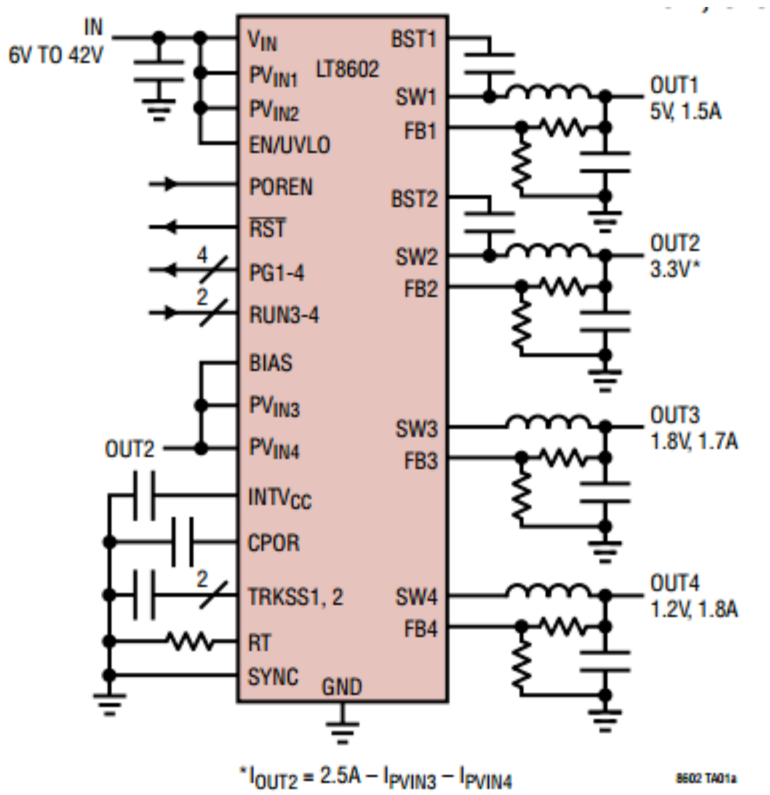

Figure 1. LT8602 Schematic Delivering 5V, 3.3V, 1.8V & 1.2V Outputs

For noise sensitive applications, the LT8602, with a small external filter, can utilize its pulse-skipping mode to minimize switching noise and can meet the CISPR25, Class 5 EMI requirements as shown in Figure 2.

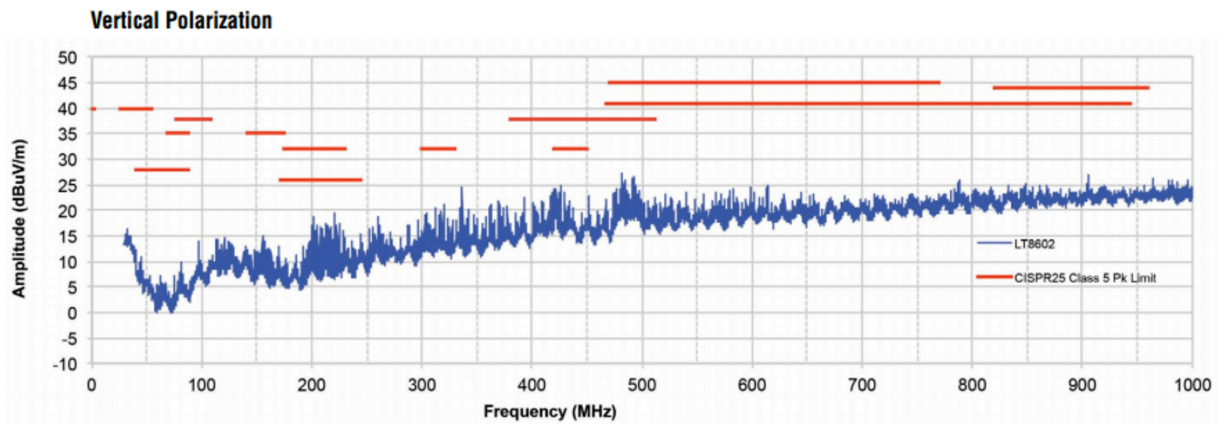

Figure 2. LT8602 Radiated EMI Performance,
(CISPR25 Radiated Emission Tests with Class 5 Peak Limit)

The LT8602's switching frequency can be programmed from 250kHz to 2MHz and can be synchronized throughout this range. Its 60ns minimum on-time enables $16V_{IN}$ to $2.0V_{OUT}$ step-down conversions on the high voltage channels with a 2MHz switching frequency. As the high voltage V_{OUT2} channel feeds the two low voltage channels (V_{OUT3} and V_{OUT4}), these can deliver outputs as low as 0.8V while also switching at 2MHz, offering a very compact (~25mm x 25mm) quad output solution as shown in Figure 3.

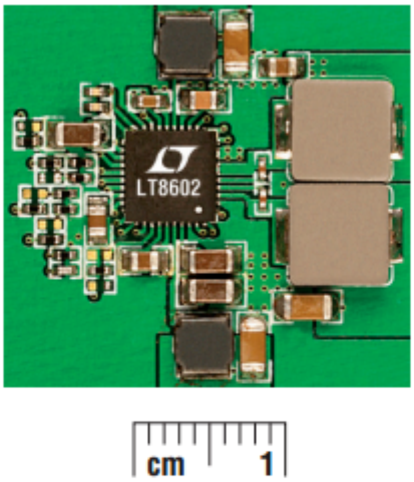

Figure 3. LT8602 Quad Output Solution Footprint
(2x actual size)

In addition the minimizing the solution footprint, the LT8602's 2MHz switching frequency enables designers to avoid critical noise-sensitive frequency bands, such as AM radio. Each channel of the LT8602 maintains a minimum dropout voltage of only 200mV (@1A) under all conditions, enabling it to excel in scenarios such as automotive cold-crank. Programmable power-on reset and power good indicators for each channel helps to ensure overall system reliability. The LT8602's 40-lead thermally enhanced 6mm x 6mm QFN package and high switching frequency keeps external inductors and capacitors small, providing a compact, thermally efficient footprint.

The LT8602 utilizes quad internal top and bottom high efficiency power switches with all the necessary boost diodes, oscillator, control and logic circuitry integrated onto a single die. Channel 1 and 3 switch 180deg out of phase with channel 2 and 4 to reduce output ripple. Each channel has a separate input for added design flexibility, but most applications will run the two low voltage channels directly from the two high voltage channels to offer a very simple, high frequency quad output design. Low ripple Burst Mode® operation maintains high efficiency at low output currents while keeping output ripple below $15mV_{PK-PK}$. Unique design techniques and a new high speed process enable high efficiency over a wide input voltage range and the LT8602's current-mode topology enables fast transient response and excellent loop stability. Other features include internal compensation, a power good flags, output soft start/tracking, short-circuit and thermal protection.

Conclusion

The rapid increase in the number and complexity of electronic systems in automobiles has necessitated even higher demands on power management IC performance. By having quad output power ICs, automotive designers can dramatically reduce the space required by their power conversion circuits. Combined with switching frequencies of 2MHz, the size of the external components, namely the inductors and output capacitors, can also be dramatically reduced offering a very compact quad rail solution footprint. These compact designs are also very rugged, capable to withstand the required transient behavior found in stop-start, cold-crank and load-dump conditions while accurately regulating all outputs. Additionally, ultralow quiescent currents make them ideal for always on systems. As more electronic systems are added into ever shrinking spaces, minimizing the solution footprint while maximizing efficiency is also critical. Fortunately a new generation of multi-output power ICs which meet these demands are already available paving the way for even higher electronic content in future vehicles.