Matching automotive power needs

Tony Armstrong describes how automotive 'always-on' systems demand low quiescent currents.

Modern automobiles continue to include increasingly complex electronic systems. Furthermore, the automotive environment continues to be very harsh for any type of electronics. Wide operating voltage requirements coupled with large transient voltages and large temperature excursions combine to make life tough on electronic systems. What's more, the performance requirements continue to become even tougher. Multiple supply voltages are required for different portions of the system.

A typical navigation system can have six or more different supplies including 8V, 5V, 3.3V, 2.5V, 1.8V, and 1.5V. At the same time, as the number of components increases space requirements continue to shrink. Therefore, efficiency becomes more critical because of the space limitations and temperature requirements.

Switching regulators

At low output voltages and even with moderate current levels, above a few hundred milliamps, it is no longer practical to simply use a linear regulator to generate these system voltages. As a result, over the last several years, primarily due to thermal constraints, switching regulators have been replacing linear regulators.

The benefits of a switcher, including the increased efficiency and smaller footprint, outweigh the additional complexity and EMI considerations.

Taking into account these constraints, for a switching regulator to be considered, it would need the following features and characteristics:

- A wide input operating range.
- Good efficiency across a wide load range.
- Low quiescent current during normal operation, standby and shutdown.
- Low thermal resistance.
- Minimal noise and EMI emissions.

Lets consider each of these essential capabilities in more detail:

Wide Input Operating Range: Any switching regulator would need to be specified to work over a wide input voltage range of 3V to 60V, and could be used in automotive systems capable of running on either 14V or 42V. The 60V rating gives a good margin for 14V systems that are usually clamped in the range of 36 to 40V. Furthermore, the 60V rating allows the device to be used in future 42V systems. This means that one design done now for a 14V system can be easily up-graded for a 42V systems without any significant re-design.

Efficiency: High efficiency power conversion across a wide load range is essential in most automotive systems. As an example, power conversion efficiency of around 85% is expected for a 5V output over a 10mA to 1.2A load range. At high currents the internal switch needs to have good saturation, typically 0.2W at 1A. To improve light load efficiency, drive current is reduced or is proportional to load current. Also, power for the internal control circuitry could be supplied through a Bias pin, which can be powered from the output. This takes advantage of the power conversion efficiency of a buck converter. The fact that this bias current is drawn from the output rather than the input, decreases the input supply current required for the control circuit by the ratio of the output to input voltage. For example an output current of 100µA at 3.3V only requires an average input current of 30µA at 12V. This minimizes the input current required by the control circuitry and increases light load efficiency.

Low Quiescent Current: There are many applications in automotive systems that require continuous power even when the car is parked. A key requirement for these applications is low quiescent current. The device would run in normal continuous switching mode until the output current drops below about 100mA. Below this level the switching regulator must skip pulses to maintain regulation. The regulator can go into a sleep mode between pulses where only a portion of the internal circuitry is powered. At light load currents a switching regulator needs to automatically switch to burst mode operation. In this mode, the quiescent current should drop below 100µA for a 12V to 3.3V converter. The internal reference and power good circuit will remain active in sleep mode to monitor the output voltage. Quiescent current should be less than 1µA in shutdown.

Low Thermal Resistance: Ideally, the junction to case thermal resistance should be low. If the backside of the device is exposed copper and is soldered to the surface of the PC board, then the PC board can be used conduct heat away from the device. Four layer boards with internal power planes that are commonly used today can achieve thermal resistance in the range of 40∞C/Watt. High ambient temperature applications that have good thermal conduction to a metal housing can get thermal resistance numbers approaching a typical junction to case number of 10˚C/Watt. This helps to extend the useful operating temperature range.

Noise & EMI Considerations: Although switching regulators generate more noise than linear regulators, their efficiency is far better. Noise and EMI levels have proven to be manageable in many sensitive applications as long as the switcher behaves predictably. If a switching regulator switches at a constant frequency in normal mode, and the switching edges are clean and predictable with no overshoot or high frequency ringing, then EMI is minimized.

A small package size and high operating frequency can provide a small tight layout, which minimizes EMI radiation. Furthermore, if the regulator can be used with low ESR ceramic capacitors, both input and output voltage ripple can be minimized, which are additional sources of noise in the system.

Monolithic device

The LT1976 from Linear Technology is the latest part in a growing family of 60V capable monolithic step down switching regulators. This device addresses many of the key issues required for automotive applications as outlined above. It operates over a input voltage range of 3.3V to 60V. It provides high efficiency at load currents up to 1.2A. Reference accuracy is ±2% over all conditions of line, load and temperature. Due to its burst mode feature the quiescent current is 90µA for a 12V to 3.3V application. It is packaged in a small low profile TSSOP package with very low thermal resistance.

Finally it uses a current mode topology for good transient response and easy compensation, as well as patented circuitry to maintain constant peak switch current across all duty cycles. Switching frequency is a constant 200kHz and the device can be synchronized to a higher frequency. It provides tight regulation over the automotive temperature range and includes Power Good/Reset, Soft Start, and UVLO functions. The circuit provides a robust, efficient, small footprint solution for Automotive step down applications at current levels up to 1.2A.

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