Using DC/DC Buck Converters With Ultra-Low Quiescent Current for Industrial Battery-Pack Applications

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E-bikes, drones, and hand-held power electronic applications such as vacuum cleaners and power tools, are powered using high cell count Lithium-ion stack battery packs. The voltages for these battery packs can be as high as 20S (~72 V) and in some cases, even higher due to charging and transients generated in the system. Consumer electronics with battery packs are built with a viewpoint to improve user experience that, in one way, is achieved by extended battery life. The auxiliary power supply requires a unique design to ensure high transient voltage and low quiescent current requirements are satisfied.

Selecting a highly efficient, wide V_{IN} range DC/DC converter with low I_Q can help provide outstanding user experience in the form of longer battery life with fewer charge and discharge cycles. This application note describes industrial battery pack architectures and their requirements while highlighting the benefits of using the LM5163 (0.5-A) and LM5164 (1-A) family of synchronous buck converters for these applications.

Understanding Industrial Battery-pack Systems

Figure 1 is a system-level block diagram of a battery-pack application with protection, gauge, and communication functionality. The auxiliary power supply block, highlighted in red, consists of a low-dropout linear regulator (LDO) and a buck DC/DC converter to power various sub-systems integrated within the battery pack, such as communications and battery management sub-systems.

Innovative industrial battery packs often require:

- Reliable indication of real-time battery capacity and state-of-health
- Robust and complete protection for overvoltage, excessive temperature, and overcurrent
- Low idle and standby current consumption during transportation and storage

There are typically two modes of operation for the battery pack system associated with maximizing battery life:

- Idle Mode: The system is being shipped and all integrated chips are turned off.
- Standby Mode: Diagnostic circuits are always powered on with the load currents extremely low.

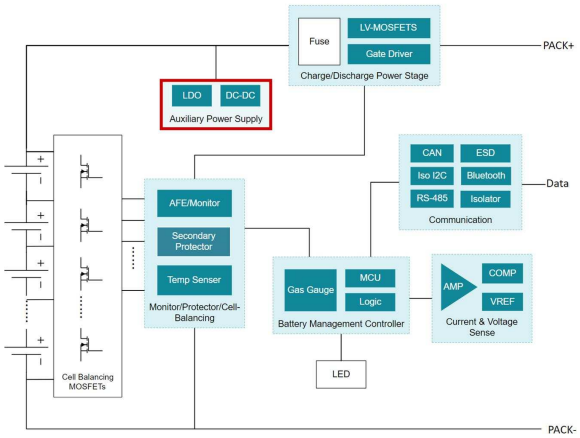

Figure 1. High-cell Battery-pack System Block Diagram

Auxiliary Power Supply Requirements

The auxiliary power supply, built to support up to 5 W output power, is used to facilitate the idle and standby modes of operation while the main power supply (not included in Figure 1) is used to provide power in the full-load mode. To facilitate its operation in idle and standby modes, it is imperative to choose the right DC/DC converter for the auxiliary power supply.

Standby mode requires always-on state-of-health (SOH) diagnostics where internal circuits are always powered on to ensure battery health and proper functionality. The system could also be in idle mode when in transportation and all internal circuits are turned off. In both cases, the system must ensure minimal current consumption from the battery to ensure its long lifetime and improve user experience.

An efficient way to accomplish this task is to use a DC/DC converter with low shutdown and standby currents and high efficiency that can sustain a wide V_{IN} range when connected directly to the battery.

Auxiliary Power Supply Solution

The LM5163 and LM5164 family of synchronous buck DC/DC converters provide innovative solutions for high-cell count battery applications. Based on the schematic of Figure 2, the converters are designed to regulate over a wide input voltage range up to 100 V.

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This alleviates the need for transient suppression when motor-generated back-EMF returns energy to the input bus that results in transient spikes at the input of the DC/DC converter. With a minimum controllable on-time of 50 ns, the LM5163 and LM5164 converters enable the direct step-down from a high cell-count battery pack to low-voltage rails.

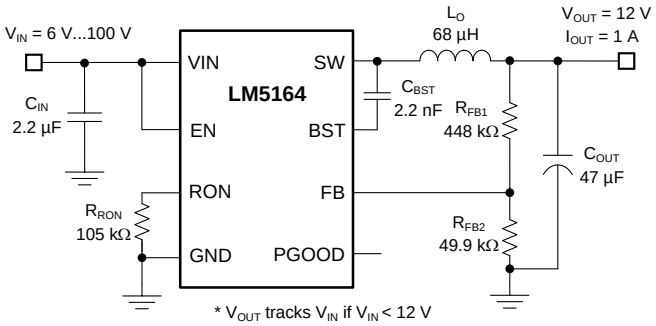

Figure 2. LM5164 Converter Typical Schematic

As shown in Figure 3, a synchronous switching converter like the LM5163 and LM5164 in high conversion ratio applications offers a larger light-load efficiency (above 80%) relative to the higher power dissipation of the external diode with a non-synchronous converter.

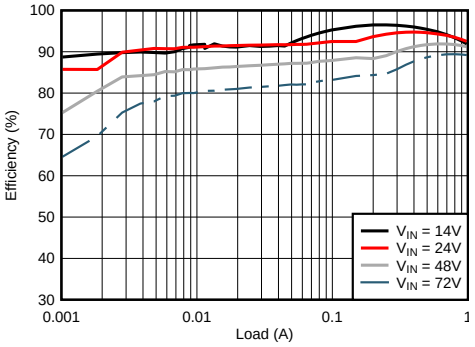

Figure 3. LM5164 Converter Efficiency, V_{OUT} = 12 V

An ultra-low shutdown current specification of 6 µA at 48-V input (see Figure 4) enables extended battery life when in idle mode, and its low operating quiescent current specification of 10 µA ensures minimum battery discharge when diagnostics are active. Even though an LDO can provide the same low I_Q performance, it cannot deliver high efficiency (above 75%) at light loads or support ultra-high efficiency (above 85%) at heavier loads.

Placed in a popular low pin count (8-pin) SOIC leaded package, the LM5163 and LM5164 converters require few external components and can be designed with reduced system complexity and solution cost.

The SOIC leaded package pin-pitch is 1.27 mm and satisfies the 1-mm spacing requirement dictated by IPC-9592B for high-voltage designs up to 100 V.

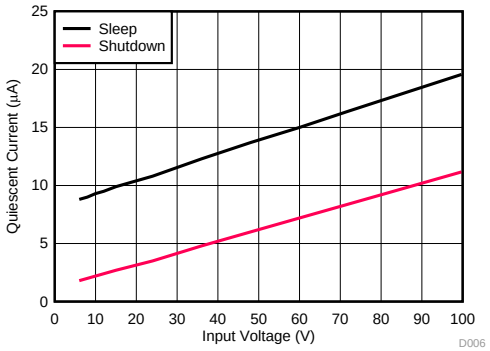

Figure 4. LM5164 Typical I_Q vs. V_{IN}

High-Cell Battery-Pack System Implementation

With a well-designed auxiliary power supply that incorporates a high efficiency, low I_Q DC/DC buck converter, Texas Instruments' *Accurate Gauging and 50 µA Standby Current, 13S, 48-V Li-ion Battery Pack Reference Design* achieves 50-µA standby and 15-µA "ship" mode current consumption, saving more energy and allowing longer ship time and idle time.

This reference design enables high state-of-charge (SOC) gauging accuracy using a 13S, 48-V Li-ion battery pack. It monitors each cell voltage, peak current, and temperature with high accuracy and protects the Li-ion battery pack against overvoltage, undervoltage, overtemperature, and overcurrent situations. Based on the *BQ34z100-G1*, the SOC gauging takes advantage of an impedance-tracking algorithm and achieves as high as 2% accuracy at room temperature.

The reference design uses a low-cost, 2-layer PCB and supports an optimized firmware that enables reduced product development time.

Table 1. Buck Converter Recommendations

Device	V_{IN} Range, Rated I_{OUT}	Performance Feature	Package
LM5163	6 V to 100 V, 0.5 A	Wide V_{IN}, low I_Q	SO-8
LM5164	6 V to 100 V, 1 A	Wide V_{IN}, low I_Q	SO-8
LMR36006	4.2 V to 60 V, 0.6 A	Low EMI, low I_Q	VQFN-12
LM5166	3.5 V to 65 V, 0.5 A	Low EMI, low I_Q	VSON-10

Table 2. Related TI Application Notes

SNVA804	IC Package Features Lead to Higher Reliability in Automotive and Communications Equipment Systems
SNVA806	Powering Drones With a Wide V_{IN} DC/DC Converter

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