Optimizing Battery Accuracy for EVs and HEVs

Introduction

Automotive battery management system (BMS) technology has advanced considerably over the last decade. Today, several multi-cell balancing (MCB) IC features play a key role in meeting the stringent safety, reliability and performance requirements of battery systems in electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs). IC manufacturers are now focusing their efforts on further functional optimization by integrating key features such as internal cell balancing and current measurement.

One of the critical functions of a BMS IC is the accurate measurement of individual cell voltages, which has a direct influence on battery life and range over the vehicle's service life. Accuracy is particularly important for battery cell types that have a flat discharge curve, like lithium-iron phosphate cells, which benefits smaller packs due to their low internal impedance. These cell types make it necessary for system engineers to detect small changes in cell voltage as the battery discharges. Measuring small cell voltage changes requires a sophisticated combination of accurate and stable voltage reference, an analog front end (AFE), and a precision ADC, which is a considerable design challenge for MCB IC designers. Adding to the system design challenge is the fact that detecting these changes has become critical for accurate state of charge (SOC) and state of health (SOH) calculations.

This white paper discusses the decisions a system designer must make when selecting a BMS IC that can provide accurate cell measurement across the entire operating environment and life of the vehicle. For automobile manufacturers, successful BMS implementation requires careful selection of the MCB IC at the outset of system design, and that requires understanding the differences in measurement accuracy and stability between the various IC vendor offerings. Achieving the highest levels of automotive safety integrity level (ASIL)-D compliance is another important consideration, and we'll show how a redundant back-up battery management device enables an ASIL-D compliant system.

Key Elements in a Multi-Cell Balancing IC

At the core of any MCB IC is a precision reference. The types of reference topologies employed can vary, although bandgaps tend to be the most commonly used due to their optimal trade-off in accuracy versus die area. For example, the ISL78600 multi-cell Li-ion battery manager uses a precision bandgap reference design that has a solid track record, and is well suited for demanding automotive applications. The technology is stable, mature, well characterized, and has been optimized over many years of use, underpinned by a substantial amount of real-world performance data. Its excellent performance characteristics make the precision bandgap reference very stable and linear over an MCB IC's deployed lifetime. This is a key consideration when designers make vehicle battery-life calculations, and it directly influences an automaker's warranty and cost of ownership metrics.

Along with a precision reference, the ADC is another key functional block for measuring accuracy. IC designers must now decide which type of ADC to use as the main cell-voltage-measurement block. Two of the most popular and commonly used types of ADCs are successive approximation register (SAR) and delta-sigma. Having the fastest sampling rate of the two technologies, the SAR offers high-speed voltage conversion and excellent noise immunity, but tends to require a larger die area. SAR ADCs also offer the best combination of data acquisition speed, accuracy, robustness and immunity to the effects of EMI.

On the other hand, IC designers like delta-sigma ADCs because they typically require less die area, and are relatively easy to implement. However, they tend to be slower because they use a decimation filter, which reduces the sample rate and data acquisition speed. To overcome this issue, designers will use two or more delta-sigma ADCs in an interleaved configuration. Another consideration when implementing delta-sigma ADCs is their tendency to saturate when subjected to EMI, which causes the misreporting of cell voltages.

The individual cells' interface is managed by the AFE, which integrates input buffers, level shifters and fault detection circuitry. The AFE is key to handling hot plug transients when the cells are initially connected to the BMS. The ISL78600 is designed with a fully differential AFE that enables negative input voltages to be measured without affecting the adjacent cell measurements. This is advantageous in systems where bus bar interconnection is required. To improve robustness under transient conditions, an external low-pass filter is added to the cell voltage inputs. The input filtering requirements have been optimized for maximum EMI and hot plug immunity, without compromising speed or accuracy. By contrast, ICs that use a bipolar AFE rather than a charge coupled AFE can have their accuracy detrimentally affected by the component values selected for the input filter. Figure 1 shows a simplified diagram of the ISL78600's three functional blocks and their interconnection.

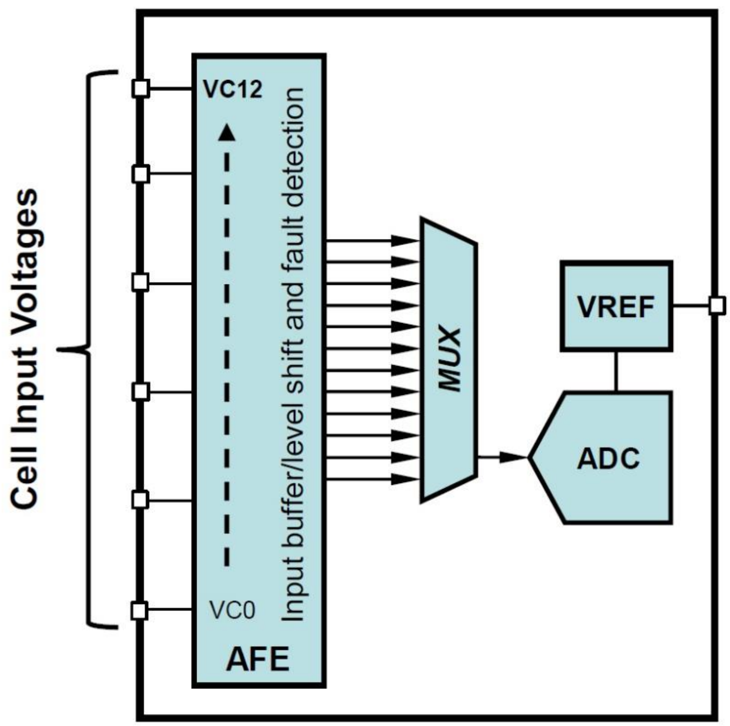

Figure 1. Simplified block diagram of the ISL78600 multi-cell Li-ion battery manager

The combination of a stable and linear bandgap reference, SAR ADC and fully differential AFE gives a multi-cell Li-ion battery manager fast data acquisition capability combined with robustness and precision accuracy. Rather than relying simply on the measured accuracy values as it leaves the factory, the ISL78600's high accuracy is independently verified after mounting on a PCB.

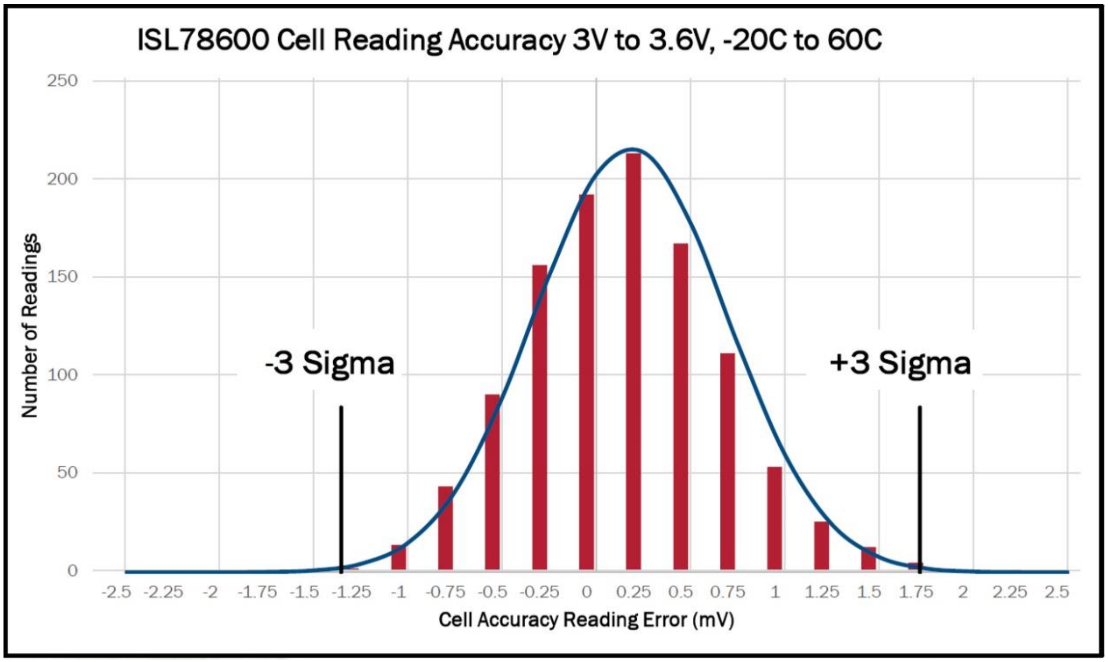

Figure 2. 1080 total readings collected from 10 MCB evaluation boards with a voltage scan rate of 240µs for all 12 cells

Figure 2 shows the ISL78600's accuracy over a range of cell voltages and temperatures. This is of critical importance to battery system designers, because they work with a system error budget for the vehicle's service life, and-must be able to factor in reliable and predictable accuracy figures. Therefore, a careful examination is recommended, and a detailed comparison should be made between each IC vendor's data sheets, particularly in the areas of accuracy, data acquisition speed, and input filter requirements, including their effect on accuracy.

Achieving ISO 26262 ASIL-D Compliance

For hybrid and electric vehicles that require a redundant back-up battery management device, the ISL78610 battery pack monitor can be combined with the high accuracy ISL78600 multi-cell battery manager, as shown in Figure 3. This powerful combination enables automobile manufacturers to achieve the higher ASIL-D rating.

Together, the ISL78610 and ISL78600 offer internal and external fault detection such as open wire, over and under voltage as well as temperature and cell balancing faults to mitigate battery pack failures. Multiple devices can be daisy-chained together to support systems with up to 168 cells using a proprietary communications system that provides excellent transient and EMC/EMI immunity, which exceeds automaker requirements.

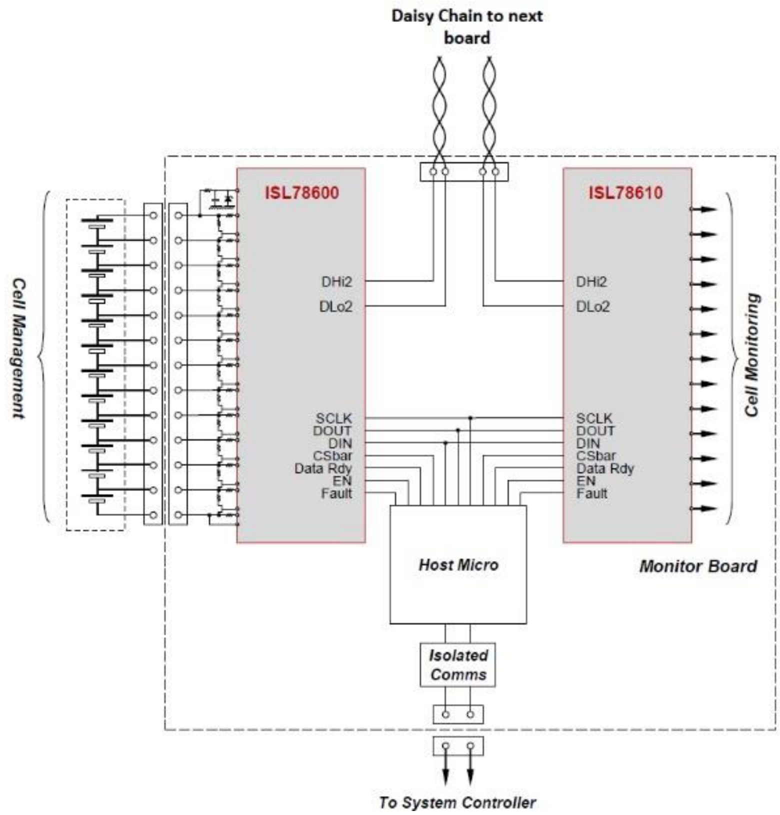

Figure 3. The ISL78610 12-cell battery pack monitor serves as the redundant back-up device in an ASIL-D-compliant HEV/PHEV/EV system

PCB Layout and Configuration Considerations

Soldering induces stresses across the PCB, which “flexes” the MCB IC in the X and Y plane, and results in sub-atomic changes in the silicon’s properties. This effects the IC’s behavior and, in particular, the reference circuit block. Since the reference is a critical part of the measurement circuitry, any variation in its characteristics has a direct effect on the accuracy of the ADC. This is a well-known and understood phenomenon in the precision IC industry, and designers make allowances for this by carefully placing sensitive circuitry in areas of the die less likely affected by soldering and other manufacturing stresses.

Alternatively, there are more costly reference design techniques available to designers, such as placing a separate reference circuit on its own die within the same IC package, or using a completely separate discrete reference IC. No matter which technique is used, the PCB design and manufacturing stage are both critical, so making use of standard precision part PCB layout and careful consideration for IC mounting and soldering profiles can help mitigate any issues.

For example, if designers follow the ISL78600’s recommended PCB layout guidelines and soldering reflow profiles, the IC’s board-level cell reading accuracy and long-term drift characteristics are logarithmic and predictable. This results in a typical cell reading error of only 1.2mV over 10 years of service life, as shown in Figure 4.

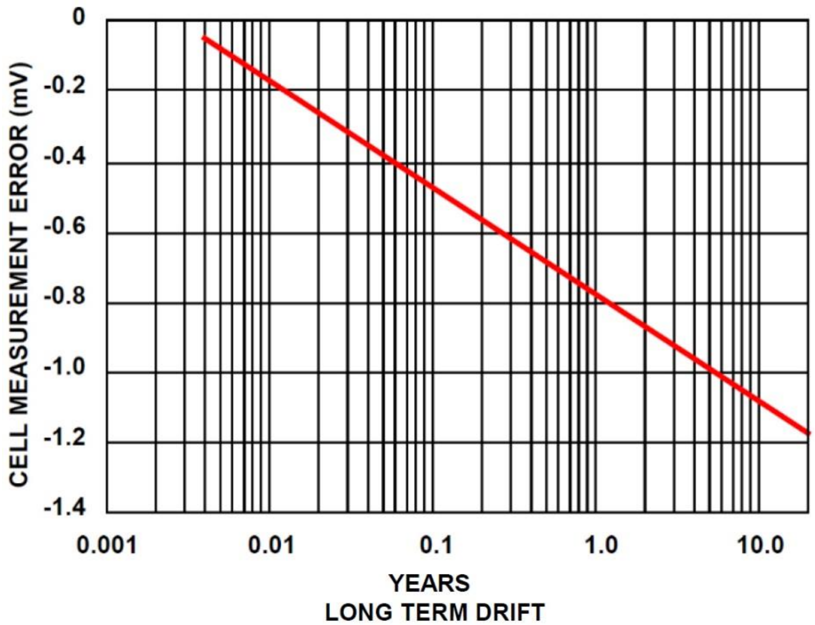

Figure 4. MCB IC cell error vs. lifetime

Conclusion

A key element of battery management design is factoring in battery performance, which is directly affected by the MCB IC's ability to maintain its precision measurement accuracy over the vehicle's service life. Any drift or instability in battery cell measurement directly influences the vehicles range and battery life, which in turn affects the automaker's warranties and cost of ownership. There are various MCB ICs available to choose from with different accuracy measurement topologies and technologies, so system designers must carefully select their IC. Understanding the underlying differences in measurements, schemes and topologies, and their interrelationship goes a long way in selecting the most appropriate device for a BMS application. And finally, selecting the right back-up IC to combine with the primary MCB IC must be considered for the redundancy requirement of ASIL-D. Optimized battery system designs are essential to next-generation EV, PHEV and HEV automobiles.

Next Steps

- Learn more about the ISL78600 and ISL78610
- Get the datasheets
- Watch a demo video

# # #

About Renesas Electronics Corporation
Renesas Electronics Corporation delivers trusted embedded design innovation with complete semiconductor solutions that enable billions of connected, intelligent devices to enhance the way people work and live—securely and safely. A global leader in microcontrollers, analog, power, and SoC products, Renesas provides the expertise, quality, and comprehensive solutions for a broad range of Automotive, Industrial, Home Electronics, Office Automation and Information Communication Technology applications to help shape a limitless future. Learn more at renesas.com