Application Brief

How High-Voltage BMS Enhance Safety and Battery Lifetimes

A battery energy storage system (BESS) plays an important role in the management of residential, commercial, industrial, and grid energy storage. In a modern BESS, the battery management system (BMS) serves as the brain of the battery pack, monitoring parameters such as voltage, current and temperature and providing insight into the state of charge (which assesses the remaining energy available) and state of health (which assesses the overall condition and aging of the battery cells). By ensuring better battery-monitor accuracy and increasing system-level safety, the BMS helps maintain efficient energy usage and delays premature battery degradation, prolonging BESS lifetimes.

Ensuring Battery-Monitor Accuracy

A battery pack monitor can not only increase the accuracy of cell voltage measurements; it can also help improve state-of-charge estimations and overvoltage protection. State-of-charge algorithms and other high-voltage system diagnostics also need accurate reports of pack voltage and current.

In lithium-iron phosphate (LiFePO4) batteries, which are a popular battery type for BESSs given their reliability and reasonable cost, having highly accurate measurements are directly related to reliable operation. The voltage profile of an LiFeP04 battery is distinctly characterized by its largely flat charge and discharge curve for most of its useful capacity, resulting in a more stable operating voltage before reaching its end of charge, where the voltage level quickly drops off. Failure to detect slight voltage variations in the flat region of the charge and discharge curve can increase the risk for error in state-of-charge estimations.

Increasing System-Level Safety

Various factors can directly affect battery degradation, including overcharge and overdischarge conditions, high temperatures, low temperatures, and high charge currents. The integrated monitoring and protection suites in a BMS can help reduce the incidence of these conditions. For example, features such as integrated cell balancing can greatly improve overall cell lifetimes by ensuring closely balanced cells, preventing weaker “unbalanced” cells from straining the overall pack. Precise balancing and high-accuracy cell measurements make it possible to mitigate and detect inefficiencies in the operation and conditioning of the cell.

Variations among cells continue to increase over the lifetime of a battery pack. Active cell balancing and active pack balancing can help increase ESS lifetimes and decrease manual maintenance as cell capacity keeps increasing, since passive balancing is not enough in an ESS.

An active balance design approach for pack-to-pack balancing, using bidirectional isolated DC/DC to achieve energy transfer, helps the overall system improve utilization.

Achieving Long Lifetimes

The cycle life of storage batteries grows from 10,000 times to 12,000 times or even 15,000 times with every subsequent generation. Such increases have the potential for product lifetimes to one day reach 20 to 25 years. Extending battery lifetimes are important considerations in the development of BESSs, enabling designers to deliver competitive and efficient products.

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Application Basics

Figure 1 shows a BESS architecture. This system is for high-voltage (1,500V) lithium-ion and LiFePO4-based battery systems consisting of multiple reference designs for a complete system approach.

The Up to 1,500V Stackable Battery Management Unit Reference Design for Energy Storage Systems combines several battery-management units that leverage the BQ78706 battery monitor in a stacked fashion to detect battery faults with redundant data-measurement capability.

Next, the 1,500V High-Voltage Rack Monitor Unit Reference Design for Energy Storage Systems depicts one high-voltage monitoring unit (HMU) that uses the BQ79731-Q1 pack monitor to support detection and measurement of bus voltage and current, and also integrates redundant data-measurement capability. The battery control unit (BCU) reliably drives the system switches to help maintain system safety.

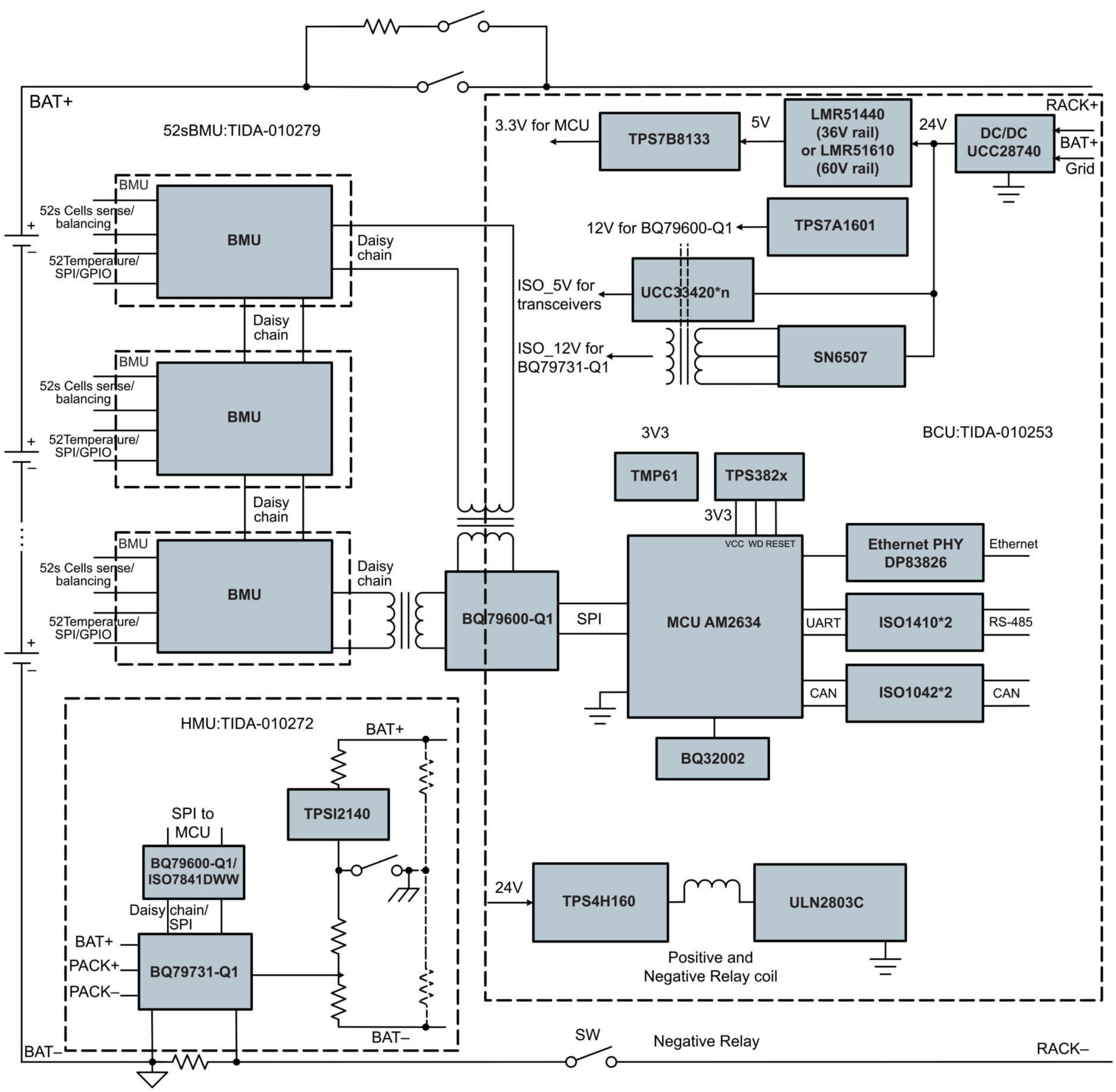

Figure 1. Block Diagram of a BESS Architecture

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Enabling Accurate Cell Sensing and a Reliable System Architecture

Figure 1 shows how the combination of a BCU and HMU works to achieve a reliable system level of safety. The BQ79731-Q1 in the HMU enables high-accuracy bus voltage measurements, with a maximum accuracy of ±3.16mV. This level of accuracy helps improve the resulting reliability and simplicity of calibration for isolation impedance measurements and contact welding detection. The BQ79731-Q1 also combines a continuous sampling analog-to-digital converter with a low gain error (±0.065%) and low offset (–2.5µV to 7.5µV). The voltage and current measurement diagnostics can be performed using safety mechanisms (TI Functional Safety-Compliant to Automotive Safety Integrity Level [ASIL] D), supported by the BQ79731-Q1, to enable system-level safety with a reliable measurement result.

Figure 2 demonstrates TI's Battery Control Unit Reference Design for Energy Storage Systems, which achieves ±2.4mV cell voltage error from –40°C to 125°C using the BQ78706 battery monitor. The design measures each individual cell channel temperature with TMUX expansion and the TMP61 high-accuracy (±1°C at –25°C to 65°C) thermistor sensor. As in the BMU, cell voltage and temperature diagnostics are performed using the BQ78706's integrated safety mechanisms (TI functional safety compliant to ASIL B) to obtain a reliable result. A software development kit based on the MSPM0G3519 helps simplify the design process for faster time to market.

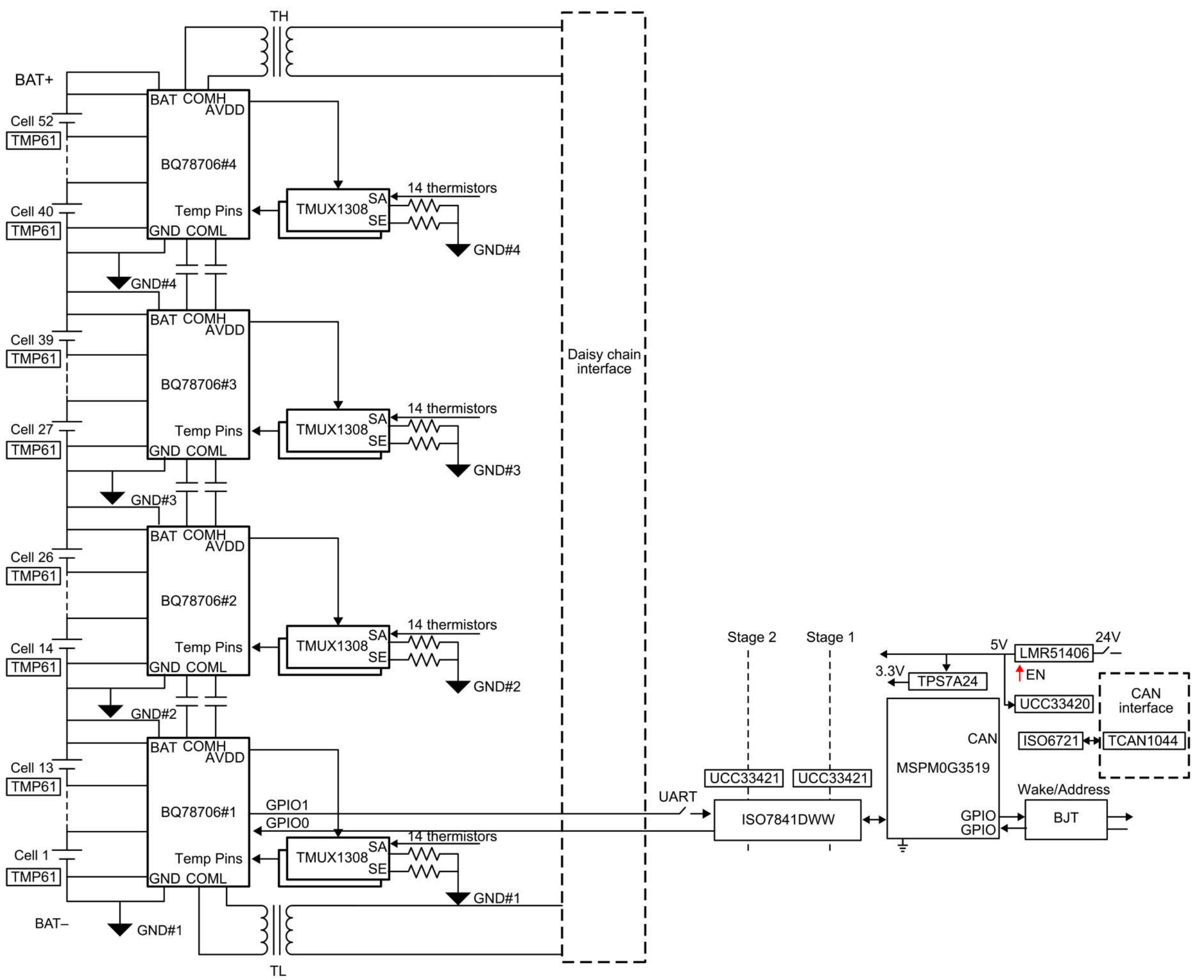

Figure 2. Diagram of Battery Control Unit Reference Design for Energy Storage Systems Reference Design Showing a Stackable BMU Architecture

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The BMU and HMU design is compliant to International Electrotechnical Commission 62477-2 and Underwriters Laboratories 1973 reinforced insulation requirements up to 1,500V. This design can be used with reinforced isolators such as the ISO7841 and UCC33421, or daisy-chained with an extra-wide creepage transformer ensure sufficient system-level safety.

Conclusion

Safe and reliable BMS play a pivotal role in advancing the longevity, efficiency, and most importantly safety of ESS, particularly as it relates to the trend from Li-ion to LiFePO4 chemistries and beyond. By providing accurate data sensing and enabling pack and cell-level balancing of all modes of ESS, BMS design approaches maximize energy utilization from renewables like solar power, and wind that can help to stabilize power grids during periods of high demand or for backup power during outages.

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