Framework for Radiation-Hardened Space Battery Management

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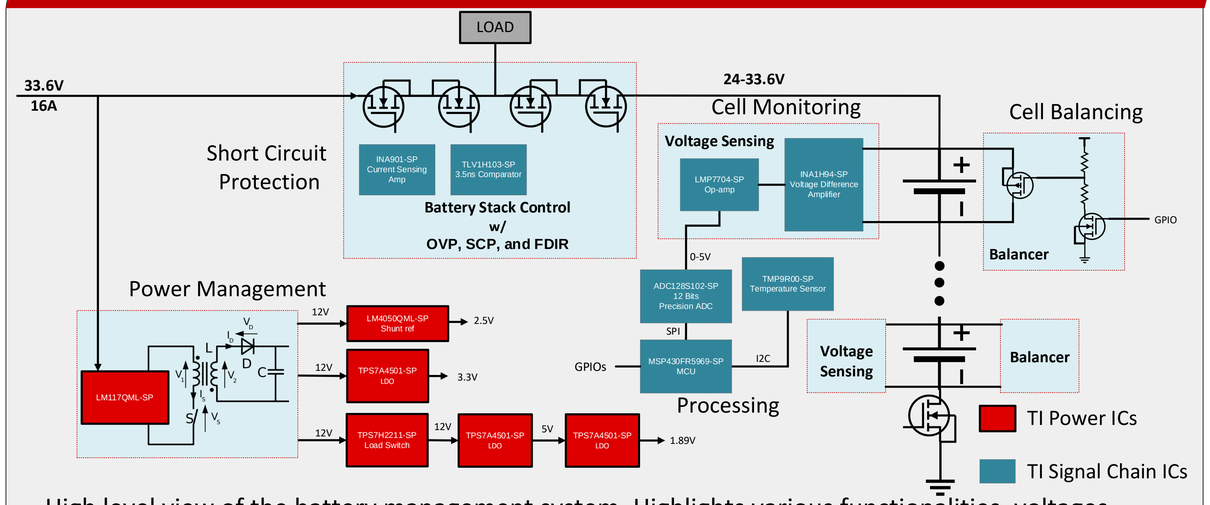
Abstract

Battery management systems (BMS) are crucial for satellites to maintain a reliable energy source. Today, lithium-ion batteries act as the solution to reduce the cost and weight of satellites, yet still come with safety concerns.

The combination of the high energy density of Li-ion and flammable material associated with batteries can be hazardous due to thermal runaway, overcharging, improper balancing, and the chance of experiencing a short. Currently, there are no radiation-hardened balancer/monitor ICs with the ability to sense battery state of health and state of charge.

This poster highlights a discrete, autonomous, and reliable BMS approach that provides high radiation performance, precise cell voltage monitoring, fast overcurrent protection, temperature sensing, and balancing capabilities.

System Solution



High level view of the battery management system. Highlights various functionalities, voltages required, and programming peripherals that make up the system.

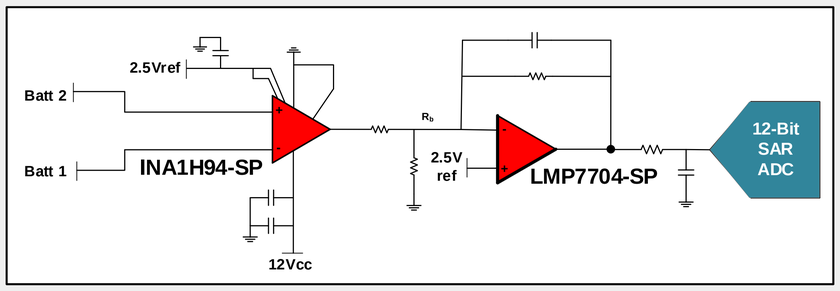
System Specifications

- Radiation performance **75krad/72 MeV**
- Manage eight 4.2V Li-ion batteries
- **± 1mV accuracy** (Batt = 3 to 4.2V)

System Features

- Battery cell voltage monitoring system
- GPIO controlled battery cell balancing
- Temperature sensor to monitor battery cells
- A battery stack control to protect battery and load from over charging and short circuit

Cell Monitoring



- The INA1H94-SP, a precision unity-gain difference amplifier, accurately measures the voltage from each battery. It can measure small differential voltages in the presence of a **common-mode signal up to 150V at a 18V supply**.
- The LMP7704-SP adjusts the common mode and range of the signals to maximize **the dynamic range of the ADC input**.

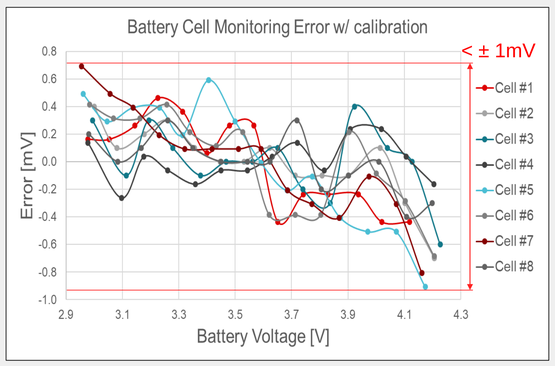
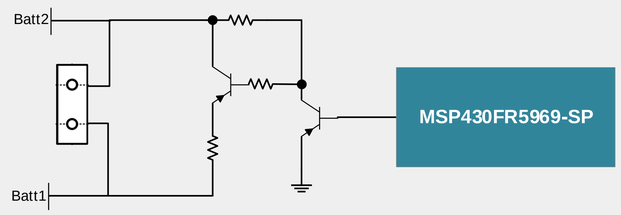


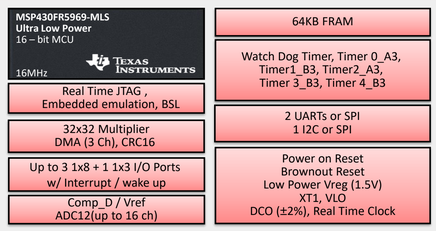
Fig 1. Battery cell **voltage monitoring error is <±1 mV** for battery voltages ranging from 3.0V-4.2V after offset calibration

Cell Balancing



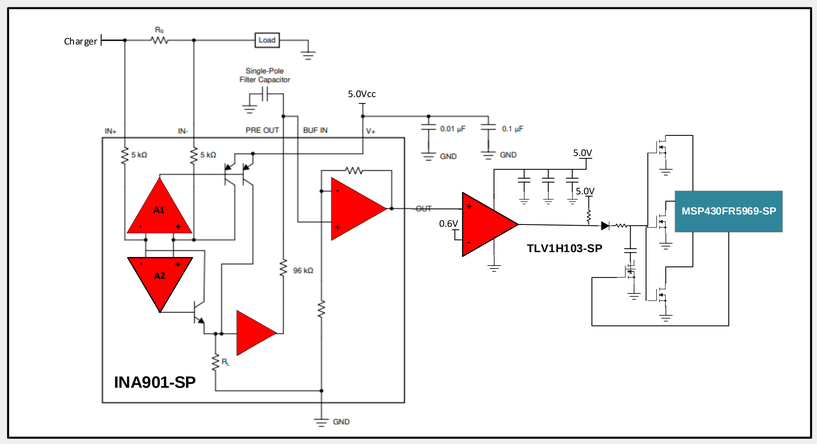
- This is a low complexity passive balancing design. When the GPIO from the **MCU is low there is no balancing occurring (**No current drawn).
- When the GPIO from the **MCU is high the transistor gets turned on** and around 15mA is drawn from the battery cell. This can easily be optimized by changing a resistor value.

Processing



- The MSP430-SP is optimized **for ultra low power consumption** (.32uA), a flexible clock system, and a wide supply voltage range from 1.8V to 3.6V.
- This design uses UART, I2C, and GPIO serial communication

Short Circuit Protection



- The INA901-SP, current sense amplifier, has a built in gain of 20V/V allowing for a **smaller current sense resistor which minimizes the power drop** across the sense resistor.
- It is paired with the TLV1H103-SP, voltage comparator, to drive the MCU

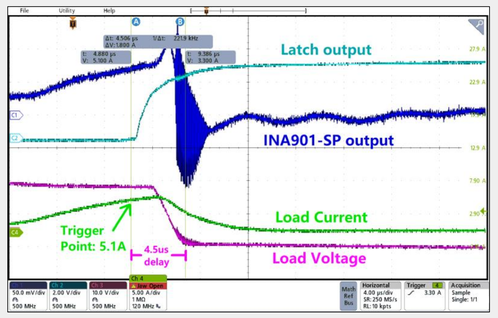
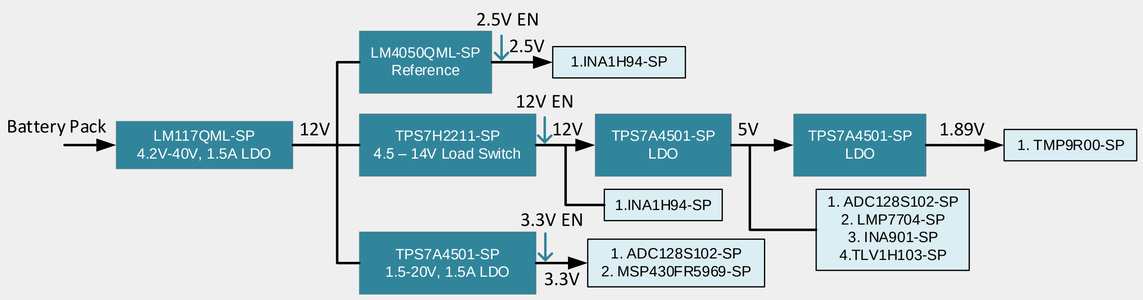


Fig 2. With the power turned off, the voltage **shuts down within 4.56us.**

Power Management



- The LM117QML-SP is an easy to use, wide input range, 1.5A linear regulator that converts voltage from the battery pack (33.6V) to 12V.
- The LM4050QML-SP is a 2.5V shunt voltage reference that supplies a low-noise reference for battery cell monitoring. The TPS7A4501-SP, adjustable LDO, converts voltage from 12V to 3.3V, 12V to 5V, and 5V to 1.89V.
- Each section of the power supply can be **enabled/disabled** from the MSP430 to **reduce current consumption** when not in use.

Summary

- Discrete radiation hardened battery management solution
- Scalability to measure up to 28 batteries
- High accuracy battery cell monitoring
- MCU controlled cell balancing
- Optimized power management
- Quick short circuit protection
- Temperature monitoring of cells
- Potential opportunity to include current monitoring

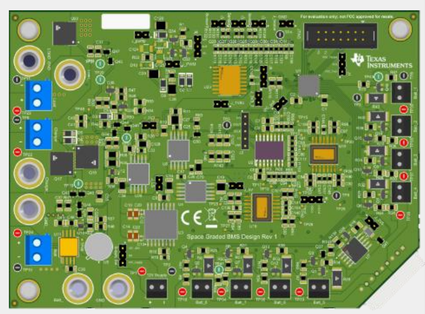


Fig. 3 Full design as a PCB

Additional Resources

INA1H94-SP (samples in 3Q24)
TLV1H103-SP (releasing in 4Q24)
For more information on these devices contact your local TI representative

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