ELECOMP CAPSTONE SUMMIT
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THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Battery Management System for Lithium-Based Batteries

AcuBMS

Acumentrics
TRUSTED POWER INNOVATIONS®

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Project Motivation

Mobile technology is one of the largest growing markets in today's world. In order for these devices to be viable to consumers, it is necessary that batteries within these devices are not only powerful, but more importantly; safe. Smart batteries include many features, with their primary function as keeping the battery's cells and the user safe during all stages of operation. As a result of these protection methods, smart batteries are less prone to hazardous conditions and thus more likely to outlast other types of batteries. This benefit has numerous applications in the automotive, medical, and government industries. Another advantage of typical battery management systems is the ability for the user to request different messages, such as voltage level, cycle count, and manufacture date, from the battery. From the vital battery information in these messages, it is possible for a user to observe the status of the battery and plan for maintenance or replacement of poorly-performing batteries. This need for safety is the project motivation for Team Acumentrics.

Key Accomplishments

Microcontroller Programming: The MSP430FR5969 microcontroller in the AcuBMS utilizes the timers and interrupt service routines (ISR) to sample from the built in analog-digital-convertor. Programming these features requires knowledge of the relationship between the MCU hardware and register programming.

Smart Battery Specification: The MCU is programmed to conform to the Smart Battery Specification 1.1 (SBS 1.1). The SBS 1.1 is a standard guide that defines the relationship between a Smart Battery and other devices. This specification includes details on the communication protocol used to communicate to the product and the battery data that can be transmitted from the Smart Battery.

ADC Sampling and Finite State Machine: The internal analog-to-digital (ADC) convertor on the MSP430 has been programmed to convert signals from multiple channels (**Fig. 1**). The timer and ISR of the MCU work together as parts of the finite state machine (**Fig. 2**) to trigger ADC interrupt. Within this interrupt, the ADC samples from each channel and stores the signals into memory. The signals are converted into current, voltage, and temperature values respectively. The SBS 1.1 battery messages are calculated using these three values, and then stored into memory. This entire process runs at a fixed rate of 10 Hz.

SMBus Implementation: The System Management Bus (SMBus protocol) is used to communicate the stored data between a smart battery and a host device. This protocol allows a user to access the battery data at any time. The MSP430 is programmed as a slave device such that is continuously waits for a master to initiate communication. When the master requests data from the slave, the ADC sampling process is interrupted to access a data register corresponding with the request. The slave then transmits this data to the master.

Circuits Simulations: Using National Instruments' Multisim simulation software, we created our sub-circuits and a total system simulation. In order to protect our battery from reaching voltage levels that are too low or too high we created an Under-Voltage Circuit, a minimum Under Voltage Circuit and an Over-Voltage Circuit. Also, in order to limit the current draw and charge current we designed a Bidirectional Current Sense Circuit. These circuits completes our AcuBMS Analog Front End (AFE) protection. Each subcircuit was designed and simulated individually to verify proper functionality. The circuits were then combined into a full system simulation (**Fig. 3**). The simulations verified our concept and compatibility between the different subcircuits.

Circuit Schematic for PCB Fabrication: The battery management system was designed in Eagle schematic software and then fabricated a printed circuit board (PCB) composed of the selected components (**Fig. 4**). The AFE sub circuits are supplied with battery power or a charger input, therefore functioning independently of the MCU's power. This design prevents dangerous voltage/current levels from reaching the more sensitive components in the system. After the transition from simulations to real-world board design, the team had to consider the importance and relevance of industry-standard components that would be compatible with the voltage and current levels in the board.

Hardware and Software Integration: Upon completion of the PCB, the microcontroller was flashed over JTAG. This uploads all instructions to the MCU to ensure proper operation with the rest of the system.

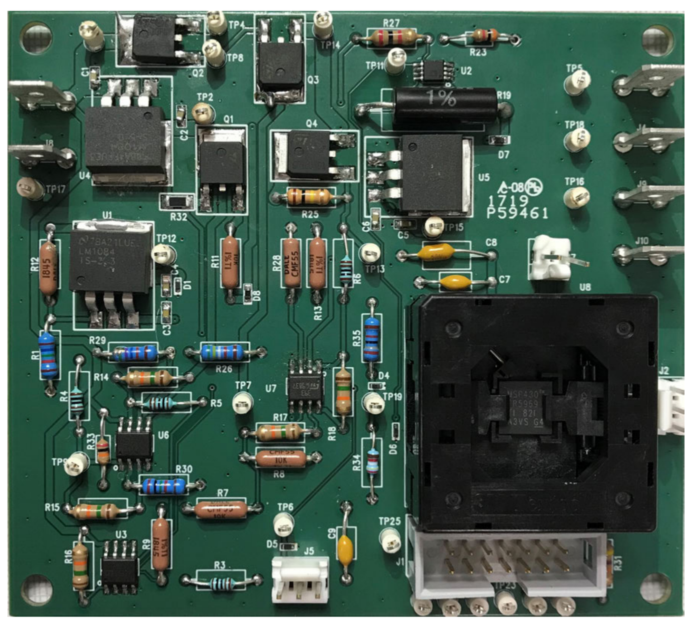

Figure 4: Fully assembled prototype

Anticipated Best Outcome

The Anticipated Best Outcome for Team Acumentrics was to create a functional battery management system that can convert a regular rechargeable Lithium-Ion battery to a smart battery. The system is designed to protect the battery's cells from potential hazardous conditions, such as over-voltage, under-voltage, and overcurrent states. When any of these conditions are detected at the analog front end, the circuits quickly cut off the input or output from the rest of the system to prevent damage. Additionally, the BMS must implement SMBus communication, and conform to standard smart battery specifications. This allows users to read characteristics of the battery such as remaining capacity, cycle count, and estimated time to empty.

Project Outcome

Results towards achieving the Anticipated Best Outcome will be presented at the Summit..

Figures

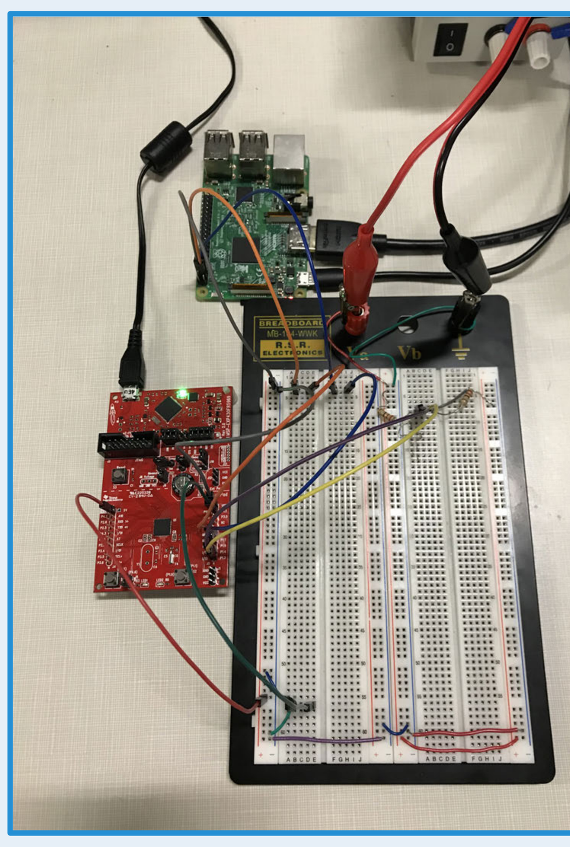

Figure 1: Multi-channel sampling using analog to digital converter

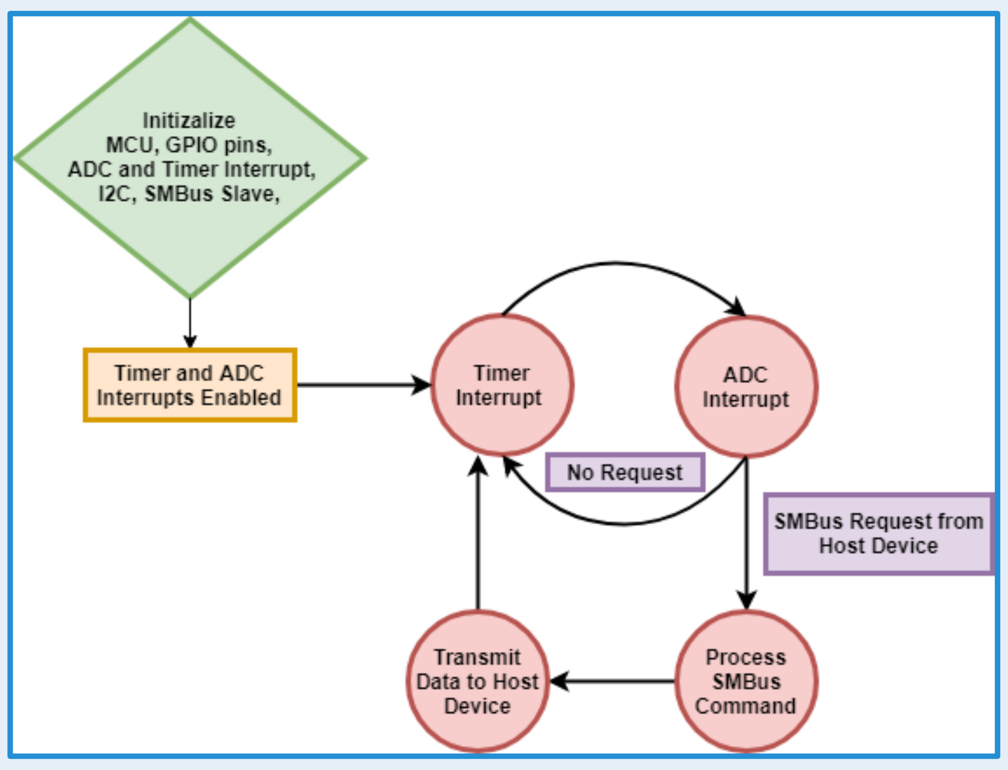

Figure 2: Finite State Machine for MSP430 Programming

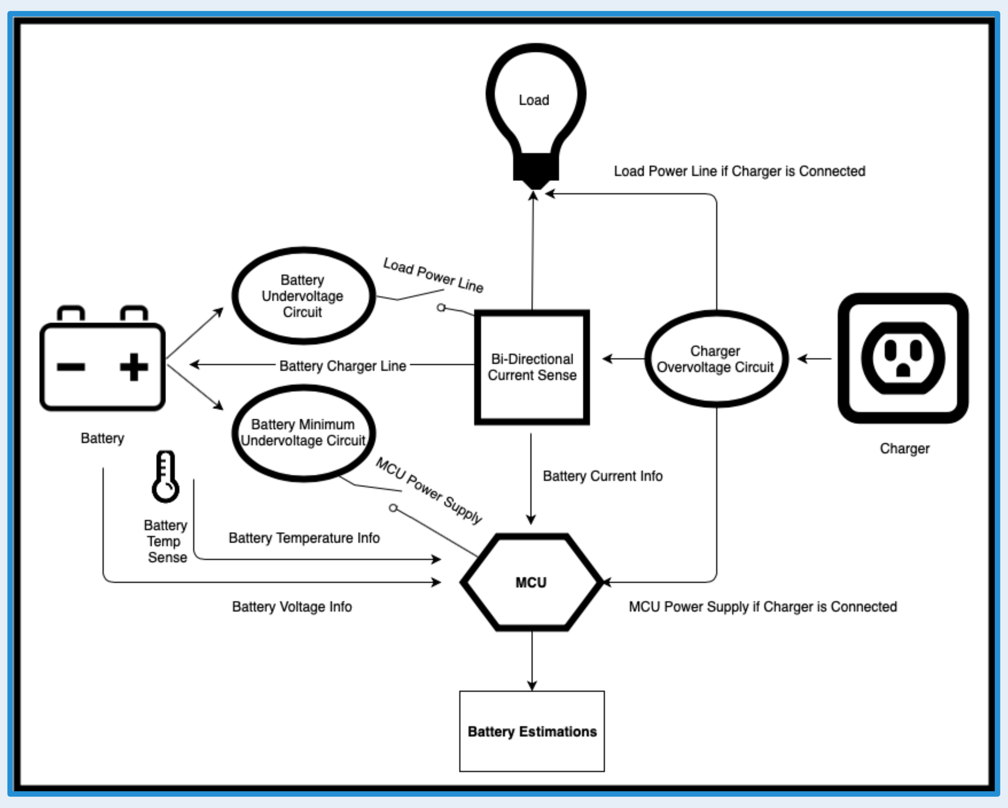

Figure 3: Block diagram of battery management system

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