ELECOMP CAPSTONE SYMPOSIUM
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THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

AM-BATS Part Deux

Determining battery health

EAGLEPICHER TECHNOLOGIES

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Project Motivation

EaglePicher specializes in providing battery solutions for very demanding applications. Their batteries are frequently required to perform at extremes in temperature, vibrations, power delivery and service life. Achieving the performance that their customers demand requires advancements in the tools and methods used to evaluate battery cell designs, integrated with the battery management systems to control them. Tradeoffs typical in BMS product designs create limitations that make laboratory instrumentation challenging. A battery management system with the ability to collect high fidelity performance telemetry could prove invaluable in evaluating battery cell designs. Illuminating the unique characteristics of candidate battery cells will aid in establishing the minimum requirements for a deliverable BMS design. Ultimately, a better understanding of cell characteristics, and how those characteristics can be observed and interpreted by the BMS, is the next step in optimizing the use of the batteries in both first and second life applications.

Key Accomplishments

Test Fixture Design: We have created a 3D model **(Fig 2.)** and a block diagram **(Fig 1.)** to visualize how our test fixture will be designed and all the connections that are added.

Key Component Selection: Researched and selected components within power specifications dictated by the design. Completed a bill of materials for the majority of the components needed to run data collection with an electronic load supply.

Data Collection Systems: Our project's main objective is to be able to compare the data collected from a commercial off the shelf (COTS) BMS system to a real time data acquisition system. We researched data collection systems and chose the National Instruments DAQ due to its high 24-bit resolution and high sampling rate. The Orion BMS 2 was chosen over the foxBMS as a good representation of a widely available COTS BMS.

Temperature and Current Measurement: Designed circuitry to allow us to measure the temperature of the battery cells **(Fig. 3)** and the current going in or out of the battery pack. This circuitry includes the necessary signal conditioning required to put the measured output voltages in a readable range. We designed a buffer amplifier and voltage divider circuit to read the temperature. We designed signal conditioning for the current sensor to operate on a 10V scale to represent the range of current (0-10A) from the battery pack.

Equation Sheet Conversion: Our DAQ system will output raw data unlike our BMS, therefore we will need to do multiple mathematical conversions to be able to synchronize and compare our data. We have compiled a list of all mathematical equations needed to do so.

Programmable Load Design: Designed a programmable load **(Fig. 3)** with eight channels that is capable of creating 256 different current levels between 0 amps and 10.24 amps. Simulated a working load profile circuit with non-ideal components.

Graphical User Interface: Developed a GUI to allow us to test different fake generated Battery Cell Data in preparation for our predictive modeling. This GUI will allow us to see how a Battery pack works in parameters identical to what ours will be once we receive all our components.

Battery Board: Designed a PCB **(Fig. 4)** that will contain all battery holders and make all connections necessary from the battery pack and associated telemetry to both the DAQ and BMS. This board also allows connection between the batteries and the programmable load and charger.

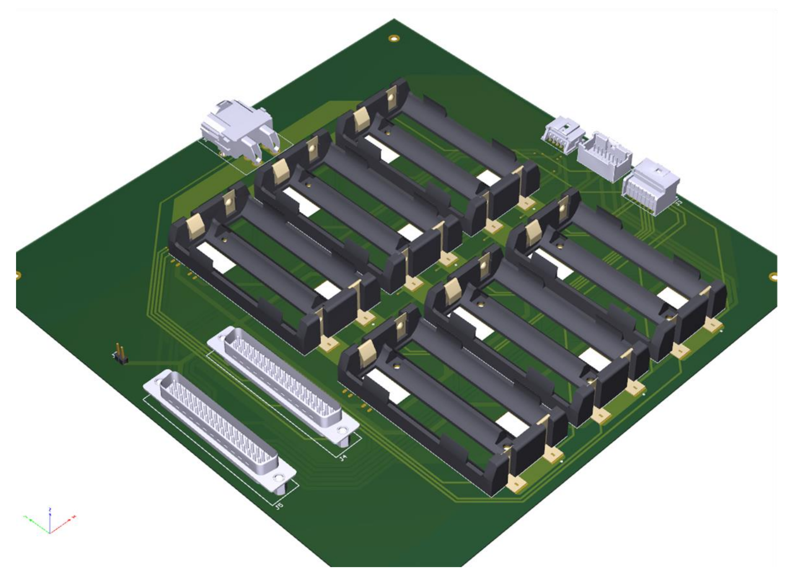

Fig. 4: Battery Board, where our battery cells and all connections to them will reside

Implications for Company & Economic Impact

Some of EaglePicher's batteries are currently on Mars and delivering cutting edge performance, as you read this. Achieving the performance that their customers demand requires advancements in the tools and methods used to evaluate battery cell designs, integrated with the battery management systems to control them. EaglePicher would be able to advance their studies into the usefulness of worn batteries and what they can be used for after their primary use has been exhausted. The technology would be capable of being mass produced and be capable of detecting damaged/malfunctioning battery cells that otherwise would not be able to be diagnosed in the field. By optimizing the BMS around the most important parameters to measure, for both safety and state of health/charge, EaglePicher Technologies will set the standard for providing rapid solutions for critical applications.

Anticipated Best Outcome

Our Anticipated Best Outcome for AM-BATS Part Deux, is to design and build a battery management System platform to investigate battery cell performance for demanding applications. This will include the ability to synthesize the charge and load characteristics for a variety of applications. Using the AM-BATS platform, demonstrate the safety protocols and performance of Li-Ion batteries in various applications. EaglePicher will provide usage profiles ranging from electric bikes, to vehicles, to directed energy weapons and hybrid load conditioners. Identify the correlation between BMS measurements and the prediction of aging for various cells and usage profiles.

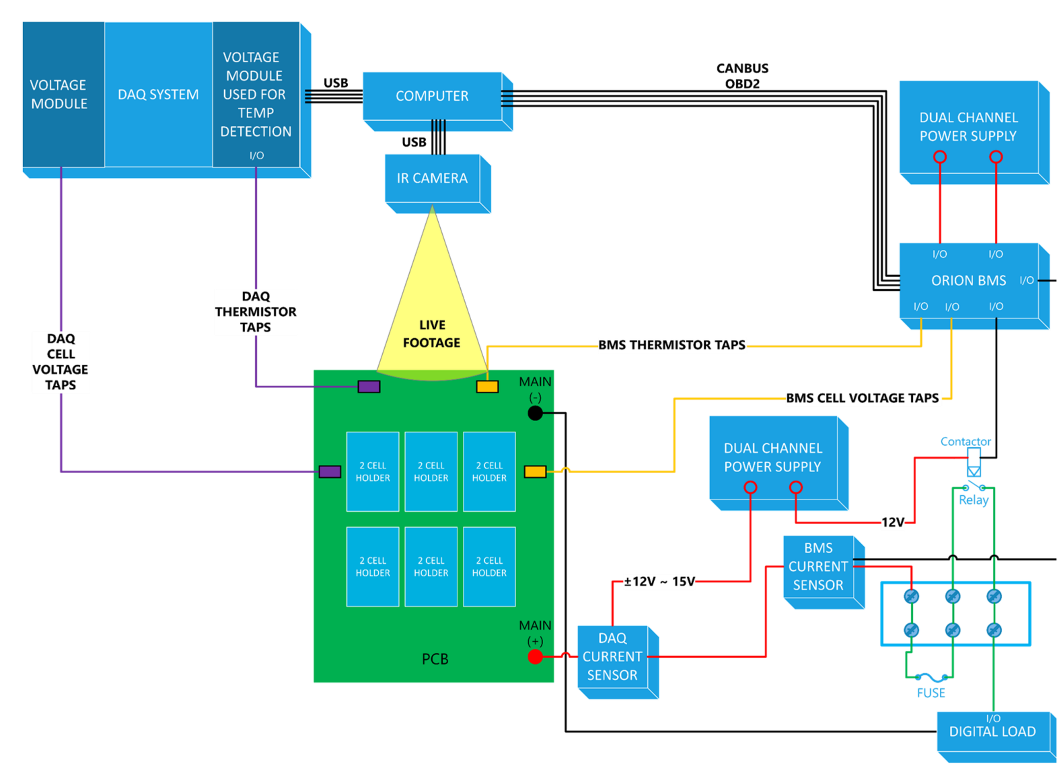

Fig. 1: Overall visualization of our system including all virtual and physical connections.

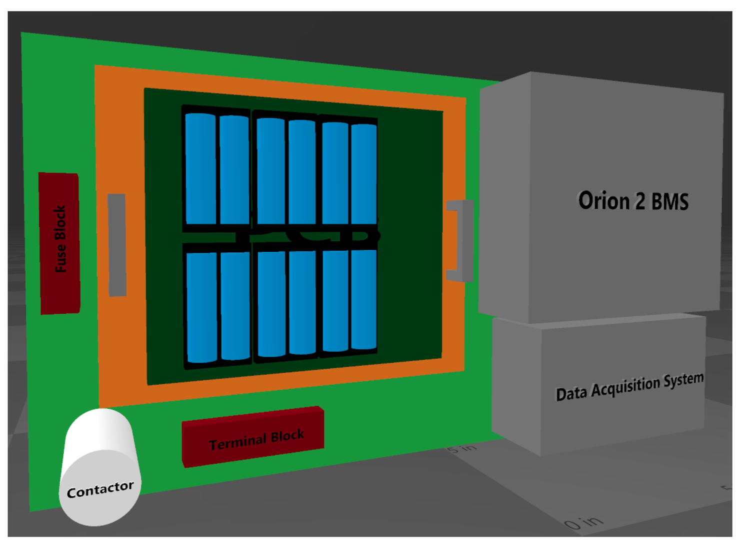

Fig. 2: 3D model of our test fixture

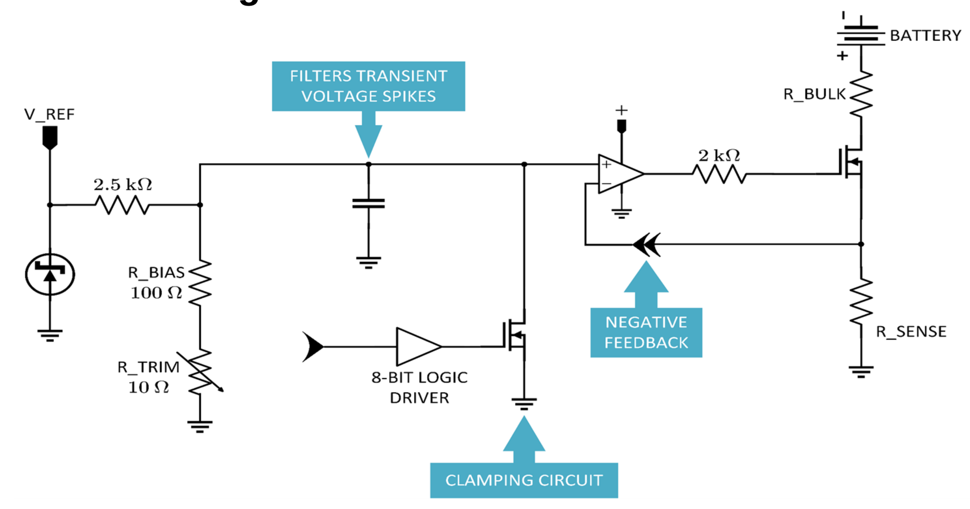

Fig. 3: Load Profile Circuit

Remaining Technical Challenges

Signal Conditioning: There are a lot of different components to this setup that will require different voltage and current levels, which demands a good amount of signal conditioning. A reference voltage for the thermistors will need to be buffered to support 12 thermistor readings to the DAQ. The current sensor will need to be conditioned to obtain a 10V scale to read the current draw from the battery pack from 0 to 10A.

Load Profile Circuit: Components need to be selected that will meet the design specifications. The form factor of the load profile circuit also needs to be determined, whether it will be on protoboard or PCB. Specifically, the high power bulk resistors are too large to be placed on a circuit board, and we need multiple, so we need a stable setup branching off a protoboard or PCB for each channel of the load profile circuit.

Test Fixture Assembly: The battery board PCB needs to be populated and the swappable battery blocks need to be assembled, along with the rest of the fixture.

Data Collection: Completing a cycle of running a discharge profile and recharging the battery pack will take several hours, and will need to be monitored throughout the process. Obtaining a lab space where the physical setup can complete this process without interruption is not fully determined.

ML Data Synchronizing Model: The BMS has a much slower sampling rate compared to the high speed DAQ, which will complicate the process of synchronizing the data in order to determine what the BMS is seeing when significant data points appear on the DAQ.

Predictive Models: As we collect our data one of our final achievements will be creating predictive models that will be utilized to forecast individual cells' parameters and how their life cycles will look like. This is a complicated process that requires a large amount of data and ML, but it will be what our project is working towards.