ECE 445: Senior Design

Automated Cell-Tester: Project Proposal

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1 Introduction

1.1 Problem

Lithium-ion batteries are being increasingly employed in industries such as EVs and solar power systems. The biggest drawback with this technology is that lithium-ion batteries have a tendency to start extremely dangerous and destructive chemical fires. Generally, the cause of this can be traced to either a manufacturing defect or improper use of the battery. The latter cause is often avoidable and in many cases is due to a lack of insight and knowledge of how a battery is currently behaving versus the expectation. This leads to either many not being prepared to work with these batteries or just refusing to work with them altogether. One specific example is the battery management system (BMS), which uses different sensors to manage these large battery packs. But most BMS's on the market today do not work across all battery chemistries because they lack the knowledge of the characteristics of the cell's chemistry that is being managed, leading to very serious implications. On the contrary, a battery chemistry that has well-defined characteristics can be optimized for performance as well as allowing for safe and dependable operation. One problem with this is that defining these characteristics is a bit difficult for those less inclined towards working with batteries; these characteristics that can be unique to each battery cell depending on the chemistry, temperature, and stage of life of the battery. Therefore, the issue we would like to address is the lack of testing equipment available to people working with lithium-ion batteries and make working with batteries in all applications more safe, optimized, and achievable.

1.2 Solution

We are proposing an automated cell-tester that extrapolates the necessary cell characteristics from various types of batteries by running a few tests determined necessary by the user. Complete characterization of any given cell can only be achieved by testing at various temperatures, therefore we will design this device with a thermal chamber for a thorough definition of battery characteristics at all temperatures. The chamber would house a single cell of various form factors and chemistries and run that cell through the necessary tests to accurately and succinctly communicate the cell's characteristics to the end user. Specifically, we will implement a test for each of the following: **(1)** the overall capacity (in Ah), **(2)** the state-of-charge to open circuit voltage relation (SoC-OCV curve) of the cell, and **(3)** the equivalent circuit model (using two time constants) of the cell. Based on previous data captured by the device for a specific cell, it will recommend which tests to run, we will then allow the user to select which tests they would like to run, press "play", walk away, and return hours later to a very understandable representation of the battery characteristics at different temperatures.

1.3 Visual Aid

See figure 1 below.

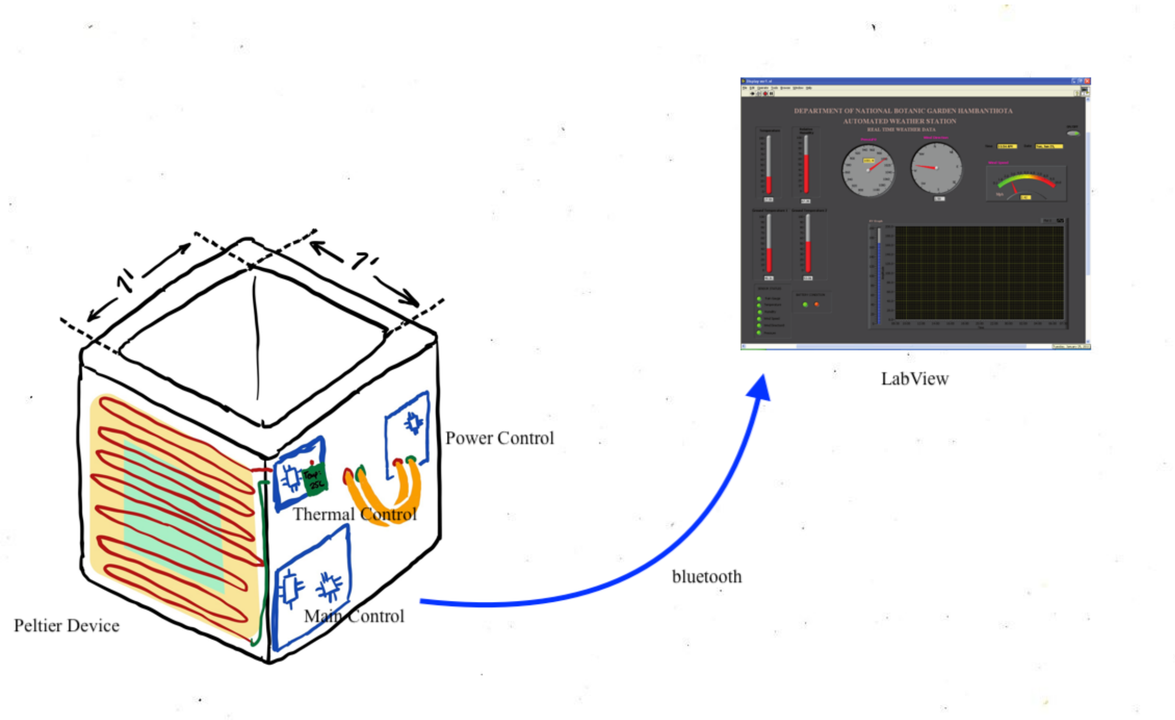

Figure 1: Visual aid for representing the system and its components such as thermal and power control, as well as the interface with the LabView application.

1.4 High-Level Requirements

- The device will perform the necessary tests to accurately characterize a battery cell's capacity, charge/discharge curve, and RC polarization characteristics.

- The user interface program will store results from old tests of specific cells and will display the battery characteristics and performance over time in an easy to understand way.
- The device will control a thermal unit that will need to maintain a constant temperature throughout any given test.

2 Design

2.1 Subsystem Overview

2.1.1 Power Electronics Unit

The device will require power electronics for ensuring safe operation of any cell placed under load, including IC chargers, power resistors, BJTs, fuses, and whatever circuitry as well as decoupling necessary to isolate the battery completely from the parts of the system not required for managing power such as the chip. The BJTs and power resistors are what the controller will use to control current flow while the IC will do coulomb counting and voltage reads. This unit will also contain all the necessary sensors such as ADCs as inputs to the main control unit. We will need other external ADCs for generating more precise information back to the main control (e.g. 10-bit ADC vs. 12-bit ADC).

Requirements: Given that we are testing lithium-ion cells, this circuitry is required to do many things regarding safety and power consumption. These things include

- Isolate the battery and avoid any inrushes of current to the chip, board, or power supply.
- Successfully control current flowing in and out of the battery to within 1%.
- Measure voltage and current on the battery to within 1% of the true measurement.

2.1.2 Computer Interface

This unit will include the bluetooth connection from the device to the computer itself as well as the end-user LabView applet. This will also allow us to store data from the device's tests on the local machine as well as keep old data from previous tests to track performance over time.

Requirements: This includes a rather wide range of functions the device will perform, such as the LabView GUI and the bluetooth interface between the device and the users computer. As such this unit is required to do many things including the following

- Successfully relay information about the current test being performed or the start/end of a test to the users computer over bluetooth.
- LabView application should store data from tests on the users computer (”save data to file”).
- LabView should convey information about a cell’s history, as well as its current behavior.
- LabView will have an option for viewing the current state of the cell and information on the test provided that it is currently performing one.

2.1.3 Thermal Unit

The device includes a thermal chamber, about a cubic foot on the interior, which will control the internal temperature between 5 degrees Celsius and 40 degrees Celsius as a minimum range due to the drastically changing characteristics of these cells under extreme temperatures. This will include a somewhat large array of Peltier devices that separate thermal components in a system based on polarity. For this we will also need to include several accommodations to make the Peltier devices as efficient as possible, such as fans, ducts and ventilation of the exterior side of the devices.

Requirements: This is the most challenging part of the project. It must control a wide range of heating and cooling as well as isolate the system at a certain temperature. Therefore this unit must perform the following:

- Set the internal temperature of the thermal chamber by causing a change in the polarity or power consumed by the Peltier devices.
- Maintain a given temperature over long stretches of time (e.g. $\sim$10 hours) by controlling the output of fans and Peltier devices to ensure optimal efficiency and minimize needless power consumption.

- Identify a valid range of testing temperatures in given environment (e.g. outdoors vs. in a refrigerator).

2.1.4 Power Supply

We will be using an off the shelf DC power supply to give the board its rails as well as the necessary current to safely manage the power electronics within the device.

Requirements: The power supply will be our reference for any given test. Therefore it must perform the following:

- The power supply must be completely stable as it is our reference and if something were wrong with the supply, we would likely not be able to detect an issue with the battery.
- The supply will likely need to supply the necessary current to charge the battery so it should be rated for probably about 100 W to accommodate both the charging and the power consumption of the Peltier devices.

2.1.5 Block Diagram

See figure 2 below.

2.2 Tolerance Analysis

We had originally hoped to attain a ~5mV delta in our estimations which would be about 0.1% error. We have since found that many of the electronics we may have to use are likely going to provide less accuracy than even this as well as only having one semester to work on this, we have since recalibrated to about a .5% error which would translate to ~25mV deltas. We know this is large but we believe it is actually attainable in the time span and money we have available. We are also finding that our thermal unit will have inaccuracies at lower temperatures. The implications of this in terms of tolerance/error have not yet been calculated, but we foresee the device having troubles maintaining a constant temperature during a test with no great solution having been proposed for the cooling mechanism and control.

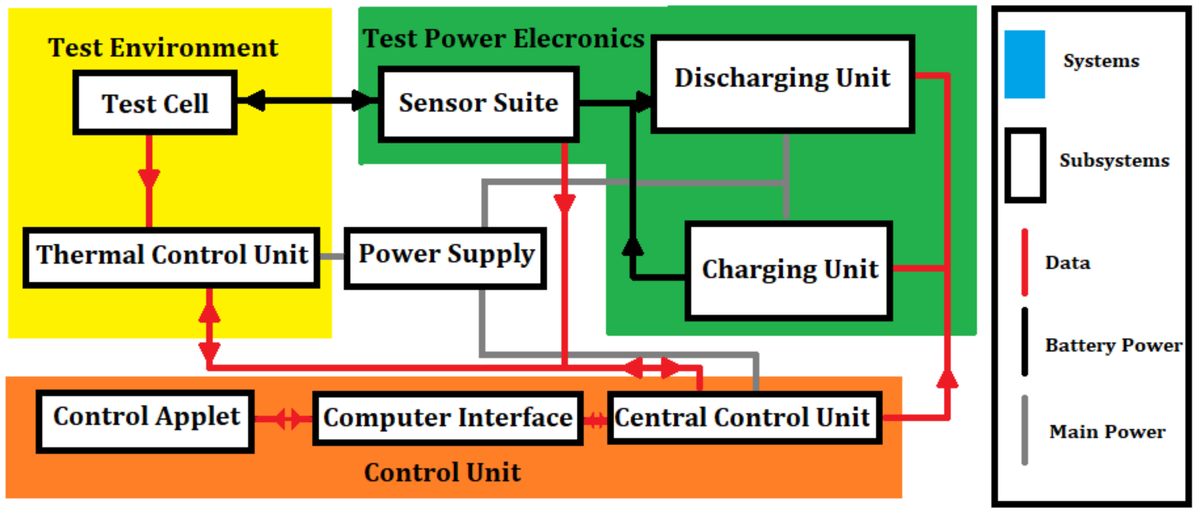

Figure 2: Block diagram representing the various subsystems of the device, including thermal unit, power unit, and control unit.

3 Ethics and Safety

As with any lithium-ion battery application, one main concern is operating safely within the limits of any cell. This means even when the cell is broken, there must be some way for the device to determine this without actually demanding too much current to or from the cell. It will also need a method for putting out any fires easily, should they arise. The final safety concern will be huge rushes of current and any voltages present in the cell being tested. Therefore, we are implementing the proper isolation in order to avoid electric shock.

The ethical concern for this device will be money. Given that this device is supposed to allow anyone to work with batteries in a safe manner, we want to be able to market it to everyone. Another reason we call attention to the cost of the device is because batteries and systems involving batteries are expensive as is, it not likely that users will want to spend half their budget on testing equipment.