University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document (PDD)
ProBE (Programmable Battery Examiner)

Approvals

	Name	Affiliation	Approved	Date
Customer	Jacqueline Maldonado	EnerSys		
Course Coordinator	Kathryn Wingate	CU/AES		

Project Customers

JACQUELINE MALDONADO Jacqueline.Maldonado@eas.enersys.com	BOJAN GAVRAN Bojan.Gavran@eas.enersys.com
BRENDAN CUNNINGHAM Brendan.Cunningham@eas.enersys.com	DYLAN GUDERIAN Dylan.Guderian@eas.enersys.com

Team Members

ANDRUSS BLACK anbl5834@colorado.edu	QIHAN CAI qica9589@colorado.edu
ALEXANDER CHENG alch1065@colorado.edu	RUIZE LIU ruli3584@colorado.edu
JOSEPH MOSER jomo8363@colorado.edu	ZEHARIAH OGINSKY zeog1488@colorado.edu (
WALKER TIFFANY wati3724@colorado.edu	BARTEK WARDEGA bawa7614@colorado.edu (
ZHIXING YAO zhya2029@colorado.edu	

Problem or Need

Batteries are heavily used throughout the Aerospace industry. Whether for aircraft or spacecraft, reliable batteries are imperative to the success of any given mission. To ensure their batteries are project ready, the EnerSys team has developed a robust testing system that each battery must go through before being sent out to customers. These batteries are tested for continuity, voltage, resistance and isolation, to ensure quality. They are tested by a technician who uses a breakout box to interface between the battery and a digital multimeter. The technician is required to manually take measurements between each pin combination, typically having to do so 3 times. One flaw of this process is its lack of automation. These tests are tedious for humans to perform and limits their ability to be utilized for other tasks. As a result EnerSys has requested that ProBE design an Automated Functional Battery Tester (AFBT).

The AFBT will streamline the battery testing process for a variety of reasons. First off, the AFBT will eliminate the need for a technician to test each battery. With the AFBT, the technician will merely need to specify to the program what tests need to be performed and let it take care of the rest. This will cut down on human error, as the AFBT will run through a programmed set of tests and collect the required data automatically. The AFBT will cut down on the cost of each test. After the overhead expense of either purchasing or manufacturing the AFBTs, there will be no additional cost for them to run a test. This contrasts to the wages required for a technician to complete the battery test. Finally the AFBT will provide reliable and concise conclusions about the readiness of the battery for industry use. The AFBT will streamline the current testing system used by EnerSys by making it more efficient, affordable and reliable.

Previous Work

Lithium-ion batteries have a wide range of applications. The batteries that this project will be handling have been produced with a focus on the aerospace industry, but their applications are far broader than this. Another industry that relies heavily on these types of batteries is the automotive industry. As the electric vehicle market has grown, so has the demand for accurately and efficiently testing new and recycled batteries. Towards this end a group of engineers set out on a project to "... for the first time, this article proposes proof of concept to automate the process of collecting the impedance data from a retired 24kWh Nissan LEAF battery module."[2]. As this quote says, this article was for a proof of concept and came out in the year 2021, this is a new area of development. While the team behind this article are focused on reusing and testing old batteries, ProBE's aim is to automate a system proven to certify batteries for industry use. The industry standard for conducting these tests has taken shape in the lab, being done by technicians. Projects like ProBE's and the one mentioned above aim to shake this up. Automating the testing systems used for these batteries will increase the efficiency with which high quality batteries can be produced. ProBE is excited to be on the frontline of this research and development.

Specific Objectives

Table 1: Specific Objectives for Varying Levels of Success

Requirements by Objective Level	
Level 1	**Level 2**
Hardware & Electrical: An interface (from here on referenced as a *Data Acquisition Unit or DAU*) with the 8s16p which may be called by software to take a 'measurement'. This measurement may be of voltage, resistance, or isolation/continuity each with TBD ranges and precision on any pair of pins on the battery. This DAU must interface with the battery via harness, be of 'lab bench' size, be ESD compliant with TBD standards, and must have its own protections against "abuse". **Software:** A GUI, on which a user must be able to define a new or choose from an existing 'test' consisting of any number of 'measurements' (described above) to be executed sequentially. The user should then be able to begin the test (automatically calling the DAU as prescribed by the test) and monitor its progress (status of present and previous measurements, number of measurements left, potentially other TBD statistics). Upon completion or cancellation of the test, a user should be able to save all data points taken as a .csv file.	**Hardware & Electrical:** The DAU may be made modular, such that it may be used to diagnose other battery types. This shall include a swappable harness(s) and an electrical subsystem requiring no modification in order to accept varying input hardware and electrical signals.. Potentially higher measurement precision (also TBD). **Software:** In addition to Level 2 hardware & electrical considerations, software may be designed to make a modular platform possible. This software shall allow for custom test creation on an expanded set of the customer's battery solutions without any backend modification.

High Level Functional Requirements

Requirements provided by customer for this project:

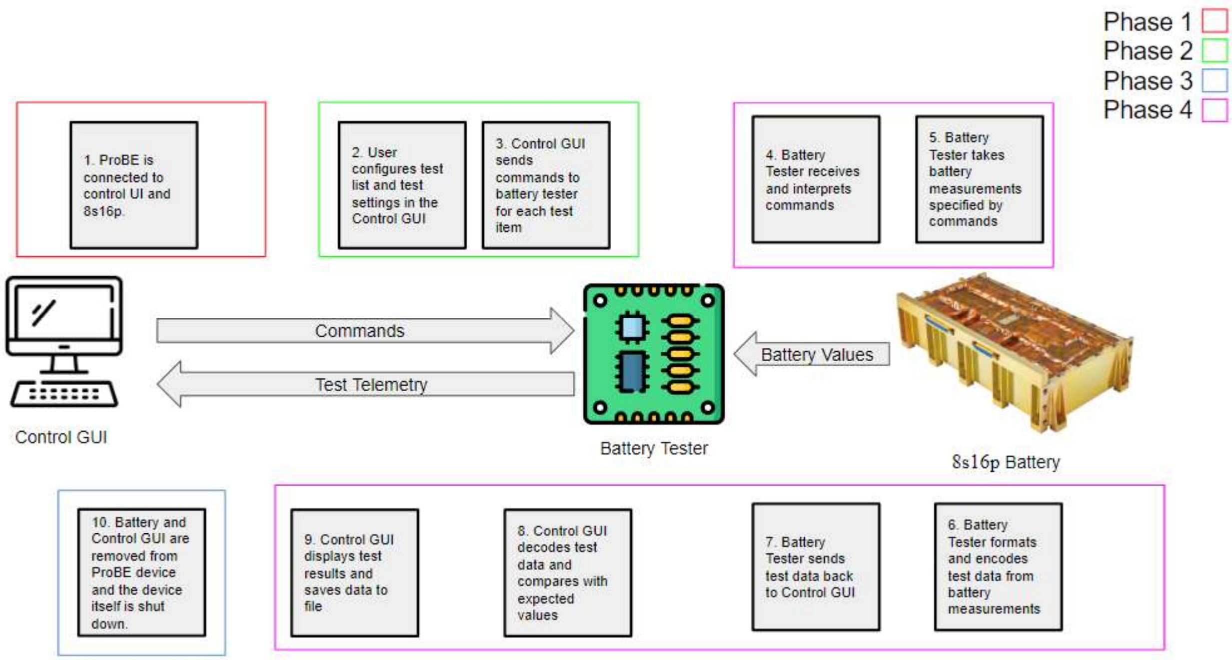
No.	Requirement Description	Rationale
FR1	The system shall be able to measure continuity, voltage, resistance, and isolation.	These are the measurements needed to validate battery functionality
FR2	The system shall be able to automatically select any pin/combination of pins on the battery to measure.	Must be able to check all pin combinations of battery connector without user input
FR3	The GUI shall report measurements/results to the user and save test data to file.	Testing process can be monitored by user and results saved for later use
FR4	The GUI shall allow the user to configure test parameters.	Enersys customers may require different validation parameters
FR5	The GUI shall provide start/stop/pause features	User can pause/resume or stop testing at any point
FR5	The system shall be ESD compliant.	The tester cannot damage the battery
FR6	The system shall be powered by a mains-compatible grounded power supply.	Needs good grounding for the purposes of ESD protection and measurement accuracy
FR7	The system shall have a footprint no larger than that of a laptop.	There is limited bench-top space in the Enersys lab

As this project is not part of a larger system, all of the requirements above will be addressed by the team.

Concept of Operations

Figure 1 below outlines the concept of operations. The misson will be split into four phases. Hardware setup, test configuration, test execution, and hardware/software teardown. Phase one begins with connecting the control GUI and battery to the ProBE device. Next, phase two begins with user configuration of test list and parameters. Phase three then begins with test execution. The ProBE will iterate through each test, display measurements, report pass/fail results and write test data to file. Finally in phase four, the battery is removed and the tester is shut down.

Figure 1: ConOPS



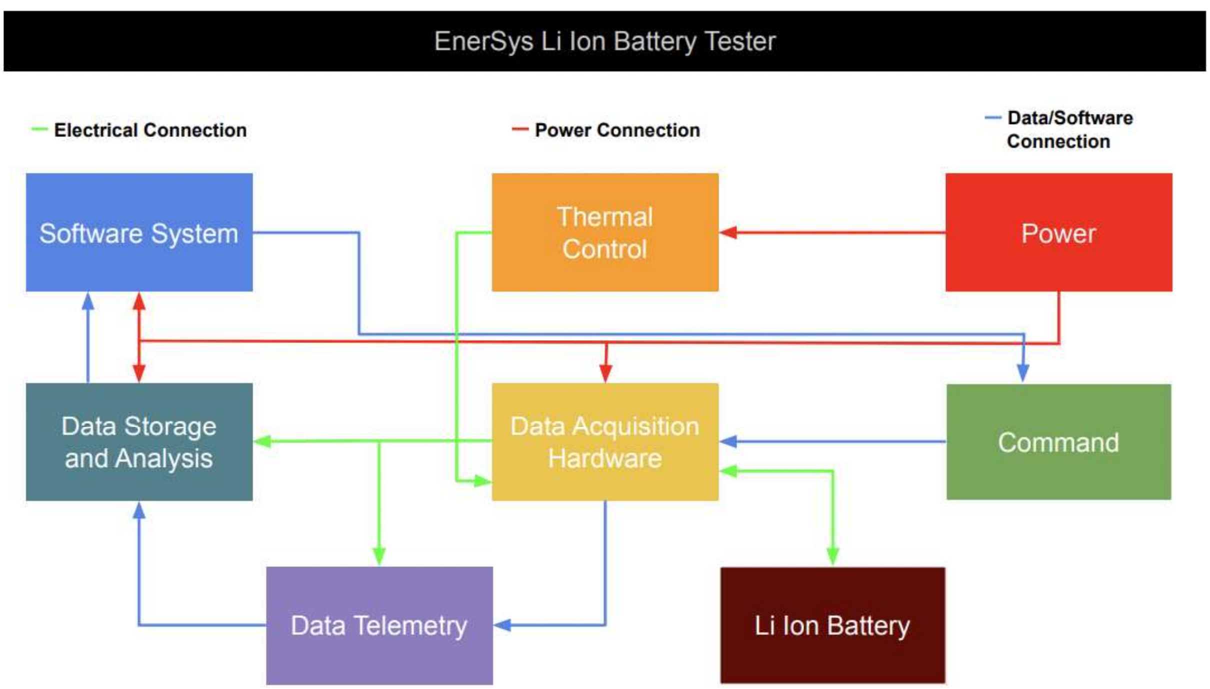
Critical Project Elements

Table 2: Critical Project Elements

ID	Critical Element	Reasoning
CPE 1	Data Acquisition Unit (Internals, Electrical Hardware)	A Data Acquisition Unit is needed for interfacing directly with the battery via battery pinouts; cycling between pins for varying durations and taking measurements.
CPE 2	Data Acquisition Unit (Containment, Physical Hardware)	Physical housing is required for the device to protect the internal components and prevent damage.
CPE 3	Communication Interface	The software shall have a means to communicate with the Data Acquisition Unit, either wired or wirelessly, in a speedy and reliable fashion.

CPE 4	Graphical User Interface	The graphical user interface will provide testing interfaces as well as reporting battery measurements. It is one of the key deliverables specified by the customer.
CPE 5	Software Backend	The software backend will handle all necessary computations: commanding test pin sequences and acquiring data from Data Acquisition Unit, data output/rendering and determining data pass/fail with given parameters.
CPE 6	Testing	The system shall work without bugs and errors. The testing procedures will ensure full coverage of functionalities of all sub-systems and validate each of its correctness.

Sub-System Breakdown and Interdependencies



Team Skills and Interests

Table 3: Skills and Interests

Name	Skills/Interests	CPEs
Bartek Wardega	CAD experience including CFD and FEM analysis. Experience in software including C, Labview, and Matlab. Applied Leadership and Management.	CPE 1,2,3,4,5,6
Walker Tiffany	Software and Manufacturing experience. Interested in gaining electrical experience.	CPE 1,2,3,4,5,6
Andruss Black	Electrical engineering. Elementary programming. Professional level CAD, additive/subtractive fabrication skills.	CPE 1, 2, 3, 6
Qihan Cai	Finance, coding skills.	CPE 4, 5, 6
Alexander Cheng	Experience in 3D Modeling (CAD, NX, SOLIDWORKS), Interest in learning more software and electrical skills.	CPE 2,3,4,5,6
Ruize Liu	Interest in learning more software and electrical skills.	CPE 2, 4, 5, 6
Joseph Moser	Basic CAD skills, Electrical design using ANSYS HFSS, Software skills (MATLAB, C++, Python). Applied leadership skills	CPE 1, 2, 3, 6
Zehariah Oginsky	Circuit design and manufacture. Embedded systems software (C/C++). Windows app dev (C#/.NET). Basic CAD skills	CPE 1, 3, 5, 6
Zhixing Yao	Software architecture, gui design. Elementary electrical skills.	CPE 3, 4, 5, 6

Resources

Table 4: Resources

Critical Project Elements	Resources/Source
CPE 1	Outside Expertise: Professor Matt Rhode Facilities: Smead Aerospace Electronics Lab Materials: 8s16p battery likely to be required, sourced from EnerSys
CPE 2	Outside Expertise: Professor Matt Rhode Facilities: Smead Aerospace Meeting Rooms
CPE 3	Outside Expertise: Professor Matt Rhode Facilities: Smead Aerospace Meeting Rooms Materials: 8s16p battery likely to be required, sourced from EnerSys
CPE 4	Outside Expertise: Professor Matt Rhode Facilities: Smead Aerospace Meeting Rooms
CPE 5	Outside Expertise: Professor Matt Rhode Facilities: Smead Aerospace Meeting Rooms Materials: 8s16p battery likely to be required, sourced from EnerSys
CPE 6	Outside Expertise: Professor Matt Rhode Facilities: Smead Aerospace Electronics Lab Materials: 8s16p battery likely to be required, sourced from EnerSys

References

[1]A. Rastegarpanah *et al.*, "Towards robotizing the processes of testing lithium-ion batteries," *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*, vol. 235, no. 8, pp. 1309–1325, Sep. 2021, doi: 10.1177/0959651821998599.

[2] "AES Senior Projects - EnerSYS ABSL 2022.pptx." *ASEN 4018,* 2022,pp.1-10