Design of a battery electrolyte wetting measurement machine

Bram Vanderwegen

Master of Electronics and ICT Engineering Technology

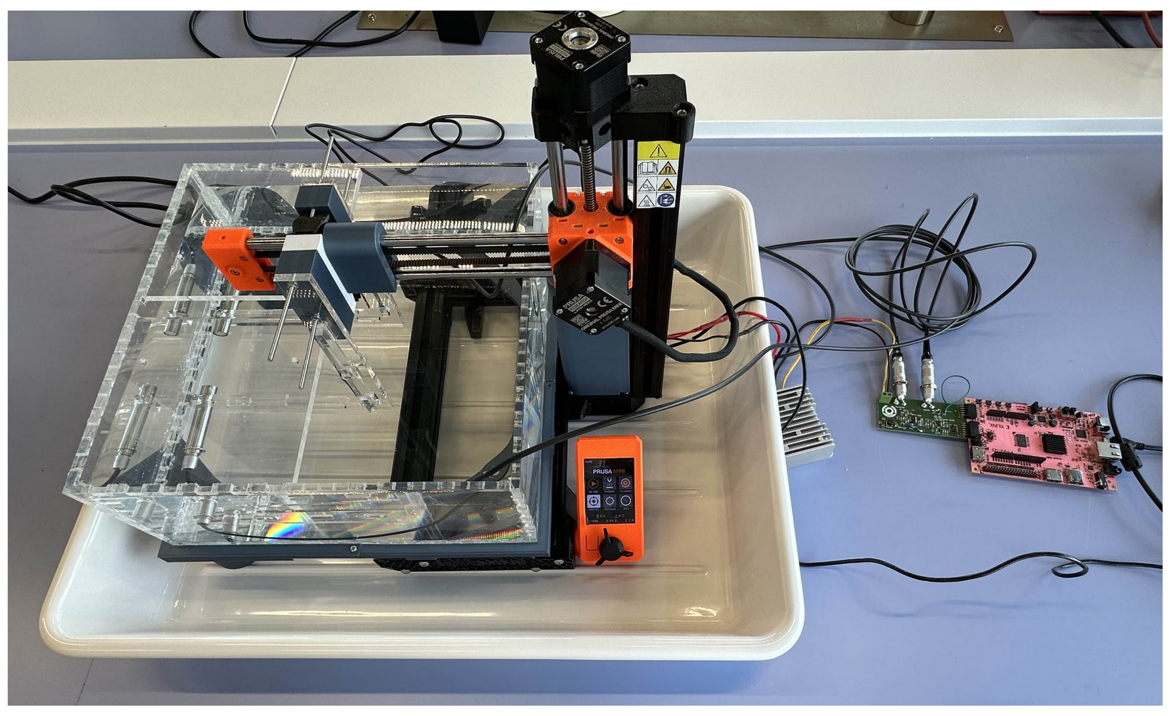
Introduction

Batteries constitute critical components across diverse applications, ranging from portable electronics to electric vehicles, driving substantial research interest in advanced battery technologies. Electrolyte distribution (battery wetting) represents a pivotal design parameter, directly influencing performance metrics including capacity and discharge rate. Wetting characteristics evolve over a battery's operational lifespan, with desiccation serving as an indicator of aging. Non-destructive evaluation methods are essential for preserving battery integrity during inspection. Ultrasonic measurement at 2 MHz has emerged as an effective technique for quantifying electrolyte thickness through analysis of signal attenuation [1].

Research objective

This work addresses the need for accessible instrumentation to characterize electrolyte distribution in next-generation batteries. While commercial ultrasonic scanning systems exist (~€200,000), this research demonstrates the feasibility of a functionally analogous system at significantly reduced cost (~€5,000). The primary objective was to design and construct an automated platform capable of performing X-Y scans across full battery surfaces, generating spatial wetting maps through ultrasonic attenuation measurements and providing non-destructive evaluation capabilities

Image 3:
final assembly of the machine.
Consisting of the Gantry, the basin, the transducers, the PCB, the Pynq-Z2. Raspberry Pi was not yet implemented



Result & Conclusion

The system shows partial success. It cannot perform battery surface mapping but can discriminate material types through differential attenuation measurements. Signals have significant noise, requiring amplification due to the limited voltage (3.3V), which places the signal near the noise floor. The filtration algorithms and control software are still in early development, and the mechanical assembly needs structural optimisation.

In summary, this apparatus provides a foundation for future development. It achieves precise transducer positioning and localized measurements, though accuracy is limited. The prototype validates the approach and offers a cost-effective framework for further refinement in battery wetting analysis.

Materials & Results

Multiple components were used to construct this machine

The main controller used is a **Raspberry Pi 5**, a mini computer equipped with HDMI and USB ports, along with a pin header for low-level communication protocols like SPI and UART. This setup enables effective communication with downstream components.

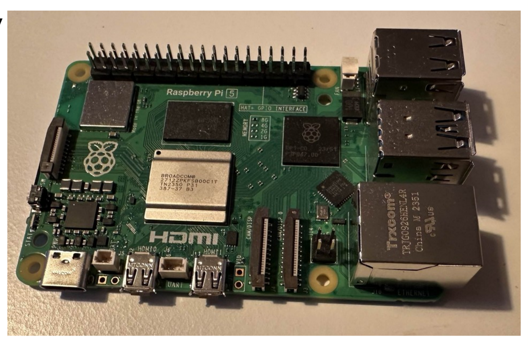


Image 1: Raspberry Pi 5

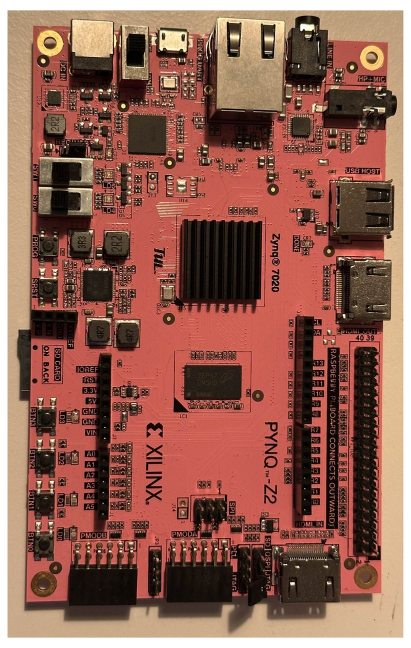


Image 2: Pynq-Z2

The **Pynq-Z2 SoC** serves as a combined **microprocessor** and **FPGA** solution. The FPGA performs parallel processing to generate 10 pulses at 2 MHz and reads an 8-bit signal from the ADC at 100 MHz, utilizing moving average filtering for noise suppression. The microcontroller manages the FPGA by controlling the pulse train and receiver, providing automatic amplification gauging and additional filtering.

The PCB houses **connectors** for the transducers and for the FPGA. The test pulses from the fpga are amplified and sent to the send transducer. The receive transducer receives a signal and is amplified using a **variable gain amplifier** to be read with an **ADC** and output the corresponding 8 bit value.

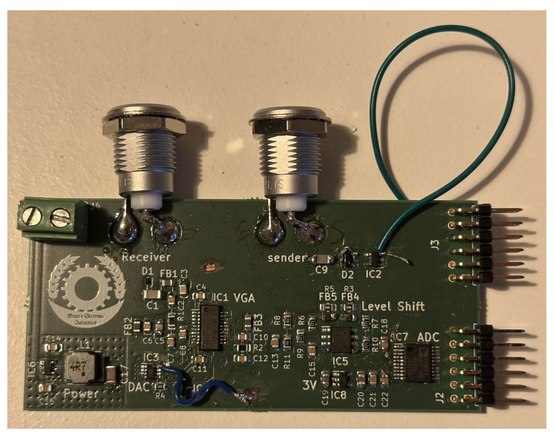


Image 4: PCB

Image 5: Ultrasonic transducer

The **transducers** are a component that convert electrical energy into acoustic and vice-versa. It is used to generate and receive the ultrasound. It needs a liquid medium such as **water** or **silicon oil** to conduct the **ultrasound**.

The **3D printer gantry** moves the transducers across the battery surface to scan each point.

The plexiglass **basin** provides a container to submerge the components in. It is fit so the battery can be clamped and inserted easily

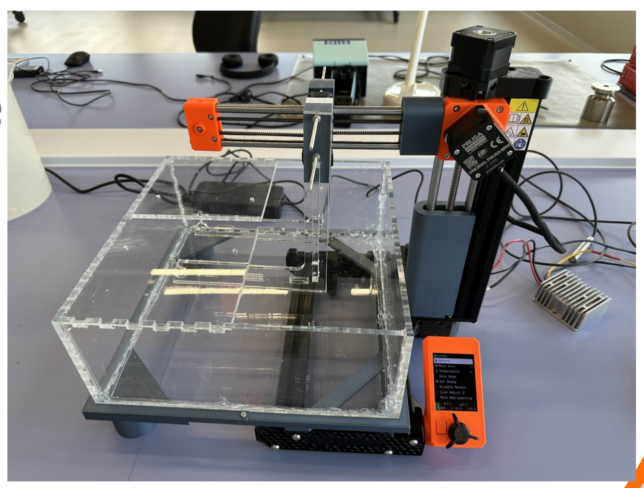


Image 6: gantry and basin

[1] Z. Deng *et al.*, 'Ultrasonic Scanning to Observe Wetting and "Unwetting" in Li-Ion Pouch Cells', *Joule*, vol. 4, no. 9, pp. 2017–2029, Sep. 2020, doi: 10.1016/j.joule.2020.07.014.

Supervisors / Co-supervisors / Advisors: Prof. Dr. Momo Safari
Dr. Saeed Yari