

Problem Statement

- Conical-type rock picks are used to extract precious minerals and support construction and infrastructure
- Rock picks are often replaced prematurely, wasting resources and money
- The goal of this project is to collect sensor data that enables real-time estimation of rock pick wear and characterization of the rock being mined.



Load Cell Design and Integration

$$C = \frac{\epsilon_0 \epsilon_r A}{d_{start}}$$

$$\Delta C = \epsilon_0 \epsilon_r A \left(\frac{1}{d_{start} - \Delta d} - \frac{1}{d_{start}} \right)$$

$$\Delta d = d_{start} - \frac{1}{\left(\frac{\Delta C}{\epsilon_0 \epsilon_r A} + \frac{1}{d_{start}} \right)}$$

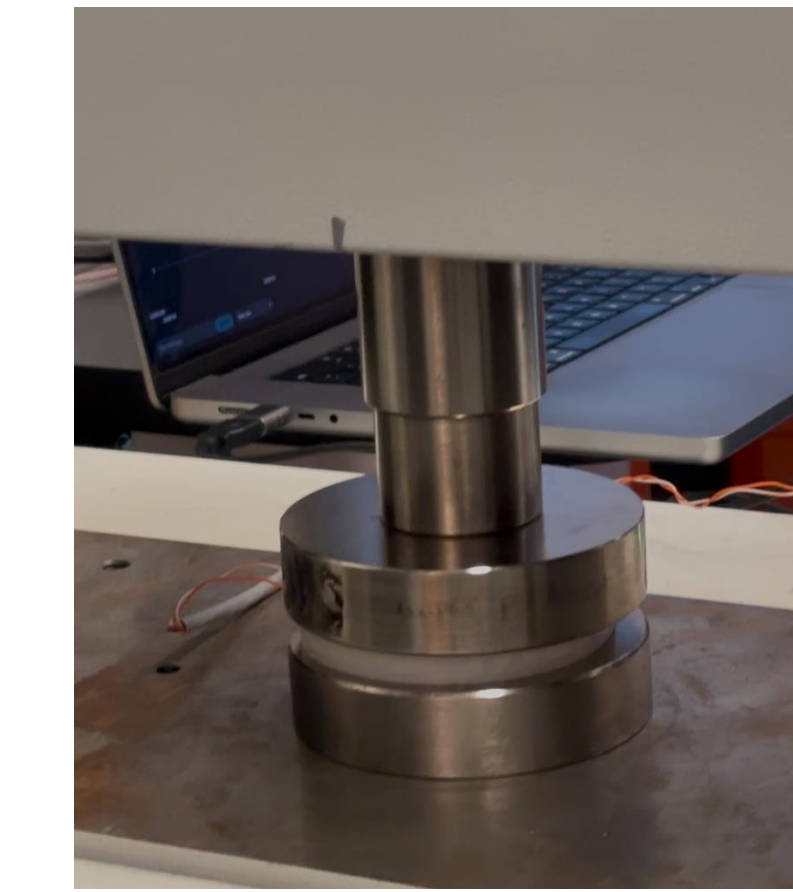
Load Cell

- Loading parameters were compiled from historical LCM test data and mine metrics to determine the load range for the load cell
- Materials meeting the required electrical & mechanical properties were chosen from a database and analyzed to find the best materials for dielectric, conductor, & protection layers
- FEA analysis on various thicknesses and load scenarios provided guidance on geometry optimization
- Iterated through manufacturing processes to increase durability & manufacturability
- Normal cutting load is measured by a change in capacitance of the load cell
- Load cell placed under protective sleeve with wires routed through the block to the PCB integrated into the back of the block.

Experimental Setup

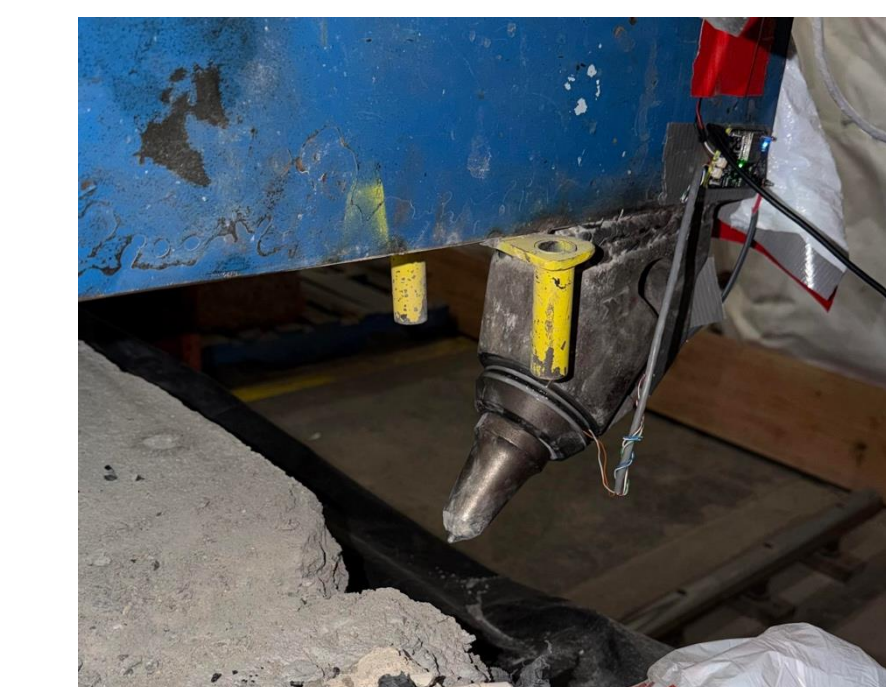
Validation of Load Cell Under Static Loads

- Apply known compressive loads for calibration
- Record voltage vs. force response
- Generate calibration curve
- Evaluate linearity & repeatability
- Establish force conversion factor



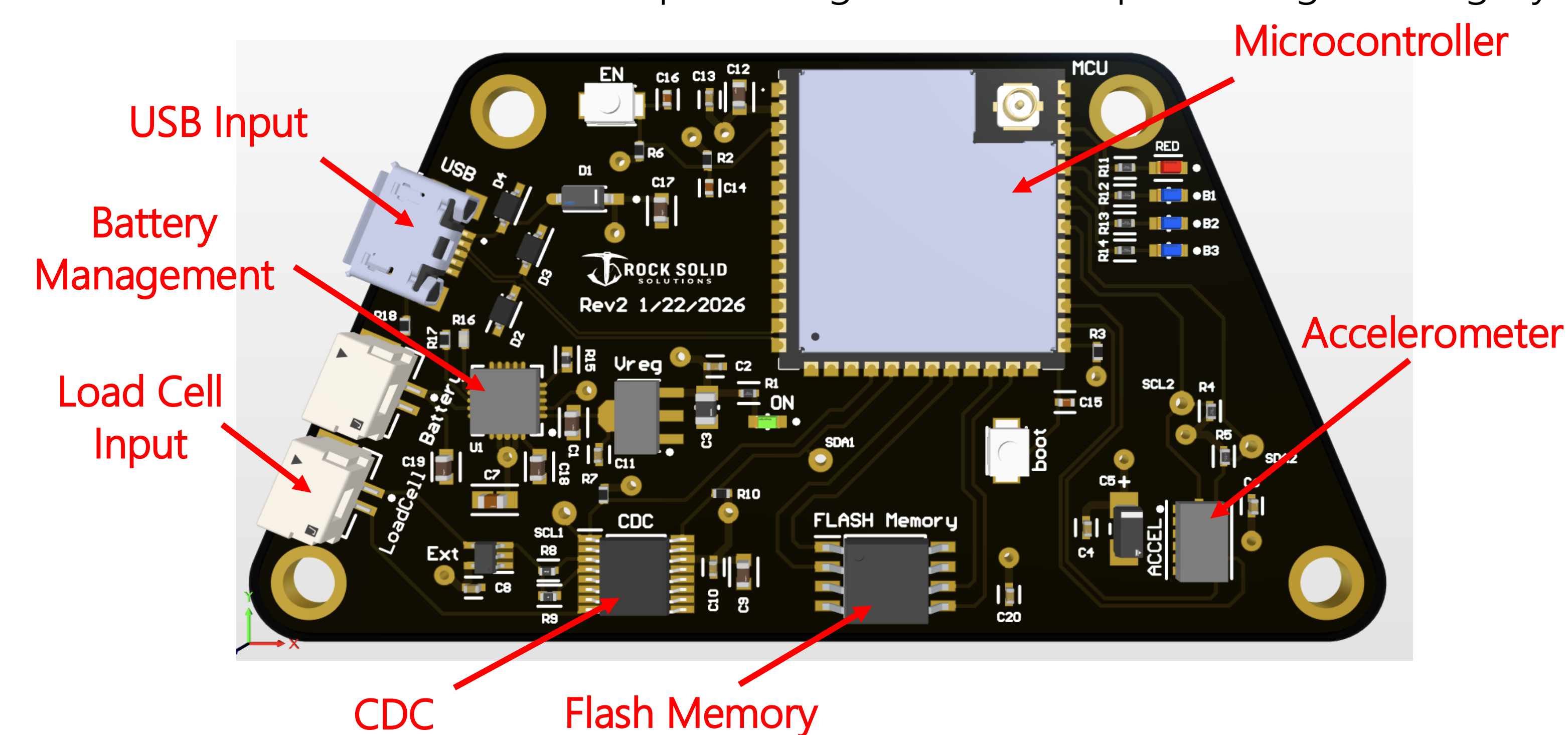
LINEAR Cutting Machine (LCM)

- Full-scale rock cutting simulation
- Measure forces during pick-rock interaction
- Compare to auxiliary load cell
- Validate under dynamic loading conditions
- Assess durability in harsh environment



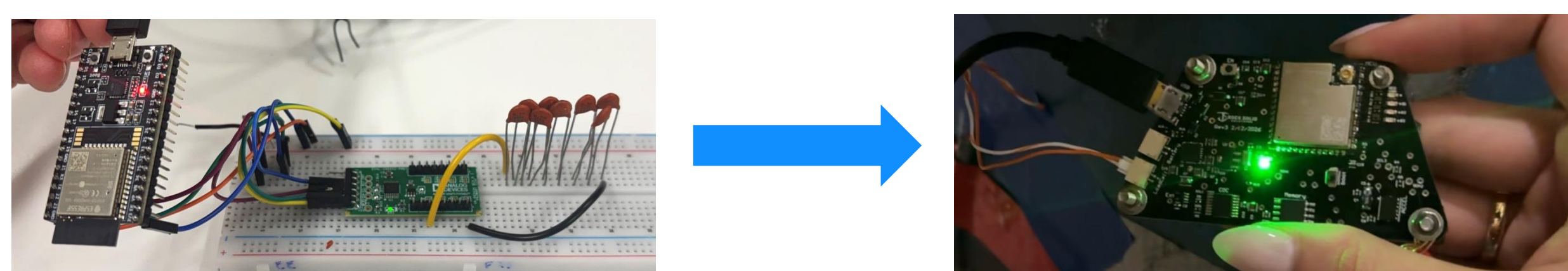
Printed Circuit Board Design

Motivation: custom PCB for compact integration and improved signal integrity



Considerations

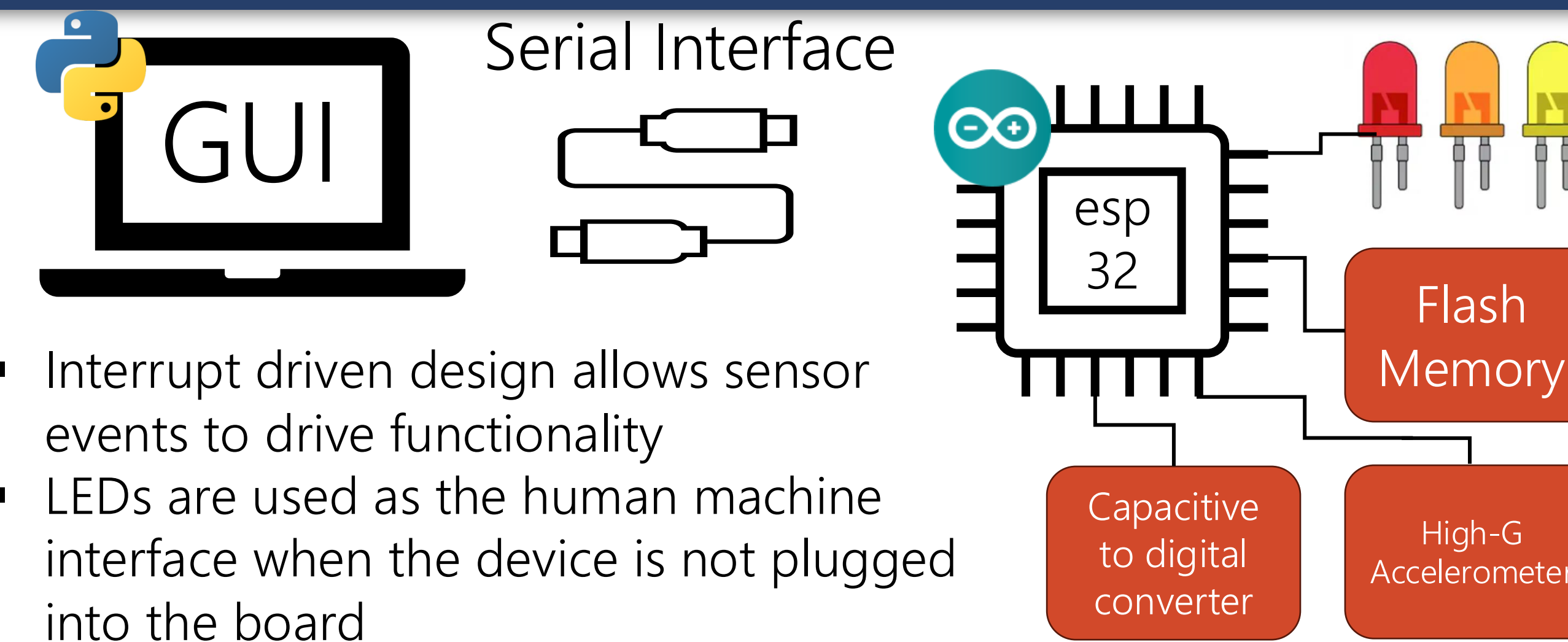
- EMI noise is high in mining environments and could jeopardize signal integrity.
- Space for and shape of the PCB is limited by the mining machine.
- The circuit must be energized while also minimizing wires
- The PCB should be both electrically and physically robust for operation in high-vibration, dusty, and noisy environments



Design Highlights (Solutions)

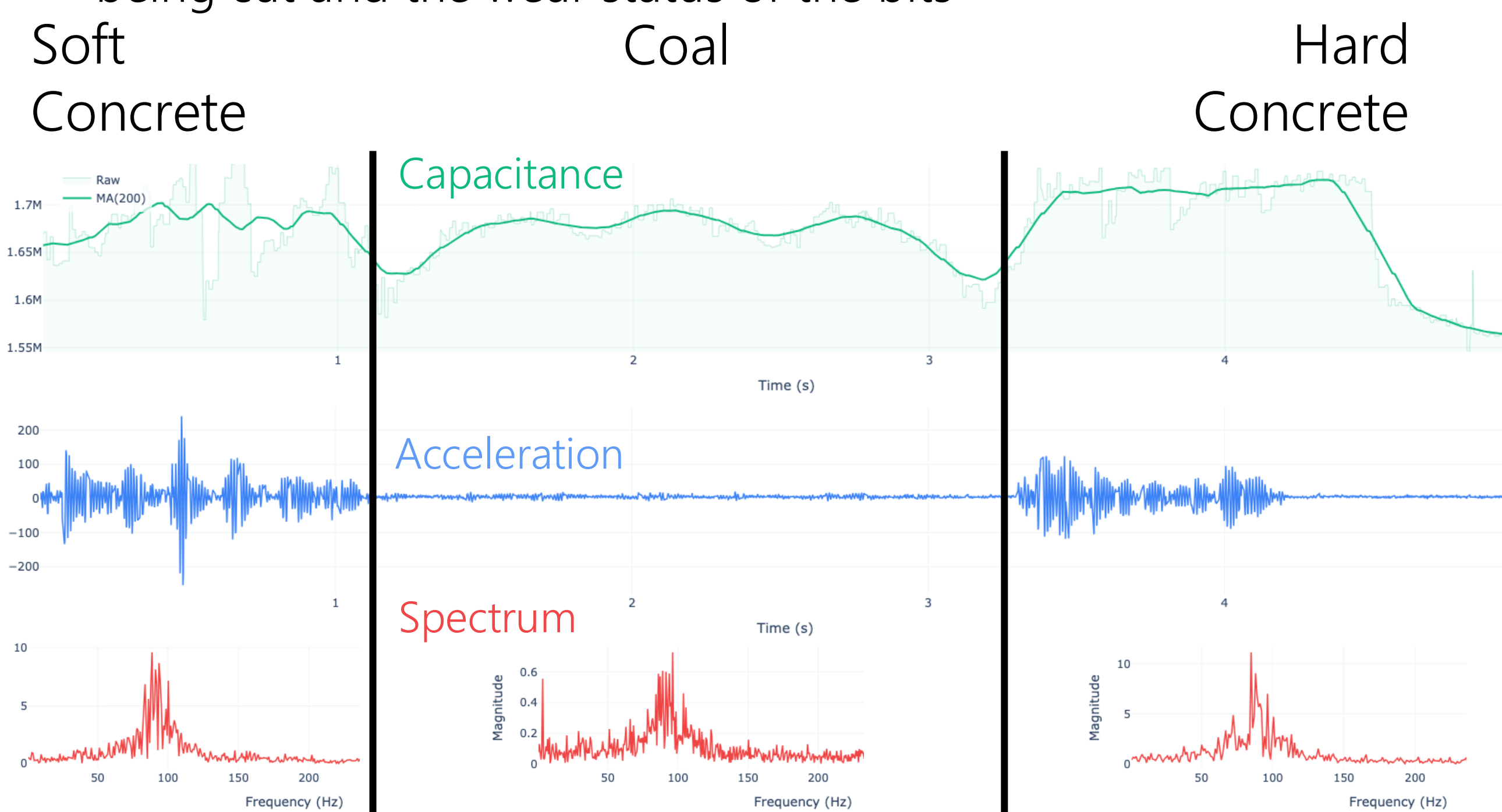
- Common-mode filtering and careful analog routing to suppress EMI and preserve signal integrity
- Integrated battery management system with USB charging, minimizing external wiring while enabling portable operation
- Accelerometer-triggered sensing, allowing the system to remain in a low-power state until motion is detected
- Custom compact PCB geometry optimized for the constrained mechanical envelope of the mining system

Software Architecture



Measured Results and Outcomes

- Load and Vibrational Harmonics give insight about the material being cut and the wear status of the bits



- It is necessary to have multiple measurement types
- A single measurement of load might incorrectly classify a rock because of the wear status of the bit
- Magnitude of acceleration coupled with load helps to correctly categorize each parameter: wear status and rock type

Conclusion and Future Work

- Rock Solid Solutions delivered a fully integrated solution to measuring the interactions at the rock-pick interface including a force analog and vibration data.
- This data is sufficient to predict trends in forces across different rock types and wear statuses
- Harmonic analysis of vibrational data further supports the estimation of rock type
- Future work involves training a machine learning model on a very large data set with different rock types, different wear status bits, etc. to perform real time classification of pick wear and rock classification
- Ultimately, the Smart Pick will move miners from the mine to the office



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