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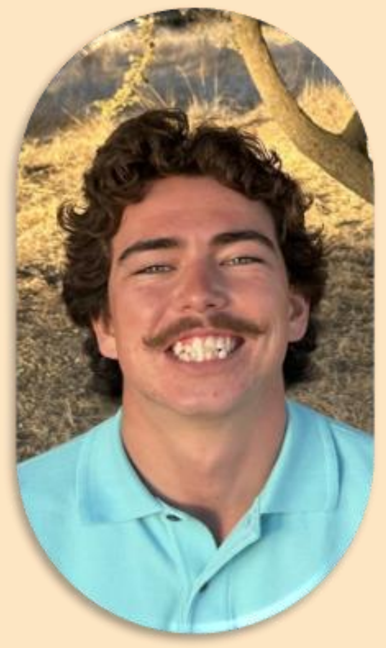
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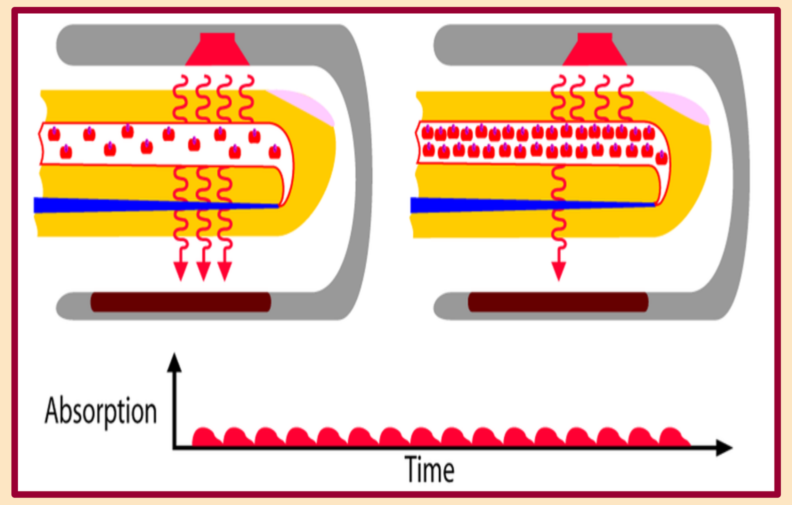
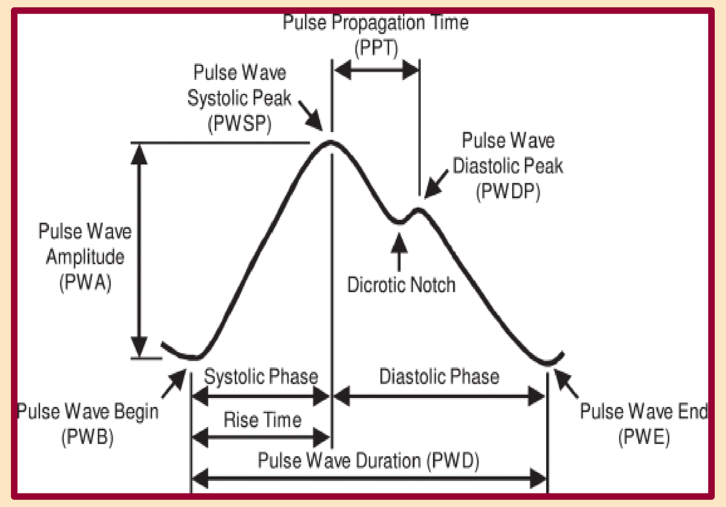
EEE 489: Electrical Engineering Capstone Project

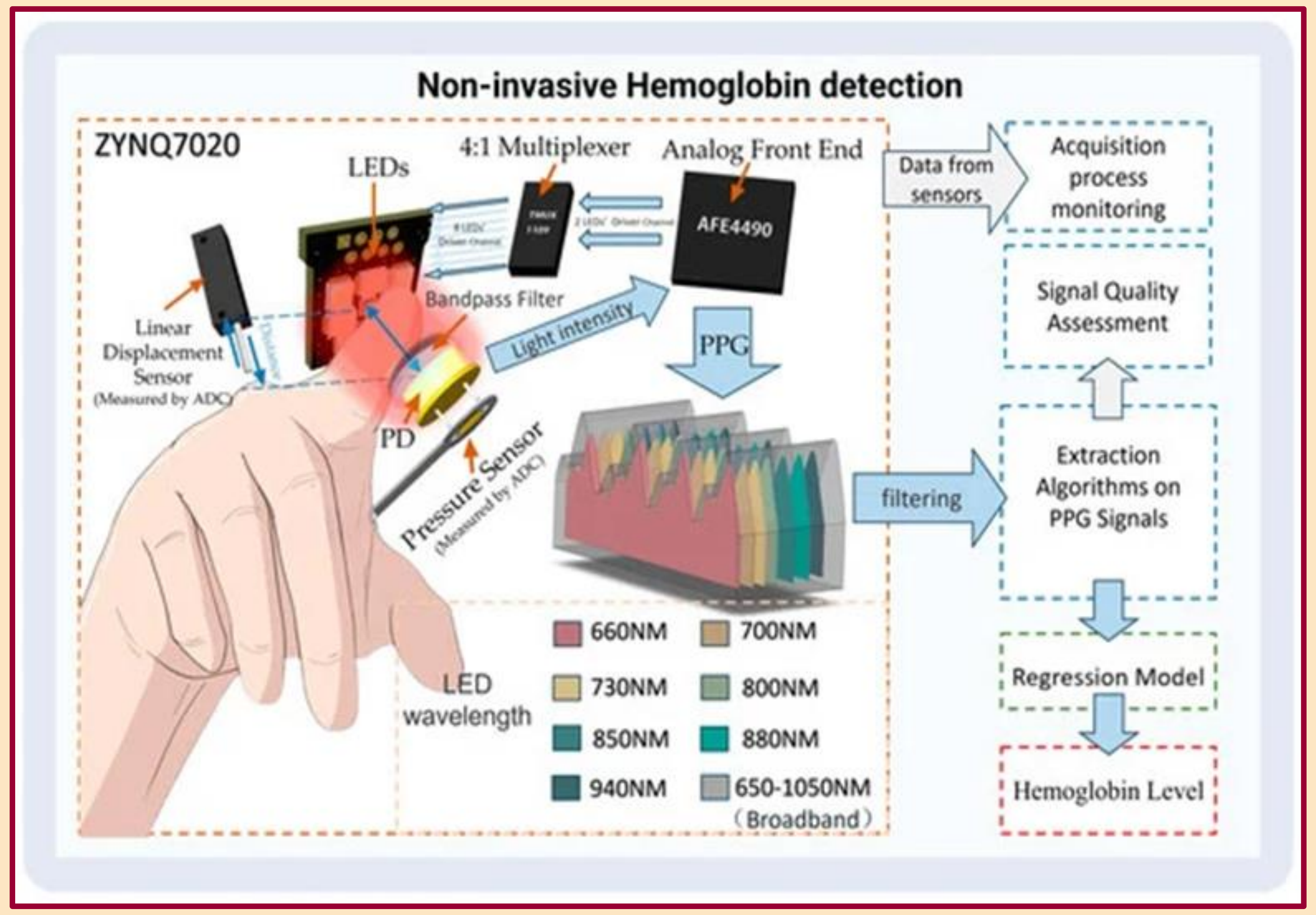
Non-Invasive Blood Iron Monitor

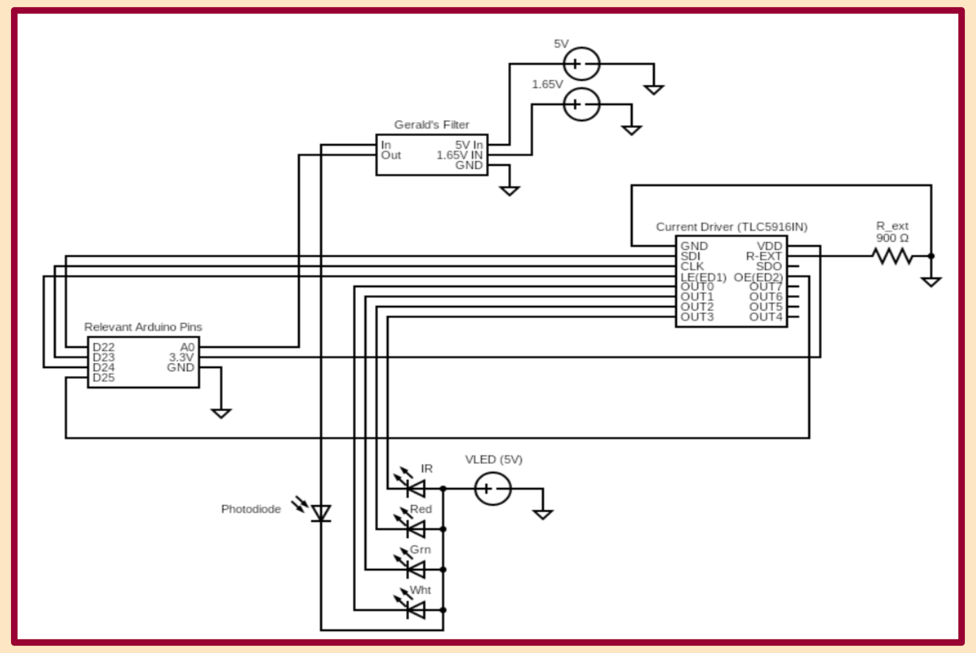
Introduction

Monitoring blood-iron levels is vital for diagnosing conditions such as anemia and hemochromatosis. Current diagnostic methods require invasive blood draws followed by laboratory processing, which is costly, uncomfortable, and inaccessible in many regions. This project aims to design a portable, non-invasive device that estimates iron concentration in real time using photoplethysmography (PPG)—an optical technique that measures blood flow through light absorption. By combining PPG sensing, analog signal processing, and machine learning, the system seeks to achieve lab-comparable accuracy (±1 g/dL) while eliminating the need for needles or lab testing. The final goal is a low-cost (<$200), patient-friendly, and clinically reliable solution that improves accessibility and comfort for frequent monitoring.









Theory

The device operates on the principle that hemoglobin-bound iron alters light absorption at specific wavelengths. Four LEDs—green (525nm), red (660 nm), near-IR (845nm) and infrared (940 nm)—emit light through the fingertip, and a photodiode sensor detects reflected intensity variations as blood pulses through the tissue.

Hardware Path

- Transimpedance amplifier converts optical current into voltage.
- High-pass and low-pass filters isolate cardiac-frequency components (0.5–3.4 Hz).
- Arduino Due digitizes and transmits data for software processing.

Software Path

- Signals are pre-processed using Python/MATLAB to remove noise and drift.
- Features are extracted from amplitude, frequency, and waveform shape.
- Machine learning regression models trained on reference datasets (e.g., PhysioNet) estimate blood-iron concentration from PPG characteristics.

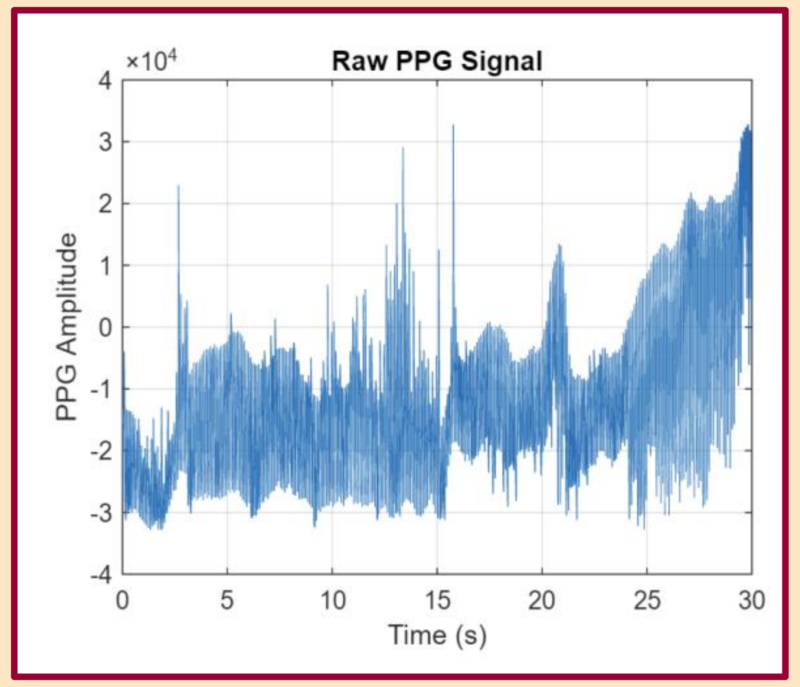
This multi-wavelength optical approach provides the foundation for a non-invasive diagnostic alternative to conventional testing.

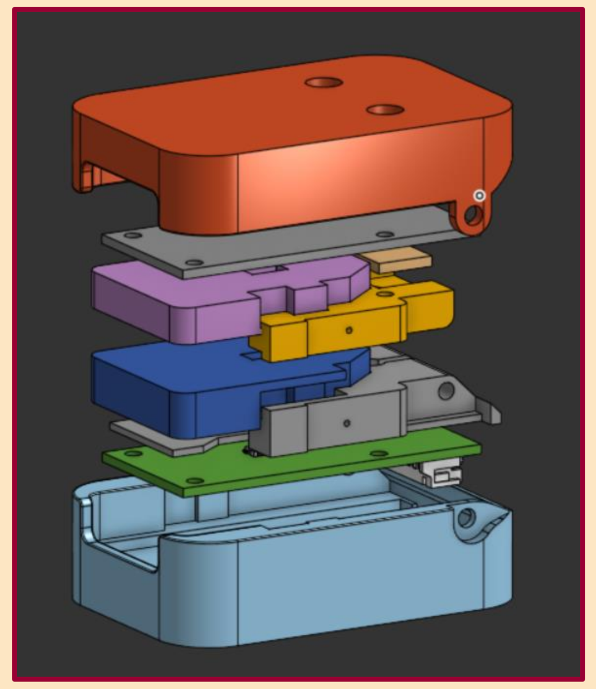
Results

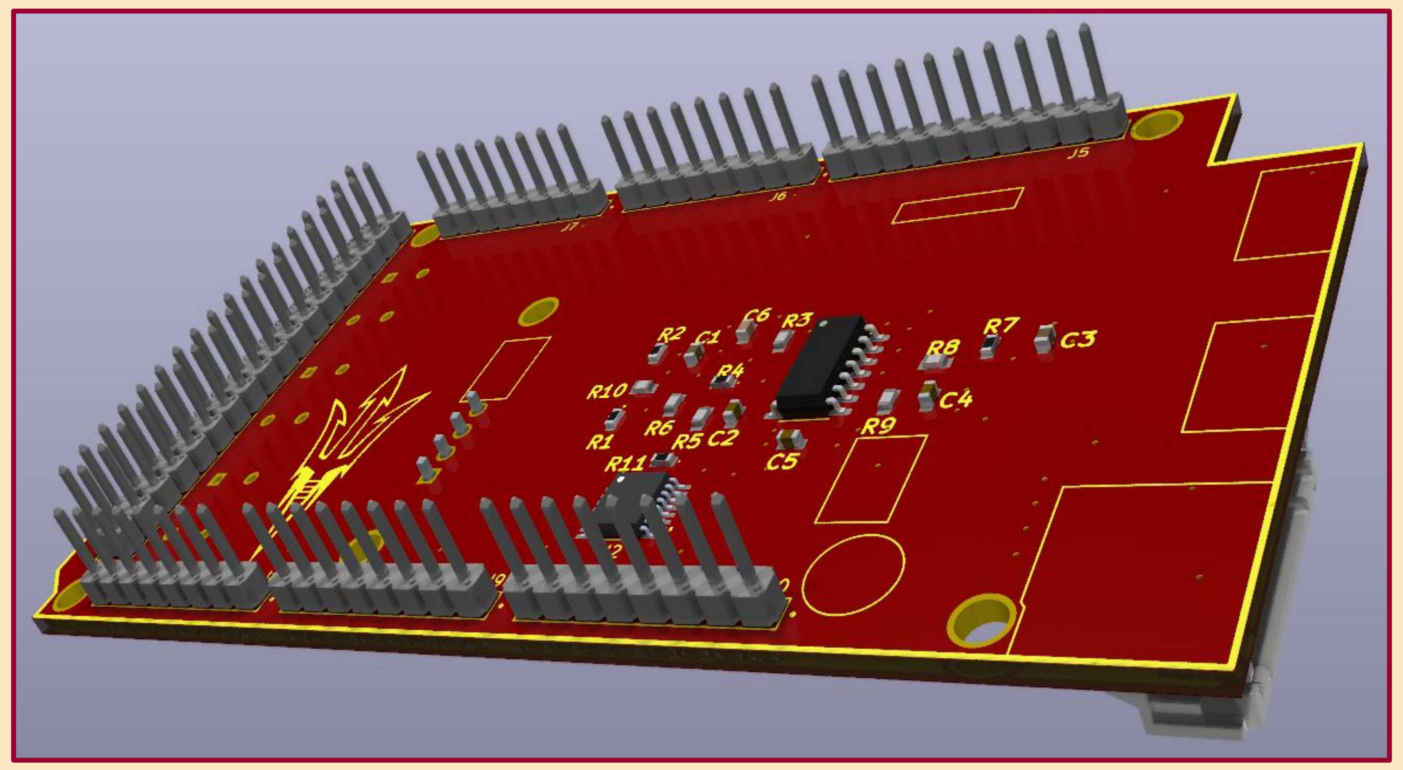
Because PCB fabrication was delayed by component shortages, the fully assembled device could not be tested. However, the breadboard prototype produced useful preliminary findings:

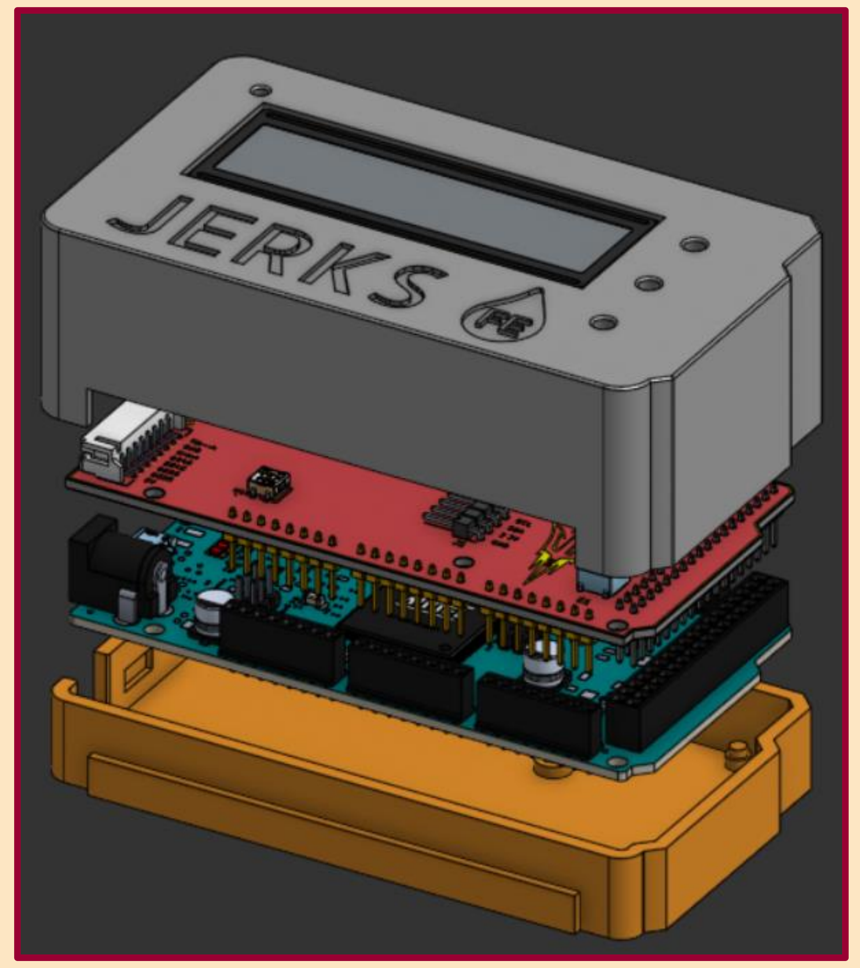
- The four wavelength PPG setup generated repeatable percentage-based readings for all team members, generally falling within healthy iron-level ranges.
- The sensor worked on most subjects, indicating basic feasibility of the optical approach.
- Absolute iron-level estimation was not possible with the limited dataset; a much larger and more diverse sample would be required to train reliable predictive models.
- The four-wavelength analysis proved significantly more complex than anticipated and exceeded the scope of this project.

These results show that while signal acquisition works, full accuracy validation requires substantial additional data and analysis.









Conclusion

Although the final PCB was not completed in time for testing, early prototype results show the feasibility of non-invasive iron measurement using dual-wavelength PPG and basic signal processing. The analog front end and software pipeline performed as expected, providing a solid foundation for continued development.

Meaningful accuracy will require a large, stratified dataset paired with clinically verified iron levels, along with machine-learning models to map optical signals to absolute values. Completing the compact PCB, refining LED–photodiode timing, and adding faster components are logical next steps.

Regarding project goals—durability, portability, accuracy, and cost—durability and portability were well met through the small, sturdy enclosure. Accuracy was not achieved but can improve significantly with expanded testing. Current cost is just above $200, with higher initial expenses expected for data collection and certification; however, mass production would greatly reduce per-unit cost.

With further refinement and a robust dataset, this system could develop into an affordable and reliable tool for estimating iron levels non-invasively.