Project 7: Portable ECG Module for Educational Outreach

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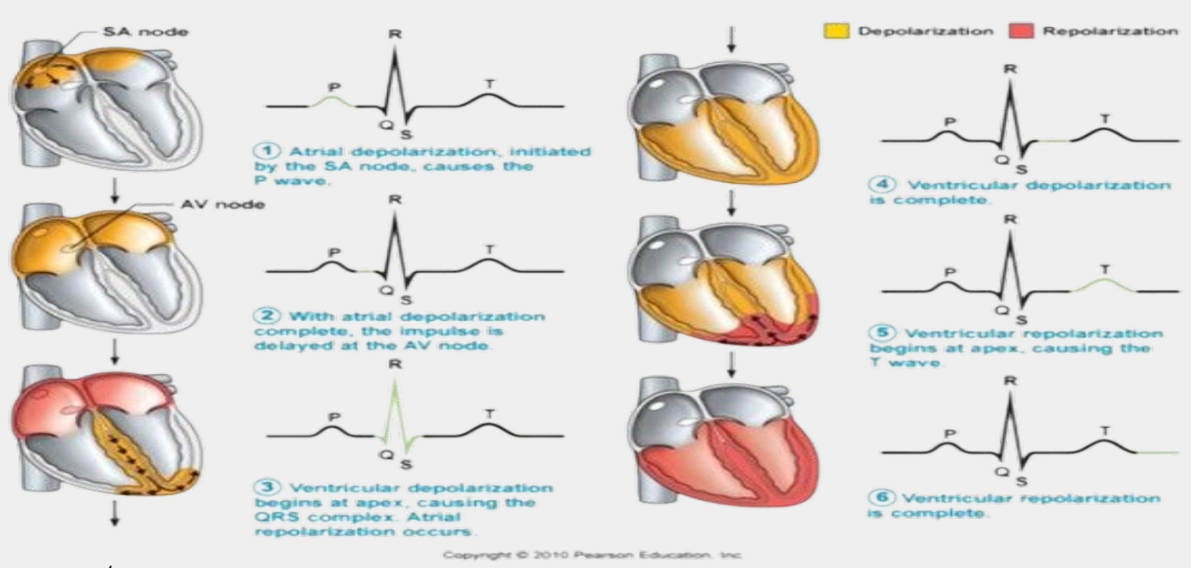
Background

- Electrocardiogram (ECG) records the heart's electrical activity from the body surface, where each cardiac cycle produces a characteristic P wave, QRS complex, and T wave.
- Measurable electrical signals reflect cardiac physiological events (contraction and relaxation).
- Demonstrates how physiological events translate into measurable electrical signals that can be amplified, filtered, and interpreted.

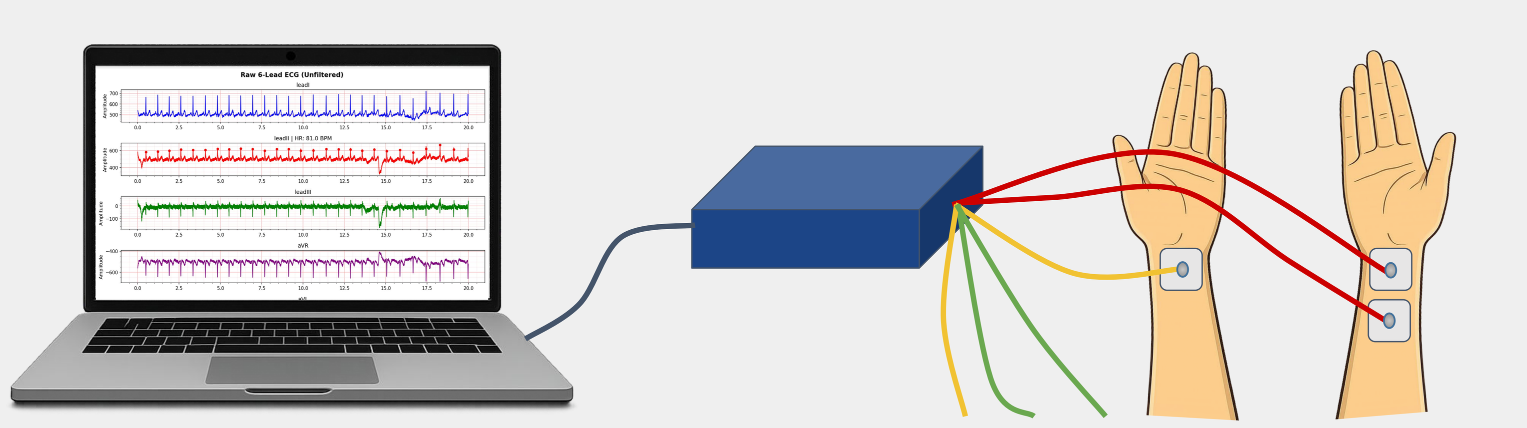


Problem Statement:
Over 16 million high school and undergraduate students take STEM courses each year in the United States. Clinical ECGs cost between \$1,000–\$10,000, making them prohibitively too expensive for classrooms. Students continue to learn cardiac physiology from static diagrams, rather than interact with real physiological signals. A low-cost educational ECG tool is needed.

Objectives

Design, build, and validate a portable ECG amplifier for high school and undergraduate students to visualize real-time cardiac signals during classroom outreach. The system must acquire 0.5-5 mV signals, achieve sample rate at 500 Hz for adequate temporal resolution, operate safely at 5V USB power, and cost under \$50 to support reproducible educational use.

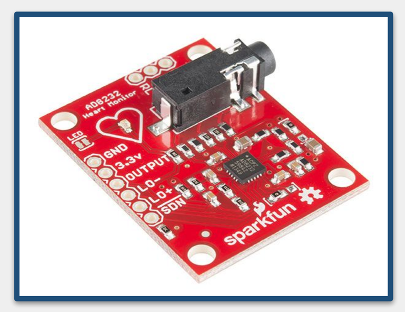
A complete educational outreach package, including a slide presentation on heart physiology and ECG waveform components, along with pre- and post-session surveys to assess student learning and interest in biomedical engineering.

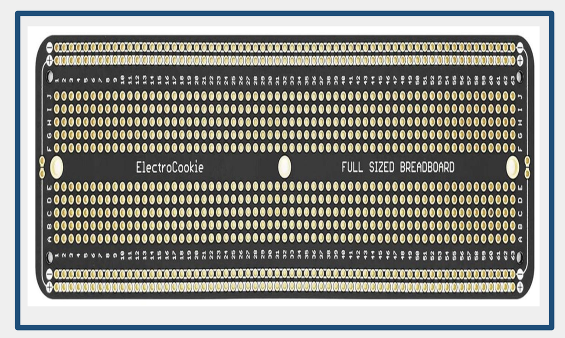


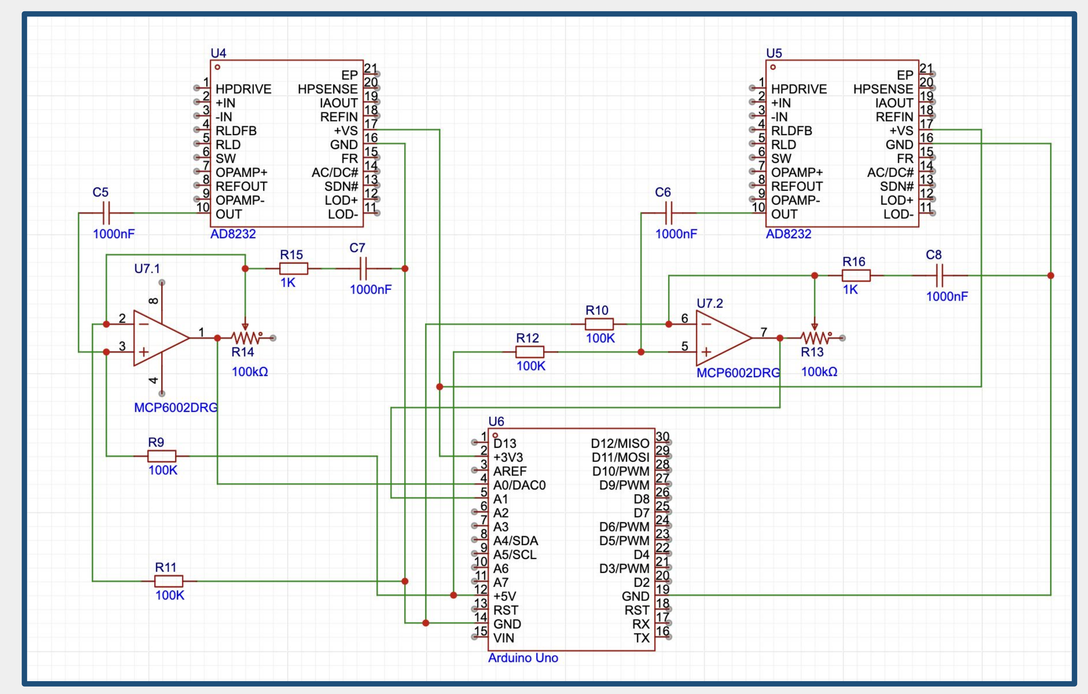
Schematic of portable multi-lead ECG acquisition system: surface electrodes placed on both wrists and forearms record electrical activity, which is transmitted through lead wires to a signal acquisition module, then relayed to a computer for real-time visualization and analysis of cardiac waveforms.

Hardware Design

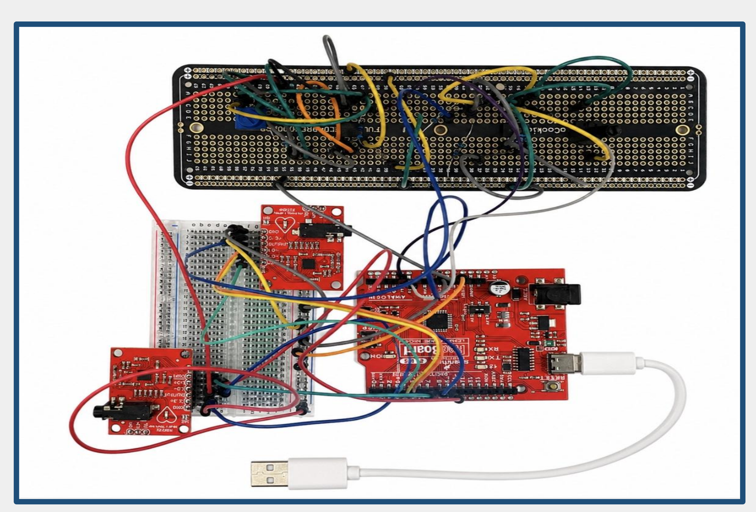
- Two AD8232 modules with integrated instrumentation amplifiers acquired Lead I and Lead II from surface electrodes; the remaining four limb leads were derived mathematically using Einthoven and Goldberger relationships.
- Two potentiometers provided adjustable gain and offset control to optimize waveform amplitude for different subjects.

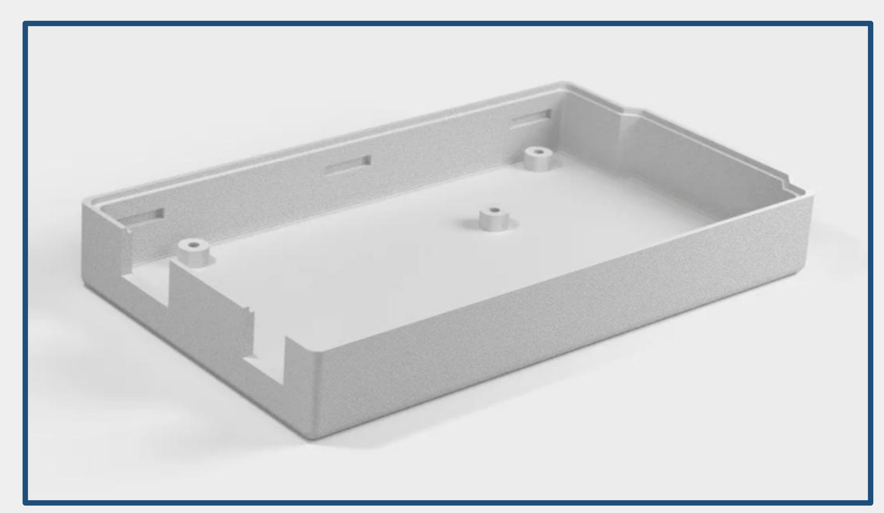






- The modules and wiring system were soldered onto a prototype printed circuit board (PCB) to improve portability and ensure safe operation.
- The device is housed in a custom 3D-printed enclosure, designed using Fusion 360 and AutoCAD, to enhance electrical safety and provide effective cable management.

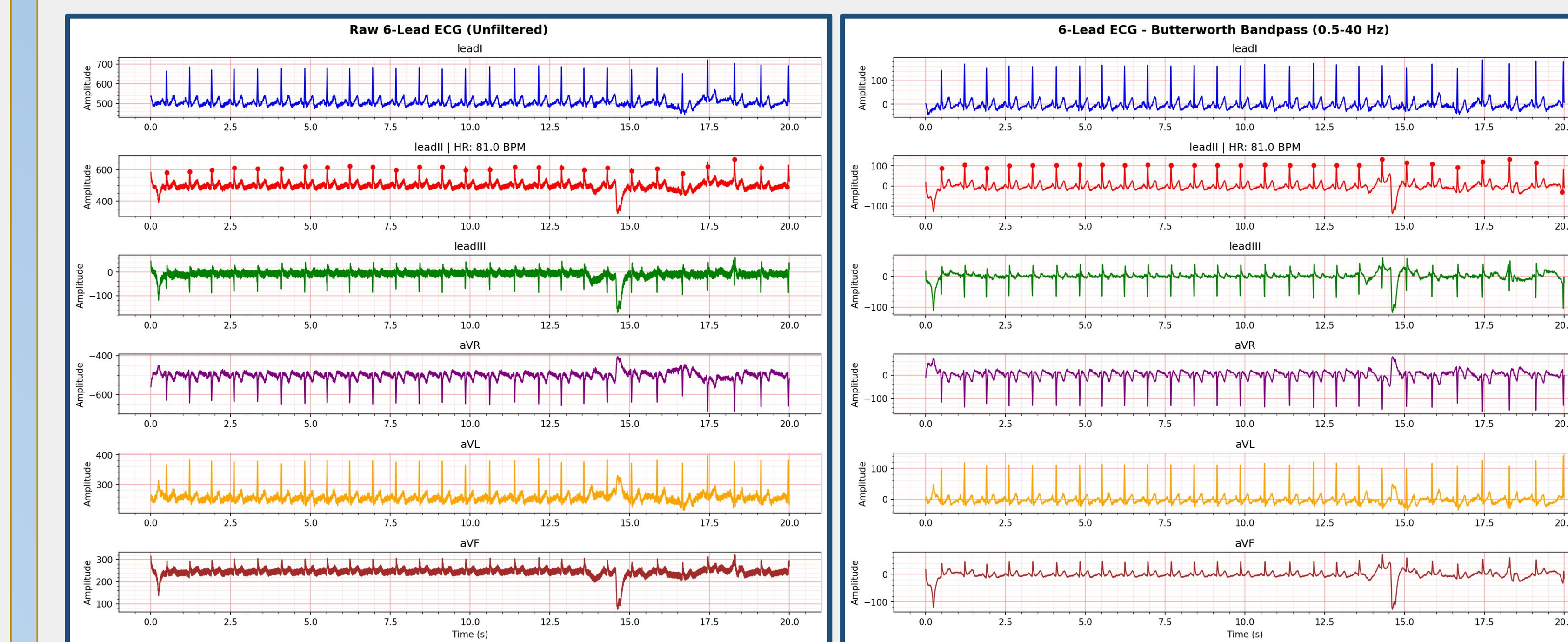




Software Design

- Processed signals were transmitted to MATLAB for data acquisition and Butterworth filtering, then visualized as six-lead waveforms in Python.
- Different filters were tested on acquired physionet data to assess for quality signal clean-up without distortion.
- The filters were the applied to the code and used on the live data captured by the ECG.
- Finalized code is uploaded onto GitHub so that students may access it and continue learning about the project.

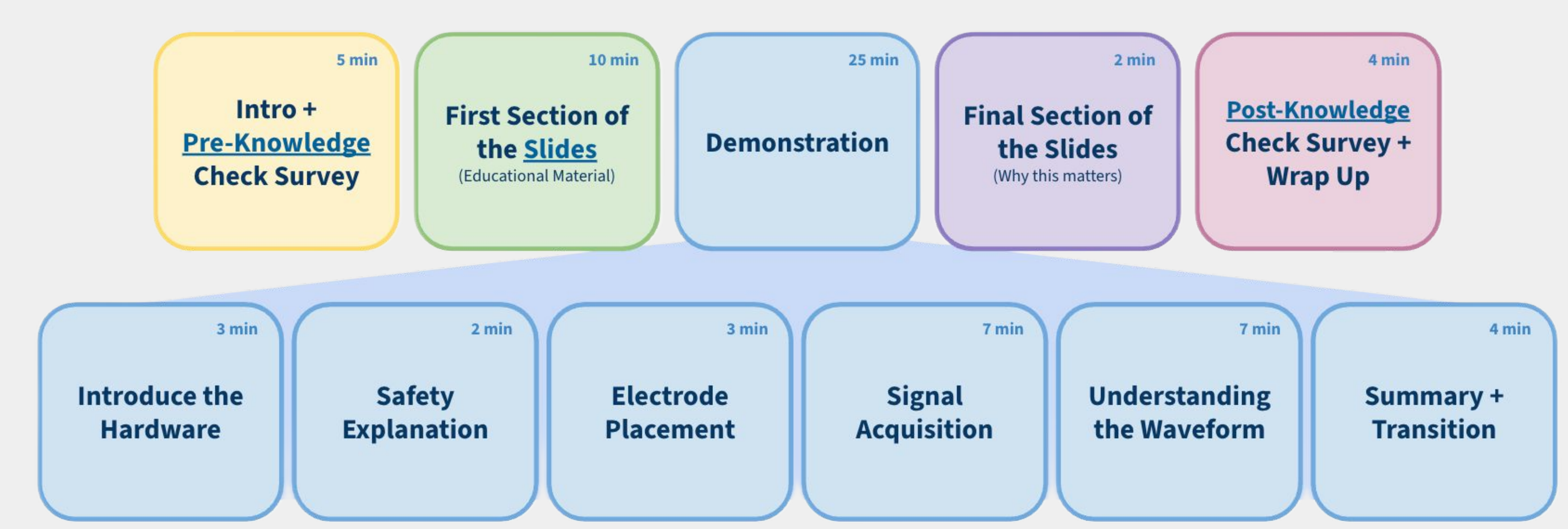
Signal Results



The system successfully isolated cardiac signals within the target 0.5–40 Hz frequency range, effectively eliminating 60 Hz power-line interference and muscular artifacts. The Butterworth filter had the best performance out of the ones tested, allowing for clear identification of the P-wave, QRS complex, and T-wave across all six derived leads.

Educational Outreach and Future Directions

Looking ahead, our team aims to scale this design into multiple deployable kits, enabling hands-on learning for larger student groups simultaneously. Further development will also pursue a 12-lead configuration to demonstrate spatial cardiac activity, broadening the system's educational impact and opening the door for more advanced biomedical instruction.



Acknowledgements

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