Ensc 351 Project
Cost Effective ECG Machine
The Innovators:

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Project Purpose and System Explanation:

The primary objective of this project is to design and prototype a highly cost-effective, portable Electrocardiogram (ECG) system. This system aims to provide medical professionals and remote clinics with a reliable alternative to expensive commercial equipment. By utilizing a specific 3-electrode configuration (Left Chest, Right Chest, and Right Leg), the device captures essential biopotential data to visualize cardiac waveforms. Ultimately, this project lowers the barrier to entry for cardiac monitoring, making diagnostic-quality heart data accessible in low-resource environments. The system acquires a clean, reliable ECG signal from raw biopotential measurements taken from the body. Its purpose is to isolate the meaningful cardiac waveform while suppressing the noise, interference, and baseline drift that typically contaminate direct recordings. The final output is a stable, low-noise signal suitable for interpretation, visualization, and digital processing.

The system accomplishes this through a sequence of carefully designed analog signal-conditioning stages. First, the incoming biopotential passes through a high-pass filter with a 0.05 Hz cutoff frequency to remove baseline wander caused by respiration and electrode motion. The signal is then amplified using an AD620 instrumentation amplifier, which provides precise differential gain and a high Common-Mode Rejection Ratio to suppress power-line pickup common to both leads. Following amplification, the signal is processed by a 60 Hz notch filter to attenuate power-line interference. It then enters a multi-stage low-pass filter using TL074 op-amps with an approximate 40 Hz bandwidth. This removes high-frequency muscle noise and electromagnetic disturbances while preserving diagnostic content. Finally, the signal passes through a DC biasing stage to ensure it sits within the 0V to 3.3V window required by the Analog-to-Digital Converter. The digitized signal is further filtered in software and plotted for real-time visualization, where a beat-per-minute algorithm analyzes the waveform to detect R-peaks and calculate the heart rate.

System Features and Implementation:

The final product integrates several distinct features to achieve this functionality. The Analog Front End is built on a custom circuit using the AD620 and TL074 chips to fully amplify and filter the physical signal. The digital processing is handled by a custom Digital Filter implemented in C, which cleans the signal digitally to remove any remaining noise. Data Capture is managed through a high-throughput Python and C interface that reads values from the ADC reliably. The user interface is a Python-based GUI that plots the signal in real-time, offering smooth rendering. Additionally, a Heart Rate Monitor algorithm detects peaks to calculate beats per minute. A proof-of-concept Web Dashboard was also developed using HTML and JavaScript to display data on a local web server. The webpage was having some trouble plotting the data properly, but it’s working somewhat. We just didn’t have the time to finish it.

Regarding the specific hardware used, we moved beyond the standard course kit to build a custom Analog Front End. We selected the AD620 Instrumentation Amplifier for its low cost and high precision, which is essential for extracting millivolt-level heart signals from body noise. The TL074 Quad Operational Amplifier was used for the active notch and low-pass filter stages due to its low noise profile. We used standard disposable electrodes to transduce ionic skin currents into electrical signals, connected via shielded alligator clip leads to minimize environmental noise pickup.

Technical Difficulty and Software Complexity:

We exceeded standard course requirements by integrating custom analog hardware with a hybrid software architecture. In terms of hardware complexity, rather than using pre-made sensors, we built the custom Analog Front End described above. This required resolving complex real-world signal processing issues, such as manually tuning notch filters to reject 60Hz power-line hum and impedance matching the skin-electrode interface. These are challenges not present in pure digital simulations.

For software, we implemented a cross-compiled architecture to ensure real-time performance. We did not rely solely on high-level scripts; instead, the core digital filtering algorithms were implemented in C for performance efficiency. This C code was cross-compiled for the BeagleY-AI target architecture to ensure minimal latency. We then integrated this low-level code with a Python visualization layer. This hybrid design demonstrates the ability to manage low-level compilation complexity while maintaining a responsive user interface.

Cost Analysis and Societal Impact:

One of the project's main goals is cost reduction. A standard commercial ECG unit, such as one from Welch Allyn, typically costs between $2,000 and $5,000. In contrast, our prototype was built for approximately $180 CAD. This includes the processing unit, the analog components like the AD620 and TL074, and the necessary cables and probes. By using open-source software instead of proprietary licensing, we further reduced the total system cost.

This cost reduction directly impacts society by democratizing diagnostic access for remote clinics in low-resource environments. It offers a potential solution for communities that cannot afford expensive infrastructure. However, we must also acknowledge the potential risks of deploying low-cost medical technology.

Conclusion:

In summary, this project successfully delivers a functional, low-cost ECG prototype that bridges the gap between affordable electronics and medical diagnostics. By combining a custom high-fidelity analog front end with an efficient hybrid software stack, the system achieves real-time signal visualization and heart rate calculation. While it remains an educational prototype, the device demonstrates that essential health monitoring tools can be engineered at a fraction of the commercial cost, offering a viable proof-of-concept for accessible healthcare technology.

Screenshots:

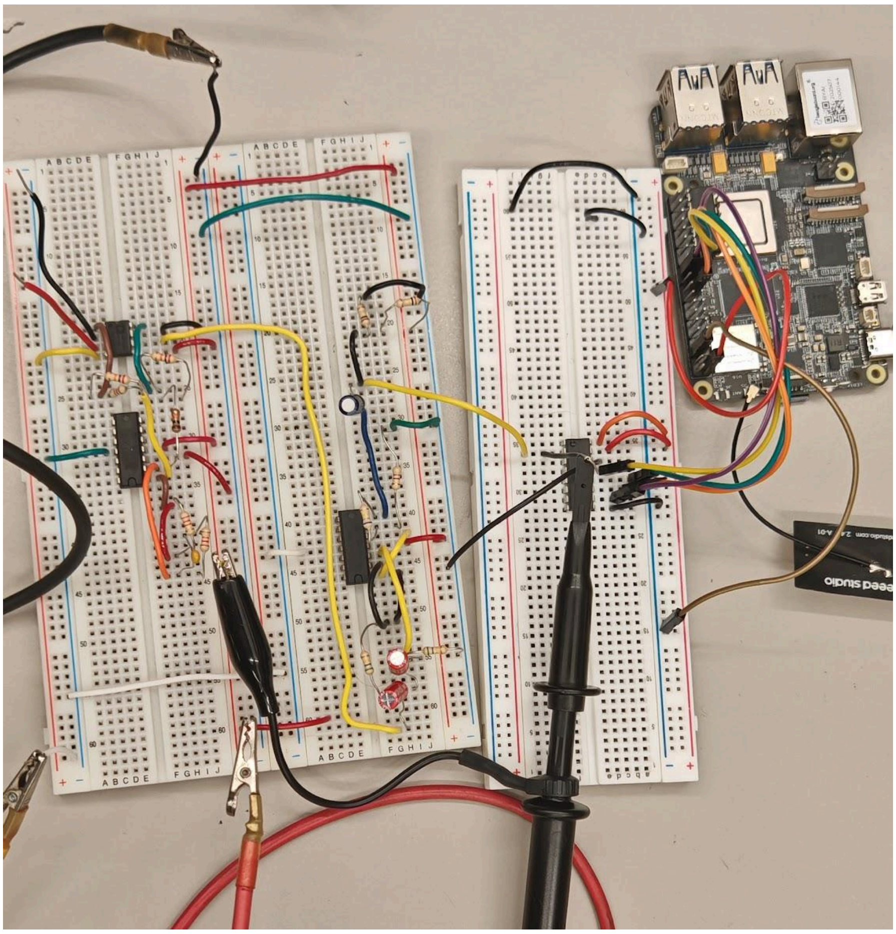

Figure 1.ECG system circuit

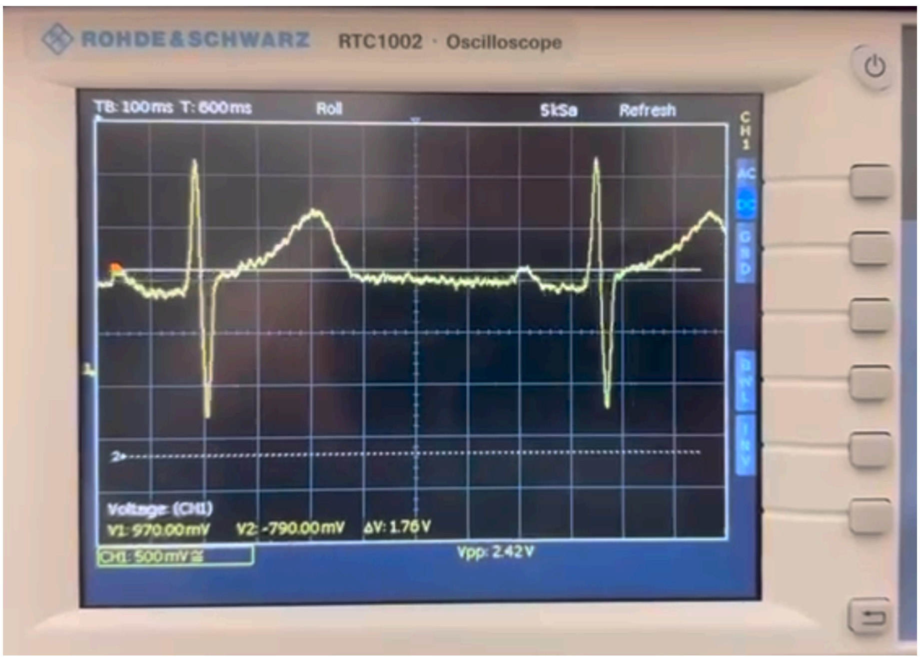

Figure 2. Heart signal from oscilloscope

Cost comparison:

Item	Our Prototype (Est. Cost)	Commercial Equivalent (e.g., Welch Allyn)
Processing Unit	$0 (Student Kit) / $150 (Beagle-Y-AI)	N/A (Proprietary)
Analog Components	$30 (AD620, TL074)	N/A
Software License	$0 (Open Source)	$1000+ (Proprietary software)
Probes/Cables	$0 (Lab tech)	$150+
TOTAL	**~ $180 CAD**	**$2,000 - $5,000+ CAD**

Feature Tablet:

Description	Host/Target	Comp	Code	Author(s)	Notes
Digital filter	Host	4.5	C	Prasanna, Hasan	Cleans our signal digitally
Data capture	Host	5	Python	Prasanna, Hasan	Plots signal
Bpm reader	Host	4	Python	Prasanna	Calculates BPM
Website	Other	3	HTML /JS	Hasan	Showing the signal on a website, it does show but just not the same shape as expected

Extra hardware component:

Description	Comp	Notes
TL074	**5**	Low/High pass filtering: low pass to filter out 60hz noise and makes the signal 180 degree out of phase
AD620	**5**	Differential op-amp
Alligator clips	**5**	Signal Transmission. Shielded cables used to bridge the connection between the PCB and the body electrodes. Transfers the differential biopotentials from the chest and reference voltage from the right leg.
Electodes	**5**	These convert the ionic currents generated by the heart on the skin surface into stable electrical currents for the circuit.