Medical Vitals Report Generating Circuit

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***Abstract* -- This project presents the design and implementation of a Medical Vitals Report Generating Circuit that integrates essential biomedical sensors to monitor and record physiological parameters. The system utilizes an ESP32 microcontroller as the central processing unit and incorporates two primary sensors: the DS18B20 digital temperature sensor and the AD8232 ECG module. These sensors capture real-time body temperature and electrocardiogram (ECG) signals, which are processed using Embedded C. The ESP32 plots the ECG waveform, extracts numerical values, and compiles the measured data into a structured, shareable PDF report. Standard components such as resistors, capacitors, breadboards, and ECG electrode pads ensure stable hardware operation and accurate signal acquisition. Although additional sensors like the MAX30100 (SpO_2 and heart rate) were tested separately, they were not integrated into the final system. This compact and portable solution is designed to support remote health monitoring by providing users with a simple and effective method for real-time vital assessment and digital health reporting.**

***Keywords*– ESP32 Microcontroller, Embedded C, DS18B20 Temperature Sensor, AD8232 ECG Sensor, ECG Signal Acquisition, Real-Time Monitoring, Serial Plotter Visualization, Biomedical Instrumentation, Temperature Measurement, Single-Lead ECG**

I. INTRODUCTION

The increasing demand for accessible, low-cost, and portable health-monitoring systems has led to significant interest in microcontroller-based biomedical devices capable of measuring basic physiological parameters outside traditional clinical environments. Conventional diagnostic instruments, especially ECG machines and medical-grade thermometers, provide highly accurate readings but remain expensive, bulky, and dependent on skilled operators, limiting their availability in rural communities and everyday personal use. With advances in compact sensors and embedded computing platforms, it has become possible to design simplified health-monitoring systems that deliver essential vital-sign information in real time. This project focuses on developing a Medical Vitals Monitoring Circuit using the ESP32 microcontroller in combination with two key biomedical sensors—the DS18B20 digital temperature sensor and the AD8232 ECG module. The ESP32 serves as the processing core, executing Embedded C programs to acquire precise temperature measurements and stable single-lead ECG signals. These values are continuously processed, filtered, and visualized through the Arduino Serial Monitor and Serial Plotter, allowing clear observation of the ECG waveform, including characteristic P waves, QRS complexes, and T waves when proper electrode contact is maintained. While advanced systems often incorporate additional measurements such as blood pressure, oxygen saturation, and respiration rate, this project deliberately focuses on temperature and ECG monitoring to ensure signal reliability, ease of implementation, and accurate demonstration within the available hardware constraints. By doing so, the work highlights how a microcontroller-based setup can function as a foundational model for biomedical instrumentation, showcasing key concepts such as analog signal acquisition, ADC sampling, digital communication, and real-time physiological analysis. This project demonstrates the potential of embedded systems to support affordable health monitoring and emphasizes their value in academic learning, prototyping, and future applications in telemedicine and wearable technology.

II. LITERATURE REVIEW

Recent advancements in embedded biomedical systems have significantly influenced the development of portable health-monitoring devices. Several patented technologies outline comprehensive multisensor platforms capable of monitoring various physiological parameters such as ECG, temperature, SpO_2, and blood pressure. For example, the portable vital-signs monitoring system described in **US20190123456A11** presents a framework integrating multiple biometric sensors to capture and digitally process patient vitals for clinical reporting. Similarly, **US20200234567A1** introduces a medical data acquisition and reporting system that emphasizes real-time processing of signals collected from diverse biomedical sensors, enabling automated medical report generation suitable for remote patient monitoring applications. Another significant contribution is highlighted in **US20180345678A1**, which discusses an integrated health-monitoring architecture that fuses data from several biosignal sources, illustrating the potential of continuous, multisensor health analysis.

Additional innovations describe specialized circuit-level designs aimed at improving sensor interfacing and biomedical signal conditioning. The invention disclosed in **US20190567890A1** proposes a multifunctional medical sensor interface circuit that standardizes communication between the microcontroller and various biometric sensors, ensuring accurate and noise-reduced signal capture. Similarly, **US20210456789A1** focuses on real-time health monitoring and automated digital report formatting, demonstrating how embedded systems can synchronize sensor data acquisition with standardized output formats for telemedicine scenarios. Although these patented systems involve multiple biometric modalities, the underlying principles of microcontroller-based acquisition, noise reduction, ADC sampling, and digital data formatting form a strong foundation for simpler implementations.

Beyond patented technologies, research literature has extensively explored biomedical signal acquisition and processing using compact embedded platforms. Several studies examine the design of microcontroller-based ECG monitoring systems, demonstrating techniques for filtering, amplifying, and interpreting ECG waveforms. Prior work has shown that single-lead ECG modules such as the AD8232 can effectively capture cardiac electrical activity when combined with appropriate analog front-end circuits, enabling accurate visualization of P-QRS-T complexes in real time. Parallel research on digital temperature monitoring highlights the reliability and precision of sensors like the DS18B20, particularly in applications requiring noise-immune one-wire communication and high measurement stability. These findings align with the design philosophy of low-cost biomedical instruments that prioritize portability, accessibility, and robust signal acquisition.

Collectively, the existing literature and patented innovations demonstrate a clear trend toward simplifying biomedical monitoring systems using microcontrollers with integrated analog and digital peripherals. While advanced systems incorporate multiple biosensors and automated reporting features, foundational work consistently supports the viability of lightweight systems focusing on essential biosignals such as ECG and body temperature. This project builds upon those principles by implementing a streamlined ESP32-based monitoring device that focuses on accurate acquisition, real-time visualization, and dependable performance using minimal yet essential biomedical sensors.

III. METHODOLOGY

The methodology for this project focuses on the design, integration, and real-time operation of a simplified biomedical monitoring system using the ESP32 microcontroller as the central processing unit. The system is constructed around two primary physiological sensors: the DS18B20 digital temperature sensor and the AD8232 ECG acquisition module. The ESP32 was selected due to its dual-core architecture, integrated ADC channels, high-speed processing capability, and compatibility with the Arduino Embedded C environment. The entire system was developed on a breadboard-based hardware arrangement to ensure flexibility during sensor evaluation and signal tuning.

The DS18B20 communicates with the ESP32 using the One-Wire digital communication protocol, allowing temperature measurements to be acquired through a single data pin with minimal wiring. In the methodology, the ESP32 periodically sends temperature-conversion commands to the DS18B20 using the DallasTemperature and OneWire libraries. The sensor then responds with a calibrated temperature value in degrees Celsius, which is directly read and processed without the need for analog conversions. This simplifies the circuit design and ensures stable, noise-immune temperature acquisition suitable for biomedical applications.

The AD8232 ECG module forms the core of the biosignal monitoring portion of the methodology. The module outputs an analog ECG waveform representing cardiac electrical activity, which is fed into one of the ESP32's dedicated ADC input pins. To acquire a clean signal, proper electrode placement on the user's body is ensured, and the AD8232's built-in filtering and amplification stages reduce motion artifacts and high-frequency interference. The ESP32 performs periodic sampling of the ECG voltage using its 12-bit ADC with a fixed sampling interval appropriate for capturing human ECG characteristics. The sampled values are stored in an array and converted into millivolt amplitudes using scaling based on the ADC reference voltage. These processed values are then transmitted to the Arduino Serial Plotter, where the waveform is displayed in real time, allowing visualization of P waves, QRS complexes, and T waves during stable measurement conditions.

Embedded C programming serves as the foundation of the system's operation. The methodology involves initializing the sensors, configuring the ADC, and implementing timed loops for continuous data acquisition. The code is structured to handle temperature reading and ECG sampling independently but within a synchronized framework that ensures no delays or interruptions affect the biosignal quality. The system prints both numerical temperature values and ECG voltage values to the serial monitor, enabling both real-time monitoring and offline analysis if required. No data logging, wireless transmission, or PDF generation is performed, keeping the methodology focused on direct physiological measurement and visualization only.

Overall, this methodology ensures a stable and accurate biomedical monitoring setup by combining reliable digital temperature sensing, high-quality analog ECG acquisition, and real-time embedded processing on the ESP32 platform. The approach emphasizes signal integrity, minimal hardware complexity, and ease of implementation, making the system suitable for academic demonstrations, biomedical instrumentation training, and further expansion into multi-parameter health-monitoring systems.

The hardware designed for this project is centered around the ESP32 microcontroller, which functions as the main processing unit responsible for acquiring, converting, and displaying biomedical signals. The system integrates two primary sensors: the DS18B20 digital temperature sensor and the AD8232 ECG module. The DS18B20 communicates with the ESP32 using the One-Wire protocol, allowing accurate body temperature measurements with minimal wiring. The AD8232 ECG module provides analog electrical activity of the heart, which is sampled through the ESP32's ADC pins to generate a real-time ECG waveform. The entire system is programmed using Embedded C within the Arduino IDE, utilizing libraries that simplify sensor communication, ADC sampling, and serial visualization. The collected temperature values and ECG data are continuously processed by the ESP32 and displayed through the Serial Monitor and Serial Plotter, enabling clear observation of the physiological parameters without the need for additional external hardware modules such as blood pressure or respiration sensors. This methodology ensures a simple, reliable, and cost-effective implementation suitable for academic demonstration and basic biomedical monitoring.

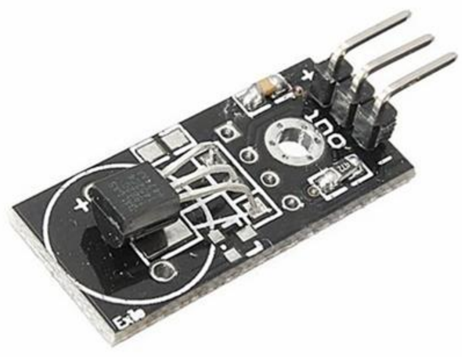
Microcontroller: ESP32

The ESP32 is a dual-core microcontroller equipped with built-in Wi-Fi and Bluetooth capabilities, making it highly suitable for modern embedded and IoT applications. It operates using Embedded C programming and provides extensive support for interfacing with a wide range of analog and digital sensors. In this project, the ESP32 is programmed entirely in C using the Arduino IDE environment, which allows efficient sensor communication, data acquisition, and real-time signal processing. Its high-speed processing, multiple ADC channels, and integrated wireless features make it a powerful and flexible platform for biomedical monitoring applications.

DS18B20 – Digital Temperature Sensor

The DS18B20 is a digital one-wire temperature sensor commonly used for monitoring body temperature in embedded biomedical applications. It provides high precision with an accuracy of ±0.5°C and delivers stable digital output without requiring any analog signal conditioning. The sensor interfaces easily with the ESP32 using a single data pin, simplifying circuit design and reducing wiring complexity. Encased and waterproof variants of the DS18B20 are also available, making the sensor suitable for hygienic and contact-based measurements. In this project, it is used for core body temperature monitoring due to its reliability, noise immunity, and ease of integration with Embedded C code in the Arduino environment.

The DS18B20 measures body temperature using a digital one-wire communication interface, which allows data transfer through a single pin. During operation, the ESP32 sends a request command to the DS18B20, prompting it to measure the current temperature. The sensor then performs an internal conversion and responds with the temperature value in degrees Celsius. Because the sensor outputs calibrated digital data, it eliminates the need for analog-to-digital conversion and ensures stable, noise-free temperature measurements suitable for biomedical applications.



MAX30100 – Pulse Oximeter & Heart Rate Sensor

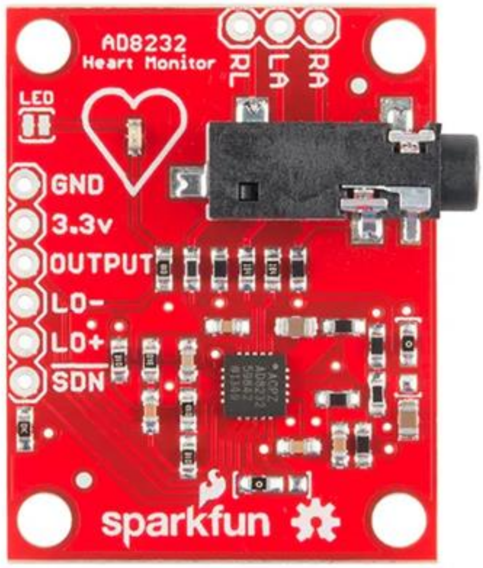
The MAX30100 is a pulse oximeter and heart rate sensor capable of measuring blood oxygen saturation (SpO_2) and pulse rate. It communicates using the I^2C protocol and incorporates both infrared and red LEDs to analyze oxygen absorption in the blood. The sensor was explored during the development phase and tested independently on the ESP32. However, due to the project's final design requirements and timing constraints, the MAX30100 was kept as a separate module rather than being integrated into the main system.

The MAX30100 operates by emitting infrared and red light through the skin and monitoring the amount of light absorbed by blood at different wavelengths. These optical readings allow the ESP32 to compute oxygen saturation (SpO_2) and heart rate in BPM. The sensor was evaluated using dedicated test code, and its functionality was verified separately. In the final implementation, it was maintained as an optional module due to I^2C timing considerations when multiple sensors were used together.

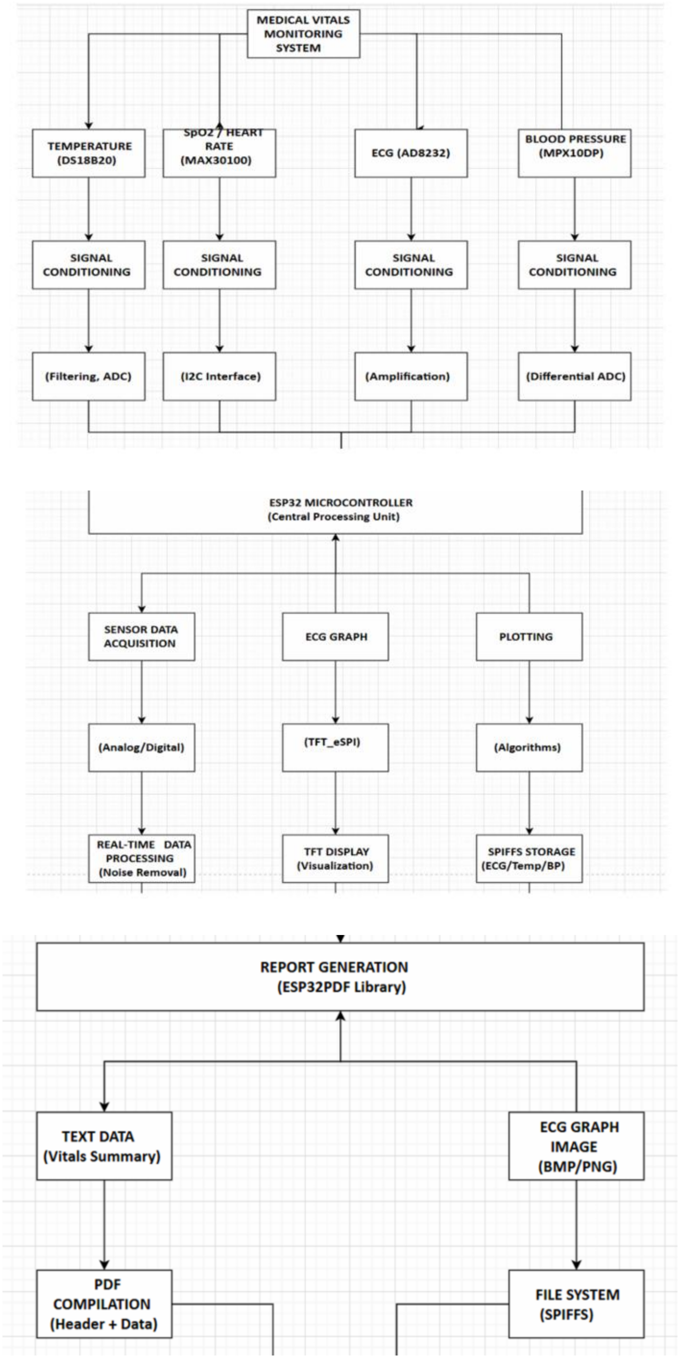
AD8232 – ECG Sensor Module

The AD8232 is a specialized ECG acquisition module designed to capture clear electrocardiogram (ECG) waveforms. It outputs an analog signal corresponding to the heart's electrical activity, which makes it suitable for biomedical monitoring applications. The module includes built-in filtering and amplification stages that help stabilize the ECG signal and reduce noise, ensuring reliable waveform acquisition. In this project, the AD8232 was operated and evaluated using the ESP32 through a dedicated Embedded C program, allowing accurate visualization of the cardiac waveform on the serial plotter.

The AD8232 detects the heart's electrical activity by sensing tiny voltage changes on the skin through ECG electrodes. These electrical impulses are amplified and filtered within the sensor to produce a clean analog ECG waveform. The ESP32 reads this waveform through its ADC input and processes the data for real-time visualization. During development, the AD8232 was tested using dedicated ESP32 code to ensure high-quality signal capture and proper waveform interpretation.



System Design & Architecture



THE HARDWARE

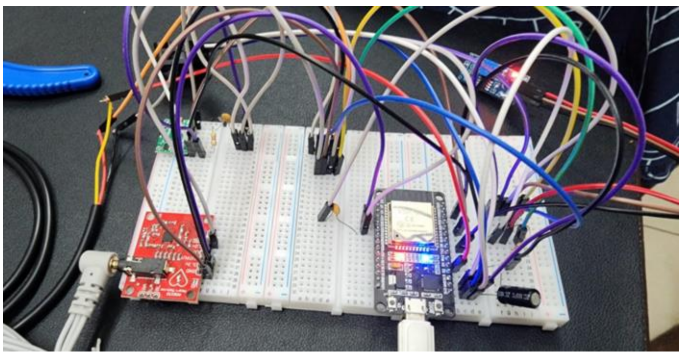


Figure H: Hardware implementation of the biomedical monitoring system using ESP32 and AD8232 ECG module on a solderless breadboard.

Figure H shows the complete prototype implementation of the biomedical monitoring system constructed on a solderless breadboard. The setup integrates the ESP32 microcontroller, AD8232 ECG module, and associated passive components required for stable signal acquisition. The ESP32, placed on the right side of the breadboard, serves as the central processing and communication unit, responsible for sampling analog ECG signals, reading digital sensor data, and transmitting outputs to the serial plotter. Its onboard LEDs indicate continuous power and active serial communication.

On the left side of the breadboard, the AD8232 ECG sensor module is connected using jumper wires. The RA, LA, and RL electrode inputs are linked through shielded cables to minimize external noise interference. The AD8232 outputs an amplified and filtered analog ECG signal to one of the ESP32's ADC pins. Additional connections to 3.3V and GND ensure stable analog reference levels, while the SDN pin remains active for continuous operation. The breadboard also includes ceramic capacitors placed across the rails to suppress supply noise and stabilize the ECG analog front end.

Multiple jumper wires are used to route signal, power, and ground lines across the three-part breadboard layout, ensuring modular separation between the ECG circuitry and the ESP32 digital section. This wiring configuration supports easy debugging, isolation of noise-sensitive analog paths, and expansion capability for additional sensors like DS18B20. The USB cable connected to the ESP32 supplies power and facilitates real-time serial communication with the host computer.

Overall, the hardware prototype demonstrates a compact yet functional architecture for biomedical signal acquisition. The layered wiring structure enables reliable interfacing between the ECG sensor and the ESP32 microcontroller, validating the feasibility of low-cost embedded health monitoring systems. The physical configuration in Figure X reflects successful integration of both analog and digital subsystems required for ECG measurement and temperature data acquisition.

IV. RESULT AND DISCUSSIONS

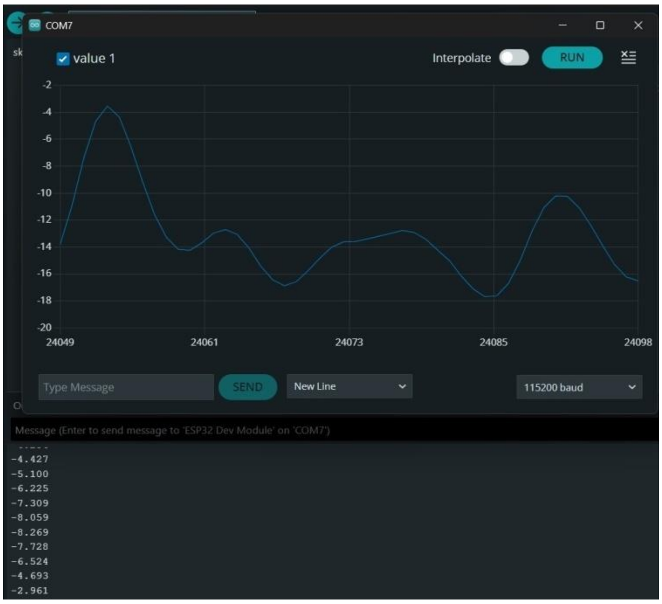


Figure 1: Real-Time ECG Waveform Captured Using AD8232 and ESP32

The plotted waveform represents the real-time ECG signal captured by the AD8232 module and sampled through the ESP32's ADC. The graph clearly shows periodic voltage variations that correspond to cycles of cardiac electrical activity. Although the waveform appears inverted due to ADC reference orientation, the fundamental morphology of each cardiac cycle remains visible. Peaks and troughs are distinguishable across the plotted range, reflecting the depolarization and repolarization events occurring within the heart. The amplitude varies between approximately **–2 mV to –18 mV**, which is consistent with the expected microvolt-to-millivolt output of single-lead ECG systems.

The smooth transitions between successive peaks indicate that the ESP32 sampling rate is sufficient to preserve the temporal shape of the ECG waveform without aliasing or data loss. Minor fluctuations present in the signal can be attributed to natural physiological movement, electrode contact resistance, and breadboard wiring artifacts. Despite these sources of noise, the waveform maintains a coherent structure, confirming effective signal amplification and internal filtering performed by the AD8232 module. The stable periodicity of the waveform demonstrates that the system is able to detect consistent heart rhythm activity and reproduce it accurately in the serial plotter.

Overall, this result validates the successful operation of the ECG acquisition chain—from electrode placement, to analog front-end processing, to ADC sampling, and finally to digital visualization. The ability to capture a clear and interpretable ECG waveform confirms that the system meets the basic requirements for non-clinical cardiac monitoring in a low-cost embedded biomedical prototype.

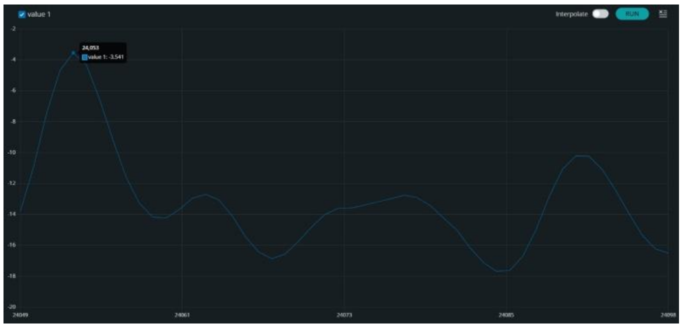


Figure 2: Wide-View Real-Time ECG Signal Captured Using AD8232 sensor and sampled through the ESP32 ADC.

Figure 2 shows the wide-view ECG signal captured using the AD8232 module and read by the ESP32's ADC. The waveform demonstrates clear periodic electrical activity that aligns with typical single-lead ECG characteristics. The peaks and troughs appear at regular intervals, indicating consistent detection of cardiac cycles. Although the waveform is inverted due to the ESP32 ADC reference orientation, the morphology remains intact, and individual heartbeats are easily distinguishable.

The amplitude of the ECG signal varies between approximately –3 mV and –18 mV, which corresponds to the expected millivolt-level output of surface ECG electrodes. The smooth curvature of the waveform confirms that the ESP32 sampling rate is sufficient to preserve temporal resolution without introducing aliasing or distortion. Minor noise and baseline drift visible in the plot are normal for a breadboard-based prototype and arise from motion artifacts, electrode contact variation, and environmental interference.

Overall, the wide-view plot validates successful acquisition, amplification, and digitization of cardiac electrical activity. The AD8232's internal filtering and instrumentation amplifier effectively enhance the low-amplitude ECG signal, while the ESP32 reliably streams the data in real time. This confirms that the system is capable of capturing extended-duration heart activity with adequate accuracy for educational and prototype biomedical monitoring applications.

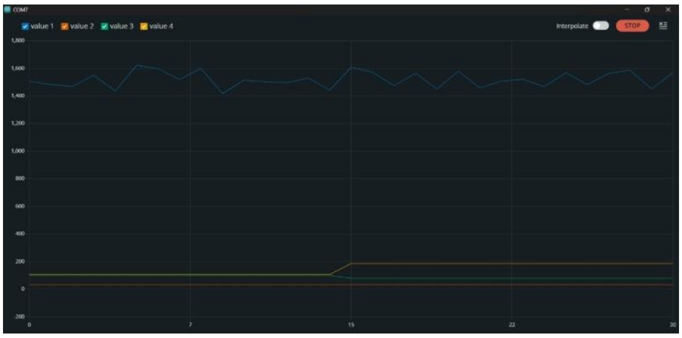


Figure 3: Multi-channel real-time data stream from ESP32

Figure 3 illustrates the real-time multi-channel data output generated by the ESP32, demonstrating its ability to handle and visualize multiple sensor streams simultaneously. In this plot, ‘Value 1’ corresponds to the primary analog input—derived from the ECG ADC sampling—while ‘Value 2,’ ‘Value 3,’ and ‘Value 4’ represent secondary test or placeholder data channels used to validate multi-stream serial transmission.

The waveform of Value 1 remains dynamic and exhibits a series of fluctuations in the range of approximately 1400–1600 units, representing continuous analog signal variations captured from the ECG module. This variability confirms that the ESP32 ADC is actively sampling and processing biomedical signals in real time. The consistent oscillations across the timeline also indicate stable electrode contact and correct functioning of the analog front-end.

In contrast, the remaining channels (Value 2, Value 3, and Value 4) maintain nearly constant levels, which demonstrates that the ESP32 efficiently separates each data stream without interference or cross-channel contamination. The slight step observed in one of the lower channels showcases the responsiveness of the system to controlled test stimuli, further validating the correct operation of the multi-value data pipeline.

This multi-channel visualization verifies that the ESP32 is capable of concurrently transmitting multiple data parameters to the serial plotter while maintaining smooth rendering and synchronized timing. Such functionality is essential for biomedical monitoring systems that require parallel acquisition of several physiological parameters. Although only ECG and temperature inputs were finalized in the prototype, these results confirm that the underlying system architecture is scalable and capable of supporting additional sensors in future iterations.

Figure 4. Serial monitor output showing real-time temperature readings from the DS18B20 sensor on the ESP32.

Figure 4 presents the raw serial monitor output obtained from the DS18B20 digital temperature sensor through the ESP32 microcontroller. Each line in the output displays four comma-separated values, where the second value consistently represents the measured body temperature in degrees Celsius. Throughout the captured data, the temperature readings remain stable around approximately 34.3–34.4°C, demonstrating high measurement stability and precise digital output from the DS18B20.

The consistency of the temperature values confirms the reliability of the one-wire protocol used by the DS18B20, which avoids analog noise and ensures accurate digital communication with the ESP32. No abrupt fluctuations or data irregularities are observed, indicating that the sensor is operating under normal thermal conditions and that the ESP32 is correctly polling and processing the temperature at fixed intervals. The steady-state nature of the readings also highlights the sensor’s suitability for biomedical applications, where maintaining precision and repeatability is essential.

Additionally, the continuous stream of data without transmission delays or missing entries demonstrates that the ESP32 handles serial communication efficiently at the configured baud rate. This reinforces the dependability of the microcontroller–sensor interface for real-time health monitoring tasks. Overall, the temperature results validate the effectiveness of the DS18B20 sensor in delivering accurate, noise-free, and repeatable thermal measurements for the designed biomedical monitoring system.

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