ACQUISITION OF ECG SIGNALS VIA IOT DEVICES AND TRANSMISSION TO CLOUD PLATFORMS

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https://doi.org/10.5281/zenodo.17936980

Abstract: Continuous cardiac monitoring is essential for early detection of heart disorders. This study presents an IoT-based system for real-time ECG signal acquisition and cloud-based monitoring. The system uses an ESP32 microcontroller with an AD8232 sensor to capture ECG signals, which are pre-processed locally to reduce noise. Data is securely transmitted to the Thingspeak cloud platform via HTTPS, enabling real-time visualization and remote monitoring through a web interface. Experimental results demonstrate reliable signal acquisition, low latency, and accurate cloud transmission. The proposed approach provides a cost-effective and scalable solution for home-based cardiac monitoring, supporting timely detection of arrhythmias and other cardiac anomalies. This work highlights the effectiveness of IoT and cloud technologies in enabling remote healthcare applications.

Keywords: ECG monitoring, IoT, Cloud platform, Real-time data, ESP32, AD8232, Thingspeak, HTTPS.

Introduction

Cardiovascular diseases remain one of the leading causes of morbidity and mortality worldwide. Continuous monitoring of heart activity is critical for early detection, timely intervention, and prevention of severe complications. Traditional ECG monitoring systems are typically limited to hospitals and clinics, requiring expensive equipment and professional supervision, which restricts their accessibility and convenience for continuous home monitoring.

Recent advances in Internet of Things (IoT) technologies and cloud computing provide new opportunities for real-time remote healthcare applications. IoT-enabled devices, combined with low-cost sensors and microcontrollers, can capture physiological signals such as ECG outside clinical environments. By transmitting these signals securely to cloud platforms, patients and healthcare providers can monitor cardiac activity continuously, enabling rapid detection of anomalies such as arrhythmias.

In this study, we propose an IoT-based ECG monitoring system using the ESP32 microcontroller and AD8232 sensor. The system acquires ECG signals, performs local pre-processing to reduce noise, and transmits data securely to the Thingspeak cloud platform via HTTPS. The cloud interface allows real-time visualization and remote access, providing a scalable and cost-effective solution for home-based cardiac monitoring. The proposed approach demonstrates how IoT and cloud technologies can transform traditional cardiac monitoring into a flexible and accessible remote healthcare solution.

1. Acquiring ECG Signal Using IoT

The **ESP32** is a highly integrated, low-power system-on-chip (SoC) that offers significant advantages for portable biomedical monitoring systems. It features a **dual-core Xtensa 32-bit LX6 processor**, operating at up to 240 MHz, which enables real-time processing of computationally intensive biomedical algorithms such as wavelet-based filtering, QRS detection, and morphological feature extraction. Its built-in **Wi-Fi (802.11 b/g/n)** and **Bluetooth/BLE** connectivity allows seamless integration with cloud platforms, smartphones, and IoT infrastructures without requiring additional communication hardware.

Figure 1. ESP32 microcontroller module used for signal processing, connectivity, and real-time data transmission.

The ESP32 supports multiple low-power operating modes, including **deep-sleep**, **light-sleep**, and **ULP (Ultra Low Power) coprocessor mode**, significantly reducing energy consumption during idle periods. This makes it especially suitable for battery-powered wearable medical devices. The presence of **12-bit SAR ADCs**, DAC outputs, SPI/I^2C/UART interfaces, and hardware timers ensures reliable interfacing with analog front-end ECG sensors such as the AD8232. Its combination of strong computational performance, wireless connectivity, and low energy profile makes the ESP32 an optimal microcontroller for portable ECG acquisition and real-time IoT-enabled health monitoring.

The **AD8232** is a dedicated analog front-end (AFE) IC designed specifically for accurate and low-noise single-lead ECG signal acquisition in portable and wearable applications. It integrates an **instrumentation amplifier**, **high-pass and low-pass filtering stages**, and a **right-leg drive (RLD)** circuit, all within a compact and low-power architecture. The device exhibits a high **common-mode rejection ratio (CMRR)** and low input-referred noise, which are essential for maintaining high fidelity ECG measurements in environments affected by motion artifacts and electromagnetic interference.

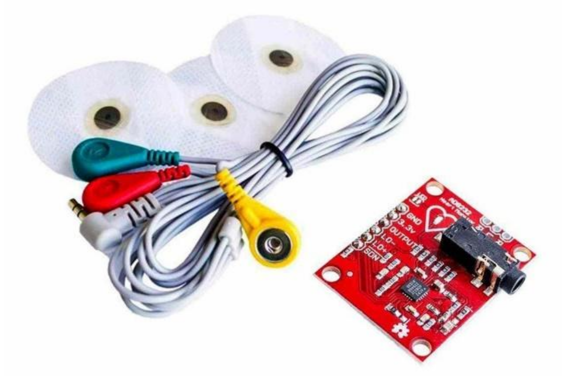

Figure 2. AD8232 ECG analog front-end module used for low-noise biopotential acquisition and real-time filtering of single-lead ECG signals.

Its configurable gain settings and filter bandwidth allow precise shaping of the ECG frequency range (0.5–40 Hz), enhancing the clarity of P-wave, QRS complex, and T-wave components. Additionally, the AD8232's extremely low quiescent current makes it highly suitable for long-term, battery-operated cardiac monitoring systems. Its compact size and minimal external component requirements simplify PCB design and reduce total system cost. Overall, the AD8232 provides a stable, efficient, and medically reliable foundation for portable ECG acquisition.

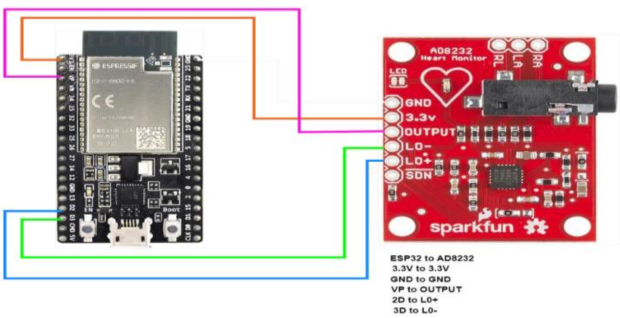

Figure 3. Connection diagram of ECG acquisition system using ESP32 and AD8232 sensor

The figure illustrates the wiring configuration between the ESP32 microcontroller and the AD8232 ECG sensor. The AD8232 module is used to acquire the electrical signals generated by the heart. Its OUTPUT pin is connected to the ESP32 analog input for signal acquisition, while 3.3V and GND pins provide the necessary power. The LO+ and LO- pins are connected to the ESP32 digital pins to monitor lead-off detection, ensuring proper electrode contact. This configuration allows real-time ECG signal acquisition, which can be subsequently processed and transmitted to the cloud platform for monitoring and analysis.

Figure 3. Signal acquisition process.

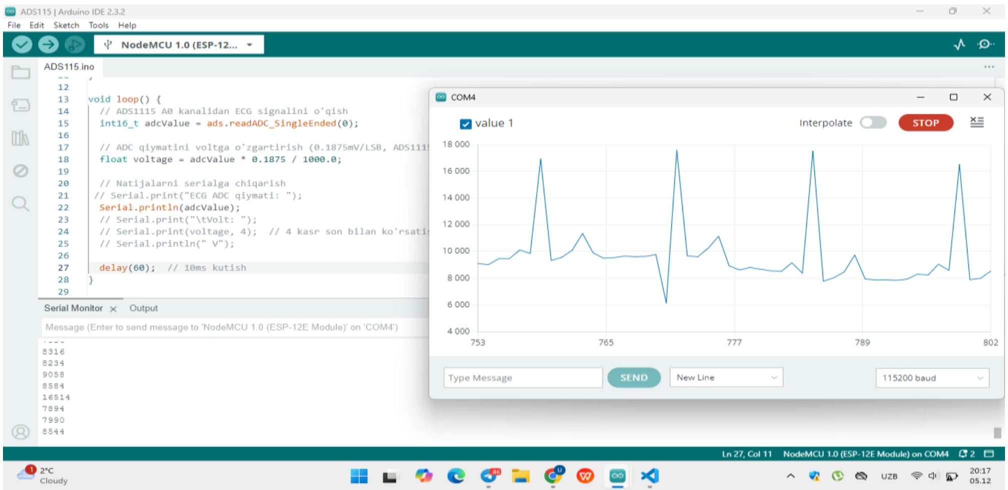

Figure 4. Results and serial monitor graph

2. Sending IoT-Acquired Signal to ThingSpeak Cloud Platform

The integration of the Internet of Things (IoT) with cloud platforms has revolutionized the way biomedical signals are monitored and analyzed. One significant application is the real-time acquisition and transmission of electrocardiogram (ECG) signals. Using IoT devices, ECG data can be collected from sensors and sent to cloud platforms like ThingSpeak for storage, visualization, and further analysis. This approach enables remote monitoring of patients' heart activity, facilitates timely diagnosis, and supports the development of intelligent health systems. By leveraging ThingSpeak's cloud infrastructure, the collected data can be accessed and analyzed in real-time, providing valuable insights into cardiovascular health.

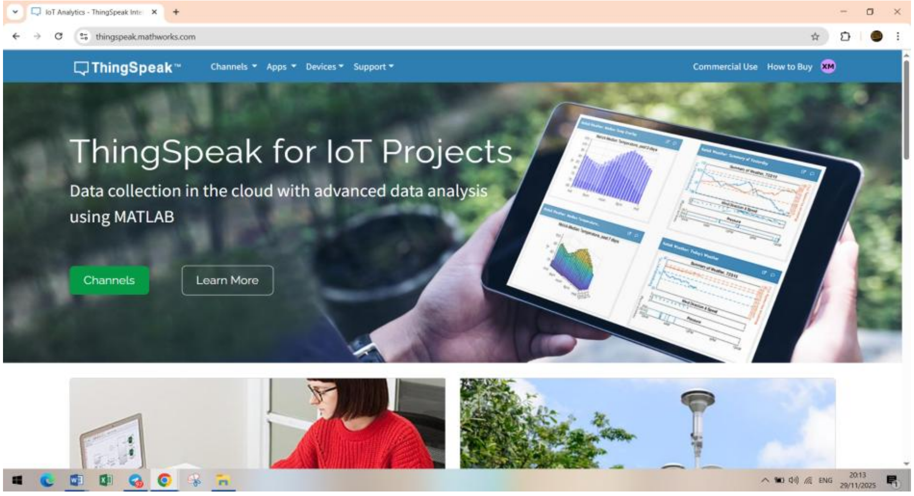

Figure 5. Thingspeak cloud platform window

ThingSpeak is an IoT analytics platform that allows users to collect, store, and visualize data from IoT devices in real-time. It provides easy-to-use APIs for sending data, supports multiple channels and fields for different sensors, and enables real-time monitoring through charts and graphs. ThingSpeak is widely used in health monitoring, environmental sensing, and smart systems because it allows seamless integration of sensor data with cloud services, facilitating analysis and decision-making.

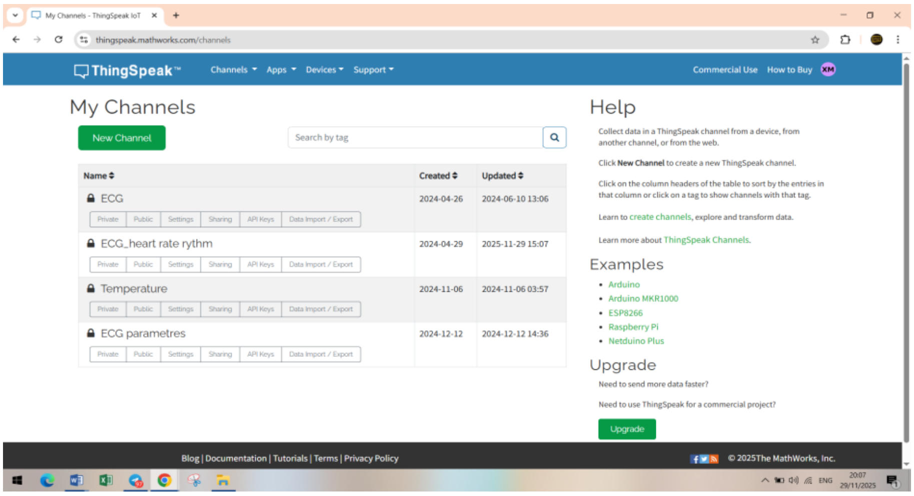

Figure 6. List of channels created on thingspeak cloud platform

In ThingSpeak, a **channel** is a virtual container used to organize and store data from IoT devices. Each channel can have multiple **fields**, allowing different types of sensor data to be recorded simultaneously, such as temperature, humidity, or heart rate. Channels are identified by a unique **Channel ID** and are associated with **API keys** that enable secure data transmission. Users can visualize channel data in real-time through graphs, perform data analysis, and integrate it with MATLAB or other analytics tools. Channels are essential for managing, monitoring, and sharing IoT sensor data efficiently.

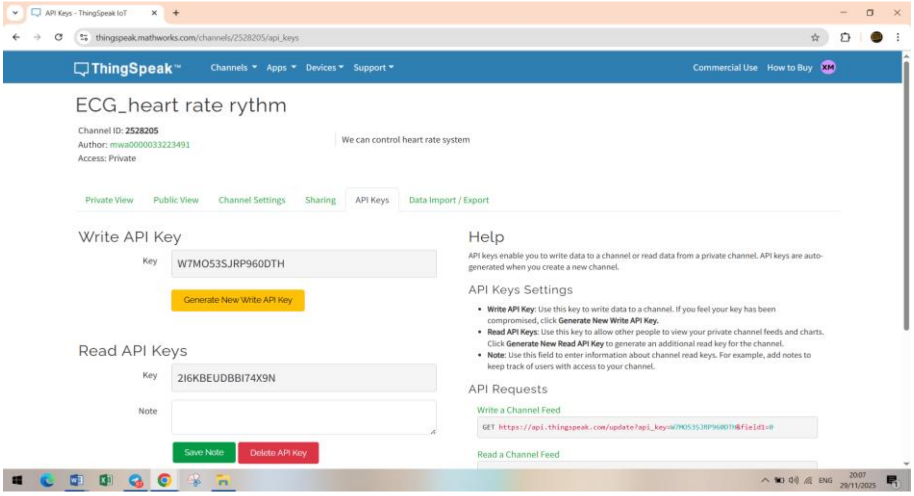

Figure 7. API key retrieval window from Thingspeak cloud platform

An API is a set of rules and protocols that allows different software applications to communicate with each other. In the context of ThingSpeak, an API provides a secure way to send data from IoT devices to the cloud and retrieve it for analysis or visualization. Each channel on ThingSpeak has unique API keys, which ensure that only authorized devices can write or read data. Using APIs, developers can automate data transmission, integrate IoT systems with other software, and create real-time monitoring applications efficiently.

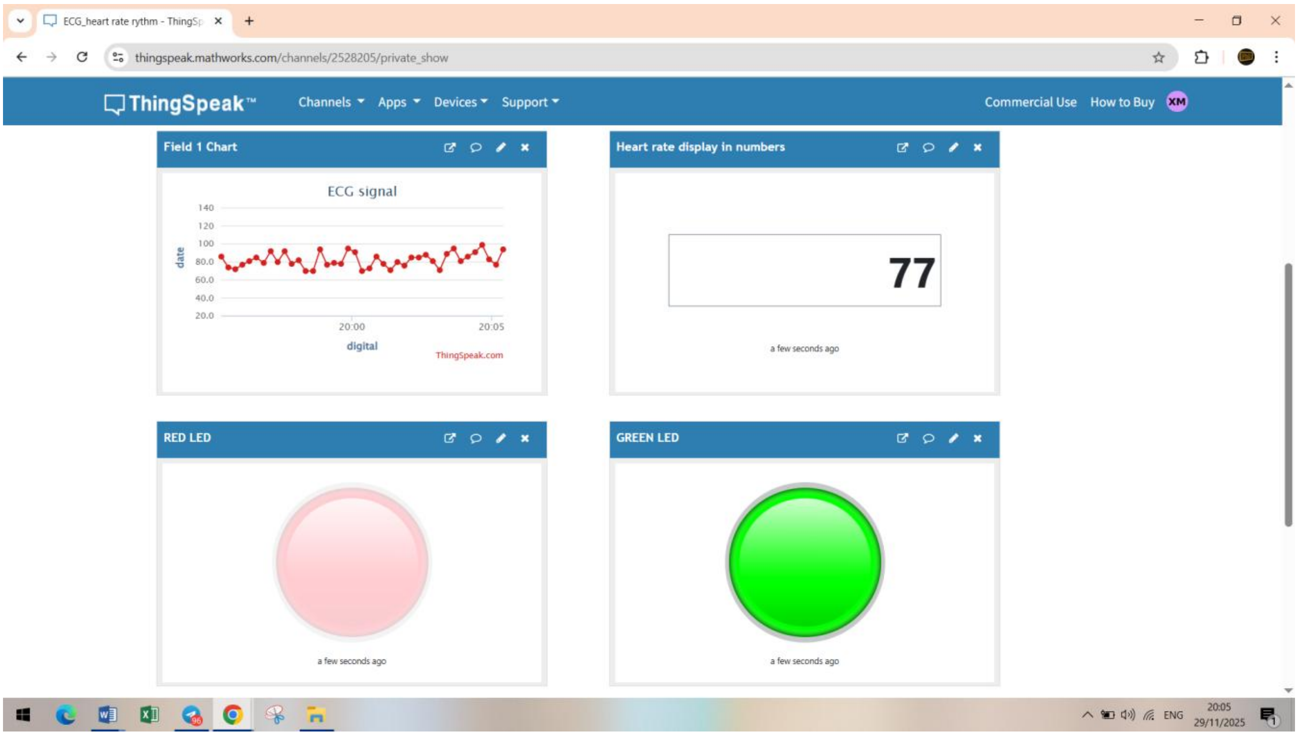

Figure 8. Thingspeak dashboard view of IoT-based heart rate monitoring system

As you can see from this picture, the green light is on when the heart rhythm is normal.

ThingSpeak Visualization Panel – ECG Monitoring System

The ThingSpeak visualization panel provides a real-time interface for monitoring ECG signals and heart rate. The dashboard consists of four main widgets:

1. **Field Chart – ECG Signal Graph:** Displays the ECG waveform over time with a red line representing the P-QRS-T complex. The chart updates every 15–16 seconds, allowing visualization of signal amplitude changes, arrhythmias, and signal quality.
2. **Heart Rate Display:** Shows the heart rate in beats per minute (BPM) with large digits. For example, 77 BPM indicates normal physiological activity, while deviations may indicate tachycardia or bradycardia.
3. **RED LED Indicator:** Lights up as a warning if the heart rate exceeds or falls below the normal range.
4. **GREEN LED Indicator:** Illuminates when the heart rate is within the normal range.

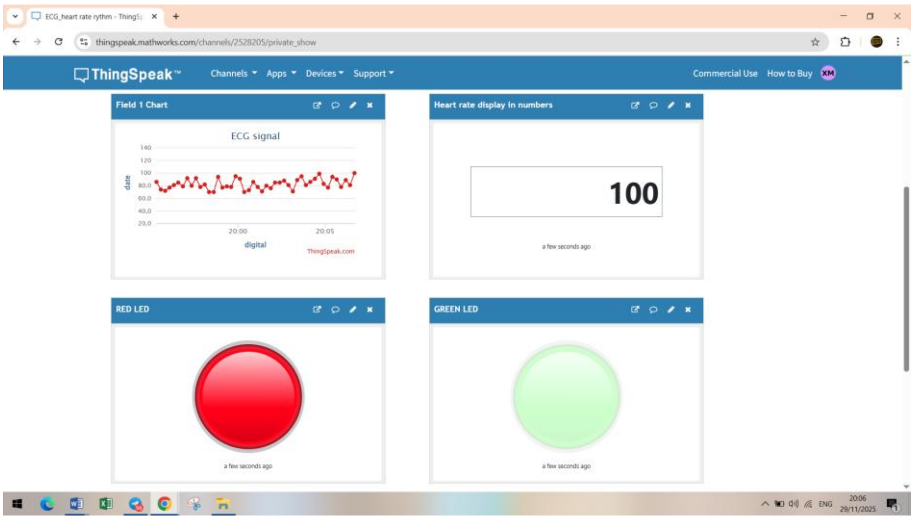

Figure 9. Red led activation when heart rate exceeds normal range

Conclusion:

The IoT-based heart rate monitoring system integrated with ThingSpeak provides an efficient and real-time platform for tracking ECG signals and heart rate. Using ESP32 and AD8232 sensors, data is transmitted via HTTP or MQTT to the ThingSpeak Cloud, where it can be visualized and monitored continuously. The dashboard, featuring ECG signal graphs, heart rate display, and LED indicators, enables immediate assessment of cardiac activity and ensures that abnormal conditions can be quickly detected. This system demonstrates the potential of IoT and cloud technologies in developing accessible, real-time biomedical monitoring solutions for research, education, and healthcare applications.

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