

**SCHOOL OF COMPUTING AND INFORMATION  
TECHNOLOGY**

**Bachelor of Technology**

**in**

**Computer Science and Information Technology**

**Major Project Phase-II Report**

**An Investigation Hardware design for portable ECG monitoring using Machine Learning**

by

**Md Kaif Mustafa – R21EJ020**

**Rahul Kumar Singh – R21EJ026**

**Under the supervision of**

**Dr. Syed Thouheed Ahmed**

**Associate Professor**

**School of Computing and Information Technology**

**Rukmini Knowledge Park, Kattigenahalli, Yelahanka, Bengaluru-560064**

[**www.reva.edu.in**](http://www.reva.edu.in)

**2024 -2025**



**SCHOOL OF COMPUTING AND INFORMATION**

**TECHNOLOGY**

**Rukmini Knowledge Park, Kattigenahalli, Yelahanka, Bengaluru-560064**

**CERTIFICATE**

This is to certify that the Major Project Phase-II work titled “**An Investigation Hardware design for portable ECG monitoring using Machine Learning**” is carried out by **Md Kaif Mustafa (R21EJ020) Rahul Kumar Singh (R21EJ026)**, are bonafide students of Bachelor of Technology in **Computer Science and Information Technology** at the School of Computing and Information Technology, REVA University, Bengaluru in partial fulfillment for the award of degree in Bachelor of Technology in **Computer Science and Information Technology**, during the year **2024-2025**.

**Dr.Syed Thouheed Ahmed**

Guide

Associate Professor

School of Computing and

Information Technology,

REVA University

Date:

**Name of the Examiner Signature of Examiner**

**1.**

**2.**

**DECLARATION**

We, **Md Kaif Mustafa (R21EJ020) Rahul Kumar Singh (R21EJ026)**, are students of 8th semester B.Techin **Computer Science and Information Technology** at the **School of Computing and Information Technology**, **REVA University**, **Bengaluru**, hereby declare that the Major Project Phase-II title “**An Investigation Hardware design for portable ECG monitoring using Machine Learning**”has been carried out by us and submitted in partial fulfilment for the award of degree in **Bachelor of Technology in Computer Science and Information Technology** during the academic year **2024-2025**.

Student Signature

Name: Md Kaif Mustafa

SRN: R21EJ020

Name: Rahul Kumar Singh

SRN: R21EJ026

Place: Bangalore

Date:

## ACKNOWLEDGEMENT

It is a great pleasure for us to acknowledge the assistance and support of many individuals who have been responsible for the successful completion of this project work.

First, we take this opportunity to express our sincere gratitude to School of Computing and Information Technology, REVA University for providing us with a great opportunity to pursue our bachelor’s degree in this institution.

A special thanks to our Director Madam **Dr. Shobana Padmanabhan** and **Dr. Lithin Kumble,** HOD**, CSIT** for their continuous support and providing the necessary facilities with guidance for carrying out the project work.

We would like to thank our guide **Dr. Syed Thouheed Ahmed, Associate Professor**, **School of Computing and Information Technology, REVA University**, for sparing her valuable time to extend help in every step of our project work, which paved the way for smooth progress and fruitful culmination of the project.

We are also grateful to our family and friends who provided us with every requirement throughout the course.

We would like to thank one and all who directly or indirectly helped us in the Project work.

**Signature of Students**

**Md Kaif Mustafa** (R21EJ020)

**Rahul Kumar Singh** (R21EJ026)

## TABLE OF CONTENTS

Page

ABSTRACT……………………………………………………………………………………...vi

[CHAPTER 1: INTRODUCTION………………………………………………………………….1](#_bookmark0)

[CHAPTER 2: LITERATURE REVIEW…………………………………………………………..2](#_bookmark1)

[CHAPTER 3: PROBLEM DEFINITION………………………………………………………….4](#_bookmark2)

[CHAPTER 4: METHODOLOGY…………………………………………………………………5](#_bookmark3)

[CHAPTER 5: DELIVERABLES…………...……………………………………………………...7](#_bookmark4)

CHAPTER 6: REFERENCES…………………………………………………………………….8

**ABSTRACT**

The portable ECG machine project aims to develop an affordable, compact, and user-friendly device capable of capturing and wirelessly transmitting heart activity signals, making ECG monitoring accessible beyond traditional clinical settings. Utilizing the AD8232 ECG sensor module and an Arduino Nano, the device processes electrical signals from the heart and transmits data wirelessly through a Bluetooth module, enabling real- time monitoring on compatible devices. This project addresses the need for accessible and reliable cardiac monitoring tools, particularly beneficial for home use, remote patient monitoring, and telemedicine applications. By focusing on simplicity, low-cost components, and high accuracy, the design ensures that patients and healthcare providers can benefit from continuous, convenient cardiac data tracking.

This project investigates the design and development of a portable Electrocardiogram (ECG) monitoring device that leverages Machine Learning (ML) to enhance real-time heart health diagnostics. As cardiovascular diseases remain one of the leading causes of mortality worldwide, continuous monitoring and early detection are crucial. The proposed hardware design integrates lightweight, power-efficient components with a compact form factor, making it highly portable for everyday use. The ECG signals are collected through bio-electrodes, which are processed and analyzed using embedded ML algorithms trained to detect arrhythmias and other cardiac abnormalities. The ML models are optimized to operate on low-power microcontrollers, enabling real-time analysis directly on the device without reliance on external servers or high computational resources. This approach ensures both user privacy and reduced latency in anomaly detection. In addition, the device is designed to be user-friendly, with a simple interface to display results and wireless connectivity for easy data transfer to mobile devices or cloud storage for extended monitoring and medical consultation.

# CHAPTER 1: INTRODUCTION

Cardiovascular diseases (CVDs) are a leading cause of death globally, accounting for millions of lives lost each year. Early detection and continuous monitoring of heart health are essential for effective intervention and treatment. Traditionally, ECG monitoring is conducted in clinical settings using bulky, stationary equipment. However, with the rise of wearable technology and advancements in low-power electronics, there is a growing opportunity to bring ECG monitoring into everyday environments through portable devices.

This project aims to design and develop a portable ECG monitoring device that integrates hardware and machine learning (ML) to enable accurate, real-time cardiac health monitoring outside of clinical environments. Unlike conventional ECG devices, this device will use bio-electrodes to capture ECG signals and will process these signals through embedded ML algorithms capable of detecting common cardiac irregularities, such as arrhythmias, in real time. The ML algorithms are optimized to run on a low-power microcontroller, minimizing power consumption while maximizing device portability and battery life.

In addition to hardware design, the system incorporates an intuitive user interface and wireless connectivity, allowing users to easily view their heart data and transfer it to mobile devices or cloud storage for long-term monitoring and analysis. The device's real-time monitoring and user-friendly design make it suitable for individuals who need continuous heart monitoring such as elderly patients, athletes, or those at risk of cardiovascular conditions.

This project addresses the need for accessible, portable, and accurate health monitoring tools, empowering individuals to manage their heart health proactively. By integrating machine learning with portable ECG hardware, this device represents a significant step toward improving health outcomes through technology-driven, preventative healthcare solutions.

# CHAPTER 2: LITERATURE REVIEW

[1] ECGs are essential for the diagnosis of heart conditions, their expensive cost prevents them from being widely available in developing nations. In order to increase accuracy and lower noise in portable systems, research emphasises the use of AgCl electrodes, analogue circuits, and signal processing approaches. Replication, cost, and web-based monitoring for scalability are the main areas of focus. In order to improve accessibility in environments with limited resources, this study suggests a portable, inexpensive ECG machine that combines these developments.

[2]Due to restricted access to healthcare, heart disease is more common in rural areas. This is addressed by IoT-based ECG systems, which make predictive analysis, cloud data transmission, and real-time monitoring possible. In order to enhance accessibility and diagnoses in underprivileged areas, this study suggests a smart ECG system.

High data rates and power consumption in [3] are problems for portable ECG systems. VPW-FRI and IF-TEM are two examples of sub-Nyquist sampling techniques that provide effective, asynchronous, and power-efficient solutions. In order to achieve precise heart rate monitoring, this work creates an IF-TEM-based ECG sampling technique with strong filters for noise resistance, which is verified by hardware implementation.

[4]Cardiovascular diseases are the leading cause of death globally, with abnormal heart signals as key indicators. Existing ECG devices lack portability and rely on manual data analysis, limiting efficiency. Recent studies have applied machine learning, combining traditional models like SVM and XGBoost with deep learning models like CNNs and LSTMs, to improve ECG classification.

The integration of AI in [5], particularly deep learning (DL) models, has significantly advanced ECG signal analysis and arrhythmia detection. Models like CNNs, LSTMs, and hybrid architectures (e.g., CNN-AE and CNN-SVM) have achieved high accuracy, outperforming cardiologists in some cases.

[6]ECG equipment are essential for identifying cardiac issues, low-income groups frequently cannot afford them. In order to save costs, this study suggests a portable, inexpensive ECG device that uses an Arduino Uno microcontroller. The system is widely usable since it provides wireless connectivity for data transfer to PCs and smartphones. It was discovered that the designed machine's ECG reading accuracy had acceptable error margins and was on par with commercial ECG devices.

The necessity for accessible in [7], reasonably priced healthcare solutions is underscored by the rising incidence of sudden cardiac arrest in emerging nations. Cost-effective cardiac monitoring devices that record critical data including BPM, ECG, and SpO2 have been developed using IoT technology. With real-time data transfer to a smartphone app via a Raspberry Pi3b+, this system improves emergency response by providing immediate notifications.

[8]To avoid cardiac arrest, ECG abnormalities must be detected early. This paper suggests a portable ECG gadget that uses a Raspberry Pi to interpret real-time data collected by an ECG sensor. To identify the commencement of an arrhythmia, the collected characteristics are subjected to Discrete Wavelet Transform (DWT) analysis and then classified using a trained SVM algorithm. By using real-time monitoring and anomaly detection, the system seeks to facilitate timely medical intervention.

This study in [9] presents a real-time ECG signal acquisition system based on the TMS320VC5509A DSP chip. The system captures and processes ECG signals through analog filtering, amplification, and digital conversion, followed by low-pass filtering in the DSP for display on an LCD. It offers advantages such as compact size, low power consumption, low cost, and real-time processing.

[10] Paper presents a portable ECG recorder combining a signal amplifier, ADC, and USB storage for easy ECG measurement and data transfer. It allows real-time monitoring and heart rate calculation using the R-wave peak. The system offers a convenient, portable solution for ECG recording and analysis.

# CHAPTER 3: PROBLEM DEFINITION

Cardiovascular diseases (CVDs) are among the leading causes of morbidity and mortality worldwide. Early detection and continuous monitoring of cardiac health are critical in reducing the risks associated with these conditions. Traditional Electrocardiogram (ECG) monitoring, typically performed in clinical settings, requires bulky, stationary equipment that is inaccessible for daily, real-time monitoring outside of healthcare facilities. This gap in accessibility often delays diagnosis and treatment, particularly for at-risk individuals who need ongoing heart health monitoring.

Heart disease remains one of the leading causes of mortality worldwide, necessitating early detection and continuous monitoring to improve patient outcomes. Traditional ECG (electrocardiogram) machines, while effective, are often bulky, expensive, and limited to clinical settings. These constraints make it challenging for many individuals, especially those in remote or under-resourced areas, to access routine cardiac monitoring. Furthermore, the inconvenience of frequent hospital visits for ECG tests discourages consistent monitoring, posing risks for patients with known cardiac conditions or those at high risk.

To address these issues, this project aims to develop a portable, low-cost ECG machine capable of accurately capturing heart activity. By utilizing an AD8232 ECG sensor module and an Arduino Nano, this device will deliver real-time data processing, while a Bluetooth module will enable seamless wireless transmission. This compact, easy-to-use ECG device is designed for at-home use, making it an ideal solution for telemedicine and continuous heart monitoring outside of clinical settings. It empowers users to monitor their cardiac health independently, facilitating early detection of abnormalities and reducing healthcare disparities. This document details the complete hardware configuration, component specifications, cost analysis, and potential future upgrades to enhance device functionality and accessibility

4

# CHAPTER 4: METHODOLOGY

This project will follow a structured approach to design, develop, and test a portable ECG monitoring device enhanced with machine learning capabilities for real-time cardiac anomaly detection. The methodology includes system design, hardware and software development, signal processing, machine learning model integration, data transmission, and testing phases. Each phase ensures the device meets functionality, accuracy, and usability requirements in real-world scenarios.

**Step 1: System Design and Requirements Analysis**

**Define Functional Requirements**

Identify the core features required for the device, including real-time ECG monitoring, signal processing, machine learning-based anomaly detection, data display, wireless transmission, and secure storage.

**Component Selection**

Choose hardware components based on performance and power efficiency:

* + - **ECG Electrodes**: Select suitable electrodes for accurate ECG signal capture.
    - **Analog Front End (AFE)**: Use an AFE chip (such as AD8232) to amplify and filter ECG signals.
    - **Microcontroller**: Select a low-power microcontroller (e.g., ARM Cortex-M series) capable of running the ML model.
    - **Wireless Module**: Integrate Bluetooth or Wi-Fi module for data transmission.

**5**

**Step 2: Hardware Development**

1. **Circuit Design**

Design the device's circuitry, focusing on the connectivity between ECG electrodes, AFE, microcontroller, display, and wireless module.

1. **PCB Design**

Create a printed circuit board (PCB) layout for compactness and durability, ensuring efficient placement of components for minimal power consumption and signal integrity.

1. **Assembly and Prototyping**

Assemble the hardware prototype and test individual components to ensure each performs as expected, especially the AFE and microcontroller connection

**Step 4: Machine Learning Model Integration**

1. **Model Selection and Training**

Train a machine learning model, such as a convolutional neural network (CNN) or support vector machine (SVM), on a dataset of ECG signals to classify normal and abnormal rhythms (e.g., arrhythmias).

1. **Model Optimization for Embedded Systems**

Optimize the trained model for deployment on the microcontroller by using techniques like model quantization, pruning, or converting it to a TensorFlow Lite or TinyML format. This ensures the model runs efficiently with limited computational resources.

1. **Embedded ML Integration**

Program the optimized model into the microcontroller to analyze ECG data in real-time and detect anomalies. Configure the system to trigger alerts when abnormal patterns are detected.

**6**

**Step 5: Data Transmission and Mobile Application Development**

1. **Bluetooth/Wi-Fi Communication Setup**

Configure the wireless module for seamless communication between the device and a mobile application or cloud storage.

1. **Mobile App Development**

Develop a mobile application to display real-time heart rate data, ECG visualizations, and alert notifications. Include secure data storage and encryption protocols for user privacy.

1. **Remote Monitoring Integration**

Enable options for data storage on the cloud to allow users and healthcare providers to monitor long- term cardiac health trends remotely.

6

**CHAPTER 5: DELIVERABLES**

**1. Hardware Prototype**

* Fully assembled and functional Portable ECG Machine
* Integration of AD8232 ECG Sensor Module, Arduino Nano, and Bluetooth Module
* Rechargeable battery pack for portability

**2. Circuit Design and Schematics**

* Circuit diagram showing all electrical connections
* Block diagram outlining the working of the ECG system

**3. Software Implementation**

* Arduino Code for data acquisition, processing, and Bluetooth transmission
* Mobile/PC interface (App or Software) for real-time ECG visualization
* Data storage (PDF/CSV) for record-keeping

**4. Testing and Validation Reports**

* Signal Accuracy Comparison with standard ECG machines
* Noise Filtering Efficiency analysis
* Bluetooth Connectivity Testing results
* Power Consumption and Battery Performance evaluation

**5. Future Enhancements Plan**

* Mobile App Integration for better user experience
* Cloud Storage and Remote Access for advanced monitoring
* AI-based Signal Processing for abnormality detection

# REFERENCES

1. Rakin, Rafaeal & Siam, Asad & Hossain, Md & Zaman, Hasan. (2019). A Low-Cost and Portable Electrocardiogram (ECG) Machine for Preventing Diagnosis. 48-53. 10.1109/ICREST.2019.8644425.
2. Nagdive, Arundhati. (2024). Portable ECG Machine with Future Prediction. International Journal for Research in Applied Science and Engineering Technology. 12. 96-101. 10.22214/ijraset.2024.59705.
3. Naaman, Hila & Bilik, Daniel & Savariego, Shlomi & Namer, Moshe & Eldar, Yonina. (2024). ECG-TEM: Time-based sub-Nyquist sampling for ECG signal reconstruction and Hardware Prototype. 10.48550/arXiv.2405.13904.
4. Su, Shi & Zhu, Zhihong & Wan, Shu & Sheng, Fangqing & Xiong, Tianyi & Shen, Shanshan & Hou, Yu & Liu, Cuihong & Li, Yijin & Sun, Xiaolin & Huang, Jie. (2023). An ECG Signal Acquisition and Analysis System Based on Machine Learning with Model Fusion. Sensors. 23. 1-21. 10.3390/s23177643.
5. Lichaee, Fatemeh & Salari, Arsalan & Jalili, Jalil & Dalivand, Sedigheh & Rad, Mahdis & Mojarad, Mohadeseh. (2024). Advancements in Artificial Intelligence for ECG Signal Analysis and Arrhythmia Detection: A Review. International Journal of Cardiovascular Practice. 8. 10.5812/intjcardiovascpract-143437.
6. [Muhibul Haque Bhuyan](https://www.researchgate.net/profile/Muhibul-Bhuyan?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19) , Md. T. Hasan, Hasan Iskander, Low-Cost Microcontroller Based ECG Machine, Vol:14, No:7, 2020
7. Stepheny Lucas, Mitali Desai, Amisha Khot, Sincee Harriet, Kavita Jain, Mobile Heart Sync: An IoT Based Portable ECG Monitor, [10.56155/978-81-955020-7-3-27](https://doi.org/10.56155/978-81-955020-7-3-27)
8. [Niyatha Malepati,](https://ieeexplore.ieee.org/author/37088504459) [Rubia Fatima,](https://ieeexplore.ieee.org/author/37089040241) [Swarnima Gupta](https://ieeexplore.ieee.org/author/37088506683) [,Vaishnavi Ramsali,](https://ieeexplore.ieee.org/author/37088507382) [Shobha K.R.](https://ieeexplore.ieee.org/author/37088550052) , [Portable ECG Device for Remote Monitoring and Detection of Onset of Arrhythmia](https://ieeexplore.ieee.org/document/9198658/), [10.1109/CONECCT50063.2020.9198658](https://doi.org/10.1109/CONECCT50063.2020.9198658)
9. [Khushi Singh,](https://ieeexplore.ieee.org/author/37089328045) [Malaya Kumar Hota](https://ieeexplore.ieee.org/author/37086521745) , [Design and development of DSP enabled low-](https://ieeexplore.ieee.org/document/9768423/) [cost ECG machine](https://ieeexplore.ieee.org/document/9768423/) , [10.1109/ICEEICT53079.2022.9768423](https://doi.org/10.1109/ICEEICT53079.2022.9768423)
10. [C. S. Ho](https://ieeexplore.ieee.org/author/38129685600), [T. K. Chiang,](https://ieeexplore.ieee.org/author/38121948400) [C. H. Lin](https://ieeexplore.ieee.org/author/37089092433), [P. Y. Lin](https://ieeexplore.ieee.org/author/38127901600), [J. L. Cheng](https://ieeexplore.ieee.org/author/38126923000), [S. H. Ho](https://ieeexplore.ieee.org/author/38127780800), [Design](https://ieeexplore.ieee.org/document/4450319/) [of Portable ECG Recorder with USB Storage,](https://ieeexplore.ieee.org/document/4450319/) [10.1109/EDSSC.2007.4450319](https://doi.org/10.1109/EDSSC.2007.4450319)