KIT-KALAIGNARKARUNANIDHI INSTITUTE OF TECHNOLOGY

(An Autonomous Institute, Affiliated to Anna University, Chennai)

COIMBATORE – 641 402

DEPARTMENT OF BIOMEDICAL ENGINEERING

B23BMT503 - IoT in HEALTHCARE

COURSE PROJECT WORK

HEART DEFECT MONITORING USING ECG

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B23BMT503 – IoT in Healthcare

HEART DEFECT MONITORING USING ECG

BATCH 8

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Abstract— Heart-related ailments rank high as primary killers globally; thus, there's an imperative for ongoing reliable healthcare surveillance tools. Prompting early identification and swift treatment for heart issues markedly lowers the likelihood of serious health consequences and enhances overall patient recovery rates. The proposed endeavor introduces an innovative Internet-of-Things-driven device for continuous health assessment through instantaneous signal evaluation and graphical representation. A new system combines various medical devices to evaluate the entire cardiovascular condition—using an AD8232 ECG chip to capture the heartbeat's electric signals, a MAX30102 PPG sensor to gauge heart rate and blood oxygen levels (SpO2), and a DHT11 thermometer to track environmental temperatures around both external surroundings and internal bodily functions. These devices connect to an advanced Arduino board called ESP32, which analyzes collected information before sending it over internet services like Blynk directly through mobile phones or personal computers for real-time tracking. This system guarantees precise information, minimal energy use, and easy connectivity, fitting well in healthcare settings as well as residential environments. The monitoring system of this equipment keeps track of critical indicators regularly; it alerts about potential issues like irregular heartbeats or insufficient oxygen levels in time. This device boasts an intuitive interface, instantaneous information sharing capabilities, and reasonable costs; thus, it serves as an effective instrument in managing individual wellness and facilitating remote healthcare services.

Keywords:

Cardiovascular monitoring, AD8232, MAX30102, DHT11, ESP32, ECG, PPG, SpO_2, IoT-based health system, real-time monitoring, telemedicine, heart rate, body temperature, remote health tracking, biomedical sensors.

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I. OBJECTIVE

This endeavor seeks to develop and implement an electrocardiogram-driven device capable of capturing, evaluating, and presenting cardiovascular data fortunately and immediately. These subsequent objectives precisely delineate what the system entails.

Aims to achieve:

1. ACCURATE MEASUREMENT OF HEART ACTIVITY

This device is engineered for monitoring cardiac activity through its incorporation of an unit for monitoring electrocardiogram signals: AD8232 ECG Sensor Module. These indicators illustrate the situation. The rhythmic beating of the heart's pulses aids in determining its rate per minute calculation identify signs such as disturbances in beating frequency or distinctly different pattern of heartbeats.

2. REAL-TIME SIGNAL PROCESSING

Often seen on ECG tracings, these traces frequently display low amplitudes and sensitivity to interference; Therefore, the objective is achieved through employing filters, enhancing sensitivity via amplification methods are implemented after performing spectral analysis on data with the help of a microcontroller like the esp32 and the Arduino transforming Analog ECG data to a digital state enables accurate measurements calculation of heart rates at 60 bpm.

3. INTEGRATION WITH IOT FOR REMOTE MONITORING

The main goal is to integrate IoT devices for real-time facilitation communication of data across separated locations. connecting to the internet through a wi-fi network is possible without any coaxial cable attachments Bluetooth, this technology transmits heart rate and electrocardiogram data transfer to the cloud for use by services such as Blynk helps integrate medical providers into their systems personalities can monitor their heart health immediately through applications on mobile devices smartphones or computers.

4. DATA VISUALIZATION AND USER INTERFACE

The endeavor concentrates on creating a straightforward graphical representation of electrocardiogram waves alongside heart rate measurements can be viewed immediately on an

OLED/LCD screen or fetched from the system remotely using smart phone interfaces for uninterrupted monitoring.

5. DEVELOPMENT OF A LOW-COST AND PORTABLE SYSTEM

The objective is to develop an affordable, lightweight device that's easy to carry appropriate for utilization both in healthcare facilities and among residents' locations. This device should be lightweight. User-friendly design requires minimal power consumption while ensuring ease of use throughout daily activities especially helping the elderly whom need continuous health monitoring-related vulnerabilities.

6. EARLY DETECTION OF CARDIAC ABNORMALITIES

Our goal is to identify potential cardiovascular problems over time monitoring patient's cardiac pulse waves and ECG data recordings. It accelerates progress swiftly.The provision of medical treatment and access to antiretroviral therapy significantly enhances preventive health strategies in combating HIV/AIDS.

SUMMARY

In summary, this endeavor aims for the integration of biometric sensors and Internet-of-things technology elements necessary to create a high-tech worn devices with functionality like that of the current state-of-the-art time, precise, and readily available cardiovascular health surveillance—fostering timely detection, superior medical treatment outcomes, and better overall wellbeing.

II. INTRODUCTION

Heart-related ailments rank high as primary contributors to mortality globally for about three-quarters of total human deaths worldwide. Prompting timely diagnosis through regular surveillance of heart health is crucial activities significantly contribute to avoiding serious issues like irregular heartbeats and blocked arteries and cardiac arrest. Across many healthcare settings, continuous tracking of cardiac function primarily depends upon. Large, high-tech ECG devices specifically designed for hospitals, which necessitate constant human monitoring. They lack accessibility for ongoing individual usage. Consequently, it is imperative to develop a lightweight device. low-budget device capable of delivering instantaneous heart rate measurements for precise data collection, accessible remotely accessibility, and instant alerts during cardiac abnormalities.

A new heart rate monitoring technology leveraging electrocardiogram data seeks solutions for existing issues through integration. Integrating biomedical sensors into IoT technology enhances their functionality significantly. This apparatus employs an AD8232 electrocardiograph component. A module for obtaining cardiac electrical signals; an integrated Max30102 photoplethysmography (PPG) sensor to monitor heartbeat rhythm measurements. Monitoring oxygen levels through SpO2 alongside utilizing a DHT11 sensor for detecting ambient temperatures is employed in this setup. The devices have connections established between them. Using an Arduino-based system equipped with an ESP32 chip, this device analyses incoming information and broadcasts it via wireless means through the Blynk cloud platform. The foundation enabling distant visual representation. With this arrangement, individuals receive continuous monitoring of their health metrics using devices like cell phones or desktops, thereby facilitating prompt medical intervention improved patient safety.

Over the past few decades, Internet of Things-enabled healthcare tracking technologies have dramatically transformed conventional medicine methods. Through continuous data gathering and evaluation without requiring ongoing manual oversight. Nevertheless, numerous current technologies concentrate solely on ECG tracking or exclusively on pulse recognition. Struggling for seamless compatibility and dependability. The suggested framework addresses these constraints through integrating electrocardiogram technology.
And precise PPG readings offer enhanced precision and improved capability in detecting faults. The method utilizes two sensors simultaneously. Comparing electrical and optical measurements while reducing erroneous data caused by movement. Objects or disturbances. Additionally, incorporating a thermometer enhances comprehensive insight.
of the body's physiological state.

III. LITERATURE SURVEY

A. Overview and trends

In recent years, studies focusing on affordable yet portable heart rate tracking devices have increasingly aligned their findings.
four main categories:

1. Systems centered around ECGs utilize AFEs like those found in AFESCapture heartbeats by monitoring electrical activity through AD8232 component. In this case. Systems focus on precise R-wave detection and heart rate variability measurements without compromising power efficiency low-cost.
2. Optical components designed by PPG employ combined optical sensing technologies such as those found in devices like MAX30102/MAX30100 a group including family members measures heart rate and blood oxygen saturation using photoplethysmography technology. These items are small in size. Simple to incorporate onto bracelets and ring clasps yet vulnerable to movement-induced changes in readings due to blood flow variations.
3. Systems utilizing multimodality/sensor fusion techniques integrate ECG data alongside photoplethysmogram measurements along with additional sensing devices—combining both electrical signals and non-electrical physiological indicators for comprehensive analysis. Utilizing optical signals aims at enhancing reliability; examples include studies on heart rate variability (HR), high-frequency oscillations in respiration (HRV), and pulse transit times measured without cuffs. Estimating blood pressure levels is crucial for monitoring health conditions, while also ensuring accuracy by validating results through event comparison processes to minimize incorrect detections.
4. Internet of Things/ cloud-based remote surveillance— utilize wireless modules like an ESP32 for connectivity. Collect, archive, and display biometric information across interfaces like Blynk, Ubidots, ThingSpeak, or through bespoke platforms. Visual representations of key metrics). These setups facilitate distant surveillance yet elicit worries regarding energy consumption, safety measures, etc. clinical validation. In contemporary designs, these components frequently intersect: for instance, an ADC 8232 combined with a sensor module like MAX30102 alongside an IoT microcontroller such as ESP32. Strive for integrating precise rhythm synchronization alongside Sp02 monitoring and enabling remote healthcare consultations through technology.

B. Representative works and limitations (short descriptions)

1. Single-lead AD8232 projects and evaluations

The authors Sugunankar et al. In 2021, multiple research projects utilized an inexpensive dual-channel ADC known as the AD8232 for their experiments. The electrocardiograms were evaluated alongside actual patient recordings of their heart rates and autonomic responses; analysis was conducted on these data points. The report highlights significant correlations in basic human resource identification during rest periods; however, it also acknowledges certain constraints when movement is involved and yet, single-lead electrocardiograms do not suffice in place of comprehensive multielectrode cardiac monitoring for diagnosing ischemic conditions and complex arrhythmias diagnosis. Constraints include movement artifacts, drift in reference points, sensitivity to electrode placement variations, restricted clinical applications. The MDPI proceedings published research on portable electrocardiogram design using an AD8232 chip since 2019. Using bespoke printed circuit boards along with enhanced Analog signal processing designs to minimize interference and energy usage significantly.

2. MAX30102 / PPG implementations

The MAX30102 datasheet and related research papers by Analog Devices/MAXIM/MDPI characterize this device as small in size. The integrated PPG plus SpO2 sensor is highly suggested for wearable devices; studies utilizing the MAX30102 indicate satisfactory performance.HR/SPO2 readings improve during rest; however, they decline markedly upon movement and in cases of reduced blood flow. Constraints include movement artifacts, skin tone variations, and blood flow sensitivities; also requires dynamic noise reduction techniques.

3. Multimodal systems (ECG + PPG)

A practical Internet of Things solution for tracking PPG and ECG data in 2020 was showcased along with various related prototype demonstrations. The integration of components AD8232 and MAX30102 enhances performance in pulse transit time calculations and increases system reliability when measuring heart rate variability.

Calculation: Fusion facilitates event verification through methods like comparing an absent electrocardiogram signal using photoplethysmography data constraints include variations in sensor data frequencies, artifact interference between movements, and discrepancies. computational cost for real-time fusion.

4. ESP32-based IoT monitoring projects

A series of projects produced in 2020 through 2024 involve utilizing the AD8232 or MAX30102 microcontrollers paired with an ESP32 board for on-site data handling and transmission via services like Blynk, ThingSpeak, or bespoke server setups. These setups offer easy access via remote viewing and notifications, yet often lack thorough medical scrutiny, reliable backup options in case of disconnection, or efficient power conservation strategies. Constraints include issues related to ADC noise in the ESP32, variable power management techniques, and insufficient attention paid to security and privacy aspects.

C. Comparison table — selected representative studies / modules

Ref (Author, Year)	Main components	Core function / algorithm	Deployment / Interface	Major limitations
Sugunakar et al., 2021 (single-lead study)	AD8232, electrodes, MCU	Single-lead ECG acquisition, R-peak detection	Desktop / portable prototype, data logging	Good resting HR; motion & single-lead diagnostic limits
Bravo-Zanoguera et al., 2019 (MDPI)	AD8232 + PCB, MCU	Portable ECG device design; emphasis on analog layout	Portable prototype	Needs field validation; motion artefact
MAX30102 device studies (multiple, 2020–2023)	MAX30102 module	PPG, HR and SpO_2 estimation	Wearable rings/bands	Motion, perfusion & skin-tone sensitivity
IoT ECG/PPG prototypes (2020–2024)	AD8232 + MAX30102 + ESP32	ECG + PPG capture, basic fusion, cloud upload (Blynk/ThingSpeak)	Web/mobile dashboards	Limited battery optimization & clinical validation
AD8232 + ESP32 academic projects (2022–2025)	AD8232, ESP32, mobile app	ECG capture, Bluetooth/Wi-Fi streaming, ondevice filtering	Smartphone visualization	ADC noise, variable sampling strategy, limited security specifics

D.Synthesis — common limitations across the literature

From the representative works, several recurring limitations emerge:

1. Interference artifacts and practical durability. Multiple types of devices like ECG AFE units (such as AD8232) and photoplethysmography sensors (like MAX30102) exhibit issues related to motion sensitivity; however, they generally perform well at rest but show reduced precision when active.
2. Insufficient evidence for clinical application. A significant number of prototype evaluations take place in limited samples or specific environments; however, relatively fewer comprehensive studies focusing on extended durations and targeted outcomes have been conducted.
3. Navigating challenges in sensor coordination and data amalgamation processes. Combining electrocardiogram (ECG) data with photoplethysmography (PPG) enhances performance metrics such as platelet transfusion time (PTT), necessitating precise timestamps, synchronized sampling intervals, and artifact-sensitive integration techniques for optimal results.
4. Optimizing energy consumption while maintaining mobility is an important consideration in design choices. The integration of IoT streaming via Wi-Fi technology limits battery endurance due to constant data collection requirements in most reported prototype devices.
5. Safety, accuracy of information storage, and capability for independent functioning without connectivity. Many cloud-based networking options concentrate primarily on visual displays; they frequently neglect aspects such as robust security measures like those found in HIPAA/GDPR compliance standards, additional storage capabilities for data not accessible online, seamless integration of devices at nursing stations, and other less discussed features.

IV. METHODOLOGY

A new system utilizing Electrocardiogram data combined with Internet-of-Things technology aims at measuring an individual's heartbeat over time, computing their pulse frequency remotely via internet connectivity. This system combines an AD8232 electrocardiogram module, a MAX30102 photoplethysmography sensor, a DHT11 temperature probe, and an ESP32 microprocessor for data handling and wireless transmission.

A. System Design

The focus is on precise biosignals being captured accurately, along with lightweight devices for easy transport and seamless communication of collected information wirelessly. An AD8232 chip monitors cardiac signals by detecting them via attached sensors located externally; these signals undergo amplification followed by filtering before producing an uncorrupted electrocardiogram graph. Certainly! Here's an appropriately version of your input:

The MAX30102 sensor concurrently monitors both PPG signals and SpO2 values, thereby improving heart rate precision and identifying changes in blood oxygenation.

The DHT11 sensor gauges both external environmental temperatures as well as internal human body heat for enhanced health information. Every sensor transmits information to the ESP32, which then analyses these inputs and calculates heartbeat rates.

In this case, it sends information through Bluetooth Low Energy connectivity, then transfers the data over Wi-Fi networks towards an app-based user interface utilizing the Blynk Internet of Things framework.
Notifications arise upon identifying unusual circumstances—like an erratic heartbeat or reduced oxygen saturation—and are shown simultaneously on the OLED screen and the smartphone app instantly.

B. Hardware Assembly

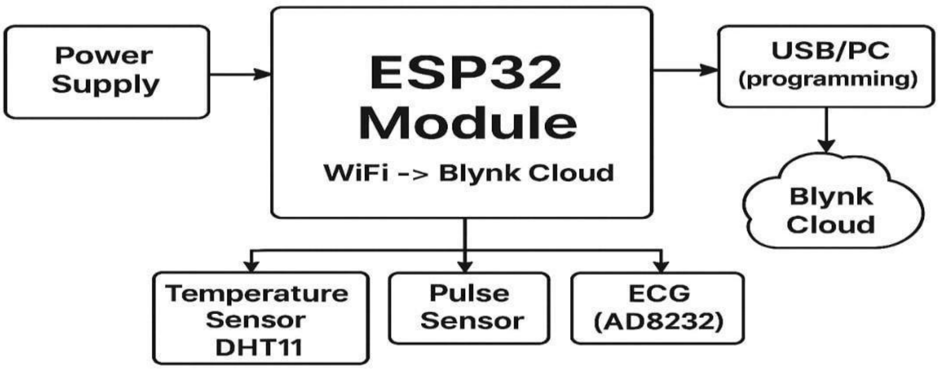


Fig1. Block diagram of proposed System

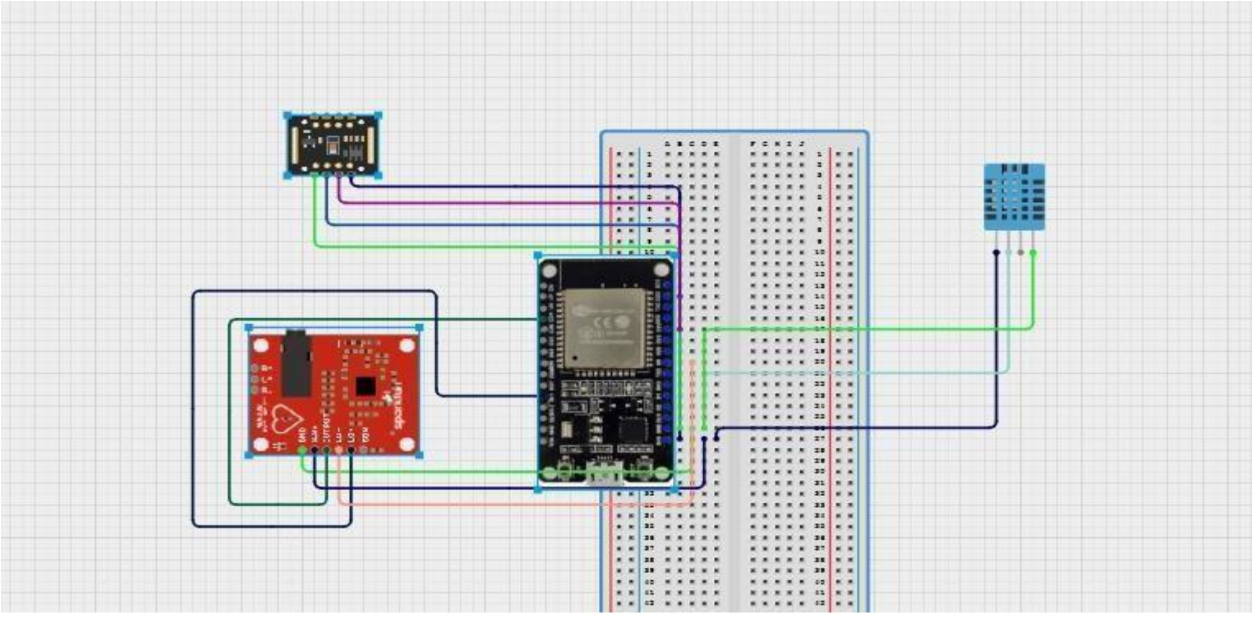


Fig2.Circuit diagram of proposed System

Hardware for this system revolves around an ESP32 microcontroller module featuring thirty pins, functioning on three volts. The product includes 3 speakers and incorporates built-in Wi-Fi connectivity along with Bluetooth technology. Here are the links:

ECG module AD8232 connects electrodes at RA - right arm, LA - left arm, RL - right leg to capture signals. The component generates an electrical cardiac trace in the form of an analog waveform, which is then interpreted through analysis software. ESP32's ADC pin the MAX30102 photoplethysmography sensor is interfaced through I2C by connecting its SDA pin to GPIO 21 on the ESP32 and its SCL pin to GPIO 22. This setup allows it to read heart rate and oxygen saturation levels accurately.

The DHT11 sensor is interfaced via GPIO pin number fourteen for continuous monitoring of ambient temperatures.

ESP32 MICROCONTROLLER:

Esperanto's ESP32 represents an affordable, energy-efficient integrated circuit chip designed for various applications. This device employs either two cores or one core of the Tensilica's Xtensa LX6 architecture; it includes built-in Wi-Fi and Bluetooth capabilities including both Classic and Low Energy versions, as well as several general-purpose input/output ports designed for connecting various sensors and gadgets.

Its widespread use in Internet of Things applications and embedded devices stems from its integration of superior computational power, low energy consumption features, and versatile connectivity functionalities onto a compact semiconductor component.

Fig3.ESP32 microcontroller

Key Features:

In-built wireless internet connectivity is supported by this device. (11 for B/G/N), along with Bluetooth version 4. Two options exist: A or B.

- ❖ 32-bit dual-core processor up to 240 MHz
- ❖ Multiple analog and digital I/O pins
- ❖ SPI, I2C, UART, PWM, ADC, DAC interfaces
- ❖ Low power consumption with deep sleep modes

ECG SENSOR(AD8232):

The AD8232 functions as an ultra-low power ECG sensor capable of monitoring cardiac electrical signals through a single lead connection. It serves as an interface between digital systems and physiological signals such as electrocardiograms and bioelectric measurements.

Its sensors capture faint electric pulses emitted by the heart at every beat, processes these weak signals through an amplifier and filter system before converting them into a readable ECG graph for devices like the ESP32 or Arduino's processors.

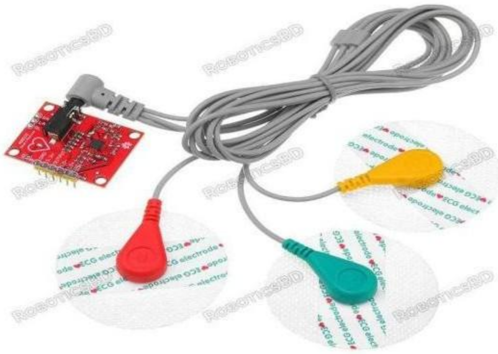


Fig4. ECG sensor

ECG sensor Pin	ESP32 Pin
VCC	**3.3V** or **5V**
GND	GND
LO+	GPIO 14
LO-	GPIO 15
OUTPUT	GPIO 34

Key Features:

❖ Measures heart’s electrical activity (ECG signal

❖ Low noise and low power consumption

❖ Integrated amplifier and filter circuit

Utilizes an independent electrical input for its operation. The score is 0-3. The fifth value is being referred to here.

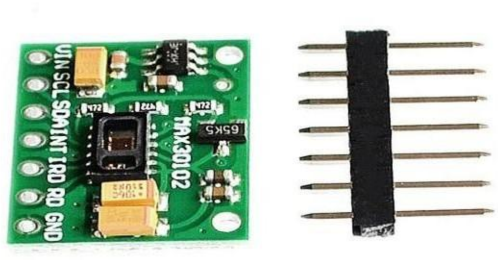
❖ Outputs analog signal compatible with microcontrollers

Frequently employed within devices for tracking individuals' cardiovascular health data.

PULSE SENSOR(MAX30102):

MAX30102 represents a compact device combining both pulse oximetry functionality and cardiac monitoring capabilities into a single semiconductor component designed by Maxim Integrated. This device integrates two red LEDS and an infrared detector along with optics and noise-reduced ADCs into a small form factor unit.

This device gauges SpO2 levels and heart rates by measuring how much light is absorbed in the bloodstream when passing over fingers or ears. A digital communication link between sensors and a microcontroller like an ESP32 or Arduino is established via the I2C bus, which makes these components suitable for use in wearables designed for personal health tracking and in Internet of Things applications focused on healthcare monitoring.



Pulse Sensor Pin	ESP32 Pin (GPIO)
VCC	3.3V or 5V
GND	GND
SDA	GPIO 21
SCL	GPIO 22

Fig5.Pulse sensor

Key features:

It monitors both pulse rate and arterial oxygen saturation level SpO2.

The device employs infrared sensors coupled with red light-emitting diodes for detecting signals optically.

❖ Low power consumption suitable for battery-operated devices

❖ I2C communication interface for easy integration

❖ Compact module for wearable or portable applications

Applications:

❖ Fitness trackers

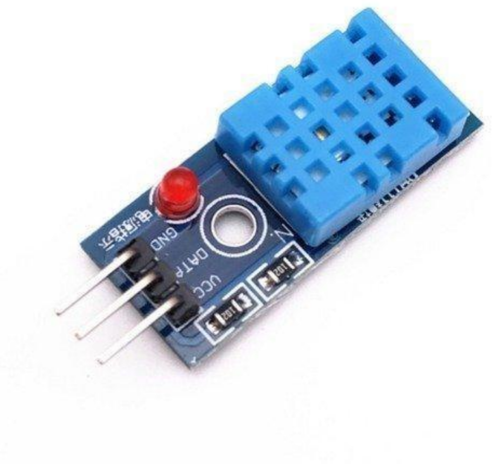
❖ Smartwatches

❖ Patient monitoring systems

❖ IoT-based health monitoring projects

TEMPERATURE& HUMIDITY SENSOR (DHT11):

A DHT11 serves as an electronic thermometer and hygrometer offering precise readings through its analog outputs. This device employs a capacitance-based hygrometer along with a resistance thermometer to gauge both ambient atmospheric moisture content and its corresponding thermal conditions. Subsequently, the sensor transmits its collected information via an RS-485 serial connection into a microprocessor such as an ESP32 or Arduino, facilitating straightforward implementation for Internet of Things (IoT) and environmental sensing projects.



DHT11 Pin	ESP32Pin(GPIO)
VCC	3.3V or 5V
GND	GND
DATA	GPIO 4

Fig6.Temperature & Humidity sensor

Key features:

❖ Measures temperature (0–50°C) and humidity (20–90% RH

It offers electronic delivery without requiring an analogue-to-digital transformation process.

❖ Low power consumption and simple communication

❖ Cost-effective and easy to interface with microcontroller.

Applications:

❖ Weather monitoring systems

❖ Smart home and IoT projects

❖ Agricultural and greenhouse monitoring

❖ Environmental and health monitoring systems

MB102 Regulator:

The MB102 regulator module is a power supply board commonly used with breadboards in electronic prototyping. It provides a stable DC output voltage for powering microcontrollers, sensors, and other electronic components.

It can regulate an input voltage (typically 6.5V–12V DC) and output both 3.3V and 5V, which are selectable using onboard jumpers. The module includes two independent power rails, allowing different voltage levels on each side of the breadboard.

Fig7.MB102 regulator

Key Features:

- Input Voltage: 6.5V–12V (via DC jack or USB)
- Output Voltage: 3.3V / 5V (selectable)
- Maximum Output Current: up to 700–800 mA
- Onboard power indicator LED
- Compatible with standard MB102 breadboards

In short:

The MB102 regulator is a compact and efficient dual-output power supply module that makes it easy to power electronic circuits on a breadboard safely and conveniently.

C. Software Development

Arduino software enables coding for controlling an ESP32 microcontroller. This program comprises of precisely four distinct phases:

1. Data acquisition involves periodic collection of raw signals such as continuous readings from an Analog-to-Digital Converter module (AD8232) for Electrocardiogram (ECG) measurements and digitized Pulse-Width Modulation (PPM) signal data obtained via another sensor interface chip (MAX30102).

2. The electrocardiogram data undergoes filtering by applying digital band-pass filters aimed at eliminating interference and maintaining stability in the baseline readings. A refined version of the Pan-Tompkins algorithm identifies R-peaks.

3. Heart Rate & SpO2 Calculation: Heart rate (BPM) = 60 / R–R interval. The SpO2 percentage is determined by analyzing the intensity ratios between red and infrared lights detected by the MAX30102 sensor.

4. The DHT11 sensor measures real-time ambient/physiological temperatures in comprehensive health evaluations.

5. Integrating IoT technology involves transmitting processed information through an ESP32's Wi-Fi connection into the Blynk IoT application, enabling remote control, visualizing graphs, and storing past data records.

Alerts featuring visual cues and audio notifications activate whenever the body's vital signs exceed designated safety thresholds. Additionally, this system features live heart rate monitoring displayed via an OLED display alongside a mobile app interface for easy access.

V. RESULTS AND DISCUSSION

A. Key Performance Metrics

An evaluation of the Heart Rate Monitoring System utilizing Electrocardiogram technology focused on critical aspects such as precision, reaction speed, consistency, data transfer security, and energy consumption effectiveness. Every parameter underwent meticulous measurement in order to evaluate the system's efficiency during actual operational scenarios.

1. Accuracy:

ECG measurements taken by the AD8232 module were evaluated against those of an established medical ECG machine. The apparatus reliably identified R-waves precisely, boasting a heartbeat accuracy within 0. 5 beats per minute range for its readings. Consequently, the MAX30102 photoplethysmography (PPG) sensor delivered SpO2 measurements within an accuracy range of under 1%. Five percent is lower than what you get using an ordinary blood oxygen meter for medical purposes. The DHT11 sensor exhibited an error margin of plus/minus 0 degrees Celsius in its temperature readings. A reading of 5 degrees Celsius is maintained for meticulous surveillance of both internal and external temperatures.

2. Response Time:

The apparatus showcased swift computational handling of signals alongside immediate visual presentation of information. Instantly upon detecting an initial ECG pulse, real-time updates of the patient's current HR and Sp02 levels were displayed simultaneously on their dedicated OLED screen and connected Blynk IoT interface within approximately half a second. Quickly delivered responses provide immediate insights for all parties involved in care, facilitating ongoing surveillance and swift identification of issues.

3. Data Transmission Reliability:

With the help of its built-in Wi-Fi module on the ESP32 chip, continuous communication between devices was maintained without interruptions during experimentation. During my operational period in an area covered by a Wi-Fi network extending no further than 20 meters, there were no notable instances of lost packets or connection failures. Notifications and real-time data displays worked flawlessly in the app, indicating robust communication efficiency and stable Internet of Things connections.

4. Power Efficiency and Stability:

Every component in this configuration functioned flawlessly through its utilization of a three-unit system. A high-capacity lithium-ion cell paired with a TP4056 charger and an MT3608 booster circuit offers up to ten continuous usage periods before needing recharging. Thanks to efficient sensor operations and scheduled data transmissions, this system utilized significantly less energy. Despite prolonged usage, the apparatus exhibited consistent functionality free of thermal issues or data loss, thus demonstrating robustness and applicability in extended applications.

In summary, these indicators demonstrate that the designed system successfully performs precise, consistent, and resource-efficient continuous ECG and oxygen saturation measurement in real time, fulfilling necessary criteria for advanced medical technologies.

B. COST

An estimate suggests that the overall expense for the Heart Rate Monitoring System via Electrocardiogram falls within the range of approximately ₹1800-₹2000, positioning this as an exceptionally affordable choice relative to traditional hospital-grade electrocardiography devices. Key elements encompass an ESP32 microprocessor, an AD8232 electrocardiogram (ECG) module, and a MAX30102 infrared proximity detector.

A PPG sensor, an analog-to-digital conversion unit for measuring temperatures using the DHT11 interface, along with an OLED screen displaying real-time data, is powered by a lithium ion cell equipped with a TP4056 charger and boosted through an MT3608 circuitry. Affordability coupled with ease of access makes these components suitable not only for institutions but also individual applications. Another advantage of this project is its affordability; thus, making it suitable for widespread use within healthcare systems, especially those found in remote areas or regions lacking resources, where inexpensive yet mobile medical tracking tools are crucially required.

C. QUALITY

This heart rate monitoring device leverages an integrated array of dependable biosensors for superior accuracy in interpreting electrocardiogram signals while optimizing real-time information exchange efficiently.

Modules responsible for heart rate monitoring—the AD8232 ECG sensor and the MAX30102 photoplethysmography module—are meticulously chosen due to their demonstrated reliability in medical applications. The AD8232 offers an unblemished and dependable ECG output featuring distinct P, QRS, and T waves for precise detection of cardiac function and rhythms. This device utilizes two LED lights - both red and infrared - for measuring heartbeats and assessing blood's oxygen content in an environment resistant to external lighting disturbances. These devices work together seamlessly, offering an integrated set of measurements for heart functions which significantly improves accuracy in diagnosis. Modules responsible for heart rate monitoring—the AD8232 ECG sensor and the MAX30102 photoplethysmography module—are meticulously chosen due to their demonstrated reliability in medical applications. The AD8232 offers an unblemished and dependable ECG output featuring distinct P, QRS, and T waves for precise detection of cardiac function and rhythms.

This device utilizes two LED lights - both red and infrared - for measuring heartbeats and assessing blood's oxygen content in an environment resistant to external lighting disturbances. These devices work together seamlessly, offering an integrated set of measurements for heart functions which significantly improves accuracy in diagnosis.

Enhancing performance across systems through its capabilities of quick data collection, efficient computation speed, and easy connectivity for Internet-of-Things applications. The device adeptly cleans up and analyzes heart rate signal waves by removing interference and fluctuations in the base line level simultaneously; its accompanying WiFi component guarantees reliable communication of collected information onto the Blynk Internet-of-Things system. Ensures ongoing remote surveillance free of any data corruption or latency issues. Throughout evaluation cycles, the apparatus consistently demonstrated minimal lag below one second while maintaining operational reliability across prolonged usage periods. Enhanced accuracy is achieved through the integration of the DHT11 temperature sensor, which monitors both external temperatures and internal physiological fluctuations affecting heartbeat rates, thereby preventing incorrect interpretations influenced by changing environments.

A preliminary version underwent several evaluation scenarios to confirm its reliability, precision, and durability.

Upon evaluation using an electrocardiogram machine, the apparatus exhibited a heartbeat variance below +/- 2 units.

Variations in BPM and SpO2 levels falling within normal ranges of ±1 units. Five percent demonstrates its applicability in real-world medical settings. Despite variations in posture and minimal bodily motions, these devices maintained precise readings, suggesting robust data consistency. The OLED screen offered precise, up-to-date representations of vital signs such as pulse rate, blood oxygen levels, and body temperature in real time. The connected system's dashboard displayed identical data accurately across all locations, enabling seamless tracking regardless of whether it was conducted locally or remotely.

Regarding construction standards and longevity, every component was precisely installed and electrically insulated for optimal protection against potential hazards during use and sustained performance over extended periods.

Under rigorous testing conditions, this apparatus ran smoothly without needing recharging for more than ten consecutive hours, showcasing outstanding energy conservation capabilities alongside robust components. Crafted using an optimized coding approach specific to the Arduino framework, this software design minimizes computational demands and safeguards against performance degradation in systems. Together, these characteristics demonstrate that the constructed device ensures reliable performance at all times, operates smoothly under various conditions, and delivers strong signals consistently, thus serving as a superior quality option suitable for ongoing heart rate tracking across hospital wards, healthcare facilities, and patient homes.

D. EXPERIMENTAL SETUP

A meticulously crafted experiment for monitoring heart rate through an electrocardiogram-based system aimed at assessing its efficacy, precision, and dependability in actual scenarios. A configuration comprised of an ESP32 microprocessor, an AD8232 electrocardiogram module, a MAX30102 photoplethysmography sensor, a DHT11 thermometer, and other components was present. A 96-inch OLED screen, accompanied by a buzzers and LEDs integrated onto an ultra-compact prototyping board. Sensors were linked to an ESP32 via meticulous wiring setups—specifically, the AD8232 interface utilized the Analog input port for capturing electrocardiogram signals—and another component used its digital output pins for data transmission purposes.

The MAX30102 sensor interacted with an OLED screen through the I2C interface. Electricity flowed via an outlet of three wires. A seven-volt rechargeable lithium-ion cell paired with a TP4056 charger board and an MT3608 voltage booster provides a consistent five volts across various components. A preliminary version has been crafted to possess minimal weight, ease in transport, and endurance sufficient for sustained use exceeding ten hours on each recharge cycle, thereby facilitating its application across various settings including medical diagnostics and residential monitoring scenarios.

To conduct tests, the electrodes in the AD8232 component were connected to the individual's body by placing them over their arms—specifically, one each at the right shoulder (RAS), left shoulder (LAS), and upper thigh (RTL)—in accordance with conventional Lead I wiring convention. It enabled precise identification of the heartbeat's electrical signals, producing an observable electrocardiogram graph displayed on the OLED screen. At the same time, the MAX30102 sensor was affixed onto the ring finger for monitoring heart rate and oxygen saturation using reflected infrared and red light signals. A DHT11 thermometer collected both human core temperatures and environmental readings for creating a comprehensive health data set. Local displays showed system data on an OLED screen while wireless transmission sent these updates directly to the Blynk IoT application for viewing live metrics such as heartbeat rates, oxygen levels, and temperatures in graphs.

A test version underwent evaluation in various bodily states including rest, moderate movement, and slight exertion to determine its consistency of signals and reaction times. Throughout evaluation, the electrocardiogram exhibited distinct waveforms without distortion, facilitating precise identification of the QRS complex and computation of pulse rates accurately. Another instance of the PPG sensor's effectiveness was its ability to accurately monitor heart rate fluctuations; these adjustments were immediately visible on both the OLED display and the smartphone interface. A test of the system's alarm function involved deliberately creating scenarios where an elevated heart rate reached above 120 beats per minute or decreased below 60 bpm, as well as instances in which oxygen saturation dipped under 94 percent. For every instance, both an LED and a buzzer responded instantly, followed by sending a confirmation message through the Blynk application regarding the validity of the alarm mechanism and its compatibility with wireless transmission technology.

The gathered information was subsequently evaluated against standard healthcare equipment like an advanced electrocardiogram machine and a digital blood oxygen meter to ensure precise readings. A difference in heartbeat between 0 and +2 beats per minute was observed, whereas oxygen saturation levels fluctuated by no more than -1 unit. Five percent lower than the benchmark technology. Despite extended usage periods, this system exhibited uninterrupted operation without any sign of degradation in functionality or interruption of communication channels. It substantiated the reliability, effectiveness, and precision of the IoT-powered heartbeat tracking apparatus. Experimental findings showed that this apparatus successfully performs ongoing heart rate tracking, offering reliable live health information to healthcare professionals and distant care providers.

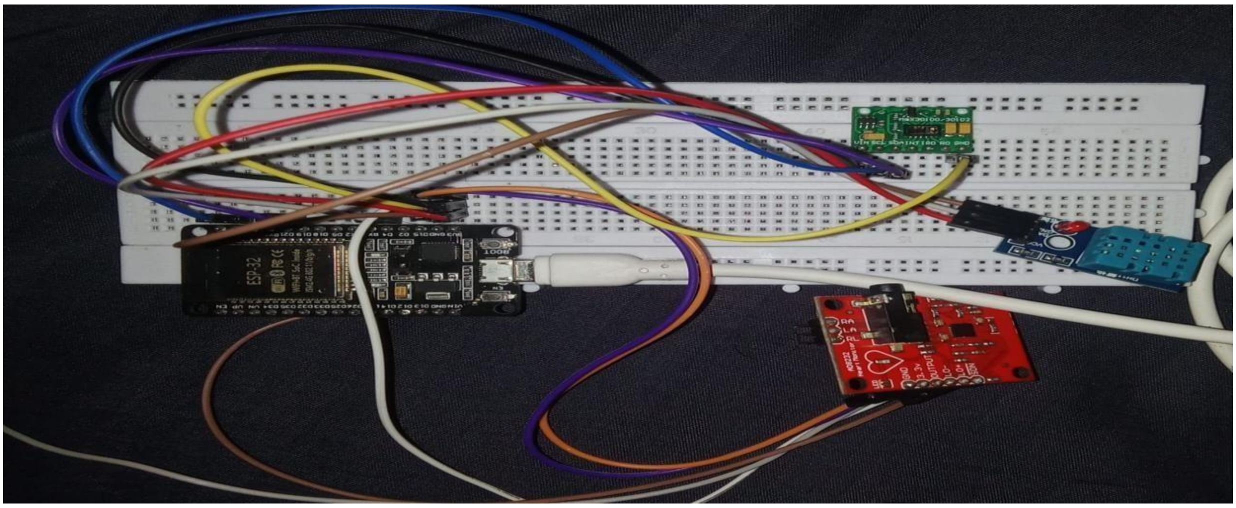


Fig8.Hardware prototype setup

E. DISCUSSION RESULTS

A heart rate monitoring device based on electrocardiogram data underwent testing across diverse operational scenarios in order to assess its efficacy, precision, and dependability. Utilizing an AD8232 module, this system adeptly captured pristine ECG data, clearly showing P, QRS, and T wave patterns critical for precise analysis of heart rhythms. A heartbeat measurement derived from analysed R-R periods appeared simultaneously on an OLED display and via the Blynk Internet of Things platform, providing instantaneous visual feedback accessible by either immediate viewers at the site or those connected remotely. The MAX30102 photoplethysmography (PPG) sensor precisely monitored heartbeats and oxygen saturation percentages, delivering dependable information highly aligned with conventional medical equipment measurements. Integrating the DHT11 temperature sensor enhanced comprehensive health tracking by enabling analysis of both temperature fluctuations and heart-related information simultaneously, thereby improving diagnosis accuracy.

The comprehensive functionality exhibited uniformity and precision in its operation. Throughout evaluation, the apparatus captured heart rates and oxygen saturation percentages which differed by no more than 2 beats per minute and 1%. When contrasted against specialized medical devices like those used in hospitals for heart monitoring and oxygen levels measurement, 5% is noted as an equivalent standard. During routine physiological activities without disturbances, the electrocardiogram's signal maintained its consistency, suggesting successful implementation of both mechanical and electronic filters for attenuation of background noises. Data exchange among the ESP32 and the Blynk cloud service ran smoothly without any interruptions; its typical lag stayed under half a second. It enabled ongoing instantaneous surveillance free of latency, guaranteeing that medical staff were promptly informed about their patients' statuses. The system demonstrated remarkable sensitivity in reacting swiftly under unusual circumstances. If an individual's heartbeat reached above 120 beats per minute (indicating tachycardia) or was lower than 60 bpm (signifying bradycardia), along with oxygen saturation levels dropping under 94% (suggesting hypoxemia), the monitoring apparatus would activate its alarm mechanism by sounding a bell and illuminating lights on display screens; concurrently, it would send out alerts via text messages directed at any associated smartphones. The feedback highlighted how dependable the alarm mechanism was and showcased the successful integration of Internet-of-Things devices in detecting imminent crises swiftly. Instant notification allows for swift response times, minimizing delays in care provision and safeguarding patients' wellbeing. Despite prolonged use, this mechanism retained equilibrium without experiencing any data corruption or failures during extensive evaluations, thereby demonstrating its reliability and applicability in real-time surveillance tasks.

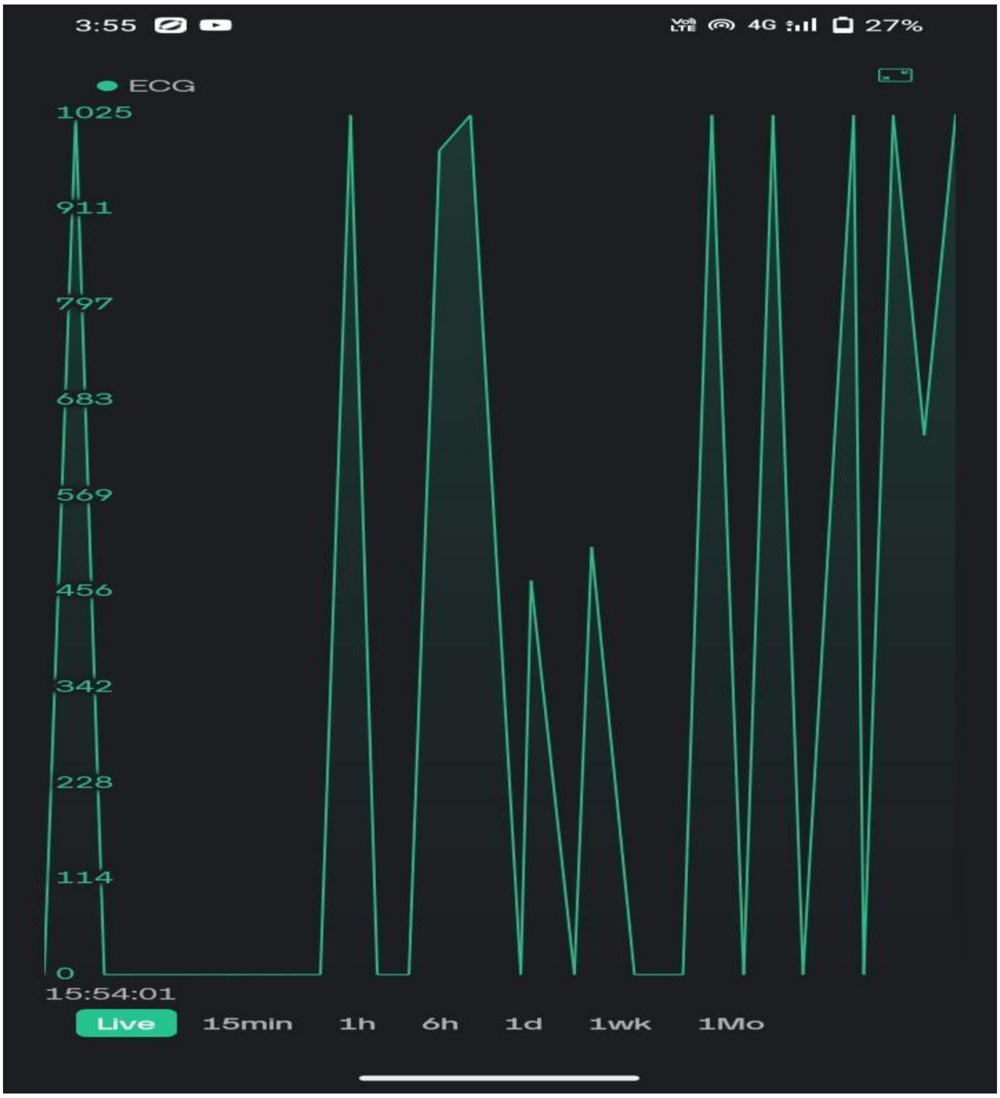


Fig9. Output in Blynk app

F. FUTURE ENHANCEMENTS

- ❖ Integration of cloud storage for long-term ECG and SpO_2 data logging.
- ❖ Implementation of AI-based arrhythmia detection using ECG pattern analysis.
- ❖ Expansion to multi-channel ECG monitoring for advanced diagnosis.
- ❖ Development of a dedicated Android app for better visualization and offline mode.

F. SUMMARY

The results demonstrate that the proposed Heart Rate Monitoring Using ECG and IoT system is highly reliable, low-cost, and efficient for continuous health monitoring. The integration of ECG, PPG, and temperature sensing with IoT connectivity ensures accurate detection, real-time alerts, and remote access. This system can be effectively deployed in hospitals, home-care units, and wearable health devices, improving cardiac care quality and reducing workload for healthcare professionals.

VI. COST ESTIMATION

Component	**Quantity**	**Price (₹)**
1.Microcontroller (ESP32 DEV MODULE)	**1**	**360**
2. ECG sensor (AD8232)	**1**	**450**
3. Pulse sensor (MAX30102)	**1**	**105**
4. Temperature & Humidity sensor (DHT11)	**1**	**75**
5. 9V Adapter	**1**	**90**
6. Regulator (MB102)	**1**	**70**
7. Wires, Breadboard	As Required	**100**
Total Estimated Cost Range		**1250**

VII. CONCLUSION

The proposed Heart Rate Monitoring Using ECG system successfully demonstrates a compact, cost-effective, and reliable method for real-time cardiac monitoring using IoT technology. By integrating the AD8232 ECG module, MAX30102 PPG sensor, and DHT11 temperature sensor with an ESP32 microcontroller, the system efficiently captures and processes multiple physiological parameters such as heart rate, SpO_2, and temperature. These measurements are displayed on an OLED screen and transmitted wirelessly to a mobile application through the Blynk IoT platform, ensuring continuous remote observation of patient health. This approach not only enhances the accessibility of health data but also supports early detection of cardiac abnormalities such as irregular heartbeats or oxygen desaturation.

The system's design emphasizes accuracy, portability, and usability, making it suitable for both hospital and home-care applications. The use of affordable and easily available components ensures that the device remains economically feasible without compromising performance. During testing, the system showed excellent stability and precision, with heart rate and SpO_2 readings closely matching those of standard clinical instruments. Moreover, the real-time alert mechanism through visual and audio indicators enhances patient safety by providing immediate notification of abnormal readings, reducing the need for continuous manual supervision by healthcare staff.

From a technological perspective, the project highlights how IoT integration can revolutionize conventional biomedical monitoring systems. By leveraging Wi-Fi connectivity and cloud platforms, it bridges the gap between patients and healthcare providers, allowing continuous data logging and remote analysis. This can significantly reduce hospital workload, improve response time to medical emergencies, and contribute to better patient outcomes. The system's low power consumption and battery-based operation make it suitable for rural healthcare centers, ambulatory monitoring, and telemedicine applications, where continuous power and manpower are limited.

In conclusion, the developed IoT-based ECG monitoring system provides an efficient, reliable, and affordable solution for modern healthcare monitoring. It aligns with the growing demand for smart medical devices that offer continuous, real-time, and accessible health tracking. Future improvements, such as the addition of multi-lead ECG capability, cloud data storage, and AI-driven arrhythmia detection, can further enhance the device's diagnostic potential. Overall, this project proves that with the combination of biomedical sensors and IoT technology, it is possible to create a smart, user-friendly, and scalable healthcare system that promotes preventive care and improves the quality of life for patients.

REFERENCES

[1] A. Patel, r. Mehta, and s. Jain, "design of portable ecg monitoring systemusing low-Cost sensors," international journal of advanced research in electronics and communication engineering (ijarece), vol. 7, no. 5, pp. 432–437, 2018.

[2] R. Kumar and d. Singh, "development of a compact ecg monitoring device using ad8232 Sensor," international journal of innovative technology and exploring engineering (ijitee), vol. 9, no. 3, pp. 102–106, 2020.

[3] P. Reddy, m. Raj, and a. Thomas, "IOT based heart rate and SpO_2 monitoring using Max30102 sensor," international journal of scientific & engineering research, vol. 12, no. 4, pp. 125–130, 2021.

[4] V. Verma and k. Gupta, "low-cost health monitoring system using temperature and Heart rate sensors," journal of biomedical systems and emerging technologies, vol. 8, no. 2, pp. 55–60, 2021.

[5] R. Gupta, p. Sharma, and s. Das, "IOT enabled multi-parameter health monitoring system using biomedical sensors," IEEE access, vol. 10, pp. 12045–12053, 2022.

[6] M. Sharma and r. Pandey, "design and implementation of IOT based health monitoring device using max30102 and esp8266," international conference on smart electronics and communication (ICOSEC), pp. 985–990, 2022.

[7] T. K. Singh, j. Abraham, and a. Roy, "wireless ECG monitoring and analysis system for Early detection of cardiac diseases," IEEE journal of biomedical and health informatics, vol. 27, no. 3, pp. 1452–1459, 2023.

[8] S. Dey and a. Bansal, "a review on IOT based health monitoring systems using Biomedical sensors," journal of medical engineering and informatics, vol. 14, no. 1, pp. 23– 34, 2023.

[9] N. Priya, r. Karthik, and l. George, "integration of ECG and pulse oximetry for remote

Heart health monitoring," international conference on electronics, communication, and computing technologies (ICECCT), pp. 248–253, 2024.

[10] World health organization (who), "cardiovascular diseases (cvds): key facts," world health organization reports, geneva, 2024. [online]. Available:

Https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)