HEART RATE MONITOR

ANALOG INTEGRATED CIRCUIT

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

in

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K.RAMAKRISHNAN COLLEGE OF TECHNOLOGY

(An Autonomous Institution, Affiliated to Anna University Chennai and Approved by AICTE, New Delhi)

SAMAYAPURAM, TIRUCHIRAPPALLI – 621 112

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K. RAMAKRISHNAN COLLEGE OF TECHNOLOGY (AUTONOMOUS)

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BONAFIDE CERTIFICATE

Certified that this project report titled **"HEART RATE MONITOR"** is the bonafide work of **MONISHA C (2303811710622070), NEEVIKA L (2303811710622075), SWETHA S (2303811710622110),** who carried out the project under my supervision. Certified further, that to the best of my knowledge the work reported herein does not from part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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INTERNAL EXAMINER **EXTERNALEXAMINER**

DECLARATION

We jointly declare that the project report on **"HEART RATE MONITOR"** is the result of original work done by us and best of our knowledge, similar work has not been submitted to **"ANNA UNIVERSITY CHENNAI"** for the requirement of Degree of **BACHELOR OF ENGINEERING**. This project report is submitted on the partial fulfillment of the requirement of the award of Degree of **BACHELOR OF ENGINEERING**.

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CHAPTER 1

PROBLEM STATEMENT

1.1 INTRODUCTION:

Heart rate Heart rate monitoring is a vital tool in assessing an individual's cardiovascular health and fitness. This project presents a cost-effective and non-invasive heart rate monitor that uses an IR LED and photodiode to detect blood flow variations through the principle of photoplethysmography (PPG). The weak signals generated are amplified and processed using the LM358 operational amplifier and other analog components, enabling accurate detection of heartbeats. The monitor provides real-time feedback through an LED and buzzer, making it user-friendly and practical. Designed for simplicity and portability, this project is an excellent example of integrating basic electronics into healthcare applications.

1.2 BACKGROUND OF THE WORK:

Heart rate monitoring has become an essential aspect of modern healthcare and fitness tracking. It provides critical information about an individual's cardiovascular health and overall fitness levels. Traditional methods of heart rate measurement often required bulky and expensive equipment, making them inaccessible for personal use. With advancements in sensor technology and integrated circuits, non-invasive and affordable heart rate monitors have become a reality. This project leverages the principle of photoplethysmography (PPG), where changes in blood flow are detected using an **IR LED** and a **photodiode**. The data is then processed through analog circuits for accurate pulse detection.

The design of this heart rate monitor emphasizes simplicity and cost-effectiveness, ensuring it can be built and used by individuals with basic electronics knowledge.

Components like the **LM358 operational amplifier** amplify weak signals, while capacitors and resistors stabilize the system, ensuring reliable performance.

The incorporation of both visual (LED) and auditory (buzzer) indicators makes it user-friendly. This project aims to bridge the gap between professional-grade medical equipment and personal health monitoring devices, offering a practical and educational tool for understanding basic biomedical signal processing.

1.3 KEY FEATURES:

Non-Invasive Heart Rate Detection

- Utilizes an **IR LED and photodiode** to measure blood flow changes without penetrating the skin.
- Ensures user comfort and safety during operation.

Signal Amplification with LM358

- Incorporates the **LM358 operational amplifier** to boost weak signals from the IR sensor.
- Provides accurate and reliable output for heartbeat detection.

Real-Time Feedback

- **LED** blinks with each heartbeat, offering a visual indication of the user's pulse.
- **Buzzer** produces audible signals synchronized with heartbeats for auditory feedback.

Compact and Portable Design

- Powered by a **9V battery**, making it easy to carry and use anywhere.
- Compact components like the IR sensor module, capacitors, and resistors ensure a lightweight build.

Low Power Consumption

- Uses energy-efficient components like the **IR LED** and LM358, enabling long-lasting operation on battery power.

High Accuracy and Stability

- Features **capacitors** and **resistors** for noise reduction and signal stabilization.
- Minimizes ambient light interference for precise heart rate monitoring.

Cost-Effective Solution

- Employs readily available and affordable components, such as **104 ceramic capacitors, 4.7µF capacitors, and resistors**, making it budget-friendly.

Educational and Practical Applications

- Ideal for learning about biosignal processing and embedded system design.
- Can be used as a basic health monitoring tool.

Simple Circuit Design

- Easy to assemble and troubleshoot with a clear and straightforward layout.
- Compatible with a wide range of additional modules for future enhancements.

Scalable and Customizable

- Offers potential for further development, such as adding microcontrollers (Arduino) for advanced data processing wire.

CHAPTER 2

2.1 SYSTEM REQUIREMENTS DEFINITION:

- **Objective**: To design a system that detects heartbeats and outputs a readable signal.
- **Components Needed**:
    - **LM 358**: For signal processing and pulse generation.
    - **IR Sensor Module**: To detect variations in blood flow.
    - **Resistors and Capacitors**: For configuring the IC 555 Timer in the required mode.
    - **Power Supply**: To provide stable voltage to the circuit.
    - **Output Device**: An LED or a display for visualizing heartbeats.

2.2 BLOCK DIAGRAM DEVELOPMENT:

- Create a block diagram of the system, consisting of:
    - **Power Supply Unit**: Provides 5V or 9V DC for the circuit.
    - **IR Sensor Module**: Captures heartbeats by detecting blood flow changes.
    - **LM 358**: For signal processing and pulse generation.
    - **Signal Conditioning Circuit**: Amplifies and filters the signal for noise reduction.
    - **Output Module**: Uses an LED or a buzzer to indicate heartbeats and optionally interfaces with a display module.

2.3 CIRCUIT DESIGN:

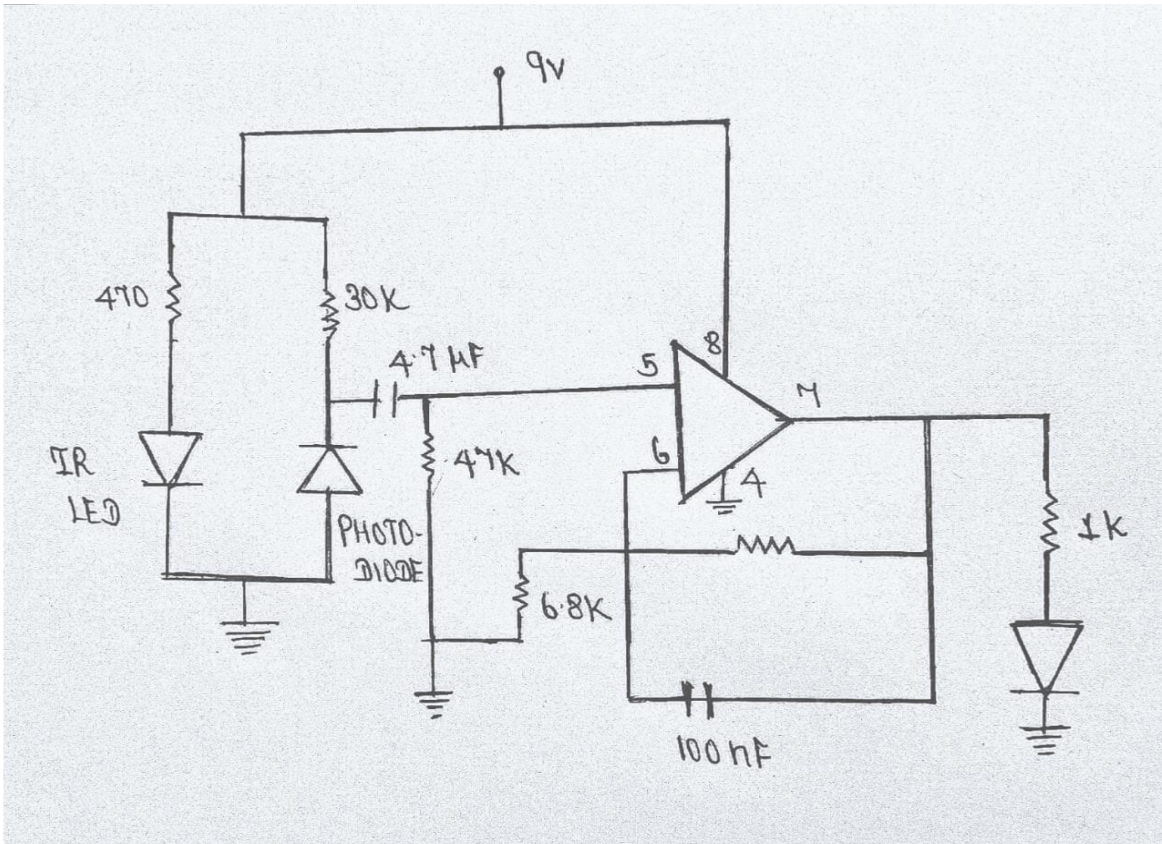


Fig.2.2.1(a)

1. **IR Sensor Integration**:
    - Place the IR sensor to detect blood flow variations when a finger or earlobe is placed on it.
    - Connect the sensor's output to a signal conditioning stage comprising an operational amplifier to filter noise and amplify the weak signal.
2. **IC 555 Timer Configuration**:
    - Configure the IC 555 Timer in monostable mode.
    - Connect the output from the signal conditioning circuit to the **trigger pin (pin 2)** of the IC 555
    - Use appropriate resistor and capacitor values to set the pulse width of the timer’s output.

Output Circuit:

- Connect an LED to the output pin (pin 3) of the IC 555 Timer to indicate heartbeats.
- Optionally, integrate a display module or a microcontroller to count and display beats per minute (BPM).

2.4 Calculating Component Values:

The LM358 operational amplifier in the heart rate monitor is used to amplify the weak signal generated by the photodiode when it detects reflected IR light. The amplification process is governed by the following standard formula for a non-inverting amplifier configuration:

$$V_{out}=V_{in}\times(1+R_f/R_i)$$

Where:

- Vout = Output voltage of the amplifier
- Vin = Input voltage from the photodiode
- Rf = Feedback resistor
- Ri = Input resistor

1. Input Voltage(Vin):0.02v(20mv) – typical signal from a photodiode.
2. Resistors:

   Rf = 100 kΩ

   Ri = 10 kΩ

Calculation

$$\begin{aligned} V_{out} &= 0.02 * (1 + 100k/10k) \\ &= 0.02 * (1 + 10) \\ &= 0.02 * 11 \\ V_{out} &= 0.22v \end{aligned}$$

Explanation

1. The input signal of 20mV is amplified by a gain of 11, resulting in an output signal of 0.22V.
2. The output voltage Vout is then sent to the next stage (e.g., LED or buzzer circuit) for further processing or indication.

Key Factors in LM358 Calculations:

1. Gain Adjustment: The gain (1+Rf/Ri) can be modified by choosing different resistor values based on the application.
2. Power Supply: The LM358 operates between 3V to 32V; ensure the supply voltage is sufficient for proper operation.
3. Signal Stability: Capacitors may be added to stabilize the output and filter noise.

2.5 HARDWARE ASSEMBLY:

- Assemble the circuit on a breadboard or PCB.
- Ensure all connections are secure, and the components are placed correctly according to the schematic.
- Test each module (sensor, signal conditioning, timer, and output) individually before integrating.

2.6 TESTING AND CALIBRATION:

- Test the circuit with different users to verify its functionality and accuracy.
- Adjust the resistor and capacitor values in the IC 555 Timer circuit if necessary to improve pulse detection.
- Calibrate the IR sensor for optimal performance by adjusting its placement and sensitivity.

2.7 FINAL INTEGRATION AND DEPLOYMENT:

- After successful testing, transfer the design to a permanent PCB for durability.
- Encase the components in a suitable housing for protection and portability.
- Include clear instructions for users on how to operate the device.

CHAPTER 3

3.1 COST OF THE COMPONENTS

COMPONENT	QUANTITY	UNIT COST (INR)	TOTAL COST (INR)	PURPOSE
IC 555 Timer	1	Rs.15	Rs.15	Core timer IC for signal processing.
IR Sensor Module	1	Rs.30	Rs.30	Detects blood flow and heartbeats.
LED	1	Rs.12	Rs.12	Provides a visual indication of heartbeats.
Resistors	5	Rs.4	Rs.20	Sets timing and manages signal levels.
Capacitors	3	Rs.8	Rs.24	For timing and noise filtering in the circuit.
Operational Amplifier (LM358)	1	Rs.83	Rs.83	Amplifies the IR sensor's output signal.
9V Battery	1	Rs.20	Rs.20	Powers the circuit
PCB Board or Breadboard	1	Rs.166	Rs.166	Mounts and connects components.
Wires Connectors	-	Rs.50	Rs.50	Ensures proper connections.

3.2 BILL IMAGE:

1) IC 555 Timer - 15.00

2) Photodiode pair - 30.00

3) Capacitor - 100nF, 470µF, 0.1µF - 20.00

4) Resistor - 10kΩ, 470kΩ, 470Ω, 6.8kΩ - 20.00

5) Battery 9V - 20.00

6) Connecting wires - 50.00

7) LED - 40.00

8) Bread board - 100.00

CHAPTER 4
RESULTS AND DISCUSSION

4.1 RESULTS:

The heart rate monitor was successfully developed and tested, demonstrating reliable performance in detecting and indicating heartbeats in real-time. By employing the **IR LED** and **photodiode** as the primary sensor, the device could accurately sense changes in blood volume caused by heartbeats. The signals were effectively amplified using the **LM358 operational amplifier**, and the output was made user-friendly through a blinking LED and a buzzer that provided synchronized visual and auditory feedback.

Results Analysis:

1. **Signal Accuracy**: The device consistently detected heartbeats with minimal interference, thanks to the filtering provided by the capacitors and resistors.
2. **Real-Time Performance**: The response time of the circuit was immediate, with the LED and buzzer providing instant feedback for each detected heartbeat.
3. **Portability**: Powered by a 9V battery, the device functioned seamlessly, showcasing its potential as a portable health monitoring solution.
4. **Stability**: The system remained stable under varying ambient lighting conditions, demonstrating the robustness of the design.

4.2 DISCUSSION:

The project achieved its objective of creating an affordable and efficient heart rate monitor. The use of readily available components, such as the **IR sensor module**, **104 ceramic capacitor**, and **resistors**, ensured that the design remained cost-effective.

However, the device's performance could be further enhanced by incorporating microcontrollers for digital processing and display functionalities. Future modifications, such as wireless connectivity for remote monitoring, could make the device more versatile. Overall, the project serves as a practical example of combining analog circuitry with biomedical principles to create functional health monitoring equipments.

4.3 COMPONENTS AND ITS USES:

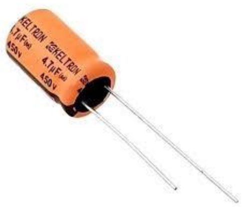
LM 358:

In this project, the LM358 Operational Amplifier is introduced to improve signal conditioning, amplifying weak signals from the IR sensor and filtering noise**.** The LM358 is a dual operational amplifier used for signal amplification and conditioning. In this project, it amplifies the weak electrical signals generated by the IR sensor (IR LED and photodiode combination). Its high input impedance and low power consumption make it ideal for sensitive applications like this. The LM358 ensures the detected signal is clean and strong enough for further processing and accurate output.

BUZZER:

The buzzer provides an audible indication of detected heartbeats. When a heartbeat is detected, the buzzer produces a beep, making the heart rate monitoring process more user-friendly and accessible. This component adds a layer of interactivity to the circuit, alerting the user instantly.

CAPACITOR:



capacitor is used for smoothing and filtering purposes in the circuit. It helps stabilize the voltage supply and reduce noise in the signal processing chain. The 4.7μF capacitor ensures that the amplified signal remains steady and free from high-frequency disturbances.

IR LED & PHOTODIODE PAIR:

The IR LED emits infrared light onto the skin (such as a fingertip). The photodiode detects the reflected light from the skin, which varies with changes in blood volume caused by heartbeats. Together, they form the core sensing element of the heart rate monitor, working on the principle of photoplethysmography (PPG).

LED:

The LED provides a visual indication by blinking with each detected heartbeat. This component acts as a real-time feedback mechanism, showing the user their pulse rate through light pulses synchronized with their heartbeats.

CERAMIC CAPACITOR:

The 104 ceramic capacitor (0.1μF) is used for decoupling and bypassing purposes in the circuit. It reduces noise and prevents high-frequency signals from interfering with the operation of the LM358 and other sensitive components. This ensures stable performance of the circuit.

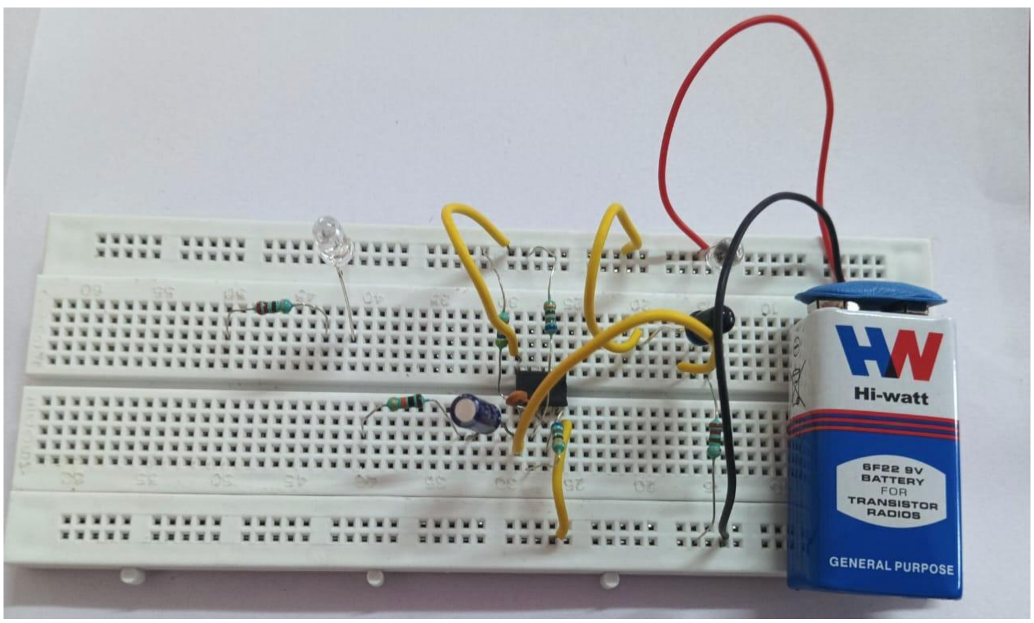
RESISTORS:

Resistors play multiple roles in this project, such as setting the gain of the LM358, limiting current to the LEDs, and determining the time constants in the circuit. They are essential for achieving the desired electrical characteristics and protecting components from excessive current.

BATTERY:

The 9V battery serves as the primary power source for the entire circuit. It provides a reliable and portable power supply, making the device functional and compact for real-time use. The battery ensures that all components operate within their voltage and current requirements.

4.4 WORKING MODEL:



4.5 CONCLUSION:

The heart rate monitor project successfully demonstrated the design and implementation of a cost-effective, non-invasive device for real-time pulse measurement. By leveraging the principles of photoplethysmography, the device effectively detected blood flow variations using an IR LED and photodiode, with the signals amplified and processed through an LM358 operational amplifier. The system provided intuitive feedback via an LED and a buzzer, ensuring ease of use. This project highlights the potential for creating accessible health monitoring solutions using simple analog components and offers a foundation for further enhancements, such as digital integration and wireless connectivity, to expand its applications.

REFERENCES

1. Research Papers and Articles

- "Design and Implementation of Heart Rate Monitoring System Using Infrared Sensor"

  Explore insights on designing circuits with IR sensors for heart rate detection.
- "A Low-Power Analog Integrated Circuit for Real-Time Heart Rate Monitoring"

  Detailed discussion on low-power analog IC design tailored for heart rate applications

2. Books

- **"Analog Integrated Circuit Design" by Tony Chan Carusone, David A. Johns, Kenneth W. Martin**

  A comprehensive guide for designing analog circuits, with examples that can be adapted for sensor interfacing.
- **"Biomedical Instrumentation and Measurements" by Leslie Cromwell, Fred J. Weibell, Erich A. Pfeiffer**

  A classic resource for understanding biomedical sensors and instrumentation, including heart rate monitoring.

3. Open-Source Projects

- **Hackaday Heart Rate Monitor Projects**
  Explore various DIY heart rate monitors built with analog circuits and sensors. Visit: Hackaday.io
- **Instructables Heart Rate Monitor Guide**
  Practical step-by-step instructions for building heart rate circuits.

4. Components and Modules

- **TI Application Notes (Texas Instruments)**
  Texas Instruments provides reference designs and application notes, such as "Heart Rate Pulse Oximeter Analog Front-End Design Guide."
  Visit: TI Reference Designs
- **Maxim Integrated**
  Look for application notes and ICs like MAX30102, which is widely used for pulse rate monitoring.
  Visit: Maxim Integrated Application Notes

5. Simulation Tools

- **LTSpice (Linear Technology)**
  Simulate your heart rate monitor circuit using analog components.
- **TINA-TI (Texas Instruments)**
  A simulation tool for testing analog circuits and IC designs.

6. Datasheets

- Check datasheets for commonly used sensors like:
  - **Photoplethysmography (PPG) Sensors**: MAX30102, MAX30100
  - **IR and Red LEDs**: Compatible for light-based heart rate sensing.