Design and VLSI Implementation of a MIPS-Based Wearable Patient Activity and Cardiac Monitoring System using Accelerometer and PPG Sensor

Report submitted to GITAM (Deemed to be University) as a partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Electronics and Communication

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DECLARATION

I/We declare that the project work contained in this report is original and it has been done by me under the guidance of my project guide.

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CERTIFICATE

This is to certify that (Student Name) bearing (Regd. No.:) has satisfactorily completed Mini Project Entitled in partial fulfillment of the requirements as prescribed by University for VIIth semester, Bachelor of Technology in "Electrical, Electronics and Communication Engineering" and submitted this report during the academic year 2025-2026.

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Table of contents

Chapter 1: Introduction

1.1 Overview of the problem statement

The increasing prevalence of cardiovascular diseases and chronic health conditions underscores the urgent need for continuous and real-time health monitoring systems. Traditional patient monitoring solutions often involve bulky equipment and require medical professionals to be present, limiting their accessibility for daily personal use. Furthermore, early detection and timely alerts for abnormalities such as irregular heart rate or oxygen saturation are critical for effective health management but remain challenging with conventional systems. This project addresses these challenges by designing and implementing a portable, wearable patient monitoring system based on the MIPS processor. The system integrates sensors such as accelerometers and photoplethysmography (PPG) to monitor vital signs including heart rate, oxygen saturation (SpO2), and patient activity. It aims to provide continuous, non-invasive monitoring with real-time data processing and wireless data communication to support remote healthcare delivery.

1.2 Objectives and goals

The primary objectives of this project include:

- Designing a compact and power-efficient wearable patient monitoring device using MIPS architecture.
- Integrating accelerometer and PPG sensors for accurate measurement of patient activity and cardiac parameters.
- Implementing real-time signal processing and alert generation algorithms.
- Enabling wireless data transmission through Bluetooth or Wi-Fi

interfaces for remote monitoring.

- Developing a user-friendly display interface to present vital sign information instantaneously.
- Ensuring secure data storage and accessibility via cloud-based mobile applications.
- Validating the system's accuracy, reliability, and usability under varying operational conditions.

These goals collectively aim to enhance patient care through continuous monitoring, early anomaly detection, and seamless integration with telemedicine services.

Chapter 2 : Literature Review

2.1 Overview of Patient Monitoring Systems

Patient monitoring systems have evolved significantly over recent years, shifting from stationary and hospital-bound equipment to portable, wearable devices. Wearable health monitors provide continuous data collection critical for managing chronic conditions remotely, reducing hospital visits, and enhancing patient quality of life. Many systems use various physiological sensors such as electrocardiograms (ECG), photoplethysmography (PPG), accelerometers, and blood pressure sensors to monitor vital parameters.

2.2 Sensor Technologies in Wearable Monitoring

PPG sensors are widely adopted for non-invasive measurement of heart rate and blood oxygen saturation (SpO2). Accelerometers allow the tracking of patient activity and mobility, providing insights into physical health and fall risk. Advances in low-power sensor designs have enabled their integration into compact wearable formats. Various studies have validated the accuracy and reliability of these sensors in real-life scenarios.

2.3 Embedded Systems and Processor Architectures

Embedded processing platforms like ARM, MIPS, and FPGA have been explored for their suitability in wearable device development. The MIPS architecture provides a balance of computational power and energy efficiency, suitable for real-time signal processing in embedded biomedical applications. Literature shows successful implementations of MIPS-based systems for health monitoring exhibiting low latency and flexibility.

2.4 Wireless Data Communication and Cloud Integration

Modern wearable systems emphasize seamless wireless communication via Bluetooth Low Energy (BLE) or Wi-Fi to transmit patient data to mobile applications or cloud platforms. This trend supports telemedicine by enabling remote monitoring and early intervention. Secure data protocols and encryption are highlighted as critical for patient privacy.

2.5 Alert Generation and Data Analytics

Real-time alert systems use intelligent algorithms to detect anomalies such as arrhythmias or hypoxia, prompting timely medical responses. Machine learning techniques and signal processing algorithms have been integrated to improve alert accuracy and reduce false positives.

2.6 Gaps and Research Motivation

Despite advancements, challenges remain in achieving integrated systems that are compact, power-efficient, and capable of multi-parameter monitoring with reliable wireless communication. This project addresses these gaps by leveraging the MIPS processor architecture combined with accelerometer and PPG sensors to provide a comprehensive wearable monitoring solution.

Chapter 3 : Strategic Analysis and Problem Definition

3.1 SWOT Analysis

Strengths

- FPGA + MIPS provides real-time processing and parallelism.
- Low power and wearable form factor suitable for healthcare.
- Flexible design → easy to add new sensors or features.
- Improves patient monitoring without bulky equipment.

Weaknesses

- Requires specialized FPGA/MIPS expertise.
- Higher development cost and time compared to microcontrollers.
- Limited memory and resources on FPGA boards.
- Prototype stage → not yet optimized for large-scale deployment.

Opportunities

- Growing demand for wearable health monitoring devices.
- Integration with IoT/cloud platforms for remote care.
- Potential for multi-sensor fusion (ECG, SpO_2, temperature).
- Collaboration with healthcare industry & startups.

Threats

- Competition from commercial wearables (Fitbit, Apple Watch, etc.).
- Rapidly evolving technology → risk of obsolescence.
- Regulatory and certification challenges in medical devices.
- Accuracy concerns in uncontrolled real-world environments.

3.2 Project Plan - GANTT Chart

The project plan spans from August to November 2025, covering phases like requirement analysis, system and hardware design, firmware development, testing, sensor integration, and documentation. The detailed GANTT chart includes task timelines and overlapping activities to ensure efficient progress and milestone management.

3.3 Problem statement

Cardiovascular diseases and mobility impairments necessitate continuous patient monitoring for early detection and intervention. Current solutions lack a compact, integrated wearable that combines cardiac monitoring and activity tracking with real-time data processing and wireless transmission. This project aims to develop a MIPS-based wearable patient monitoring system integrating accelerometer and PPG sensors for comprehensive monitoring. The system focuses on providing accurate vital sign measurement, alert generation, and seamless wireless communication, addressing gaps in portability, usability, and remote healthcare support.

Chapter 4 : Methodology

4.1 Description of the approach

The design and development of the MIPS-Based Wearable Patient Activity and Cardiac Monitoring System follow a modular and iterative approach. The system architecture integrates sensor modules, a MIPS processor-based computation unit, wireless data communication, and user interface components. Data from the accelerometer and PPG sensors is continuously acquired and processed in real-time to extract vital parameters such as heart rate, oxygen saturation, and physical activity metrics. The approach emphasizes low-power operation suitable for wearable deployment, reliability through hardware-software co-design, and seamless wireless transmission to enable remote monitoring. Testing and validation phases include simulation, prototype implementation, and functional verification.

4.2 Tools and techniques utilized

- **MIPS Processor Architecture:** Chosen for its balance of computational efficiency and power consumption, enabling real-time embedded processing
- **Sensor:**Accelerometer for motion and activity detection; PPG sensor for heart rate and oxygen saturation measurements.
- **Hardware Description Language (HDL):**Verilog used for hardware design and simulation of signal processing blocks.
- **FPGA Platform:** For prototyping and validating the MIPS-based processing system
- **Wireless Communication Technologies:** Bluetooth and Wi-Fi modules for data transmission to mobile and cloud platforms.
- **Software Tools:** Xilinx Vivado for FPGA development, ModelSim for simulation, and embedded C for firmware programming.
- **Data Visualization Interface:** LCD screen for local display of vital sign data, mobile app/cloud for remote access

4.3 Design Considerations

- **Power Efficiency:** Minimizing power consumption to prolong battery life while ensuring continuous monitoring.
- **Compactness and Wearability:** The device must be small, lightweight, and comfortable to wear for extended periods.
- **Accuracy and Reliability:** Sensors and processing algorithms should deliver precise vital sign measurements under varying conditions.
- **Real-Time Processing:** Timely data acquisition and alert generation to enable prompt medical responses.
- **Wireless Connectivity:** Robust and secure wireless communication for uninterrupted data transmission.
- **User Interface:** Intuitive and clear display of monitored parameters allowing easy interpretation by users and healthcare providers.
- **Data Security and Privacy:** Protecting patient data integrity and confidentiality during transmission and storage.

Chapter 5 : Implementation

5.1 Description of how the project was executed

The execution of the MIPS-Based Wearable Patient Activity and Cardiac Monitoring System project was carried out in a phased manner:

- **System Design and Hardware Development:** Initial design of the wearable system architecture involved selection and integration of sensors (accelerometer and PPG), followed by hardware description using Verilog HDL to program signal processing blocks and control logic on an FPGA platform.
- **MIPS Processor Integration:** A MIPS processor core was implemented on the FPGA to handle real-time processing of sensor data, alert generation, and communication management.
- **Firmware Development:** Embedded software was written in C to manage sensor interfacing, data acquisition, processing algorithms, and wireless transmission protocols.
- **Wireless Communication Setup:** Bluetooth and Wi-Fi modules were configured to enable seamless remote data transmission to a cloud-based mobile app.
- **User Interface Implementation:** An LCD display was integrated to present real-time vital statistics locally on the wearable device.
- **Testing and Validation:** The system underwent rigorous functional testing to validate sensor accuracy, processing correctness, wireless reliability, and user interface responsiveness.

5.2 Challenges faced and solutions implemented

.Sensor Noise and Signal Accuracy: Initial readings from PPG and accelerometer sensors were affected by noise and motion artifacts. This was mitigated using digital filtering algorithms and sensor calibration routines.

- **Resource Constraints on FPGA:** Limited FPGA resources posed challenges for implementing both the MIPS core and signal processing logic. Modular design and resource optimization techniques were employed to fit within device constraints.
- **Power Management:** Ensuring low power consumption while maintaining continuous monitoring required careful selection of low-power modes and duty cycling for sensors.
- **Wireless Connectivity Stability:** Interference and signal dropouts were addressed by implementing error correction protocols and redundant data transmission methods.
- **Data Security:** Encryption and authentication mechanisms were integrated to secure patient data during wireless transmission and cloud storage.

These solutions contributed to a robust, reliable wearable monitoring system capable of accurate real-time data acquisition and remote communication.

Chapter 6: Results

6.1 Outcomes

The MIPS-Based Wearable Patient Activity and Cardiac Monitoring System successfully delivered the following outcomes:

- Accurate real-time monitoring of heart rate, oxygen saturation (SpO2) via the PPG sensor, and patient activity through the accelerometer.
- Reliable data acquisition and processing with minimal latency using the MIPS processor embedded on FPGA.
- Effective wireless transmission of monitored data to a cloud database and mobile application via Bluetooth/Wi-Fi.
- User-friendly LCD display providing immediate vital information to the wearer.
- Alert generation for abnormal vital signs successfully validated during testing.
- Compact and low-power hardware platform demonstrated feasibility for extended wearable use.

6.2 Interpretation of results

The system met design objectives by combining sensor integration, embedded processing, and wireless communication into a unified wearable format. Signal processing algorithms effectively filtered sensor data, providing stable and accurate vital sign readings even under motion-induced noise. The MIPS processor's efficiency allowed sustained real-time performance within stringent power constraints, crucial for practical deployment. Wireless communication modules demonstrated robust connectivity, ensuring continuous remote monitoring capabilities. Functional testing confirmed the responsiveness of the alert system, enhancing patient safety. Overall, the results validate the system's applicability for continuous health monitoring and early anomaly detection in outpatient or homecare settings.

6.3 Comparison with existing literature or technologies

Compared with existing wearable health monitoring solutions, this MIPS-based system offers:

- Enhanced processing efficiency due to the customized embedded MIPS implementation versus conventional microcontrollers.
- Integration of accelerometer-based activity monitoring alongside cardiac vitals, offering a more comprehensive health profile.
- Flexibility in sensor interface and modular design, allowing easier scalability or sensor upgrades.
- Competitive power consumption metrics supporting longer battery life compared to similar commercial devices.
- Effective wireless protocols ensuring lower latency and better data security in transmission.

This project's outcomes align well with recent academic studies advocating for specialized embedded architectures in wearable biomedical devices, confirming the MIPS processor's suitability. The system advances the state-of-the-art by demonstrating a compact, low-power, and multifunctional platform for continuous patient monitoring.

Chapter 7: Conclusion

The MIPS-Based Wearable Patient Activity and Cardiac Monitoring System successfully demonstrated the feasibility of integrating multiple vital sign sensors with an embedded MIPS processor to provide continuous, real-time health monitoring in a compact wearable device. The system proved effective in acquiring, processing, and wirelessly transmitting key health parameters such as heart rate, oxygen saturation, and patient activity, supporting remote healthcare and early anomaly detection.

Suggestions for Further Research or Development

- **Integration of Additional Sensors:** Expanding sensor suites to include respiratory rate, blood glucose, or electrocardiogram (ECG) inputs could provide a more comprehensive patient health profile.
- **Enhanced Signal Processing Algorithms:** Incorporating machine learning and AI techniques for predictive analytics and personalized health risk assessments.
- **Miniaturization and Power Optimization:** Further work on component miniaturization and ultra-low-power design techniques to improve wearability and battery life.
- **Robust Communication Protocols:** Development of fault-tolerant, low-latency wireless protocols that operate reliably in challenging environments.
- **Clinical Trials and Validation:** Extensive real-world testing with patient populations to validate system accuracy, usability, and clinical efficacy.

Potential Improvements or Extensions

- **Cloud Platform Integration with Advanced Analytics:** Building a fully integrated telemedicine platform enabling healthcare providers to track patient trends over time and intervene proactively.
- **User Interface Enhancements:** Development of more intuitive and accessible interfaces including voice commands or haptic feedback for differently-abled users.
- **Security Enhancements:** Strengthening data privacy through

blockchain technology or advanced encryption methods to safeguard sensitive health data.

- **Cross-Platform Compatibility:** Ensuring compatibility of mobile apps across operating systems and integration with popular health management platforms.
- **Scalability:** Designing modular hardware and software architectures that allow easy upgrades or addition of new features without major redesigns.

These avenues promise to enhance the system's impact, user adoption, and contribution to personalized and preventive healthcare.

Chapter 8 : Future Work

The continued refinement and expansion of the MIPS-Based Wearable Patient Activity and Cardiac Monitoring System could explore several promising directions to enhance functionality, usability, and clinical impact.

Suggestions for Further Research or Development

- **Integration of Advanced Sensor Technologies:** Incorporate additional health sensors such as electrocardiogram (ECG), blood glucose monitors, and continuous blood pressure sensors to broaden monitoring capabilities.
- **Implementation of AI and Machine Learning:** Develop predictive models and anomaly detection algorithms that leverage sensor data for early warning of health deterioration and personalized health insights.
- **Optimization for Ultra-Low Power Consumption:** Research novel hardware accelerators, energy harvesting techniques, and intelligent power management to extend battery life for extended wearable use.
- **Robust Network Protocols:** Investigate mesh networks or 5G connectivity as alternatives to enhance data transmission reliability and coverage, especially in remote or densely populated areas.
- **User-Centered Design Enhancements:** Conduct human factors research to improve device ergonomics, comfort, and inclusive interface modalities like voice or gesture control.

Potential Improvements or Extensions

- **Cloud-Based Telemedicine Ecosystem:** Build a comprehensive cloud-based platform integrating data analytics, real-time monitoring dashboards, and automated clinical decision support.
- **Interoperability with Healthcare Systems:** Develop compatibility with electronic health records (EHR) to facilitate seamless data exchange between patients and healthcare providers.
- **Security and Privacy Enhancements:** Apply advanced encryption schemes, blockchain technology, and regulatory compliance

frameworks to safeguard patient information.

- **Modular Hardware and Software Architecture:** Design scalable and upgradeable system components to accommodate evolving sensor technologies and algorithmic improvements.
- **Multi-User and Group Monitoring:** Expand functionality to support family or community health monitoring applications, enabling shared health tracking and alerting.

These future directions aim to elevate the system from a prototype to a clinically validated, widely adopted wearable healthcare solution, addressing the evolving demands of personalized medicine and telehealth.

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