**REDESINING TPMS/HAVC AND BCM FOR ZONAL ARCHITECTURE**

**Submitted**

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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 2024-2025.**

**[Signature of the Guide] [Signature of HOD**

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# Chapter 1: Introduction

# Overview of the problem statement

The problem of redesigning TPMS (Tire Pressure Monitoring System), HVAC (Heating, Ventilation, and Air Conditioning), and BCM (Body Control Module) for zonal architecture involves addressing the inefficiencies of traditional centralized vehicle architectures, where each system operates independently with dedicated sensors, controllers, and wiring. This approach results in increased complexity, weight, and costs, as well as limited scalability and flexibility for future enhancements. The zonal architecture aims to consolidate and distribute these systems' functionalities across different vehicle zones, reducing wiring and complexity while improving modularity, scalability, and maintainability, ultimately leading to more efficient, lightweight, and flexible vehicle designs.

## 1.2 Objectives and goals

The objective of this project is to redesign the Tire Pressure Monitoring System (TPMS), Heating, Ventilation, and Air Conditioning (HVAC) system, and Body Control Module (BCM) to fit a zonal architecture in modern vehicles. This involves developing an optimized, modular system architecture that enhances the efficiency, responsiveness, and integration of these systems. The redesigned systems should improve overall vehicle performance, reduce complexity, and support advanced functionalities like real-time monitoring, zonal temperature control, and enhanced safety features while ensuring scalability for future automotive technologies.

Efficiency and Performance: Enhance system efficiency and performance through optimized algorithms and local decision-making in zonal controllers.

Safety and Reliability: Improve safety with more accurate TPMS data and reliable HVAC control tailored to cabin zones.

Scalability: Design for scalability to support future technologies and additional features with minimal changes.

Cost and Weight Reduction: Lower costs and vehicle weight by reducing wiring and simplifying the electrical architecture.

User Experience: Enhance user comfort and convenience with precise climate control and proactive maintenance alerts.

**CHAPTER 2: Literature Review**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SI.no | Title of the paper | Year | Author | Key Findings | Link |
| 1 | Tire Pressure Monitoring System based on Resonant Frequency of Wheel Speed Spectrum | 2022 | Tianshi Shan dept. school of vehicle and mobility  d Liang Li dept. school of vehicle and mobility Tsinghua university | Approach:-The tire pressure monitoring system(TPMS) is the module implemented in vehicles detecting whether the tire is under-inflated to avoid puncture and destabilization. This paper presents a scheme for indirect TPMS based on wheel speed sensors and onboard hardware. Firstly, a wheel speed signal processing method is raised, including denoising, rim error filtering, and resampling. Secondly, a resonance frequency identification method based on the wheel speed spectrum is proposed based on the characteristics of tire vibration. Finally, the whole process of the method was deployed on the actual vehicle, and the test results proved the effectiveness of the proposed methods | <https://drive.google.com/file/d/1LgOtiieA1q21_qdSvKRc6qMQqQ6tOr9a/view?usp=sharing> |
| 2 | Real Time Tire Pressure Monitoring System in Automobiles using SPLUNK Enterprise | 2019 | S. Yogashri  S. Jayanthy  A. Rathinavel | Approach: The Tire pressure Monitoring system is proposed to monitor the changes in the tire pressure and temperature using Splunk Enterprise. The proposed system is implemented using the Raspberry Pi interfaced with 5 inch HDMI Touch Display, SPD100g Pressure Sensor and DS18B20 Temperature Sensor. The system senses the high and low pressure, temperature of the tire and displays the information on the display. The log of the Tire Pressure Monitoring system is indexed with Splunk Enterprise. Splunk Enterprise is a platform for searching, analyzing and visualizing the machine generated data from the applications, sensors and devices. It communicates with the different log files and stores the file data in the form of events into local indexes. By using Splunk Enterprise Pivots, Dashboards and Reports can be created. | <https://drive.google.com/file/d/1-ul7UJp7bu1OEHf6gTvsQEC9P8qqk8fE/view?usp=sharing> |
| 3 | DESIGN OF TIRE PRESSURE MONITORING SYSTEM USING A PRESSURE SENSOR BASE | 2019 | Lukman Medriavin Silalahi  Mudrik Alaydrus  Agus Dendi Rochendi  Muhtar | Approach :- the Tire Pressure Monitoring System (TPMS) only monitors the condition of a tire pressure. However, there are no particular reactions taking place after the value of its tire pressure is discovered. In fact, the value of a tire pressure determines driving comfort and safety Therefore, this research proposed a method to integrate a TPMS and a Pressure Sensor Base (PSB) with a particular reaction required to fulfill tires automatically. The proposed TPMS has an electronic device unit directly attached to a tire’s valve. This unit includes pressure sensors, microcontrollers, Bluetooth transmitters and batteries. An alert system is generated whenever tire pressure exceeds the maximum or minimum safe pressure level. Moreover, if the pressure measured is below the lowest level of the desire pressure, it will automatically activate the compressor. Several experiments have been carried out to analyze the proposed system. | <https://drive.google.com/file/d/1URRH8Tlz9QjoTr4a-uOCdp9gxS61-9HG/view?usp=sharing> |
| 4. | A hybrid tire pressure monitoring system for road vehicles | 2021 | Luca Onesto  Tommaso  Colombo  Alessandro Pozzato  Sergio M. Savaresi | Approach:- Since under-inflated wheels may lead to unsafe driving conditions, in many countries all the new cars must  be equipped with tire pressure monitoring systems (TPMS). Such devices can be ‘‘direct’’, in case air pressure  sensors are employed, or ‘‘indirect’’, if low tires are detected by comparing relative wheel speeds, typically  via already available speed sensors. While the former are perfectly suited but costly, the latter are cheaper  but they typically cannot be used to detect four deflated wheels. In this work, we present a ‘‘hybrid’’ solution,  which is able to estimate the pressure of all four wheel by employing a single pressure sensor. Then, such a  solution turns out to be a good trade-off between the systems cost and the measurement performance. The  effectiveness of the approach is illustrated via experimental tests carried out on a real vehicle setup. | <https://drive.google.com/file/d/1prgiwGPRbP08j4M0P3JFnGBEYilejtiI/view?usp=sharing> |

# Chapter 3 : Strategic Analysis and Problem Definition

## 3.1 SWOT Analysis

Strengths

* Improved System Efficiency
* Enhanced Modularity and Scalability
* Better Integration with Other Systems
* Localized Control and Functionality

Weaknesses

* Higher Initial Development Costs
* Increased System Complexity
* Potential Reliability Issues
* Cybersecurity Risks

Opportunities

* Growing Market Demand for Smart Vehicles
* Potential for Advanced Features and Upgrades
* Energy Efficiency and Environmental Benefits
* Leadership in Next-Generation Vehicle Technologies

Threats

* High Competition from Established Technologies
* Regulatory and Standardization Challenges
* Market Resistance to Change
* Rapid Technological Advancements

### 3.2 Project Plan - GANTT Chart

##### 3.3 Refinement of problem statement

How can we redesign the Tire Pressure Monitoring System (TPMS), Heating, Ventilation, and Air Conditioning (HVAC), and Body Control Module (BCM) systems to transition from a centralized architecture to a scalable, energy-efficient, and fault-tolerant zonal architecture that reduces wiring complexity and improves real-time performance in modern vehicles?

This refined problem statement will guide the development and implementation of the project, ensuring that the redesigned systems are optimized for the challenges posed by traditional centralized automotive architectures.

# Chapter 4 : Methodology

# 4.1 Description of the approach

The approach for redesigning TPMS, HVAC, and BCM systems for zonal architecture is structured around decentralizing control functions, reducing complexity, and enhancing system efficiency. The primary objective is to distribute the control tasks to individual zones within the vehicle, allowing for localized control, faster response times, and more efficient communication between systems.

* **TPMS**: The Tire Pressure Monitoring System will shift from a centralized to a distributed model, where each wheel or zone of the vehicle independently monitors tire pressure and communicates with a local zonal controller. Data processing is minimal at the sensor level, with critical processing done by the zonal controller.
* **HVAC**: The Heating, Ventilation, and Air Conditioning system will use local sensors and actuators in each zone of the vehicle to dynamically adjust temperature, airflow, and humidity. Zonal controllers handle real-time data from these sensors to ensure comfort without the need for centralized decision-making.
* **BCM**: The Body Control Module will be decentralized, with each zone managing the control of vehicle functions such as lighting, windows, and doors. Zonal controllers will reduce wiring complexity and allow localized processing of inputs from switches and sensors.

This zonal approach enhances scalability, reduces wiring, and provides real-time, localized control, leading to improved performance and reduced latency.

### 4.2 Tools and techniques utilized

* Simulation Software: Tools like MATLAB/Simulink are used to simulate the system performance for HVAC, TPMS, and BCM in a zonal architecture. These simulations help analyze control strategies, energy efficiency, and fault tolerance.
* Vehicle Communication Protocols:
  + CAN FD (Controller Area Network Flexible Data Rate) and Ethernet will be employed for communication between zonal controllers, ensuring high-speed data transfer with minimal latency.
  + Wireless Protocols (BLE, UWB) for the redesigned TPMS to send data from sensors to zonal controllers.
* Embedded Development Platforms:
  + Microcontrollers and Processors (e.g., STM32, NXP) are used for developing the zonal controllers, which will handle the processing for HVAC, TPMS, and BCM within the distributed architecture.
  + Sensor Development Kits are used to integrate temperature, pressure, and actuator control functions in the zonal HVAC and TPMS systems.
* Testing and Validation Tools:
  + FMEA (Failure Mode and Effects Analysis): Used to identify potential failure points and improve system reliability.
  + Hardware-in-the-loop (HIL) Simulation: For real-time testing of the redesigned systems before deployment in vehicles.

#### 4.3 Design considerations

* Modularity and Scalability:
  + Each zone (e.g., front-left, rear-right) is designed as an independent module that can be scaled based on the number of zones in the vehicle.
  + The system should allow easy addition or removal of zones without affecting overall functionality, making it adaptable to different vehicle models and configurations.
* Energy Efficiency:
  + Minimizing power consumption, especially for TPMS and HVAC, by optimizing data transmission and processing algorithms. Wireless TPMS needs low power modes to ensure battery longevity, and HVAC systems should dynamically adjust energy use based on environmental and vehicle occupancy conditions.
* Real-time Data Processing:
  + Zonal controllers must process and act on data (temperature, pressure, vehicle controls) in real-time to ensure safety, comfort, and efficiency. The communication architecture must ensure low latency between zones.
* Communication Redundancy and Fault Tolerance:
  + Zonal architecture should provide communication redundancy to ensure fault tolerance. For example, if one zonal controller fails, others should maintain functionality without significant system-wide failures.
* Wiring Reduction:
  + One of the main objectives is to reduce the length and complexity of wiring. Zonal controllers connected via Ethernet or CAN FD will reduce the need for extensive wiring, simplifying vehicle assembly and maintenance.
* System Integration:
  + TPMS, HVAC, and BCM components need to be seamlessly integrated within the zonal architecture without compromising performance. This involves ensuring that the communication protocol and network topology can support the data exchange requirements of all three systems.

# Chapter 5 : Implementation

## 5.1 Description of how the project was executed

### 5.2 Challenges faced and solutions implemented

# Chapter 6:Results

## 6.1 outcomes

### 6.2 Interpretation of results

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#### 6.3 Comparison with existing literature or technologies

# Chapter 7: Conclusion

Here write Suggestions for further research or development and Potential improvements or extensions

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# Chapter 8 : Future Work

#### Here write Suggestions for further research or development Potential improvements or extensions

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# References