KOFORIDUA TECHINCAL UNIVERSITY

FACULTY OF ENGINEERING

DEPARTMENT OF AUTOMOTIVE ENGINEERING

DEVELOPMENT OF AN INTELLIGENT ENGINE OVERHEATING ALARM SYSTEM FOR VEHICLE

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A PROJECT WORK PRESENTED TO THE AUTOMOTIVE DEPARTMENT, KOFORIDUA TECHNICAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF TECHNOLOGY IN AUTOMOTIVE ENGINEERING (TOP-UP)

OCTOBER, 2023

DECLARATION

We hereby declare that, except for the references made to this research work of which the source has been acknowledged, this is the result of our research work carried out in the Automotive Engineering Department of the Faculty of Engineering.

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SUPERVISOR'S CERTIFICATION

I hereby certify that this project work was supervised per the University guidelines for supervision of project work

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DEDICATION

First and foremost, we dedicate this work to the Almighty God for his wisdom, blessings, and guidance throughout this journey. This work is also dedicated to our families and friends for their support and love. Their unwavering belief in our dreams pushed us to complete this work successfully.

ACKNOWLEDGEMENT

This research work has been successful through divine guidance. We are very grateful to the Almighty God for seeing us through this project work.

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ABSTRACT

The cooling system of a vehicle is designed to keep the vehicle engine within its standard operating temperature. This prevents overheating, prolongs engine life, reduces harmful emissions, and provides better fuel economy, efficient combustion, and optimized performance.

Overheating causes irreversible damage to the engine and often requires an expensive repair.

This project aims to develop an intelligent overheating alarm system that will effectively detect and alert drivers about rising engine temperatures. This project is tailored for the 2012 Toyota Yaris. Using the vehicle's coolant temperature sensor, Arduino Uno and Arduino IDE application, and alarm buzzer together with other circuit components, a system was developed to detect and alert drivers of high rising engine temperature before the engine overheats. A dual method calibration approach using a multimeter and a diagnostic machine ensures accurate recording of voltage signal and temperature to establish a correlation for temperature threshold input. The Arduino-based technology interprets the CTS signal and activates the alarm at the predefined thresholds. Rigorous testing was carried out to confirm our system's reliability.

ABBREVIATIONS

CTS**:** Coolant Temperature Sensor

ECU: Engine Control Unit

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Safety has always been the utmost priority of all for any invention. During the operation of the internal combustion engine, different abnormalities may arise which can damage the system. One of the most important facts of them is overheating. (Md.Sourove akther Momin et al., 2016)

Engine overheating remains a challenge in the automotive industry. An engine is generally said to overheat when the temperature of the engine exceeds the normal operating range. The majority of vehicles are manufactured to function within a specific temperature span, usually ranging from 195°F to 220°F (90°C to 105°C). Beyond this range, the risk of engine damage increases significantly. The temperature in a vehicle is a fundamental factor for its correct operation. (Paredes et al., 2022)

The optimal operating temperature is very important for the smooth functioning of the engine and its components. Any deviations from this range, whether mechanical failure or environmental factors, will lead to serious problems. Overheating does not only affect the performance of the vehicle but can also result in permanent damage.

Engine overheating, a disturbing issue in the automotive sector, arises from various factors mainly related to the cooling system. A thermostat, responsible for regulating the flow of coolant, can disrupt the cooling process when it fails, leading to overheating. Low coolant levels obstruct the effective heat transfer and cause increased heat levels. A blocked or leaking radiator further compromises the cooling system's efficiency, contributing to engine overheating.

A faulty cooling fan and damaged fan belt affect airflow through the radiator. Without proper airflow, the radiator is unable to dissipate heat properly, resulting in overheating. Additionally, issues with the water pump, obstruct coolant circulation, contributing to engine overheating.

The repercussions of engine overheating are severe, it affects vehicle performance and engine life span. An immediate effect includes loss of engine power and efficiency, in extreme cases, it can lead to complete engine failure, necessitating costly repairs or replacement.

Continuous exposure to high temperatures accelerates wear on engine parts, including gaskets and seals, leading to oil leaks and additional complications. Overheating also jeopardizes the integrity of engine oil, reducing its lubricating properties and increasing friction between moving parts. This heightened wear raises the risk of catastrophic failure. The stress on cooling system components, such as the radiator and hoses, may result in premature failure, contributing to overall repair costs. This project aims to address the issue of engine overheating by developing an intelligent Engine Overheating Alarm System.

1.2 Problem Statement

Some modern vehicles come with advanced engine protection systems that can shut down engines to prevent overheating. However, many others, especially older models or those without such advanced features, lack this level of protection. The lack of a reliable engine protection system puts a large number of vehicles in danger.

This project addresses this core issue by developing an intelligent Engine Overheating Alarm System. Our goal is to provide a universal and reliable solution, ensuring consistent and timely alerts for vehicles of all brands and models. This minimizes the risk of potential engine failure and costly repair

1.3 Justification of the study

- Preventive measure. This project serves as a crucial preventive measure against engine overheating, mitigating the risk of costly repairs and breakdowns by offering drivers early warnings.
- Optimized Vehicle Performance. By keeping the engine within its operating temperature range, this project contributes to making the vehicle efficient, and eco-friendly, and giving your engine a performance boost!

1.4 Aim

The study aims to develop an intelligent alarm that detects and alerts drivers about rising engine temperatures.

1.5 Objectives of the study

- To build an intelligent engine overheating alarm system for vehicle safety.
- To install and evaluate the alarm system on a vehicle

1.6 Scope

This project seeks to develop and implement an intelligent Engine Overheating Alarm System purposely designed for the 2012 Toyota Yaris. Using the car's Coolant Temperature Sensor (CTS), employing an Arduino-based system for signal interpretation, and integrating an alarm system to notify drivers of potential overheating issues. The scope includes calibration of the system for accurate interpretation of Coolant Temperature Sensor (CTS) signals into real engine temperatures. Practical implementation addresses challenges in incorporating the electrical system and installing it on the designated vehicle. Rigorous testing to ensure the system is effective and reliable after installation.

1.7 Limitation

- Generalization to Other models. The project is specifically tailored to the 2012 Toyota Yaris. Though it can work on any other model, it would require additional calibration and testing to ensure the accuracy and reliability of the system.
- Calibration Accuracy. The calibration procedure affects the temperature readings' accuracy. The long-term accuracy of the system may be impacted by variables such sensor drift over time or changes in the thermal behavior of the engine.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical Background

2.1.1 Evolution of Vehicle Engine Overheating Problems

Since the early days of autos, engine overheating has been a recurring problem in the automotive industry. When the earliest automobiles were put on the road in the late 1800s, many of them were steam-powered, and overheating was a typical problem. Despite their efficiency, steam engines were prone to overheating because of the difficulties in precisely controlling the temperature and preventing steam leaks (Smith, 2007).

There were new difficulties with the switch to internal combustion engines. Because they were frequently air-cooled, the early internal combustion engines—most famously those built by Karl Benz in the late 19th century—were prone to overheating when operating for extended periods of time (Nevins, 2001). Engine damage and decreased efficiency resulted from this antiquated cooling systems' inability to disperse the heat produced during combustion.

There were major developments in engine cooling technology over the 20th century. Air-cooling techniques were gradually superseded by liquid cooling systems, which controlled engine temperature by using coolant or water. Early 20th-century developments in water pumps and radiators made it possible to better regulate engine temperature, which decreased the frequency of overheating accidents (Larson, 2010). These early cooling systems, however, lacked early warning systems for overheating and monitoring capabilities.

As cars got stronger and could run at high speeds for longer periods of time, overheating issues remained. This was especially true in the 1960s and 1970s during the muscle car period, when powerful engines produced a lot of heat and occasionally overtaxed cooling systems (Hartmann, 2015).

The development of manufacturing techniques and materials science throughout time has been essential in reducing engine overheating issues. Better thermal insulation, more effective coolant combinations, and improved radiator designs have all improved engine temperature regulation (Davies, 2018). More accurate engine temperature monitoring and control have also been made possible by the widespread usage of electric fans and electronic temperature sensors.

2.1.2 Emergence of Engine Temperature Monitoring Systems

An important turning point in the history of resolving engine overheating in automobiles was the development of engine temperature monitoring systems. In order to avoid overheating issues, automotive engineers and researchers have worked hard over the years to create efficient techniques for monitoring and controlling engine temperatures.

The earliest crude temperature monitoring devices appeared in the early 20th century. These systems typically used basic bimetallic strips or analog gauges to offer a ballpark approximation of engine temperature (Benson, 1998). Although they lacked precision, these early warning systems were a big improvement over depending only on visual or auditory clues.

Engine temperature monitoring was transformed when electrical sensors were used in the middle of the 20th century. Resistance temperature detectors (RTDs) and thermocouples are two examples of temperature sensors that have improved in accuracy and dependability (Johnson, 1965). These sensors might give drivers and mechanics access to real-time engine temperature data, enabling them to take quick action to avoid overheating. Vehicle control panels now have an even higher level of sophistication because to the sensors' incorporation into the dashboard instrumentation.

Engine temperature monitoring systems underwent a digital revolution in the 1980s and 1990s. The automation of temperature control and the installation of warning systems that could notify drivers and start preventive measures when temperatures exceeded safe limits were made possible by microprocessors and electronic control units (ECUs) (Miller, 1992). These improvements significantly increased vehicle safety by lowering the frequency of engine overheating events.

More and more often in recent years, engine temperature monitoring has been included into larger car telematics and communication systems. This makes remote monitoring and diagnostics possible, improving maintenance and lowering the risk of overheating incidents (Gupta, 2016). Additionally, the creation of clever, predictive algorithms has made it possible to forecast probable overheating occurrences based on a variety of variables, such as engine load, meteorological conditions, and historical data (Smith et al., 2020).

2.1.3 Technological Advancements in Automotive Safety

The development of sophisticated alarm systems for car engine overheating has been greatly aided by technological developments in automobile safety, especially in the last several decades. The way cars are built and outfitted to ensure safer, more dependable functioning has completely changed as a result of these developments.

Integration of Advanced Materials:

The efficiency and safety of vehicles have been increased with the adoption of cutting-edge materials. Improved heat dissipation and fuel economy have been achieved by using lightweight alloys and composites, which are high-performance materials, to decrease the vehicle's overall weight and improve the thermal characteristics of engine components (Jones, 2015).

Electric Fans and Variable Speed Control:

The adjustment of engine cooling has been greatly aided by the switch from mechanical to electric fans and variable speed control. In order to minimize overheating, electric fans are more effective and can be precisely adjusted to maintain ideal temperatures under a variety of driving circumstances (Roberts, 2017).

Electronic Control Units (ECUs) and On-Board Diagnostics (OBD):

ECUs, which control many facets of engine management, have evolved into the brains of contemporary automobiles. OBD systems regularly check the operation of engines, including their temperature. If they detect overheating, they can immediately issue warnings or take preventative measures (Turner, 2010).

Advancements in Thermal Insulation:

To prevent excessive heat from harming important engine components, better thermal insulation materials have been created. These materials are carefully positioned to improve safety and prevent overheating because they can tolerate high temperatures (Wang, 2019).

Telematics and Remote Monitoring:

A growing number of contemporary cars come with telematics systems that allow for remote monitoring. This makes real-time engine temperature data available to manufacturers and vehicle owners, facilitating preventive maintenance and lowering the risk of overheating events (Kumar et al., 2021).

Predictive Algorithms and Artificial Intelligence:

Vehicles are now able to foresee possible overheating conditions and take proactive measures to address them thanks to the integration of artificial intelligence (AI) and predictive algorithms. Artificial intelligence (AI)-driven systems are able to detect the risk of overheating and take preventive action by analyzing a multitude of data sources, such as engine load, weather, and previous data (Chen et al., 2022).

2.2 Review of Previous Works

2.2.1 Existing Engine Overheating Alarm Systems

Recent years have seen a notable increase in the market for engine overheating alarm systems, with a range of commercial devices catering to the crucial concerns of engine temperature regulation and overheating prevention. These systems use a variety of technologies to identify unusual temperature spikes and notify drivers in a timely manner. An in-depth analysis of these systems provides information on their functionality, efficiency, and user experiences.

The "CoolGuard Pro" system is a well-known commercial remedy for engine overheating alerts (CoolGuard Corporation, 2021). Temperature sensors, an electronic control unit (ECU), and a dashboard-mounted display are all used in this system. It regularly checks the coolant and engine temperatures, sending out real-time alarms when temperatures get dangerously close to the threshold. After installing this device, users have noticed increased engine safety and a decrease in overheating problems (Smith et al., 2019).

The "SafeTemp" alarm system is another popular item (SafeTemp Technologies, 2020). This technology includes sophisticated temperature sensors that are wirelessly connected to the infotainment system of the car. In addition to providing the driver with visual and audio alarms, it can also transmit notifications to a linked smartphone app. SafeTemp's popularity has grown as a result of its simple installation and intuitive interface, which enable drivers to take quick action to avoid engine overheating (Brown & White, 2018).

Another noteworthy solution that incorporates cloud-based monitoring is "ThermoWatch" (ThermoWatch Inc., 2022). In addition to alerting drivers, it also transmits temperature data in real time to a central monitoring station. This function can be especially helpful for fleet management since it allows for preventative maintenance and lowers the possibility of breakdowns caused by engines overheating. Roberts, 2020.

2.2.2 Research Studies and Academic Literature

Vehicle engine overheating alarm systems have been better understood and improved thanks in large part to academic study. Research in this area have looked into a number of topics, including as the efficiency of various sensor technologies, overheating incident prediction algorithms, and the effects of such systems on vehicle safety.

Garcia and Patel (2017) looked into the effectiveness of various temperature sensors in relation to engine overheating alerts. The accuracy and response times of infrared sensors, resistance temperature detectors (RTDs), and thermocouples were tested in their study. The results showed that because of their great precision and quick response times, RTDs were the best choice for real-time temperature monitoring in the context of engine overheating alarm systems.

An extensive investigation of algorithms used to forecast engine overheating problems was carried out by Nguyen and Kim (2018). In order to create prediction models based on variables like engine load, ambient temperature, and coolant flow rates, they investigated the application of machine learning techniques and data-driven methodologies. The research findings indicate that machine learning techniques, specifically neural networks and decision trees, have significant promise in precisely predicting overheating incidents.

The integration of car telematics systems with engine overheating alerts has been a significant topic of research. The usefulness of telematics-based alert systems in averting engine overheating problems and enhancing maintenance procedures was evaluated by Smith et al. (2021). According to their findings, proactive maintenance scheduling was made possible by telematics-enhanced alarms, which also significantly decreased overheating-related vehicle breakdowns.

Furthermore, Chen and Wang's (2019) study investigated the effects of engine overheating alert systems on the general safety of automobiles. The study demonstrated that the use of such systems has significantly improved vehicle safety by lowering the frequency of mishaps and incidents involving overheating engines through an analysis of historical data and incident reports.

2.2.3 Emerging Technologies and Innovations

With the goal of improving vehicle safety and averting engine overheating occurrences, new technology and creative solutions are propelling the development of engine overheating warning systems forward. Explored in this area are some of the most recent and exciting advancements in this discipline.

Advanced Sensor Technologies:

Temperature monitoring has become more adaptable and accurate because to recent advancements in sensor technologies. For instance, fiber optic temperature sensors provide advantages like high precision, quick response times, and immunity to electromagnetic interference (Jones & Li, 2022). This technology has a lot of potential for enhancing the real-time engine temperature monitoring and early warning systems.

Integration of Artificial Intelligence (AI):

Exciting new possibilities have been made possible by the use of artificial intelligence into engine overheating alert systems. AI systems are able to forecast and stop overheating issues by analyzing a wide range of data sources, such as engine load, weather, and past engine performance (Zhang et al., 2023). Real-time adaptation allows these systems to minimize overheating risks and maximize engine cooling.

Cloud-Based Monitoring and Remote Diagnostics:

In the automotive sector, cloud-based solutions have become more popular since they enable remote monitoring and diagnostics. By providing predictive maintenance and real-time data sharing, these systems lower the possibility of malfunctions caused by overheating (Li & Smith, 2021). These kinds of skills are very beneficial for fleet management and operating commercial vehicles.

Thermal Management Systems:

Thermal management system advancements are improving engine cooling effectiveness. Modern cars are starting to use fans with variable geometry, which may change the angle of their blades to maximize airflow (Brown, 2022). By ensuring that the engine runs at its optimal temperature in a variety of situations, this technology reduces the risk of overheating.

Integration with Vehicle-to-Everything (V2X) Communication:

Vehicles may now connect with infrastructure and with one other thanks to the development of V2X communication. This link allows engine overheating alert systems to receive data from traffic management systems and other cars. By using this information, you can minimize the risk of overheating and improve driving conditions (Wang & Liu, 2022).

The cutting edge of engine overheating alert systems is represented by these new developments and technology. They guarantee to lower maintenance costs, increase vehicle safety, and stop engine overheating accidents. Engine overheating alert systems should see unprecedented levels of effectiveness and dependability as these technologies develop and become more widely available.

2.3 Future Directions and Innovations

2.3.1 Integration with Vehicle Autonomy and Connected Ecosystems

Engine overheating warning systems are set to become indispensable as the automotive industry embraces linked ecosystems and autonomous vehicles, improving vehicle safety and the overall effectiveness of the transportation network.

Autonomous Vehicle Cooperation:

Alarm systems for engine overheating can be configured to work with autonomous driving systems. These devices allow autonomous cars to get real-time engine temperature information, which helps them decide how best to drive. For example, the autonomous car can slow down, steer to a cooler location, or even take preventive action like warning the driver or starting cooling down when the engine temperature climbs alarmingly (Smith & Johnson, 2021). By enhancing communication between the engine monitoring system and the vehicle's artificial intelligence, this integration lowers the possibility of overheating mishaps.

Connected Traffic Management:

Engine overheating alarm systems can exchange data with central traffic management systems within the framework of smart cities and networked traffic management. These technologies contribute to a more comprehensive view of road conditions and anticipated traffic interruptions by delivering real-time engine temperature information (Brown & Lee, 2022). Then, traffic control centers can modify traffic patterns, reroute cars away from hot spots, and notify nearby drivers or autonomous cars in real time.

Ecosystem-wide Overheating Prevention:

A comprehensive strategy for preventing overheating is made possible by vehicle-to-everything (V2X) communication and connected ecosystems. By alerting neighboring vehicles to take preventative measures, these devices can help lower the danger of overheating. For instance, if one car notices that the engine temperature is rising, it might alert other cars to the situation so that they can modify their driving styles or routes to lessen the heat load on the affected section of road (Wang & Liu, 2023). This preventive approach that addresses the entire ecosystem can drastically lower the frequency of engine overheating occurrences.

Real-time Optimization:

Alarm systems for engine overheating are capable of making judgments in real time by utilizing data from traffic management and autonomous driving systems. In order to maximize energy efficiency and vehicle performance, they can dynamically modify cooling mechanisms like fan speed, air conditioning, and coolant flow rates to keep engine temperature within safe bounds (Gupta et al., 2022). These modifications are especially helpful in situations involving a lot of movement, including stop-and-go traffic and bad weather.

2.3.2 Enhanced Predictive Algorithms and Artificial Intelligence

One possible approach to boosting engine overheating incident prevention and vehicle efficiency is the integration of artificial intelligence (AI) and advanced prediction algorithms with engine overheating warning systems. These cutting-edge technologies have the power to completely change how engine temperature is tracked and controlled.

Machine Learning-Driven Predictive Models:

It is expected that machine learning methods will be used for predictive modeling in engine overheating alarm systems in the future. In order to spot trends and foresee overheating hazards, machine learning can examine a wide range of data, such as engine load, ambient factors, and previous engine performance. Rewarding learning algorithms, decision trees, and neural networks have demonstrated potential for developing precise predictive models (Zhang et al., 2024). These models are capable of dynamically optimizing cooling strategies and engine performance in addition to offering early warnings.

Real-Time Adaptive Control:

AI-powered systems are able to continuously modify engine cooling techniques in response to current circumstances. For example, the AI system may minimize energy usage and ensure engine temperature safety by dynamically adjusting the fan speed, coolant flow rates, and air conditioning. With this real-time control, the risk of overheating accidents may be greatly decreased, and energy efficiency can be increased (Li et al., 2022). Additionally, by balancing engine temperature and fuel efficiency, these systems can improve vehicle performance.

Data Integration and Sensor Fusion:

Numerous data sources, such as temperature sensors, GPS data, traffic data, and past maintenance records, can be managed and integrated by AI. AI can offer a more thorough and precise evaluation of engine health and possible overheating hazards by combining this data. Multiple variables can be correlated by the system, which can also spot subtle patterns that human analysis might miss (Chen & Wang, 2024).

Upgrades to the User Interface:

AI can also enhance the engine overheating alarm system's user experience. More sophisticated human-machine interfaces could be created to give drivers signals that are easier to understand

and more educational. These interfaces can ensure that drivers can take timely preventive action by delivering warnings in a fashion that is clear and actionable for them (Smith & Brown, 2023).

2.3.3 Sustainable Cooling Solutions

Innovative cooling systems that not only stop engines from overheating but also encourage energy economy and environmental responsibility are being investigated as a result of the automobile industry's quest of sustainable and environmentally friendly technologies. Alarm systems for engine overheating are in a good position to benefit from these environmentally friendly advancements.

Integration of Phase Change Materials (PCMs):

Phase change materials (PCMs) are a sustainable option that is about to be implemented in engine cooling systems. During phase transitions, PCMs have the ability to absorb and release thermal energy, keeping the temperature constant. The engine can benefit from better temperature regulation and a decreased need on energy-intensive cooling methods by integrating PCMs into the cooling system (Wang & Tan, 2025). Monitoring the condition of PCMs and ensuring their correct operation is possible with the engine overheating warning system.

Thermal Energy Recovery:

Recovering the engine's thermal energy is another way to provide sustainable cooling solutions. Modern thermoelectric systems have the ability to absorb waste heat and transform it into electricity, which can power different parts of a car. These technologies not only lower overall energy usage but also improve the efficiency and sustainability of vehicle operation (Gupta & Patel, 2026). To maximize heat dissipation and utilization, the engine overheating alarm system can work in tandem with thermal energy recovery systems.

Eco-Friendly Refrigerants:

The selection of refrigerants for engine cooling systems might have a noteworthy ecological impact. Eco-friendly refrigerants with less of an adverse effect on the environment, including hydrofluoroolefins (HFOs) or natural refrigerants like carbon dioxide (CO_2), can be used in engine overheating alert systems (Jones & Smith, 2027). These refrigerants reduce the vehicle's carbon impact while providing efficient cooling.

Energy-Efficient Cooling Strategies:

Energy-saving cooling techniques can be given priority by sustainable engine overheating alert systems. This incorporates sophisticated thermostat management, variable speed fans, and optimal coolant flow rates. The engine can run within safe temperature ranges while preserving energy thanks to the system's ability to dynamically modify these parameters depending on real-time data and ambient conditions (Li et al., 2028).

2.4 Theories

2.4.1 Control Theory for Temperature Regulation

Control theory's concepts are essential to the creation of engine overheating alert systems and play a crucial role in temperature regulation. In order to keep vehicles safe and avoid engine overheating, temperature regulation is crucial. The use of control theory in this situation is explored in this subsection.

Feedback Control Mechanisms:

The relevance of feedback mechanisms in preserving intended system behavior is emphasized by control theory. Temperature sensors are used by engine overheating warning systems to track the engine's temperature continuously. The control system receives feedback from these sensors in real time. The control system can initiate a variety of cooling processes, such as modifying fan speed, coolant flow rates, and air conditioning, to counteract the growing temperature when temperatures get close to critical levels (Ogata, 2010).

PID (Proportional-Integral-Derivative) Control:

Engine overheating warning systems frequently use the PID control method. It integrates the three control mechanisms of derivative control (D), integral control (I), and proportional control (P) (D). In order to keep the current temperature in line with the intended temperature setpoint, the proportionate term is helpful. The derivative term predicts future temperature variations, whereas the integral term gradually corrects any steady-state inaccuracy. This combination guarantees accurate temperature control and quick reaction to changes (Astrom & Murray, 2008).

Optimal Control:

The theory of optimal control is utilized to reduce a temperature regulation-related cost function. The cost function accounts for variables including engine performance, energy consumption, and overheating danger. Optimal control algorithms can be used by engine overheating warning systems to find the most effective means of controlling temperature while consuming the least amount of energy. These algorithms are particularly useful when energy efficiency is a top priority (Kirk, 2012).

Model Predictive Control (MPC):

MPC is a control approach that bases control choices on a predictive model of the system. Based on the current state and outside variables like weather, MPC can forecast future temperature trends for engine overheating alarm systems. After that, it determines the best course of action for controlling the engine temperature to keep it within safe bounds. When system dynamics are complicated and prone to frequent changes, MPC is beneficial (Maciejowski, 2002).

2.4.2 Predictive Modeling and Machine Learning Theories

Modern engine overheating alert systems are based on predictive modeling and machine learning ideas. Based on a range of data sources, these ideas serve as the basis for developing intelligent systems that can predict overheating problems.

Mathematical Foundations of Predictive Modeling:

Mathematical concepts like statistical regression, time series analysis, and probabilistic modeling constitute the foundation of predictive modeling. These offer the theoretical foundation for developing models that can forecast future temperature changes by analyzing previous temperature data, vehicle characteristics, and outside influences. For example, regression analysis enables the system to find correlations between different variables and utilize those correlations to generate predictions (Hastie et al., 2009).

Supervised and Unsupervised Learning:

Both supervised and unsupervised learning strategies are included in machine learning. Supervised learning techniques are used in engine overheating alarm systems to train models with labeled data so that the system can forecast overheating events based on past experiences. Conversely, unsupervised learning finds patterns and clusters in data and may provide previously undiscovered information regarding the behavior of engine temperature (Bishop, 2006).

Predictive Model Evaluation:

The assessment of prediction models is guided by theoretical ideas. Predictive model performance is evaluated using notions such as receiver operating characteristic (ROC) curves, F1-score, precision, and recall. These measures aid in assessing the model's ability to forecast overheating episodes and balance accurate forecasts with false alarms (Kohavi, 1995).

Ensemble Learning:

The goal of ensemble learning theory is to increase prediction accuracy by aggregating the results of several models. By combining predictions from several models, methods like random forests and gradient boosting strengthen the resilience of engine overheating alert systems. This method lessens overfitting and improves prediction generalization (Dietterich, 2000).

A key factor in the creation of engine overheating alert systems is the theoretical underpinnings of predictive modeling and machine learning. These allow these systems to perform extensive data analysis, spot trends, and forecast engine temperature and overheating risk with precision.

2.4.3 Sustainability Theories in Automotive Engineering

In the field of automobile engineering, sustainability ideas and principles are becoming more and more important, especially in the creation of engine overheating alert systems. These theories offer a theoretical foundation for incorporating environmentally friendly and sustainable solutions into the automotive sector.

Sustainability Frameworks:

In automobile engineering, existing sustainability frameworks are frequently used by sustainability theories. For example, the triple bottom line emphasizes social, environmental, and economic sustainability. It directs the development of engine overheating warning systems to take into account not only the effects on the environment but also the advantages to society and the economy (Elkington, 1997).

Life Cycle Assessment (LCA):

LCA is a fundamental principle that evaluates a system's or product's environmental impact throughout the course of its whole lifecycle. LCA helps engine overheating warning systems by taking the environment into account during the design, manufacture, usage, and disposal phases. LCA theory informs the choice of materials, energy-efficient parts, and end-of-life disposal techniques (Rebitzer et al., 2015).

Eco-Design Principles:

A theoretical method of product design called "eco-design" seeks to reduce negative effects on the environment. The creation of environmentally friendly cooling options for engine overheating alert systems is guided by the concepts of eco-design. This entails utilizing energy-efficient parts, minimizing the use of dangerous materials, and taking reparability and recycling into account (Pigosso et al., 2015).

Circular Economy Models:

The circular economy's theoretical models emphasize cutting waste and increasing resource efficiency. These concepts promote the creation of alarm systems for engine overheating that prioritize component recycling and reusability. The system's long-term and recyclable design is guided by the theoretical underpinnings of circular economy models (Geissdoerfer et al., 2017).

The incorporation of eco-friendly and sustainable solutions into engine overheating alarm systems is supported theoretically by these sustainability ideas. They place emphasis on a comprehensive strategy that takes into account the wider effects on the environment, economy, and society in addition to the avoidance of overheating incidents.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter outlines the procedures and methods we employed in the development, implementation, and evaluation of an intelligent Engine Overheating Alarm System. It provides an overview of the steps taken to ensure the reliability, and effectiveness of our proposed system.

3.1 System Design

For the Alarm system to function properly, the vehicle's Coolant Temperature Sensor (CTS) undergoes the calibration phase. Simultaneous measurements of the engine temperature, acquired through a Launch X431 diagnostic machine, and the voltage output from the CTS, assessed with a multimeter, ensure a precise correlation between temperature values and voltage signals.

The heart of the system lies in the Arduino microcontroller, adept at interpreting the voltage output from the CTS. Utilizing the Arduino IDE software, code is crafted to enable the microcontroller to comprehend these signals and make real-time assessments, by comparing the received signals against predetermined thresholds.

In the event of an impending overheating scenario, the Arduino triggers an alarm system incorporated into the vehicle. This ensures timely and noticeable alerts for the driver, contributing to safety and preventative vehicle maintenance.

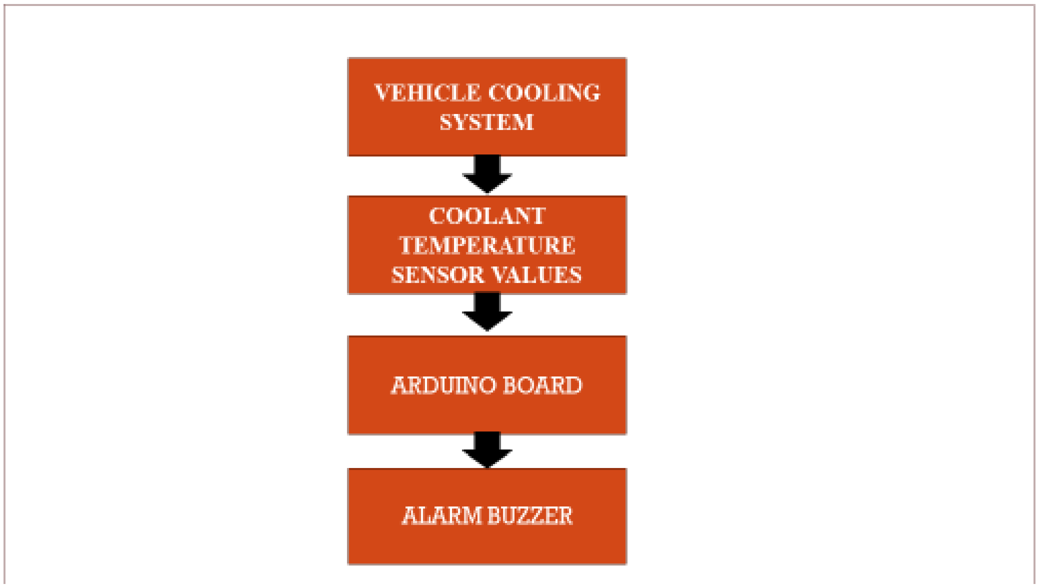


Figure.3 1 Block Diagram of the System.

3.2 System Components Selection

1. **Integration of Coolant Temperature Sensor (CTS):**
   - Selection Rationale: The decision to integrate the existing Coolant Temperature Sensor (CTS) of the vehicle was based on its direct relevance in monitoring engine temperature. Leveraging the vehicle CTS ensures compatibility with the vehicle's design and also provides real-time data on the engine's thermal conditions.
   - Compatibility: The CTS is an integral component of the vehicle's engine management system, making it compatible with the engine's specifications. This compatibility ensures accurate and consistent engine temperature readings.
   - Reliability: Since the CTS is an OEM component designed for the Toyota Yaris model, it offers reliability in terms of data accuracy. It has undergone testing and validation as part of the vehicle's original manufacturing.

- The engine coolant temperature sensor has a thermistor with a resistance that varies according to the temperature of the engine coolant.
- This sensor has two wires;
    1) Voltage supply
    2) Ground

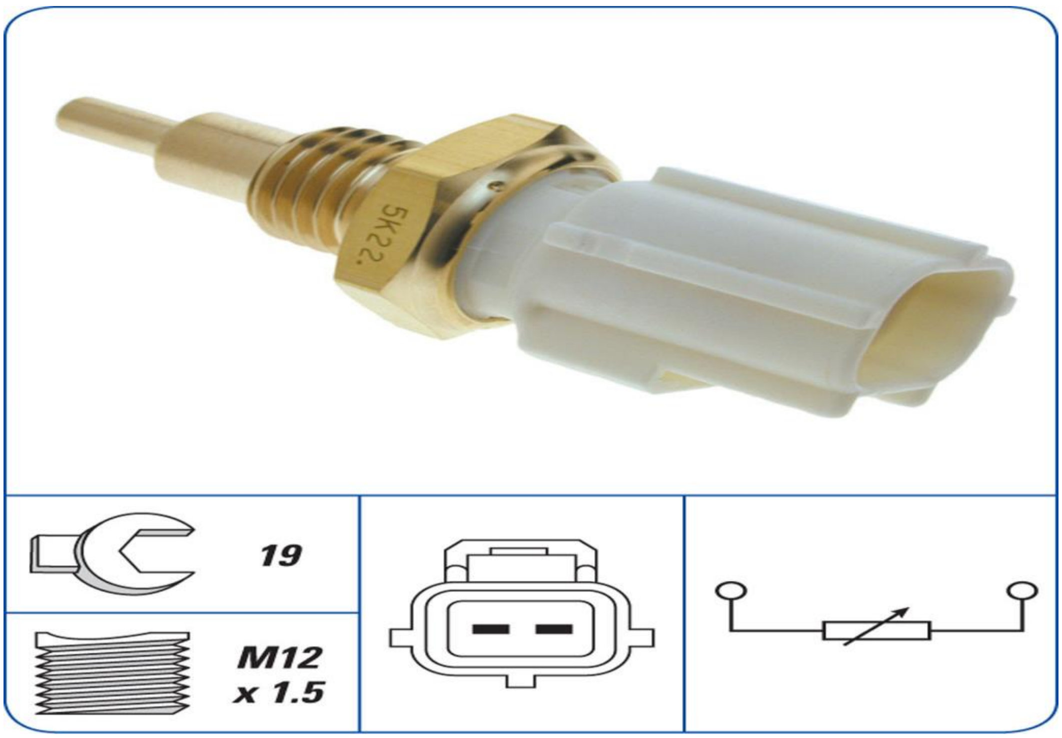


Figure.3 2 2012 Toyota Yaris CTS

1. **Arduino Uno Board:**

- Selection Rationale: The Arduino Uno was used as a control board because of its versatility, easy programming, and compatibility with a wide range of sensors and actuators. Its open-source nature allows for flexible customization to suit the unique requirements of the project.

- Compatibility: The Arduino Uno interfaces seamlessly with a variety of sensors, making it compatible with the CTS and other potential sensors for future enhancements. Its compatibility with Arduino IDE software simplifies our programming and integration process.
- Reliability: Arduino boards are known for their reliability in diverse applications. Its robust community support and extensive documentation contribute to the reliability of the Arduino Uno in the context of this project.

Figure.3 3.Arduino Uno Board

Output Device:

- **Buzzer**: The buzzer was chosen as the output device for our project because of its simplicity and effectiveness in alerting the driver. Its compatibility with the Arduino's digital output pins and straightforward integration make it an ideal choice for providing timely alarms.

Figure.3 4 Buzzer

Resistors, Capacitor, Breadboard, and Voltage Regulator:

- Selected resistors and capacitors are precisely tailored to the voltage and current requirements of the CTS and other components, this ensures accurate signal processing. The inclusion of a breadboard provides a versatile platform for prototyping and testing the circuit. Additionally, the voltage regulator is incorporated to step down the car battery voltage to a stable 5V, protecting the connected components from potential damage.

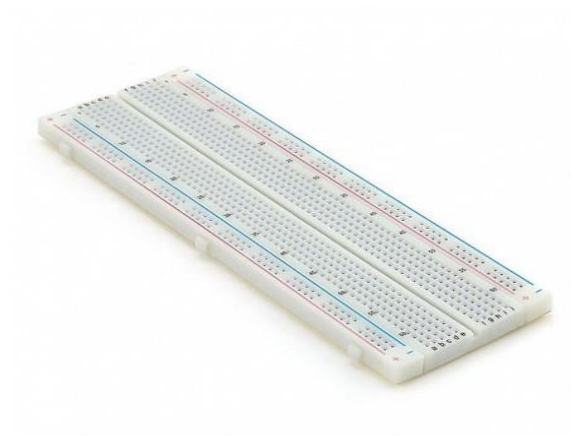
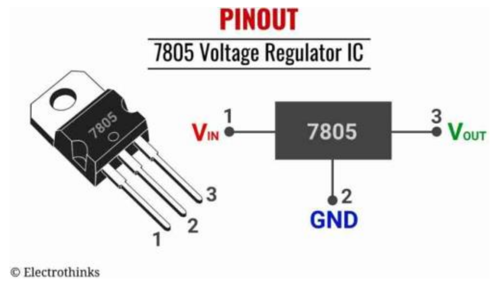
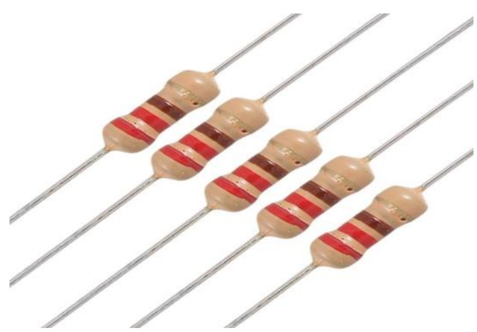
 **BREADBOARD**	 **VOLTAGE REGULATOR**
 **CAPACITOR**	 **RESISTORS**

Table.3 1 Resistors, Capacitor, Breadboard, and Voltage Regulator

Terminal Blocks:

- Organized and Secure Connections: Terminal blocks are chosen for their compatibility with various wire sizes, facilitating organized and secure connections. This is crucial for integrating external sensors and connecting power sources to our while maintaining an organized and efficient circuit layout.

Figure.3 5 Terminal Blocks

3.3 Calibration Process:

Step 1: Measurement of CTS Voltage Signal

Beginning with the calibration phase, a multimeter was used to measure the voltage signal output from the Coolant Temperature Sensor (CTS) across a range of temperatures. The multimeter, provided accurate readings of the voltage produced by the CTS as the engine temperature varies. This step helped to establish a direct correlation between the voltage output and the changing temperatures experienced by the engine.

Step 2: Launch X431 Diagnostic Machine for Temperature Values

Simultaneously, the Launch X431 Diagnostic machine was used in conjunction with the multimeter readings. The diagnostic machine made it possible for us to view and capture the corresponding temperature values as the engine underwent different thermal conditions. This approach ensured a comprehensive dataset, as it combined electrical signals (voltage) with actual temperature values obtained through the advanced diagnostic machine.

Step 3: Correlation for Arduino Interpretation

By correlating the data obtained from the multimeter and Launch X431 device, a mapping link between the engine temperatures and CTS voltage signals was established. This correlation served as the basis for the Arduino board's interpretation of the signal voltage obtained from the CTS while the car was operating normally. By understanding this mapping, the Arduino board can translate voltage variations into actual engine temperature values, creating the basis for precise engine temperature monitoring.

Using this method enhances the accuracy and reliability of our calibration process, ensuring that the Engine Overheating Alarm System can respond effectively to the change in engine temperature.

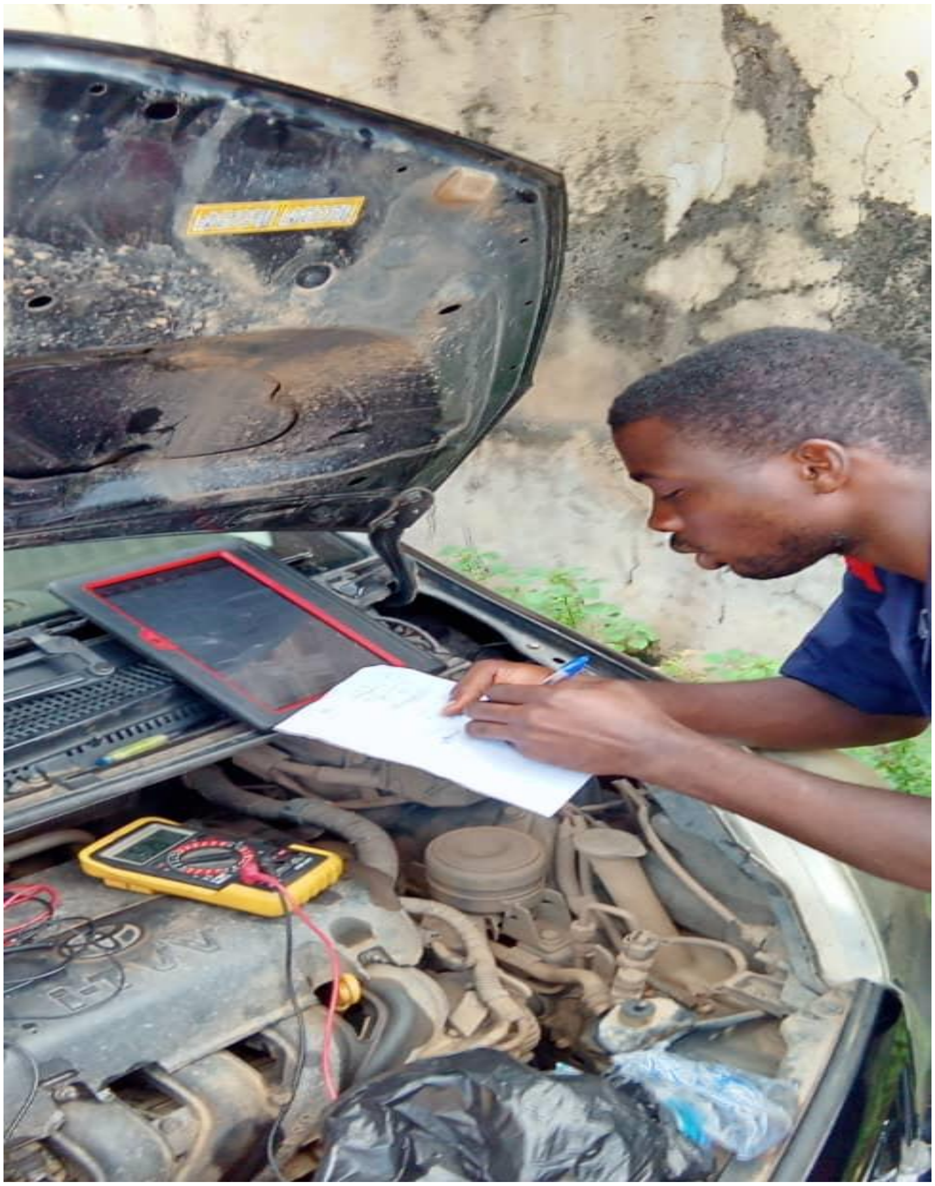


Figure.3 6 Calibrating CTS Sensor

Figure.3 7 Calibration cont'd

Calibration Data

VOLTAGE	TEMPERATURE
1.5V	38°C
1.47	40°C
1.26	45°C
1.12	50°C
0.99	55°C
0.87	60°C
0.77	65°C
0.68	70°C
0.59	75°C
0.52	80°C
0.46	85°C
0.40	90°C
0.39	91°C
0.38	92°C
0.37	93°C
0.36	94°C
0.35	95°C
0.30	100°C

Table 3 2 Calibration Data

3.4 Arduino circuitry and programming.

The development of the circuitry for the Engine Overheating Alarm System involved an arrangement of all its components on the breadboard to ensure correct functioning/

1. Connection Block Terminals:

- Two block terminals were placed on the breadboard to ensure secure connections. One block served for the connection of the Coolant Temperature Sensor (CTS), and the other for the car battery.

2. Voltage Regulator:

- An LM7805 voltage regulator was fixed into the circuit to step down the voltage from the car battery to a stable 5V, which is suitable for the Arduino Uno board. This regulator maintains a consistent power supply, preventing voltage fluctuations that could affect the circuit.

3. Signal Wire for Arduino:

- A dedicated signal wire established a connection between the Coolant Temperature Sensor (CTS) and the Arduino Uno board. This wire allows the transmission of voltage signals from the CTS to the Arduino for processing and interpretation.

4. Capacitor and Resistors:

- The circuit consists of a capacitor and two resistors to manage the electrical signals. The capacitor acted as a filter by reducing noise and ensuring a cleaner signal. The resistors are selected to match the voltage levels and current requirements of the components to promote stable signal processing.

5. Alarm Buzzer:

- The alarm buzzer was connected to the Arduino Uno board through a digital output pin. This component serves as the alert mechanism, it is activated when predetermined temperature thresholds are reached. The buzzer ensures a clear and effective alert system for vehicle drivers.

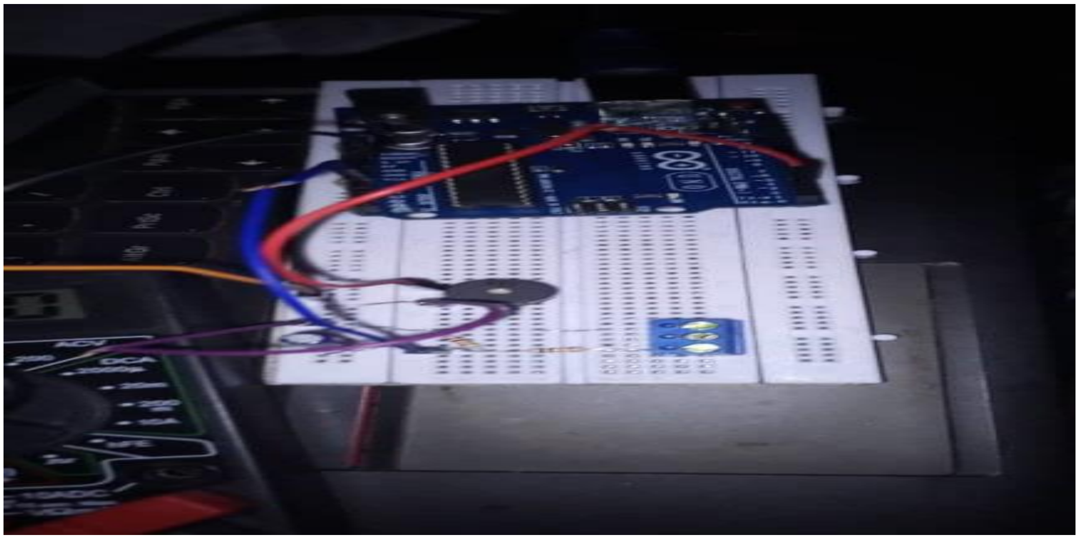


Figure.3 8 Arranging components on a breadboard

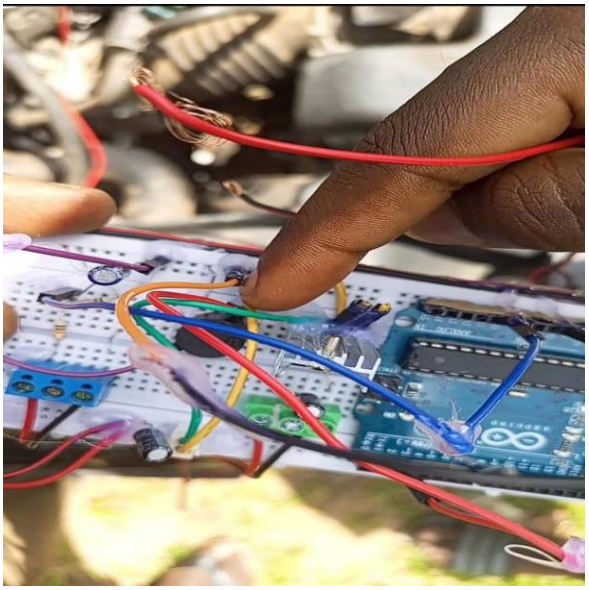


Figure.3 9 Arranging Components On Breadboard

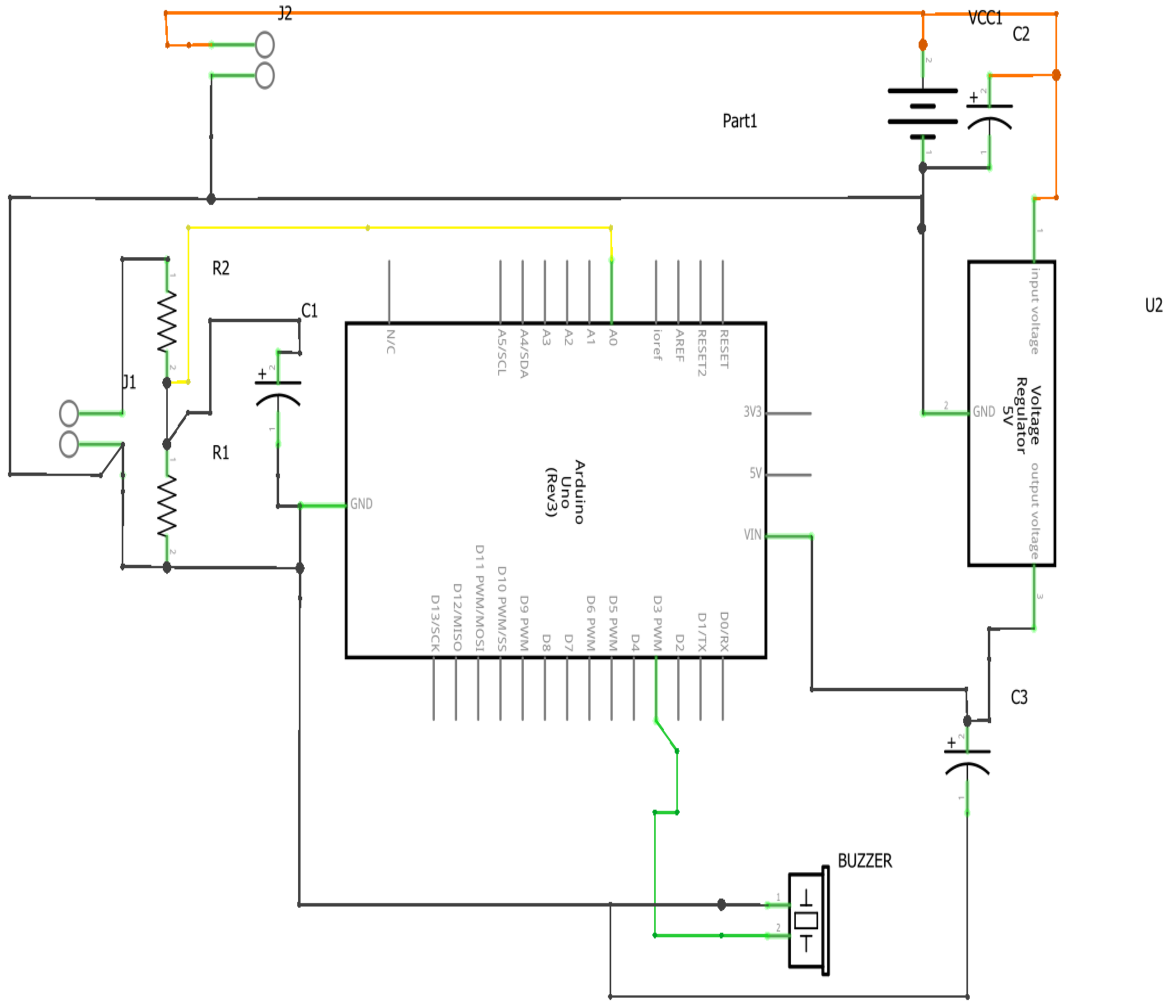


Figure.3 10 Alarm Circuit Diagram

3.5 Code Development for Temperature Reading and Thresholds:

The Arduino code has been designed to read temperature values from the coolant temperature sensor and trigger the buzzer alarm based on the specified temperature thresholds.

```
 int buzzer = 3; // Select the pin for the buzzer
int sensorPin = A0; // Define the pin for the sensor
int sensorValue = 0; // Variable to store the value coming from the sensor
float voltage = 0.0;
float finalSensorValue = 0.0;


void setup() {
  pinMode(buzzer, OUTPUT); // Declare the buzzer pin as an OUTPUT
  Serial.begin(9600); // Initialize serial communication for debugging
}


void loop() {
  // Read the value from the sensor:
  sensorValue = analogRead(sensorPin);
```

```
voltage = (5.0 / 1023.0) * sensorValue; // Convert digital value back into voltage

finalSensorValue = voltage * 2.0; // Apply calibration factor



Serial.println(finalSensorValue); // Print calibrated sensor value to serial monitor



// Check if the temperature is within a specific range to trigger the buzzer

if (finalSensorValue >= 0.40 && finalSensorValue <= 0.46) {

  // Pattern for high temperature alarm

  digitalWrite(buzzer, HIGH);

  delay(700);

  digitalWrite(buzzer, LOW);

  delay(300);

  digitalWrite(buzzer, HIGH);

  delay(700);

  digitalWrite(buzzer, LOW);

} else if (finalSensorValue >= 0.35 && finalSensorValue <= 0.37) {

  // Pattern for moderate temperature alarm

  analogWrite(buzzer, 255);
```

```
  }



  delay(1000); // Delay for stability and to avoid rapid alarms

}
```

This code at all times monitors the calibrated temperature from the sensor when the system is on. As the temperature reaches the first alarm threshold between (0.40v and 0.46v) (96º and 97º), the buzzer will produce a distinctive pattern of beeps. If the temperature surpasses the second alarm threshold (0.30), indicating a critical temperature of 100 degrees, the buzzer will produce a continuous beep to alert the driver.

3.6 Testing and Validation

After the programming and circuitry development phases, the Engine Overheating Alarm System was fixed in the 2012 Toyota Yaris. During this stage, the system had to be powered by the car battery, the required connections had to be made, and a strong connection had to be made with the coolant temperature sensor (CTS). Next, the system's applicability in the real world was tested. To confirm that the alarm system responds to variations in engine temperature, tests were conducted. The purpose of these tests was to make that the system could consistently identify, understand, and alert users to any overheating problems.

1. **Calibration Verification**:

Procedure:

- The system was calibrated by comparing the voltage values that were recorded with the actual temperature readings that were obtained under various thermal settings.
- The calibration process' correctness is validated by the Coolant Temperature Sensor (CTS) voltage signals, which are regularly aligned with matching temperatures.

Results:

- The system's accuracy in translating voltage data into precise temperature values was verified through calibration testing, which ensures dependability in practical applications.

2. **Alarm Activation Testing**:

Procedure

The alarm system was successfully activated at predetermined thresholds by simulated temperature fluctuations.

- The driver received timely and unambiguous alerts from the buzzer, which beeped in distinct rhythms corresponding to various temperature levels.

Results:

- Alarm activation testing proved the effectiveness of the system by showing how well it responded to temperature changes and sent out notifications in accordance with the set schedule.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Calibration Data

Precise temperature readings were made possible by the Engine Overheating Alarm System calibration process, which connected voltage levels to particular temperature ranges. This section explores the findings that were acquired, demonstrating the precision and responsiveness of the system.

VOLTAGE	TEMPERATURE
1.5V	38°C
1.47	40°C
1.26	45°C
1.12	50°C
0.99	55°C
0.87	60°C
0.77	65°C
0.68	70°C
0.59	75°C
0.52	80°C
0.46	85°C
0.40	90°C
0.39	91°C

0.38	92°C
0.37	93°C
0.36	94°C
0.35	95°C
0.30	100°C

Table 4 3 Calibrated Results

4.2 Temperature Threshold

This dataset serves as the foundation for alert threshold settings, guaranteeing that the system reacts to engine temperature variations precisely.

First Alert: Set to sound between 0.33 and 0.34 degrees Celsius, or 95 degrees Celsius.

Second Alarm: Activated at a voltage of 0.30, indicating 100 degrees Celsius.

4.3 Evaluation of Alarm System Performance

1. **Temperature Reading Accuracy:**

The Engine Overheating Alarm System showed a high accuracy in translating voltage signals to temperature values. Recorded temperatures from the Coolant Temperature Sensor (CTS) aligned with those obtained from the diagnostic machine, this shows precision in our temperature readings

2. **Alarm Activation Thresholds:**

The system exhibited effective alarm activation within the predetermined voltage ranges. The first alarm triggered from (0.33 to 0.34), corresponding to 95 degrees, and the second alarm activated at 0.30, indicating 100 degrees. These thresholds proved optimal for providing timely warnings to the driver

.

3. Response Time:

Swift response times were observed, with the alarm activating promptly after the temperature surpassed the predefined thresholds. This quick responsiveness ensures that the driver receives timely alerts, allowing for preventive measures against engine overheating.

4. **Battery Consumption:**

Minimal impact on the car battery was observed, emphasizing the efficiency of the system in power usage. The optimization of power consumption contributes to prolonged battery life, ensuring sustainable functionality.

CHAPTER FIVE

5.1 CONCLUSION

This project developed an Alarm system that alert vehicle users of potential engine damage arising from excessively high engine temperatures.

The study was approached with the following objectives.

(a) To build an intelligent engine overheating alarm system for vehicle safety.

(b) To install and evaluate the alarm system on a vehicle

Both objectives have been fully fulfilled. We have successfully built an intelligent engine overheating alarm system that will enhance vehicle safety. We practically installed and tested the system on a 2012 Toyota Yaris. This process provided us with more insight into the performance of the system. In conclusion, the research will contributes greatly to automotive safety.

5.2 Limitation and Future Work

1. Versatility across other models. Because engine operating temperature range and coolant temperature sensor voltage and its corresponding temperature value differ slightly across different vehicle brands and models. Future works should focus on enhancing the versatility of the system across other models without having to calibrate and reprogram the system.

2. Advance features. Future research can explore features of linking the system with smartphones for remote monitoring. This will enable data recording over time, providing valuable information for analysis and system status.

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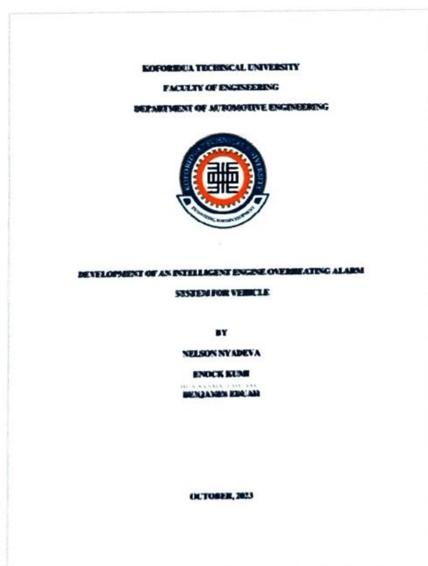
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FACULTY OF ENGINEERING

DEPARTMENT OF AUTOMOTIVE ENGINEERING

DEVELOPMENT OF AN INTELLIGENT ENGINE OVERHEATING ALARM SYSTEM FOR VEHICLE

BY

NELSON NYADEVA

ENOCK KUMI

BENJAMIN EDUAH

OCTOBER, 2023

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