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PCB-BASED DIGITAL THERMOMETER DESIGN WITH 7-SEGMENT DISPLAY FOR ACCURATE TEMPERATURE MONITORING

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Abstract—
This project involves designing a PCB for a temperature-based protection system that uses an LM35 temperature sensor to monitor a circuit's thermal conditions. The LM35 provides real-time temperature data, which is processed to detect any abnormal rise in temperature. When the temperature exceeds a predefined threshold, the system automatically activates a relay to disconnect the circuit, effectively tripping it to prevent overheating. This design is compact, reliable, and helps protect sensitive electronic and electrical components by ensuring safe operating conditions. It is applicable in environments where temperature control is essential for circuit longevity and stability.

Keywords—
Temperature sensor LM-35,7-segment display, Overheat protection

INTRODUCTION:

This project is centred around the design and implementation of a temperature-based protection system using a printed circuit board (PCB). At the heart of this system is the LM35 temperature sensor, which provides accurate and real-time monitoring of a circuit's thermal conditions. The LM35 is known for its precision and reliability, making it a suitable choice for applications where temperature sensitivity is critical.

The system operates by continuously monitoring the temperature of the circuit. When the temperature rises and crosses a predefined safety threshold, it identifies the abnormal condition. In response, the system triggers a relay to disconnect the circuit, effectively shutting it down to prevent further heating. This mechanism serves as a safeguard against overheating, which. could otherwise lead to damage or failure of sensitive components.

This temperature-based protection system is designed to be compact and efficient, ensuring that it can be easily integrated into various environments. Its primary purpose is to maintain the safe operating conditions of electronic and electrical circuits, thereby extending their lifespan and ensuring consistent performance. The system is particularly valuable in environments where temperature regulation is essential, such as in industrial settings, electronic devices, and systems where overheating poses a significant risk.

By implementing this design, users can achieve a reliable solution for protecting their circuits from thermal stress. The combination of real-time monitoring, automated response, and the use of the LM35 sensor ensures that the system delivers both precision and reliability, making it a versatile and essential tool for circuit protection.

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In addition to its core functionality, this temperature-based1)ARDUINO UNO

The Arduino Uno is a versatile and beginner-friendly microcontroller board based on the ATmega328P, widely used for electronics projects, prototyping, and educational purposes. It offers a range of features, including 14 digital input/output pins (with 6 supporting PWM), 6 analog input pins, and an easy-to-use interface for connecting various sensors, actuators, and peripherals. The board is programmed through the Arduino IDE using a simple C/C++-based language, making it accessible to both novice and experienced developers. Powered through USB or an external supply, the Arduino Uno provides flexibility in various applications, from simple circuit designs to more complex systems. Its compatibility with a wide range of shields and modules expands its potential, enabling projects in areas such as motor control, wireless communication, and Internet of Things (IoT) devices. With a large, active global community, extensive online resources, and continuous support, the Arduino Uno has become the go-to platform for learning, experimenting, and developing innovative solutions across industries, making it a foundational tool for both hobbyists and professionals alike.

2) LM-35 TEMPERATURE SENSOR

The LM35 is a highly accurate and reliable precision temperature sensor, commonly used for measuring ambient temperature across a wide variety of electronic applications. This sensor outputs a voltage directly proportional to the temperature in degrees Celsius, with a linear scale factor of 10 mV/°C, making it easy to interface with microcontrollers and analog-to-digital converters (ADC). One of its key advantages is that it requires no external calibration, providing a high level of convenience for users. The LM35 offers an impressive accuracy of ±0.5°C at room temperature, ensuring precise readings in everyday use. Its operating temperature range spans from -55°C to +150°C, allowing it to function effectively in diverse environments, from freezing cold conditions to high-heat industrial settings. Moreover, the LM35 is designed with low power consumption, making it ideal for battery-operated systems or power-sensitive applications. Its compact size and straightforward integration make it an excellent choice for a variety of projects, including industrial automation, consumer electronics, and educational kits, where real-time, precise temperature monitoring is essential. Whether used in temperature control systems, weather stations, or medical devices, the LM35 stands out as a versatile and efficient sensor for accurate temperature measurement.

3)7-SEGMENT DISPLAY

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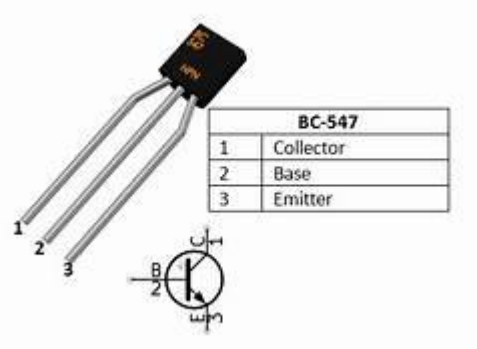
A 7-segment display is a widely used electronic display device for representing numeric data in digital form, commonly seen in applications ranging from clocks to calculators and electronic meters. The display consists of seven individual LED segments arranged in a figure-eight pattern, which can be selectively lit to form any number from 0 to 9. Additionally, some displays come with a decimal point for applications requiring fractional numbers. Available in both common cathode and common anode configurations, these displays can be easily interfaced with microcontrollers, making them ideal for embedded systems. The flexibility in configuration allows for straightforward integration into various digital designs, whether for simple educational projects or more complex consumer devices. The 7-segment display's simplicity, low power consumption, and high readability make it an excellent choice for applications where numeric information needs to be clearly presented to users. It is especially suitable for devices requiring a compact, energy-efficient solution for displaying numerical data in real-time. The widespread availability and ease of use make the 7-segment display a go-to component for a range of electronic projects, both for hobbyists and professionals alike.

4)RELAY SPDT

A Single Pole Double Throw (SPDT) **relay** is an electromechanical switch with one input (pole) and two output terminals (throws), allowing it to connect a common terminal to one of two other terminals. It operates by energizing a coil that moves an internal switch mechanism, toggling between the two throws. SPDT relays are versatile components used in applications such as switching between two circuits, controlling devices, and enabling logic functions in electrical systems. Their ability to handle different voltage levels and currents makes them suitable for automotive, industrial, and home automation purposes

5)MOSFET BC547



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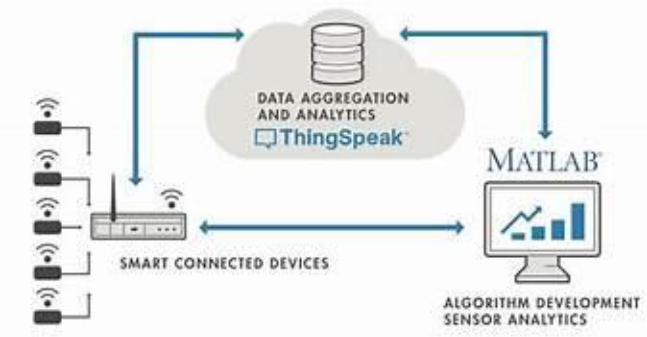
The BC547 is a versatile and widely used NPN bipolar junction transistor (BJT) that operates at low power and is primarily designed for general-purpose amplification and switching in electronic circuits. It features three terminals: the collector, base, and emitter. The transistor works by allowing a small current to flow into the base terminal, which then enables a larger current to flow between the collector and emitter, effectively amplifying the signal. Due to its ability to handle low currents and its efficient switching characteristics, the BC547 is an ideal choice for low-power applications, including audio amplifiers, LED drivers, signal processing circuits, and other simple switching tasks. Its reliability, affordability, and ease of integration make it a popular component in a wide range of electronic projects, from hobbyist designs to commercial products. The BC547 also offers moderate gain, making it suitable for low-frequency amplification and low-voltage circuits. Its robustness in basic electronic tasks, combined with its small size and low cost, contributes to its widespread use in numerous everyday applications6)KICAD SOFTWARE

KiCad is an open-source, powerful electronic design automation (EDA) software suite used for designing printed circuit boards (PCBs) and creating schematic diagrams. It provides a comprehensive set of tools for both beginners and professionals, offering everything from schematic capture and PCB layout to 3D visualization and manufacturing output generation. KiCad supports multi-layer PCB design, component libraries, and a wide range of import/export options for file compatibility. The user interface is intuitive, making it easy to place components, route traces, and define board layers. Additionally, KiCad features advanced capabilities like auto-routing, interactive PCB layout editing, and electrical rule checking, which help ensure design accuracy. With a large and active user community, KiCad is constantly updated with new features and improvements, making it a highly reliable and accessible choice for PCB designers across various industries, from hobbyist projects to professional-grade circuit boards. Its open-source nature means it's freely available, fostering a collaborative environment where users can contribute to the development of the software and share their design libraries.

7)THINGSPEAK



ThingSpeak is an open-source Internet of Things (IoT) platform that enables users to collect, analyze, and visualize data from connected devices over the internet. It provides a cloud-based infrastructure for IoT projects, allowing users to easily store and retrieve sensor data, control devices, and perform real-time analytics. ThingSpeak integrates seamlessly with hardware platforms like Arduino, Raspberry Pi, and ESP8266, making it a popular choice for IoT applications. Through its user-friendly interface, users can create channels to store data, configure triggers for alerts, and display the data through customizable visualizations like graphs, charts, and dashboards. ThingSpeak also supports

Industrial Engineering Journal
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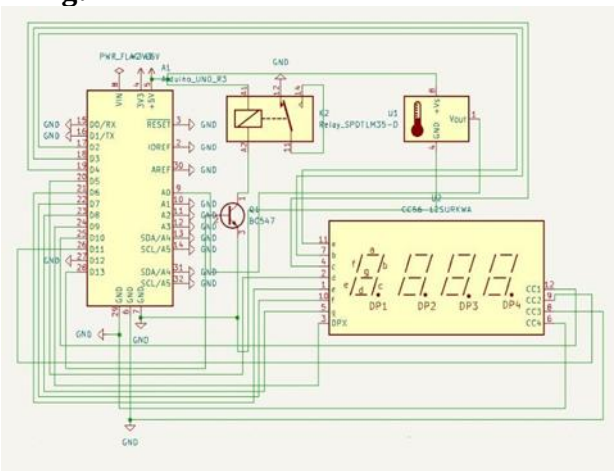
Volume : 54, Issue 2, No.4, February : 2025

MATLAB integration for advanced data analysis and algorithm development, making it ideal for both simple and complex IoT projects. With features such as easy data logging, cloud connectivity, and integration with other services like Twitter or email, ThingSpeak allows developers to monitor and control their devices remotely, making it a go-to solution for building IoT-based systems for industries, research, and personal projects. The platform's open-source nature encourages collaboration and innovation within the IoT community.

Schematic diagram & working:



The PCB uses a temperature sensor, such as an LM35, to continuously monitor the temperature of the connected circuit. The sensor generates a signal proportional to the measured temperature. This signal is fed into a microcontroller, which reads the sensor's output and compares it to a predefined threshold value stored in its program. If the temperature remains below the threshold, the microcontroller keeps the relay in its default position, allowing the connected circuit to operate normally.

When the temperature exceeds the threshold value, the microcontroller sends a signal to trigger the relay, cutting off power to the connected circuit to prevent overheating or potential damage. The relay acts as a switch, breaking the circuit connection safely and effectively. An optional LED or buzzer can be integrated into the PCB to provide a visual or audible alert when the threshold is exceeded. This design ensures real-time temperature monitoring and automatic circuit protection, making it ideal for applications where temperature control is critical.

Block Diagram Explanation:

This system utilizes an Arduino Uno to efficiently monitor temperature using the LM35 temperature sensor and displays the readings on a 7-segment display. The LM35 generates an analog voltage output that corresponds to the temperature, and the Arduino processes this data, converting it to a readable format and displaying it on the 7-segment display. When the temperature exceeds a predefined threshold, the Arduino activates a Single Pole Double Throw (SPDT) relay through a BC547 transistor (acting as a switch), allowing it to control low-voltage devices such as fans, heaters, or other automation systems.The relay functions by switching ON or OFF the connected device based on the temperature conditions, ensuring temperature-based automation. This is particularly useful in scenarios like controlling a fan to cool down a room when it gets too hot, or activating a heater when the temperature drops below a set value. The BC547 transistor amplifies the control signal from the Arduino to trigger the relay, enabling it to handle the higher currents required by the connected devices, while the microcontroller ensures the system remains safe and responsive. This system provides an easy-to-implement solution for temperature-controlled automation, ideal for home appliances, industrial applications, or energy-saving solutions.

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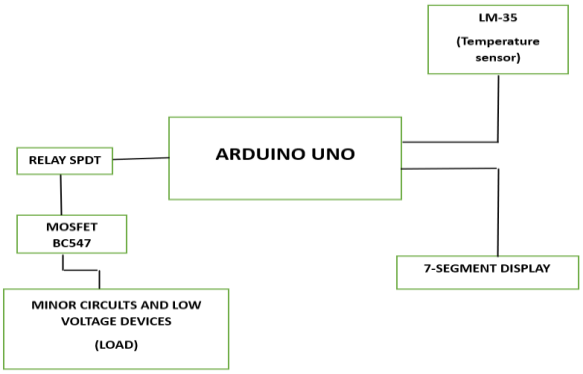
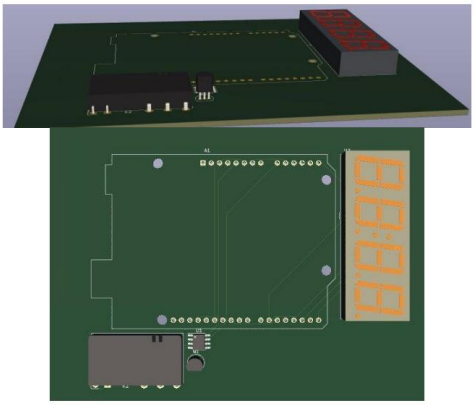


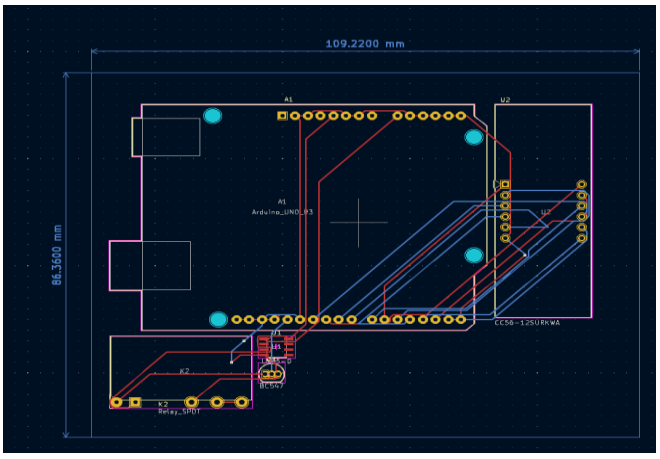
Block architecture of Digital thermometer with 7-segment display.

3D VIEW PCB BOARD



3D View of PCB in KICAD software.

OUTPUT:



The above Figure shows the actual routing of the PCB.

This image appears to depict a PCB layout design created using kiCAD software, specifically tailored for a project involving an Arduino-based system. The layout showcases various features, including mounting holes for securing the board within an enclosure, and traces represented by red and blue lines, which correspond to different layers of the PCB. These traces connect the components and form the electrical pathways that enable the circuit to function properly. The presence of through-hole and surface-mount components indicates careful consideration of component placement for ease of assembly and optimal performance. The Arduino footprint is prominently visible, suggesting that this

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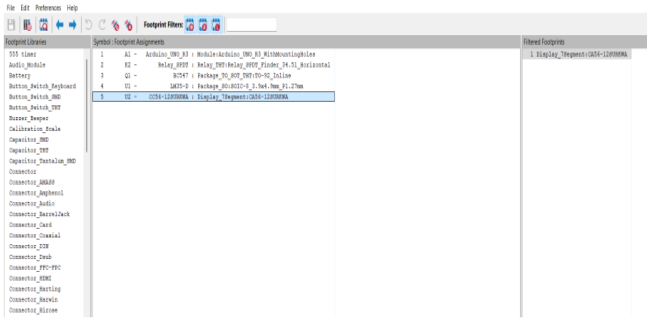
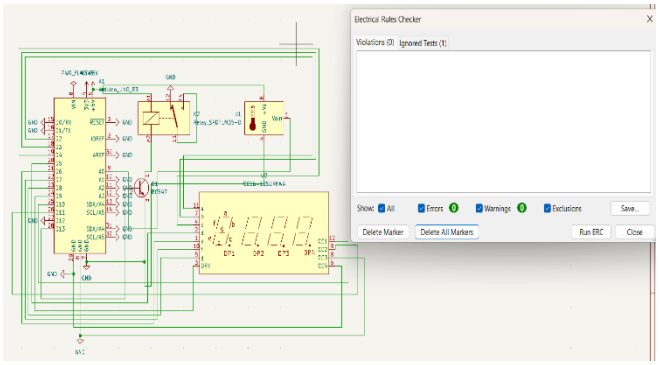
board is designed to either integrate with an existing Arduino board or function as a custom shield or expansion board. The design also includes connections for external modules, such as sensors, relays, or displays, indicating the board's potential to interface with various peripherals, providing greater flexibility in applications like automation, monitoring systems, or embedded projects.The dimensions of the PCB, 109.22 mm × 84.33 mm, suggest a compact design, likely intended to fit within a standard housing or enclosure, which is common for custom shields or standalone systems. This layout ensures that all components are neatly arranged, minimizing space while maintaining accessibility for external connections, making it an ideal design for a wide range of Arduino-based projects.



Here assigning the footprints in kicad simulation.



Running Electrical Check in the KICAD Software.

CONCLUSION:

The designed PCB offers a reliable and efficient solution for temperature monitoring and circuit protection, ensuring optimal performance and longevity of the system it's integrated into. By incorporating a temperature sensor, microcontroller, and relay, this system is capable of continuously monitoring the temperature within the circuit and reacting to fluctuations in real-time. When the temperature exceeds the preset threshold, the relay is triggered to disconnect the circuit, preventing potential overheating, system failures, or permanent damage to sensitive components. The microcontroller manages the logic, processing the sensor data and controlling the relay, while the temperature sensor provides accurate, real-time readings that allow the system to maintain optimal thermal conditions.To further enhance usability, features such as LED indicators or buzzers are integrated into the design. These alert mechanisms provide immediate, visual or auditory feedback to the user when the temperature exceeds the safe operating range, allowing for prompt corrective actions. This intuitive feedback system is particularly valuable in environments where fast response times are essential to avoid damage or downtime.The versatility of this PCB makes it suitable for a wide range of applications, including industrial equipment, power electronics, home automation, and even automotive systems. Its ability to protect high-value electronics from thermal damage makes it an essential tool in preventing costly repairs and ensuring the safety of both users and equipment. In industrial settings, for example, this system can protect machinery from overheating, while in home

automation, it can safeguard appliances and electronics from excessive heat, thereby enhancing the longevity and reliability of everyday devices.Additionally, the compact nature of the PCB and its efficient integration of key components ensure that it can be easily incorporated into various devices without significant changes to existing designs. This makes it not only a cost-effective solution for temperature management but also a practical addition to the design of future-proof electronics.

FUTURE SCOPE:

The PCB design can be enhanced further by incorporating advanced features such as wireless communication, like Wi-Fi or Bluetooth, which would enable remote monitoring and control of the system. This integration could allow users to track temperature data in real time, set dynamic threshold values, and receive instant alerts on mobile devices or through web interfaces, providing greater flexibility and convenience. By connecting the system to IoT platforms, users could gain access to comprehensive insights and control mechanisms, facilitating easier management and response to temperature fluctuations. Furthermore, the addition of data logging capabilities would allow for the continuous collection of temperature data, enabling users to analyze trends over time and make informed decisions on system performance. Implementing machine learning algorithms for predictive maintenance could take this design to the next level by identifying patterns in temperature variations and predicting potential failures before they occur, reducing downtime and extending the lifespan of equipment. Additionally, the system could be adapted to support multi-sensor configurations, enabling the simultaneous monitoring of multiple temperature points across large systems, which is particularly beneficial for complex industrial applications or smart home environments. This expanded functionality would not only make the design more versatile and scalable but also improve its overall applicability in a wide range of scenarios, from industrial machinery to residential energy management and beyond.

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