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INDUSTRIAL MACHINE OVERHEAT DETECTION SYSTEM

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Abstract— **Industrial machines generate heat during operation, and excessive temperature can lead to equipment failure, reduced efficiency, and safety hazards. This paper presents the design and implementation of an Industrial Machine Overheat Detection and Alarm System using an Arduino Uno, a DHT22 temperature sensor, and a passive buzzer. The system continuously monitors the machine's temperature and triggers an alert when a critical threshold is exceeded. The Arduino Uno processes real-time temperature data from the DHT22 sensor and activates the passive buzzer as an alarm when overheating is detected. This simple yet effective system enhances industrial safety, reduces maintenance costs, and minimizes downtime due to overheating issues.**

Keywords— **Overheat, Industrial Machine, Maintenance, Microcontroller, Monitoring.**

I. INTRODUCTION

Machines in factories emit a lot of heat when in use. Unless such heat is regulated, it can cause overheating, leading to machine malfunction, reduced efficiency, and even pose a risk to operators. It's therefore crucial to have a device that can detect overheating early and alert operators to act immediately. Traditional industrial equipment fault detection and diagnosis have long relied on manual inspection and intuitive judgment, which not only takes a lot of time but also introduces human error. Furthermore, traditional approaches are prone to issuing delayed warnings, making preventive maintenance a significant task. As [1] pointed out, conventional methods cannot perform real-time monitoring and predictive analysis, which are critical in identifying looming overheating accidents in time before serious damage results [1]. With advancements in technology, overheat detection systems today are highly advanced and utilize real-time monitoring, intelligent data analysis, and automated response. Hu and Liu have proposed a wireless sensor-based electrical equipment monitoring system that provides an efficient solution for remote temperature monitoring and early warning detection, enabling prompt intervention in the event of an abnormal temperature rise [2]. This implies a greater utilization of sensor technology in anticipatory fault management. Similarly, in transport, Momin et al. designed an engine-overheating avoidance alarm and signalling system. They used temperature sensors and microcontrollers to continuously monitor engine temperature and sound alarms when temperatures exceeded thresholds, enabling immediate corrective measures [3]. This use illustrates how sensor integration anticipates danger in mechanical systems arising from thermal abnormalities. More research by Akangbe et al. proposed a GSM-based industrial machine overheating protection system. Their system not only detected overheating conditions but also automatically delivered real-time SMS notifications to operators for remote monitoring and instant decision-making, thereby ensuring operational continuity and machinery protection [4]. In addition, [5] furthered this concept by incorporating a Raspberry Pi-based automatic cooling system. Their application enabled the system to detect overheating and automatically initiate cooling systems, thereby preventing thermal damage without human intervention [5]. This process shows the effectiveness of using smart controllers in automatic decision-making in industrial protection systems. Embedded systems have also contributed significantly towards enhancing overheat detection mechanisms. Singh employed an embedded alert system designed to detect and respond to overheating conditions. The system used microcontroller-based technology to initiate early detection and alarm generation, hence minimizing the likelihood of equipment failure [6]. Kumar and Verma further emphasized the importance of early detection systems by proposing an AI-based approach to predict overheating conditions. Their system employed machine learning algorithms to analyze temperature trends and forecast potential overheating incidents, aligning with the industry's shift towards data-driven maintenance strategies [7]. Beyond these advancements, fault detection techniques in power distribution systems have also influenced overheat management strategies. The work conducted [8] is a comprehensive review of fault detection methods, emphasising the role of real-time data analysis in improving response accuracy and minimising equipment downtime [8]. In [9], a spectral kurtosis-based feature extraction method was introduced for detecting motor bearing faults. Their method combined this technique with k-nearest neighbor distance analysis, enhancing the accuracy of fault detection in industrial motors, which can be adapted for more accurate detection of overheating conditions [9].

Additionally, data fusion techniques have proven effective in improving the reliability of overheat detection systems. The study in [10] demonstrated how multi-sensor data fusion could enhance fault diagnosis in industrial bearings, indicating that integrating multiple sensor inputs leads to more reliable detection outcomes [10]. The application of artificial intelligence (AI) and machine learning (ML) techniques has further revolutionized fault detection and diagnosis in industrial settings. Liu et al. provided a comprehensive review of AI applications in rotating machinery fault diagnosis, highlighting the effectiveness of ML algorithms in identifying and predicting faults, thereby enhancing the reliability of overheat detection systems [11]. Moreover, the integration of deep learning techniques has shown promise in fault diagnosis. Also, in [12], a convolutional neural network (CNN) was utilised to analyse time-frequency representations of vibration signals, achieving high accuracy in fault classification [12]. Similarly, [13] developed a novel fault diagnosis method for rotating machinery based on CNNs, demonstrating the potential of deep learning in this domain [13]. Time-frequency analysis techniques have also been employed to detect and diagnose machine faults. The study by [14] applied continuous wavelet transform scalograms in conjunction with CNNs to identify bearing faults, showcasing the effectiveness of time-frequency representations in capturing fault characteristics [14]. The work proposed by [15] is an intelligent fault diagnosis method that uses unsupervised feature learning to handle large-scale mechanical data and to effectively enhance fault detection accuracy. An optimized deep belief network is explored for rolling bearing fault diagnosis, demonstrating the potential of deep learning models in extracting meaningful features from complex datasets [16]. Jia et al. highlighted the promise of deep neural networks for intelligent diagnosis of rotating machinery, emphasizing their ability to handle massive data and extract fault characteristics [17]. In addition to AI and deep learning approaches, traditional signal processing methods remain relevant. Also, the study in [18] explored feature vector regression with efficient hyperparameters tuning, offering a geometric interpretation that aids in fault diagnosis. Furthermore, the integration of Internet of Things (IoT) technologies has enhanced the performance of overheat detection systems. Additionally, a machine-overheating detection system for electric vehicles using microcontrollers exemplifies the application of IoT for real-time monitoring [19]. Lastly, the importance of adaptive algorithms in fault detection cannot be overstated. Verdier and Ferreira introduced an adaptive Mahalanobis distance and k-nearest neighbor rule for fault detection in semiconductor manufacturing, illustrating the significance of adaptive methods in dynamic industrial environments [20]. The rest of the paper is organised as follows: The Design Methodology is explained in Section II. Experimental results are presented in Section III. Concluding remarks are given in section IV.

II. METHODOLOGY

The design methodology encompasses the system's conceptualization, hardware and software integration, circuit design, and testing processes. The goal is to ensure that the system reliably detects overheating and activates an alarm to prevent damage to industrial machinery and enhance workplace safety.

A. System design overview

The proposed system monitors the temperature of industrial machines using a DHT22 temperature sensor. If the detected temperature exceeds a predefined threshold, the system triggers a passive buzzer to emit a loud alert, signalling the overheat condition. The system's design includes both hardware components for sensing and alerting, and software logic for data processing and decision-making. Figure 1 shows the block diagram of the system's mechanism of operation. The description of the functionality of the system, as represented in the block diagram, is as follows:

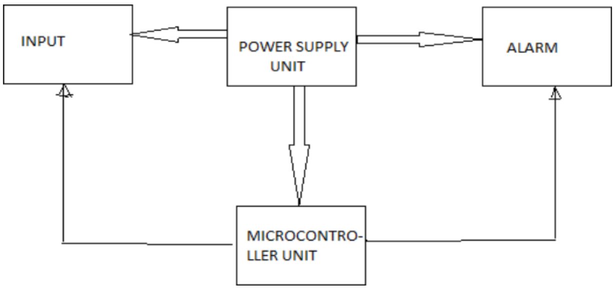

Fig. 1. Design block diagram

Description:

- Power Supply: The Power Supply block provides the necessary electrical power to the system. It powers the microcontroller (Arduino) and the DHT22 sensor. The power can come from a standard DC adapter or a battery, depending on the specific application. This block ensures that all components receive the correct voltage to function correctly.
- Microcontroller (Arduino): The Microcontroller block represents the Arduino, which is the brain of the system. The Arduino receives temperature data from the DHT22 sensor and processes it to determine whether the machine's temperature has exceeded the preset threshold. If the temperature is above the threshold, the microcontroller triggers the alarm.
- Input (DHT22 Sensor): The Input block represents the DHT22 sensor, which is responsible for measuring the temperature of the industrial machine. It sends temperature readings to the Arduino for processing. The sensor continuously monitors the environmental temperature.
- Alarm (Buzzer): The Alarm block represents the buzzer, which is activated by the microcontroller when the

temperature exceeds the predefined threshold. The buzzer serves as an alert to warn operators about potential overheating of the machine. It sounds off until the temperature falls back below the threshold.

A. Workflow Description

The power supply sends power to the microcontroller (Arduino) and the DHT22 sensor. The Microcontroller (Arduino) continuously receives temperature data from the DHT22 sensor (Input). The Arduino processes the data and checks whether the temperature is above the set threshold. If the temperature exceeds the threshold, the Microcontroller triggers the Alarm (Buzzer) to alert the operators about the overheating condition. The system continuously repeats this monitoring and alarming cycle until the temperature is brought back to a safe level.

B. The Hardware Design and Implementation

The system's circuit consists of

- Sensor Connection: The DHT22 sensor's data pin is connected to digital pin 2 on the Arduino Uno.
- The VCC pin is connected to the 5V pin on the Arduino, and the GND pin is connected to the GND pin on the Arduino.
- A 10kΩ resistor is connected between the sensor's VCC and data pins to act as a pull-up resistor, ensuring stable data transmission.
- Buzzer Connection: The passive buzzer's positive terminal is connected to digital pin 3 on the Arduino.
- The negative terminal is connected to the GND pin on the Arduino.
- Power Connection: A 9V battery supplies power to the Arduino via the barrel jack or the Vin pin and GND.
- The battery provides sufficient voltage and current for the entire system.

The components are mounted on a prototyping board to ensure compactness and ease of connection. The setup is designed for portability and durability, providing reliable performance in industrial environments. This is shown in Fig. 2.

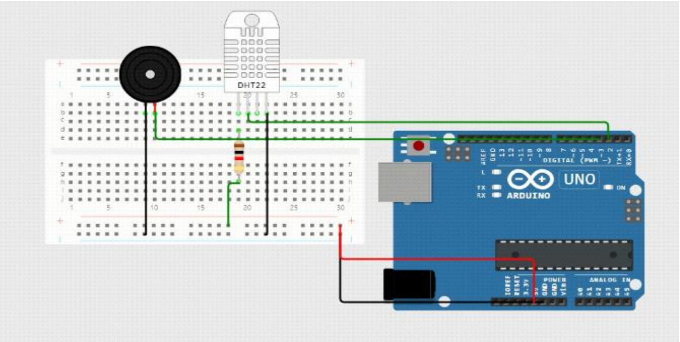

Fig. 2. Schematic diagram of the implementation

The hardware implementation began with the selection and integration of key components. The system included the Arduino Uno microcontroller, the DHT22 temperature sensor, a passive buzzer, a 10 kω resistor, and a 9V battery for power. Breadboard assembly was also performed to facilitate easy modification during the project's testing stage, as shown in Fig. 3.

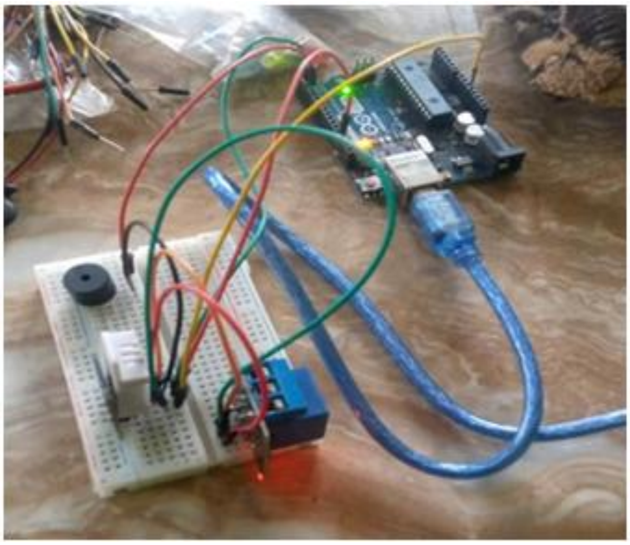

Fig. 3. Physical connection of the system

D. System Software

The software for the system was developed using the Arduino Integrated Development Environment (IDE). The program was written in C++ and utilized the DHT library to facilitate communication with the DHT22 sensor. The code was structured into modules to simplify debugging and enhance scalability.

The following algorithm describes the system's operation:

- Initialize the Arduino Uno, DHT22 sensor, and buzzer.
- Continuously read temperature data from the DHT22 sensor.
- Compare the temperature reading to the predefined threshold (e.g., 60°C).
- If the temperature exceeds the threshold, activate the buzzer to emit a continuous alert sound.
- Deactivate the buzzer when the temperature falls below the threshold.
- Output real-time temperature readings and system status to the Serial Monitor for monitoring and debugging purposes.

The program included functions for initializing components, reading temperature data, and controlling the buzzer. The modular approach ensured that the code was easy to understand and modify if future upgrades were needed.

E. Software Design Algorithm

- The software follows this sequential algorithm:
- Initialize hardware and software components.
- Continuously read temperature data from the DHT22 sensor.
- Compare the temperature with the predefined threshold (e.g., 60°C).
- Activate the buzzer if the threshold is exceeded.
- Stop the buzzer when the temperature falls below the threshold.
- Output temperature readings and system status to the Serial Monitor.

Figure 4 shows how the system functions. The sensors continuously read the temperature and check whether it equals or exceeds a set threshold of 40 degrees Celsius. A busser is activated if the answer is affirmative; otherwise, the process is repeated.

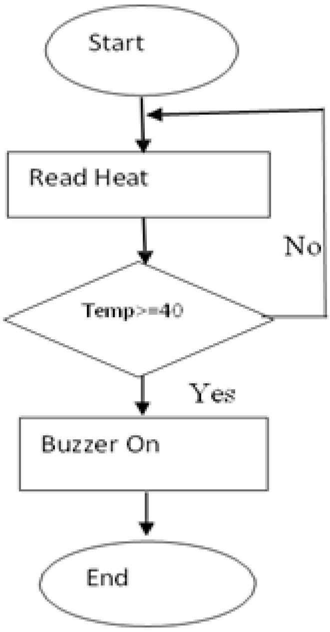

Fig. 4. The System Flowchart

III. SYSTEM RESULTS AND DISCUSSION

The results from the tests confirm the system’s effectiveness in monitoring temperature and issuing alerts. Key performance metrics and observations are outlined below:

- Accuracy of Temperature Detection: The DHT22 sensor consistently provided accurate temperature readings, with a margin of error that fell within acceptable limits. This ensures that the system is dependable for real-world applications.
- Response Time: The system exhibited an immediate response to temperature changes, with the buzzer activating almost instantaneously upon detecting overheating. This rapid response is critical for preventing potential damage to industrial machinery.
- System Reliability: Extended testing revealed that the system operates without interruption or false alarms, confirming its suitability for continuous use in industrial environments.
- Limitations Observed: The system’s coverage is restricted to the area monitored by the DHT22 sensor. For larger environments, additional sensors would be required to ensure comprehensive monitoring.
- The absence of an LCD or LED display limits the ability to view real-time temperature readings on the system itself.

Table 1 Experiment Result Summary

Test case	Input Condition	Expected Output	Observed Output	Results
Normal temperature	Below 40 deg	No alarm	nil	Pass
Overheating detected	Above 40 deg	Buzzer activated	Buzzer activated	Pass
Return to normal temperature.	From above to below 40 degrees	Buzzer deactivated	Buzzer deactivated	Pass

Table 1 summarizes the results obtained after system implementation and testing. When the system temperature is normal (i.e., 40 degrees Celsius), no alarm is triggered. Above this, the buzzer sends out an alarm alerting management to an overheating situation. Also, when the temperature comes down from abnormal (above 40 degrees) to normal (below 40 degrees), the buzzer is deactivated.

IV. CONCLUSIONS

The development of an industrial machine overheating detection and alarm system utilizing an Arduino Uno, DHT22 temperature sensor, and a passive buzzer presents a straightforward, cost-effective, and dependable solution for monitoring machine temperatures. This system continuously measures the ambient temperature and promptly activates an audible alert when the temperature surpasses a predefined threshold. As a result, operators are immediately informed of any overheating concerns, enabling swift intervention to prevent equipment damage, minimize downtime, and enhance workplace safety. This project illustrates how integrating basic electronic components with microcontroller programming can effectively tackle real-world industrial challenges. The Arduino Uno simplifies the system's design and implementation, while the DHT22 ensures precise temperature readings. The passive buzzer serves as an efficient alert mechanism, delivering clear and immediate feedback during critical situations.

Overall, the system enhances safety and operational efficiency by mitigating the risk of machine overheating. Future enhancements could involve integrating wireless modules for remote monitoring, adding data-logging capabilities for analysis, or incorporating advanced alert systems, such as SMS notifications. These improvements would further elevate the system's effectiveness across various industrial environments.

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