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DEVELOPMENT OF A TEMPERATURE MONITORING SYSTEM FOR MRI CHILLER AND HELIUM COMPRESSOR USING ESP32 WITH WEB-BASED INTERFACE

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ABSTRACT The cooling system in Magnetic Resonance Imaging (MRI) machines plays a critical role in maintaining imaging performance and preventing quench, a failure event caused by the evaporation of liquid helium in the cryogenic tank. This study presents the design and development of a web-based monitoring system for chiller temperature and helium compressor status using the ESP32 microcontroller. The system integrates a DS18B20 digital temperature sensor to measure water temperature and transmits the data to a web interface for real-time visualization. Automatic alerts are configured to deliver push notifications and email warnings when the temperature exceeds safe thresholds or anomalies in compressor operation are detected. Initial testing demonstrated system functionality with a sensor accuracy of 98.24% and an average error of 1.76%. The system successfully simulated fault conditions and issued timely alerts, indicating its effectiveness in preventive maintenance. With these capabilities, the proposed solution offers a reliable, low-cost method to enhance equipment safety, reduce downtime, and support the longevity of MRI cooling components.

INDEX TERMS Monitoring System, MRI Cooling, Web Based, Helium Compressor.

I. INTRODUCTION

Magnetic Resonance Imaging (MRI) is a non-invasive imaging technique that uses a strong magnetic field and radiofrequency waves to generate detailed images of internal organs and tissues [1]. MRI systems rely on superconducting magnets that must be kept at cryogenic temperatures (~4 Kelvin) to maintain stability and ensure diagnostic performance. This cooling is achieved through the continuous circulation of liquid helium, supported by a helium compressor and an external water chiller unit [2], [3].

The helium compressor, such as the Sumitomo F-70 series, is responsible for maintaining helium gas pressure in a closed-loop system. At the same time, the water chiller dissipates heat generated by components like gradient coils and RF amplifiers, stabilizing the compressor's operation [4], [5]. Disruptions in either system—such as a rise in chiller fluid temperature or compressor malfunction—can trigger a quench. A quench is a sudden loss of superconductivity marked by the evaporation of liquid helium, which can damage the magnet and result in costly helium loss and operational downtime [6].

Despite the critical role of these subsystems, many MRI installations still rely on manual inspection or basic on-site indicators. Although helium compressors provide diagnostic interfaces, such as DB-25 output terminals for fault status, this information is often not integrated with real-time monitoring or alert systems [7]. As a result, minor anomalies may go undetected, increasing the risk of preventable failures.

Recent advances in IoT (Internet of Things) technology have introduced cost-effective solutions for real-time equipment monitoring. The ESP32 microcontroller, equipped with Wi-Fi and GPIO capabilities, enables seamless integration with digital sensors and web platforms [8], [9]. It can connect to cloud services such as TagoIO, which allows data visualization, logging, and automated alerts via email or push notification [8]. In this study, the DS18B20 digital temperature sensor is employed to monitor the chiller fluid, offering $\pm 0.5^\circ\text{C}$ accuracy and waterproof packaging suitable for industrial environments [10], [11].

Previous studies have explored similar monitoring systems. Elallam and Hamlich [6] developed a remote alert system for MRI cooling failures but did not integrate direct communication with the helium

compressor. Dalchau et al. [12] introduced an intelligent compressor design but lacked web-based features. Orndorff and Hope [13] created an interface for cryogenic sensor readout, though their work focused on analog circuitry rather than wireless transmission. To date, no study has combined temperature and compressor fault monitoring in an MRI system using ESP32 with real-time web alerts.

This paper presents the design and implementation of a web-based monitoring system for MRI chiller temperature and helium compressor status. It uses an ESP32 microcontroller to read data from a DS18B20 sensor and detect compressor fault conditions via optocoupler isolation. The system publishes data to a web dashboard and issues alerts when abnormal conditions are detected. The goal is to enhance preventive maintenance, reduce the risk of quench, and improve the operational reliability of MRI cooling systems. When abnormal conditions are detected. The goal is to enhance preventive maintenance, reduce the risk of quench, and improve the operational reliability of MRI cooling systems.

II. RESEARCH METHODS

This study proposes the design of a monitoring system that combines hardware and software to detect critical parameters in an MRI cooling system. The core processing unit is an ESP32 microcontroller, which is responsible for acquiring data from a DS18B20 digital temperature sensor attached to the chiller line and reading fault signals from the helium compressor through dry contact points on a DB-25 diagnostic interface. These input signals are electrically isolated using an optocoupler module (PC817) to ensure circuit protection. The processed data is wirelessly transmitted to the Tago.io cloud platform via the ESP32's built-in Wi-Fi, where it is visualized on a web dashboard. The system also issues automated alerts through email and push notifications in response to abnormal conditions.

A. BLOCK DIAGRAM

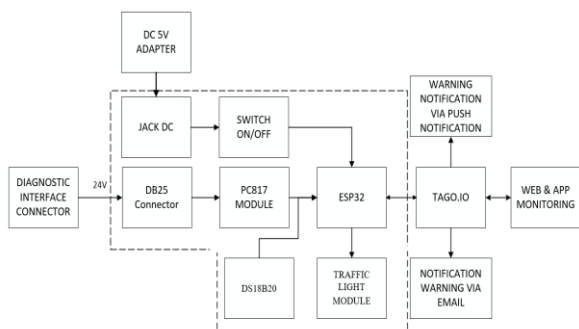


FIGURE 1. Block Diagram

From Fig. 2, it can be explained the system operates on a 5 V DC supply from an external adapter. When the ON/OFF switch is activated, the ESP32 microcontroller powers on and connects to the configured Wi-Fi network. Diagnostic signals from the helium compressor are received via a DB25 connector and converted from 24 V to 3.3 V using a PC817 optocoupler. The ESP32 reads these signals alongside temperature data from a DS18B20 sensor. The microcontroller processes the inputs to determine system status and controls a traffic light module as a local visual indicator. All data are then sent to the Tago.io platform in JSON format via Wi-Fi. On the Tago.io dashboard, temperature trends and compressor status are visualized using graphs and dynamic icons. The platform also handles alert automation, sending push notifications and emails when faults or overtemperature conditions are detected.

B. FLOWCHART

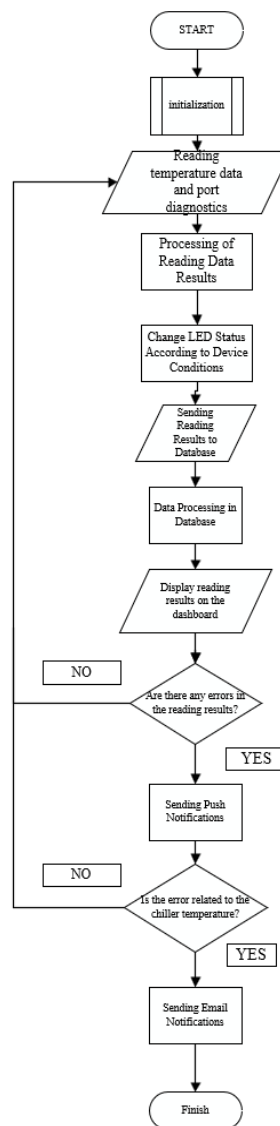


FIGURE 2. Block Diagram

The system flow begins when the device is powered on, initiating the Wi-Fi connection and communication setup with the Tago.io platform. Once connected, the ESP32 reads data from the DS18B20 temperature sensor and the diagnostic interface of the helium compressor.

The microcontroller processes the incoming data to assess the compressor's operational status and verify that the chiller temperature remains within safe limits. These values are then formatted and transmitted to the Tago.io database in real time.

On the Tago.io platform, incoming data are displayed on a monitoring dashboard. The system continuously evaluates whether the data indicate a fault condition or abnormal temperature. If an error is detected, a corresponding push notification is sent to the assigned technician. If the chiller temperature exceeds the normal threshold, both push and email notifications are triggered.

C. HARDWARE DESIGN

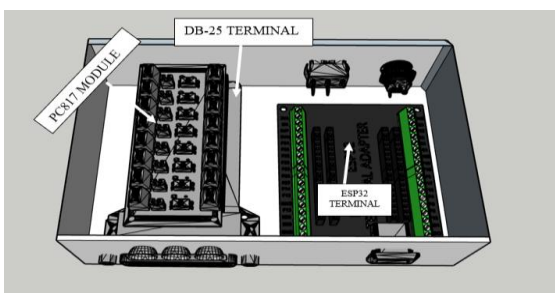


FIGURE 3. Module Design

From Fig. 3, it can be explained that the design functions of each part are as follows. The ESP32 DevKit V1 microcontroller as the central processing unit, a DS18B20 digital temperature sensor for monitoring chiller water temperature, and a PC817 optocoupler module for receiving diagnostic signals from the helium compressor. Fault signals are obtained from a DB-25 terminal, where each pin corresponds to a specific compressor condition, including overtemperature, low water flow, and high pressure.

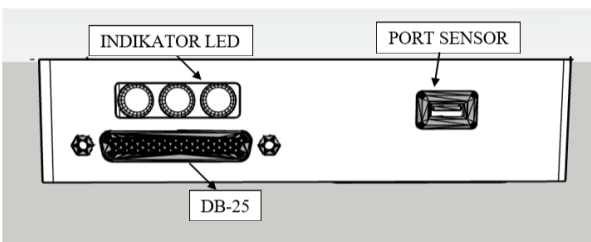


FIGURE 4. Front Module Design

From Fig.4, it can be explained to display system status locally, a traffic light module (three-color LED) is installed. The green LED indicates normal operation,

the yellow LED is active during standby or acknowledgment, and the red LED lights up during fault conditions. The system is powered by an external 5V DC adapter connected through a rear-mounted power switch.

All components are mounted within a custom-designed hardcase fabricated from PLA+ using 3D printing. The front panel provides access to the DB-25 interface, LED indicators, and sensor input, while the rear panel contains the power interface and switch.

D. SOFTWARE DESIGN

The firmware was developed using the Arduino IDE and programmed in C++. The ESP32 initializes Wi-Fi and I/O configurations at startup. Temperature readings are obtained from the DS18B20 sensor via the OneWire protocol, while compressor status signals are received through the PC817 optocoupler module connected to dedicated GPIO input pins.

Sensor and diagnostic data are structured as JSON payloads and transmitted to the Tago.io cloud platform using HTTP POST requests. Authentication is handled through a unique device token.



FIGURE 5. Website Dashboard

From Fig.5, it can be explained the Tago.io dashboard former design provides real-time visualization through customizable widgets. The chiller temperature is displayed using a graphical thermometer widget and plotted on a time-based line chart. Compressor fault conditions are visualized using icon-based widgets that change appearance when an error is detected

Automated alerts are configured using Tago.io's built-in Actions. When a specified condition is met—such as a temperature exceeding 25 °C or the presence of an active error signal—the system sends push notifications and email alerts to registered users.

E. DATA COLLECTION TECHNIQUES

The system was tested in three areas : sensor accuracy, compressor fault monitoring, and alert notification.

1) DS18B20 Sensor Accuracy

The DS18B20 temperature sensor was tested by comparing its readings with a reference thermometer.

2) Compressor Fault Monitoring

Simulated error signals were sent from the compressor's DB25 port then monitoring and sending push notifications through Tago.io.

3) Overtemperature Notifications

The DS18B20 sensor was heated above 25°C to test alert triggers. The system successfully sent both push notifications and email alerts via Tago.io when the temperature exceeded the limit.

III. RESULTS AND DISCUSSION

In this chapter, the author will explain the results of the analysis and discussion of the developed module. At this stage, after the module has been completed, several measurements have been conducted. The author will present the data obtained from these measurements.

A. PHYSICAL FORM OF THE DEVICE



FIGURE 6. Front Module Design

From Fig. 6, the device features three LED indicators on the front panel to show system status, a DB25 port for connecting to the helium compressor diagnostic interface, and a sensor port for the DS18B20. On the rear side, it includes a 5 V DC power input and a power switch, making the module compact, user-friendly, and ready for integration with MRI infrastructure.

B. WEBSITE INTERFACE

The monitoring system is integrated with the Tago.io platform, which displays real-time data from the ESP32 in a visual dashboard accessible via both web and mobile applications. Temperature trends are shown using line charts, while compressor status is represented by dynamic icons that change color according to fault conditions.



FIGURE 7. Website Dashboard

The interface supports user-friendly visualization with intuitive layouts, allowing technicians to monitor chiller temperature and compressor status remotely. In case of anomalies, the platform automatically sends push notifications to mobile devices and email alerts, ensuring fast response and effective system supervision.

C. TESTING AND DATA ANALYSIS

To evaluate the overall performance, accuracy, and reliability of the MRI cooling system monitoring device developed in this study, a comprehensive series of tests were designed and executed under controlled conditions. The primary goal of these tests was to ensure that the system could function effectively in real-world environments by accurately measuring water temperature from the chiller unit, detecting diagnostic fault signals from the helium compressor, and responding to abnormal operating conditions through real-time alerts. The validation process involved comparing the DS18B20 temperature sensor readings with a calibrated reference thermometer to assess measurement precision, simulating various error states from the compressor to confirm the system's capability in fault detection, and evaluating the responsiveness of cloud-based notifications using the Tago.io platform. Particular attention was given to the system's ability to maintain consistent data transmission, update a centralized dashboard interface in real time, and generate both push notifications and email alerts when defined threshold values were exceeded. The following subsections present the results and analysis of these three critical tests, each of which contributes to assessing the feasibility and effectiveness of the proposed monitoring solution.

1) DS18B20 Temperature Sensor Accuracy Test

To validate the sensor's accuracy, readings from the DS18B20 were compared with a calibrated reference thermohygrometer. Several measurements were taken on MRI service room.

TABLE I
TEMPERATURE MEASUREMENT RESULTS

DATA COLLECTION No. -	MEASUREMENT RESULTS (%) THERMOHYGROMETE		ERROR/ CORRECTION
	R	MODULE	
1	21°C	21,2°C	-0,2
2	21°C	21,2°C	-0,2
3	20,8°C	21,1°C	-0,3
4	20,5°C	20,9°C	-0,4
5	20,5°C	20,8°C	-0,3
6	20,5°C	20,8°C	-0,3
7	20,7°C	20,5°C	0,2
8	21,9°C	22,8°C	-0,9
9	21,5°C	21,2°C	0,3
10	21,4°C	22,1°C	-0,7
AVERAGE	20,98°C	21,26°C	-0,28
% ERROR			1,76%
% ACCURACY			98,24%

In Table I, Temperature measurement results table The results showed that the sensor achieved an accuracy rate of 98.24%, with an average error of 1.76%, confirming its reliability for chiller temperature monitoring.

2) Monitoring and Error Notification Test for Helium Compressor



FIGURE 8. Simulating Diagnostic Signals Via DB25 Port

As shown in Fig. 8, the test was conducted by simulating diagnostic signals via the DB25 port to replicate common fault conditions, including high water temperature, low water flow, power failure, high gas temperature, motor winding error, and high pressure. These simulated errors activated the corresponding LED indicators on the monitoring device.

Simultaneously, the data were transmitted to the Tago.io platform, where real-time status updates were displayed on the web-based dashboard. Upon detecting

each fault, the system automatically sent push notifications to the technician's mobile device. This confirms the system's ability to detect compressor faults accurately and deliver timely alerts through the integrated cloud platform.

3) Temperature Alert via Push and Email Notification

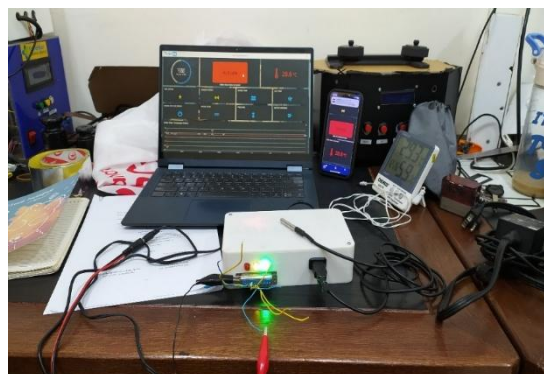


FIGURE 8. Website Dashboard

This test was conducted to validate the system's ability to detect abnormal temperature levels and deliver real-time alerts through both push notifications and email. As shown in Fig. 9, the DS18B20 temperature sensor was intentionally exposed to conditions outside the defined safety range of 4°C to 25°C.

The web dashboard, visible on both laptop and mobile interfaces, displayed the abnormal temperature in real time. Once the threshold was breached, the system immediately triggered a push notification to the technician's mobile device and sent a simultaneous email alert to the registered account.

This test also confirmed the effectiveness of Tago.io's cloud automation features in handling conditional triggers for alert delivery. It ensures that temperature anomalies in the MRI chiller system can be addressed promptly, thus reducing the risk of system failure and preserving MRI operational reliability.

IV. CONCLUSION.

Based on the results of design, implementation, and testing, this study has demonstrated the successful development of a web-based monitoring system for the helium compressor and chiller temperature in MRI cooling systems using an ESP32 microcontroller. The system integrates a DS18B20 temperature sensor and a diagnostic interface, with real-time data displayed via a website and mobile application connected through the Tago.io platform. Testing confirmed that the system functions reliably, with the DS18B20 sensor achieving an accuracy rate of 98.24% and an error rate of only 1.76%. The compressor diagnostic status was correctly detected, with corresponding LED indicators and successful delivery of push notifications.

Moreover, the system effectively triggered both email and push alerts when chiller temperatures exceeded the safe threshold of 4°C–25°C, demonstrating its value as a real-time early warning solution.

To enhance system resilience and functionality, it is recommended that future improvements include the implementation of internal data logging and a backup power supply to ensure continued operation during internet or power outages. Additionally, integrating alternative communication protocols could expand the monitoring capabilities for broader MRI system applications. With these enhancements, the system has the potential to provide even more robust and reliable support for MRI maintenance and fault prevention.

1)

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