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Journal of Educational
ISSN: 2011- 421X
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معامل التأثير العربي 1.63
العدد 23

# مجلة التربوي

## مجلة علمية محكمة تصدر عن كلية التربية

## جامعة المرقب

العدد الثالث والعشرون
يوليو 2023م

### هيئـــة التحريـر



- المجلة ترحب بما يرد عليها من أبحاث وعلى استعداد لنشرها بعد التحكيم .
- المجلة تحترم كل الاحترام آراء المحكمين وتعمل بمقتضاها .
- كافة الآراء والأفكار المنشورة تعبر عن آراء أصحابها ولا تتحمل المجلة تبعاتها .
- يتحمل الباحث مسؤولية الأمانة العلمية وهو المسؤول عما ينشر له .
- البحوث المقدمة للنشر لا ترد لأصحابها نشرت أو لم تنشر .

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يشترط في البحوث العلمية المقدمة للنشر أن يراعى فيها ما يأتي :

- أصول البحث العلمي وقواعده .
- ألا تكون المادة العلمية قد سبق نشرها أو كانت جزءا من رسالة علمية .
- يرفق بالبحث تزكية لغوية وفق أنموذج معد .
- تعدل البحوث المقبولة وتصحح وفق ما يراه المحكمون .
- التزام الباحث بالضوابط التي وضعتها المجلة من عدد الصفحات ، ونوع الخط ورقمه ، والفترات الزمنية الممنوحة للتعديل ، وما يستجد من ضوابط تضعها المجلة مستقبلا .

**تنبيهات** :

- للمجلة الحق في تعديل البحث أو طلب تعديله أو رفضه .
- يخضع البحث في النشر لأولويات المجلة وسياستها .
- البحوث المنشورة تعبر عن وجهة نظر أصحابها ، ولا تعبر عن وجهة نظر المجلة .

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# Designing an Autonomous Embedded System for Temperature Monitoring and Warning in Medical Warehouses

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**Abstract:** The protection of pharmaceutical products from temperature-related damage and contamination is a crucial challenge faced by the healthcare industry. Variations in storage conditions can have a significant impact on the efficacy and shelf life of medications, and identifying such fluctuations is of utmost importance. In this regard, the present study aims to develop a cost-effective and efficient temperature monitoring system for medicines using the Embedded systems platform. The DS18B20 sensor was utilized to record the temperature profile signal, and a warning system was designed to alert the warehouse administrator in the event of any temperature fluctuations. The results of the study revealed a stable temperature profile within the medicine warehouse, and the warning system successfully notified the administrator whenever the temperature exceeded the user-defined threshold. These findings hold significant implications for future research exploring the potential of additional sensors for temperature monitoring purposes. Overall, the study highlights the importance of temperature monitoring systems in ensuring the integrity and efficacy of medications. The proposed system holds considerable promise for implementation in healthcare settings, where a maintaining optimal storage condition is critical for preserving the quality and safety of pharmaceutical products.

***Keywords:*** *Embedded Temperature Monitoring, Warning, Medicine Warehouses*

## I. INTRODUCTION

Current research on the development of temperature monitoring systems is primarily focused on specific contexts where variations in environmental conditions can significantly impact the use of such systems. As a result, many researchers, including those cited in references [10] and [17], have conceptualized temperature measurement and control as common practices for microcontroller-based acquisition systems [8]. Four types of sensors are generally used for estimating heat ranges in commercial and industrial applications, namely thermocouples, resistive temperature devices, thermistors, and integrated circuit temperature sensors [1]. Each sensor has its unique advantages and disadvantages, and by understanding how these sensors work and which signal conditioning is required, it is possible to produce more accurate and reliable temperature measurements, monitoring, and control [23].

Sensors are transducers that detect and measure physical quantities. A transducer refers to a device that converts physical quantities from one form to another [1]. The distinction between a sensor and a transducer is that a sensor functions like a transducer, while a transducer provides actual quantity readings. Another sensor commonly used is the thermocouple, which is an inexpensive sensor suitable for a wide range of temperatures [4]. Thermocouples operate on the principle that when two dissimilar metals are joined, a voltage response is generated along the junction between the metals. By measuring this voltage, it is possible to obtain temperature readings. Different metal combinations create unique thermocouple voltages, and there are many thermocouples available for different applications [19]. However, thermocouples have a non-linear relationship with the measured temperature, and it is essential to either linearize their characteristics or use lookup tables to determine the actual temperature from the predefined measured voltage [22]. To convert analog signals into digital signals, devices must be connected to the thermocouples, which are then connected to computer-based equipment typically used in warehouses and pharmacies [15]. Additionally, the change in resistance is often small, and special circuitry is often required to measure small changes in temperature in certain contexts.

The present study focuses on developing a temperature monitoring and warning system for medicine storage, warehouses, and pharmacies using the Raspberry Pi 2 platform. Cooling systems are of great importance in the medical field due to their usage for storing and transporting medical entities such as medicines and vaccines.

## II. RESEARCH BACKGROUND

Numerous studies have focused on providing sufficient monitoring and warning systems for temperature changes in specific environmental conditions [11]. Temperature fluctuations have been shown to significantly affect the quality of stored medications in various settings [21]. Therefore, continuous monitoring of temperature changes is crucial in order to prevent any chemical damage. To this end, the design and fabrication of sensors that either are in direct contact with the medicine or indirectly linked can alert us to temperature changes and aid in safeguarding medication quality.

## III. PROBLEM STATEMENT

This study is based on current literature findings that highlight the need for a cost-effective and efficient temperature monitoring system for medicines in warehouse settings. Recent challenges in the healthcare industry have emphasized the importance of protecting medications from contamination and damage caused by high or low temperatures in pharmacies and medicine storage facilities [21]. It is essential to report and accurately identify any inappropriate variations in storage conditions that occur over short or extended periods.

Furthermore, the researcher's review of the literature revealed a need for high-quality temperature monitoring and warning services in a wide range of areas. Previous works have addressed the challenges of providing embedded temperature monitoring systems with limited coverage range of sensor nodes, which were designed for monitoring the vital signs of the human body with a small number of nodes over few meters [13]. These challenges underscore the need for the development of embedded technologies for monitoring medicine temperatures in large environmental spaces beyond the scope of currently available standardized technologies.

## IV. RESEARCH OBJECTIVES

The goal of this study is to develop an efficient temperature monitoring system of medicine in a medicine warehouse:

- To design and develop a cost effective, open source and efficient temperature monitoring and warning system using embedded systems.

- To maintain the temperature of the medicine warehouse in a range that would keep the medicine in good condition as advised by the health ministry.

## V. TEMPERATURE MONITORING

The temperature monitoring devices utilized in this study rely on a group of nodes, with each node connected to multiple sensors. However, temperature monitoring can vary across different sensors in terms of size and cost, and each may present unique constraints [3]. The sensor node consists of several sub-systems, including the computing subsystem, communication subsystem, sensing subsystem, and power supply subsystem [6]. The computing subsystem is composed of a microprocessor (MCU) used to manage the sensors through specific communication protocols.

## VI. ISSUES OF TEMPERATURE MONITORING

Every monitoring system is subject to design and resource constraints due to the limited size and battery capacity of sensor nodes, resulting in reduced bandwidth, short connection range, and limited processing capacity, which are crucial for accurately monitoring temperature changes. Recent advances in wireless communications and electronics have overcome many of these constraints, enabling the development of monitoring devices that are low power, low-cost, multifunctional, and small in size [16]. However, three key challenges—namely, energy efficiency, localization, and routing—may affect network stability and hinder the accurate interpretation of the surrounding temperature. Therefore, the development of an effective and cost-efficient solution for monitoring temperature changes is imperative.

### *A. Embedded system main board (Raspberry Pi)*

The Raspberry Pi is a highly effective credit-card-sized computer that runs the Linux operating system [Figure 1]. It includes all necessary ports for connecting other hardware components, such as an HDMI output for an interactive display, USB ports for connecting a mouse and keyboard, and a 3.5mm audio jack for warning purposes, which the researcher relied on in this study. In the Model B+, an Ethernet socket is also available for internet connection.

In essence, the Raspberry Pi is a small computer (Embedded System) that can perform the same tasks as larger hardware equipment, such as monitoring and estimating environmental conditions in specific settings. It is widely used in various electronic projects, particularly for learning programming. The Raspberry Pi is affordable, with prices starting from $30. The Raspberry Pi is used in this study due to its usefulness, although additional external computers may need to be purchased separately for extended purposes. For example, it does not have a protective enclosure, and the micro-USB power supply is not included.

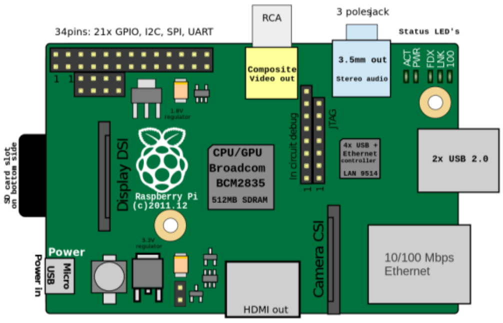

Fig. 1. Raspberry Pi circuit design

*B.PROGRAMMING LANGUAGES*

The hardware of Raspberry Pi supports a wide range of programming languages that can be adapted for use. The Raspberry Pi Foundation recommends Python programming language, especially for beginners. However, any programming language that can be compiled for ARMv6 can be used with the Raspberry Pi [2]. This means that users are not limited to using only Python. Various languages, such as C, C++, Java, Scratch, and Ruby, come pre-installed on the Raspberry Pi. However, for this study, the researcher chose to use the Raspberry Pi with the Python shell editor.

*C.DS18B20 temperature sensors*

The DS18B20 digital thermometer is capable of providing temperature measurements in Celsius from 9-bit to 12-bit precision, with a non-volatile programmable alarm function and low trigger points at an affordable cost. It communicates over a 1-Wire bus that requires only one data line (and ground) for communication with a central microprocessor [24]. With an operating temperature range of -55°C to +125°C and an accuracy of ±0.5°C within the range of -10°C to +85°C, the DS18B20 can derive power directly from the source, eliminating the need for an external power supply [12].

Each DS18B20 has a unique 64-bit serial code, allowing multiple sensors to operate on a single 1-Wire bus, as illustrated in Figure 2. Therefore, it can be concluded that using such sensors would provide a user-friendly microprocessor to control multiple DS18B20s distributed over a large area [18]. Potential applications that could benefit from this feature include HVAC environmental controls, temperature monitoring systems in buildings, equipment, or machinery, as well as process monitoring and control systems.

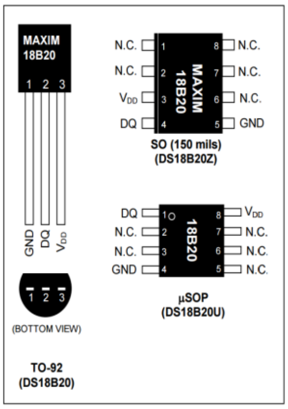


FIG. 2. DS18B20 DIGITAL THERMOMETER

*D. LCD display*

This study used 20 character LCD displays as it offer a cheap variance and easy to hook up to the GPIO pins on the Pi. A 16×2 LCD screen is used in this study for the aim of monitoring temperature changes inside the medicine warehouse. The monitor screen is connected to the Raspberry pi via the HDMI cable. The received temperature data from the USB wireless adapter is translated into digital form that stored in SD card socket. This process was essential in order to continuously monitor temperature changes every time the temperature goes beyond or above the threshold value.

## VII. METHODOLOGY

The main requirements from the user and technicians perspectives were studied in order to provide in-depth understanding of the current needs of temperature monitoring system. As such, a list of requirements have prepared and captured from a medicine warehouse to which the comments and recommendations were summarized into the following:

- Provide a cheap and cost effective configuration for the proposed temperature monitoring and alarming system.
- Provide an alarm in the event of high drop in temperature beyond the specified threshold value triggered once a node reports potential difference.

*A. Hardware*

The temperature monitoring and warning system is based on a Raspberry PI 2 model B SBC board see figure 3. The system gathers the readings for the temperature of the warehouse using a DS18B20 one wire temperature sensor. The sensor will send the readings to the Raspberry Pi every one second and these readings will be processed by the Raspberry Pi for any temperature readings that increase or decrease from the threshold that is pre-defined in the program used to monitor the DS18B20 temperature readings. If the temperature of the warehouse rises or drops from the threshold, that is

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already pre-defined, the system will trigger an alarm that will sound a buzzer while turning on the LED lights that are connected to Raspberry PI and will also send a warning SMS message to the admin of the warehouse locating the place of the warning figure 4 ,figure 5 and figure 6 show the block diagram and, block design and system schematics

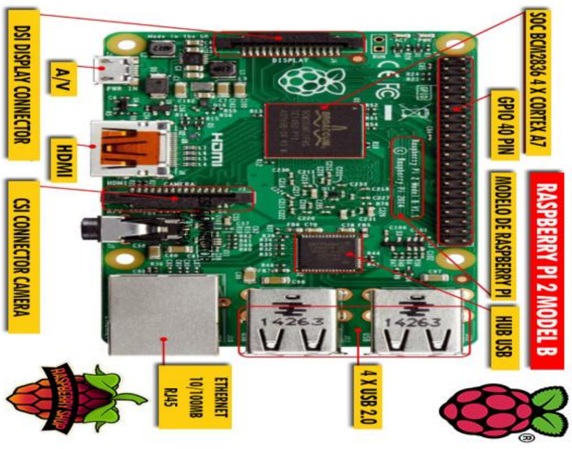


Fig. 3. Raspberry PI 2 Board

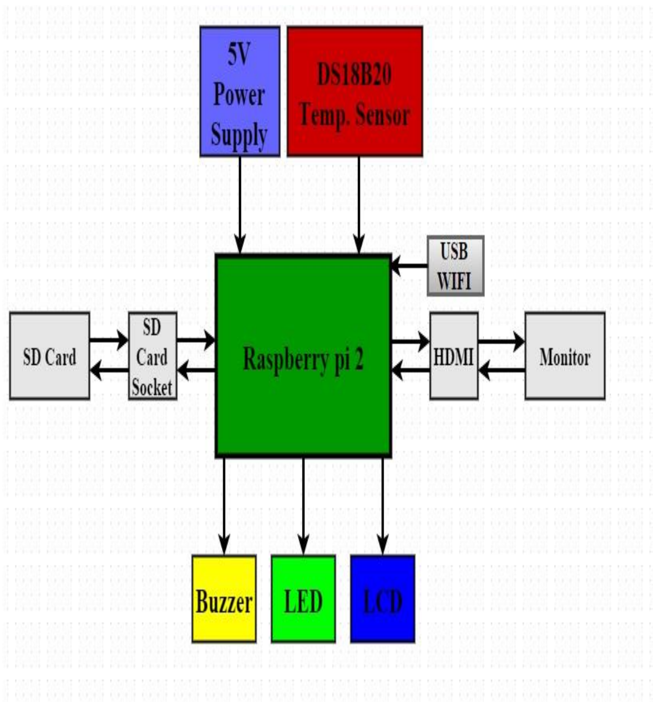


Fig. 4. Block diagram

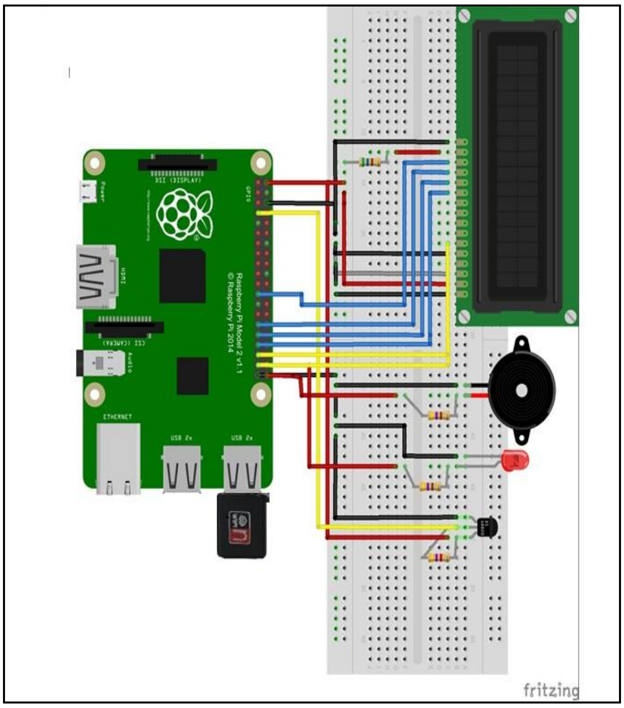

Fig. 5. Block design

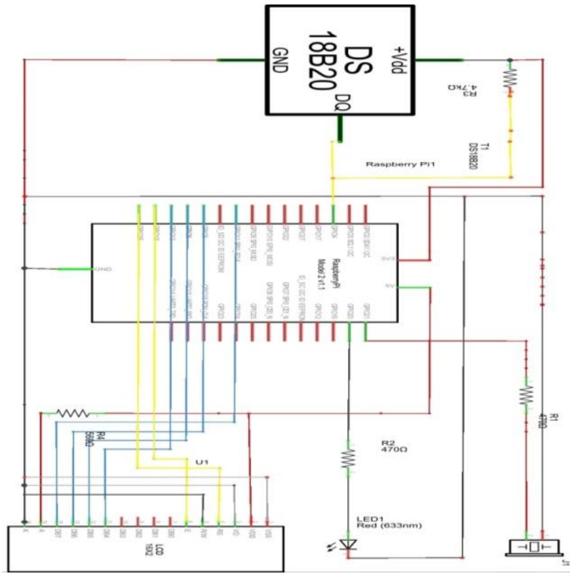

Fig. 6. System schematics

*B. System Software And Operation*

The overall software of the system is based on Python programming language which is used because the main focus of this project is to develop a cheap and open source system that can be easily configured and developed..

Figure 7 shows the procedure used by the researcher in this study to monitor the temperature and receive the alarm. The process starts when the system opens serial port to read the temperature data inside the medicine warehouse. The received temperature data then will be stored in a predefined database table that will be references to a certain date and temperature conditions. Then, the stored and captured temperature will be analyzed to determine any possible changes in temperature below or above the threshold value. In the event the temperature goes beyond the threshold value, then the system should issue the alarm, otherwise, it continue monitoring.

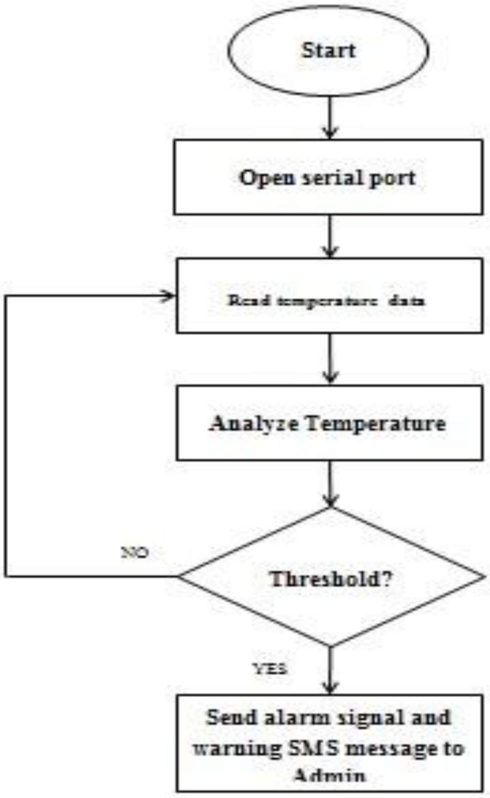


*Fig. 7. Temperature monitoring stages*

## VIII. RESULTS AND DISCUSSION

The development of the overall system presented in this study demonstrated the desired outcome that was expected. The system was systematically tested in two parts, the first being the monitoring part, and the second being the warning part, which was subjected to different external influences. In the monitoring part, the system was tested under various conditions, including with the lab's door and window shut and the cooling system set to 16°C, with the lab's door open and the window shut with the cooling system set to 16°C, with the lab's door and window open and the cooling system set to 16°C, and finally with the lab's door and window open and the cooling system turned off. These four tests were conducted for three days each, with a precision of 15-minute readings, and the readings for each test were averaged and analyzed.

The second part of the testing was to evaluate the warning mechanism of the system. The temperature was gradually increased until it reached the threshold set at 20°C. Once the temperature exceeded the maximum threshold set, the system issued a warning by sounding the alarm and blinking the LED lights while sending a warning SMS message to the phone number of the system administrator.

This testing methodology provided a comprehensive evaluation of the system's capabilities under various operating conditions, demonstrating its effectiveness in monitoring and warning of temperature changes in a medicine warehouse setting. The results obtained from the testing could be used to optimize the system's performance further and address any limitations identified during the testing process.

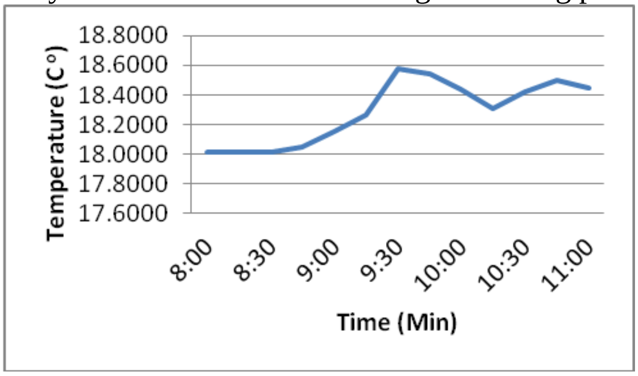


Fig.8. Temperature monitoring [ test 1 ]

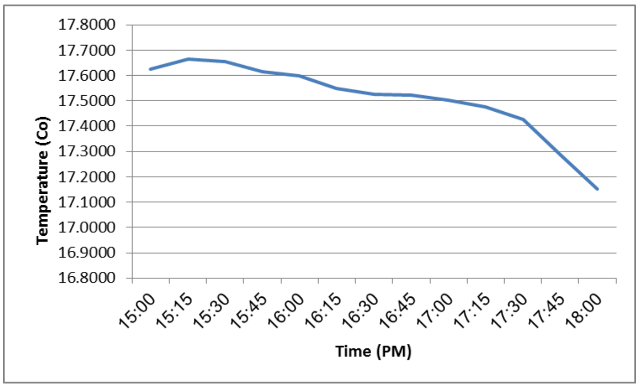


Fig.9. Temperature monitoring [ test 2 ]

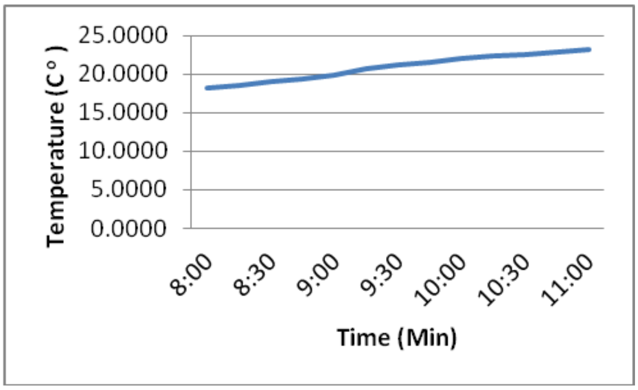


Fig. 10 Temperature monitoring [ test 3 ]

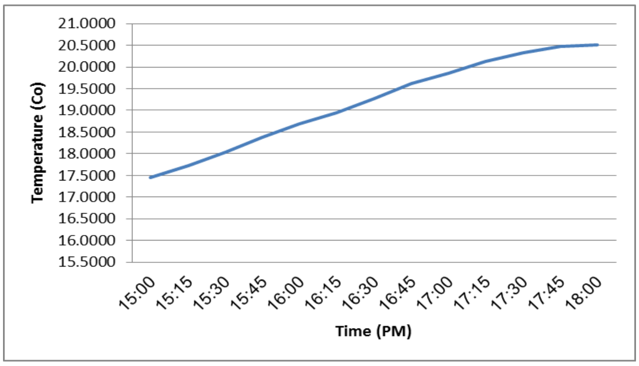

Fig. 11 Temperature monitoring [ test 4 ]

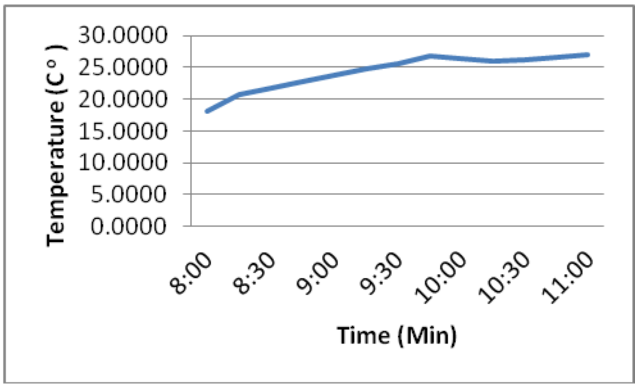

Fig. 12. Temperature monitoring [ test 5 ]

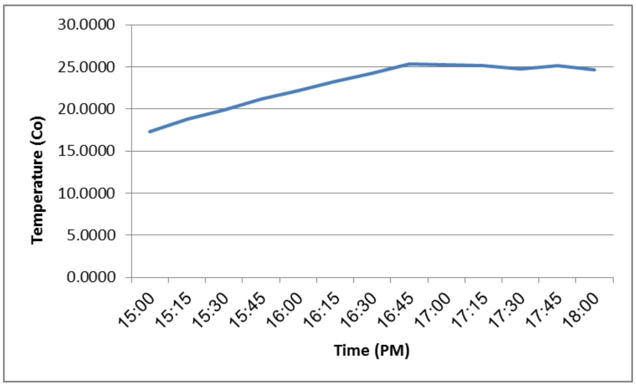

Fig. 13. Temperature monitoring [ test 6 ]

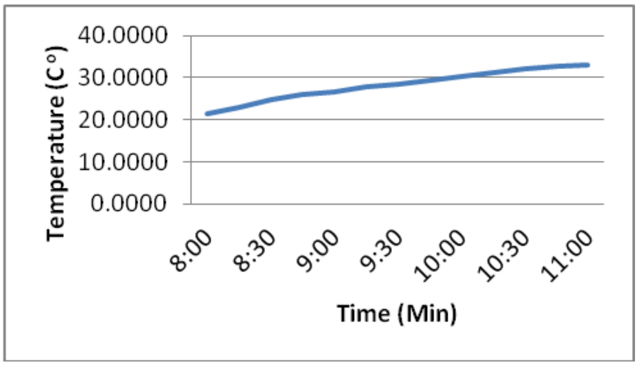

Fig. 14: Temperature monitoring [ test 7 ]

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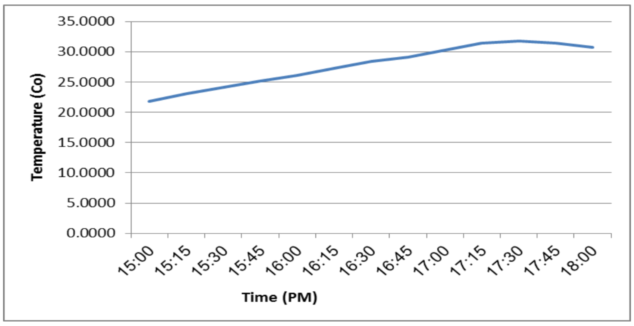


Fig. 15: Temperature monitoring [ test 8 ]

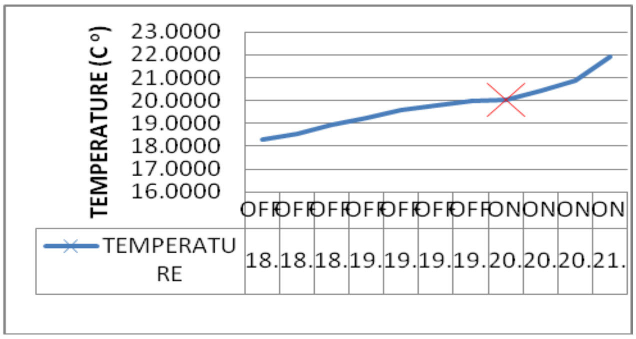


*Fig. 16: Temperature warning test 1*


*Fig. 17. SMS Temperature warning message*

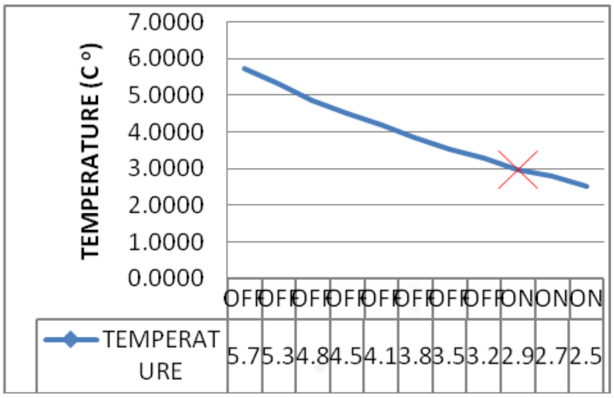


*Fig. 18. Temperature warning test 2*


*Fig. 15. SMS Temperature warning message*

## IX. CONCLUSION

The demand for small and reliable automated sensors capable of monitoring various environmental factors is currently on the rise. As a result, this study aimed to explore the use of cost-effective components for monitoring and alerting temperature changes. The study successfully employed the Raspberry Pi2 to monitor temperature changes inside a medicine warehouse, providing an efficient way to issue an alarm if the temperature falls below the predefined threshold value. The results of the study demonstrated a high potential for such a system in providing accurate readings and monitoring of temperature, while also being cost-effective and easy to use.

These findings led the researcher to conclude that using a single-board computer (SBC) monitoring and warning system technology could be an ideal solution for distributed data collection and analysis in medicine warehouses. Overall, the results of this study highlight the potential of cost-effective SBC-based systems for temperature monitoring and control in various settings.

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مجـلـة الــتربــوي
Journal of Educational
ISSN: 2011- 421X
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