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Original Article

Microcontroller-Based Environmental Temperature Measurement

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Abstract - *Technology has been moving towards automation for a long time. The basic principle of technology is to make life easier by explicitly leaving fewer things to a man. There is no doubt that automation is the future; most importantly, it takes place directly in the environment. It makes life easier and easier in all aspects. Globally, automated systems are preferred to manual systems. The increasing number of Internet users over the past few decades has made the Internet an integral part of life, and IoT is the latest and emerging Internet technology. Arduino is a newly developed open-source hardware and software system. Still, it has caught the attention of a large tech community. Its less technical design and affordable cost are fundamental features that widen its wide range of uses, the compatibility with many other electronic devices and the possibility of expansion being interesting features that widen the range of uses. Arduino hardware is simply a motherboard that, with appropriate computer programming (IDE - Integrated Development Environment), can be used to create interacting objects. This project aims to build an Arduino-based embedded temperature monitoring device. The device is built using Arduino, a temperature sensor and an LCD display. The device could sense temperature and provide information in a liquid crystal display. Out of many clones and various microcontroller boards available, Arduino Uno was used in this project. The project is divided into two parts: theoretical and experimental. The project is successful and meets the pre-established objectives. The implementation is possible with the help of magazine articles downloaded from the internet, previous work by other students on Arduino projects and related websites where most information is available.*

Keywords - *Microcontroller, Environmental temperature, Measurement.*

1. Introduction

Climate characteristics on the earth's surface differ from place to place, influenced by position relative to the Sun's orbit (latitude position), the presence of the ocean, wind patterns, the shape of the earth's land surface, and vegetation density. The earth's rotation around the Sun and its axis causes the entire surface of the earth to receive solar radiation alternately. Solar radiation affects the average temperature in each region. The more radiant energy received from an area, the higher the surface temperature in that area. The temperature will fluctuate significantly every 24 hours. The maximum air temperature is reached sometime after the maximum light intensity reaches when the light beam is perpendicular at midday. Therefore, the air temperature on the earth's surface varies from place to place. In addition, the air temperature obtained in each environment from solar radiation is not the same.

Air temperature is the state of hot air caused by the Sun's heat. Factors that affect the amount of solar heat received by the earth include the cloud, the surface plane, the angle of the incident ray, and the length of the insolation. The earth's surface heat from solar radiation influences the heat of the air. Air temperatures on the earth's surface vary because sunlight spreads unevenly across the earth's surface.

The monitoring of environmental variables such as temperature has a long history of development, and the variables have shown a significant impact on plant growth productivity, the quality of the food industry and the efficiency of many temperatures and humidity-sensitive devices (Vleeschouver et al., 2017). Monitoring the ambient temperature is important from a health and hygiene perspective. Reliable measurement and monitoring are critical in this competitive era of technology (Jarande & Patil, 2019). Arduino, the open-source hardware, has shown that it can meet the need for accurate, real-time monitoring and control of environmental variables.

The Arduino user community is a forum where many people can share their ideas, leverage each other's work, and modify it to innovate and advance many different interacting objects. Arduino is used in various projects to develop objects interacting with people, the environment, and the internet. The materials needed are readily available, inexpensive, and easy to use with the help of available open-source information. Arduino has been used to build robots, drones, remote controls, surveillance devices and many interesting objects, which is a big step towards making the world more automated and sustainable. You can tell Arduino to do such things in an appropriate language that Arduino understands: C, C++. The projects related to monitoring environmental variables are simple and common but always important; many greenhouses and household crop monitoring projects are available (Akami et al., 2015). This project should help with learning electronics and programming, as well as the documentation process.

Temperature-sensitive items used in aviation, such as aircraft rubber equipment and aircraft fuel actuation devices (PAD) (such as fire-fighting cartridges, ejection seat cartridges, signal cartridges, etc.), must be stored in temperature-controlled warehouses. Storing such items at an inappropriate temperature may affect their lifespan and the aircraft's operability on which they are installed. In a hot tropical country like Nigeria, measuring the temperature in a warehouse is a big challenge. Therefore, this project was undertaken to ensure the specified lifetime of associated equipment temperature-sensing elements during storage. The temperature sensing and protection system combine electrical and electronic instruments. This study aims to develop a temperature monitor using an Arduino microcontroller and an LCD display. The following are the objectives of the study:

1. To construct a temperature measuring system using an Arduino microcontroller.
2. To integrate the developed temperature monitor monitoring system, temperature sensor and an LCD for measuring environmental temperature.
3. To evaluate the system with different test data/environments

2. Review of Related Works

There is a lot of research on temperature control in the existing literature, but few of them have used Arduino for automatic temperature control, especially for monitoring applications. Several papers, and here are some key contributions presented. Atilla et al. (2016) presented a case study on the design of an Arduino-controlled heating system. They examined the technology, software, and hardware used in the heating system, consisting of an insulated box, dry resistor, voltage regulator, thermocouple, air blower, microcontroller, and calculator. Proportional-Integral-Derivative (PID), neural networks, and fuzzy logic are mainly used for temperature control of heating systems. The system uses a PID controller and has a satisfactory stability value, good reliability, and sensitivity. Microcontroller-based temperature control was developed by comparing theoretical temperature values. However, Arduino control and implementation were not done.

Abdullah et al. (2016) proposed a temperature control system design and implemented it on the TudungSaji microcontroller. The hardware implementation, as well as the software simulation, have been tested and obtained. The purpose of this work includes protection against bacteria after a certain temperature value. The application seems to fight bacteria rather than prevent them since the bacteria can be killed above a certain temperature. It could also be tested on the Arduino IDE system.

Widhiada et al. (2017) proposed developing and designing a temperature distribution controller for application in baby incubators. With this system, it is very important to maintain a certain temperature in the room to ensure a baby's proper health. Humidity was also included in the investigation of the experiment using a microcontroller-based system for temperature measurement and control. It has become a very important application for baby care and health.

Nagendra et al. (2017) presented a design and implementation of an Arduino-based temperature sensor also used to measure humidity levels. Kanishake et al. (2016) published a case study on temperature control systems using microcontrollers, TRIAC and bridge rectifiers. Vaibhav et al. (2013) implemented a speed control system based on temperature changes; the temperature control system was used for the changing temperature measurement. PWM and simulation software was used to design, and the computer simulated the hardware. Theophilus et al. (2012) tested the temperature monitoring mechanism using the Atmel Atmega 8385 system and the LM35 temperature sensor.

Kiranmai et al. (2018) also proposed a temperature control system, claiming that it would be very useful for Internet of Things (IoT) related applications. However, the real-time application for such an application has not been tested. Sinhala et al. (2014) studied a fuzzy-based temperature control system that was entirely simulation-based and had no hardware implementation. The proposed system was very simple and effective, but hardware implementation and realization remain a future scope of work.

Okpagu et al. (2016) proposed developing a temperature control system for egg incubator systems using sensors, PID controllers, LCDs, DC motors and a fan control system. It is an important incubator system as it becomes essential to monitor the embryo and its growth. Hence, temperature control and monitoring play an important role in this system. Meran et al. (2016) proposed designing and developing a remote temperature monitoring system. Arduino-based work aims to provide a viable solution for environmental monitoring and care.

Some researchers have performed air temperature monitoring studies using a microcontroller, such as B. Rekratn and Kaewpoonsuk (2015), who studied the ZigBee-based wireless temperature monitoring system for shrimp ponds based on ZigBee technology, and Yumang et al. (2016), who investigated ZigBee-based server room temperature and humidity monitoring using thermal imaging.

Monitoring the temperature and real-time humidity of the computer server room was very important to ensure that the server performance was not affected by excessive room temperature and humidity. Punetha and Mehta (2016) used the wireless approach for real-time remote monitoring systems to study environmental parameters through the feasibility of GSM modules. The wireless approach to monitoring remote areas that have large areas and therefore has been difficult to manage due to the lack of information from individuals.

Aliet al. (2016) achieved access to on-chip temperature monitoring devices using the IEEE 1687 standard using three temperature monitoring devices together with online temperature measurements from an IJTAG controller using the IJTAG network interface. Wen et al. (2016) investigated the RFID-based skin temperature monitoring patch through the development of RFID-based conductive fabrics for temperature measurement and demonstrated their use by measuring fluctuations in skin temperature. Khan et al. (2017) investigated the effect of temperature fluctuations on remote pressure measurements in a wireless intracranial pressure monitoring system. The implant pressure monitoring system was an urgent approach for long-term monitoring of intracranial pressure at home.

Also, from the literature review, the researchers have not attempted temperature monitoring, particularly on Arduino control and hardware-based temperature measurement, which is the focus of this research. This study suggests an Arduino control and hardware-based temperature control system, mainly highlighting temperature monitoring and measurement

3. Materials and Methods

The materials requirements for this project include the hardware and software components.

3.1. Hardware Components Required

- Arduino UNO
- LCD display
- DC Power Supply (9v alkaline batter)
- Jumper wires
- Temperature sensor (LM 35)
- Adaptable box
- Potentiometer (2 pcs).

3.2. Software requirements

- Arduino 1.0.3 (Arduino Software)
- Arduino Development Environment

3.3. System Design and Implementation

This section comprises the design of the system and its implementation

3.3.1. System Design

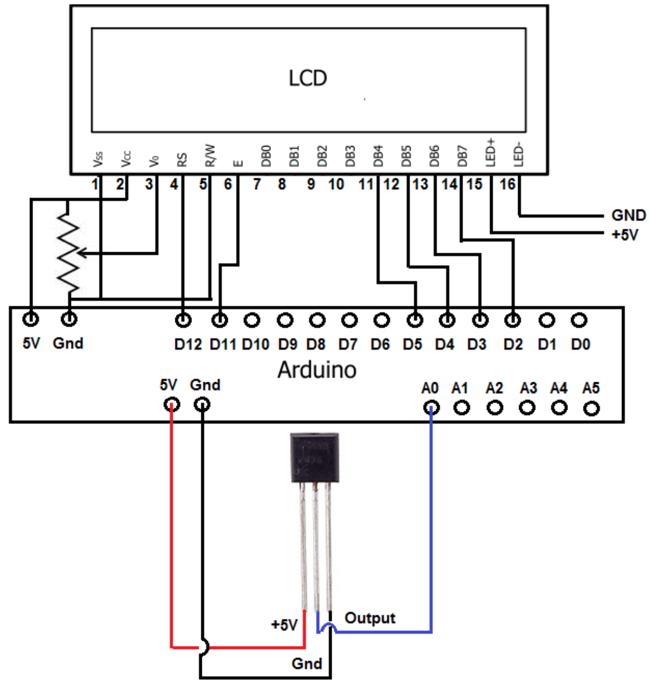

Fig. 1 Data flow and block diagram of the system

The proposed system aimed to connect an LM35 sensor and Arduino with its program. The further developed system builds a temperature display with Arduino and a 162 LCD module, which constantly monitors the temperature around the measuring field / measuring area of LM35 and displays it on the LCD module. An LM35 is an analog linear temperature sensor whose output voltage varies linearly with temperature. LM35 is a three-terminal linear temperature sensor from National Semiconductors. It can measure temperatures from -55 degrees Celsius to +150 degrees Celsius. The output voltage of the LM35 increases by 10 mV per degree Celsius increase in temperature. LM35 can operate from a 5V supply, and the standby current is less than 60uA. LM35 is an analog temperature sensor. It means that the output of the LM35 is an analog signal. Microcontrollers do not accept analog signals directly as input. We need to convert this analog output signal to digital before we can feed it to a microcontroller input.

For this purpose, we can use an ADC (analog to digital converter). If we use a simple microcontroller like 8051, we need to use an external ADC to convert the analog output from LM35 to digital. We then feed the output of the ADC (converted digital value) into the input of 8051. But modern boards like Arduino and most modern microcontrollers have an onboard ADC. Our Arduino Uno has a built-in 10-bit ADC (6-channel). We can use this in the Arduino's onboard ADC to convert the LM35's analog output to a digital output. Because Arduino uno has a built-in 6-channel ADC, 6 analog input pins are numbered A0 through A5. Connect the analog output of LM35 to one of these Arduino analog input pins.

A Liquid Crystal Display (LCD) is a flat panel display or another electronically modulated optical device that uses the light-modulating properties of liquid crystals in combination with polarizers. Liquid crystals do not emit light directly but use a backlight or reflector to create color or monochrome images. LCDs are available to display arbitrary images (as in a general purpose computer display) or low information content still images that can be shown or hidden, such as B. preset words, digits and seven-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are created from a matrix of small pixels, while other displays have larger elements. LCDs can be either normally on (positive) or off (negative), depending on the polarizer arrangement. For example, a character-positive backlit LCD has black font on a background that is the backlight's colour, and a character-negative LCD has a black background with letters the same color as the backlight. Optical filters are added to white-on-blue LCDs to give them their distinctive appearance.

3.3.2. Hardware Implementation

The hardware implementation was achieved on Arduino IDE connected to a computer. The data flow and block diagram of the hardware implementation are shown in Figure 1. Figure 1 is simple and self-explanatory where to connect the temperature sensor using Arduino and 16_2 matrix LCD display. The hardware design is very simple, with no circuit complexity. The project used the LM35 temperature sensor IC, which helps generate a small voltage to detect the temperature change across the sensor.

The proposed system is a monitor that works as a thermometer to measure temperature. It can measure outdoor temperature. Compared to expensive sensors, the Arduino-based monitoring system successfully reduces power consumption, cost and process complexity. The system's performance was accurate and reliable, with some measurement errors and limitations of the sensor used. Arduino-based monitoring devices are the new ways to develop smart devices with small budgets and easy work. The accelerating race for cutting-edge technology is rapidly overtaking the technology used in Arduino Uno; advanced software that works similarly is available. The Arduino is programmed to use a USB cable to connect to the computer, while many other boards have different functions. The project was interesting and practical for learning how to use microcontrollers (Arduino), the C programming language and basic electronics. It is a very helpful project for learning and understanding the world of microcontrollers and using microcontrollers in real life. The project is a platform for further developing the research, testing and documentation techniques learned during the course.

4. Results and Discussion

The Arduino sketch was uploaded to the Arduino microntroller after the connections (wiring) were made. The code was then uploaded to Arduino and tested for communication. Figure 2(a)-(b) below shows the connection (wiring) for communication between Arduino, LCD and LM35 temperature sensor.

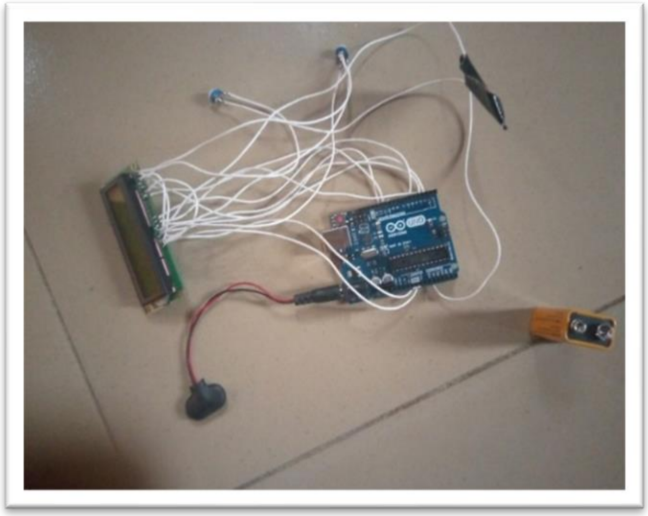

Fig. 2 (a) Arduino, LCD, and LM35 temperature sensor interfaced through wiring

Fig. 2 (b) Arduino, LCD and LM35 temperature sensor powered by a 9v alkaline battery

A 9V alkaline battery powers the connected Arduino, LCD and LM35 temperature sensor. Marked with black tape, the temperature sensor senses the temperature of the environment and then sends signals to the Arduino microcontroller. The Arduino recognizes the temperature readings and sends signals to the LCD display.

4.1. System Integration

The whole system has been integrated with an adaptable box. A 9V alkaline battery powered the Arduino. The reason for packing is that if we want to use an Arduino board in standalone mode, the first problem is how to power it once it is unplugged from the computer's USB port. Unfortunately, incorrect knowledge of power supply sometimes leads to unforgivable mistakes. The first consequence is often that the board goes up in smoke and is almost always irreversible since, from that moment, it stops working. Figure 3 below shows the fully packaged system.

Fig. 3 Packaged Arduino-Temperature senor with LCD display prototype using adapter Box

4.2. System Testing

Testing is the process of evaluating a system or its component(s) to find out whether or not it meets the specified requirements. In simple terms, testing is running a system to identify gaps, bugs, or missing requirements instead of actual requirements. A primary purpose of testing is to detect errors so that errors can be discovered and corrected. Other purposes may include validation and verification that the result of a computer program meets the business and user requirements that guided the design and development and work as expected. This study performs system tests with multiple test cases, as shown in Table 1.

Table 1. Test cases

Test Case	Data/Environments	Initial Temperature	Highest Temperature
1.	Room temperature	31.00 ºC	36.00ºC
2.	Sun rays	31.20 ºC	55.00 ºC
3.	Ice block	25.60 ºC	16.80 ºC
4.	Heat (from candle stick)	27.20ºC	103.20ºC

The device was tested using normal room temperature, sun rays and an ice block. The figures below show the results.

Figure 4 above shows the highest temperature reading from normal room temperature as measured by the device designed and constructed. The temperature started reading from 31.00 ºC to a peak of 36.00ºC**.**

Fig. 4 Peak normal room temperature

Fig. 5 Peak temperature readings from sun rays

Figure 5 above shows the temperature readings from sun rays. The initiation temperature was 31.20 ºC and read through to a peak of 55.00 ºC.

Fig. 6 Peak temperature readings from Ice block

Figure 6 above shows the peak temperature from the ice block. The temperature reading started at 25.60 ºC and peaked at 16.80 ºC.

Fig. 7 Peak temperature from heat using candle stick

Figure 7 above shows a candle stick's heat (fire) peak temperature. It began at 27.20ºC, as shown in Table 1 above, and stopped at 103.20ºC.

5. Conclusion

An automatic temperature control system is important in almost all modern devices and smart homes. The automatic temperature control system is achieved through an Arduino Uno-based microcontroller system. Arduino Uno finds a wide range of applications due to its increased popularity. Temperature Sensor LM35 and Arduino Uno are the hardware that connects to the computer, and the ambient temperature is measured. The temperature is shown on an LCD display using an A1 hardware pin using an analog pin that uses pulse width modulation (PWM). The work mainly focuses on temperature measurement; no other parameters are involved. It seems like a robust way of just handling the temperature measurement automatically. The designed tool could satisfactorily determine the ambient temperature. The test phases were carried out to check and ensure the proper functioning of the devices. The results showed that the ambient temperature monitoring with Arduino, temperature sensor and LCD display works as intended and meets the project's overall goals.

Some typical applications of the devices can be used to monitor and record temperature, e.g. B., in agriculture, in the laboratory, in the office and at home. The project is successfully implemented within a time frame. It can also be extremely useful for people with physical disabilities. A soft computing technique could make more robust and fuzzy-controlled devices. This method could also be used in refrigeration systems, where the temperature of appliances such as refrigerators is controlled automatically. The study concludes that IoT has become important in daily life and greatly impacts the future. For example, solutions for traffic flow, vehicle maintenance reminders, reduction of energy consumption, etc., can be provided immediately. Monitoring sensors diagnose pending maintenance issues and even prioritize maintenance crew schedules for repair equipment. Data analytics systems will help metropolitan and global cities function efficiently in terms of traffic management, waste management, environmental protection, law enforcement, and other important functions. Further research can be done in the following areas:

1. Monitoring the environmental temperature using Arduino and a web-based application.
2. An Arduino-based temperature sensing system and a global system for mobile (GSM) interface and alarm mechanism.

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