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Designing a Computer Network Server Room Temperature Control System for a Commercial Bank

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Abstract**—** *This research paper is based on an automatic temperature control system that automatically adjusts a computer network server room system in response to the surroundings' ambient temperature, in order to maintain it at an optimum range. A temperature control system can be realized in different forms, e.g. as an automated fan that is controlled by a temperature sensor, with the use of a fully hardware design. In this project, the researcher uses a predesigned temperature sensor circuit which monitors the temperature variations of its surroundings. The weak signal produced by the temperature sensor is then strengthened using an amplifier to enable it to drive the output section, which in this case is a fan. Pulse width modulation (PWM) is the technique is used in this case. The heat applied to the temperature sensor, respectively determines how the fan automatically responds by increasing or decreasing its speed thereby affecting the overall temperature of the server room. This system can be handy in cooling various electronics devices, by controlling fan speed whenever heat dissipation increases.*

Keywords**—** *Ambient temperature, automatic, circuit, fan, modulation, server room, sensor, signal, temperature control.*

I. INTRODUCTION

A temperature controller is a device which manipulates temperature at an ideal range, according to Debele and Qian (2020). In agreement, Fadzly, *et al*. (2020) say "temperature controller is a hardware device that regulates temperature in an optimum range". In line with the presentations noted from the previous authors, this researcher agrees with the notion that a temperature controller is a system whose purpose is to monitor and maintain a desired temperature at a specified value and/or range. A computer network server room is a room that stores computer network equipment at an optimum temperature range, says Zemarni (2014). Designing is to invent something new, according to Jones (1979). Feki (2009) further explains designing as 'a plan or specification for the construction of an object'.

II. BACKGROUND OF STUDY

In a network computer server room at a certain commercial bank, use is made of an air conditioner to maintain a desired and favourable temperature for the housed servers. The air conditioner runs 24/7 in order to achieve the desired purpose. It is manually monitored and adjusted by the responsible technicians three times a day: in the morning at 8am, at midday and in the evening at the closing hour.

2.1 Scientific Issues, Objectives and Proposition

The temperature in the server room, despite the programmed manual adjustments, is not always ideal as it sometimes appear to cause network gemming. These gemming negatively affect bank transactions, resulting in customer and the bank experiencing loses. If the status score is permitted to prevail, the bank and its customers will continue losing out from the resulting inefficient transactions. This researcher will attempt to design a better temperature control system that will prevent overheating and overcooling of temperatures in the computer network server rooms.

This researcher's plan is to implement this project in the computer network server room to automatically adjust temperature to an optimum range.

2.2 Significance, Scope and Paper Outline

This introductory chapter managed to explain the intention of the undergoing study and establish the research gap. The study is further organized as follows:
Chapter Two: Literature Review
Chapter Three: Methodology
Chapter Four: Design Analysis
Chapter Five: Recommendations and Conclusions.

III. LITERATURE REVIEW

Literature review is some piece of academic write-up that demonstrates one's understanding of a particular topic under scrutiny. It 'includes a critical evaluation of the material, this is why it is called a literature review rather than a literature report', Petit *et al* (2019). Rohak (2022) further explains literature review as a write-up that summaries studies related to a particular area of research. It identifies, scrutinizes and summarizes all the relevant studies that have been carried out on a particular subject matter of interest. Important is the fact that a literature review is much focused. Literature reviews helps in accomplishing the following: evaluating research by collecting all relevant resources that will assist in identifying the research that has already been done. This assists in avoiding duplications, identify experts in order to seek their help whenever necessary on certain aspects of similar researches and identifying key questions with an aim of bringing something new to the conversation. In this instance, the researcher used the opportunity in identifying previous studies that occurred in Network Server Rooms and Server Rooms Temperature Controls in order to lay a firm foundation for developing the ongoing study.

3.1 Network Server Rooms

Server rooms are rooms that house central computer equipment (servers) for organizations for proper and efficient management of their computer network resources. The designs of these rooms are expected to consider the following: network connectivity, electric power availability, environment temperature control, adequate space, rack security, and fire and seismic protection issues. There are two different server environments: data centres and micro data centres, according to Rocha and Verdi (2015). When analysing the design of server rooms for improvement, these characteristics are pertinent for consideration: room specifications, equipment to be housed, fire prevention, and cooling requirements.

Design choices of network server rooms must involve the server equipment capacity that an organization eventually requires and the current server user capacity it permits. "Underutilizing space can cause inefficiencies, while over-utilizing space can increase risks that can lead to added costs or even hazardous events", say Azad, *et al* (2018). Room specifications include the measurement of the room (space) for equipment location, sound isolating walls, door sizes, antistatic floors for the prevention of electrostatic discharge, window count for room security, and temperature control. Equipment considerations involve the power grounding, power density, ceiling height that can accommodate duct ventilation, room clearance necessary for equipment mobility, and the inclusion of at least one service phone.

Ashraf, *et al* (2021) say "Fire prevention considerations include the use of non-liquid fire suppression systems and the desired fire rating for server rooms, especially if the cabling runs through the ceiling or floors". Cooling considerations include the designed and installed floor air distribution or ceiling ducting. Only the few selected and authorized individuals are permitted to enter server room areas. Additionally, too much traffic must be avoided as it can result in an excess of dust particles. These considerations therefore dictate the importance of automatically maintaining optimum temperatures in the server environments.

3.2 Server Rooms Temperature Controls

Temperature measures the level of coldness or hotness of an environment or piece of an item (body). Control Systems are devices that are responsible for regulating the behaviour of other devices or systems. According to John (2011), a temperature control system is a device or group of devices that control, command, direct, or govern the actions of other devices or systems in order to modify the temperature of a given space.

An automatic temperature control system is an example of an important application used in almost all modern gadgets and smart homes. That system for controlling temperature is archived by using a predesigned Arduino Uno-based microcontroller system, say Khaing *et al* (2020). Studies on temperature control systems have long been continued until nowadays due to its growing applications in industry and household appliances for cooling or heating purposes, according to Asraf *et al* (2017). Some temperature control systems may be adequate for small server rooms, but inadequate for larger or dense ones which may require more precise thermal management using cooling solutions designed specifically for critical Information Technology equipment. "In the case of high-performance computing applications, for example, liquid cooling systems may be the most appropriate solution", Akbarzadeh, *et al* (2021). It is for such systems that the researcher will attempt to design a more efficient temperature control system.

3.3 Summary

This chapter made a spirited attempt to establish the research gap in the desire to produce stable temperatures in Network Server Rooms, for the protection of the housed Information Technology equipment. The following chapter on Methodology will unravel the method applied in the study.

IV. METHODOLOGY

Methodology refers to the overarching strategy used in solving a research project. It involves the process of selecting the method(s) used in the research work and the theories or principles behind them, in order to develop an approach that matches the researcher's objectives. A well-written methodology not only describes the tactics used but also presents the case for why one chose the method(s) used. Methodology is another important chapter in a research project. In this chapter, one states the research method adopted, the instruments used, where and how one collected the used data and/or materials. The researcher also tells the readers why he/she chose a particular method, which leads to the method of analysing the data. Generally, researchers talk of the following methods: qualitative, quantitative, and hybrids methods.

4.1 Qualitative Methods

Qualitative research is a type of research that is scientific research in nature and consists of an investigation that generally seeks answers to questions, systematically uses predefined set of procedures to answer the questions, collects evidence, and produces findings that were not determined in advance but are applicable beyond the immediate boundaries of the study. Furthermore, it seeks to make an understanding of a particular given research problem or topic. Qualitative research particularly concentrates in producing culturally specific information on the values, opinions, behaviours, and social contexts of a specific population.

The strength of qualitative research is evident in its ability to provide complex textual descriptions of how people experience and interpret a given research issue. It provides information about the humanity of an issue – that is, the often-contradictory opinions, behaviours, beliefs, feelings, and relationships of individuals or groups of people. Qualitative methods are also used when investigating intangible factors, such as gender roles, social norms, ethnicity, socioeconomic status, and religion, whose role in the research issue may not be readily apparent. When used together with another method called quantitative, it helps in interpreting and bringing better understanding of complex realities of given situations and the implications of established quantitative data.

There are three most common qualitative approaches: focus groups, participant observation and in-depth interviews. Each strategy is particularly suitable for obtaining a specific type of

research data. Focus groups are useful for gathering information on a group's cultural norms and for producing high-level summaries of topics that are important to the represented cultural groups or subgroups. Participant observation is appropriate for collecting data on naturally occurring behaviours in their usual contexts. When gathering information about people's backgrounds, viewpoints, and experiences, in-depth interviews work best, especially when delicate subjects are being covered. This method however, is inappropriate for this kind of study because the study is independent from the subjective qualitative aspects such as human feelings, moods and thoughts.

4.2 Quantitative Methods

Quantitative methods rely in numbers, they emphasize objective measurements and mathematical, statistical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by interpreting pre-existing statistical data using computational techniques.

This method is favoured in cases of a descriptive, correlational, or experimental nature of research. In a descriptive research, one desires to fully describe and elucidate the understanding of some focused study variables. In an experimental research, the researcher aims at examining the cause-and-effect relationship between some given or identified variables. Results from an experimental research may be generalized through correlation to broader populations, based on the sampling method used.

Qualitative researchers believe that numbers do not lie. Again, this method is not very suitable for the current study, due to the irrelevance of the objective quantitative characteristics such as numbers and measurements.

4.3 Hybrid / Triangulation

Triangulation method is essentially a combination of at least two methods, e.g. Qualitative and Quantitative methods. It applies multiple datasets, methods and theories which help the researcher enhance the validity and credibility of his/her findings and mitigate the disadvantages derived from any particular method. Triangulation method protects a research work in avoiding the flaws and research biases that are associated with reliance on a single research technique. In data triangulation, researchers use multiple data sources in answering the research questions. The researcher has the option to vary his/her data collection across time, space, or different people. That way, the results obtained are more likely and easier to generalize to other situations. With investigator triangulation, one involves multiple observers or researchers to collect, process, or analyse data separately. This helps the researcher reduce the risk of observer bias and other pre-construed experimenter biases.

4.4 Selected Method

In this research, the method that this researcher chose is experimental because the study is purely technical, highly analytical and investigative. Experiments are best carried out in a laboratory environment where there is an opportunity to test the functionality of an established design or arrangement between the established independent and dependent variables. Implementation follows through the Project launch in the respective market.

V. Design Analysis

Design analysis is the systematic process of developing a design, including all the components used plus the design testing processes. This can be applied to any type of a design, including that of physical things such as buildings and intangible things such as software, information, and processes.

5.1 Components

The components used in the circuit design of this Project are as detailed below.

	Component name.	Quantity
1	Arduino UNO Board.	1
2	LM35 Temperature Sensor	1
3	12V DC Fan	1
4	16x2 LCD Display.	1
5	Transistor 2N2222.	1
6	Resistor 1K	2
7	Diode 1N4007	1
8	Capacitor 10uF	1
9	LED 5mm any colour	1
10	12V Power Supply/Adapter.	1
11	Jumbper Wires	20
12	Breadboard	1

Arduino UNO Board

An ATmega328P-based microcontroller board is the Arduino UNO. Six of its fourteen digital input/output pins can be utilized as PWM outputs.

LM35 Temperature Sensor

LM35 is a temperature measuring device having an analogue output voltage proportional to the temperature. It provides output voltage in Centigrade (Celsius). No external calibrating circuitry is needed for it. The LM35 has a sensitivity of 10 mV/°C. The output voltage increases in tandem with temperature.

12V DC Fan

DC fan motors driven by direct current voltage rotate fan to cool the inside of home electrical appliances and other office automation. This 50mm *12V DC Fan* offers excellent airflow while maintaining near-silent noise levels makes it ideal for small to medium electronics, Arduino, and PCB projects.

16x2 LCD Display

An LCD that is 16 by 2 may show up to 16 characters on each of its two lines. Every character on this LCD is shown as a 5x7 pixel matrix. The 16 x 2 intelligent alphanumeric dot matrix display can display 224 different characters and symbols.

Transistor 2N2222.

A popular NPN bipolar junction transistor (BJT) for general-purpose low-power switching or amplifying applications is the 2N2222. It can run at somewhat high speeds and is intended for low to medium current, low power, and medium voltage.

Resistor 1K

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This is a passive electrical component, with two unpolarized terminals. It is used for limiting and/or regulating the flow of electric current in various electronic circuits.

Diode 1N4007

The 1N400 is a rectifier diode with moulded plastic case. Diffused junction, low forward voltage drop, high current capability, and low forward voltage drop are characteristics of the rectifier diode.

Capacitor 10uF

The capacitor is *a two-terminal electrical device that stores energy in the form of electric charges*.

LED 5mm any colour

A semiconductor device known as a light-emitting diode (LED) releases light when an electric current passes through it. Based on the semiconductor material used. 5mm represents the diameter.

12V Power Supply

The power that we get from a 12 Volt battery, or any other battery is in the *form of direct current*. This power supply is used to power up the Arduino Uno board.

Connecting Wires

A wire is a metal strand that is flexible and typically cylindrical. In order to create electrical conductivity between two components of an electrical circuit, wires are utilized.

Breadboard

This is a rectangular plastic board with a bunch of tiny holes in it. The holes are meant to enable the insertion of electronic components onto the board when realizing a prototype. A breadboard is a solderless device for temporary prototype creations and testing circuits. Most electronic components in electronic circuits can be interconnected by inserting their leads (terminals) into the holes of the breadboard and then making connections using jumper wires where necessary.

5.2 Circuit Design & Code

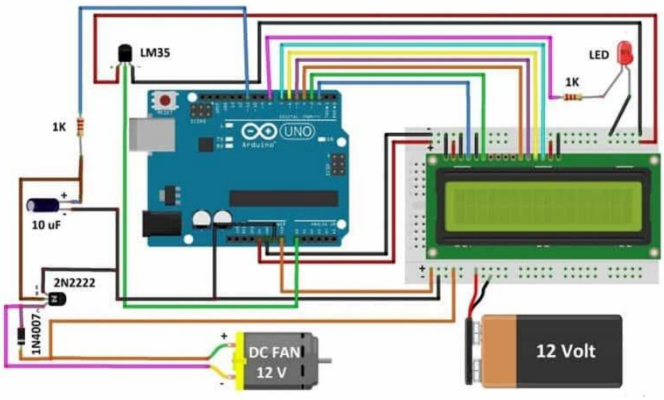

Figure 1: Circuit diagram

Source Code/Program

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(2,3,4,5,6,7);
int tempPin = A0; // the output pin of LM35
int fan = 11; // the pin where fan is
int led = 8; // led pin
int temp;
int tempMin = 30; // the temperature to start the fan 0%
int tempMax = 60; // the maximum temperature when fan is at 100%
int fanSpeed;
int fanLCD;

void setup() {
pinMode(fan, OUTPUT);
pinMode(led, OUTPUT);
pinMode(tempPin, INPUT);
lcd.begin(16,2);
Serial.begin(9600);
}

void loop()
{
temp = readTemp(); // get the temperature
Serial.print( temp );
if(temp < tempMin) // if temp is lower than minimum temp
{
fanSpeed = 0; // fan is not spinning
analogWrite(fan, fanSpeed);
fanLCD=0;
digitalWrite(fan, LOW);
}
if((temp >= tempMin) && (temp <= tempMax)) // if temperature is higher than minimum temp
{
fanSpeed = temp;//map(temp, tempMin, tempMax, 0, 100); // the actual speed of fan//map(temp, tempMin, tempMax, 32, 255);
fanSpeed=1.5*fanSpeed;
fanLCD = map(temp, tempMin, tempMax, 0, 100); // speed of fan to display on LCD100
analogWrite(fan, fanSpeed); // spin the fan at the fanSpeed speed
}

if(temp > tempMax) // if temp is higher than tempMax
{
digitalWrite(led, HIGH); // turn on led
}
else // else turn of led
{
digitalWrite(led, LOW);
}

lcd.print("TEMP: ");
lcd.print(temp); // display the temperature
lcd.print("C ");
lcd.setCursor(0,1); // move cursor to next line
lcd.print("FANS: ");
lcd.print(fanLCD); // display the fan speed
lcd.print("%");
delay(200);
lcd.clear();
}

int readTemp() { // get the temperature and convert it to celsius
```

```
temp = analogRead(tempPin);
return temp * 0.48828125;
}
```

5.3 Circuit Design Functionality

The circuit diagram is shown on Figure 1. An Arduino Uno microcontroller board controls all functions of the circuit. The LM35 temperature sensor monitors the room temperature. The 2N2222 transistor acts as a switch that controls the fan and its speed, with response to the impending temperature. The diode (1N4007) controls the fan from being damaged, while the LED glows whenever the temperature exceeds 40°C.

When the LM35 senses the temperature variations, it converts it into an electrical (analogue) signal which is applied to the ATmega328 microcontroller of the Arduino UNO Board. The analogue value is then converted into a digital value so that the sensed values of the temperature and speed of the fan are displayed on the LCD. When the temperature exceeds 30°C the fan starts rotating.

5.3.1 Pre Implementation Testing

The researcher was able to test the proposed design using a thermostat-controlled room temperature. When the temperature was set below 30°c, the temperature control system was off as the temperature was ideal. When temperature reached 30°c, the fan turned on at 1% speed as the temperature became out of an ideal range. As the temperature exceeded 30°c the fan speed increased speed in proportion to the temperature increment. When the temperature reached 40°c, the LED turned on, notifying higher temperatures and the fan speed reached its maximum speed at 100% as it optimized the temperature.

5.3.2 Quasi Implementation Testing

The researcher conducted his/her experiment in three different server rooms under the same building, so as to avoid biased outcomes. Server room A had a thermostat frequently monitored. Server room B had an automatic temperature control system. Lastly, Server room C had neither a thermostat nor temperature control system. After some time, different temperatures were observed. Server room A temperature was controlled frequently to an ideal range using a thermostat. Server room B temperatures were always at an optimum range as the automatic temperature control system optimizes the temperature automatically. Server room C temperature was not controlled; hence room temperature was collected depending on the surrounding weather.

5.4 Design Conclusion

In this chapter, the researcher described the designed Temperature Control System with the use of an Arduino Uno microcontroller board and LM35 Temperature Sensor and its various testing stages. The designed microcontroller evidently managed to automatically control the speed of the cooling fan, according to the expectations of the researcher to allow dynamic and fast control of the temperature in the Network Server Room. The attached LCD makes the system become user-friendly by displaying the prevailing temperatures in the room.

VI. Recommendations and Conclusions

This is the last chapter of the research which provides the recommendations and a summary from the entire study, after the successful pre and post testing implementation.

6.1 Recommendations

Following the success obtained from the tests conducted on the circuit design from the study, the researcher recommends the following:

- Production of a commercial proto-type for launching in the respective market.
- Evaluation of production costs of a commercial product in preparation for commercializing the circuit design.
- Testing the product in other temperature variation sensitive environments, in preparation for expanding application areas.
- Conducting a similar study, but powered by a solar system instead of a 12V battery so that it becomes usable in the absence of a battery.

6.2 Conclusions

This research project was about designing a temperature control system of a computer network server room for a bank. As already proved, it can be applied in any bank or organization with a temperature sensitive environment. This documentation unravels the steps taken by the researcher in designing the project. The project promises to be a very valuable asset that has the potential to save Banks, their clients and other organizations from financial losses that are likely to arise from malfunctioning computer servers due to unstable temperatures.

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