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Design and Construction of a Temperature Detection and Monitoring System in a Server Environment

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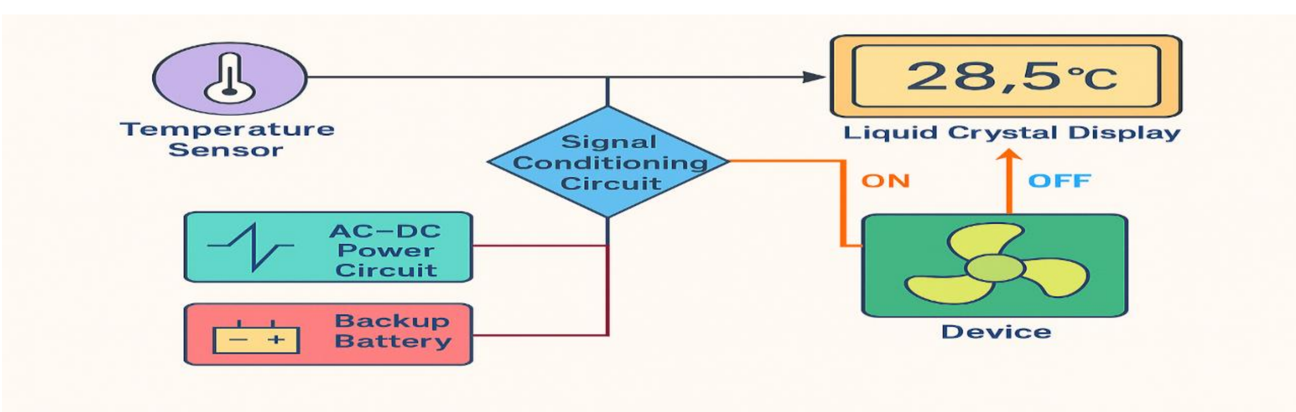
Abstract

This research outlines the development and execution of a system for detecting and monitoring temperature. A system capable of automatically controlling electrical appliances based on ambient thermal conditions. The system is designed to switch OFF electrical appliances when the temperature falls below 20 °C and switch them ON when it exceeds 30.8 °C, ensuring optimal thermal regulation in sensitive environments. The core components include an LM35DZ temperature sensor, flash-type ADC (ICL7107), a signal conditioning circuit, a relay-based switching mechanism, and a 555-timer alarm for real-time alerts. Power is supplied through an AC–DC converter with battery backup, enabling uninterrupted operation. The system was tested across 14 computer centers in Benin metropolis over a 7-day period, with average temperature readings ranging from 23.4 °C to 35.8 °C. The device consistently demonstrated an output voltage accuracy within ±0.11 V of the design values and a current drain of 104 mA, confirming its reliability and responsiveness. Due to its low cost and use of locally sourced components, the system is suitable for deployment in laboratories, server rooms, industrial facilities, and other temperature-sensitive environments.

Keywords: *Temperature Monitoring, LM35DZ Sensor, Flash ADC, Relay Control, Embedded System.*

Graphical Abstract



1.0 INTRODUCTION

In server environments and other industrial systems, precise temperature control is critical for ensuring high-quality outcomes, operational safety, and efficient resource utilization. Temperature fluctuations can significantly affect system integrity and compromise system stability [1, 2]. Although current temperature monitoring systems generally function as designed, they often lack the flexibility needed for effective management and accurate recording in high-demand environments [3].

A temperature switching system is needed to monitor and control temperatures in various applications, ensuring equipment safety, efficiency, and optimal performance by automatically activating or deactivating devices based on temperature thresholds [4]. Temperature switches are designed for controlling and monitoring temperatures in various systems and applications. They switch an electrical contact when the temperature exceeds or falls below a certain level, thereby preventing overheating or ensuring sufficient heating [2].

Temperature switches are utilized to regulate and observe temperature across different industrial and residential settings. Temperature switches that deactivate at a specified temperature threshold are referred to as safety temperature monitors or temperature limiters [1, 5]. This device activates an electrical contact when temperatures rise above or drop below a predetermined level. These instruments guarantee that systems function within safe and efficient temperature limits, thereby improving performance and preventing failure issues. [5, 6].

In environments where computers, laboratory and industrial equipment are kept, strict temperature conditions must be maintained, with a temperature monitoring system. The device can be used in areas such as livestock (broiler) production centers, which essentially provides four basic functions such as indication, alarm, control and measuring of temperature [7], computer centers, and monitoring in industrial and domestic applications.

The system gauges the environmental temperature by detecting the infrared waves released, all without making physical contact [3, 8]. Temperature monitoring involves measuring and recording the temperature of a specific environment in order to control it and take necessary steps to protect equipment by switching ON and OFF air conditioners or fans. Temperature is a variable parameter [9]. It is a measure of the thermodynamic state of an object [10]. Most electronic and industrial centers under consideration are maintained at a temperature of 21-23°C which is assumed normal to prevent their breakdown.

The objective of this study is to design and construct temperature detecting and monitoring system that ensures temperature remain within a set range, to switch ON and OFF electrical appliances in an environment and alert users through an alarm.

2.0 MATERIALS AND METHODS

2.1 Materials

Table 1: Materials.

S/N	Name of components	No. of components
1	Rechargeable battery 6V 4.5AH	1
2	8Ω Loud Speaker	1
3	Sensor LM35DZ (Transducer	1
4	ICL7107CL (Digital Dual Display)	1
5	Seven Segment Display	3
6	Relay of 12 volts 30Amp	1

2.2. Methods

The Figure 1 is the block diagram of alternating current (AC) to direct current (DC) converter consisting of battery charging unit. The AC–DC in the system supplies a constant voltage of 12 volts to the temperature and monitoring system. It is a common EV battery charger. The operation of an EV battery charger depend on the components for construction and the control strategies employed, which provide the required power to drive the entire system. The first stage is the sensing circuit which detects the room temperature and input the data to ADC. Temperature sensor detects temperature of surrounding without any physical contact with it and in turn converts it to electrical signal [11]. The ADC converts the analog signal to digital form for the microcontroller to process the data. Fig 2 is the block diagram of the device which is made up of AC to DC converter.

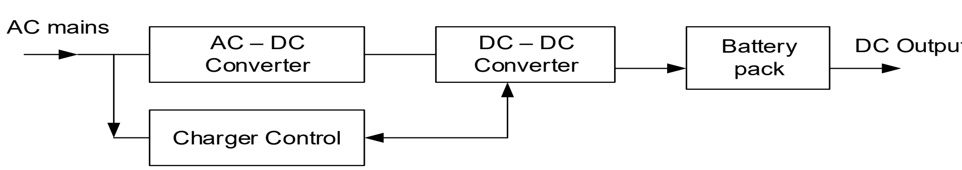


Figure 1: block diagram of AC to DC converter with battery charging unit

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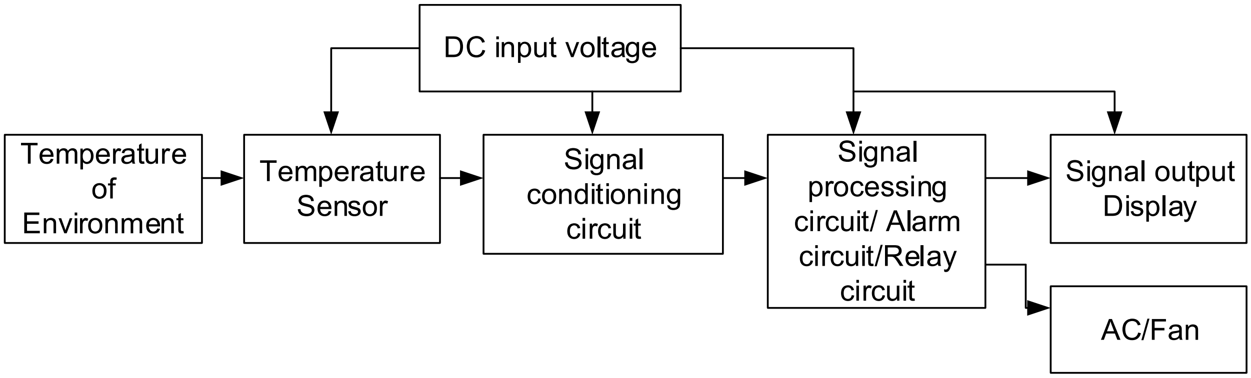

Figure 2: Block diagram of temperature detection and monitoring system

The factors for selecting the temperature sensor include: range of operation, durability, susceptibility, maintainability and calibrability [12, 7]. A temperature sensor is a device that gauges temperature and translates the information into a signal that can be interpreted by a user or by a measuring instrument. The essential functions of a temperature sensor include measurement, conversion, monitoring and control [13]. The temperature transducer chosen and used in this study is LM35DZ. This component functions as an integrated-circuit temperature sensor, providing an output voltage that corresponds directly to the temperature in Celsius (Centigrade) [12, -14]. It offers a benefit compared to linear temperature sensors that are calibrated in Kelvin, as users do not need to subtract a significant constant voltage from the output to achieve a more practical Centigrade scale. The sensor is a high-precision integrated-circuit temperature sensing device, with an output voltage that is directly proportional to the Celsius (Centigrade) temperature. The LM35DZ series comes in a hermetic TO-46 transistor package, and it is also available in an 8-lead surface mount within a plastic TO-202 package. The sensor is equipped with the following features. [15].

- Linear + 10mV/°C scale factor
- 0.5°C accuracy guarantee able (at + 25°C)
- Rated for full – 55° to + 1 50°C range
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 μ A current drain
- Low self-heating, 0.08°C in still air
- Low impedance output, 0.1 Ω for 1mA load.

However, the signal conditioning circuit processes may be linear such as amplification, attenuation or nonlinear such as modulation, detection, filtering, chopping and clipping that produces output that reflects the condition, state or value of the measurand [15].

The signal conditioning unit included the analogue to digital converter; a connection route utilized when a linear analog system delivers a specific input to a digital system. Figure 3 illustrates the Analogue to Digital Converter (ADC), which employs a parallel comparator to assess the linear input signal against different reference voltages created by a voltage divider. When the input voltage surpasses the reference voltage, a high signal is generated at that comparator's output. The ADC produces a 3-digit binary number at its output, which corresponds to the values of the analog input voltage as it varies. The converter requires a total of seven comparators. Generally, for the conversion to n-digit binary numbers, 2n – 1 comparator are needed. The flash ADC is connected to seven segment display unit as shown in Figure 3. Flash ADC is implemented in the circuit using the ICL7107 integrated circuit [16, 17].

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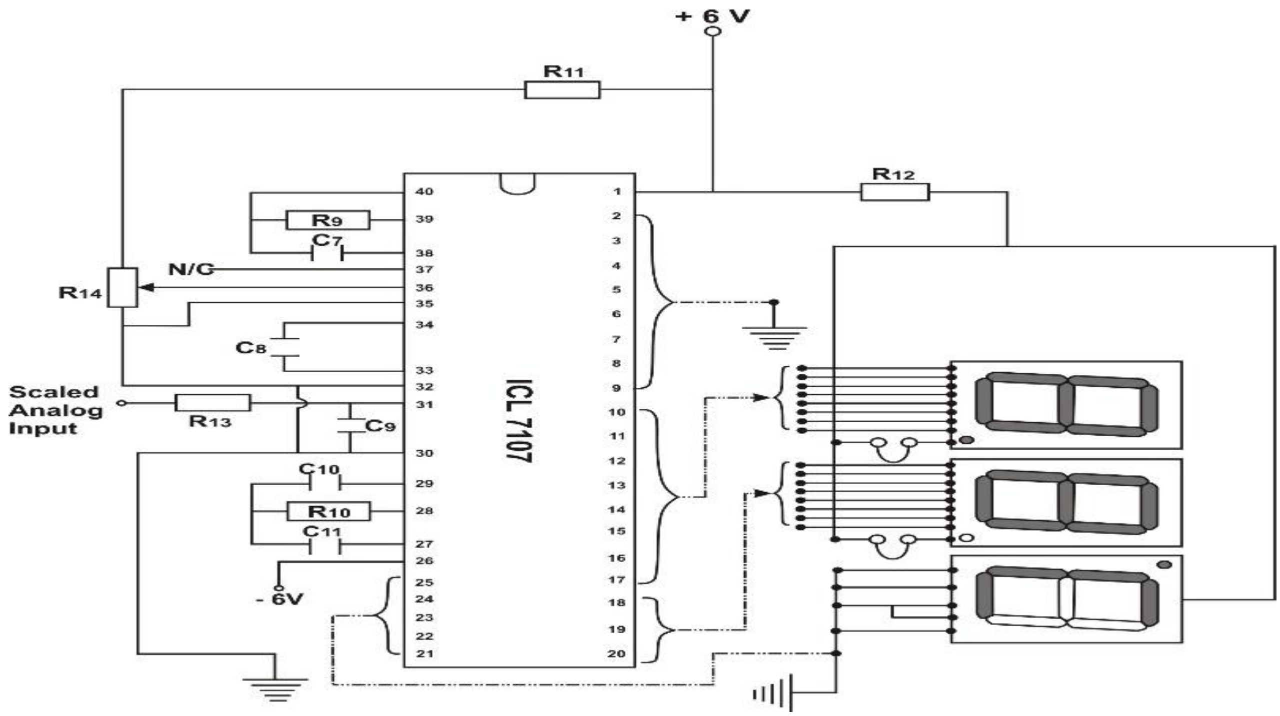

Figure 3. ADC connected to the seven segment display unit.

The signal conditioning unit also feeds the relay circuit, which triggers a fan or air conditioner to switch ON or OFF. It includes the alarm circuit which alerts users of a variation in temperature. Fig 4 is the alarm circuit which use 555 timer connected as an astable multivibrator. In this study, the 555 timer operate as a free running relaxation oscillator. Trigger input (TRIG), R_7, R_8 and C_{ext} form the timing circuit that set the frequency of oscillation. Decoupling capacitor C_D = 0.01µf connected to control (CONT) input has no effect on the operation [17].

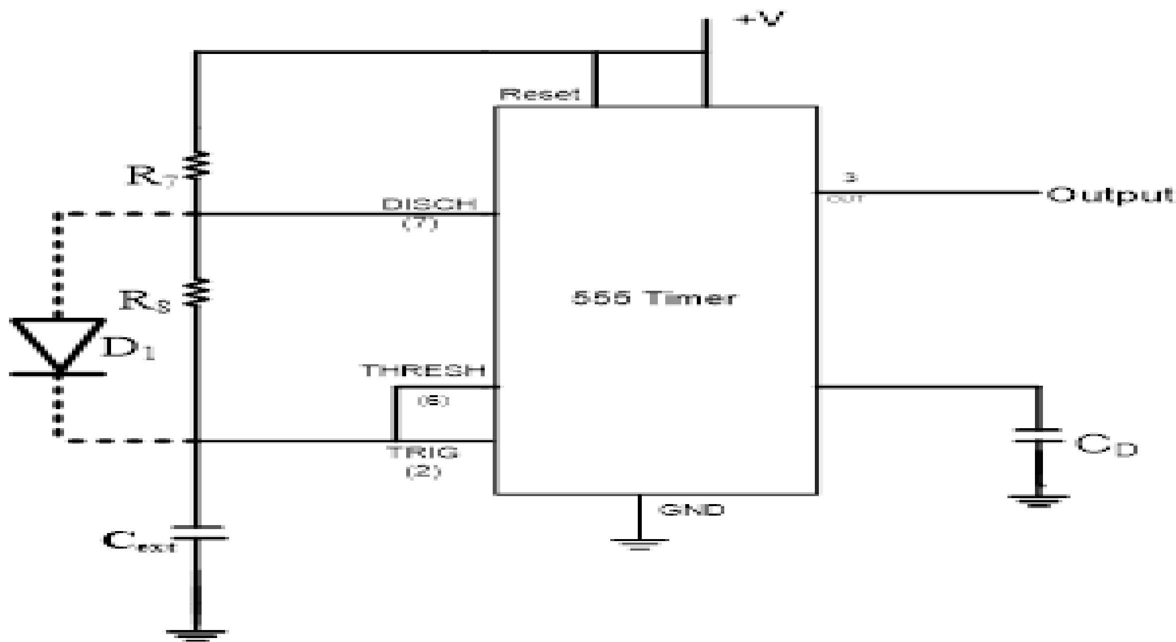

Figure 4: 555 timer circuit

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The current needed to operate a relay is called the pull-in current [17]. Fig 5 is the relay circuit. When the critical voltage is reached, transistor Q_2 is driven into saturation and collector current energies the relay. The diode connected across the relay coil prevents, by its limiting action, a large voltage transient from occurring at the collector of Q_2 when the transistor turns off.

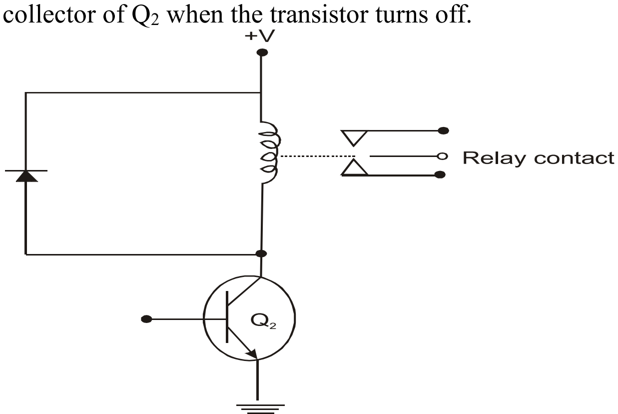

Figure. 5: Relay circuit

The temperature detection and monitoring device as constructed is housed in a simple casing of fig 6 which shows the front and side view and fig 7 is the back view of the casing. The casing is an enclosure for the constructed circuit. It houses the circuit against damage, and to beautify the system. The perforated holes at the rear side and the two other sides allow for the circulation of air into the circuit. Fig 8 shows the complete circuit diagram of the temperature detecting and monitoring system.

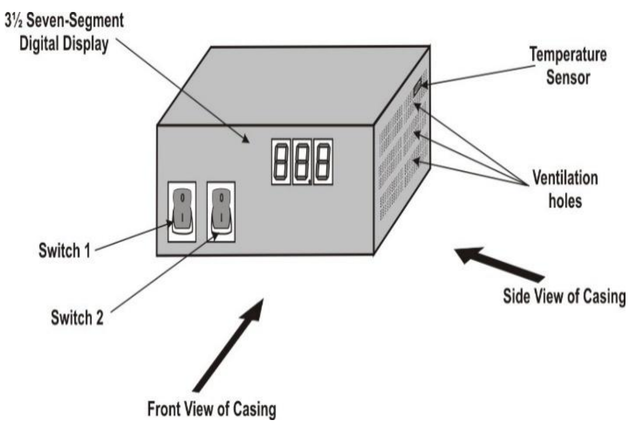

Figure 6 front and side view of the casing

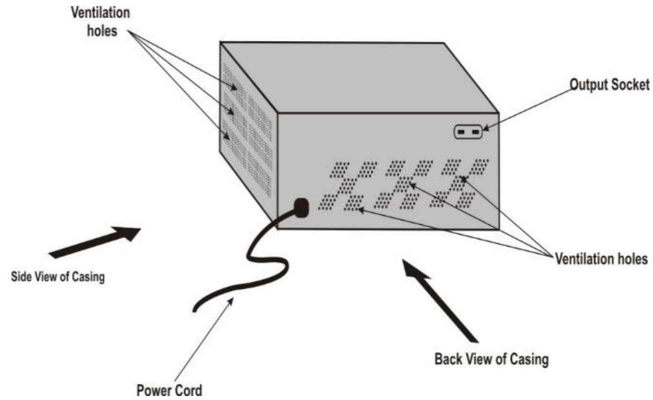

Figure 7 back view of the casing

3.0 RESULTS AND DISCUSSION

The constructed circuit, as illustrated in supplementary section below, was assembled across different sections of the circuit board. A digital multimeter was employed to measure the voltages at various terminals. The testing process was carried out in two stages. The first stage involved taking precise voltage measurements at each stage of the circuit and comparing the obtained values with the theoretical results derived during the design analysis. This step was essential to validate the accuracy of the circuit implementation. The second stage focused on evaluating the performance characteristics of the LM35DZ temperature sensor, particularly in relation to temperature detection and load control functions. The corresponding test measurements and results are summarized in Table 1.

Table 1 Characteristics of the LM35DZ IC

S/N	Circuit Characteristics	Calculated value in Volts	Measured value in Volts
1	Output Voltage of LM 35 DZ:		
	at 0%:	0V	0V
	at 100%:	1V	1V
2	Output from the four identical Op- Amp's with the switches at logic 1	Nil	3.2V

The last test was on the Analogue to Digital circuit as shown in Table 2

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Table 2 Test result of the Digital Display IC (ICL 7107)

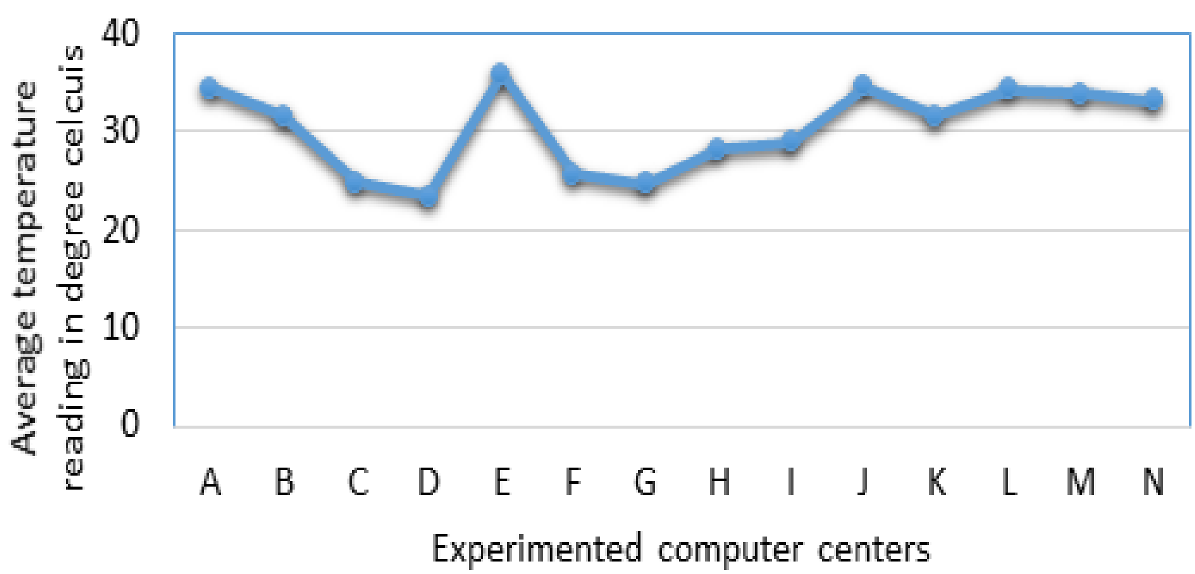
S/N	Circuit Characteristics	Calculated value in Volts	Measured value in Volts
1	Pin 1	+ 6V	5.89V
2	Pin 26	- 4V	- 4V
3	Pin 36	100mV	100mV (preset)
4	Output frequency from the clock generator	45kHz	45kHz
5	All digital output with no input signal	4.9V	4.3V
6	Maximum current drain by the seven- segment diode	106mA	104mA

The device was used to monitor the temperature of 14 electronic and computer centers in Benin metropolis. The test results obtained are as shown in Table 3. The fixed ambient temperature is 38°C. The temperature readings were taken morning and evening for seven days and the average reading recorded.

Table 3 Test result

S/N	Server centers	No of computers	AC and Rating of AC (Horse Power)	Ventilation (Fan or Natural Air)	Average temperature reading °C
1	A	57	Nil	Fan	34.4
2	B	34	1.0	Fan	31.6
3	C	31	1.5	Fan	24.8
4	D	28	2.0	Fan	23.4
5	E	63	Nil	Fan	35.8
6	F	25	1.5	Fan	25.6
7	G	24	2.0	Fan	24.6
8	H	25	1.5	Fan	28.2
9	I	33	2.0	Fan	28.9
10	J	30	Nil	Fan	34.6
11	K	54	2.0	Fan	31.6
12	L	45	Nil	Fan	34.2
13	M	45	Nil	Fan	33.8
14	N	36	1.5	Fan	33.1

The graph 1 described the behaviour of the device when the Temperature reading was taken at the various computer centers



Graph 1 Temperature versus experimented computer centers

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4.0 CONCLUSION

The design and successful implementation of a temperature detection and monitoring system has been achieved using the LM35DZ temperature sensor, integrated with signal conditioning circuits, ADC interfacing, and a relay-controlled actuator. The system is capable of continuously monitoring environmental temperatures and automatically switching electrical appliances ON or OFF when preset thresholds of 20 °C and 30.8 °C are crossed. A flash-type analog-to-digital converter (ICL7107) enables accurate real-time temperature display via a seven-segment interface, while an integrated 555-timer-based alarm circuit provides immediate alerts in the event of abnormal thermal conditions. This system offers a simple, cost-effective, and reliable solution for temperature measurement, monitoring, and device switching. However, limitations include reduced suitability for extremely high-temperature environments and a requirement for regular maintenance. Comprehensive testing was conducted at both the component and system levels across 14 electronic and computer centers. Voltage, current, and temperature readings closely aligned with design expectations, confirming the system's reliability and stability—even under varied ventilation and computing load conditions. All system components were locally sourced, ensuring affordability and ease of replication on a larger scale. With its robust construction, backup power support, and real-time feedback capabilities, the system is particularly well-suited for use in laboratories, server rooms, manufacturing plants, and other temperature-sensitive environments. Future developments may include the integration of wireless IoT modules for remote monitoring, control, and data logging.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

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Authors' Contribution.

Akhideno, I.O. was responsible for the conceptual design, fabrication, and performance analysis of the temperature detecting and monitoring. Ayidu J.N. provided technical guidance, and critically reviewed the manuscript for intellectual content. Akhideno O. contributed to the supply of components, construction and documentation of the experimental procedures and results.

Authors' Declaration

The authors affirm that the content of this manuscript is original, has not been published elsewhere, and is not under consideration for publication in any other journal. The authors accept full responsibility for the integrity and accuracy of all data and interpretations presented herein.

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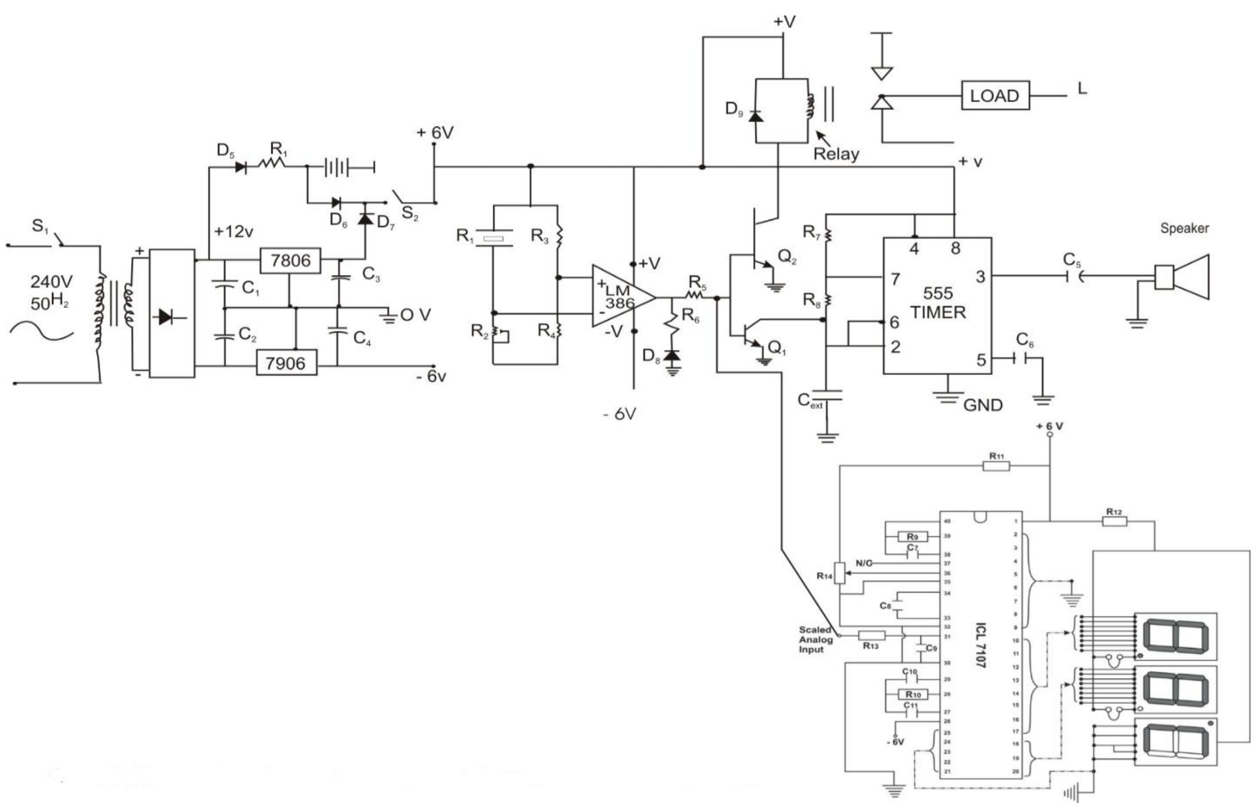
Supplementary Section



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