Design and Implementation of Micro-controller Based Variable Temperature Controller

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Abstract— **Abstract:** This research involves the design and implementation of a microcontroller based variable temperature controller using the ATMEGA328 microcontroller which can control temperature ranging from -45 to +140°C. The temperature of the environment to be controlled is measure using a temperature sensor integrated circuit, whose output is fed into the analog input pin of the microcontroller and later converted to a digital value. The software was written and compiled using the Arduino Integrated Development Environment (IDE) software in C++ programming language and then simulated using Proteus Computer Aided Design (CAD) software. Experimental setup alongside with measurements were taken in the laboratory, the average sensitivity of the temperature controller was calculated as 9.38mv/°C which is close to the 10mV/°C of the temperature sensor thus showing the accuracy of the temperature controller.

Index Terms— *Microcontroller, Variable Temperature Controller, Liquid Crystal Display and Complex Instruction Set Computer.*

1. Introduction

Automation started as a way to solve problem on issues relating to improvement of quality, saving of labor and energy. It is also use to find ways to improve accuracy and precision of a system [1]. It involves the use of control systems for operating other equipment with minimal human intervention. Temperature control has to do with keeping temperature of a particular environment within a required range which is done by measuring the change in temperature within an environment [2]. In the field of Engineering, Temperature controllers are design using heat sensing devices; such as thermistors or integrated circuits to measure and note the change in temperature [3]. Switching circuits are designed to respond to the change in temperature by automatically switching on a means to add or remove heat from the environment.
The temperature control systems is increasingly playing an important role in industrial production as well as in research laboratories [4].

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In conventional temperature control systems, devices such as bimetallic strips and fluid columns are used as the major temperature controllers/regulator. Bimetallic strips respond to temperature changes by expansion and contraction. There has been an increasing interest in microwave drying which can overcome certain limitations of conventional thermal food treatment methods [5]. The applications of such mechanical devices in the temperature control have great limitations in recent times: for bimetallic strip its gaining effect always reduces its switching response, while for the fluid column there is a decrease in uniformity with time. Both methods of the temperature control lack the ability of being calibrated to desired precision are unstable and their cost implications are undesirable.

To address some of these limitations, micro controllers and semiconductor based devices was introduce to achieve this control at lower cost, higher efficiency and accuracy at the same time overcoming the limitations of mechanical devices and hence the motivation of this research work.

Considerable amount of researches has been carried out on micro-controller for temperature control and measurement. The implementation of fuzzy algorithm embedded in microcontroller for temperature control in microwave hyperthermia device was proposed by [6]. The researchers focused on keeping the standard of hyperthermia therapy temperature using Microwave heating mechanism by using artificial biological medium to represent the human body tissue. Experiment result showed that the microwave hyperthermia system had temperature stability in specified hyperthermia temperature during microwave heating. However, the temperature response of microwave hyperthermia system without fuzzy logic control condition cannot be controlled.

The development of Microcontroller based Temperature and lighting control system in smart home to ensure security and energy saving was carried out by [7]. The research focused the development the room temperature controller with PIC. The micro controller based temperature and lighting control system for energy saving is used for one story building with only six rooms. Experimental results indicate that the model can provide energy saving for home appliances in the smart home environment.
Microcontroller-based fuzzy logic controller to stabilize at the desired temperature, when sudden changes in temperature occur was conducted by [8]. In their research, they considered Integrated- circuit temperature sensor LM35 which delivers an output voltage linearly proportional to the centigrade temperature. The research focused on the development of an intelligent temperature control system with heater and cooling control system that can be controlled automatically and manually as well.

A device for real time weather monitoring to monitor the real time temperature, atmospheric pressure, relative humidity and dew point temperature of the atmosphere via GSM network, using analogue and digital components was proposed by [9]. The program was written in C programming for the transmitter to extract the data, process and transmit the data format to the receiver. [13] Carried out research to control temperature based on PIC16F877A microcontroller interfaced with LM35DZ temperature sensor, seven segments led display and a buzzer. In their research, the system designed was both in hardware and software. The hard ware design consist of five units namely powers supply, microcontroller, temperature sensor, display and the alarm units. Similarly, the software design was carried out using firmware with source code written in assembly language. The result was compared with standard mercury in glass thermometer. After testing, the system result recorded a Mean Absolute Percentage Deviation (MAPD) of 4.69%. And lastly, [14] Conducted a research where LM35 temperature sensor is used which works linearly with increase of temperature to control and monitor temperature smartly. The microcontroller is used to compare the requesting temperature with the real time temperature through a cooling and heating device for activation and deactivation. The researchers use two voltage regulators 7412 and 7405 at fixed voltage of 5V. C++ programming language was used to compile the microcontroller code and the hard ware validation was carried out using normal testing, LM35 and standard industrial thermometer. An LCD was used to display both the requesting temperature and real time temperature and results shows that the temperature can be maintained between 39^oc to 41^oc.

The aim of this research is to design and implement a microcontroller based temperature controller using the ATMEGA328 with Liquid Crystal Display (LCD) that shows the temperature of the environment. This can be achieved by using a push buttons which serve as an interface to adjust the temperature range which in turn can be saved to the Electrically Erasable Programmable Read Only Memory (EEPROM) of the ATMEGA328 in order to avoid loss of the values after power has been switched off.
The choice of these components over other components is prompted by its affordability, availability, reliability and low power.

This paper is divided into different sections: section one covers the introduction, section two deals with the description of components. Section three is all about system design and implementation while section four deals with the simulation and section five finally concludes the paper.

2. Description of Components

This section discussed the design aspects of the microcontroller.

a. Architecture of ATMEGA328P Microcontroller

The ATMEGA328 is a complete computer on a chip and it consists of a processor, registers, as well as program and data memory. It is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. In Harvard architecture, data bus and address bus are separated as opposed to the tradition Von Neumann architecture which uses the Complex Instruction Set Computer (CISC) architecture and uses the same bus for data and address [!!].The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic

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Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

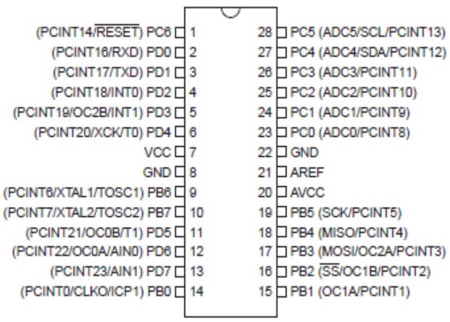

Figure 1 shows the pin description of ATMEGA328P [10].

The ATMEGA328P provides the following features: 32K bytes of In-System Programmable Flash with Read-While-Write capabilities, 1K bytes EEPROM, 2K bytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable Watchdog Timer with internal Oscillator, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, USART, 2-wire Serial Interface, SPI port, and interrupt system to continue functioning

b. LM041L Liquid Crystal Display

The LM041L is 16 characters by 4 lines LCD that has the HD44780 controller inbuilt and runs on a 5V power supply which can display data that is sent to it via bit operations. Basically an LCD is made using two line polarized glasses arranged at an angle of 90º in order to stop the passage of light through them.

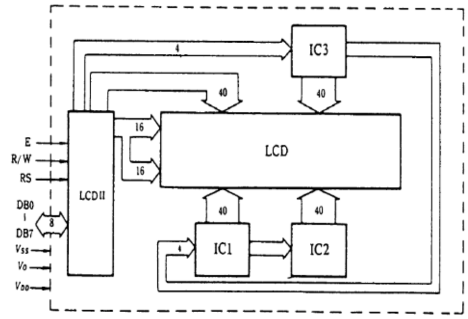

Figure 2: Block diagram of LM041L LCD [11]

The LCD uses the HD44780 controller which is a very common means of controlling LCD displays that has two modes of operation. It either receives data in two 4 bit operations which is more complex than its other mode which receive data in 8 bit whose downside is its requirement for more number of connections.

c. LM35 Temperature Sensor IC

The LM35 is an integrated circuit temperature sensor whose output voltage is directly proportional to the temperature. Internally it is made up of 3 transistors, 4 resistors, 2 operational amplifiers and constant current sources as shown in Figure 3.

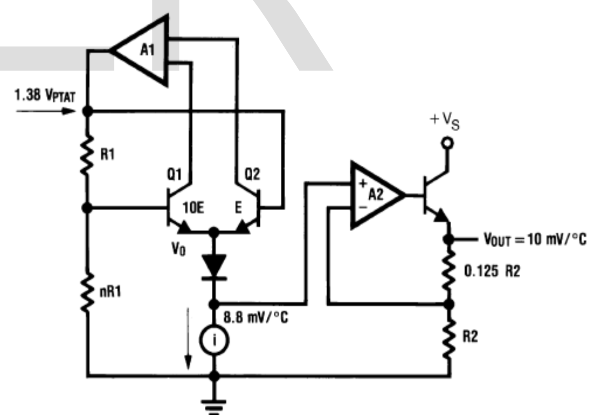

Figure 3: Circuit of LM35 Temperature sensor [12]

The two transistors Q1 and Q2 in the center of the circuit in figure 3 are set in a way that one will have one tenth the current density of the other, since they have the same amount of current going through them. As a result of this, a voltage is gotten across the R1 resistor which is proportional to the absolute temperature so as to give a linear relationship between the absolute temperature and voltage. Comparison to make sure voltage at the base of the transistor Q1 is proportional to the absolute temperature is done by the amplifier A1 by comparing the output of the two transistors. The Amplifier A2 converts the absolute temperature into Celsius and the output in volts with the resistors R1 and R2 factory calibrated in order to get very high. The sensitivity of the temperature controller can be calculated using equation 1.

$$Ave. Sensitivity = \frac{Change\ in\ Volt.}{change\ in\ Temp.} \ldots\ldots\ldots\ldots 1$$

Average sensitivity is measured in Volts per temperature.

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d. Proteus CAD software

Proteus is software for microprocessor and circuit simulation, schematic capture and printed circuit board (PCB) design development and it is shown in Figure 4.

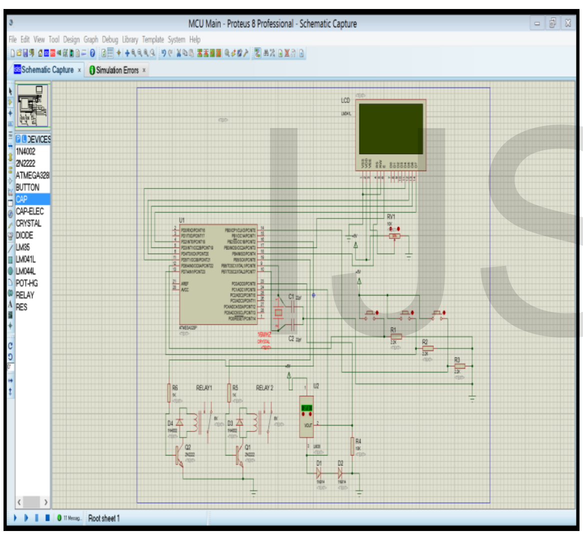

Figure 4: Proteus CAD software window

It has functionalities such as flexibility for the creation of different footprints and putting them into libraries, support for PADS ASCII file format which is a widely recognized PCD footprint description, support for Boundary Scan Description Language (BSDL) which is a description language for electronics testing using Joint Test Action Group (JTAG).

3. System Design and Implementation

The design of the temperature controller involves both the hardware and the software for the proper operation of the project. Microcontroller design ensures flexibility while minimizing the number of components. This is essentially due to the fact that most control functions are performed in software rather than hardware. In the design of the temperature controller, a flow chart was drawn and an algorithm was also developed to ensure accuracy. The program was written, debugged, compiled and then burned into the microcontroller based on the flow chart designed. The temperature controller is expected to read out the temperature, the inbuilt analog to digital in the microcontroller whose input is connected to the temperature sensor Integrated Circuit (IC), test to determine if the temperature falls out of the desired range, execute necessary control actions and display the measured temperature using an LCD display.

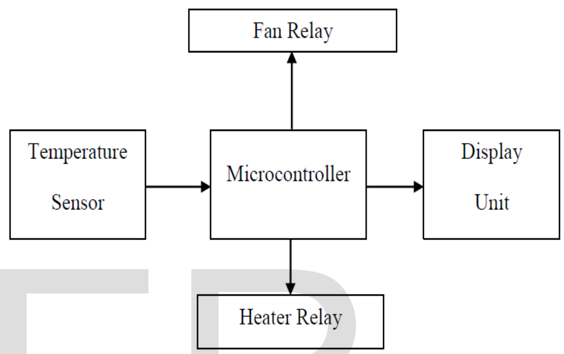

Figure 5: Micro-controller based Variable Temperature Controller

The Hardware was designed by including the microcontroller interface board to interface the ATMEGA with the display unit and relay driver circuit. The interface is linked to the LCD display directly from the ATMEGA by using its LCD connection capability. A 5 volt regulated power supply is also required and this is illustrated in Figure 5.

The program consists of 3 main parts. The routine to read the digital value from the analog to digital converter, routine to compute display the temperature and the routine to compare the read temperatures with the preset values and perform necessary operations.

The syntax used in writing the program is as follows:

i. Setting aside variables to use for program execution
ii. Initializing the port pins as outputs or inputs
iii. Configuring the ADC of the microcontroller
iv. Read input values of the ADC and convert to temperature
v. Store the temperature value
vi. Display the temperature on the LCD

vii. Subtract the read temperature value from the lower set temperature, if result is positive go to end else turn heater on
viii. Display heater state on LCD
ix. Subtract the read binary value from the upper set temperature if the result is negative turn on the fan else go to the end
x. Display fan status on LCD

4. Simulation

The program was simulated using Proteus Design Suit 8.1. The simulator required the path to the hex file of the program and the complete circuit connected to the microcontroller. Lamps were used as loads for the simulation to indicate the switching on and off of the fan and heater. The temperature for the simulation is varied from the control button of the LM35 in the circuit which in turn gives the desired response of either turning the heater or the fan on/off.

The push buttons was programmed as menu button, + and – buttons, the menu button if pressed and held down for 3 seconds enters the maximum temperature setup screen, if pressed again it moves to the minimum temperature setup screen and then saves after it is pressed again. The + button is used to increase the value of the preset temperature, the – button is used to decrease the value which all worked successfully during the simulation process. Figure 4, shows simulated display of splash screen in Proteus.

After the simulation was carried out successfully, an experiment was setup to monitor the communication format from the microcontroller to the LCD. This was done by adding an oscilloscope with the horizontal axis set at 500 milli seconds and the vertical axis at 2.2V. The Oscilloscopes has four channel which are channel A (yellow), channel B (blue), channel C (pink), channel D (green) and were connected to terminal D4, D5, D6, D7 of the LCD respectively. This is illustrated in Figure 6.

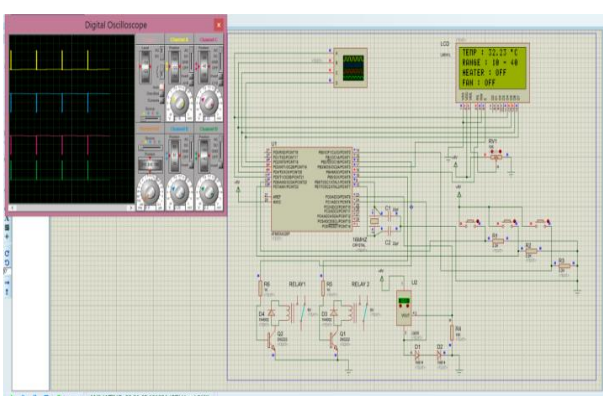

Figure 6: Simulated Experimental setup

The Output readings were taking for various states of the LCD such as the main menu, max menu settings, min menu settings, main menu when fan is on and max temp saved screen. The results are displayed as shown in Figure 7.

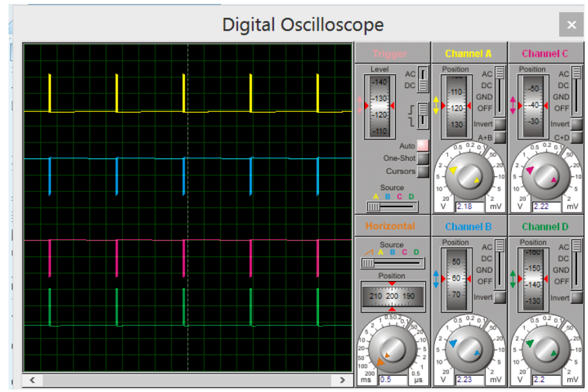

Figure 7: Oscilloscope reading for Main menu Display with Fan and Heater off

5. Result and Discussion

This section presents the experimental results of the Micro-controller based variable temperature Controller. Table 1 shows the Test Values for sensitivity test.

Table 1: Test Values for the sensitivity test

Temperature (^{o}c)	Test 1	Test 2	Test 3	Average
23.93	224	223	224	223.67
24.41	229	227	228	228.00
25.39	240	239	240	239.67
26.37	249	249	247	248.33

The graphical representation of the values obtained in Table 1 is shown in Figure 8.

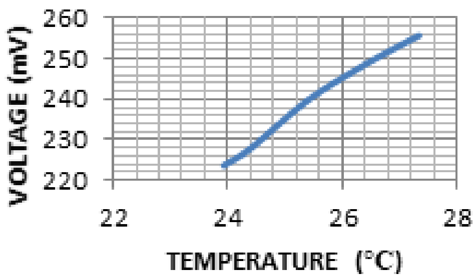

Figure 8: Graph of voltage against temperature

From Figure 8, the average sensitivity of the temperature controller can be determined using equation 1.

Conclusion

The design, construction and testing of a microcontroller based variable temperature controller using ATMEGA328P microcontroller was implemented. The Average sensitivity was calculated as 9.38mV/°C which is very close to the 10mV/°C written in the datasheet of the LM35 temperature sensor.

The design was implemented and Figures 9, 10 and 11 shows Red Light Bulb going on with the LCD displaying the Heaters Status. Temperature Sensor Close to an Ice Block and Blue Bulb going on with the LCD displaying the Fan's Status.

Figure 9: Red Light Bulb going on with the LCD Displayed the Heaters Status

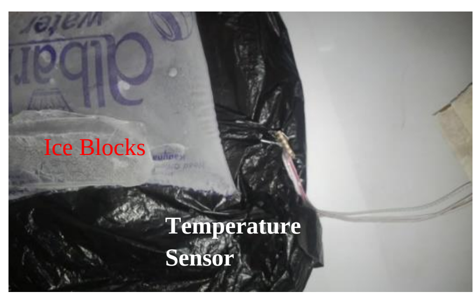

Figure 10: Temperature Sensor Close to an Ice Blocks

Figure 11: Blue Blub going on with the LCD Displaying the Fan's Status

Sources of error such as environmental factors, lack of a high precision multimeter and the delays in the program code of the temperature controller had their impact on the calculated average sensitivity value. The automatic temperature controller is a vital aspect requirement for industrial process. It can be used as a means for temperature control for both industrial and residential uses. The contribution of this research to the existing body of knowledge is the use of Micro-controller Based Variable Temperature Controller in thermal flow processing in which temperature has to be kept at a specific value, temperature control incubators, nurseries, digital thermometer and also for room temperature control.

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