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Construction of an Automatic Temperature Controller for Monitoring Heating and Cooling Systems

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ABSTRACT: The Automatic Temperature Controller (ATC) is a locally designed microcontroller-borne electronic circuit system capable of monitoring and controlling the temperature of a thermally isolated enclosure or chamber, provided the heating or cooling source is powered electrically. Monitoring and automation are achieved with the aid of Temperature sensor, Microcontroller IC, Analogue-to-Digital Converter (ADC), Liquid Crystal Display (LCD) unit, Switching circuit and other essential components. The Microcontroller has been programmed to monitor and control instantaneous temperature values received from a temperature sensor. The preset values determine whether a relay is energized or de-energized. The switching terminal of the relay has been connected in series to the live terminal of the mains that powers an electrical heating or cooling systems. The circuit can be employed in managing the temperature of drying compartments such as House warmer, heating furnace, incubators, and others. The temperature range of the system is between -4^{o}C and 130^{o}C with a resolution of 0.5^{o}C.

Keywords: Microcontroller, ATC, MCU, ADC, LCD, Relay, Energize

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INTRODUCTION

Temperature is a fundamental quantity that expresses the level of hotness or coldness of matter. Everybody is interested in knowing his/her body temperature and if possible the ambient temperature as well. This is because temperature reveals microscopic information about matter at any given time. Temperature is an ever-changing parameter because of exposition to huge array of stimuli from their environment (Deepika, 2006). When measuring temperature of a system or a confinement, it is paramount to ensure that the measuring instrument does not generate heat. Under some conditions heat from the measuring instrument can cause a temperature gradient, so the measured temperature is different from the actual temperature of the system. In such a case the measured temperature will vary not only with the temperature of the system, but also with the heat transfer properties of the system (Temperature Measurement, 2010).

Temperature is generally measured with instrument called thermometer. Although the most commonly used and readily available type of thermometer is the Analogue Liquid-in-glass. The constructed circuit explores the microcontroller technology to design and construct a microcontroller based automated temperature controller system. The Microcontrollers and Embedded systems are the latest Technology rapidly replacing both the common analogue and digital electronic circuits. This is simply because the system has a central heart (microcontroller)

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which is capable of controlling all the activities within the circuit. The Microcontroller is very versatile in operation being that it can be programmed and reprogrammed at any time to suite the desired purpose. Microcontrollers are being designed into more and more sophisticated products e.g. motor cars, watching machine, mobile phones, robots, measuring and monitoring instruments in various fields such as digital thermometer, rainguage, voltmeters, ammeters, magnetometer and others. The heart of the circuit designed is the AT89C52 Microcontroller IC which is a member of the famous 8051 family. The 8051 family of micro controllers is based on an architecture which is highly optimized for embedded control systems thereby making them suitable for temperature control and monitoring. It is used to achieve automatic power ON and OFF switching system based on preset values input into the IC.

For instance, in the local design of heating and cooling electrical systems, it is mostly desirable to integrate an automatic temperature monitoring, display and control sub-circuits into the system. This enables such system to regulate its temperature within a preset value or range of values. For instance, if this sub-circuit is programmed to switch a relay OFF at 0^0C and turn it ON at 4^0C and then connected to a power terminal that powers the compressor of a refrigerator, the compressor would be automatically powered OFF when the evaporator temperature cools down to 0^0C. The temperature will definitely begin to rise until when the sensor senses 4^0C and the microcontroller energize the relay which powers the compressor. This process is repeated infinitely, thus maintaining the refrigerator within this temperature range. The major objective of the constructed temperature controller is to explore the technology of microcontroller and embedded systems to design and construct a sub-circuit which can monitor and control the temperature of an electrical cooling or heating system. An added advantage of the designed system is that it provides a digital display of measured temperature value, thereby shifting the world from the use of famous analogue mercury-in-glass thermometer to a modern digital thermometer so that instrumentation can meet up with the advancement of Technology.

METHODOLOGY

The circuit is made up of five major sections as shown in Figure 1. Temperature measurement is achieved with the aid of semiconductor temperature sensor (LM35). The sensor responds linearly to temperature changes with a resolution of 10mV/^{o}C. The Analogue-to-Digital Converter section contains an 8-bit ADC (ADC0804) which receives the analogue voltages from the first stage and sends its digital equivalent to the Microcontroller Unit (MCU). Decisions are made within the MCU based on the self-programmed instructions and the display section is interfaced with the MCU so as to display the measured temperature, the on-set and off-set values that control the switching section.

The components used for the circuit design are: Temperature Sensor (LM35), Analog to Digital Converter (ADC 0804), Microcontroller (AT89C52), Liquid Crystal Display (16x2 HD44780), Relay (9V), Voltage Regulator (7805), Resistors and Transistors. The whole circuit is powered with 5V dc supply which can be tapped from a 9V battery or from a regulated dc power supply system. The transducer section is an important stage in the system where temperature (a component of heat energy) is converted to voltage (which is a component of electrical energy) with the aid of temperature sensor. The temperature sensors used in many fields include Thermocouples, Resistive Temperature Devices (RTDs and thermostats) and bimetallic devices. The factors for the selection of sensor taken into account includes the inherent accuracy for durability, range of operation, susceptibility to

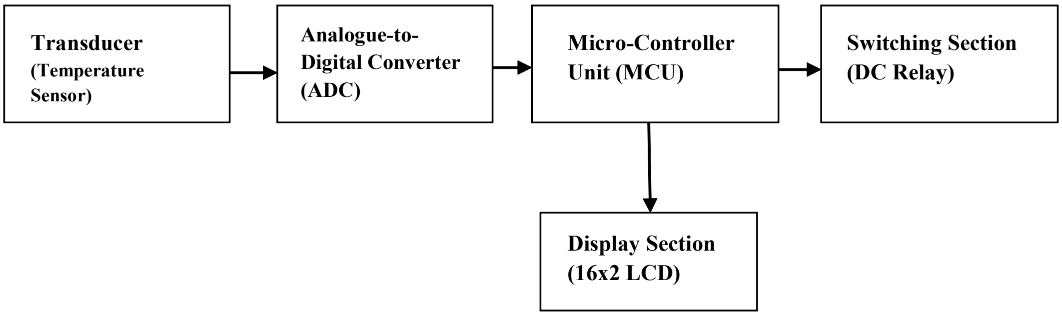

Figure 1: Block diagram of the designed system

external noise influences, ease of maintenance and installation, handling during installation (delicacy), ease of calibration, and type of environment it will be used in. Having considered all the factors above, the temperature sensor suitable for this work is LM35 due to its linearity over the temperature range. The LM35series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the temperature in degrees Celsius (Muhammad and Janice, 2009).

THE ADC CONFIGURATION AND CONVERSION PROCESS

In the physical world, parameters such as temperature, pressure, humidity, and velocity are analog in nature. To convert a continuously varying physical quantity into electrical signals, we need an analog to digital converter to translate the analog signals to digital numbers so that the microcontroller can read them. Thus, an analog-to-digital converter (ADC) is an electronic circuit that converts continuous signals to discrete digital numbers. Analog to digital converters are the most widely used devices for data acquisition (National Semiconductor Corporation, 2002). The ADC used in this work is the ADC0804, an 8-bit resolution single channel converter. ADC0804 is chosen because it is a single channel converter, suitable for a single analogue signal input and its 8-bit output matches the 8-bit port of the 8051 microcontroller family. It takes in one analogue signal through pin 9 and sends out an 8-bit digital signal through pins 11-17 as shown in Figure 2. The ADC achieves conversion by summing up analogue signal to a particular level called STEP SIZE. The Step size is the smallest voltage change that can be measured by an ADC. It is a function of the set reference voltage V_{ref} and the resolution of the ADC as shown in equation (1).

$$\text{step size} = \frac{\text{V(ref)}}{2^{(\text{resolution})} - 1} \qquad (1)$$

For instance, if the reference voltage V_{ref} is set to 5V, then the step size of an 8-bit resolution ADC will be $5/(2^8\text{-}1)$ or 19.5mV/count. This simply means that the ADC will respond to the analogue input whenever the voltage sum is up to 19.5mV. Since the scale factor of the temperature sensor (LM35) used is 10mV/ °C, the ref voltage of the ADC was adjusted to 2.56V so as to achieve 10mV/count in the ADC. The implication of this is that the ADC will deliver digital output to the microcontroller for every degree change in temperature. Pins 2, 3 and 5 are interfaced to the microcontroller as shown in Figure 2. Pin 1,7,8 and 10 are grounded while Pin 20 is used to power the ADC. Pin 9 takes half of the ref voltage i.e 1.28V through the voltage-dividing resistors R1 and V.R.

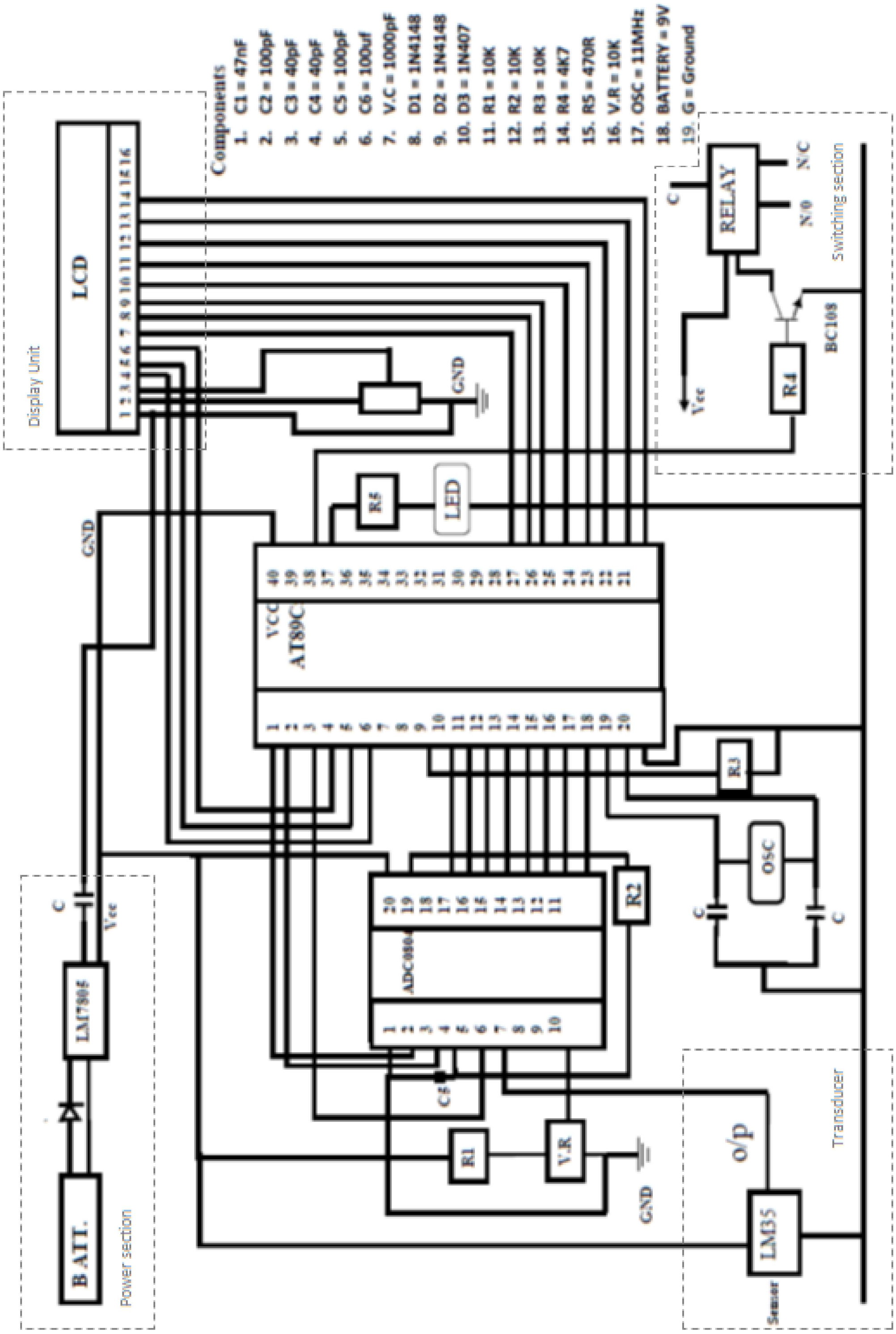

Figure 2: Circuit diagram of the designed system

THE MCU AND SWITCHING SECTION

This section is the heart of the whole system as it governs all activities within the circuit. The AT89C52 used for this work is a low-power, high-performance CMOS 8-bit microcomputer with 8kilobytes of Flash Programmable and Erasable Read Only Memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional Non-volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a 25 monolithic chip, the Atmel AT89C52 is a powerful microcomputer, which provides a highly-flexible and cost-effective solution to many embedded control applications (Atmel Corpoaration, 2000).

The Microcontroller IC consist of four 8-bit ports (port 0: pin 32-39, port 1: pin 1-8, port 2: pin 21-28 and port 3: pin 10-17). The 8-bit digital output signal from the ADC is interfaced with port 3 of the microcontroller while port 2 is interfaced with the address line of the 16x2 LCD. Pins 1-3 of port 1 are used to provide necessary pulse to the ADC during READ/WRITE operation.

The microcontroller has been programmed with conditional statements (using micro-C language) as per when to send a high or low signal at its pin 38 of port 0. The automatic ON/OFF switching ability of system is achieved with the aid of signal supplied by pin 38 to the 9v Relay via an amplifying transistor (BC108). For instance, if pin 38 is low, the transistor is cut-off, the relay is energized via the transistor collector, hence the normally closed (N/C) terminal becomes opened while the normally open terminal gets closed. If the (N/C) and Common (C) terminals of the relay are connected in series to the live terminal of the mains of any heating or cooling system, the system can be effectively maintained between any range of preset temperature. The display section employs Liquid Crystal Display (LCD) HD44780 module. It is a double line display system with each line containing maximum of 16 characters. The pin configuration and address line are shown in Figure 2. The LCD displays the temperature value measured by the sensor, the preset values, as well as the status of the relay.

SOFTWARE IMPLEMENTATION, RESULT AND TESTING

Software design includes developing algorithm for the system, allocating memory banks and registers as per functionality, writing the separate routines for different interfacing devices and testing them on the designed hardware. A suitable program was written in assembly language using MIDE-51 software. The software is able to show the real time values from the analog channels for immediate analysis. The hardware design was simulated before construction using Proteaus 7.4 ISIS. The HEX file for the written code was generated and loaded on the simulated hardware. The hardware and software both were modified and verified before embarking on real circuit construction.

The constructed circuit was tested by comparing it readings with that of the famous Mercury-in-glass thermometer under the same condition. The results obtained during testing are shown in Table 1. The percentage error of the system is about 2.3% which makes it highly recommendable for temperature measurement and control.

Table 1: Temperature readings taken by Mercury-in-glass and the constructed Thermometers

Hg-in-glass Thermometer (^oC)	0	0	1	3	4	6	7	11	16	25	28	34	42	58	70
Constructed Thermometer (^oC)	0	1	2	4	4	5	8	11	16	24	28	35	44	59	72

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CONCLUSION

The Automatic Temperature Controller is an invaluable tool for measuring and managing the temperature of a confined system within pre-determine temperature range. It has the ability to clearly present real time monitoring and control, with the sensor being able to respond linearly within the target temperature range. In this work, an automatic temperature controller system has been designed and constructed. It is of less cost, portable, very low power consumption, self contained. The results obtained from the measurement have shown that the system perform well within the aimed temperature range. It can be employed in scientific research where temperature stability is at premium, it can be used in experimental analysis. It has a vast application in manufacturing industries such as plastic production, metal alloying, if the circuit is modified to handle large temperature range.

REFERENCES

Atmel Corporation (2000). AT89C51 data sheet, 8-bit microcontroller with 4k bytes flash, Atmel Data book, 1999 and 2000 update.

Deepika (2006). "Designing a Microcontroller Based Temperature Data logger" Master Thesis submitted to the department of Electronic and Instrumentation, Thiapar Institute of Engineering and Technology, Patiala, 2006, Pp1.

Muhammad Ali Mazidi and Janice Gillispe Mazidi (2006). "The 8051 microcontroller and embedded systems",Real-world interfacing, 2nd Edition, Vol. No 6, pp 24.

National Semiconductor Corporation (2000). ADC0804 data sheet for 8-bit Microprocessor compatible A/D converters with 8-channel multiplexer, October 2002 update.

Wikipedia (2012). Temperature Measurement; http://en.wikipedia.org/wiki/temperature-measurement (Accessed on 24th May, 2012)