A Control and Security System for Internal Temperature Breaches using the ATMEL AT89C52 Microcontroller

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***Abstract* – Advancements in globalization and certain requirements of 21st century industrial processes have necessitated the creation of certain temperature-critical locations – where it is important that environmental temperatures within the confines of such locations be kept within a certain range or never beyond certain critical limits. Such environments have increasingly continued to necessitate the development and progressive evolution of monitoring and control systems with capabilities for monitoring environmental temperatures; and either activating adequate control equipment to correct these breaches, or sounding out alarms when such temperature breaches occur so that the appropriate authorities could initiate prompt actions to contain the breach. This research project experiments with the development of a working prototype for a control and security system for securing against internal temperature breaches using the Atmel AT89C52 microcontroller integrated circuit. The prototype is built from scratch and tested with a miniaturized fan / blower system, and the prototype was able to drive the load, resulting in changes in the environmental temperature.**

Keywords – Control System; Security System; Temperature Control; Prototype; Microcontroller.

1.0 INTRODUCTION

The requirement of maintaining temperatures within certain critical levels in the 21st century has resulted in increased overhead costs in most cases for schools, industries, and organizations. Such costs are primarily related to the purchase of such equipment as combustion / cooling chambers in research laboratories where temperature critical research is carried out, hiring of expert engineers to handle temperature situations in industrial warehouses / critical storage location, purchase of expensive cooling equipment in large numbers for morgues, hospitals, computer / server rooms and data centres, amongst other locations like aircrafts, power and gas plants, energy stations infant cradles and incubators, to mention but a few.

ISO 1984 standards defined thermal comfort as that condition of mind, body or functionality that expresses satisfaction with the thermal environment. Dissatisfaction in this case would basically refer to conditions that make the body / equipment too warm or cold as a whole [1].

In the same vein, temperature control could be referred to as the processes or series of actions that are aimed at maintaining the temperature in a given environment at a certain maximum / minimum level, or within a certain range. The increasing concerns over the contributions of rapidly fluctuating high and low temperatures to the greenhouse effect have further necessitated the need for temperature control in certain parts of the world.

Control Systems in their most basic form refer to systems that comprise a device(s) that manage, command, direct or regulate the behaviour of other devices or systems in such a way as to influence certain states, outcomes or occurrences in the physical environment. A control system generically works like a feedback system that has a control loop, sensors, control algorithms / programs and actuators / effectors arranged in such a way as to regulate a particular variable(s) within a particular range, a set point or a reference value. When such a variable relates to the degree of hotness or coldness of a body or environment, it can be called a Temperature Control System.

A Temperature Control System functions like a *programmable thermostat* (or a thermostat with automated capabilities). Such systems work to keep the environmental temperature within a desired limit, regardless of fluctuating exterior weather conditions. One of the advantages boasted by a temperature control system over a regular thermostat is its ability to save cost and energy by automatically monitoring and maintaining different temperature points at all times depending on the nature and robustness of its control program. As an example, one implementation of such a system may require that actuators / effectors increase the fuel supply to a furnace when a measured temperature drops below a certain point.

One indispensable component of control systems is a small Programmable Digital Logic Controller device (also known as a micro-controller). This electronic device was before now prominently used in the automation of industrial processes, such as the control of machinery on factory assembly lines. Its application is essentially real-time, because output results need to be produced in response to input conditions within bounded time constraints.

1.1 HISTORY OF TEMPERATURE CONTROL SYSTEMS

The use of Automatic Temperature Control Systems began way back in the 18th Century when the idea was first conceived by Warren S. Johnson while he was teaching at Norman School, Wisconsin. Before then, Janitors had to enter each classroom to find out if it was too hot or too cold, after which dampers in the basement were adjusted accordingly. Johnson wanted to end, or at least reduce the frequency of classroom interruptions of the janitors in order to increase the comfort level of the students. His Automatic Temperature Control System was to meet this very need [2].

In 1883, Warren Johnson resigned teaching for full time to researching and development of his ideas. He moved to Milwaukee and established the Johnson Electric Service Company in 1885. In 1895, Johnson patented the pneumatic temperature control system which allowed for temperature control on a room by room basis in buildings and homes. It became the first such device of its kind. By the beginning of the 20th century the Automatic Temperature Control System had already become popular and was being used in such places as the New York Stock Exchange, Royal Palaces of Spain and Japan, West Point, the Smithsonian, the US Capitol Building, and the home of Andrew Carnegie [2].

As described in [3], the human body provides one of the most comprehensible examples of temperature control, and is used in most research scenarios to create a more vivid understanding of how temperature control systems work. The human body regulates its temperature continuously and may increase or decrease its temperature when it finds that it is too cold or too hot. In this case, temperature is being regulated by a control system known as ***homeostasis***. Somewhere in the brain, perhaps the Hypothalamus, the optimum temperature of the body (set point) is stored (about 37°C). That information is continuously available to some structure that may be called the comparator. The comparator sends signals either to the:

a) Heat gain mechanisms in the pre-optic area or anterior hypothalamus leading to Shivering, Increased thyroid hormone output, Increased activity in the sympathetic nervous system, Piloerection, Cutaneous vasoconstriction, etc.; or to the
b) Heat loss mechanisms in the posterior hypothalamus leading to Decreased thyroid hormone output, Sweating, Cutaneous vasodilation, etc.

The output of these mechanisms will end as either a net increase or a net decrease in body temperature. The body temperature is sensed by thermal receptors (thermo-receptors) in the brain and peripherally in the body, and the value is sent to the comparator where it is compared with the set point. If the value is less than the set point, then signals go mainly to the heat gain mechanisms; if it is greater than the set point, then they go mainly to the heat loss mechanisms. In this way (homeostasis), body temperature is constantly sensed and maintained constant.

2.0 SYSTEM COMPOSITION / DESIGN

From the Human Body Temperature Control System, the following generic components of Temperature Control Systems can be deduced, and which would form the major components of the prototype that would be experimented in this research:

I. The Power Supply Unit: This unit supplies power to the control system. A 12V DC linear power supply is needed to power this system. This unit comprises a 12V step-down transformer, a bridge rectifier (to convert the AC from the power mains to DC), a high-valued electrolytic filter capacitor (to further smoothen the current), and a 5V L7805CV[1] voltage regulator IC with a positive output.
II. The Temperature Sensing Unit: This unit senses / detects the temperature in the environment. This system is made with a

[1] *Refer to manufacturers' website for full datasheet.*

ceramic Negative Temperature Coefficient Thermally Sensitive Resistor (NTC Thermistor). This type of temperature sensor exhibits a decrease in electrical resistance with increasing temperature. It is a semi-conductor based ceramic device. It generally has an operating temperature range of –50°C to +150°C and is accurate to ±0.1°C. The NTC Thermistor has a relatively large change in resistance with respect to temperature – of the order of -3% per °C to -6% per °C. This sensor is well suited for sensing temperature at remote locations via long two-wire cables, because the resistance of the long wires is insignificant compared to its relatively high resistance.

III. The Temperature Control Unit: This unit processes the temperature detected by the NTC THERMISTOR IC, and controls the overall operation of the system. It consists of an ATMEL AT89C52[2] microcontroller IC[3] which contains a non-volatile FLASH program memory that is parallel programmable. A Crystal Oscillator is necessary when using the Micro-controller. The Crystal Oscillator helps in regularizing and stabilizing the voltage signal that is being fed into the Micro-controller. In this project, a 4MHz Crystal Oscillator is used. This unit receives control parameters from a Menu / Function Unit that is made up of a variable resistor that is used to increase and decrease the set-point temperature in the microcontroller. Turning the variable resistor in a clockwise direction increases the maximum temperature while turning it in an anti-clockwise direction decreases the maximum temperature.

An op-amp (operational amplifier) configuration without a feedback is used as a comparator. The purpose of the comparator is to compare two voltages and produce a signal that indicates which voltage is greater. Any difference in the two voltages, no matter how small drives the Op-Amp into Saturation, but if the voltages supplied by the two inputs are of the same magnitude and polarity, the output from the Op-Amp is 0 volts. An Operational Amplifier is used here for comparing the sensed temperature value (in form of voltage signals) from the thermistor with the set-point temperature that has been set using the variable resistor. The Op-Amp Comparator will produce a negative voltage at its output when the voltage at the non-inverting input is more positive than the voltage at the inverting input. Owing to the fact that one of the inputs of the Op-Amp is inverted, the output from the OpAmp is again passed through a NAND Gate that inverts the signal back to its original state.

The microcontroller was programmed with a source programme in the low level Assembly Programming Language. The source file with the file name "*Program.asm*"[4] can be retrieved online at: https://www.dropbox.com/s/q982lmhw65celo7/Program.asm?dl=0.

IV. The Switching Circuit: The output from the micro-controller pin 24 triggers the switching circuit. The signal is passed through a MOSFET. The **Metal–Oxide–Semiconductor Field-Effect Transistor** (MOSFET) is a transistor used for amplifying or switching electronic signals. The basic principle of this kind of transistor

[2] This microcontroller features a 80C51 Central Processing Unit, On-chip FLASH Program Memory, Speed up to 33 MHz, Full static operation, RAM expandable externally to 64 k bytes, 4 level priority interrupt, 6 interrupt sources, Four 8-bit I/O ports, Full-duplex enhanced UART with Framing error detection and Automatic address recognition, Power control modes (Clock can be stopped and resumed, Idle mode, Power down mode), Programmable clock out, Second DPTR register, Asynchronous port reset, Low EMI (inhibit ALE), 3 16-bit timers and Wake up from power down by an external interrupt *(refer to the manufacturers' website for complete datasheet)*

[3] A **microcontroller** (sometimes abbreviated **µC**, **uC** or **MCU**) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

[4] The file could be viewed using any text editor or any environment that enables the viewing of assembly language codes. **Note:** For the assembly language code to be compiled successfully, the "*reg_51.pdf*" file must be included. This can be downloaded at: http://www.8051projects.net/download-d189-include-files-for-binus-projects.html as at the time of documenting this research.

is based on the fact that a voltage on the oxide-insulated gate electrode can induce a conducting channel between the two other contacts called source and drain. The MOSFET activates the relay which turns on the external heating or cooling system. This is the activator / effector unit of this system.

V. The Security / Alarm Unit: This consists basically of a buzzer or a wailer alarm sounder. A buzzer is a signalling device, usually electronic, typically used in automobiles, household appliances such as microwaves, or game shows to pass alerts on system events. The buzzer in this project is used as a warning/alerting device which informs that the existing room temperature has risen above the preset temperature value. The buzzer is wired to a "driver" circuit contained in the 89C52 microcontroller IC, and to a 555 Timer which pulses the sound on and off.

VI. The Display (LCD) Unit: This unit is used in this system to display the reading of the NTC THERMISTOR Temperature Sensor device as it changes in response to the current environmental temperature. It is made of a 16x1 Liquid Crystal Display (LCD).

3.0 RELATED PROJECTS / SYSTEMS

[4], designed an automatic room temperature control with security system using a PIC18F4550 microcontroller, a LM35DZ temperature sensor and an alphanumeric LCD with two lines of sixteen characters each. The system was used to secure a server room door that could only be accessed upon providing a valid password to the system.

[5], built a commercial Temperature Control System using 2 LM35 Temperature Sensors. Other components in the system included a PIC16F876A Microcontroller, Dc brushless Fans, LEDs, Buzzer and a BD135 power transistor. A difference in the design of this system over previously designed models by the company was that: in previous versions, the PIC was used to control the LEDs and Buzzers. The PIC microcontroller used here doesn't have enough current to perform this function; hence, an NPN power transistor (BD135) is used to power the brushless fans.

[6], Zilog Technologies implemented an Automatic Temperature Control System to demonstrate the possibility of an application running on Zilog's Real-Time Kernel (RZK) to be used to control various devices to maintain a certain temperature. This Temperature Control System reads a value from a temperature sensor and determines when to switch a fan (for cooling) or bulb (for heating) off or on according to minimum and maximum temperature limits settings. These settings are manipulated using upper and lower limit set switches. The RZK is a real-time, pre-emptive, multitasking kernel designed for time-critical embedded applications. RZK objects used for real-time application development are Threads, message queues, event groups, semaphores, Timers, partitions and regions (memory objects), and interrupts.

4.0 SYSTEM IMPLEMENTATION AND FUNCTIONAL FLOW

The system functionality is described below: When power is given to the system the temperature sensor detects the room temperature and sends whatever it detects to the microcontroller to process the temperature. The sensor is wired to the microcontroller's input port but it is exposed to atmosphere so that it can have direct contact with the environment. The microcontroller cannot work on its own because it is like a storage device which is empty at upon purchase of it. Therefore, some data in the form of computer codes have to be programmed into the microcontroller to make it work with its associated circuits. The microcontroller after processing the signal transmitted by the temperature sensor sends the final process to the display module.

The set-point is programmed such that when the temperature of the environment rises to the pre-set value an alarm/buzzer is sounded. The complete circuit diagram of the project is given in the figure 2 in Appendix I:

The Negative Temperature Co-efficient Thermistor is connected to the IC 741, which is the Operational Amplifier, using a Bridge Network. The Operational Amplifier functions as a Comparator. It compares the input voltage coming from the Thermistor to the Maximum possible voltage that has been pre-set into the Micro-controller using the variable Resistor. The Operational Amplifier is connected also to a Zener Diode which cuts off all irregular input voltages and signal noise from the sensor, thus, ensuring that the signal proceeding towards the Microcontroller is a clean undistorted signal. This signal is further passed through a NAND Gate IC which inverts the signal before sending it to the Micro-controller. The actual comparison is done inside the Micro-controller which sends the input temperature signal to the LCD for display, and sends an interrupt to the buzzer to turn it on when the sensed temperature exceeds the set-point.

5.0 SYSTEM TESTING

The finished Control and Security System was tested in powering a miniaturized fan, and it succeeded in driving the load needed to power the fan after a testing temperature limit of 15°C was exceeded, sounding off a buzzer alarm before the fan was switched on. All through the testing experiment, the current environment temperature was constantly being retrieved by the sensor in real-time and displayed on the LCD screen.

Figure 1 *the Control and Security System*

However, the control system could be provided with additional / backup power so that power disruptions do not take the system offline as it possesses no backup power source of its own neither any power storage capabilities.

The sensor however showed some inconsistencies in reporting temperature accurately and consistently when it was exposed to direct flame and frost. This suggests that the system may not be able to perform optimally in the face of actual disasters of the order of ice or infernos. This however seems to be a design defect on the part of the manufacturer. Future experiments would, however, test out other sensors from other manufacturers to determine their performance under similar conditions.

6.0 CONCLUSION

Controlling the temperature is a major problem in our rapidly evolving world and it needs cost-efficient solutions. This Temperature Control System shows a way to get the temperature value and displaying the value on a graphical LCD via 89C52 microcontroller. In this Project temperature values are measured in analogue form, and then it is converted to digital by the Microcontroller. Digital data is used for driving the graphical LCD by the microcontroller unit. The user can configure a set-point temperature value and control an external heating and/or cooling device by using the Temperature Control System. The system can be used as the basis for developing custom solutions for networked and standalone data collection and control equipment. It can be centrally powered due to its low current requirement and its small size makes it more portable, allowing it to be placed almost anywhere.

7.0 FUTURE RESEARCH

The design of this temperature control system could be re-implemented using some more recent micro-controllers, as well as recent versions of the components used here. This is to help prospect for wider domestic and industrial application areas.

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APPENDIX I

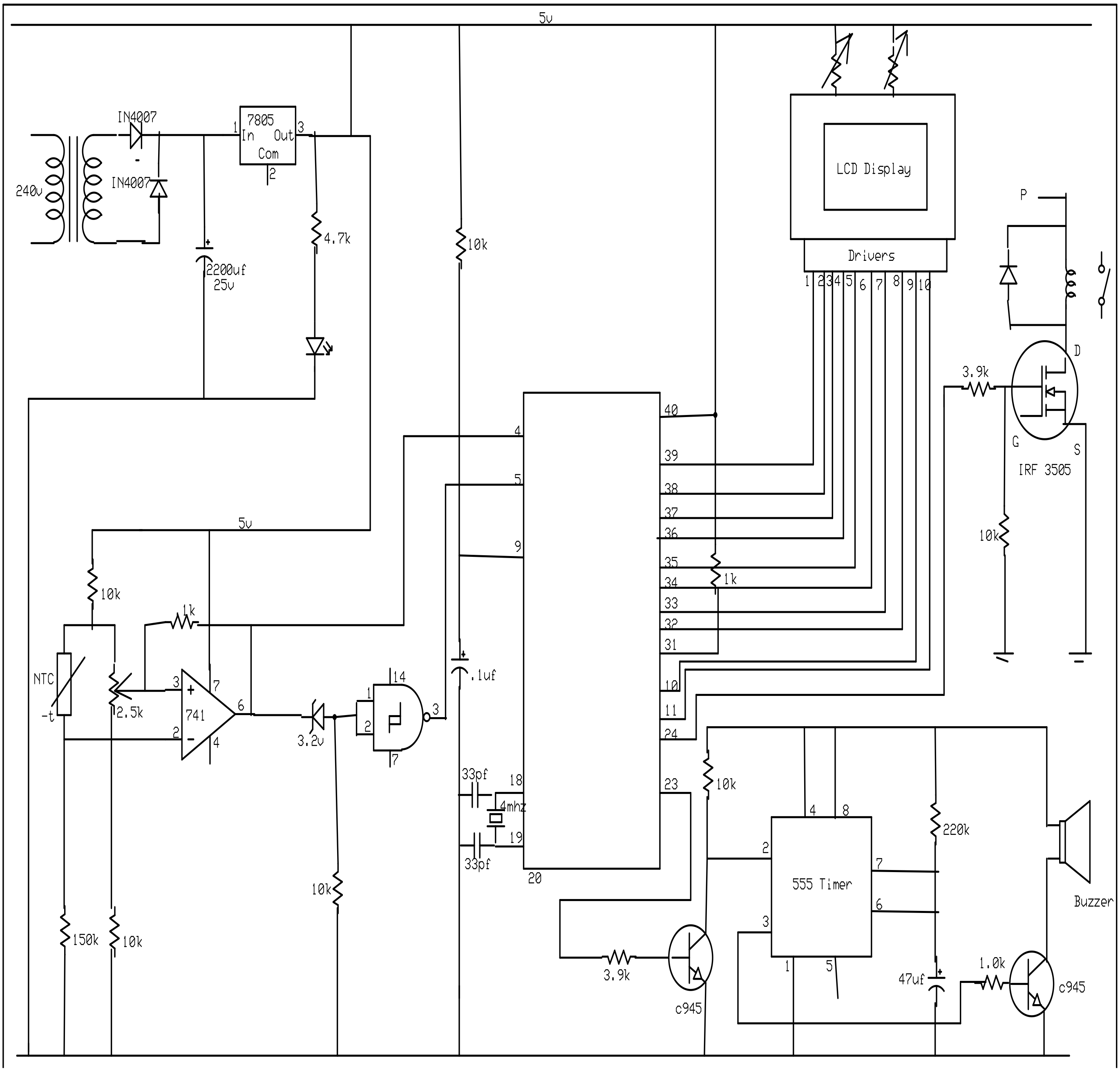

***Figure 2** Complete Circuit / Schematic Diagram of the Control and Security System*