A Microcontroller- based Room Temperature Monitoring System

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ABSTRACT
Monitoring the temperature of a computer server room is a critical task to ensure the performance of the server is not disturbed by excessive room temperature. In this paper, we designed and implemented a microcontroller-based room temperature monitoring system using Atmel ATmega8535 microcontroller and National Semiconductor's LM35 temperature sensor. The system is equipped with a Wavecom GSM modem to send and receive text message (SMS) and relay board to control electronic equipment. The experiment results show that our system works as expected. The system raises an alarm and send an alert message to administrator when the room temperature is above threshold, which is 28°C.

General Terms
Design, Experimentation

Keywords
Microcontroller, temperature sensor, server room temperature

1. INTRODUCTION
Computer server room plays an important role in the IT infrastructure of an organization to support the organization's computer network or other IT-related tasks. Therefore, monitoring the temperature of a computer server room is a critical task to ensure that the performance of the server is not disturbed by excessive room temperature. Generally, the daily computer server room's temperature is affected by several factors such as, the server room size, number of server inside the room, and the room's air conditioning system. Nevertheless, a system that capable to warn the server administrator regarding the server room temperature will be very useful in case of there is any excessive temperature.

This paper presents our design and implementation of a microcontroller-based system for monitoring server room temperature. We use Atmel AVR ATmega8535 microcontroller and LM35 temperature sensor as the main components of the system. Liquid Crystal Display (LCD) and buzzer are used to display the server room temperature and as an alarm, respectively. In order to alert the server administrator, the system is equipped with a GSM modem to immediately send text message if the server room temperature is above a predefined threshold. A relay board is also connected to the microcontroller to control other electronic appliances inside the server room.

The remainder of this paper is organized as follows. In Section 2, we provide a short background on microcontroller, specifically the Atmel ATmega8535 microcontroller, and also the LM35 temperature sensor. The design and implementation of the system is described in Section 3. Section 4 provides the results of our experiments and discussion. Finally, Section 5 concludes the paper.

2. BACKGROUND
Microcontroller can be regarded as a single-chip special-purpose computer dedicated to execute a specific application. As in general-purpose computer, microcontroller consists of memory (RAM, ROM, Flash), I/O peripherals, and processor core. However, in a microcontroller, the processor core is not as fast as in general purpose-computer, the memory size is also smaller. Microcontroller has been widely used in embedded systems such as, home appliances, vehicles, and toys. There are several microcontroller products available in the market, for example, Intel's MCS-51 (8051 family), Microchip PIC, and Atmel's Advanced RISC Architecture (AVR). We discuss Atmel ATmega8535 and LM35 temperature sensor in this section.

2.1 Atmel ATmega8535
ATmega8535 is an 8-bit AVR microcontroller. It has a 16 MHz AVR CPU, 8KB Flash, 512 Bytes EEPROM, and 512 Bytes internal SRAM. The other on-chip peripherals include two 8-bit timers/counters, one 16-bit timer/counter, 8-channel 10-bit analog-to-digital (ADC) and 32 programmable I/O lines, PORTA to PORTD, where each port has 8 lines. This microcontroller is available in 40-pin PDIP, 44-pin TQFP/MLF, and 44-pin PLCC packages. Details of ATmega8535 microcontroller are described in [1].

2.2 LM35 Temperature Sensor
The LM35 is a temperature sensor, whose output voltage is linearly proportional to the Celsius temperature. This sensor has linear output and low output impedance make it easy for connecting it to the readout circuitry [2]. Three pins, $+V_s$, *GND*, and V_{out} are defined for the sensor. When used as a basic temperature sensor (2°C to 150°C), any change in temperature by 1°C will be converted to 10 *mV* or the output voltage (V_{out}) = 0 *mV* + 10 *mV*/°C.

3. RELATED WORK
Zhu and Bai [3] proposed a system for monitoring the temperature of electric cable interface in power transmission, based on Atmel AT89C51 microcontroller. The system consists of a central PC machine, host control machines, and temperature collectors. Several temperature collectors are connected to a host control machine through RS-485 communication network, and the host control machine communicates and exchanges data with the central PC machine using General Packet Radio Service (GPRS) connection. The temperature collector itself consists of sensor temperatures (Maxim's DS18B20, 1-wire digital thermometer), decoders, and other circuits for interfacing

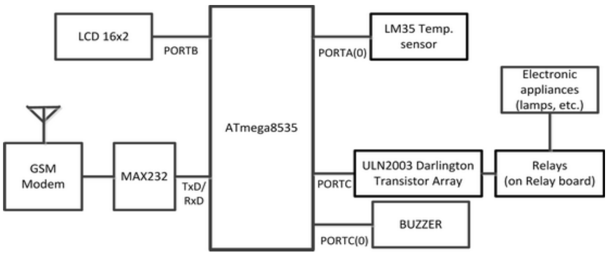

Fig 1: System block diagram

purpose. Each temperature collector saves the temperature in SRAM and sent the temperature information back to the host control machine when requested. Each host control machine also stores this temperature data in its memory (SRAM), and send it back to the central PC machine when requested. In this system, the communication using RS-485 network is limited by cable length (1200 meters). In [4], Loup et al. developed a Bluetooth embedded system for monitoring server room temperature. When the room temperature is above threshold, the system sends a message to each server via Bluetooth to shut down the server.

There are also some works on wireless temperature monitoring system based on Zigbee technology [5, 6, 7]. Bing and Wenyao [5] designed a wireless temperature monitoring and control system for communication room. They used Jennic's JN5121 Zigbee wireless microcontroller and Sensirion's SHT11 temperature sensor. The system proposed in [6] uses Chipcon's CC2430 Zigbee System-on-Chip (SoC) and Maxim's 18B20 temperature sensor. In [7] Li et al. developed a wireless monitoring system based on Zigbee, not only for temperature, but also humidity.

Different from our system, we use GSM short message service as the communication link, ATmega8535 microcontroller, and LM35 for the temperature sensor. Using short message service (SMS), our system can communicate with the administrator as long as his/her mobile phone is activated and not limited by distance. Our system also has the functionality for remotely controlling electronic equipment using the message sent by administrator.

4. DESIGN AND IMPLEMENTATION

We define our system to have specification as follows. 1) the system will raise an alarm and send a text message if the room temperature is above threshold (28°C), 2) message only sent to registered phone number in the system (i.e., the server administrator phone number), 3) system can receive text message from administrator and send back report about sensor status and current room temperature, 4) system is equipped with relay board to control electronic equipment, and 5) administrator can send text message to control electronic equipment (limited to ON/OFF control) connected to the relay board and get its status (ON or OFF).

The system consists of hardware and software parts. Simplified block diagram of the system is depicted in Fig 1. As shown, LM35 temperature sensor is connected to PORTA of ATmega8535 and the LCD to PORTB. Buzzer and relay board are connected to PORTC, and modem via MAX232 [8] interface connected to TxD and RxD pins of the microcontroller. The software for the system is written in Basic using BASCOM-AVR [9]. Fig 2 shows the software flowchart.

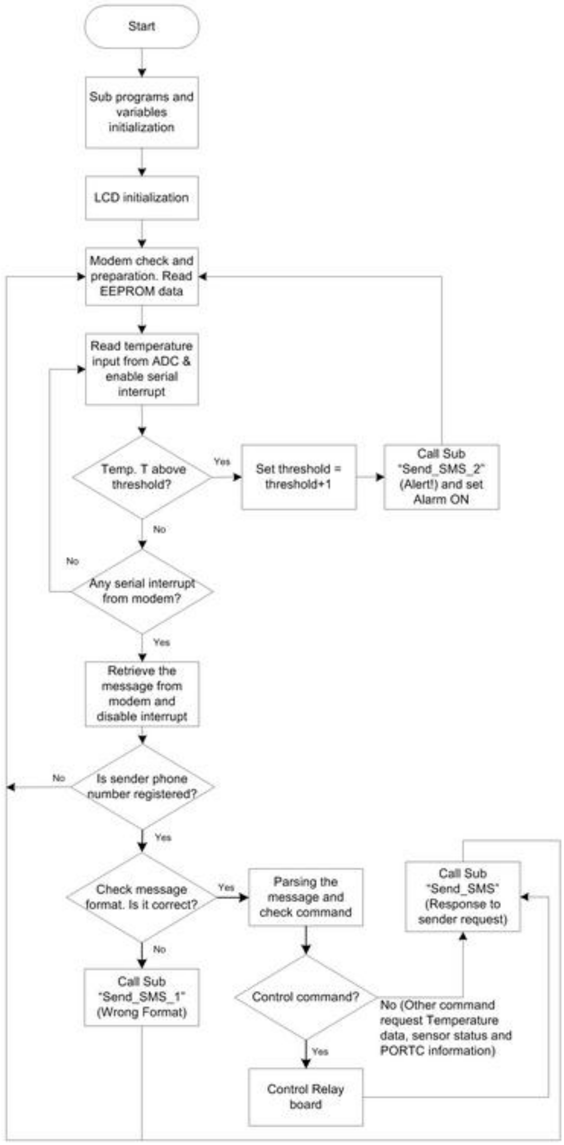

Fig 2: Software flowchart

The system works as follows. It starts with the initialization of all variables needed by the software, then initializes the LCD to display that the system starts to work. After the initialization process, it checks the modem connection and deletes the message from the first index of Message Box to free the space for incoming message. The system then enables the serial interrupt and ADC to read the temperature from LM35 sensor. The temperature is compared to predefined threshold (28°C). If the temperature is above 28°C, then the threshold is incremented by one (to 29°C) and a text message is sent to warn the administrator. Buzzer (alarm) is also activated. Otherwise, the system will only wait for serial interrupt from modem indicating there is a new incoming message.

When a new text message arrives, a serial interrupt is generated, and the system will take the new message from the modem. It checks the sender phone number whether the number is registered in the system. If it is not registered, the message will be ignored and deleted. Otherwise, the message will be checked for correct format. If message format is incorrect, system will send a reply message to the sender telling that the message format is not correct. Message with correct format will parsed to get the command. This command

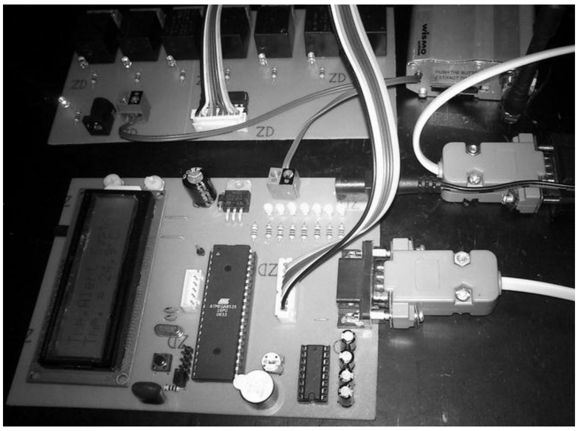

Fig 3: Room temperature monitoring system

then is checked for control command or other command such as, command to request the current room temperature and relay (PORTC) status. After execution of both kind of command, system will reply with a message to confirm the execution is complete.

The purpose of the threshold increment is to avoid the system sending message continuously to the administrator. Therefore, the subsequent message only sent when the temperature is increase by 1°C. After sending message and activating buzzer, system will back to modem check and read the temperature again. Here, the buzzer is deactivated (if it is activated) and the threshold is set back to 28°C (if it is already incremented).

4.1 Hardware

Photograph of the system is shown in Fig 3. The top part and bottom part of the figure shows the relay board and microcontroller board, respectively. As shown, the GSM modem is connected to the board via DB-9 connector.

4.2 Software

The software has four main parts: 1) read the temperature from ADC, 2) send text message, 3) receive text message, and 4) parsing text message and command selection. Code 1 shows the ADC read part. The voltage value is read from PORTA(0)/ADC(0) then stored in `Adc_vlt` variable. This value then, after some computations, is assigned to `Vlt` variable. The value of `Vlt` variable is the value to be compared to the predefined threshold. Therefore, if `Vlt` value is greater than 28°C, the system will raise the alarm.

Code 1. Read data from ADC

```
Thres = 28
'... other code...
Data_adc = Getadc(0)
Adc_vlt = Data_adc / 1024
Adc_vlt = Adc_vlt * 500
Vlt = Fusing(Adc_vlt , "##.#")
'... other code...
```

Code for sending text message is shown in Code 2. AT command [10], AT+CMGS is used to send text message. `Number` variable contains the administrator phone number and the message is ”`Warning!! Room Server Temp. Now`” followed by the temperature value. The `Chr(26)` or CTRL-Z is used to start the sending process. This code part will be called when the `Vlt` value is greater than 28°C. Code for receiving (read) text message is almost the same with Code 2, except it uses the AT+CMGR command.

Code 2. Send text message

```
'... other code...
Lcd "Send To Admin"
Print "AT+CMGS=" ; Number
Wait 1
Print "Warning!! Room Server Temp. Now
" ; Vlt ; "'C"
Print Chr(26)
'... other code...
```

After the text message parsing process, command selection part is simply done using the conditional structure (if...elseif). The code part is shown in Code 3 below. As shown in the code, if the system receives “Status” command, then it will execute another procedure called `Status`. This command is used to request the current room temperature and state of PORTC1-PORTC5 (connected to relay board, whether it is ON or OFF). The command “P1ON” is used to change the state of PORTC1 to ON. Therefore, the electronic appliance connected to one of the relays is turned on. Otherwise, if the command is “P1OFF”, the appliance is turned OFF. There are several commands defined for the system. These commands is listed in Table 1.

Code 3. Command selection process

```
'... other code...
Elseif SMS_in = "Status" Or SMS_in =
"status" Then
Gosub Status
Elseif SMS_in = "P1ON" Or SMS_in =
"P1on" Then
Temp = 1
Writeeeprom Temp , 1
Portc.1 = 1
Gosub Portcontrol
'... other code...
```

Table 1. List of command and its description

Command	Description
Temp	Request current room temp.
Status	Request the state of PORTC(1-5) & current temp.
P#On	Change the state of PORTC# to ON (# = 1-5)
P#Off	Change the state of PORTC# to OFF (# = 1-5)
P6Reset	PORTC6 ON for one second then OFF
P7Reset	PORTC7 ON for one second then OFF
PORTON	Change the state of PORTC# to ON (# = 1-5)
PORTOFF	Change the state of PORTC# to ON (# = 1-5)

5. RESULT AND DISCUSSION

We conducted the testing of our system in a real server room. Testing was done by sending every possible command to the system and observed the system's response. We also tested the system's response with the incorrect message format. Fig 4 shows the system tested with “Status” command. The administrator sent a text message whose content is "Status".

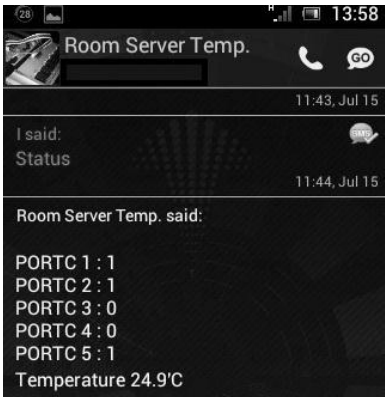

Fig 4: System testing with "Status" command

Fig 5: Message when temperature > 28°C

As shown in the figure, the system replied with the status of PORTC(1-5) and the current server room temperature. The result of this testing is as expected. Fig 5 shows the message received by administrator when the server room temperature is above 28°C. As shown, the system sent a warning message to the administrator with the current server room temperature. For all testing scenario, in general, the system can work well according to our specification and expectation. The testing results are shown in Table 2.

Table 2. Testing Results

Message sent	Reply (example)	Result
Temp	Temperature 25.1°C	Current room temperature is sent to administrator
Status	PORTC 1 : 1 PORTC 2 : 1 PORTC 3 : 0 PORTC 4 : 0 PORTC 5 : 1 Temperature 25.1°C	Status of PORTC and current room temperature is sent to administrator
P1On	OK P1on	PORTC 1 is ON
P1Off	OK P1off	PORTC 1 is OFF
P6Reset	OK P6reset	PORTC 6 is ON then OFF
P7Reset	OK P7reset	PORTC 7 is ON then OFF
PORTON	OK Porton	All PORTC is ON
PORTOFF	OK Portoff	All PORTC is OFF

In term of data communication part, compared to other approaches for room temperature monitoring system, our system has advantage by using GSM's short message service (SMS) for its data communication. Using SMS, administrator can check and monitor the room temperature from anywhere by using only a mobile phone even without Internet connection. Other approaches, for example RS-485 network, Bluetooth and Zigbee, are limited by distance.

6. CONCLUSION

In this paper, we have designed and implemented a microcontroller-based system for monitoring server room temperature. We utilized Atmel AVR ATmega8535 microcontroller and LM35 temperature sensor. Based on the testing results, the system works according to our predefined specification. This system can be used to help the administrator to monitor server room temperature and control electronic appliances in real-time using text message (SMS), in case the administrator in not inside the server room. The system also can raise an alarm and send a text message to warn the administrator if the server room temperature is above normal.

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