MICROCONTROLLER
BASED
TEMPERATURE SENSING
AND CONTROL
SYSTEM
Academic Information

“To Be Done by Student”
Acknowledgement

“To Be Done by Student”
Introduction

Monitoring the temperature of a room is a critical task to ensure the performance of the server is not disturbed by excessive room temperature or in corporate office or exceed of limit increasing rapidly. In this project, we designed and implemented a microcontroller-based room temperature monitoring system using Atmel ATmega8 microcontroller and National Semiconductor's LM35D temperature sensor. The system is equipped with alarm when temperature goes beyond threshold alarm rings and relay board to control electronic equipment. The experiment results show that our system works as expected. The system raises an alarm and when the room temperature is above threshold, which is 30°C. A Relay will be ON at 51°C and above.
Working

The working of microcontroller based temperature sensing and alarming system is totally based on ADC conversion. In this we are going to use LM35 temperature sensor that is used for temperature sensing and microcontroller ATMEGA8 for controlling part. In this project we decide a threshold value for temperature above which buzzer creates a sound but the intensity of buzzer is low at 30 degree and its intensity increases after every 5 degree and it will be maximum above 60°C. Each time ADC pin of microcontroller took sample from temperature sensor which provides temperature in analog voltage. For LM35D it shows 1°C in 10mV and so on for each degree.

![Diagram of LM35 Temperature Sensor](image)

Choose $R_1 = -\frac{V_s}{50 \mu A}$

$V_{OUT} = +1500 \text{ mV at } +150^\circ C$
$\quad = +250 \text{ mV at } +25^\circ C$
$\quad = -550 \text{ mV at } -55^\circ C$

**FIGURE** Full-Range Centigrade Temperature Sensor
Range Vs Buzzer Characteristics.

- From 30°C to 35°C Level of buzzer: Level 1 (Min)
- From 36°C to 40°C Level of buzzer: Level 2
- From 41°C to 45°C Level of buzzer: Level 3
- From 46°C to 50°C Level of buzzer: Level 4
- From 51°C to 55°C Level of buzzer: Level 5 (Relay-ON)
- From 56°C to 60°C Level of buzzer: Level 6 (Max)
Circuit & Component Description

Temperature (LM-35D)

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or
control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 - An Integrated Circuit Temperature Sensor

- You can measure temperature more accurately than a using a thermostat.
- The sensor circuitry is sealed and not subject to oxidation, etc.
- The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.

**Working of LM35**

- It has an output voltage that is proportional to the Celsius temperature.
- The scale factor is .01V/°C
- The LM35 does not require any external calibration or trimming and maintains an accuracy of +/-0.4 °C at room temperature and +/- 0.8 °C over a range of 0 °C to +100 °C.
- Another important characteristic of the LM35DZ is that it draws only 60 micro amps from its supply and possesses a low self-heating capability. The sensor self-heating causes less than 0.1 °C temperature rise in still air.

The LM35 comes in many different packages, including the following.
- TO-92 plastic transistor-like package,
- TO-46 metal can transistor-like package
- 8-lead surface mount SO-8 small outline package

- Here is a photo of the LM 35 test on a circuit board.
  - The white wire in the photo goes to the power supply.
  - Both the resistor and the black wire go to ground.
  - The output voltage is measured from the middle pin to ground.
Microcontroller (Atmega-8A)

Features

• High-performance, Low-power 8-bit Microcontroller

• Advanced RISC Architecture

  ✓ Most Single-clock Cycle Execution
  ✓ 32 x 8 General Purpose Working Registers
  ✓ Fully Static Operation
  ✓ Up to 16MIPS Throughput at 16MHz
  ✓ On-chip 2-cycle Multiplier

• High Endurance Non-volatile Memory segments

  ✓ 8KBytes of In-System Flash program memory
  ✓ 512Bytes EEPROM
✓ 1KByte Internal SRAM
✓ Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
✓ Data retention: 20 years at 85 Deg C/100 years at 25 Deg C
✓ Optional Boot Code Section with Independent Lock Bits

• In-System Programming by On-chip Boot Program

• True Read-While-Write Operation

✓ Programming Lock for Software Security

• Atmel QTouch library support

✓ Capacitive touch buttons, sliders and wheels
✓ Atmel QTouch and QMatrix acquisition
✓ Up to 64 sense channels

• Peripheral Features

✓ Two 8-bit Timer/Counters
✓ One 16-bit Timer/Counter
✓ Real Time Counter with Separate Oscillator
✓ Three PWM Channels

• Eight Channels 10-bit Accuracy

✓ 6-channel ADC in PDIP package

• Six Channels 10-bit Accuracy

✓ Byte-oriented Two-wire Serial Interface
✓ Programmable Serial USART
✓ Master/Slave SPI Serial Interface
✓ Programmable Watchdog Timer with Separate On-chip Oscillator
✓ On-chip Analog Comparator
• Special Microcontroller Features

✓ Power-on Reset and Programmable Brown-out Detection
✓ Internal Calibrated RC Oscillator
✓ External and Internal Interrupt Sources
✓ Five Sleep Modes

• Operating Voltages

✓ 2.7 - 5.5V
✓ 0 - 16MHz
Microcontroller Pin Description (Used)

- **VCC**
  
  +2.7V to +5.5V

- **GND**
  
  Ground Supply

- **AGND**
  
  ADC or Analog Ground

- **AREF**
  
  Reference voltage for ADC

- **PC5 – PC0**
  
  Bidirectional In/Out Pin Multiplex with ADC

- **RESET**
  
  Microcontroller Reset

- **PD7 – PD0**
  
  Bidirectional In/Out Pin
## Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature</td>
<td>-55°C to +125°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>-65°C to +150°C</td>
</tr>
<tr>
<td>Voltage on any Pin except <strong>RESET</strong> with respect to Ground</td>
<td>-0.5V to V\textsubscript{CC}+0.5V</td>
</tr>
<tr>
<td>Voltage on <strong>RESET</strong> with respect to Ground</td>
<td>-0.5V to +13.0V</td>
</tr>
<tr>
<td>Maximum Operating Voltage</td>
<td>6.0V</td>
</tr>
<tr>
<td>DC Current per I/O Pin</td>
<td>40.0mA</td>
</tr>
<tr>
<td>DC Current V\textsubscript{CC} and GND Pins</td>
<td>300.0mA</td>
</tr>
</tbody>
</table>
Now a days most of the high end industrial application devices have relays for their effective working. Relays are simple switches which are operated both electrically and mechanically. Relays consist of a n electromagnet and also a set of contacts. The switching mechanism is carried out with the help of the electromagnet. There are also other operating principles for its working. But they differ according to their applications. Most of the devices have the application of relays.
The main operation of a relay comes in places where only a low-power signal can be used to control a circuit. It is also used in places where only one signal can be used to control a lot of circuits. The application of relays started during the invention of telephones. They played an important role in switching calls in telephone exchanges.
They were also used in long distance telegraphy. They were used to switch the signal coming from one source to another destination. After the invention of computers they were also used to perform Boolean and other logical operations. The high end applications of relays require high power to be driven by electric motors and so on. Such relays are called contactors.
**ULN-2003 Driver**

**ULN2003** is a high voltage and high current Darlington array IC. It contains seven open collector Darlington pairs with common emitters. A Darlington pair is an arrangement of two bipolar transistors.
**ULN2003** belongs to the family of ULN200X series of ICs. Different versions of this family interface to different logic families. ULN2003 is for 5V TTL, CMOS logic devices. These ICs are used when driving a wide range of loads and are used as relay drivers, display drivers, line drivers etc. ULN2003 is also commonly used while driving Stepper Motors.

Each channel or Darlington pair in **ULN2003** is rated at 500mA and can withstand peak current of 600mA. The inputs and outputs are provided opposite to each other in the pin layout. Each driver also contains a suppression diode to dissipate voltage spikes while driving inductive loads. The schematic for each driver is given above.
Power Supply Section

Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

Here in our application we need a 5v DC power supply for all electronics involved in the project. This requires step down transformer, rectifier, voltage regulator, and filter circuit for generation of 5v DC power. A brief description of all the components is given as follows:

Circuit Diagram for power supply
Transformer

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors — the transformer's coils or "windings". Except for air-core transformers, the conductors are commonly wound around a single iron-rich core, or around separate but magnetically-coupled cores. A varying current in the first or "primary" winding creates a varying magnetic field in the core (or cores) of the transformer. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the "secondary" winding. This effect is called mutual induction.

If a load is connected to the secondary circuit, electric charge will flow in the secondary winding of the transformer and transfer energy from the primary circuit to the load connected in the secondary circuit.

The secondary induced voltage $V_S$, of an ideal transformer, is scaled from the primary $V_P$ by a factor equal to the ratio of the number of turns of wire in their respective windings:
\[ \frac{V_s}{V_p} = \frac{N_s}{N_p} \]

By appropriate selection of the numbers of turns, a transformer thus allows an alternating voltage to be stepped up — by making NS more than NP — or stepped down, by making it

**Bridge Rectifier**

A bridge rectifier makes use of four diodes in a bridge arrangement to achieve full-wave rectification. This is a widely used configuration, both with individual diodes wired as shown and with single component bridges where the diode bridge is wired internally.
Diode

A diode is a semiconductor device which allows current to flow through it in only one direction. Although a transistor is also a semiconductor device, it does not operate the way a diode does. A diode is specifically made to allow current to flow through it in only one direction. Some ways in which the diode can be used are listed here.

- A diode can be used as a rectifier that converts AC (Alternating Current) to DC (Direct Current) for a power supply device.
- Diodes can be used to separate the signal from radio frequencies.
- Diodes can be used as an on/off switch that controls current.

This symbol is used to indicate a diode in a circuit diagram. The meaning of the symbol is (Anode) → (Cathode).

Current flows from the anode side to the cathode side.
Although all diodes operate with the same general principle, there are different types suited to different applications. For example, the following devices are best used for the applications noted.

**Light emitting diode**

![Light emitting diodes and symbol](image)

The circuit symbol is . This type of diode emits light when current flows through it in the forward direction. (Forward biased)
Characteristics of Diode

The graph above shows the electrical characteristics of a typical diode. When a small voltage is applied to the diode in the forward direction, current flows easily. Because the diode has a certain amount of resistance, the voltage will drop slightly as current flows through the diode. A typical diode causes a voltage drop of about 0.6 - 1V ($V_F$) (In the case of silicon diode, almost 0.6V)

This voltage drop needs to be taken into consideration in a circuit which uses many diodes in series. Also, the amount of current passing through the diodes must be considered.

When voltage is applied in the reverse direction through a diode, the diode will have a great resistance to current flow. Different diodes have different characteristics when reverse-biased. A given diode
should be selected depending on how it will be used in the circuit. The current that will flow through a diode biased in the reverse direction will vary from several mA to just µA, which is very small.

The limiting voltages and currents permissible must be considered on a case by case basis. For example, when using diodes for rectification, part of the time they will be required to withstand a reverse voltage. If the diodes are not chosen carefully, they will break down.

**Regulator (lm7805)**

It is a three pin IC used as a voltage regulator. It converts unregulated DC current into regulated DC current.

Normally we get fixed output by connecting the voltage regulator at the output of the filtered DC (see in above diagram). It can also be used in circuits to get a low DC voltage from a high DC voltage (for
example we use 7805 to get 5V from 12V). There are two types of voltage regulators 1. Fixed voltage regulators (78xx, 79xx) 2. Variable voltage regulators (LM317). In fixed voltage regulators there is another classification 1. +ve voltage regulators 2. -ve voltage regulators. POSITIVE VOLTAGE REGULATORS This include 78xx voltage regulators. The most commonly used ones are 7805 and 7812. 7805 gives fixed 5V DC voltage if input voltage is in (7.5V, 20V).
In a way, a capacitor is a little like a battery. Although they work in completely different ways, capacitors and batteries both store electrical energy. Like inside the battery, chemical reactions produce electrons on one terminal and absorb electrons on the other terminal. A capacitor is much simpler than a battery, as it can't produce new electrons -- it only stores them.

Inside the capacitor, the terminals connect to two metal plates separated by a dielectric material. We can easily make a capacitor from two pieces of aluminum foil and a piece of paper. It won't be a particularly good capacitor in terms of its storage capacity, but it will work.
The dielectric can be any non-conductive substance. However, for practical applications, specific materials are used that best suit the capacitor's function. The dielectric dictates what kind of capacitor it is and for what it is best suited. Depending on the size and type of dielectric, some capacitors are better for high frequency uses, while some are better for high voltage applications. Capacitors serve any purpose, from the smallest plastic capacitor in your calculator, to an ultra capacitor that can power a commuter bus. NASA uses glass capacitors to help wake up the space shuttle's circuitry and help deploy space probes. Here are some of the various types of capacitors.

- **Air** - Often used in radio tuning circuits
- **Mylar** - Most commonly used for timer circuits
- **Glass** - Good for high voltage applications
- **Ceramic** - Used for high frequency purposes like antennas
- **Super capacitor** – Powers Electric & Hybrid Cars
Electricity flows through a material carried by electrons, tiny charged particles inside atoms. Broadly speaking, materials that conduct electricity well are ones that allow electrons to flow freely through them. In metals, for example, the atoms are locked into a solid, crystalline structure (a bit like a metal climbing frame in a playground). Although most of the electrons inside these atoms are fixed in place, some can swarm through the structure carrying electricity with them. That's why metals are good conductors: a metal puts up relatively little resistance to electrons flowing through it. Plastic are entirely different. Although often solid, they don't have the same crystalline structure. Their molecules (which are typically very long, repetitive chains called polymers) are bonded together in such a
Way that the electrons inside the atoms are fully occupied. There are, in short, no free electrons that can move about in plastics to carry an electric current. Plastics are good insulators; they put up a high resistance to electrons flowing through them.

This is all a little vague for a subject like electronics, which requires precise control of electric currents. That's why we define resistance
more precisely as the voltage in volts required making a current of 1 amp flow through a circuit. If it takes 500 volts to make 1 amp flow, the resistance is 500 ohms (written $500 \, \Omega$). The relationship written out as a mathematical equation:

$$V = I \times R$$

This is known as Ohm's Law. Figure above shows color coding of resistor.
Circuit/Block Diagram

Power supply → Microcontroller → ALARM

LM35 temperature sensor → Microcontroller → Relay For Fan or Other Appliances
Software Requirement

Cross Compiler : AVR Studio 6.0

Atmel Studio 6 is the integrated development platform (IDP) for developing and debugging Atmel ARM Cortex-M and Atmel AVR microcontroller (MCU) based applications. The Atmel Studio 6 IDP gives you a seamless and easy-to-use environment to write, build and debug your applications written in C/C++ or assembly code.

Atmel Studio 6 is free of charge and is integrated with the Atmel Software Framework (ASF)—a large library of free source code with 1,600 ARM and AVR project examples. ASF strengthens the IDP by providing, in the same environment, access to ready-to-use code that minimizes much of the low-level design required for projects. Use the IDP for our wide variety of AVR and ARM Cortex-M processor-based MCUs, including our broadened portfolio of Atmel SAM3 ARM Cortex-M3 and M4 Flash devices.

Atmel Studio 6.2 is now available, adding advanced debugging features such as Data and Interrupt Trace, improved RTOS integration, and better ability to debug code that has been optimized.

With the introduction of Atmel Gallery and Atmel Spaces, Atmel Studio 6 further simplifies embedded MCU designs to reduce development time and cost. Atmel Gallery is an online apps store for
development tools and embedded software. Atmel Spaces is a cloud-based collaborative development workspace allowing you to host software and hardware projects targeting Atmel MCUs.

In summary, standard integrated development environments (IDEs) are suited for creating new software for an MCU project. By contrast, the Atmel Studio 6 IDP also:

- Facilitates reuse of existing software and, by doing so, enables design differentiation.
- Supports the product development process with easy access to integrated tools and software extensions through Atmel Gallery.
- Reduces time to market by providing advanced features, an extensible software eco-system, and powerful debug integration.

**Programming Language : Embedded C**

Looking around, we find ourselves to be surrounded by various types of embedded system. Be it a digital camera or a mobile phone or a washing machine, all of them has some kind of processor functioning inside it. Associated with each processor is the embedded software. If hardware forms the body of an embedded system, embedded processor acts as the brain, and embedded software forms its soul. It is the embedded software which primarily governs the functioning of embedded systems.
During infancy years of microprocessor based systems, programs were developed using assemblers and fused into the EPROMs. There used to be no mechanism to find what the program was doing. LEDs, switches, etc. were used to check correct execution of the program. Some ‘very fortunate’ developers had In-circuit Simulators (ICEs), but they were too costly and were not quite reliable as well.

As time progressed, use of microprocessor-specific assembly-only as the programming language reduced and embedded systems moved onto C as the **embedded programming language** of choice. C is the most widely used programming language for embedded processors/controllers. Assembly is also used but mainly to implement those portions of the code where very high timing accuracy, code size efficiency, etc. are prime requirements.

Initially C was developed by Kernighan and Ritchie to fit into the space of 8K and to write (portable) operating systems. Originally it was implemented on UNIX operating systems. As it was intended for operating systems development, it can manipulate memory addresses. Also, it allowed programmers to write very compact codes. This has given it the reputation as the language of choice for hackers too.
**Result**

The system detects the level of temperature in the room. If it exceeds the safety level, it activates the audio alarm including a buzzer to alert the user whether inside or outside the room in an abnormal condition and to take necessary action. It also sets a relay output at more than 50 degrees.

We found that the sensor has high sensitivity and fast response time. The sensor’s output is an analog resistance but requires a design divider in case we need output at a low level.
Conclusion

In this project, we have designed and implemented a microcontroller-based system for monitoring room temperature. We utilized Atmel AVR ATmega8 microcontroller and LM35D 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 room temperature and control electronic appliances in real-time using alarming system, in case the administrator is not inside the room.
References

1. “AVR and embedded system” by Mazidi and Mazidi

2. All datasheets from www.datasheetcatalog.com

3. About ATMEGA8 from www.atmel.com

4. And www.triindia.co.in