CHAPTER - 3

GSM Based Remote Monitoring and Control System of Temperature
3.1 INTRODUCTION

Temperature is one of the most common real-world characteristics that systems need to measure. Many industrial processes, from steel manufacturing to semiconductor fabrication, depend on temperature. Some electronics products need to measure their own temperature, such as a computer that monitors its CPU or a motor controller that must know the temperature of the power driver IC.

Temperature [1] is a principle parameter that needs to be monitored and controlled in most food processing operations such as heating, cooling, drying and storage. Temperature sensors have been developed based on different temperature-dependent physical phenomena including thermal expansion, thermoelectricity, electrical resistance, and thermal radiation [2, 3]. Temperature sensors used in agricultural and food industries and research vary from simple liquid-in-glass thermometers to sophisticated and state-of-art thermal imaging. Some temperature sensors generate digital signals readily used for on-line monitoring and automatic temperature control purposes.

Temperature plays an important role in almost all fields of science, including physics, geology, chemistry, atmospheric sciences and biology. Many physical properties of materials including the phase, density, solubility, vapor pressure, and electrical conductivity depend on the temperature. Temperature also plays an important role in determining the rate and extent to which chemical reactions occur. This is one reason why the human body has several elaborate mechanisms for maintaining the temperature at 310 K, since temperatures only a few degrees higher can result in harmful reactions with serious consequences. Temperature also controls the type and quantity of thermal radiation [4] emitted from a surface. One application of this effect is the incandescent light bulb, in which a tungsten filament is electrically heated to a temperature at which significant quantities of visible light are emitted.
Temperature is the most commonly measured parameter, yet in many respects it is the least understood. It is a surprisingly difficult parameter to measure with the precision that one might reasonably expect. To obtain accuracies better than 0.2°C (0.4°F) great care is needed. Errors occur due to the presence of temperature gradients, drafts, sensor nonlinearities, poor thermal contact, calibration drifts, radiant energy and sensor self heating. The accurate measurement of temperature is a vital parameter in many fields.

The basic unit of temperature (symbol: $T$) in the International System of Units (SI) [5] is the Kelvin (Symbol: K). The Kelvin and Celsius scales are, by international agreement, defined by two points: absolute zero, and the triple point of Vienna Standard Mean Ocean Water. Absolute zero is defined as being precisely 0 K and −273.15 °C. Absolute zero is where all kinetic motion in the particles comprising matter ceases and they are at complete rest in the “classic” sense. At absolute zero, matter contains no thermal energy. Also, the triple point of water is defined as being precisely 273.16 K and 0.01 °C.

For everyday applications, it's very often convenient to use the Celsius scale, in which 0 °C corresponds to the temperature at which water freezes and 100 °C corresponds to the boiling point of water at sea level. Because liquid cloud droplets commonly exist in the atmosphere at sub-zero temperatures, 0 °C is better defined as the freezing point of bulk water or the melting point of ice. In this scale a temperature difference of 1 degree is the same as a 1 K temperature difference, so the scale is essentially the same as the Kelvin scale, but offset by the temperature at which water freezes (273.15 K). Thus the following equation can be used to convert from degrees Celsius to kelvins.

$$K = ^\circ C \left( \frac{1K}{1^\circ C} \right) + 273.15K$$

One must be careful when measuring temperature to ensure that the measuring instrument (thermometer, thermocouple, etc.) is really the same temperature as the material that is being measured. 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. An extreme case of this effect gives rise to the wind chill factor, where the weather feels colder under windy conditions than calm conditions even though the temperature is the same. What is happening is that the wind increases the rate of heat transfer from the body, resulting in a larger reduction in body temperature for the same ambient temperature.

3.2 TEMPERATURE MEASUREMENT DEVICES

Temperature can be measured by many methods using different types of sensors; several of the more common are described in this section.

- **Thermocouples**

  A thermocouple [6] is a junction of two dissimilar metals, which produces a tiny voltage when heated. The amount of voltage is dependent on which two metals are joined. Three common thermocouple combinations are Iron-Constantan (type J), Copper-Constantan (type T), and Chromel-Alumel (type K). The thermocouple provides a good balance of accuracy reliability and cost and is one of the most widely used temperature-measuring devices in the process industries. The thermocouple sensor is shown in Figure 3.1.

![Figure 3.1: Thermocouple](image)

- **Resistance Temperature Detectors (RTD)**

  A Resistance Temperature Detector (RTD) [7] is a wire that changes resistance with temperature. Typical RTD materials include copper, platinum, nickel, and nickel/iron alloy. An RTD element can be a wire or a film, plated or sprayed onto a substrate such as ceramic. RTD temperature sensors are used when accurate and repeatable temperature sensing is needed. They are manufactured from platinum and are available in a 2 or 3 wire configuration as shown in Figure 3.2. RTDs are commonly used for applications in which higher accuracy than provided by
thermocouples is required. These are mainly used for air temperature measurement with weather station networks [8] to provide temperature data of high quality and fidelity that can be widely used for atmospheric and related sciences.

Figure 3.2: Resistance Temperature Detectors
RTD resistance is specified at 0°C. A typical platinum RTD with 100Ω resistance at 0°C would have a resistance of 100.39 Ω at 1°C and a resistance of 119.4 Ω at 50°C. Figure 3.3 shows a comparison of a typical RTD temperature/resistance curve to that of a thermistor. The tolerance of RTDs is better than thermistors, typically ranging from .01% for platinum to .5% for nickel.

Figure 3.3: Temperature/resistance curve: RTD Vs thermistor

- Thermistor
Thermistors [9] are inexpensive, easily-obtainable temperature sensors. They are easy to use and adaptable. These are shown in Figure 3.4. Circuits with thermistors can have reasonable output voltages not the millivolt outputs thermocouples have. Because of these qualities, thermistors are widely used for simple temperature measurements. Thermistors are temperature sensitive resistors. Thermistors are
constructed of semiconductor material with a resistivity that is especially sensitive to temperature. The resistance of a thermistor decreases with increasing temperature. A graph of resistance as a function of temperature for a typical thermistor is already shown in Figure 3.3.

Figure 3.4: NTC Thermistors

- **Solid state sensor**
  
The simplest solid state temperature sensor is a PN junction, such as a signal diode or the base-emitter junction of a transistor. If the current through the forward-biased silicon PN junction is held constant, the forward drop decreases about 1.8mV per °C. A number of ICs take advantage of this semiconductor characteristic to measure temperature. These parts include the Maxim MAX1617, the National Semiconductor LM335, and the LM74. Solid state sensors have different interfaces and these are shown in Figure 3.5.

Figure 3.5: Solid state temperature sensors

- **Bimetallic sensor**
  
Metals expand with increasing temperature, and the rate of expansion differs among metals. A spiral constructed of two bonded metal strips will coil as the temperature changes. The changing position of the coil can be detected and used to
determine the temperature. This provides a rugged, low cost sensor that is often used for local displays and for on-off temperature control, i.e., a thermostat. The Bimetallic sensors are shown in Figure 3.6.

![Figure 3.6: Bimetallic sensors](image)

### 3.3 PRINCIPLES AND PROPERTIES

#### Resistance Thermometers

Resistance thermometers measure temperature of an object based on changes in electrical resistance of the sensing element. Two types of resistance thermometers are commonly used: thermistors and resistance temperature devices (RTD). In the present study we are using RTD.

The RTD uses metal materials (e.g., platinum) as the sensing element. Electrical resistance in a metal changes in a predictable manner with temperature. A general relationship [10] is used to convert electrical resistance $R$ to temperature $T$:

$$R_T = R_0 (1 + aT + bT^2 + cT^3 + ....) \quad \ldots \quad (1)$$

where $R_T$ is the electrical resistance at temperature $T$, $R_0$ is the electrical resistance at a reference temperature, usually 0°C, and $a$, $b$, and $c$ are material constants. The number of terms used in Eq.(1) depends on the material used in the sensor, the temperature range to be measured, and the accuracy required. In many cases, only constant, $a$, is used to provide satisfactory accuracy over limited temperature ranges. Figure 3.7 shows the temperature range and the output resistance ratio of the three commonly used metals: platinum, nickel, and copper. The RTD has a small positive temperature
resistance coefficient of 0.0039 for platinum RTD at 25°C as compared with a high negative temperature resistance coefficient of about -0.045 for a thermistor with a $\beta$ value of 4000.

![Resistance-temperature relationship for platinum, nickel, and copper](image)

**Figure 3.7: Resistance–temperature relationship for platinum, nickel, and copper**

### 3.4 APPLICATION OF TEMPERATURE SENSORS

Temperature sensors are selected according to required accuracy, response time, initial investment, maintenance cost, ambient condition, and stability of calibration. Examples of typical applications of temperature sensors discussed above are summarized in Table 3.1. Thermistors are generally used for measuring temperature in a narrow range, because of their high precision (±0.1°C) in small ranges. Thermocouples are widely used because of acceptable precision, rapid response time, and low cost. RTDs, however, provide better accuracy and stability. The sonic thermometer is commonly used to measure air temperature in the turbulent environment of storage houses and bins. Radiation thermometers are especially suitable for measurement of moving objects or objects inside vacuum or pressure vessels. Radiation sensors respond very quickly, but are more costly than thermocouples or RTDs. The sighting path and optical elements of the radiation detectors must be kept clean. Fiber-optic thermometers can be used in very strong electromagnetic fields.
Table 3.1: Property and examples of typical applications of Temperature sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Signal output</th>
<th>Measurement range (°C)</th>
<th>Accuracy</th>
<th>Example of typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermistor</td>
<td>Resistance</td>
<td>-50 ~ 300</td>
<td>±0.1%</td>
<td>Reference for data loggers</td>
</tr>
<tr>
<td>RTD</td>
<td>Resistance</td>
<td>-200 ~ 850</td>
<td>±0.2°C</td>
<td>Precise and stable measurements</td>
</tr>
<tr>
<td>Thermocouple</td>
<td>Voltage</td>
<td>-250 ~ 400</td>
<td>±0.5°C</td>
<td>Most food and agricultural applications</td>
</tr>
<tr>
<td>Sonic anemometer</td>
<td>Voltage</td>
<td>-10 ~ 80</td>
<td>±0.4%</td>
<td>Airflow temperature in storage and bins</td>
</tr>
<tr>
<td>Far-infrared thermometer</td>
<td>Voltage</td>
<td>~ 4000</td>
<td>&lt;1%</td>
<td>Surface temperature of foods in drying and baking</td>
</tr>
<tr>
<td>Fibre-optic thermometer</td>
<td>Voltage</td>
<td>-50 ~ 250</td>
<td>±0.5%</td>
<td>Microwave and radio frequency heating and drying</td>
</tr>
</tbody>
</table>

3.5 TEMPERATURE SENSOR (PT 100)

Platinum resistance thermometers (PRTs) [11] offer excellent accuracy over a wide temperature range (from -200 to +850 °C). Standard sensors are available from many manufacturers with various accuracy specifications and numerous packaging options to suit most applications. Unlike thermocouples, it is not necessary to use special cables to connect to the sensor.

PT100 is the common abbreviation for the most common type of resistance temperature sensor used in industry. It has a specified resistance of 100.00 ohms at 0°C and is made of Platinum which has an accurately defined resistance vs. temperature characteristic and excellent stability [12]. PT100 sensors were originally made with platinum wire wound on a ceramic former but are now made more cheaply by depositing a platinum film onto a ceramic substrate. Typical accuracies are 0.2%, 0.1% and 0.05% of value at 0°C. The higher the accuracy the higher the price. Although the sensors are sold loose, it is usual to buy them made up into stainless steel probes for insertion into processes. The PT100 sensor is shown in Figure 3.8.

Figure 3.8: PT100 Sensor
The PT100 is preferred sensor for all industrial applications from -200°C to 850°C. It is accurate, relatively inexpensive and easy to use. Its output change with temperature is relatively large compared to thermocouple which means lower drift errors on the electronics. For the majority of applications PT100 probes may be replaced with no recalibration of instruments. Because its resistance bears an absolute relationship to temperature no special compensating circuit needs to be provided in the electronics.

The principle of operation is to measure the resistance of a platinum element. The most common type (PT100) has a resistance of 100 ohms at 0 °C and 138.4 ohms at 100 °C. The relationship between temperature and resistance is approximately linear over a small temperature range: for example, if you assume that it is linear over the 0 to 100 °C range, the error at 50 °C is 0.4 °C. For precision measurement, it is necessary to linearise the resistance to give an accurate temperature. The most recent definition of the relationship between resistance and temperature is International Temperature Standard 90 (ITS-90) [13]. The resistance/temperature curve for 100 Ω platinum RTD, commonly referred to as PT100, is shown Figure 3.9.

![Resistance-Temperature Curve for PT100 sensor](image)

**Figure 3.9: Resistance-Temperature Curve for PT100 sensor**

The PT100 temperature sensing element is the most accurate and stable over time and temperature. RTD element technologies [14] are constantly improving, further enhancing the quality of the temperature measurement. Typically, a data acquisition system conditions the analog signal from the PT100 sensor, making the analog translation of the temperature usable in the digital domain.
3.6 HARDWARE DEVELOPMENT FOR TEMPERATURE WITH RMACS

The most widely measured phenomena in the process control environment is temperature. Temperature is a principle parameter needs to be monitored and controlled in process industries. It is one of the most common real-world characteristics that systems need to monitor and control. Many industrial processes, from steel manufacturing to semiconductor fabrication depend on temperature. It plays an important role in almost all fields of science, including physics, geology, chemistry, atmospheric sciences and biology. The purpose of this work is to monitor and control the temperature remotely using GSM Modem/Phone.

The present design of the system is GSM based Remote Monitoring and control of temperature. Because the wireless remote monitoring [15] and control system has more and more applications, a RMACS based on GSM is presented. Based on the total design of the system, the hardware and software of the system is designed. In this section the hardware part is discussed. In this system, GSM network [16] is a medium for transmitting and controlling the remote signal. This system can be applied for measuring temperature in Process control industries, domestic and industrial applications, boilers, heaters, nuclear power stations etc. The implementation of GSM based Remote Monitoring and Control System (RMACS) of Temperature is done by cascading several stages as shown in Figure 3.10 which depicts the system block diagram, Figure 3.11 describes the circuit diagram and the photograph 3 shows the complete set up of GSM based RMACS of Temperature.
Figure 3.10: Block diagram of GSM based RMACS of Temperature
Figure 3.11: Circuit diagram of GSM based RMACS of Temperature
GSM BASED RMACS FOR TEMPERATURE
The device hardware consists of different units and explanation for each unit is given individually. They are

1. Temperature Sensor (PT100)
2. Signal conditioning unit
   a. LM324 Amplifier
   b. Sallen-Key Filter
   c. Analog to Digital converter
3. Embedded ARM controller (ARM7TDMI-S LPC2148 Processor)
4. GSM MODEM
5. Display unit
   a. Mobile Phone
   b. Liquid Crystal Display
   c. Light Emitting Diode
   d. Personal Computer
7. Line Driver (ULN 2003)
8. Relay
9. Device 1 (FAN)
10. Power supply

3.6.1 PT100 Temperature Sensor

The Temperature PT100 sensor is a Platinum resistance thermometer (PRT) which offers high accuracy over a wide temperature range from -200 to 850 °C. PT100 sensors are also known as RTD sensors or Platinum resistance thermometers. The platinum resistance temperature sensor [17] is widely used in coal mine, automobile, household appliance, industrial automation measurement, some fields of experimental and instrumentation etc, because of its high precision, good stability, strong reliability and long life. The details of the PT100 sensor are discussed in section 3.5.

3.6.2 Signal conditioning unit

Any instrumentation measurement systems consist of various units starting from sensors to data representation units. Among that signal conditioning is a vital process. This system consists of Amplifiers, Filters, ADC, and DAC etc. The process instrumentation consists of signal conditioning and processing units for very low frequencies. During study of these signals, noise interference is a major problem and complex.
Signal conditioning unit provides amplification, filtering, converting and other processes required to make sensor output suitable for reading by microcontroller boards. Various sensor parameters are continuously being monitored by the system. The sensor output is typically being 'signal conditioned' by means of an operational amplifier [18] etc., which will be able to provide the signals with the right amount of voltages to be properly detected by the ARM processor. The signals from temperature sensors are processed by using ARM7 TDMI LPC2148 processor. The processing unit consists of Amplifier, ADC and a comparator circuit for processing the signals from the sensor. LPC2148 processor includes built-in ADC and Comparator. The interfacing circuit of Signal conditioning unit to ADC of LPC2148 is shown in Figure 3.12.

Figure 3.12: Interfacing circuit of Signal conditioning unit to LPC2148
The signal conditioning unit consists of the following parts which are explained below.

a. Amplifier

The amplifier receives the signal obtained from the previous stage and it is used to provide high gain, in order to adapt the signal to the later stage (A/D converter) to full scale. It also includes a zero adjustment. The signal is handled as a D.C signal \[19\]. In the present design we are using LM324 as an amplifier for amplifying the temperature sensor signal and the output of the amplifier is given to the Analog to Digital converter. The detailed description of LM324 is given below.

- **Single Supply Quad Operational Amplifiers LM 324**

**Description**

The LM324 series [20] are low-cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

**Features**

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum
- Four Amplifiers Per Package
- Internally frequency compensated for unity gain
- Large DC voltage gain 100 dB
- Common Mode Range Extends to Negative Supply
Advantages

- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and VOUT also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

Internal Block Diagram

The internal block diagram [21] of LM 324 amplifier is shown in Figure 3.13.

![Internal Block Diagram of LM324](image)

Figure 3.13: Internal Block Diagram of LM324

The signal conditioning circuit consisting of LM324 amplifiers are shown in Figure 3.14. This circuit uses a RTD temperature-sensitive element to measure temperatures from -200°C to 850°C. The current generator circuit consisting of U21B and U21C amplifiers excites the sensor. A U22C amplifier is used to zero wire resistance error. A U22D amplifier is used to gain the signal and filter possible alias interference. The output of the amplifier is applied to the analog to digital converter for further processing. A 10-bit ADC of LPC 2148 converts the voltage across the RTD to digital code for the ARM controller.
Figure 3.14: Signal conditioning circuit of the system
b. Filter

In the present design we have used Sallen-Key Filter in Signal conditioning unit. In 1955, R. P. Sallen and E. L. Key described these filter circuits, and hence they are generally known as Sallen-Key filters [22].

The properties of Sallen-Key Filters are
1. Simplicity of the design
2. Non-Inverting Amplifier (positive Gain)
3. Replication of elements

Figure 3.15 shows a two-stage RC network that forms a second order low-pass filter. This filter is limited because its Q is always less than 1/2. With R1=R2 and C1=C2, Q=1/3. Q approaches the maximum value of 1/2 when the impedance of the second RC stage is much larger than the first. Most filters require Qs larger than 1/2.

\[
\frac{V_o}{V_i} = \frac{1}{s^2(R_1C_2R_2C_1) + s(R_1C_2 + R_2C_1 + R_1C_1) + 1}
\]

Figure 3.15: Basic Second Order Low-Pass Filter

Larger Qs are attainable by using a positive feedback amplifier. If the positive feedback is controlled—localized to the cut-off frequency of the filter—almost any Q can be realized, limited mainly by the physical constraints of the power supply and component tolerances. Figure 3.16 shows a unity gain Sallen-Key low pass filter Capacitor C2, no longer connected to ground, provides a positive feedback path.

Figure 3.16: Unity Gain Sallen-Key Low-Pass Filter
The operation can be described qualitatively:

- At low frequencies, where $C_1$ and $C_2$ appear as open circuits, the signal is simply buffered to the output.
- At high frequencies, where $C_1$ and $C_2$ appear as short circuits, the signal is shunted to ground at the amplifier's input, the amplifier amplifies this input to its output, and the signal does not appear at $V_o$.
- Near the cut-off frequency, where the impedance of $C_1$ and $C_2$ is on the same order as $R_1$ and $R_2$, positive feedback through $C_2$ provides Q enhancement of the signal.

c. Analog to Digital converter

In the present study we are using the 10 bit inbuilt ADC of LPC2148 for analog to digital conversion. The PT100 sensor used can measure up to 850°C. The gain of the amplifier was adjusted to 7.66 so that each value coincides with each one of the possible values of the converter. The value obtained from A/D converter in binary code is applied to the digital stage of LPC2148. The LPC 2148’s ADC is set from 0 to 3.3Vdc, which corresponds with 0°C to 850°C from the PT100 sensor as given below.

- The reading of ADC at 0°C = 238
- The reading of ADC at 850°C = 926
- The resolution is 926-238=688 so the system will resolve to 0.809/°C.

3.6.3 Embedded ARM controller (ARM7TDMI-S LPC2148 Processor)

The LPC2148 is an ARM7TDMI-S based high-performance 32-bit RISC Microcontroller [23] with Thumb extensions 512KB on-chip Flash ROM with In-System Programming (ISP) and In-Application Programming (IAP), 32KB RAM, Vectored Interrupt Controller, Two 10bit ADCs with 14 channels, USB 2.0 Full Speed Device Controller, Two UARTs, one with full modem interface. Two I2C serial interfaces, Two SPI serial interfaces Two 32-bit timers, Watchdog Timer, PWM unit, Real Time Clock with optional battery backup, Brown out detect circuit General purpose I/O pins. CPU clock up to 60 MHz, On-chip crystal oscillator and On-chip PLL.
Due to their tiny size and low power consumption, LPC2148 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. Serial communications interfaces ranging from a USB 2.0 Full-speed device, multiple UARTs, SPI, SSP to I2C-bus and on-chip SRAM of 8 kB up to 40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers suitable for industrial control and medical systems. The details of block diagram, pin diagram and pin description are explained in detail in chapter 2.

In the present design ARM7TDMI-S LPC2148 Processor is the central processing unit. The LPC2148 will do the total processing of the system. The LPC2148 is connected to all external devices like GSM MODEM, RS232, Relay driver, controlling devices, LED and LCD. Every external device has their own input/output lines. The output signal of the signal conditioning unit is connected to P0-25 / AD0.4 of the LPC2148 processor. After the conversion of analog to digital in processor the digital section is interfaced with GSM modem to transmit the data over SMS to concern user(s)/server. Relay driver ULN 2003 is used to control the device. LCD communicates serially with LPC2148. Six lines are used to interface with the LPC2148 to the LCD. They are RS, E, and D4–D7. Here, we will be using the LCD in 4 Bit Mode. LED is controlled by switching the Pins High or Low. RS232 uses two lines to communicate between LPC2148 and Personal computer. Rxd is used as receive data line and Txd as transmit data line.

The schematic circuit of ARMTDMI-S LPC2148 processor and peripherals connecting to it are shown in Figures 3.17 & 3.11.

3.6.4 GSM MODEM

A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. It is a hardware component [24] that allows the capability to send and receive SMS to and from the system. The communication with the system takes place via RS232 serial port.
Figure 3.17: Schematic circuit of LPC2148

From the mobile operator perspective, a GSM modem looks just like a mobile phone. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it may be a mobile phone that provides GSM modem capabilities. A GSM modem could also be a standard GSM mobile phone with the appropriate cable and software driver to connect to a serial port or USB port on computer. Any phone that supports the "extended AT command set" for sending/receiving SMS messages, as defined in the ETSI GSM 07.05 Specification can be supported by the Now SMS/MMS Gateway.
GSM module [25] is the kernel part to realize wireless data transmission. Wireless communication module SIM300 based on standard of GSM produced by SIMCOM company is used in the developed application. SIMCOM SIM300 module consists of main frame, antenna, serial communication line, power line. It provides services of wireless modem, wireless fax, short message and speech communication. The short message service is suitable to apply in the situation of frequent transmittance of small data flow.

SIM300 [26] is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS1900 MHz. With a tiny configuration of 40mm x 33mm x 2.85 mm, SIM300 can fit almost all the space requirement in your application, such as Smart phone, PDA phone and other mobile device. The physical interface to the mobile application is made through a 60 pins board-to-board connector, which provides all hardware interfaces between the module and customers' boards except the RF antenna interface. The keypad and SPI LCD interface will give you the flexibility to develop customized applications. Two serial ports can help you easily develop your applications. Two audio channels include two microphones inputs and two speaker outputs. This can be easily configured by AT command. SIM300 provide RF antenna interface with two alternatives: antenna connector and antenna pad. The antenna connector is MURATA MM9329-2700. And customer's antenna can be soldered to the antenna pad.

The SIM300 is designed with power saving technique, the current consumption to as low as 2.5mA in SLEEP mode. The SIM300 is integrated with the TCP/IP protocol. Extended TCP/IP AT commands are developed for customers to use the TCP/IP protocol easily, which is very useful for those data transfer applications. The details of the Modem are discussed in detail in Chapter 2.

The Figure 3.18 shows the interfacing circuit of SIM300 GSM MODEM to the ARM7TDMI-S LPC2148 processor.
Figure 3.18: Interfacing Circuit of SIM300 GSM MODEM to the ARM7TDMI-S LPC2148 processor

The communication between these two is implemented using GSM. The GSM network act as a medium for the communication of control signals. The ARM7TDMI-S LPC2148 is connected to a GSM Modem to provide communication capabilities to the system operated by issuing a string of commands from either the system via the processor or from the user(s) concerned to the plant via SMS over mobile handsets. In the system whenever the temperature of the device crosses its set point the LPC2148 processor will sends an SMS to a user(s) mobile phone through GSM Modem. The User(s) concerned to the plant can control the set point by changing the temperature value or can switch on the controlling device (FAN) by sending AT commands to GSM MODEM, which will be directed to the LPC2148 processor. The user can also monitor the status of the temperature values through his mobile phone by issuing a string of AT commands to GSM Modem and in turn to the processor.

3.6.5 Display Unit

The display unit is used to display and indicate the status of the temperature. In the present system the following units are used as display units.

a. Mobile Phone

A mobile phone also known as a wireless phone, cell phone, or cellular telephone is a little portable radio telephone. Mobile Phone can serve as powerful tool for world-wide communication. The Mobile Phone is a natural choice, since it is a
communication resource generally available by people, which makes them practically always contactable and capable to send commands to operate the parameters in the industries. The use of mobile phones [27] or handsets has grown exponentially over the years.

In the present work the Mobile phone containing SIM card has a specific number through which communication takes place. It communicates with the GSM Modem via radio frequency. Mobile user transmits SMS using GSM technology. It also used to monitor and control the status of the temperature. The Figure 3.19 shows the overview of the system connecting to Remote Mobile phone through GSM Modem. The Figure 3.20 shows the status of the temperature in the Remote Mobile Phone User.

![Figure 3.19: Overview of the System connecting to Remote Mobile phone through GSM Modem](image)

![Figure 3.20: Status of the Temperature in the Remote Mobile Phone User](image)
b. Liquid Crystal Display

The output of the Processor is given to a liquid crystal display to display the data of the temperature and warning message to user if the device crosses its set point. In the present design we are using Liquid Crystal Display of JHD162A LCD. The displayed data is sent to LCD serially. The pin description and the specification are shown in Table 3.2. The interfacing diagram of LCD display with LPC2148 processor is shown in Figure 3.21.

A LCD [28] is an electronically-modulated optical device shaped into a thin, flat panel made up of any number of color or monochrome pixels filled with liquid crystals and arrayed in front of light source (backlight) or reflector. It is shown in Figure 3.22. It is often utilized in battery-powered electronic devices because it uses very small amount of electric power. The main advantage of LCD over LED is it can display alphanumeric, easy to interface and has got self test property.

![Figure 3.21: Interfacing diagram of LCD display with LPC2148 processor](image-url)
The LCD Display module used is 16 x 2 lines LCD [29], 16 characters and 2 lines. Its type is JHD162A. It has a total of 16 pins. The pins connection is as shown in the circuit diagram of Figure 3.23. A 1KOhms Preset potentiometer is used here to give a variable voltage to the pin 15 of the LCD module, which is for contrast adjustment. Another 10 ohms resistor is connected between VCC and pin 3 of the LCD to get the background light. The Port2 pins are connected to the LCD display. The LCD connection pins and function of each pin are shown in Table 3.2.
Table 3.2: LCD Pin Connection and its Function

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Pin function</th>
<th>Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VSS</td>
<td>Ground</td>
<td>GND</td>
</tr>
<tr>
<td>2</td>
<td>VCC</td>
<td>Positive supply for LCD</td>
<td>5V</td>
</tr>
<tr>
<td>3</td>
<td>VEE</td>
<td>Brightness adjust</td>
<td>Connected to preset to adjust brightness</td>
</tr>
<tr>
<td>4</td>
<td>RS</td>
<td>Select register, select instruction or data register</td>
<td>RB3</td>
</tr>
<tr>
<td>5</td>
<td>R/W</td>
<td>Select read or write</td>
<td>RB2</td>
</tr>
<tr>
<td>6</td>
<td>E</td>
<td>Start data read or write</td>
<td>RB1</td>
</tr>
<tr>
<td>7</td>
<td>DB0</td>
<td>Data bus pin</td>
<td>RC0</td>
</tr>
<tr>
<td>8</td>
<td>DB1</td>
<td>Data bus pin</td>
<td>RC1</td>
</tr>
<tr>
<td>9</td>
<td>DB2</td>
<td>Data bus pin</td>
<td>RC2</td>
</tr>
<tr>
<td>10</td>
<td>DB3</td>
<td>Data bus pin</td>
<td>RC3</td>
</tr>
<tr>
<td>11</td>
<td>DB4</td>
<td>Data bus pin</td>
<td>RC4</td>
</tr>
<tr>
<td>12</td>
<td>DB5</td>
<td>Data bus pin</td>
<td>RC5</td>
</tr>
<tr>
<td>13</td>
<td>DB6</td>
<td>Data bus pin</td>
<td>RC6</td>
</tr>
<tr>
<td>14</td>
<td>DB7</td>
<td>Data bus pin</td>
<td>RC7</td>
</tr>
<tr>
<td>15</td>
<td>LED+</td>
<td>Backlight positive input</td>
<td>RB0</td>
</tr>
<tr>
<td>16</td>
<td>LED-</td>
<td>Backlight negative input</td>
<td>GND</td>
</tr>
</tbody>
</table>

C. Light Emitting Diode

A light-emitting diode (LED) [30] is a semiconductor light source. LEDs are used as indicator lamps in many devices. It is shown in Figure 3.24. The LED is based on the semiconductor diode. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, and greater durability and reliability. LED is controlled by switching the Pins High or Low. The interfacing diagram of LED display with LPC2148 processor is shown in Figure 3.25.

Figure 3.24: LED
d. Personal Computer

A personal computer is a programmable machine that receives input, stores and manipulates data, and provides output in a useful format. A personal computer may be a desktop computer, a laptop, a tablet PC, or a handheld PC. Software applications for personal computers include word processing, spreadsheets, databases, Web browsers and e-mail clients, games, and myriad personal productivity and special-purpose software applications. Modern personal computers often have high-speed or dial-up connections to the Internet allowing access to the World Wide Web and a wide range of other resources. Personal computers may be connected to a local area network (LAN), either by a cable or a wireless connection.

In the present work, Personal Computer is used to display graphical representation of temperature measurement, log data, current data and high limit value of the temperature sensor. These are discussed in detail in Chapter 7. The data logging is achieved continuously by the ARM7 TDMI LPC2148 processor to the personal.
Computer via the MAX232. This data is received by the software running on the PC and continuously updates a database by using Visual Basic and also we can generate reports and graphs automatically.

Focusing on the client requirements, the following capabilities have been provided in the software.

**Monitoring** – This is the main feature of the system where extracted information is presented for the operator in near real-time. Monitoring has been divided in two sections.

- **Full graphical data representation** – In this section, the user is able to monitor the plant in a very user friendly manner where details are represented in dynamic graphical interfaces in personal computer.

- **Text base data representation** – In this section, the near real time details are represented in tables without graphical objects.

The interfacing diagram of Personal computer with LPC2148 through MAX232 is shown in Figure 3.26.

![Interfacing diagram of Personal computer with LPC2148 through MAX232](image)

Figure 3.26: Interfacing diagram of Personal computer with LPC2148 through MAX232
3.6.6 Serial Communication (RS 232)

The Serial Port is harder to interface than the Parallel Port. In most cases, any device you connect to the serial port will need the serial transmission converted back to parallel so that it can be used. This can be done using a UART. The advantages of using serial data transfer rather than parallel are:

- Serial Cables can be longer than Parallel cables. The serial port transmits a '1' as -3 to -25 volts and a '0' as +3 to +25 volts whereas a parallel port transmits a '0' as 0v and a '1' as 5v. Therefore the serial port can have a maximum swing of 50V compared to the parallel port which has a maximum swing of 5 Volts. Therefore cable loss is not going to be as much of a problem for serial cables as they are for parallel.

- You don't need as many wires as parallel transmission.

- Microcontrollers have also proven to be quite popular recently. Many of these have built SCI (Serial Communications Interfaces) which can be used to talk to the outside world. Only two pins are commonly used, Transmit Data (TXD) and Receive Data (RXD) shown in Figure 3.27 compared with at least 8 pins if you use a 8 bit Parallel method (You may also require a Strobe).

The electrical specifications of the serial port are contained in the RS232C standard. It states many parameters such as:

- A "Space" (logic 0) will be between +3 and +25 Volts.
- A "Mark" (Logic 1) will be between -3 and -25 Volts.
- The region between +3 and -3 volts is undefined.
- An open circuit voltage should never exceed 25 volts. (In Reference to GND)
- A short circuit current should not exceed 500mA. The driver should be able to handle this without damage.

Figure 3.27: Pin diagram of RS232
Pin Description

The pin description of RS232 is shown in Table 3.3.

Table 3.3: Pin Description of RS232

<table>
<thead>
<tr>
<th>PIN NO</th>
<th>ABBREVIATION</th>
<th>FULL NAME</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CD</td>
<td>Carrier Detect</td>
<td>This is the opposite to DSR. This tells the Modem that the UART is ready to link.</td>
</tr>
<tr>
<td>2</td>
<td>RD</td>
<td>Receive Data</td>
<td>Serial Data Input(RXD)</td>
</tr>
<tr>
<td>3</td>
<td>TD</td>
<td>Transmit Data</td>
<td>Serial Data Output(TXD)</td>
</tr>
<tr>
<td>4</td>
<td>DTR</td>
<td>Data Terminal</td>
<td>This line informs the modem that the UART is ready to exchange data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ready</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SG</td>
<td>Signal Ground</td>
<td>This tells the UART that the modem is ready to establish a link.</td>
</tr>
<tr>
<td>6</td>
<td>DSR</td>
<td>Data Set Ready</td>
<td>When the modem detects a &quot;carrier&quot; from the modem at the other end, this line becomes active</td>
</tr>
<tr>
<td>7</td>
<td>RTS</td>
<td>Request to Send</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>CTS</td>
<td>Clear to Send</td>
<td>This line indicates that the modem is ready to exchange data</td>
</tr>
<tr>
<td>9</td>
<td>RI</td>
<td>Ring Indicator</td>
<td></td>
</tr>
</tbody>
</table>

RS-232 is a standard for serial binary data signals connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment). It is commonly used in computer serial ports.

RS-232 communications in relation to the Personal computer is asynchronous i.e a clock signal is not sent with the data. Each word is synchronized using its start bit, and an internal clock on each side, keeps tabs on the timing. Almost all digital devices use either TTL or CMOS logic levels. Therefore the first step for connecting a device to the RS-232 port is to transform the RS-232 levels back into 0 and 5 volts.

The typical line driver/Receiver used in the present work is MAX232. The details of this are discussed below. The interfacing diagram of MAX232 with LPC2148 processor is as shown in Figure 3.26.

- MAX 232 Level Converter

MAX 232 Level converter is used to convert RS 232 levels to TTL/CMOS levels. The conversion levels are shown in Table 3.4.
Since the RS232 is not compatible with today's Microprocessors and Microcontrollers, we need a line driver or voltage converter to convert RS232's signals to TTL voltage levels. One example of such a converter is MAX 232 from Maxim corp. The MAX232 converter converts from RS232 voltage levels to TTL voltage levels and vice versa. One advantage of the MAX232 chip is that it uses a +5v power source, which is the same as the source voltage for the microcontroller. In other words, with a single +5v power supply we can power both the microcontroller and MAX232, with no need for the dual power supplies that are common in many older systems.

The pin diagram and circuit diagram of MAX232 are shown in Figures 3.28 and 3.29.

### Table 3.4: Conversion Levels of MAX 232

<table>
<thead>
<tr>
<th>Logic level</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS232 0</td>
<td>(-3) - (-25)</td>
</tr>
<tr>
<td>RS232 1</td>
<td>(3) - (25)</td>
</tr>
<tr>
<td>TTL/CMOS 0</td>
<td>0.0 - 0.5</td>
</tr>
<tr>
<td>TTL/CMOS 1</td>
<td>4.5 - 5.0</td>
</tr>
</tbody>
</table>

![Figure 3.28: Pin diagram of MAX232](image1)

![Figure 3.29: Circuit diagram of MAX232](image2)
The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply EIA-232 voltage levels from a single 5-V supply. Each receiver converts EIA-232 inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V and a typical hysteresis of 0.5V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into EIA-232 levels.

In the present design, the TXD1- pin 33 of the LPC2148 processor is connected to the pin 11-T1IN of the MAX232, and the RXD1- pin 34 of the LPC2148 processor is connected to the pin 12-R1OUT of the MAX232. The interface between the MAX232 and RS232 serial port is shown in Figure 3.26 i.e. from pin 14 of MAX232 to pin 2 of the DB-9 connector and pin 13 of the MAX232 is connected to the pin 3 of the DB-9 connector. By connecting the configuration as shown in Figure 3.29, we can establish communication between the LPC2148 processor and personal computer i.e. can transmit and receive data between the processor and PC. In the present work we are transmitting the measured data of temperature to the Personal computer. The transmitted data can be seen in the form of log data, graphical representation and Report generation for further analysis.

3.6.7 Line Driver (ULN 2003)

The microcontroller generates the control signals for activate the relays. But this signal is not sufficient to drive the relays. Because the microcontroller I/O lines has 0.25mA for drive current only. But the drive relays required 100mA. So we have to use power booster circuit. This power booster circuit is called as driver circuit.

In the present work Relay driver ULN 2003 is used to control the device Fan through Relay. The ULN2003 is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN darlington pairs that feature high-voltage outputs with common-cathode clamp diode for switching inductive loads. The collector-current rating of a single darlington pair is 500mA. The darlington pairs may be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED gas discharge), line drivers, and logic buffers. The ULN2003 has a 2.7kΩ series base resistor for each darlington pair for operation directly with TTL or 5V CMOS devices. The pin diagram and schematic of each darlington pair of ULN 2003 is shown in Figure 3.30 (a) & (b).
- **FEATURES**
  - 500mA rated collector current (Single output)
  - High-voltage outputs: 50V
  - Inputs compatible with various types of logic.
  - Relay driver application

![Figure 3.30(a): Pin diagram of ULN 2003](image)

![Figure 3.30(b): Schematic of each darlington pair ULN 2003](image)

### 3.6.8 RELAY

The relay used in the present work is 1 CO (SPDT), 10 A. It is used to turn ON and OFF the device Fan. It is driven using the relay driver IC ULN2003. When the relay is excited by applying the voltage the relay gets activated and in the process turns ON the device and when the excitation voltage is stopped the relay gets deactivated and in the process turns OFF the devices.
The Change-over (CO) Single Pole Double Throw (SPDT) is a 10A Sugar cube size PCB mount. It is shown in Figure 3.31.

![Image of 1 CO (SPDT), 10A Relay](image)

**Figure 3.31: 1 CO (SPDT), 10A Relay**

The features of 1 CO (SPDT), 10 A are

- **Features**
  - Printed circuit mount 10 A relay
  - 1 Pole changeover contacts or 1 Pole normally open contact
  - Miniature - "Sugar cube" package
  - DC coil - 360 mW
  - Wash tight: RT III
  - Cadmium Free contact material option

### 3.6.9 Device 1 (Fan)

In the present working environment we have connected a device 1 as Fan which will get switched ON/OFF depending on the temperature ranges. Here the Fan will be acting as controlled equipment depending on the temperature. The initial set point is set by default at the start up time and is hard coded. However, the same can be changed by sending an SMS to the RMACS and from that point forward the new value acts as the set point. Whenever the temperature crosses the set point the relay gets activated an SMS is shot to the user (pre-defined numbers) intimating them about the deviation and the controller also switches ON the Fan. When the relay gets deactivated the Fan will be OFF. Further the Device can also be switched ON / OFF depending on the requirement from the user incase he wishes to configure the system in the manual mode by sending AT commands from the mobile phone.
The interfacing circuit of ULN2003 to controlling device through relay is shown in Figure 3.32.

![Interfacing circuit of ULN2003 to Fan through Relay](image)

**Figure 3.32: Interfacing circuit of ULN2003 to Fan through Relay**

### 3.6.10 Power supply

In the present design the system operates on 3.3V, 5V, 12V power supply where GSM module uses 12V and 5V. LCD display uses power supply of 12V. RS-232 uses 5V power supply and the remaining parts of the design uses 3.3V. The circuit diagrams of the power supply are shown in Figures 3.33 & 3.34.

![3.3V Power supply circuit](image)

**Figure 3.33: 3.3V Power supply circuit**
3.7 SOFTWARE DEVELOPMENT FOR TEMPERATURE WITH RMACS

The software program developed and implemented with the hardware design is used to monitor and control the liquid level remotely. The program measures the input signals from the Float sensor and also controls the external devices. It displays the processed information on the LCD, PC and Mobile phone.

The algorithms used for the Remote Monitoring and Control System of liquid level using GSM are given below.

3.7.1 Algorithm depicting the Monitoring process

1. Initialize LPC2148 processor
2. Initialize ADC and enable interrupts
3. Initialize GPIO, LCD
4. Initialize serial port, GSM MODEM
5. Initialize ADC sampling rate using Timer
6. Clear the output ports
7. Read the input from the Temperature sensor (PT100) connected to 10 bit ADC
8. Display the processed values on LCD
9. Send data to the PC for logging in database
10. Compare the data with set point value
11. If the measured value is within limit, keep the Fan OFF
12. If the measured value is beyond the limit, keep the Fan ON
13. Alert the user(s) by sending an SMS alert through GSM MODEM to user Mobile phone
14. Repeat steps from 7 to 14 continuously

3.7.2 Algorithm depicting the Manual Control & Status request process

1. User(s) sends an SMS in the required format to the GSM MODEM
2. GSM MODEM sends signal to the LPC2148 Processor
3. The LPC2148 Processor is interrupted
4. The message is loaded in the local memory of the processor via UART
5. The message is decoded in the processor
6. If the decoded message contain device control command then device
   switching ON/OFF action is performed
7. If the decoded message contains status command, SMS is shot back to
   User(s) Mobile phone containing the status in the requested format by the user
8. Repeat all the above steps

3.7.3 Flowchart depicting the Monitoring process

The flowchart depicting the Monitoring process is shown in Figure 3.35.
Figure 3.35: Flowchart depicting the Monitoring process

1. Start
2. Initialize LPC 2148 Processor
3. Initialize ADC and enable interrupts
4. Initialize GPIO, LCD, Serial port, GSM MODEM
5. Set ADC sampling rate using timer
6. Clear the output ports
   - Read the input from PT100 sensor
   - Start A/D conversion
   - Display the value on LCD
   - Send data to PC for logging in database
   - Compare data with set point
     - IS Temperature > Set point
     - YES Switch ON the Fan
     - NO Switch OFF the Fan
6. Send SMS to user(s) through GSM MODEM to user mobile phone
7. END
3.7.4 Flowchart depicting the Manual Control & Status request process

The flowchart depicting the Manual Control and Status request process is shown in Figure 3.36.

Figure 3.36: Flowchart depicting the Manual Control & Status request process
3.7.5 Software implementation

In the present work the embedded C language in Keil is used for the development of GSM based RMACS for temperature. The development tool used is Keil development tool. This tool offers numerous features and advantages that help us to develop embedded applications quickly and successfully. They are easy to use and are guaranteed to help us to achieve the design goals in a timely manner. Keil [31] development tools for the Microcontroller architecture support every level of software developer from the professional applications engineer to the student just learning about embedded software development. The Keil development tools are designed to solve the complex problems facing embedded software developers. The integrated development environment used here is Keil μVision4 IDE. The developed software program for the GSM based RMACS for temperature is given in Annexure-I.

3.7.5.1 Keil μVision IDE

μVision [32], the popular IDE from Keil Software, combines Project Management, Source Code Editing, Program Debugging, and Flash Programming in a single, powerful environment. The μVision IDE is, for most developers, the easiest way to create embedded system programs. The features of this are

- μVision windows can be re-arranged, tiled, and attached to other screen areas or windows respectively
- It is possible to drag and drop windows, objects, and variables
- A Context Menu, invoked through the right mouse button, is provided for most objects
- Keyboard shortcuts can also be employed to your own shortcuts
- You can use the abundant features of a modern editor
- Menu items and Toolbar buttons are grayed out when not available in the current context
- Graphical symbols are used to resemble options, to mark unsaved changes, or reveal objects not included into the project
- Status Bars display context-driven information
- You can associate μVision to third-party tools
3.7.5.2 Keil μVision3 IDE

In the present work the embedded C language in Keil is used for the development of GSM based RMACS for Level. The development tool used is Keil development tool. This tool offers numerous features and advantages that help us to develop embedded applications quickly and successfully. They are easy to use and are guaranteed to help us to achieve the design goals in a timely manner. Keil development tools for the Microcontroller architecture support every level of software developer from the professional applications engineer to the student just learning about embedded software development. The Keil development tools are designed to solve the complex problems facing embedded software developers. The integrated development environment used here is Keil μVision4 IDE.

Keil μVision4 IDE [33] is the framework with all necessary tools integrated and is available for a large number of ARM processors. It ensures easy and consistent Project Management. A single project file stores source file names and saves configuration information for Compiler, Assembler, Linker, Debugger, Flash Loader, and other utilities. It has powerful simulation capabilities that give you serious benefits for rapid, reliable embedded software development. When we start a new μVision4 project, we select the target device from the Device Database and μVision4 automatically sets required tool options and customizes dialogs. μVision4 displays only those options that are relevant to the selected device and prevents selection of incompatible directives.

The developed software program for the GSM based RMACS for Temperature is given in Annexure-I. The project creation and execution are discussed in detail with snapshots in chapter 7. Specific reasons for its use include

- It is a midlevel with high level features (such as support for functions and modules) and low level features (such as good access to hardware via pointers)
- It is very efficient
- It is popular and well understood
- Editor facilities for Creating, Modifying, and Correcting Programs
Good well-proven compilers are available for every embedded processor
- Target Debugging or CPU & Peripheral Simulation
- Books, training courses, code samples and World Wide Web sites discussing the use of language are all widely available.

3.8 OPERATION OF GSM BASED RMACS FOR TEMPERATURE

The circuit diagram of GSM based RMACS for temperature is as shown in Figure 3.11. Temperature is taken as a parameter and the temperature sensor PT100 will sense the temperature and will give a voltage output corresponding to the temperature. This signal is amplified in the amplifier circuit and taken into LPC2148 processor through the analog input channel for comparison. This signal is digitized using the inbuilt 10-bit ADC of the LPC2148 processor and compare the data with its set point for any status changes or value crossing the limit. If the value is more than the set limit alert the user(s) by sending an SMS through GSM MODEM to his/her Mobile phone and switch the FAN ON. If the values are within limits switch the FAN OFF. The user(s) concerned to the plant can control the set point by changing the temperature value or by switching ON the device Fan by sending AT commands to GSM MODEM, which will be directed to the processor. The user(s) can also monitor the status of the temperature value remotely through his/her mobile phone by issuing a string of commands to GSM MODEM and in turn to the processor. The measured values are displayed in personal computer for further analysis to download reports and graphs.

3.9 CALIBRATION AND ANALYSIS

Instrumentation system employed for the measurement of process parameters needs systematic calibration. The calibration process involves study of influence of various parameters on the final measurement systems. Malfunctioning and bad calibration of the system leads to wrong diagnosis leading to catastrophic results. Hence the calibration regarding the process parameters need vast studies and precautions.
Calibration of a given temperature is important to ensure reliable measurement. The temperature measurement device is often a determining factor in the development of processes and in the quality control of the final product. That is why it is essential to apply metrological controls based on a carefully planned, methodical approach, especially given that there are many significant factors influencing calibration uncertainties. In general, two calibration methods [34] are used. One method is to expose the sensor to an established fixed-point environment, such as the triple point of pure water and the freezing and boiling points of water. Another method is to compare readings with those of calibrated and traceable temperature sensors when they are placed in the same thermal environment.

In the present work the second method is used. To carry out this the instrument has been subjected for measurement of temperature by a standard instrument ST-9269 multi-stem thermometer with external sensing probe. The PT100 itself used as the standard during automatic calibration procedure. The PT100 sensor and the thermometer probe are placed inside an industrial oven to maintain 100°C. Once the temperature is stabilized in the oven then we observed the temperature in RMACS. Now this reading is compared with the calibrated standard meter. It is observed that both the readings are well matched and found with good repeatability for temperature measurement purpose as shown in Table 3.5.

Table 3.5: Measured and Calibrated Temperature values of the system

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Temperature value set</th>
<th>Temperature as per calibrated device</th>
<th>Temperature recorded by RMACS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>2</td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>119</td>
<td>119</td>
</tr>
<tr>
<td>4</td>
<td>130</td>
<td>130</td>
<td>128</td>
</tr>
<tr>
<td>5</td>
<td>150</td>
<td>151</td>
<td>149</td>
</tr>
<tr>
<td>6</td>
<td>175</td>
<td>175</td>
<td>174</td>
</tr>
</tbody>
</table>

The total measurement we corrected the accuracy within 98%. The error was not allowed beyond 2%. The actual measurements are carried out with designed
instrument as well as with standard meter. The empirical calibration process, the measurements exhibited slight deviation, but all these measurements are within the tolerance range. Besides accuracy, precision and resistance to corrosion an important consideration is the sensors response time. The response time is a measure of how quickly a sensor follows rapid temperature changes. The smaller the response time, the more closely the sensor follows the temperature change of the measured medium. The response time of the instrument was equal with standard meter.

### 3.10 RESULTS AND DISCUSSIONS

The aim and objective of the present work is to develop an integrated wireless RMACS for monitoring, controlling and accessing the performance of remotely situated parameters such as temperature, pressure, humidity and level on real time basis. Hence an attempt has been made by the author to develop a GSM based RMACS for temperature as a part of integrated wireless RMACS using the advanced processor ARM-TDMI-S LPC2148 which is tiny, rugged, low cost and low power consumption ideally suited for industrial control systems.

The system is tested with the standard set point and also with different set point values as temperature as a process parameter in the present study. The results are presented in Table 3.6.

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Fan Status</th>
<th>SMS status</th>
<th>SMS Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>OFF</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>OFF</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>OFF</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>ON</td>
<td>YES</td>
<td>Temperature crossing limit</td>
</tr>
<tr>
<td>120</td>
<td>ON</td>
<td>YES</td>
<td>Temperature crossing limit</td>
</tr>
<tr>
<td>150</td>
<td>ON</td>
<td>YES</td>
<td>Temperature crossed limit</td>
</tr>
</tbody>
</table>

The above results confirm that the monitoring and control device is always with the user(s) and also it is possible to read the data from any remote place. If the input value is near or more than the set limit then the processor will sends an SMS as
“Temperature crossing limit” or “Temperature crossed limit” to a user(s) mobile phone through GSM MODEM. The user(s) concerned to the plant can control the set point by changing the input value or can switch ON the fan by sending AT commands to GSM MODEM, which will be directed to the processor. The user(s) can also monitor the status of the temperature remotely by issuing a string of commands to GSM modem and in turn to the processor. The measured values are stored in personal computer for further analysis to download the reports and graphs. The graphical representation of process parameters, log data, current data values and high limit values of sensors, status of the parameters in the mobile phone are discussed in detail in chapter 7. The system was tested by measuring temperatures up to +200°C and the results are in good agreement with experimental values.

In RMACS if there is any deviation observed in the measured value the remote user can change the set point value with his mobile phone by sending command “ SET TEMP XXX °C” where XXX indicates the value. The designed RMACS tested with remote user mobile phone for different set points along with measured values of temperature with real time is shown in Figure 3.37.

Figure 3.37: Graphical Representation of Temperature with different set point values
3.11 ADVANTAGES AND APPLICATIONS

The GSM based Remote Monitoring and Control System of temperature has numerous advantages and applications. Few are listed below:

3.11.1 Advantages

- Extremely low cost device which can be adapted for many different applications
- Provides a feasible technology frame-work for monitoring and controlling of process parameters by using wireless technology
- Operate independently and automatically with minimal human interaction
- Efficient and cheap means of communication by use of SMS
- Robust and Reliable

3.11.2 Applications

- Used in Remote Telemetry
- Used in Process control industries
- Used in domestic and industrial applications (boilers and heaters)
- Used in online testing of machines
- Used in home automation
REFERENCES


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