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Design and Implementation of a Smart Home System

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The goal of the project was to implement a smart home by controlling electronic devices at home remotely and to get an alert on intrusion or movement around the restricted premises. The devices were controlled by a mobile phone using the SMS service available and the alerts were also received as an SMS mentioning the activity occuring around the premises.

The application consisted of two units, the microcontroller and the mobile unit. The mobile unit acted as a recipient to get responses from the mircontroller as well as a controller for giving instructions. Different operations were performed based on the given instructions. In addition to this, the microcontroller unit was responsible for reading input from the sensors. The Arduino platform was used as the system platform with Arduino Uno Board as the microcontroller board. The SIM900 GPRS/GSM module was used to communicate between the microcontroller unit and the mobile unit.

The system could be installed at any place and could be controlled by any mobile phone supporting the SMS service. The mobile phone neither needs to have any special features nor hardware nor any special application to use the system. The system consists of three sensors which are used as heat detector, intrusion detector and motion detector along with a remotely managed light system.

The goal of the project was achieved successfully. However, the system is limited to the availability of the GSM network as the GSM network is responsible for communication between the mobile station and the GPRS module. The project could be extended further by using wireless communication or Internet communication along with the GSM network to reduce the limitation in the absence of GSM network.

Keywords	GSM, Arduino, SIM900, AT command, sensor, SMS, LM35, PIR, hall effect, mobile station.

Contents

List of Abbreviations

ADC – Analog to Digital converter

ALU – Arithmetic Logic Unit

AT – Attention

CMOS – Complementary Metal Oxide Semiconductor

CPU – Central Processing Unit

EEPROM – Electrically Erasable Programmable Read Only Memory

FTDI – Future Technology International

GPRS – General Packet Radio Service

GSM – Global System for Mobile Communication

ICSP – In Circuit Serial Programming

IR – Infrared

MCU – Microcontroller Unit

MISO – Master In Slave Out

MOSI – Master Out Slave In

PWM – Pulse Width Modulation

RISC – Reduced Instruction Set Computer

SCLK – Serial Clock

SIM – Subscriber Identity Module

SMS – Short Messaging Servicing

SMSC – Short Message Service Centre

SPI – Serial Peripheral Interface

SRAM – Static Random Access Memory

SS – Slave Select

USART – Universal Synchronous/Asynchronous Receiver/Transmitter

USB – Universal Serial Bus

1 Introduction

Lifestyle in the modern society along with human behaviour and thinking is changing dramatically with the advancement of technology, and the concept of a simple home is changing into a smart home. The advancement of technology has increased the safety and security of people along with their belongings. One of the reasons for the rise of the smart home is the increasing risk of burglary and robbery and the busy lifestyle. The busy lifestyle of people is leading to the necessity of controlling the devices at home remotely and increasing the necessity of keeping surveillance over their homes.

Mobile phones today are not just used to make calls. The use of mobile phones is changing with the development of technology and they can be used for different purposes. They can be used as clocks, calendars or controllers instead of being used just as phones. Today smart phones are available in the market with different applications and hardware which can be implemented without any further development or enhancement. With the help of the GSM network, a mobile can be used to implement a smart home by controlling devices and getting alerts on robbery and burglary.

There are different types of built smart home systems in the market, and they do not have flexibility over choosing the types and number of sensors used and the cost of the system. These systems are prebuilt devices with a limited number of sensors, with a limited area of coverage and with a limited capacity to control the electronic devices. Therefore the idea of a smart home system was proposed, to overcome the limitations of the systems already available in the market. The user can choose the number of sensors, types of sensors, the area of coverage of the systems along with the number and types of electronic devices to be controlled. The cost of the system can be determined by the user as the cost depends on the hardware used in the system chosen by the developer.

The goal of the project is to implement a smart home system by controlling the electronic devices at home remotely with the help of a mobile device and getting alerts on intrusion or movement around the restricted premises. The SIM900-GPRS module and the Arduino Uno Board are used to communicate between the mobile phone and the devices and sensors installed at home. The mobile phone can be used as a controller from anywhere in the world if the GSM network is available. The project consists of a led light which is controlled by the mobile phone to show the demo of controlling mechanism of the household devices such as light, fan or television. In addition, three sensors are used as a heat detector, motion detector and intrusion detector which trigger the alarm upon reaching the critical limit. The system is limited to the area with the GSM network available and the whole system does not work without the network.

2 Theoretical Background and Hardware Overview of the System

The system consists of two units: the mobile station and the microcontroller unit with the SIM900-GPRS module, sensors and the light system. Arduino Uno Board is used as the microcontroller board. The mobile phone is used as a controller to send instructions and as a recipient to receive the responses and alerts from the microcontroller unit, whereas the Arduino Board is the unit responsible for controlling the different parts and acts as the brain of the system. The SIM900 GSM/GPRS module is responsible for communication between the microcontroller unit and the mobile station. It is important to have some idea about the physics and the working principle behind the sensors and other hardware devices before using it.

2.1 Arduino Platform

Arduino is an open source electronics prototyping platform based on flexible hardware and software. The arduino is a simple yet sophisticated device which is based on Atmel's ATmega microcontrollers. The arduino software is supported by Windows, Macintosh OSX and Linux operating systems despite the fact that most microcontrollers are limited to Windows operating system. The software language is based on AVR C programming language and can be expanded through C++ libraries. There are various types of arduino microcontroller board available in the market including the arduino kits and arduino shields. [1]

2.1.1 Arduino Uno Board

Arduino Uno is one of the microcontroller boards manufactured by the Arduino and it is a microcontroller board based on the Atmel's ATmega328 microcontroller. "Uno" means one in Italian and the uno board is the latest in a series of USB (Universal Serial Bus) Arduino boards which is the reference model for the Arduino platform. The Arduino Uno board has a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, a reset button, 6 analog inputs and 14 digital input/output pins (of which 6 can be used as PWM outputs). It uses the Atmega16U2 programmed as a USB-to-serial converter instead of FTDI USB-to-serial driver chip which was used in all the preceding boards. The board has 32 KB flash memory of which 0.5 KB is used by bootloader, 2 KB of SRAM, 1 KB of EEPROM and 16 MHz clock speed. [2]

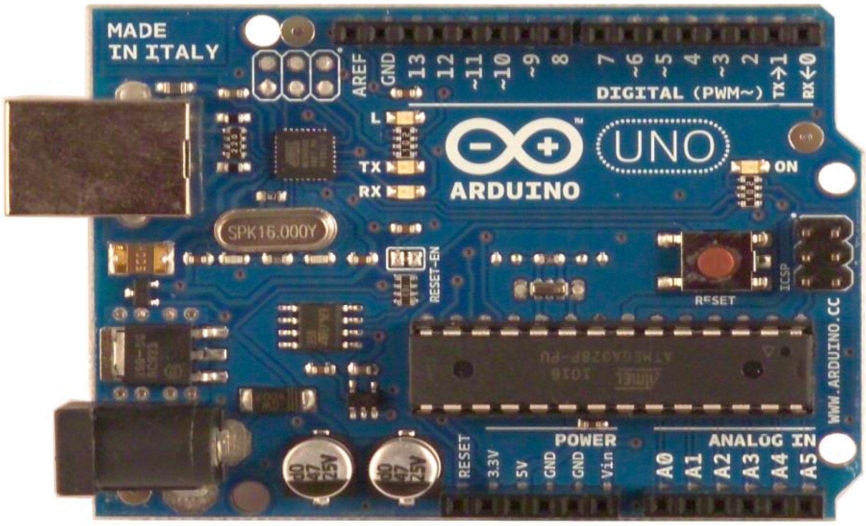


Figure 1: The Arduino Uno Board

Reprinted from the Arduino Board Uno [2]

Figure 1 shows the Arduino Uno Board manufactured by the Arduino in Italy. It can be powered via a USB connection or with an external power supply. As can be seen in figure 1, pins A0 to A5 are the analog input pins, pins 0 to 13 are 14 digital input/output pins and the pins with a "~" sign can be used as the PWM output pins. The digital pins can be used as input or output pins by selecting the mode by using the function pin-mode() and then using the function digitalRead() or digitalWrite() according to the necessity. Pins 0(RX) and 1(TX) are used for serial communication while pins 10(SS), 11(MOSI), 12(MISO) and 13(SCK) are used for SPI (Serial Peripheral Interface) communication. In addition to pin 0 and 1, a SoftwareSerial library allows serial communication on any of the Uno's digital pins. [2]

2.1.2 ATmega328 Microcontroller

The microcontroller is a low-power CMOS (Complementary Metal Oxide Semiconductor) 8-bit microcontroller based on the AVR enhanced RISC (Reduced Instruction Set Computer) architecture. The powerful execution of instructions in a single clock cycle leads to the achievement of 1 MIPS per MHz throughputs allowing the designer to optimize power consumption versus processing speed. [3]

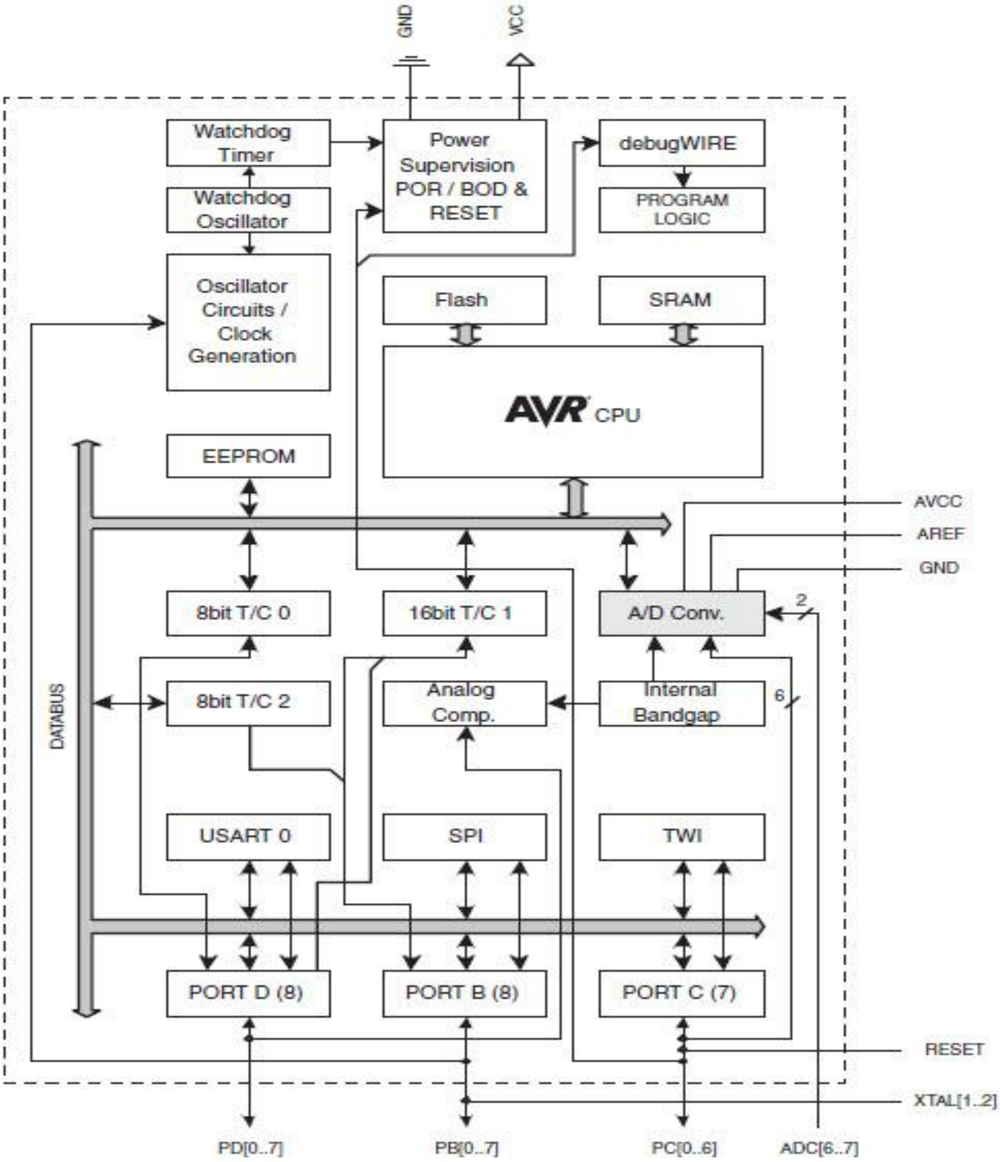


Figure 2: ATmega328 Microcontroller Architecture

Reprinted from Datasheet of ATMega328 [3]

The internal architecture of the microcontroller is shown in figure 2. The central processing unit (CPU) is the brain of the microcontroller which controls the execution of the program. The MCU (Microcontroller unit) consists of 4K/8K bytes of in-system programmable flash with read-while-write capabilities, 256/412/1K bytes EEPROM along with the 512/1K/2K bytes of SRAM. Along with this, the MCU consists of many other features: [3]

- 23 general purpose I/O lines and 32 general purpose working registers

- 3 flexible timer/counters with compare modes, internal and external interrupts and a serial programmable USART
- A byte-oriented 2-wire serial interface, an SPI serial port ,a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable watch-dog timer with an internal oscillator and 5 software-selectable power saving modes.[3]

The five, software selectable, power saving modes are Idle mode, Power-down mode, Power-save mode, ADC Noise Reduction mode and the Standby mode. As mentioned in section 2.1.2, the CPU is the brain of the microcontroller which controls the execution of the program. Therefore the CPU is able to access the memories, perform calculations, control peripherals and handle interrupts. The AVR uses the Harvard architecture – with separate memories and buses for program and data to maximize the performance as well as the parallelism. The principle of execution of instructions in the program memory is the single-level pipelining. The concept of pre-fetching the next instruction while executing one instruction enables the instructions to be executed in every clock cycle and the program memory is in the System Reprogrammable Flash memory. [3]

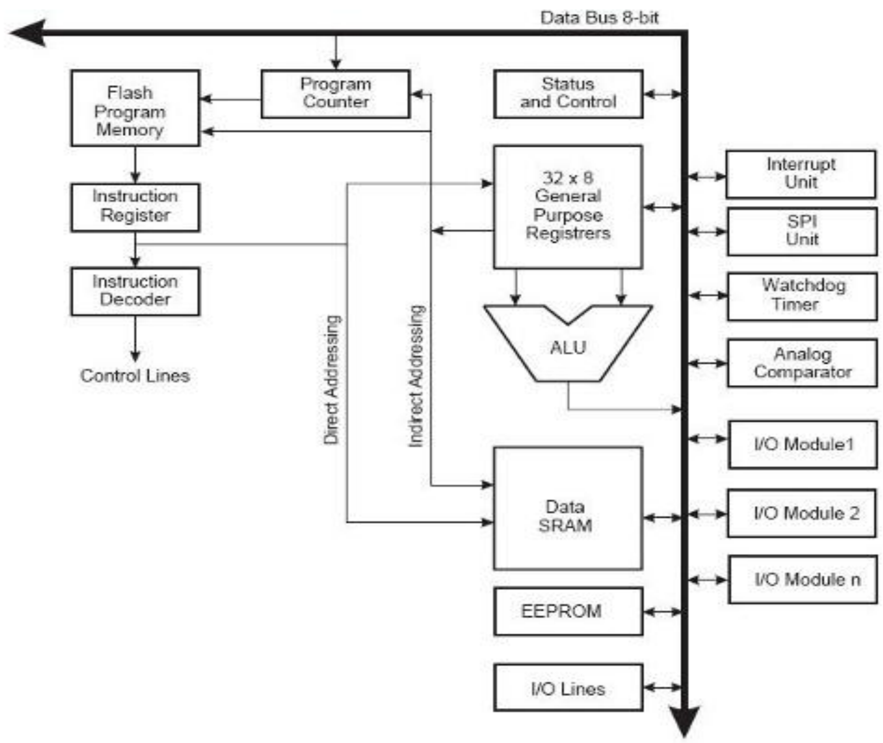


Figure 3: Block diagram of the AVR CPU Core architecture
Reprinted from from Datasheet of ATMega328 [3]

The block diagram of AVR CPU Core architecture is shown in figure 3. The fast-access Register File contains 32 x 8 bit general-purpose working registers with a single cycle access time which results in a single-cycle ALU operation. The arithmetic and logical operations between the registers or between the constant and a register are supported by the ALU. The status register is updated to reflect information about the result of the operation after an arithmetic operation. [3]

The boot program section and the application program section are the two main sections of the program flash memory. Stack stores the return address of the program counter during the interrupts and subroutine calls which is allocated in the general data SRAM. The size of the stack is limited by the total size and usage of the SRAM. The data SRAM is accessible through five different addressing modes supported in the AVR architecture while the stack pointer is read/write accessible in the I/O space. The memory spaces in the AVR architecture are all linear and regular memory maps. [3]

2.2 GPRS/GSM Network

Literally, the GSM stands for Global System for Mobile Communication. The subscription and the mobile equipment are separated in the GSM, unlike in analog networks where the two are not separated. The smart card handling and storing a subscriber’s data is the SIM (Subscriber Identity Module) card whereas the radio equipment is called mobile equipment. Hence, the combination of the Subscriber Identity Module and the mobile equipment is the mobile station. SMS (Short Messaging Service) is one of the services integrated in the GSM, which provides a means of sending messages of a limited size to and from the mobile stations. The handling of the SMS is done by the SMSC (Short Message Service Center) which has to be supported by the GSM network for the transfer of messages between the SMSC and the mobile stations. [4,212-216]

The GPRS (General Packet Radio Service) is a packet-switched transmission service supplementing the Circuit Switched data and Short Message Service over the mobile telephone network [4,229]. The circuit switched network architecture is upgraded to packet switched network by adding a couple of new infrastructure nodes and making a software upgrade to the existing network elements. The GPRS is a less costly mobile data service compared to SMS and Circuit Switched Data and the information is transmitted more quickly, immediately and efficiently across the mobile network. Several new applications are supported by the GPRS which have not been previously supported over the GSM networks due to the limitations in speed of Circuit Switched Data (9.6 kbps) and the length of the SMS (160 characters). The information to be transmitted is split into separate but related packets and is reassembled at the receiving end in the GPRS. [5]

SIM900 GSM/GPRS Module

SIM900 is an ultra-compact and reliable wireless SMT (Surface Mount Technology) type quad-band GSM/GPRS module designed with a powerful single-chip processor integrating AMR926EJ-S core manufactured by SIMCom Wireless Solutions Ltd. It delivers GSM/GPRS 850/900/1800/1900 MHz performance for voice, SMS and data. It is a low-power consumption module with current consumption as low as 1.0 mA in sleep mode. It is optimized for voice and other forms of data transfer including text and images. The module is 24 mm x 24 mm x 3 mm and is designed to meet any requirements for M2M applications. It has a GPRS multi-slot class 10/8 and a B-type GPRS mobile station class. It is compliant with GSM phase 2/2+, Class 4 (2W@850/900 MHz) and Class 1 (1W@1800/1900 MHz). AT commands are used to interface and control the GSM/GPRS module. [6]

AT is the abbreviation of attention and AT commands are instructions used to control and interface the modem. Despite the fact that every command line starts with “AT”, it is not a part of the command name but is just the prefix informing the modem about the start of a command line. For example, D is the actual command name in ATD (Dial) and +CMGR is the actual command name in AT+CMGR (Read SMS Messages). Basically, there are two types of AT commands and they are basic commands and extended commands. The AT commands starting with “+” are extended commands and almost all of the GSM AT commands are extended commands. For example, +CMGR (Read SMS Messages), +CMGL (List SMS Messages) and +CMGS (Send SMS Messages) are extended commands. Similarly, the AT commands that do not start with the “+” are basic commands. For example, H (Hook Control), A (Answer), D (Dial) and O (Return to online data state) are basic commands. [7]

The AT commands have a specific syntax and the syntax rules are described below:

1. The commands must start with “AT” and end with a carriage return.

2. The first command name should be prefixed with “AT” in a command line containing more than one AT command and the command names should be separated with semicolons. For example, the name of the manufacturer and the model number can be found by using the single command line,
   AT + CGMI ; +CGMM<CR>
3. The string is enclosed between double quotes. For example, the string “ALL” needs to be assigned as in the example shown below to read all the SMS messages from a message storage in the SMS text mode.
   Example: AT + CMGL = “ALL” <CR>
4. The information responses and the result codes (including both final result codes and unsolicited codes) always start and end with a carriage return character and a linefeed character. [7]

2.3 Sensor

The device which provides a usable output (electrical quantity) in response to a measurand (physical quantity, property or condition which is measured) is sensor according to the Instrument Society of America. There are different definitions and different views about the sensors and they have been adopted by scientists and engineers. Another common definition of sensor is “an element that senses a variation in input energy to produce a variation in another or same form of energy” [8,2]. Generally, the sensing principles are physical or chemical in nature and they can be grouped according to the form of energy in which signals are received and generated. There are six types of signals on the basis of the energy generated or received and they are mechanical, thermal, electrical, magnetic, radiant and chemical. Sensors can be classified according to the sensing principles but the classification of sensors is a vast field and they cannot be classified under one criterion. There are different classifications of sensors according to different criteria. For example, sensors can be classified according to the material and technology, application, transduction principles or property. [8,1-3]

The sensor itself may be a passive or an active device. A passive sensor is designed to receive and measure the signal whereas an active sensor is a device used for measuring signals transmitted by the sensors that were reflected, refracted or scattered. The only difference between the active and passive sensor is about transmitting the signal by the device. Independent of the active or passive nature of a sensor, there are several properties associated with a sensor that are critical to the sensor performance. Some of the more important properties are shown below: [9,14-16]

- response time and recovery time
- reproducibility
- aging
- stability (short term, long term), sensitivity and resolution
- dynamic range
- selectivity
- size, weight and cost. [9,16]

The response time of a sensor is the time taken by the sensor to reach 90% of its steady state value after the introduction of the measurand, whereas the recovery time is the time taken by a sensor to be within 10% of the value it had before the exposure to the measurand. The sensor with less response time and recovery time is considered to be a good sensor. The ability of the sensor to produce the same characteristic upon the repeated exposure to a particular measurand is referred to as reproducibility. The sensor with excellent reproducibility will have the same recovery time, response time as well as the same response for a particular measurand. However, there is some degradation on the sensor signature after a long use of the sensor and it is natural. The time taken by a sensor for the degradation is commonly known as aging. Sensitivity and resolution are the critical properties of a sensor for the application with the precise measurement system or for the application sensing the potentially dangerous measurand. The smallest change in the measurand that a sensor can detect is the resolution of the sensor and the change in the output per unit change in the measurand is the sensitivity of the sensor. The importance of properties of a sensor depends on the application where the sensor has to be used. For example: In the detection of highly toxic gas, sensitivity is the important property, in online control system where the measurand is exposed repeatedly, reproducibility and aging are the important properties whereas in application relating to the implantation of biosensor in the animals, weight and size becomes the important properties. There are different types of sensors but the sensors used in the project will be discussed in section 2.3.1, 2.3.2 and 2.3.3. [9,17-20]

2.3.1 Temperature Sensor

Thermal sensors have two connotations: i) sensors for measuring thermal properties such as temperature and heat; and ii) sensors based on thermal transfer principles.

Among the two connotations, the measurement of temperature and heat is widely practiced and can be achieved using many different principles. There are different types of thermal sensors for measuring the temperature but they can be divided into four different types according to the principles they are based on and they are microbolometers, thermocouples, resistors, thermistors and semiconductor devices. The principle to be employed and the sensor to be used generally depend on the temperature range to be detected and the resolution that is required. [10,176]

The devices designed to measure the temperature remotely by using the infrared radiations emitted are microbolometers. The principle of operation is that the infrared radiation falling on a thin film material is absorbed which will lead to the change in the resistance of the material. By measuring the change in the resistance, the temperature can be determined. There are several materials suitable as the absorbing layer such as metals, metal oxides and traditional semiconductors and these devices are uniquely suitable for the temperature imaging applications. This device is not suitable to yield the accurate absolute temperature since the temperature is measured indirectly. [11,47]

The two conducting materials with different thermoelectric temperature coefficient (also known as Seebeck coefficient) form a thermocouple. The difference between the thermoelectric temperature coefficient between the two conducting materials lead to the production of potential difference dependent on the temperature of the junction when the two materials are in intimate contact at a junction. Thermocouples are widely used for temperature sensing on the macroscale, over temperature ranges of many hundreds of Kelvin. For the localised measurement of temperature and improvement of the response time, junction of the materials is made as small as possible with the diameter of end of the tips as small as ~100 nm. [11,47-48]

Resistivity of most of the metals increases (generally non-linear) with the increase in temperature. The resistivity of a material can be determined by measuring the resistance of the material and hence temperature can be inferred. There are many microresistive temperature sensors using a variety of metals including tungsten, nickel and chromium based on this principle. [11,48]

The temperature sensors made from semiconductors are thermistors. The mixture of metal oxides pressed into a bead, wafer or other shape is heated under pressure at high temperature and then encapsulated with glass or epoxy. The result is a temperature sensor with a very distinct non-linear resistance versus temperature relationship with very small beads, less than 1 mm in some cases. Unlike a resistor, the resistance of a thermistor decreases with the increase of temperature and is called a negative temperature coefficient thermistor. The thermistors are very sensitive to small temperature changes and a detect temperature as low as 0.1 degree Centigrade or even smaller as the resistance change is very large for a small change in temperature. The typical range of the use of a thermistor is -100 to 300 degree centigrade. [12]

Semiconductor devices, generally diodes, make excellent temperature sensors. The junction temperature (Tj) – junction forward voltage (Vf) correlation is nearly linear to the second order at low values of forward current (usually referred to as measurement current (Im)). Hence, there is a change in the forward voltage with a change in the junction temperature with a constant correlation factor given by the equation below:

$$\Delta Tj = K \times \Delta Vf$$

where the correlation factor is referred to as the K factor. The value of K factor is generally in the range of 0.4 to 0.8 ºC/mV. The value of measurement current is different for different diodes and it is selected on the basis of diode size and the current value which corresponds to the break in the diode's forward voltage curve. Too small value of the measurement current will cause problems in measurement repeatability whereas too large value will cause significant self-heating giving rise to potentially large temperature measurement errors. [13]

LM35 Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the centigrade scale. This sensor is fully rated from -55 ºC to +150 ºC and with the linear scale factor of 10mV/ºC. It operates from 4 to 30 V, has less than 60 µA drain current and has low self-heating (0.08 ºC in still air). The control circuitry or the interfacing of LM35 is really easy due to the low output impedance, linear output and precise inherent calibration. The LM35 series is available in hermetic TO transistor packages, while the LM35C, LM35CA and LM35D are available in TO-92 transistor package. The LM35D is also available in an 8 lead surface-mount small outline package and a plastic TO-220 package. [14]

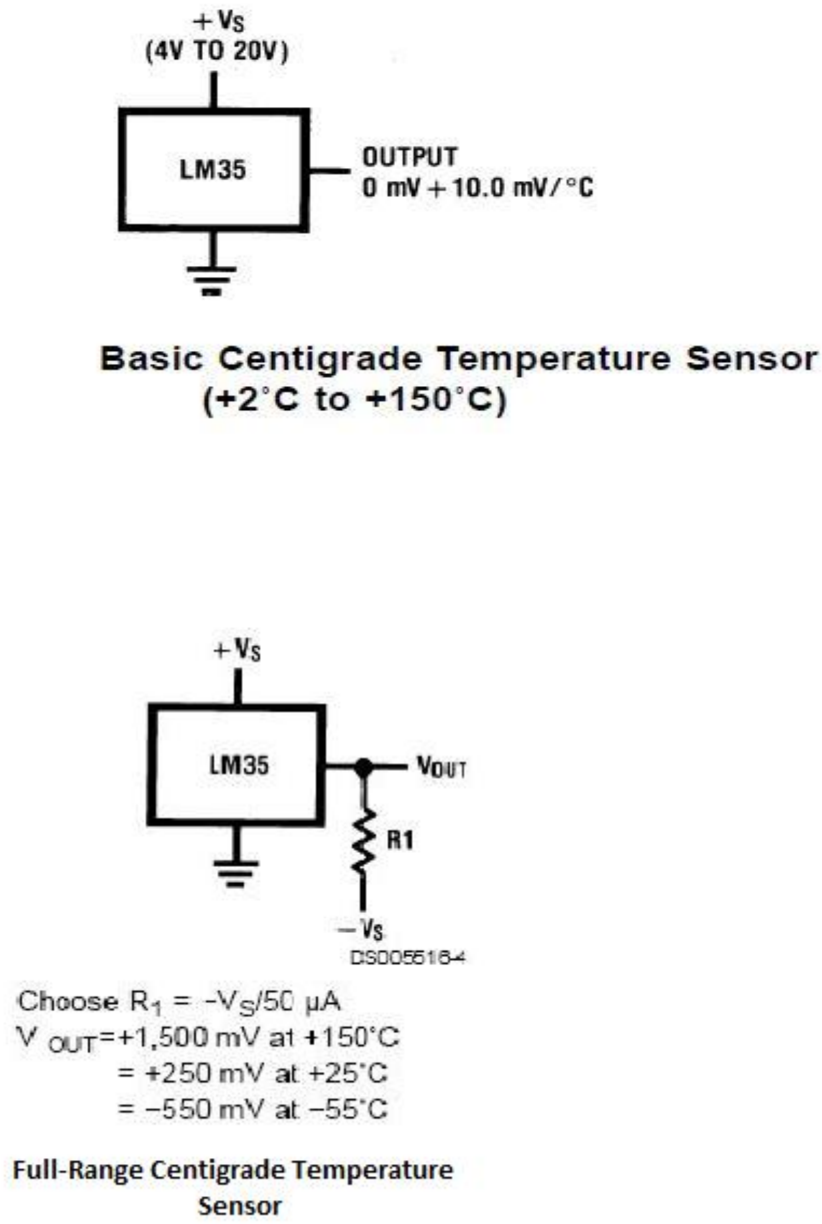


Figure 4: The circuitry of the LM35 for the Basic and Full-Range temp. sensor. Reprinted from datasheet of LM35 [14].

The LM35 can be used as a basic centigrade temperature sensor for sensing the temperature between +2 ºC and +150 ºC as well as a full-range centigrade temperature sensor for sensing the temperature between -55 ºC and +150 ºC and the circuitry for using them as basic or full-range is shown in figure 4. +Vs is the voltage supplied to LM35 and R1 is the resistance connected between –Vs and Vout (output voltage). The temperature can be obtained in degree Centigrade by just measuring the output voltage of the sensor as the output voltage is the function of the temperature.

2.3.2 Infrared Sensor

The electromagnetic radiation in the wavelength range between visible radiation (wavelength: 380-780nm) and microwave radiation (wavelength: 1mm-1m) is the Infrared radiation [15,1]. The vibration and rotation of atoms and molecules within a material whose temperature is above absolute zero produces infrared radiation and all the objects emit infrared radiation as a function of their temperature [15,1]. There are many subdivisions of IR radiation based on the wavelength by different organisations. The International Commission on Illumination (CIE) has divided the IR region into following three biologically significant bands [16]:

- IR-A: 700 nm – 1400 nm (215 THz – 430 THz)
- IR-B: 1400 nm – 3000 nm (100 THz – 215 THz)
- IR-C: 3000 nm – 1 mm (300 GHz – 100 THz)

Similarly, there is another classification specified by ISO 20473 which divides the spectrum into three regions and it is supported by astronomers and scientists as well.

Table 1: Classification of Infrared Radiation according to ISO 20473 scheme. Reprinted from Thermal Infrared Sensors [15,2]

Infrared Region	Wavelength range in µm	Temperature range of max. exitance in k	Remarks
Near Infrared (NIR)	1.2 – 1.3 1.5 – 1.7 2.1 – 2.4	2415 – 2229 1932 – 1705 1380 – 1208	Emission of hot bodies (>1000 ºC)
Mid Infrared (MIR)	3.2 – 4.1 4.4 – 5.2	906 – 707 659 – 557	Emission of hot bodies (> 300 ºC) Absorption of CO_2 and other gases
Far Infrared (FIR)	8 – 13	362 – 223	Emission of bodies at room temperature

The three classification of infrared radiation is shown in table 1. Since the infrared radiation is the function of temperature, the temperature of the source can be measured with the help of emitted radiation. In addition to it, due to some physical properties of IR radiation, it is highly suitable for a number of technical applications which are discussed below:

- Each body produces electromagnetic radiation of specific wavelength which is determined by the temperature of body. The body's temperature can be measured by using emitted radiation using contactless temperature measurement (pyrometry).
- At ambient temperature, the body produces infrared radiation of maximum 10 µm wavelength which cannot be detected by human eye. The radiation can be used to detect the motion and presence of people (motion detectors, security systems) or to record the entire scene with IR cameras. Since the IR spectrum can propagate even in the dark or in foggy conditions, the night vision devices and driver assist systems are based on it.
- The thermal images showing the thermal isolation of buildings, temperature distribution of combustion processed or temperature-dependent processes are based on the IR spectrum and can be recorded using the IR cameras.
- The distance and angle of the bonds between atoms change periodically due to the induced oscillations in atoms of molecules by the electromagnetic radiation. Each bond has a specific resonance frequency at which the radiation is almost completely absorbed. Chemical compounds absorb the radiation at characteristic wavelength and most of the absorption wavelength fall within the IR range. The presence and concentration of certain substances can be determined by using the IR radiation with a specific wavelength. This principle is used for the gas analysis as well as to draw a conclusion about the chemical composition of the samples (IR spectrometry). [15,1]

Generally the IR sensor can be divided into two classes: Passive IR sensor and Active IR sensor. The Passive IR sensor detects electromagnetic radiated energy generated by external sources, particularly the thermal energy emitted by the sources. Similarly, active infrared sensors generate a multiple beam pattern of modulated infrared energy and react to a change in the modulation of the frequency, or an interruption in the received energy. The active infrared sensor continually emits an infrared light beam with the IR-Led and the sensor measures the reflected light beam as they bounce OFF the objects. [17,379]

Panasonic Passive Infrared Motion Sensor

The motion sensor is manufactured by Panasonic and it is available in different types and different colours with a varying detection range. The sensors have simplified circuitry with fully integrated sensor design which eliminates external sensing circuits. The robust design of the sensor prevents false detection. The adverse effects of the external electromagnetic fields are minimised by enclosing the sensing circuit of the sensors in a metallic can. In addition, the high S/N ratio minimises sensitivity to false tripping when operated under various conditions. In spite of the ferroelectric ceramic (PZT) containing lead, lithium tantalate are used as a sensing element which is lead-free. [18]

Despite the different measures used to minimise the false detection, sensor might give false detection in many cases, for example a small animal entering the detection area, light source directly hitting the sensor, a sudden temperature change in the detection area etc. Similarly there will be difficulty in sensing the source if there is glass, acrylic or similar materials in between the target and the sensor as these materials may not allow correct transmission of infrared rays. [18]

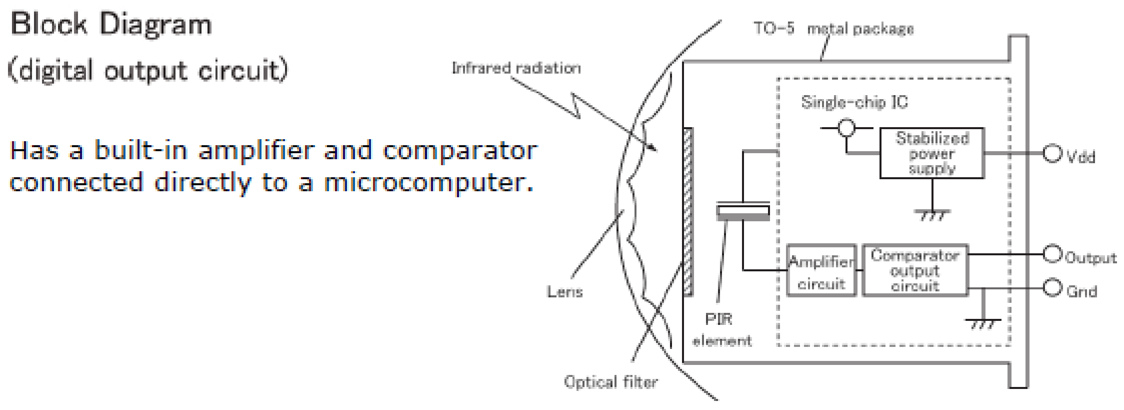


Figure 5: Block diagram of the Panasonic Passive Infrared Sensor
Reprinted from Datasheet of Infrared Sensor[18]

Figure 5 illustrates the block diagram of the Panasonic Passive Infrared Sensor. The sensing element (PIR element) along with the sensing circuit is enclosed inside the metal package. The output of the sensor is a digital output (either high or low). The stabilised power supply of 3.0 to 6.0 V should be used as the noise in the power supply may cause operating errors and the effect of the power supply noise can be reduced by using a capacitor on the sensor's power supply pin. [18]

2.3.3 Magnetic Sensors

The sensors associated with the laws and effects of magnetic or electromagnetic fields are considered the magnetic sensors. The soft and hard magnetic materials as well as other materials which are sensitive to magnetic fields play an important role in the nature and operation of magnetic sensors. A unique aspect of using magnetic sensors is that measuring magnetic fields is usually not the primary intent. The primary intent is to measure different physical and mechanical inputs which cause the change or disturbance in the magnetic fields. Once the change or disturbance in the magnetic field is detected, some signal processing will be required to change the sensor output value to the desired parameter value, which makes magnetic sensing a little more difficult to apply in most applications. There are many classifications of magnetic sensors but mostly they are classified using the following methods: [19,4]

- Types of sensors
- Physical principles
- Properties measured
- Sensor applications
- Sensor technologies.[19,4]

The classification based on the physical principles and effects are as follows:

- Magnetogalvanic sensors
- Magnetoelastic sensors
- Magnetic-field sensors: saturation-core magnetometers (flux-gate magnetometers) and induction-coil and search-oil magnetometers
- Wiegand and pulse-wire sensors
- Magnetoresistive sensors
- SQUID sensors.[19,4]

A hall sensor is a magnetic sensor based on the hall effect of the magnet. Voltage perpendicular to both the current and the field is generated when a current carrying conductor is placed into a magnetic field and this principle is known as the Hall Effect. [20,1-2]

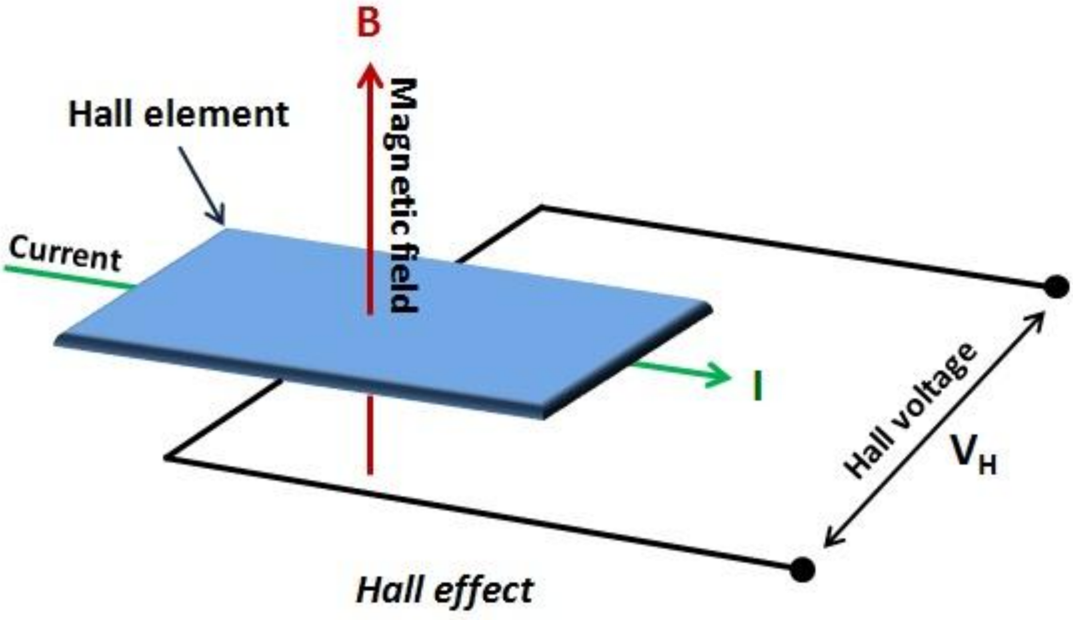


Figure 6: Hall Effect Principle

Modified from Hall Effect Sensing and Application [21]

Figure 6 illustrates the basic principle of hall effect. It shows a thin sheet of a hall element through which a current (I) is passed and is placed in a magnetic field (B). The hall element comprises of thin sheet of conductive material with the output connection perpendicular to the current flow which responds with an output voltage proportional to the magnetic field strength subjected to it. The relation between the hall voltage (V_H), current (I) and the magnetic field (B) is shown below:

$$V_H \alpha I \times B$$

The hall voltage is proportional to the vector cross product of the current (I) and the magnetic field (B). The symbol "α "is the proportionality symbol and can be replaced by "=" by multiplying the cross product with proportionality constant. The output voltage (Hall Voltage) is very small (µV) and requires some additional electronics to achieve useful voltage levels in the hall sensors. The voltage at each output terminal with respect to ground is non-zero even when the hall voltage is zero and this is the common mode voltage. Hence, the amplifier must be a differential amplifier so as to amplify only the potential difference in the sensor. [21]

The hall sensors can be divided into two categories depending upon the output voltage and they are analog output sensors and digital output sensors. The output voltage of a sensor is proportional to the magnetic field to which it is exposed and the magnetic field can be either positive or negative. As a result, the output of the amplifier will be driven either positive or negative requiring both the positive and negative power supplies. To overcome this problem of requiring two power supplies, a fixed offset or bias is introduced into the amplifier. The bias value appears on the output without the magnetic field and when a positive magnetic field is experienced, the output voltage will increase above the bias voltage whereas when the negative magnetic field is experienced, the output voltage will decrease below the bias voltage but will remain positive. [21]

The hall effect sensor with an output which is one of the two states, high or low, is known as the digital hall effect sensor. The basic analog output device can be converted into a digital output device with the addition of a Schmitt trigger circuit which acts as a comparator. The output of a differential amplifier is compared with the reference by the Schmitt trigger. The output of Schmitt trigger is turned on when the output of the amplifier exceeds the reference point and the output of the Schmitt trigger is turned off when the output of the amplifier is less than the reference point. [21]

The output of the Schmitt trigger is the output of a sensor which could be either high or low. The input characteristics of a digital output sensor are defined in terms of an operate point, release point and differential. Since there is variation in the characteristics with the variation in the sensor and temperature, they are specified in terms of maximum and minimum. The level of magnetic field that insures the output of the digital output sensor to be high is referred to as maximum operate point while the minimum release point refers to the level of magnetic field that insures the output of the sensor to be low. The maximum operate point and the minimum release point of the unipolar digital output sensor is positive and affected only by the positive magnetic field (i.e. south pole of the magnet). The bipolar digital output sensor has a positive maximum operate point and negative minimum release point and affected by both the positive and negative magnetic field (i.e. both the south pole and north pole of the magnet). Hence the output of the bipolar digital output sensor is affected by both the south pole and north pole of the magnet while the output of the unipolar digital output sensor is affected only by the south pole of the magnet. [21]

Digital Hall Effect Proximity Sensor

The digital hall effect sensor (with part number PGN-SP-002) is produced by the Comus Europe Ltd. It provides highly sensitive unipolar switching along with a reverse battery protection up to -24 V DC. The sensor meets the IEC529 IPX5 standard for water protection. It can be used for various applications such as door position sensing, flow sensing or pedal switch. [22]

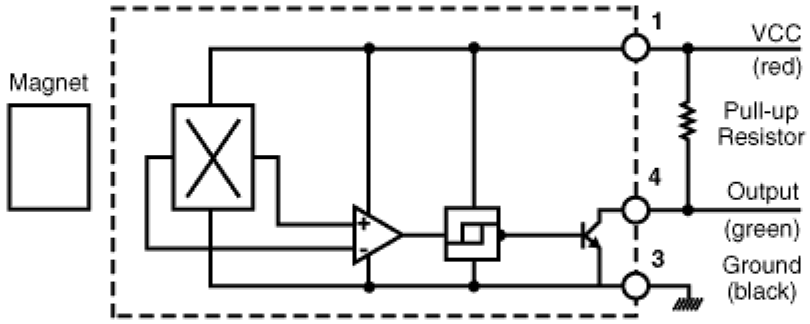


Figure 7: Block diagram of the Proximity Sensor
Reprinted from the datasheet of Proximity Sensor [22]

The block diagram of the proximity sensor is shown in figure 7. Three different colours of the sensor describe three different parameters of the sensors. The red one is the wire for the power supply to be provided, green one is the digital output of the sensor and the black one is the ground wire. A pull-up resistor should be connected between output and the power supply. The output of the sensor turns low in the presence of the magnetic south pole. [22]

3 Design and Development of the System

3.1 System Design

The system mainly comprises two parts: the mobile station and the microcontroller unit. The mobile station is responsible for giving the command and the control instruction to the devices and sensors and to get the response from them. It is just a user interface and does not control the devices. The second unit, the microcontroller unit, is responsible for controlling the devices, processing information gathered from the devices as well as from the mobile station. The microcontroller unit is the brain of the system and controls and processes information to and from all other units of the system.

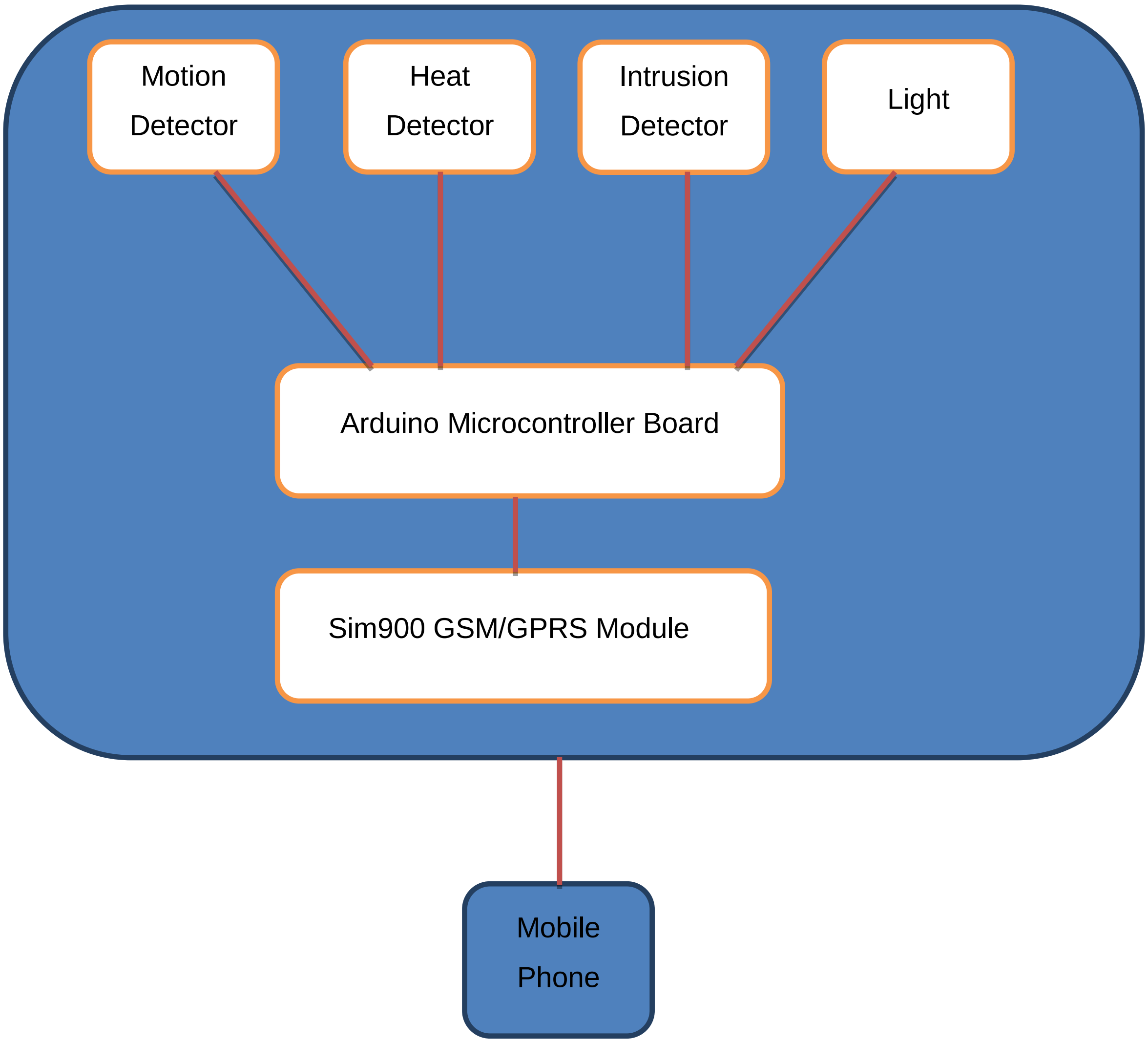


Figure 8: Block Diagram of the System

The block diagram of the system is shown in figure 8. As it is mentioned above, the system comprises two units. The microcontroller unit consists of three sensors and a light along with the sim900 module. Lm35 is the temperature detector, the digital output proximity sensor is the intrusion detector and the Panasonic passive infrared sensor is the motion detector of the system. The data from the sensors is continually processed by the microcontroller and an alert is sent to the mobile station if something is sensed or something reaches beyond the limit in case of a temperature sensor. Besides getting the alert after reaching the limit, it is possible to know the temperature at home at any time by sending an instruction to the microcontroller. These three units of the system are responsible for the security of a home. The other part of the microcontroller unit is the light system which can be operated remotely using the mobile stations. In this project, a simple led light is used to show the demo of the remote light management system. The user could get information about the state of light, whether it is ON or OFF, in the mobile station and control the state of light remotely from the mobile station.

The Sim900 GPRS/GSM module acts as the mediator between the microcontroller unit and the mobile station and is responsible for the communication between them. This unit is responsible for sending information from the microcontroller to the mobile station and for sending the instruction from the mobile station to the microcontroller. The instruction sent by the user from the mobile station is executed by the microcontroller. In addition to the microcontroller unit, the second unit of the system is the mobile station which is just a mobile phone. It does not require any special feature or any special application for the mobile phone to be a part of the system. Any mobile phone supporting the messaging application is suitable for the system. The instruction to the microcontroller is sent by using text messages and the alert from the microcontroller is received as a text as well. The system acts as a smart home system providing security to the home as well as providing a remote management system for the devices inside the home.

3.2 Interfacing Sim900 GPRS/GSM Module

The Sim900 module is an important part of the system responsible for communication between the microcontroller and the mobile phone. AT commands are used to interface the module as well as to configure it. AT commands are inserted in C-language as a string of characters which are sent to the module using the terminal program.

```
 mySerial.println("AT+CPIN=4510");  //the pin code for
the sim
  delay(5000);
  mySerial.println("AT+CMGF=1");       //sets the text
mode
```

Listing 1: AT command syntax to set the text mode

The pin code of SIM is required to activate the SIM card. The instructions are defined within a program as a C-language code which could be actuated at a specific moment. The code would then be simply compiled and uploaded into the Arduino/GPRS shield unit.

```
          pos = msg.indexOf(",");
          String index = msg.substring(pos+1);       //the index
of SMS
          mySerial.print("AT+CMGR = ");
           mySerial.println(index);
//read the incoming SMS
```

Listing 2: AT commands to read the SMS message defined within a program

Listing 2 shows AT commands to find the index of the SMS and to read the contents of the SMS message. It is necessary to read the index of the SMS every time with an incoming SMS message as the index keeps on increasing. Otherwise the program keeps on reading the same SMS again and again even if there are new SMSs. Since the storing capacity of the SIM card is limited, the SMS is deleted after it is read and the instruction is executed. The microcontroller performs the action based on the instruction sent by the mobile phone as an SMS message.

3.3 Interfacing and Implementing Sensors

There are different areas which have to be monitored frequently and devices which have to be checked in and around the house. The doors and windows need to be monitored from burglars if they try to open them as well as the movement of strangers around the house premises should be monitored. Similarly, a member of the home might want to know the state of electronic devices after leaving home and might need to turn the devices off if they are left on. In addition, the temperature of the home has to be monitored as well to trigger the alarm upon reaching the critical point. The monitoring of temperature, a stranger’s movement and the opening and closing of doors and windows are done by the designated sensors. The sensors could be implemented as different types of detectors according to the necessity of the application and the human desire. The operation of sensors is managed by software. Since there are different types of sensors, they are interfaced according to the output and properties of the sensor. The external circuit for interfacing the sensor for the application depends on the type of the sensor and it is not a must as some of the sensors do not need it and the output can be driven directly and used on the application.

3.3.1 Heat Detector

Temperature is among the areas to be monitored in a home and has to be known at any time. As there is a saying, prevention is better than cure, it is better to monitor the temperature of the house to prevent it from fire rather than extinguishing the fire, and it is better to trigger the alarm that the house might be on fire rather than trigger the alarm after it is on fire. Apart from this, a temperature sensor can be installed in a home for various purposes, other than just as a fire alarm. It can be used in places such as a cold room where the temperature has to be monitored carefully, so that the temperature would not rise above a certain point. Similarly, it can be used to check the warming up of the house, so that the house will not warm above certain a temperature and the electricity will not be used by the heating system after that point. It helps in the improvement of financial condition of the user by regulating the use of electricity. The temperature sensor can be installed in a home and the temperature can be cross-checked whenever desired by the owner. The limit could be set for the temperature to trigger the alarm that the temperature is above the critical point. The critical point set depends entirely on the place of installation. For example, the critical point for a sensor installed in a cold room is very low compared to the critical point set for fire alarm.

The LM35 temperature sensor is used as the heat detector in the system. It is used as a basic centigrade temperature sensor which can sense the temperature from +2 ºC to +250 ºC. The power supply of 5V is used from the port of Arduino Board and the input and output are connected to the input/output port of Arduino.

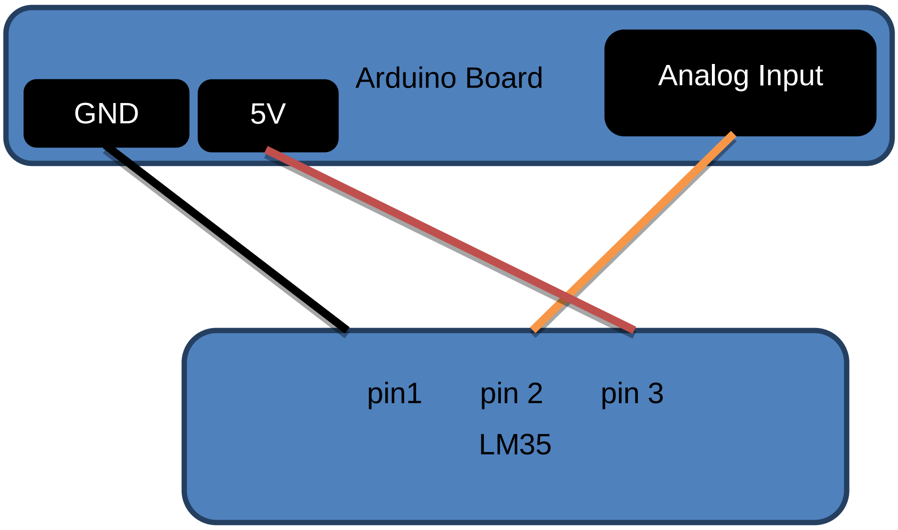


Figure 9: Block diagram of the pin connection of LM35

The pin connection of LM35 is shown in figure 9. The analog input port A0 of the arduino board is used as the input port and the 5V output port of the arduino board is used as the power supply for LM35. Since the sensor is used as a basic Centigrade temperature sensor, any external circuit is not required and the output of the sensor can be driven directly to the input port of the board.

The code used to interface the sensor and to calculate the temperature is shown below:

```
          int Temp_sensor = A0;
          pinMode(Temp_sensor,INPUT);
          volt_output         =         analogRead(Temp_sensor);
//reads the output
          delay(1000);
          temp = (5.0*volt_output*100)/1024;
          if(temp > 45)                    //if the temperature
exceeds 45C,sends a SMS
          {
                    send_SMS();
          }
```

Listing 3: C code used to read the temperature

The microcontroller reads the output voltage of the sensor every second by using the function analogRead. Temperature is the function of output voltage, and thus temperature can be calculated by using mathematics. The temperature is calculated from the output voltage by using the formula shown in listing 3 and if it exceeds the limit defined in the software, it will automatically send an SMS to the mobile phone specified in the software. The limit of the temperature to send the SMS can be changed depending on the environment of the place where the sensor is placed and on the application. For example, if the sensor is placed in a cold room to maintain the temperature of the room, the limit should be very low, and if the sensor is placed in a room to detect a fire, the limit should be high. In addition, it is possible to get the temperature of the place where the sensor is located by simply sending an SMS to the GPRS module.

3.3.2 Motion Detector

Motion detectors are used to detect the unwanted movement of people around the restricted premises. Hence, the passive Infrared sensors could be used as a motion detector and the alarm could be triggered if there is some movement around the restricted premises. The passive Infrared sensor manufactured by Panasonic is used as a motion detector in the system. The 5V power supply is given to the sensor through the board and the output of the sensor is connected to the digital input of the arduino board. The digital output timing chart of the infrared sensor is shown in figure 10.

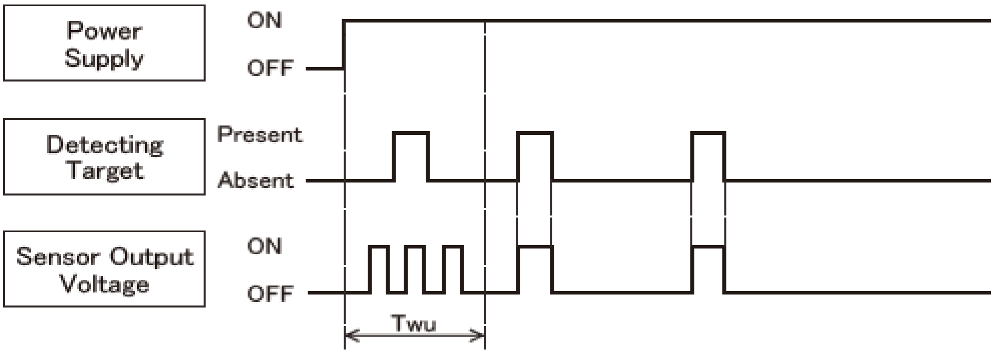


Figure 10: Digital output timing chart of passive infrared sensor
Reprinted from datasheet of Panasonic Passive Infrared Sensor[18]

As can be seen in figure 10, the sensor is activated by supplying a specified voltage provided by the manufacturer to the sensor. The output voltage of the sensor goes high whenever the target is detected in the sensor's field. Twu is the circuit stability time during which the sensor output voltage is undefined (ON/OFF) and detection is not guaranteed. Generally the circuit stability time is 30 seconds maximum.

```
int PIRSensor = 10;
pinMode(PIRSensor,INPUT);
for(i=0;i<30;i++){          //time to calibrate pir due to Twu
          delay(1000);
 }
PIR_output = digitalRead(PIRSensor);
if(PIR_output == HIGH){
          send_SMS();
}
```

Listing 4: Calibrating and interfacing PIR sensor code implementation

The C-language code implementation for calibrating and interfacing the passive infrared sensor is shown in listing 4. Since, the circuit stability time of the sensor is 30 seconds for maximum, the calibration time is provided in the software after the activation of the sensor and before the actual measurement by the sensor. There are only two possible states for the output of the sensor; either high or low. The output of the sensor is connected to the digital input port 10 of the board and the state is read in the software by using the function digitalRead. As soon as there is some person's movement around the place where the sensor is installed, an alert will be sent to the mobile phone informing about the person's movement.

3.3.3 Intrusion Detector

Generally, the intrusion sensors are placed at the doors and windows to detect the intrusion of a burglar in the home. The intrusion detector is used to give extra security along with other detectors. The hall effect proximity sensor is manufactured by Comus Europe Limited and works based on the hall effect principle. For the installation of the proximity sensor, a magnet is attached to the frame of the door or window, whereas the sensor is attached to the door or window itself. The magnet and the sensor should be installed such that they are close to each other whenever the door or window is closed. The south pole of the magnet should face the sensor on closure as the sensor is unipolar hall effect proximity sensor.

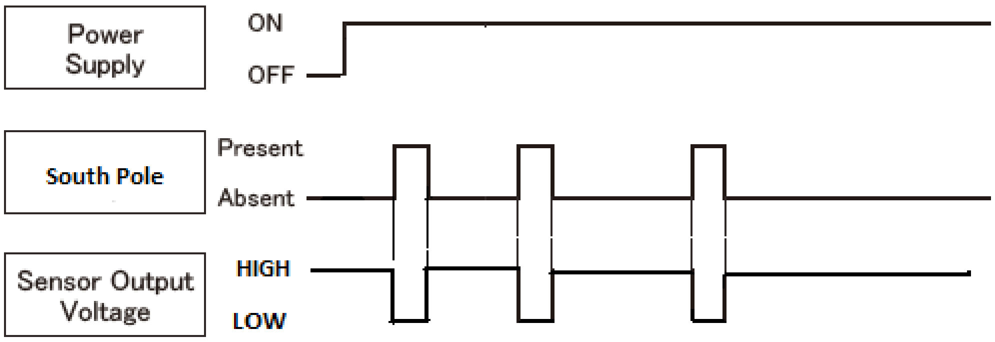


Figure 11: Digital output timing chart of a hall effect proximity sensor

Figure 11 shows the digital output timing chart for the unipolar hall effect proximity sensor. Since the sensor is a unipolar sensor, it is affected only by the south pole of the magnet. The sensor is activated by supplying the specified voltage to the sensor and the output value of the sensor goes low on the presence of the magnetic south pole, as shown in figure 11.

The output of the sensor is low when the door or window is closed as the south pole of the magnet is close to the sensor. Whenever the door is open, the door moves far from the frame, which means that the sensor moves far from the magnet and the output of the sensor goes high. The C-code implementation for interfacing the proximity sensor is shown below:

```
int door_sensor=9;
pinMode(door_sensor,INPUT);
door_output=digitalRead(door_sensor);
if(door_output == LOW){
        SMS_conten_flag_door=1;
        send_SMS();
}
```

Listing 5: C-code compilation for interfacing proximity sensor

The C-code language for the interfacing and implementation of a proximity sensor is shown in listing 5. The output of the sensor (either high or low) is read by the function digitalRead. The output of the sensor goes low whenever the south pole of the magnet comes close to the sensor and it sends the message. In this application, an SMS is sent whenever the south pole of the magnet comes close to the sensor opposite to the implementation of the door sensor installed at door/window explained above listing 5. However the mechanism is the same and the implementation of the application can be changed by changing a single C-code in the program.

3.4 Implementation of remotely managed light system

There are many electronic devices in the home whose status is unknown (on or off) and which could be left on unknowingly or accidently. The status of the device has to be known by the owner, and if the device is on, it has to be turned off. It is not always possible to go back home and turn the devices off. There arises a need to manage the electronic devices remotely to prevent the risk of some accidents as well as to decrease the use of electricity. There are different ways to implement remotely managed electronic devices, for example management using the Ethernet, management using wireless devices or management using the GPRS/GSM module. The electronic device (the light system) is managed remotely using the GPRS/GSM module (especially using the SMS) in this project. In this application, light is managed remotely, and the light represents the electronic devices as a whole. Since the light uses a 220V AC current and the arduino can provide only a 5V DC current, a relay is used in between the arduino and the light. The relay can be controlled by the I/O pins of the arduino which finally controls the light. The circuit diagram to control the electronic devices using the I/O pins of the Arduino Board via the relay shield is shown in figure 12.

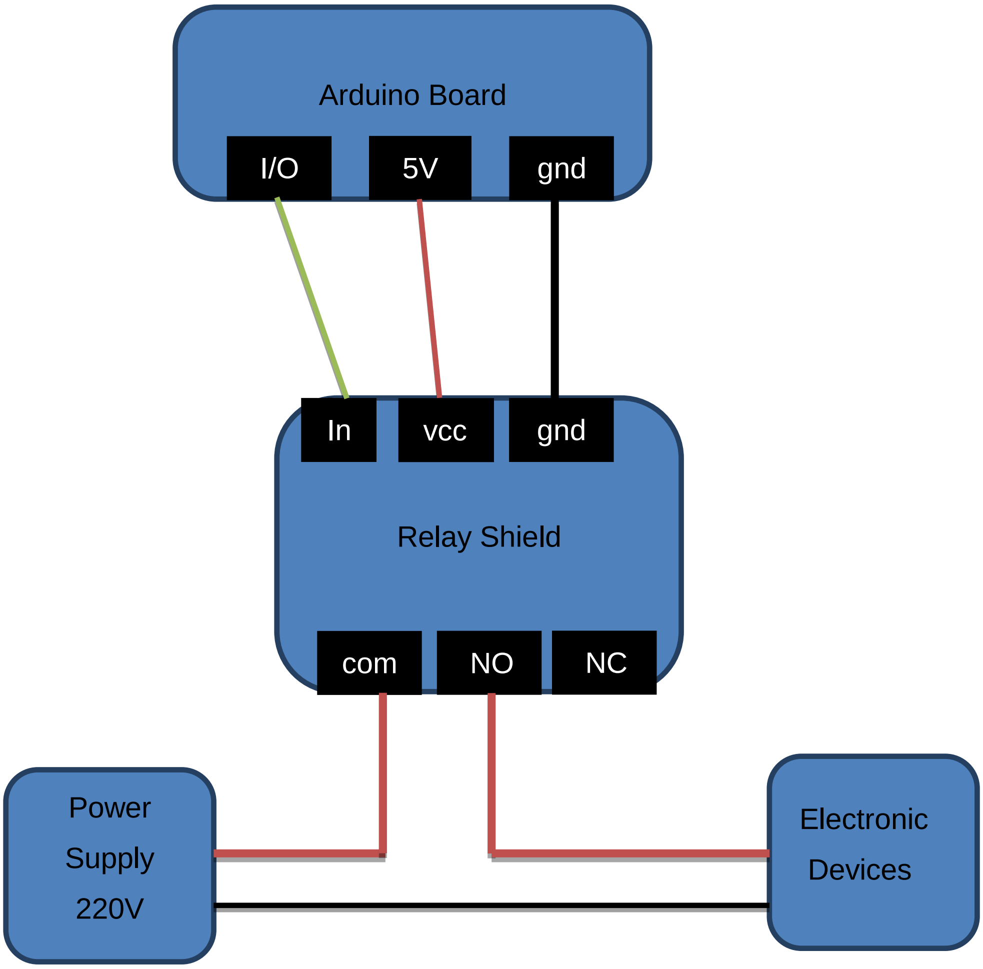


Figure 12: Circuit diagram for the control of electronic devices

The electronic device is controlled by the I/O pin of arduino connected to the relay. The com (common) is connected to NC (normally closed) when the I/O pin is low and the com is connected to the NO (normally open) when the I/O pin is high. It means that the electronic device is on when the I/O pin is high and the device is off when the I/O is low. Basically, the electronic device can be managed remotely just by managing the I/O pin of the arduino board. To show the demo of the remotely managed light, a led is used, and it is controlled remotely in this application instead of the light bulb. The principle of management of light is the same as the principle of management of led; the light is controlled by the I/O pins of the arduino via relays and the led is controlled by the I/O pins itself.

```
int led = 13;
pinMode(led,OUTPUT);
if(msg.indexOf("Turn light on") >= 0){
          digitalWrite(led,HIGH);
 }

 if (msg.indexOf("Turn light OFF") >= 0){
          digitalWrite(led,LOW);
 }

if(msg.indexOf("State of light") >= 0){
          val = bitRead(PORTB,5);
          switch(val){
          case 0:
                    send_SMS();
           break;

          case 1:
                    send_SMS();
          break;
          }
 }
```

Listing 6: C-code compilation for management of light remotely

Listing 6 shows the C-code compilation for the management of light remotely using a mobile phone. The code first checks the SMS messages and does the operation according to the content of the messages. The light will turn on or off according to the instruction sent by the mobile phone by the function shown in listing 6. The fifth bit of the B port holds the status of the light (i.e. the status of the I/O pin 13) and it is read by the function bitRead. Upon the query of the status of light, an SMS is sent back to the mobile phone containing the status of light. In this way, the status of light can be known remotely and the light can be turned on or off with the help of a mobile phone remotely.

3.5 System development

The smart home system was developed by implementing the sensors and the remotely managed light system in this project. In this project, only one light system was used to show the demo of remotely managed electronic devices along with three detectors: an LM35 temperature sensor as the heat detector, a Panasonic passive infrared sensor as the motion detector and a hall effect proximity sensor as the intrusion detector. The number of sensors used and the electronic devices managed remotely can be increased or decreased according to the necessity of the application. This project was the demonstration project of the smart home system using three sensors and a light system. The smart home system triggered alarms to intrusion into the house through doors and windows as well as to the movement of a human being around the premises and around the restricted areas. The system also kept surveillance over the temperature and triggered alarm upon reaching the critical point and above it. The whole system was the integration of implementation of the sensors and the light system described individually in chapters 3.2, 3.3 and 3.4. The system is implemented on Arduino platform using the Arduino Uno Board.

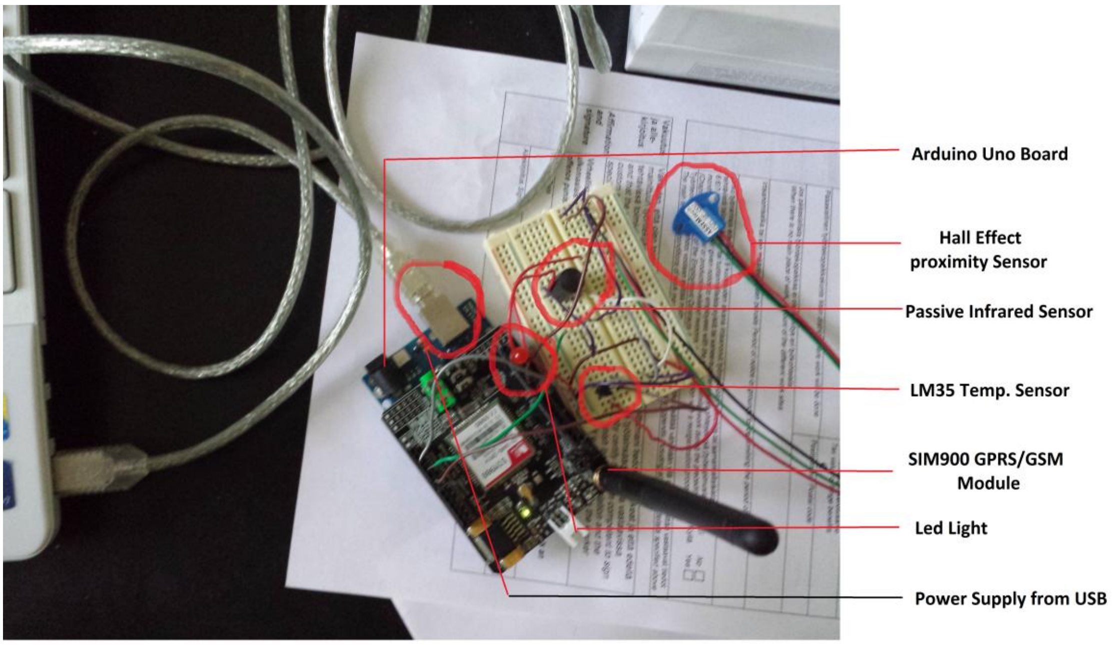


Figure 13: The final system

Figure 13 shows the microcontroller unit with the Arduino board, GPRS shield, light and sensors. Power supply to the unit can be provided externally or from the USB port of the computer. The power supply is supplied from the USB port in this project and the sensors and the GPRS shield drives the power from the unit. The connection of different sensors and the shield can be seen in figure 13. The whole system is implemented using the C-code language written on the arduino platform. The software written on the platform can be uploaded to the microcontroller (i.e. the arduino board) using Arduino IDE software.

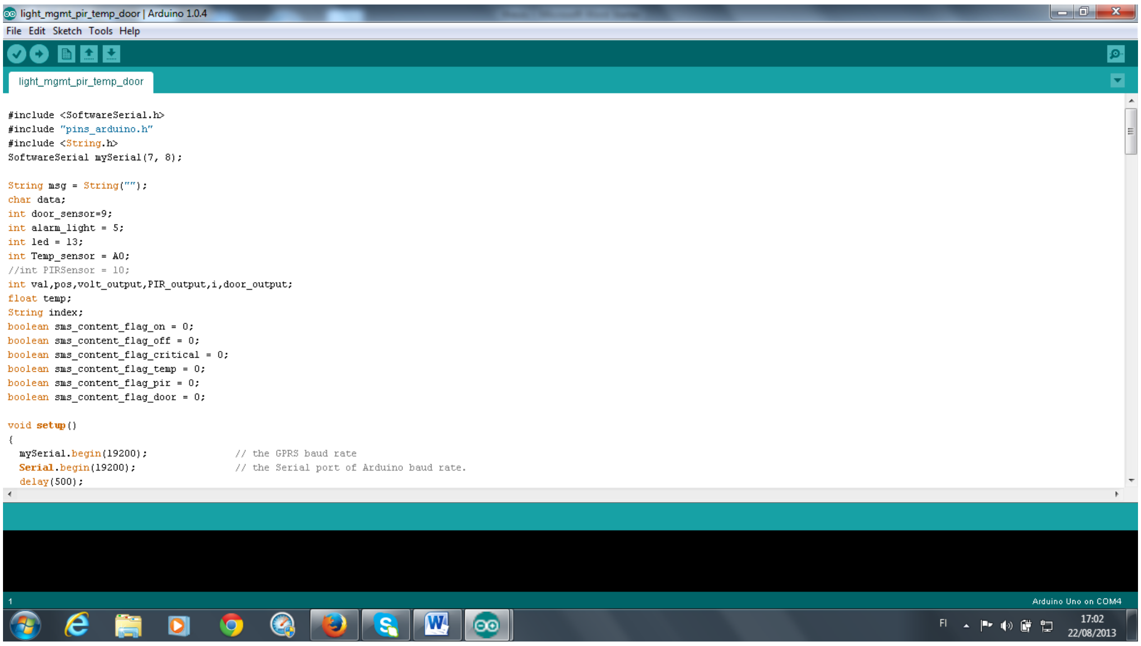


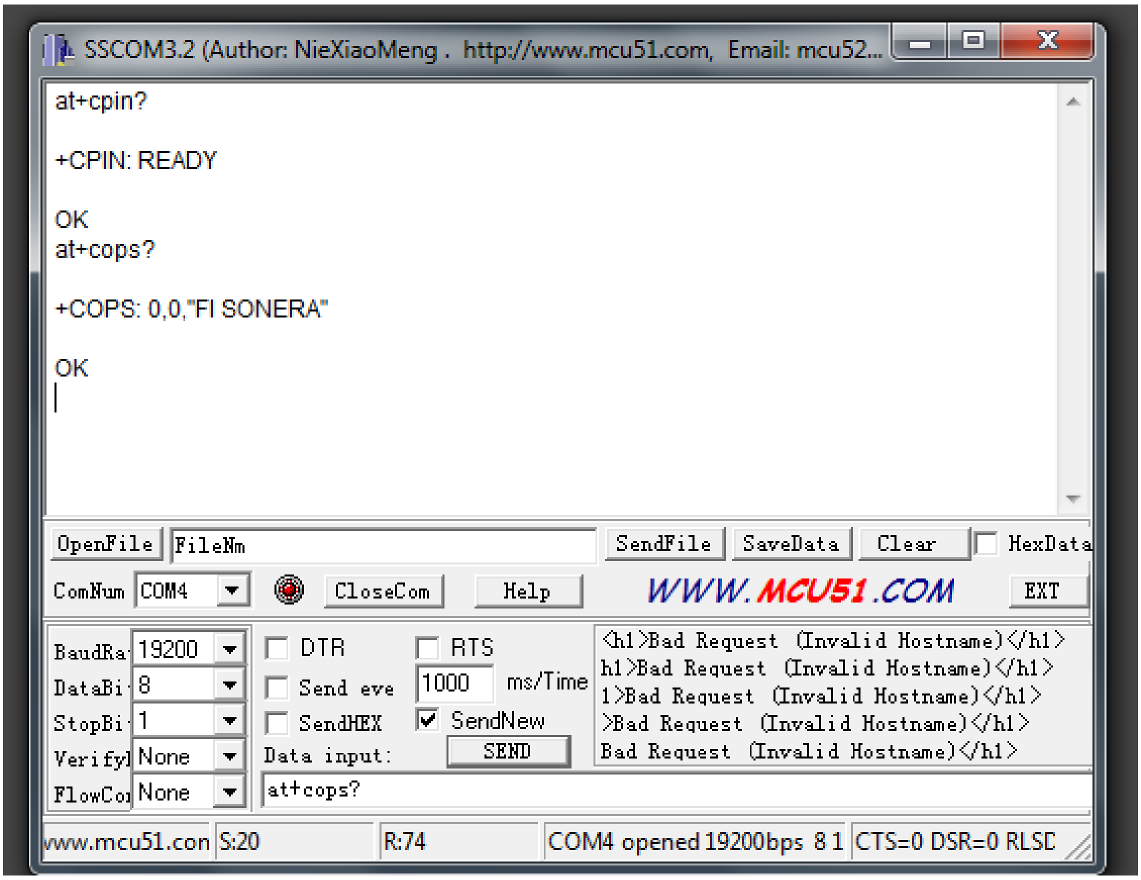
Figure 14: Screenshot of the Arduino Software IDE

The Arduino integrated development environment (IDE) is a cross-platform written in Java, whereas the programs are written in C or C++, which is shown in figure 14. The platform comes with a software library along with the code editor with features such as syntax highlighting, brace matching and automatic indentation. The whole program is written in the platform in the C language code which can be uploaded to the board by a simple upload button. Basically, the project is the integration of the software (C language code) used to interface and implement the sensors, the GPRS module and the remote management of light. In addition, the program contains some more code to co-ordinate among those parts along with some extra C code rather than the individual codes described above.

The application is a system from the hardware and software integration of different modules along with the mobile station. The sensors along with the light and the GPRS module are connected to the arduino board and the application program which controls the microcontroller is written in arduino IDE as a C language code which can be uploaded to the board with the help of a single button. It is always better to have a common ground of the system for better operation of the application, which is also followed here as the system has a common ground. The mobile station (or simply the mobile phone) interacts with the arduino board with the help of the GPRS module connected to the board. The main function of the mobile station is to give instructions to the microcontroller along with receiving the alerts sent from the microcontroller. The instructions and alerts are sent and received as an SMS message with the help of the GSM network available. There is no need for developing any new features in the mobile phone to use this system. Any simple mobile phone supporting the SMS can be used as the mobile station in this application.

3.6 Testing the system

First of all, all the hardware units of the system were tested and it was ensured that they were in a good working condition. Then, each and every unit were interfaced and implemented individually with the microcontroller board and drove with the software according to the necessity of the application. The testing of the application was not done at once after it was completed. Rather each unit of the application was tested individually. The second unit was not tested until the first unit gave the expected result and until it was not working according to the necessity of the application. After all of the units were working correctly, the units were kept together and then the whole system was developed and tested. It was easy to figure out the bugs and the problem of the system as the behaviour of each unit was known while testing it. It would be impossible to figure out the problems and the bugs in the system if the system was developed and tested after it was completed. After the hardware units were tested, the communication of the mobile station with the GPRS module was tested.



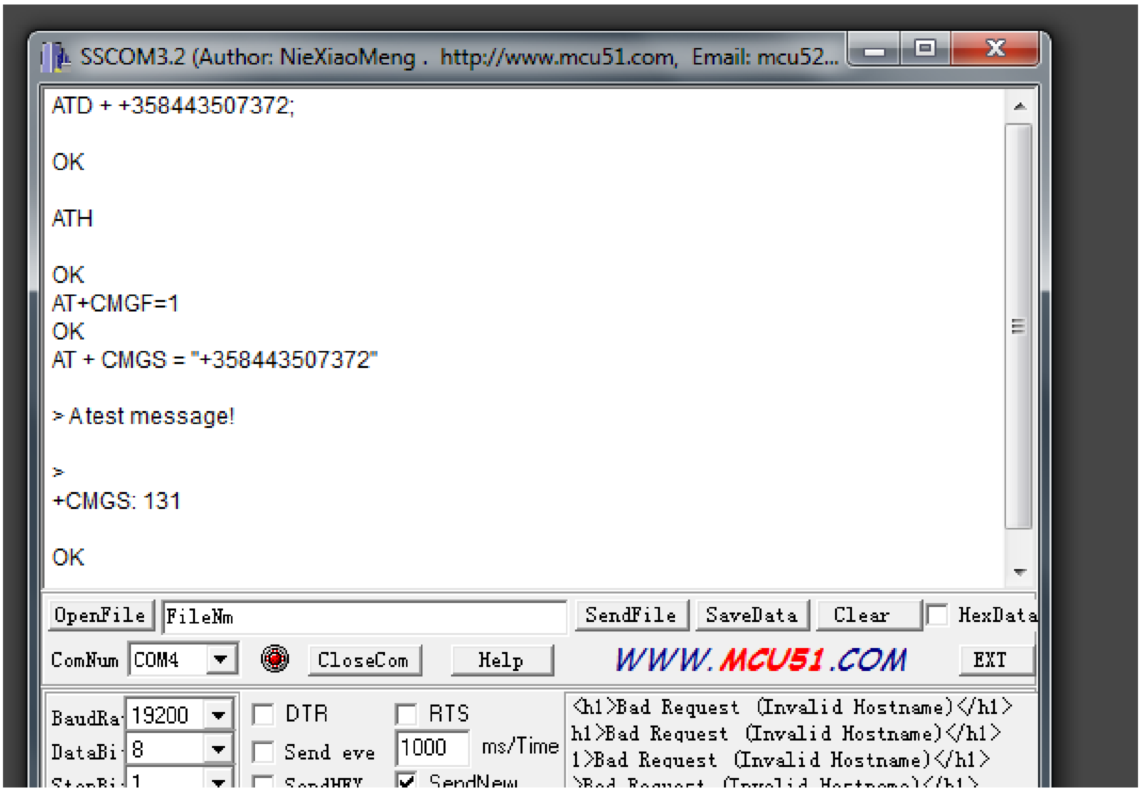


Figure 15: Screenshot of the terminal program testing the communication of the GPRS module with the mobile station

Figure 15 illustrates the communication of the GPRS module with the mobile station captured in a terminal program. It can be seen from figure 15 that the SIM is active and it is connected to Sonera's GSM network. Similarly, the module is able to call a specific number as well as the module can be operated in text mode and a message can be sent to a specific number. The mobile phones used to test communication along with the whole system are Samsung Galaxy s4 and HTC desire.

After it was made sure that the communication of the mobile station with the GPRS module was working according to our wish, the sensors were interfaced with the micro-controller and the result were captured and analysed with the help of a terminal program. Finally all the hardware and software were integrated and the whole system was developed after the sensors were working correctly.

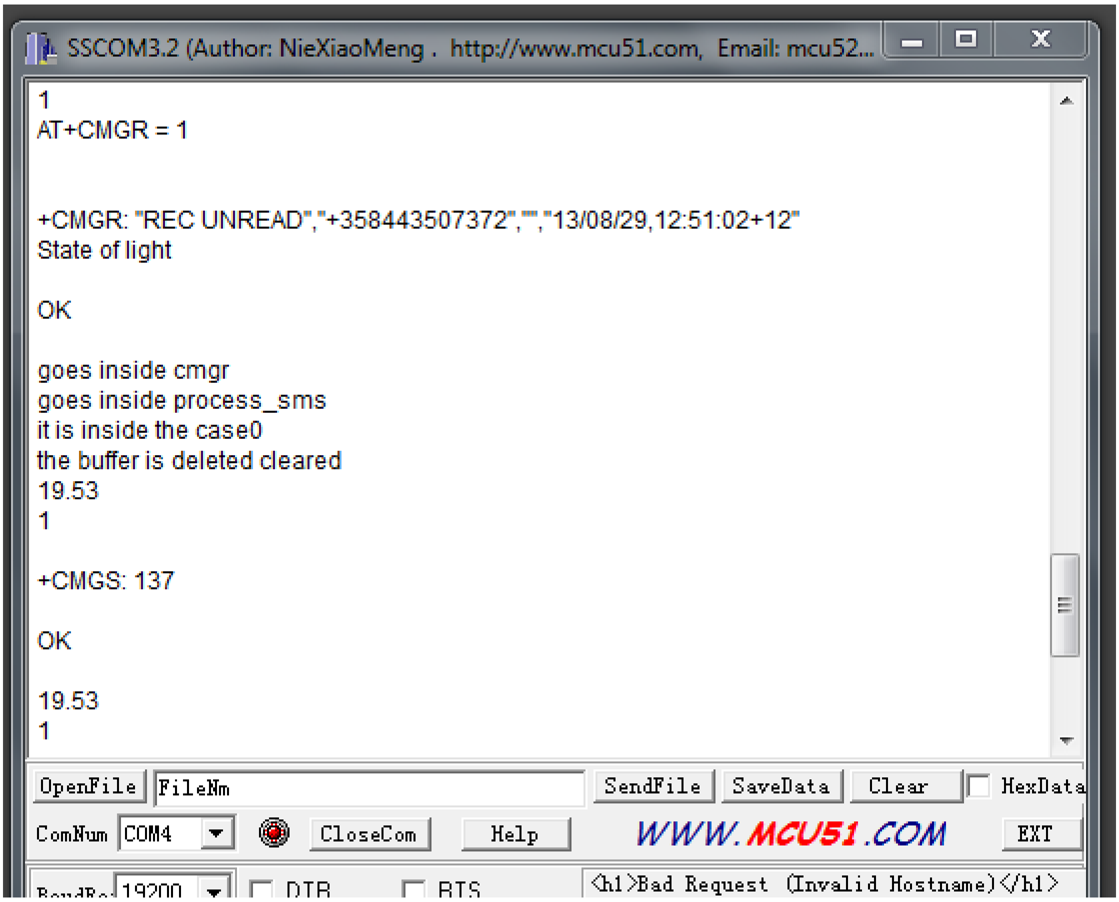


Figure 16: Screenshot of the terminal program testing the final system design

Figure 16 illustrates the screenshot of the system. The system keeps on reading the temperature continuously and the output of the proximity sensor and the infrared sensor at an interval of one second. The system will read the incoming message immediately after it is received and an SMS will be sent if any alarm is triggered in between reading the outputs. Then the system again starts to read the outputs at an interval of one second. As can be seen from figure 16, the system reads an incoming message state of light and sends back the response. The response sent can be seen as +CMGS 137 and OK in the terminal program.

4 Result

The aim of the project was to implement a smart home system and the goal was met. The microcontroller unit responds to the instructions sent by the mobile phone according to the necessity of the application as well as triggers the alarm upon a critical situation. The aim of the application to manage the electronic devices remotely was also achieved.

Table 2: Result of the instructions and the response to and from the mobile station

Unit	Instruction sent by mobile	Response to the mobile	Output/Alarm triggering condition
Light	State of light	The light is ON/OFF	
	Turn light on		Light is turned ON
	Turn light OFF		Light is turned OFF
Heat detector	What is the temperature?	The temperature is x ºC	
		The temperature is too high	If the temperature is > y ºC
Intrusion detector		Someone has opened the door	If the output of the proximity sensor is low
Motion detector		Someone is moving around the house	If the output of the PIR sensor is high

Table 2 shows the instructions sent to the microcontroller from the mobile station and output of the instructions as well as the response sent to the mobile station from the microcontroller respectively. As can be seen from table 2, the instructions are sent only to the light system and the temperature sensor and they behave according to the instruction sent by the mobile phone. However the PIR sensor and the proximity sensor will trigger alarm if there is some movement around the restricted premises or if someone tries to intrude into the building through doors or windows.

Figure 18: Screenshot of the mobile station managing the light remotely

Figure 18 shows a screenshot of management of electronic devices (light system) by the mobile station (i.e. the mobile phone). As can be seen from figure 18, the microcontroller will send a response to the mobile phone as an SMS mentioning whether the light is on or off upon the instruction (state of light) sent by the mobile phone. The light can be turned on and off by the SMS which can be visualised, and the response to the instruction will also be different when the light is on or off which can be seen in figure 18.

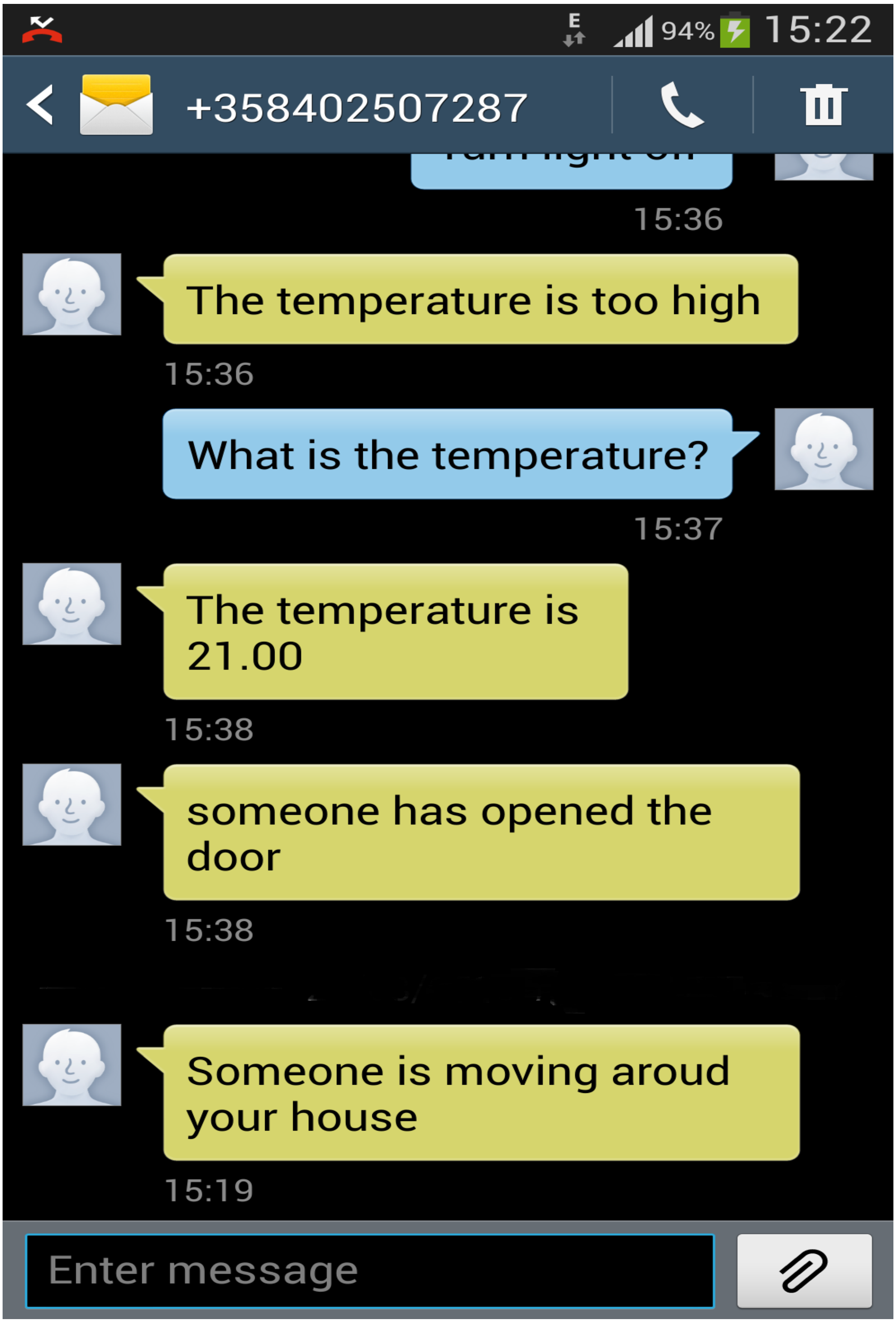


Figure 19: Screenshot of the response and alarms received by the mobile station

Figure 19 shows a response sent to the mobile station upon the instruction (What is the temperature?) sent by the mobile station and the alarms triggered upon the critical condition. The SMS sent by the microcontroller is different for the alarms triggered by different sensors. Hence, it is possible to know the sensor responsible for triggering the alarm and getting some idea of the condition of the premises. It can be seen from figures 18 and 19 that the result of the application meets the concept and the motives of the system.

5 Discussion

The development of technology has been affecting the life style of people. They are dependent on technology even to carry out daily activities and technology has made the lifestyle more sophisticated and relaxing. It seems as if it was impossible to live without technology in this century. Advanced technology has replaced the traditional lifestyle of people. For example, a coffee machine has replaced the traditional way of coffee making, finger-print and voice-controlled electronic lock have replaced traditional locks, electronic news and media have replaced the traditional paper news and media, bank cards and online shopping have replaced the traditional cash and shopping. The examples mentioned above are a few least advanced technologies replacing the traditional lifestyle. Besides these, there are many advanced technologies used by people for different purposes, they are playing significant roles in changing the lifestyle of people. With the development of technology, the concept of simple home has also been changing into smart home and the concept of home has changed drastically during the last decade.

The advancement of technology has not only played a significant role in the development of positive aspects but has also played an important role in the development of negative aspects. It has increased the risk of burglary and intrusion using the latest modern technologies available. The busy lifestyle of human beings along with the increasing risk has led to the necessity of remote surveillance of homes. There are different ways to have the surveillance but the easiest and most advanced technology accessible to everybody is mobile phone surveillance. The mobile phone can be used for different purposes with the help of the applications developed for the phones.

This project was a simple application project demonstrating a smart home system. The led light (representing the electronic devices) is controlled by the mobile phone using the SMS service and the surveillance of the home is done using the mobile phone. The mobile phone gets alerts on intrusion or movement around the restricted premises along with the rise in temperature above the limit. The movements and the temperature are detected by installing sensors at different places. The temperature of the premises where the sensors are installed can be known at any time before reaching the critical limit set by the user. The intrusion is detected by the hall effect proximity sensor, movement by the PIR sensor and temperature by the temperature sensor.

As this project was a simple smart home system demonstration project, a few sensors and a led light were used. The project can be extended by increasing the number of sensors used along with an increase in the number of installation places. The remote management of electronic devices can also be extended with the use of different real electronic devices. Similarly, the project is limited to the availability of the GSM network as the GPRS module and the mobile phone itself uses the GSM network available for communication. The application can be developed further using different wireless technologies such as the Bluetooth technology and infrared technology or the Internet to communicate between the microcontroller unit and the mobile phone. The hardware, the software and the mechanism used in this project can be implemented to develop a complete smart home system.

The project was completed within the projected time with the expected result. However, there were many hardware and software errors experienced during the development of the application. There were many bugs in the software as well as connection errors in the hardware, which came along with the development of the application and which were solved individually. Despite reading the datasheet of the sensors before using them, the PIR sensor was burnt out by accidentally connecting the wrong pins. Accidentally, the ground connection and the power supply were interchanged which burnt down the sensor and a new sensor had to be ordered. Similarly, there were some hardware errors while connecting the sensors and the led with the microcontroller. Many connection errors were faced during the project time which did not lead to the damage of any hardware unit except the PIR sensor which was fixed up later.

Besides the connection error, there were many bugs in the software of the system which were identified and fixed up eventually. The first problem was encountered while reading the SMS message containing the instruction by the mobile station. The first message was read successfully but the message after the first one could not be read.

```
           pos = msg.indexOf(",");      //search for the position of ,
           String index = msg.substring(pos+1);            //the index
of SMS to be read
           Serial.println(index);
            mySerial.print("AT+CMGR = ");
           mySerial.println(index);
```

Listing 7: C-code implementation for determining the index of SMS

Listing 7 illustrates the C code implementation for determining the index of the SMS message which has to be read. The code mentioned above finds the index of the incoming message and processes it. The index of the SMS was determined correctly for the first incoming SMS but the index of the SMS after that could not be determined and the message could not be processed. Initially it was thought that there was some problem with the code but the problem was the RX buffer of the GPRS module which was found later. Whenever the first message was processed, it was stored in the RX buffer of the module and the code was finding the position of comma to determine the index of the SMS. Hence, the output of the code was something else than the index as the code found the position of the comma of the previously processed message stored in the buffer and the string after the comma which was the index. Since the code found a different comma, the string after that was also different than the index and the message could not be processed as the index was not correct. The problem was solved by clearing the RX buffer each time after processing the SMS. The clearing of the SMS was done by the function given below:

```
mySerial.flush();.
```

The system gives the flexibility to the type and number of sensors used compared to the already built security system bought from the market. The opportunity is given to the user to choose the type of sensor and to set the limit to trigger alarm as well. The cost of the system can be determined by the user as the cost of the system includes the cost of the hardware units determined by the user. The behaviour of the system can be changed according to the necessity of the user by adjusting the hardware and software of the system. The system is more flexible and user-friendly compared to the security system available in the market. Many new experiences and knowledge were gained during the project.

6 Conclusion

The goal of the project was to implement a smart home system by controlling the electronic devices at home remotely with a mobile phone and to receive alerts on intrusion and movement around restricted premises. The goal was achieved successfully. The devices were controlled by sending instructions as an SMS and the alerts were received as an SMS as well. A hall effect proximity sensor and a passive infrared sensor were used as detectors to detect the intrusion and movement around the restricted premises respectively. A temperature sensor was used as a heat detector and a led light was used to show the demonstration of an electronic device management. Arduino Uno Board was used as a microcontroller while the SIM900 GPRS/GSM model was used for communication between the microcontroller unit and the mobile station. The mobile phone did not need to have any special application or hardware to be used as a mobile station. Any mobile phone supporting the SMS could be used as a mobile station.

There are many smart home systems available in the market costing hundreds of euros. Designing one’s own home security system will save hundreds of euros as it is cheaper and the cost could be decided by the designer who is the ultimate user of the system. Not only the economic side but also the technical side is more flexible with this concept. With this concept, the designer could be able to decide the type and number of sensors to be used and the area to be covered. The systems available in the market are limited to number, type and area of coverage as well as to the number of electronic devices that could be controlled. Flexibility to the number of electronic devices controlled was also available in the application.

Flexibility with the technical customisation and economy are the main advantages of the design. However the system is limited to the GSM network available and will not work if the GSM network is not available. The IR sensor could be triggered with the movement of some animals such as a rat around the premises or by light striking the sensor directly, which could trigger a false alarm. The project could be further extended by using other technologies for communication, for example wireless communication using radio frequency, the Bluetooth technology or the Internet. The ideas and information used in the design could be used for development of smart a home system.

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C-language code of the system

```
#include <SoftwareSerial.h>
#include "pins_arduino.h"
#include <String.h>
SoftwareSerial mySerial(7, 8);

String msg = String("");
char data;
//int alarm_light = 5;
int led = 13;
int Temp_sensor = A0;
int door_snsr=9;
int pir_snsr=10;
int val,pos,output,door_output,pir_output;
int count_pir=0;
int ind_pir=0;
int ind_temp=0;
int count_temp = 0;
float temp;
String index;
boolean sms_content_flag_on = 0;
boolean sms_content_flag_off = 0;
boolean sms_content_flag_critical = 0;
boolean sms_content_flag_temp = 0;
boolean sms_content_flag_door = 0;
boolean sms_content_flag_pir = 0;

void setup()
{
  mySerial.begin(19200);               // the GPRS baud
rate
  Serial.begin(19200);                 // the Serial port
of Arduino baud rate.
  delay(500);
  mySerial.println("AT+CPIN=4510");  //the pin code for the
sim
  delay(5000);
  mySerial.println("AT+CMGF=1");      //sets the text mode
  delay(1000);
  pinMode(led,OUTPUT);
  pinMode(door_snsr,INPUT);
  pinMode(pir_snsr,INPUT);
  //pinMode(alarm_light,OUTPUT);
  pinMode(Temp_sensor,INPUT);
  //digitalWrite(led,HIGH);
  //delay(500);
```

```
   mySerial.println("AT+CMGDA=\"DEL ALL\"");      //delete
all the messages available in the storage area
   delay(1000);
}

void loop()
{
  read_temperature();                       //function to read
the temperature
  read_doorsensor();                        //function to read
the door sensor
  read_pirsensor();                         //function to read
the pir sensor

  if (mySerial.available())                 // if date is com-
ming from softwareserial port ==> data is comming from gprs
shield
  {
    while(mySerial.available()){
      data = mySerial.read();               //read the data
available in the myserial buffer and store it in string msg
      msg += data;
    }
  Serial.println(msg);
  if(msg.indexOf("+CMTI") >= 0){                     //if
the sms is received then go to process gprs
     Serial.println("goes inside cmti");
     process_gprs();
    }
  }
}



/************************************************************
*******
                      READ TEMPERATURE VALUE

************************************************************
******/

  void read_temperature(){
    output = analogRead(Temp_sensor);                //reads
the output of LM35DZ
    delay(1000);
    temp = (5.0*output*100)/1024;
//convert the output value to the temperature in celsius
scale
    Serial.println(temp);
```

```
    if(temp > 23)                                                    //if the
temperature exceeds 45C,sends an sms to the number
    {
      count_temp=count_temp+1;
      Serial.println(count_temp);

      if(count_temp == 1 || count_temp == 5*ind_temp){
//sends the sms message after each 5 temperature value
greater than critical set
        //digitalWrite(alarm_light,HIGH);
        sms_content_flag_critical = 1;
        send_sms();
      }

    }
  }


/************************************************************
******
                      READ THE DOOR SENSOR

*************************************************************
******/

  void read_doorsensor()
  {
  door_output = digitalRead(door_snsr);
  delay(1000);
  Serial.println(door_output);

  if(door_output == LOW){
    sms_content_flag_door = 1;
    send_sms();
    }
  }


/************************************************************
                         READ THE PIR SENSOR

*************************************************************
**/

  void read_pirsensor()
  {
  pir_output = digitalRead(pir_snsr);
  delay(1000);
```

```
  Serial.println(pir_output);

  if(pir_output == HIGH){
    count_pir = count_pir+1;
    Serial.println(count_pir);
    if(count_pir == 1 || count_pir == 5*ind_pir){
      sms_content_flag_pir = 1;
      send_sms();
      }
    }
  }


/***********************************************************
************
  SEARCH THE INDEX OF THE SMS AND READ THE CONTENT OF THE
SMS MESSAGE

***********************************************************
**********/

  void process_gprs(){
   pos = msg.indexOf(",");
//search for the position of , to find the index of sms
   //Serial.println(pos);
   String index = msg.substring(pos+1);
//the index of sms to be processed
   Serial.println(index);
   mySerial.print("AT+CMGR = ");
   mySerial.println(index);
//read the incoming sms
   delay(1000);
   if(msg.indexOf("+CMGR") >=0){
     Serial.println("goes inside cmgr");
     process_sms();
    }
  }



/***********************************************************
********
   PERFORMS THE ACTION ACCORDING TO THE CONTENT OF THE MES-
SAGE

***********************************************************
******/

   void process_sms(){
```

```
    Serial.println("goes inside process_sms");
    if(msg.indexOf("Turn light on") >= 0){
      Serial.println("goes inside on");
      digitalWrite(led,HIGH);
    }

    if (msg.indexOf("Turn light off") >= 0){
      Serial.println("goes inside off");
      digitalWrite(led,LOW);
    }

    if(msg.indexOf("What is the temperature?") >=0){
      sms_content_flag_temp = 1;
      send_sms();
  }

    if(msg.indexOf("State of light") >= 0){
       val = bitRead(PORTB,5);            //reads the 5th bit of portB which stores the status of led
       switch(val){
         case 0:
         Serial.println("it is inside the case0");
         sms_content_flag_off=1;
         send_sms();
         break;

         case 1:
         sms_content_flag_on =1;
         send_sms();
         Serial.println("it is inside the case1");
         Serial.println(val);
         break;
       }
    }
    mySerial.print("AT+CMGD=");
    mySerial.println(index);           //removes the message after it is executed to keep the sim memory free
    mySerial.flush();                  //removes all the data from the RX buffer of softwareserial whether it is read or unread
    delay(1000);
    clear_msg();
    Serial.println("the buffer is deleted cleared");
  }

  void clear_msg(){
    msg="";
  }
```

```
/**********************************************
  SENDS THE SMS MESSAGES TO THE MOBILE PHONE
**********************************************/

  void send_sms(){
  //mySerial.println("AT+CMGF=1");
  mySerial.println("AT + CMGS =
\"+358443507372\"");//send sms message, be careful need to
  delay(100);
//add a country code before the cellphone number
  if(sms_content_flag_on == 1)
    mySerial.println("The light is on ");//the content of
the message

  if(sms_content_flag_off == 1)
    mySerial.println("The light is off ");

  if(sms_content_flag_critical == 1){
    ind_temp++;
    mySerial.println("The temperature is too high ");
  }

  if(sms_content_flag_door == 1)
    mySerial.println("someone has opened the door ");

  if(sms_content_flag_pir == 1){
    ind_pir++;
    mySerial.println("Someone is moving around your
house");
  }

  if(sms_content_flag_temp == 1){
    mySerial.println("The temperature is ");
    mySerial.println(temp);
  }
  delay(100);
  mySerial.println((char)26);//the ASCII code of the
ctrl+z is 26
  delay(100);
  mySerial.println();
  clear_sms_content_flags();
  msg="";
}

/******************************************************
              CLEARS THE FLAGS SET
******************************************************/

void clear_sms_content_flags(){
```

```
        sms_content_flag_on = 0;
        sms_content_flag_off = 0;
        sms_content_flag_critical = 0;
        sms_content_flag_temp = 0;
        sms_content_flag_door = 0;
        sms_content_flag_pir = 0;
    }
```

.