“IMPERIUM”- ANDROID BASED HOME AUTOMATION SYSTEM

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THIS THESIS REPORT IS SUBMITTED TO FULFILL THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

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Specially dedicated to my beloved parents for their unending support for my education, unparalleled moral and emotional motivation, love and guidance.

DECLARATION AND COPYRIGHT

Name **:** Nihit Vyas

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I hereby declare that this research is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references and a bibliography is appended.

Signature………………….. Date……………………….

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"IMPERIUM"- ANDROID BASED HOME AUTOMATION SYSTEM

BY

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"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Electronics (Communications) Engineering"

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ABSTRACT

The fundamental motivation behind the "Imperium"- Android Based Home Automation System project is to develop a low cost, high efficiency and standardised Domotics system for every household, everywhere. Inspired by the Latin word Imperium, which means control, the designed system provides its users full time connectivity with their domestic premises. The system incorporates GSM technology to allow users to control domestic electrical parameters (for example electrical appliances) wirelessly via SMS using mobile phones from anywhere in the world, thus ensuring unlimited range of operation. A Bluetooth modem is also used in order to control the electrical parameters within a close range (up to 100m) with a smart phone app or a voice recognition system, making it easier for elderly or physically challenged people to control electrical appliances and other domestic variables. The designed system incorporates sensors like PIR motion sensor which is used to detect any movement within the premises in the absence of the residents to prevent burglaries, and MQ-6 LPG sensor to detect the leakage of cooking gas, pollutants and smoke, preventing any potential accident which can result in injury or loss of life and property. Whenever any of the sensor detects a stimulus, the user is immediately notified by a text SMS allowing them to take necessary action in time. As the system is based on OSI Model, it can be easily integrated with other home automation systems like Amazon Echo. The designed system has been tested and the desired results have been obtained. The prototype works at full capacity and meets all the predefined objectives of the thesis.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Automation is today's fact; for home automation electrical appliances are being wirelessly controlled either remotely or in close proximity. Though today's automation technologies available for domestic environments do not completely eliminate human intervention, they are continuously being developed to reduce it to the lowest degree possible. With the skyrocketing growth of embedded systems, software and consumer electronics, wireless control of household devices, any time in the world today can be a widespread and standardised reality just like Smart Phones. Assume a system through which, the user, from their office desk, could operate the devices in his or her home like tuning the TV set to their favourite channel, control the cooling system say the air conditioner, and switches on or off the lights before leaving the work place only to reach home and find a comfortable and pleasant environment; or a physically disabled/ bed ridden person who otherwise has no control over their surrounding electrical appliances can simply control them through voice command.

The combination of electronics, communications, computer and information technology towards the development of applications and systems to control home appliances and features (such as lighting) is called Home Automation. Ranging from simple IR based line of sight remote control to complex computer/micro-controller based platforms; Home Automation System comes with varying degrees of intelligence and automation. Most homes in industrialized nations are wired for electrical power, telephones, TV outlets, doorbells and many other electrical appliances. In such standard households, the high tech devices operate independently and therefore the research in the field of domestic automation is directed to achieve interoperability between various devices available in the home and allows the domestic environment to stay connected to the user at all times (Miori, Russo, & Aliberti, 2008). Many household tasks are automated by the development of specialized appliances like automatic washing machines developed to reduce the manual labour of cleaning clothes, water heaters to reduce the labour necessary for bathing and microwave ovens designed to minimize the effort required for cooking. As the number of controllable devices in the home increases, interconnectivity and communication between devices becomes a useful and desirable feature. The Home Automation Systems incorporate security measures to prevent crime or accidents. For example, during the absence of the residents, the security system with a motion sensor can trigger an alarm in case of a burglary or break-in incident and notify the user through Internet or using GSM network; a gas detection system can detect the leakage of liquefied petroleum gas (cooking gas) and prevent gas explosions which cause wide scale damage to life and property in the countries like Malaysia and India.

1.2 History of Home Automation

In the recent years, a rapid development in Home Automation Systems has taken place. Companies like Amazon and Google have developed their Personal Digital Assistants which have the capability to control the variables related to the home by an interactive voice control based platform. However, the idea of home automation goes back to the 19^{th} century. Early remote control devices began emerging since the late 1800s when Nikola Tesla patented an idea of remote control of vessels and vehicles in 1889. With introduction of electricity to homes and rapid advancement in information technology since the early 20th century, home automation gained practicality. The emergence of electrical home appliances began between 1915 and 1920 and the world witnessed a decline in domestic servants. This meant that households needed cheap, mechanical replacements. One of the earliest home automation projects was “Echo IV”, developed in 1966 by a Westinghouse Electric engineer named Jim Sutherland. The initial "smart home" terminology was coined by the American Association of Housebuilders in 1984 (Harper, 2003).

Development of embedded systems, microcontrollers and microprocessors became a milestone for automation and control technologies and the cost of intelligent systems reduced rapidly. By the late 90s, the term “Domotics” was coined to describe any system in which informatics and telematics interconnects to support activities in the home (Bhatia, Bajaj, & Roja, 2014). The phrase Domotics is analogism formed from domus (Latin, meaning house) and informatics.

However, till the end of the previous century, the concept of smart homes remained a domain for hobbyists or the rich due to the lack of a single, standard design and implementation protocol, and high cost. Damian Bree, Tim Day, Paul Hodgkins, and Nicholas Thompson began the construction of the Integer Millennium House in 1997 in Watford, U.K. It was termed Smart Home after being refurbished in 2013. The Integer Millennium House incorporated a string of intelligent technologies-

- Smart Heating System: Operates only when heat is required
- Automatic Irrigation System: To water the plants in the garden which needs it
- Security System: To detect intrusions
- Power Saving: The electrical systems automatically turn off if the premises are unoccupied and automatically turn on when the presence of an occupant is detected
- Digital Keys: To allows access to only to the authorised personnel
- CCTV Cameras: CCTVs with live broadcasting which can be viewed on any screen in the house

Advanced technologies like microchip embedded programmable door keys, locally distributed telephone service, WebTV, digital satellite and terrestrial television system were also featured in the home (International Energy Agency, 2014).

1.3 Domotics

The word Domotics is a composite of Latin word Domus- meaning home, and a combination of informatics, electronics and robotics. Domotics is a discipline that investigates the applications of information technology to create intelligent home environments (Miori, Russo, & Aliberti, 2008). Domotic systems are hardware and software designed to provide domestic automation services. Some examples of Domotic systems are- X10, Konnex, Lon-Works etc. As these systems are being developed by private companies, proprietorship and closed technology limits the scope for open-source development. Domotics or home automation systems designed for elderly or physically disabled people are called Home Assistive Systems.

The following are some applications of home automation systems-

1. **HVAC**: HVAC refers to heating, ventilation and air-conditioning systems that can provide fresh air heating, cooling, humidity and temperature control in building premises. Internet of Things (IOT) based HVAC systems allows the user to control building temperature remotely. HVACs are integrated with Building Management Systems in order to provide centralized monitoring and control. Some popular HVAC systems are- APRILAIRE, Danfoss, ecobee Inc., Honeywell Environment Combustion and Controls (Preville, 2013).

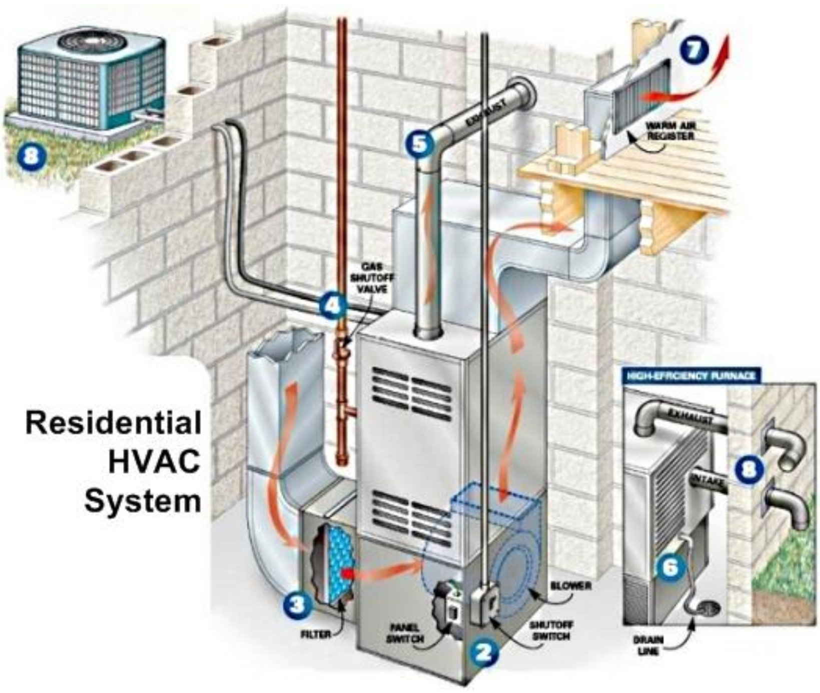


Figure 1.1- Residential HVAC system (Heating and Air-Conditioning, n.d.)

2. **Lighting**: The lighting inside a building can be controlled based on a timing cycle or by measuring the occupancy of the room. Advanced home automation systems are designed to control the brightness and colour of lighting for different tasks. Lighting can be controlled wirelessly or over the internet. Natural lighting systems can be installed to control automatic opening of windows and curtains based on the availability and timing of day light (Automation Associates, 2015).

3. **Audio Visual**: Audio and Visual devices can be controlled using domotics systems. They can be configured as input or output devices and one or more sources can be distributed in different rooms (Automation Associates, 2015). One example of Home Automation Audio devices is the Amazon Echo, which controls the house appliances, music and other variables by following the voice commands of the user.

4. **Security:** In modern domotic systems an array of security features are available. Ranging from motion sensor based intrusion detection to CCTV cameras which provide a live visual feed to the user. Various sensors for fire, smoke and gas detection are used to prevent potential accidents.

Figure 1.2- Home security systems *(*Whitehall Security Pvt Ltd, 2014*)*

5. **Intercom:** An intercom system allows communication between multiple rooms through a microphone. Intercom can be integrated with the telephone or with a video door entry system to stream live image of a visitor.

Figure 1.3- Audio-Video intercom (DSI Security Systems, 2015)

There are plenty of other home automation systems available at commercial and non-commercial level. These range from smart thermostats to state of the art security systems. Companies like Nest are dedicated to the advancement of home automation technologies and development of user friendly products (for example- automatic feeder for pets).

1.4 Problem Statement

During the recent years, with the emergence of technologies like smartphones, high speed internet, GSM, sensor arrays, Internet of Things and embedded systems, the home automation products have attained a high level of sophistication.

However, the home automation systems available in Asia and many other parts of the world are expensive in terms of production cost and lacks standardization. Therefore, it is essential to integrate the various available standard technologies to design a system that not only provides automation and security but is also cost effective. Burglaries, gas explosions, household fires claim large number of lives each year in countries like India and Malaysia; with a robust system which can detect gas leaks or smoke, an early warning can be raised and any potential accident can be mitigated. A basic motion detection system will enable the users to get notified in case of a break-in or burglary. The low cost of the system will enable people of all financial statuses to equip their homes for necessary security monitoring and electrical control, significantly reducing the large number of accidents that results in loss of life and property.

The proposed system can be integrated with voice recognition systems like Google Now, SIRI and Cortana in order to control the connected electrical appliances by voice commands. This setup will be essentially useful for elderly people or people with physical disabilities as it will allow them to easily control their domestic environment.

1.5 Project Scope

The project aims to develop a hardware prototype for the proposed home automation system. The proposed design is an AVR microcontroller based embedded system which is programmed using Embedded C language. The hardware includes subsystems like gas leakage, smoke and motion detection along with wireless control of electrical appliances. For the proposed design, GSM and Bluetooth technology is used to operate the system wirelessly in two modes. The GSM mode will allow the user to control electrical appliances and receive sensor outputs via SMS anywhere on the globe. When in the Bluetooth mode, the system can be controlled with an Android app or by a voice recognition device like Amazon Echo. The status of the connected devices and sensors can be viewed on the 16x2 LCD display.

1.6 Objectives

The objectives for the study include-

- To design a power source that converts 230V Hz AC supply to DC in order to provide a regulated 5V DC input to microcontroller, sensors, Bluetooth and GSM module
- To design drive circuitry for AVR microcontroller
- To design the interface between different sensor, communication modules and microcontroller
- To design the isolation and switching circuitry for the connected electrical appliances
- To program the microcontroller to configure GSM and Bluetooth modems, control electrical appliances depending on user input and trigger the SMS notification whenever any sensor detects an anomaly
- To configure Android app to control the system using Bluetooth

1.7 Summary

This chapter defines the problem statement, project scope and the objectives for the Home Automation System. A successful implementation will require a sophisticated hardware and software subsystem design. A detailed literature review about similar projects, systems and their theoretical background and practical implementation is given Chapter 2. The proposed methodology for the Imperium Home Automation System is discussed in Chapter 3 along with the details of different hardware and software to be used. Chapter 4 will present the details about the circuit design, processes involved in hardware implementation, programming and the details about the system operation. The results and analysis about the designed system are discussed in Chapter 5 along with the obtained system response. Chapter 6 proposes ideas about the future work possible for the development and evolution of the proposed system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will expatiate on the works of several researchers in the relative field and also on the key terms used in this research work which are explained in the reference material (articles, journal papers, books, internet etc) as well as engineering jargons which might often be encountered in this work.

2.2 Background of Study

The first smart home automation systems were developed with the idea of wireless control and interoperability of the domestic electrical appliances. The development of heterogeneous computing devices like laptops, smart phones and tablets has paved the way for ubiquitous technology which thrives to provide connectivity. The wireless control of home appliances saves time and reduces physical effort. A number of systems developed to provide some form of automation for a domestic environment have been studied.

Muhammad Izhar Ramli, Mohd Helmy Abd Wahab, Nabihah@Nornabihah Ahmad (Ramli, Wahab, & Ahmad, 2006) designed a web based home automation system with a web based controller to control electrical devices. Design using Microsoft Visual Studio .Net and set up a server with auto reset whenever the server is down. The system provides a sophisticated web platform for controlling electrical appliances, however, the web being the only form of communication available, the user will be exclusively dependent on the availability of internet. Also, been developed only for the Windows operating system, the designed system will lack mobility and will not be compatible with hand held devices running of IOS and Android.

In the paper published by Yavuz EROL, Hasan H. BALIK, Serkan INAL and Duygu KARABULUT (EROL, BALIK, INAL, & KARABULUT, 2007) a DTMF (Dual Tone Multiple Frequency) based home automation system has been proposed. The design implements a pin check algorithm processed by a PIC microcontroller. The system uses public switched telephone network to operate the domestic appliances. The system has the advantage that it can be used with both mobile phones and landlines and it has a high degree of security. However, as there is no GUI involved, the user will have to dial the number, wait for the system to connect and dial specific codes on the phone to carry out the desired operation. This makes the system difficult to use as it increases the processing time, user will have to remember the code for each appliance and keeps the telephone line busy for the entire duration. Also when the user is inside the house, they still have to control the appliances by connecting via PSTN which is both time consuming and expensive.

An 8051 microcontroller based system developed by Indrapreet Kaur (Kaur, 2010), integrates temperature and fire sensors to control the electrical appliances and the building safety system. This design provides a simplified and affordable version of the more complex and intelligent systems that can be operated remotely and provide a cornucopia of functionalities.

An advanced Brain Computer Interface Home Automation System is designed by Abdel Ilah N. Alshbatat, Peter J. Vial, Prashan Premaratne and Le Chung Tran. This BCI system has been especially proposed for elderly and for people with physical disabilities like paralysis, to facilitate them certain degree of independence when it comes to controlling appliances around them. The system provides physically disabled people control over the domestic environment by using an electroencephalogram and a graphical user interface. The authors have used an EMOTIV EPOC EEG headset which detects and records neuronal electrical activities that reflects user's intent, from different locations on the scalp. The electrical signals are processed and translated into commands to control the electrical appliances (Alshbatat, Vial, Premaratne, & Tran, 2014).

In their paper on remote controlled home automation systems, Armando Roy Delgado, Rich Picking and Vic Grout presents a detailed analysis of remote controlled technologies and its potential applications in home automation systems. Their research describes the ongoing global standardization process of home automation systems and the role played by IEEE 802 family of standards in the process.

Since the development of open source operating systems like Android, big players like Google have stepped into the R&D paradigm of smart homes. During the 2011 I/O Conference, Google announced Android@Home, an initiative to integrate Android OS with all the domestic accessories allowing the Android apps to communicate with appliances and devices in the home. This initiative has since been a developing project at Google and expected to reach consumer market soon (Google, 2011).

2.3 Embedded Systems

The IEEE defines an embedded system as- “The devices used to control, monitor, or assist the operation of equipment, machinery or plant. “Embedded” reflects the fact that they are an integral part of the system. In many cases their embeddedness may be such that their presence is far from obvious to the casual observer and even the more technically skilled may need to examine the operation of a piece of equipment for some time before being able to conclude that an embedded control system was involved in its function. At the other extreme, a general purpose computer may be used to control the operations of a large complex processing plant, and its presence will not be obvious" (Parab, Shinde, Shelake, Kamat, & Naik, 2008).

The proposed home automation system is an embedded system designed with an AVR family microcontroller and programmed using Embedded C language.

2.4 Automation and Automated Systems

According to J.G Keramas automation is defined as- "the use of machines, information technologies and systems or devices also referred to as control systems, which manages, directs and regulates the operations of other systems for productivity and service delivery optimization". The use of automation in this age, has gone beyond just industries and production plants, it is presently being used to ease difficulties in our everyday challenges or endeavours, such as in: household, transportation, mining, health care, fast food outlets and institutions where it is applicable. The fast growing demand for its use in various sectors of the society was prompted by its several benefits which includes: increased productivity, improved quality, consistency of output, safety and protection in cases of hazardous activities, reduced execution time as compared with human labour, reduced labour or running cost, increased accuracy and increased process robustness (consistency).

The disadvantages of an automation system include security threats resulting from a fixed scope of applicability or system errors, unforeseen cost of development or customization to suit a particular purpose, a high initial procurement cost and increasing unemployment. In a sense it is faced with one basic limitation; not all processes have been automated presently for several reasons. Automated systems are primarily controlled by the use of different type of automation tools, such as: Microcontrollers, Programmable Logic

Controller (PLC), Human Machine Interface (HMI), Artificial Neural Networks (ANN), Supervisory Control and Data Acquisition Systems (SCADA) and Instrumentation. All these tools could be used together or discretely depending on the complexity of the system to be created.

2.5 Wireless Communications

Wireless communication entails the information transfer from one point to another without the use of an electrical conductor line (Haykin & Moher, 2010). It uses electromagnetic waves as its means of communication; the flexibility of this form of transfer of information or information sharing has made it very common in the modern day environment. There are various forms of wireless communication such as: radio communication (with radio waves), microwave communication (with microwaves), visible light (eg. Li-Fi) and infra-red modes (eg. TV remotes), sonic mode and by electromagnetic induction. The term wireless should not be confused with Cordless, which ultimately describes an electrical or electronic device powered by a portable source, in order to eliminate restraints that could evolve as a result of the incorporation of wires- for example, a cordless telephone. This form of communication has been practiced since the 1880s, when Alexander Graham Bell and Charles Summer Tainter invented and patented the Photo-phone (Haykin & Moher, 2010). Bell and Tainter's invention and the discovery of the concepts behind it by several other researchers led to its evolution from then to this date. Wireless communication is supported by several technologies such as Wi-Fi, Li-Fi, Ethernet, Bluetooth, Cellular data services and mobile satellite communications (such as GSM). This form of communication is widely used almost everywhere in the world, since it offers minimal hazardous effect, and has a high efficiency level. Today many concepts or devices in use apply this technology, for example: Global Positioning System (GPS), keyboards, hand-phones, radios, video broadcasting and satellite television.

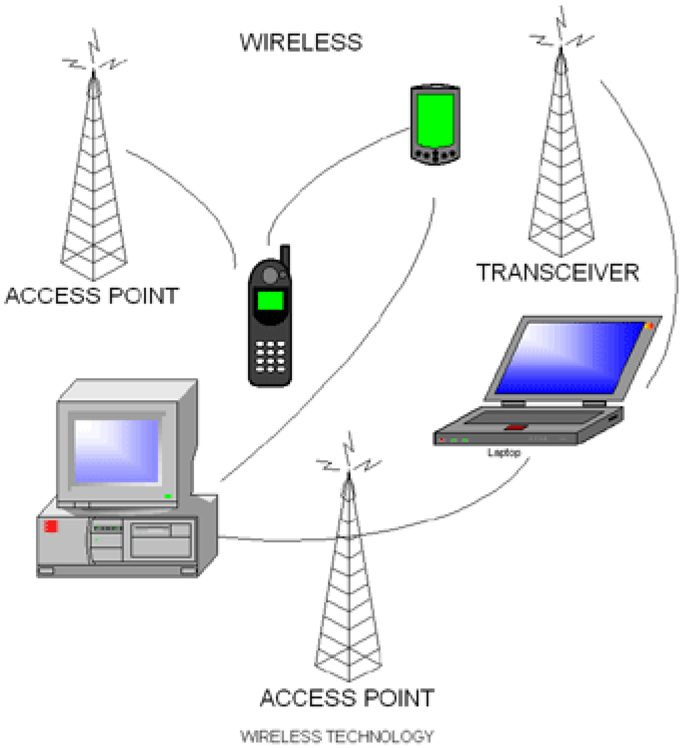


Figure 2.1- Wireless cellular network (http://worldinfovr.co.in/, 2015)

2.6 Global System for Mobile Communications

The European Conference of Postal and Telecommunications Administration (CEPT) made the Groupe Spécial Mobile committee in 1982 as a spearheading effort to build up a European standard for digital cellular voice telecommunication. It was later converted into the modern Global System for Mobile Communications (GSM) by the European Telecommunications Standards Institute (ETSI) in 1991 in order to set a standard of protocols for second generation (2G) digital cellular networks (Pour & Mehdi, 2006).

A variation of time division multiple access (TDMA) is used in GSM. Data is digitized and compressed before transmission and then transmitted over the channel with two other user data streams, each in its own time slot. The operating frequency bands for GSM are 900MHz band or 1800MHz band. 82.4% of total global mobile communication is GSM based with over 690 mobile network service providers providing GSM service across 213 countries. An approximate 2 billion people worldwide uses GSM for mobile communications with China as the largest GSM market trailing by Russia, India and USA (Rouse, 2007).

As described by Nokia, a GSM network is structured into the following sub-sections (Nokia, 2014)-

1. Base Station Subsystem – the base stations and their controllers explained
2. Network and Switching Subsystem – the part of the network most similar to a fixed network, sometimes just called the "core network"
3. GPRS Core Network – the optional part which allows packet-based Internet connections
4. Operations support system (OSS) – network maintenance

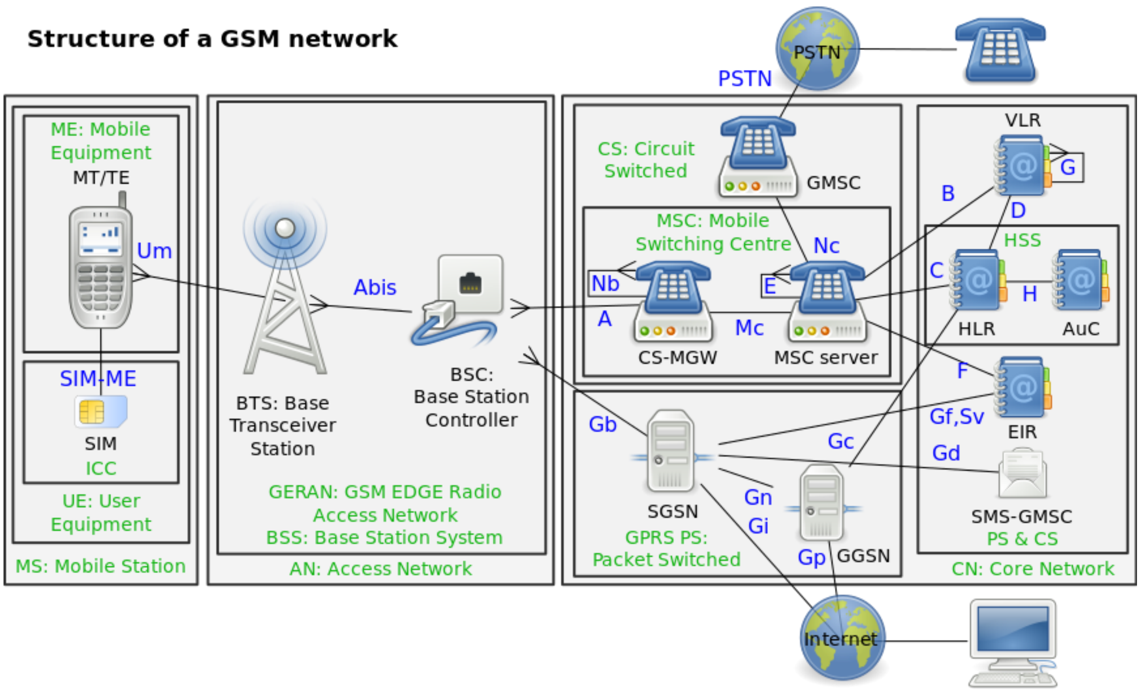


Figure 2.2- Structure of a GSM network (Shirichena, 2014)

2.7 Microcontrollers

A microcontroller is a small computer designed on a single integrated circuit chip, which forms the heart of an embedded system and comprises a memory, a processor core and input/output peripherals (Ramya, Palaniappan, & Karthick, 2012). Contrary to a microcontroller which is usually designed for specific tasks and is less expensive to use, a microprocessor does not possess a memory or input/output peripherals, it's more expensive and more versatile. Microcontroller processors process only digital signals; this has brought about the creation of Mixed Signal Microprocessors which contains analog circuits such as Analog to Digital converters and Digital to Analog Converters; these help to convert analog signal to digital signals and vice versa.

The first microprocessor was created in the year 1971, it was a four bit Intel 4004; thereafter the creation of Intel 8008, gave way to the creation of more capable microprocessors such as 8048, 8086, 8051 and many more which could operate at 8, 32 or 64 bit processing speed (Kumar, Saravanan, & Jeevanathan, 2010). Apart from the Random Access Memory (RAM) which was used for data storage these devices make use of either, a Programmable Read Only Memory (PROM), Erasable Programmable Read Only Memory (EPROM) or Electrical Erasable Read Only Memory (EEPROM) for program and operating parameter storage. A PROM is programmed only once and can never be erased, while an EPROM could be erased by exposing its light sensitive storage to ultra-violent light; and the EEPROM is erased electrically (Kumar, Saravanan, & Jeevanathan, 2010).

The features of a microcontroller includes: a central processing unit(CPU), a volatile memory for data storage called RAM, non-volatile memory such as ROM/ PROM/ EPROM/ EEPROM or Flash Memory for program and operating parameter storage, discrete input and output bits which allow the control and detection of the logic state of an individual package pin, several serial communication interfaces, peripherals, serial input/output such as serial ports, clock generators such as oscillators, in-circuit programming and debugging support, digital to analog converters/analog to digital converters or both (Kumar, Saravanan, & Jeevanathan, 2010). Today microcontrollers are programmed using various languages, such as: Assembly language which was the first, and which is still in use, C language, C++ language and Java. C, C++ and Java are high level languages and require compliers to convert them into machine language, while Assembly language which is low level requires an Assembler for conversion to machine language (Barnett, O'Cull, & Cox, Embedded C Programming and the Atmel AVR, 2E, 2007).

Microcontrollers are of many types, different producers and distributors of these components follow different architectures. Examples of major manufacturers of microcontrollers include Atmel, Intel, Toshiba, Texas Instruments, PowerPC and many others. They have different applications which could sometimes be embedded and for which some of the types listed previously might prove to be better than others. The applications include programmable control, data storage, data conversion and processing, multiplexing and many others. The microcontroller used for this project is ATmega8 which comes as 28 pin a Dual-In-Line package with flash memory, RAM and EPROM.

Figure 2.3- AVR ATmega8 (Robot Platform, n.d.)

Figure 2.4 shows the pin diagram of ATmega8 microcontroller.

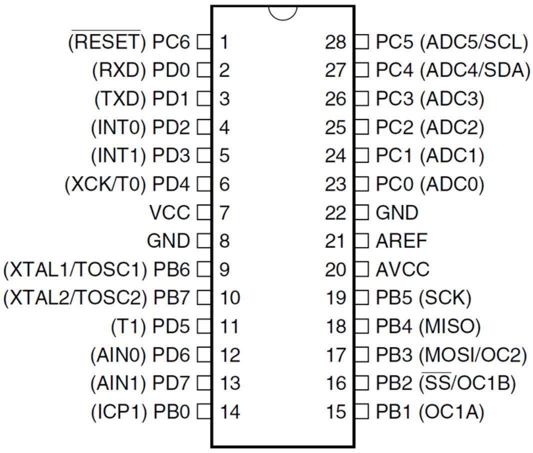


Figure 2.4- ATmega8 pin configuration (Atmel Corporation, 2015)

The table 2.1 gives the features of ATmega8-

Table 2.1- ATmega8 features (Atmel Corporation, 2015)

MICROCONTROLLER	ATMEGA328
Operating Voltage	5 V
Input Voltage	7-12 V
Input Voltage (Limits)	6-20 V
Digital I/O pins	23
ADCs	6
DC current per I/O pin	40mA
DC current for 3.3 V pin	50mA
Flash Memory	8Kb
SRAM	1Kb
EEPROM	512Bytes
Clock Speed	16MHz

2.8 C Programming Language

C programming language was created by Dennis Ritchie of Bell Labs in the year 1972, as he and Ken Thompson worked on designing the UNIX operating system. It was ultimately created as a useful tool for working programmers. C language is presently one of the most popular and widely used languages, even in the presence of a similar and more ambitious C++ language. It falls under a group of languages called high level languages, and like a few others like Pascal, Basic and Java which fall into this group it is not so difficult to understand (Barnett, O'Cull, & Cox, Embedded C Programming and the Atmel AVR, 2E, 2007).

C programming is applicable in a wide range of professional fields today due to: design features, efficiency, portability, power and flexibility, and property of being programmer oriented. In this project Embedded C, a version of C programming designed for use with embedded systems, is used for wiring or controlling the Atmega8.

2.9 Summary

Through the given literature review, the various approaches towards the implementation of automation technologies in a domestic environment have been studied. As described along each review there are pros and cons related to every approach, different sets of challenges which have to be overcome in order to implement such systems and each system has its own limitations. Communication technologies like GSM and Bluetooth along with programmable controllers allow the users to control electrical appliances wirelessly over a certain range of distance. The choice of controller and communication protocols for such systems largely depends on the intended purpose and targeted customers. The Imperium Home Automation System is an attempt to reduce the limitations of design cost, control range and mobility in order to develop a standard home automation system which can be easily installed and operated according to predefined protocols. The details of the design methodology are available in the following chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter gives an insight into the methods that will be used in this project in order to accomplish the defined objectives. The project is divided into the software subsystem and the hardware subsystem. A work flow chart as given in Figure 3.1 sheds light on the processes defined to ensure a well-organized and error free implementation of this project.

The software needed for the project include- Atmel AVR studio, Proteus CAD, Altium CAD, and National Instruments Multisim 13.0. Atmel AVR Studio is used to program the Atmega8 microcontroller; it consists of a compiler and assembler for embedded C programming. Multisim and Proteus are used to design and simulate the circuits including the power source, microcontroller drive circuitry, sensor interface and triac-load interface. The design of the printed circuit board is carried out in Altium CAD.

3.2 Work Flow Diagram

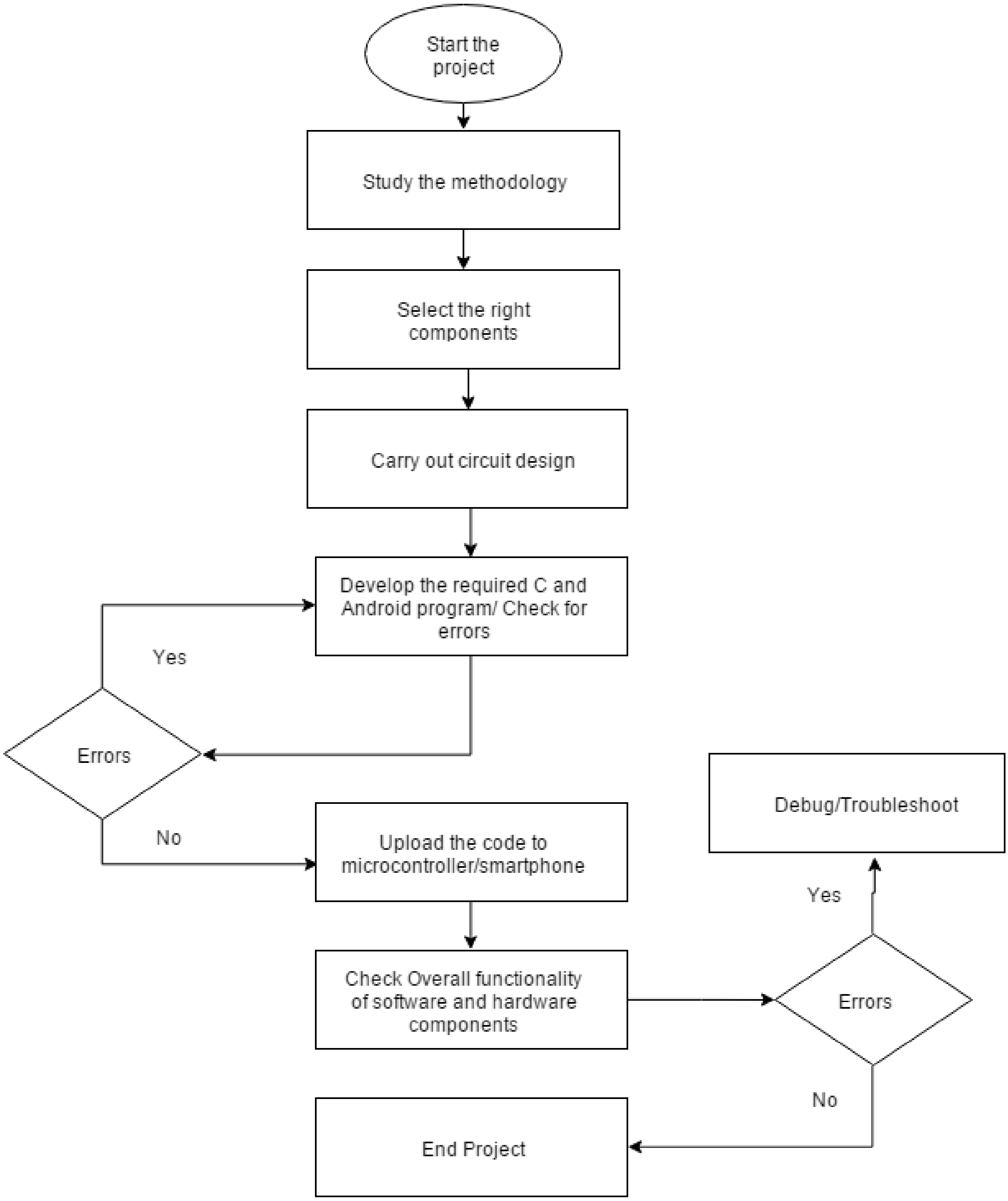


Figure 3.1-Work Flow Diagram

3.3 Overview Architecture

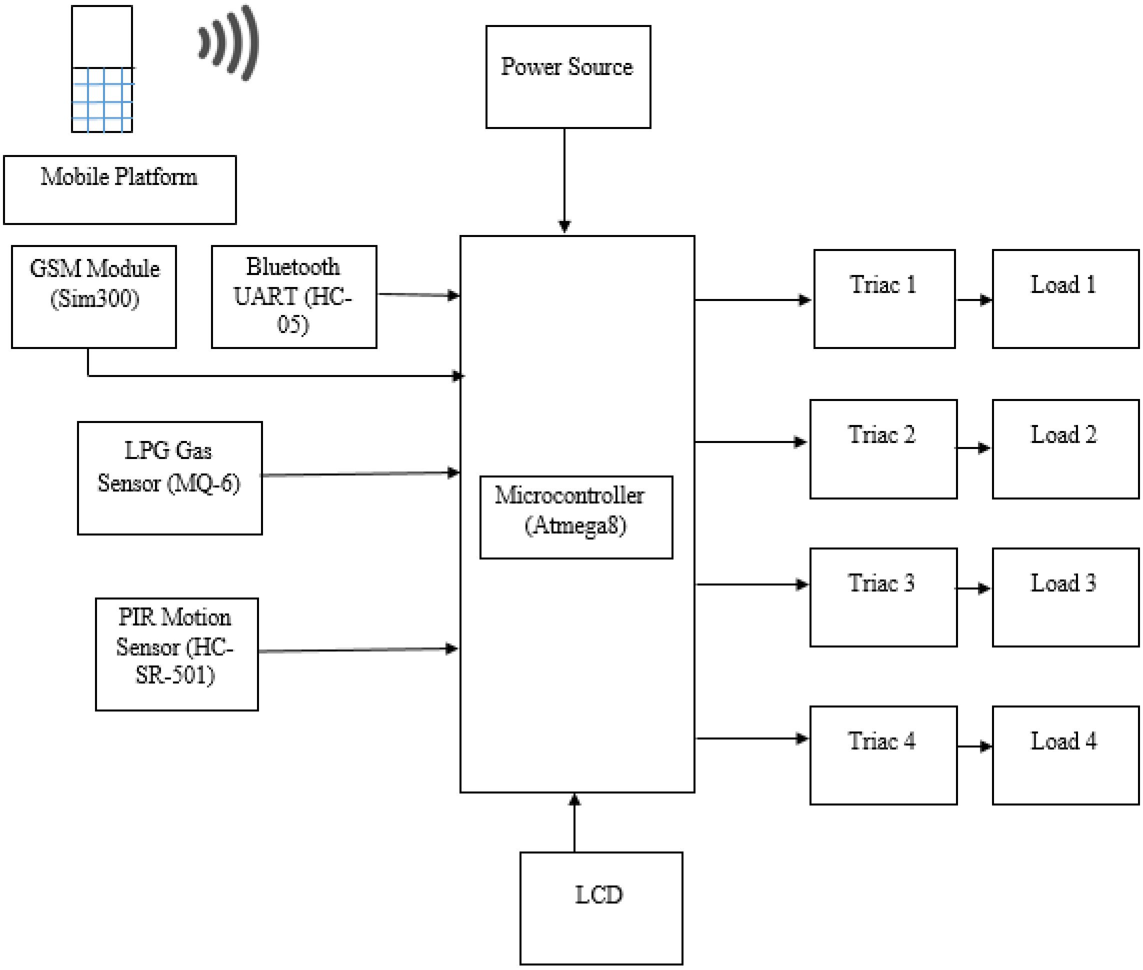


Figure 3.2- Overview architecture

The architecture proposed during the Final Year Project 1 utilised electromechanical relays to act as switches for electrical appliances. However, for better operation the relays were replaced by optocoupler-triac based switching circuitry (for comparison between triacs and relays refer to section 3.10). The figure 3.2 shows updated overview architecture of the proposed system. The system consists of a hardware subsystem and a software subsystem. The hardware subsystem consists of-

1. Microcontroller- ATmega8
2. GSM module- SIM300
3. Bluetooth module- HC-05
4. 74HC4052 Multiplexer/Demultiplexer
5. LPG gas sensor- MQ-6
6. PIR motion detector- HC SR -501
7. 16x2 LCD Display
8. Optocouplers- MOC3021
9. Triac switches- BT136

3.4 AVR ATmega8 Microcontroller

The Atmel ATmega8 is a high efficiency, low-power CMOS 8-bit microcontroller derived from the AVR (Advanced Virtual RISC) enhanced RISC (Reduced Instruction Set Computing) architecture. By executing powerful instructions in a single clock cycle, the throughput close to 1MIPS per MHz are achieved. This empowers system the designer to optimize the device for power consumption versus processing speed (Atmel Corporation, 2015). ATmega8 has an 8 bit data bus which means 8 bits of information can be transmitted or received by the input/output registers.

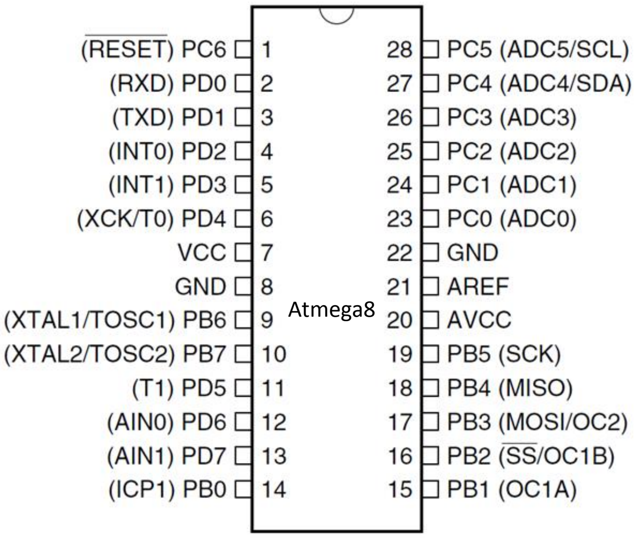


Figure 3.3- AVR ATmega8 Pinout (Atmel Corporation, 2015)

As per the datasheet obtained from the manufacturer, the specifications for ATmega8 are as follows-

1. High-performance, Low-power Atmel AVR 8-bit Microcontroller
2. Advanced RISC Architecture
   i. 130 Powerful Instructions - Most Single-clock Cycle Execution
   ii. 32 x 8 General Purpose Working Registers
   iii. Fully Static Operation
   iv. Up to 16MIPS Throughput at 16MHz
   v. On-chip 2-cycle Multiplier
3. High Endurance Non-volatile Memory segments
   i. 8KBytes of In-System Self-programmable Flash program memory
   ii. 512Bytes EEPROM
   iii. 1KByte Internal SRAM
   iv. Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
   v. Data retention: 20 years at 85°C/100 years at 25°C
   vi. Optional Boot Code Section with Independent Lock Bits
4. In-System Programming by On-chip Boot Program
5. True Read-While-Write Operation
   i. Programming Lock for Software Security

6. Atmel QTouch library support
    i. Capacitive touch buttons, sliders and wheels
    ii. Atmel QTouch and QMatrix acquisition
    iii. Up to 64 sense channels
7. Peripheral Features
    i. Two 8-bit Timer/Counters with Separate Prescaler, one Compare Mode
8. One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
    i. Real Time Counter with Separate Oscillator
    ii. Three PWM Channels
    iii. 8-channel ADC in TQFP and QFN/MLF package
9. Eight Channels 10-bit Accuracy
    i. 6-channel ADC in PDIP package
10. Six Channels 10-bit Accuracy
    i. Byte-oriented Two-wire Serial Interface
    ii. Programmable Serial USART
    iii. Master/Slave SPI Serial Interface
    iv. Programmable Watchdog Timer with Separate On-chip Oscillator
    v. On-chip Analog Comparator
11. Special Microcontroller Features
    i. Power-on Reset and Programmable Brown-out Detection
    ii. Internal Calibrated RC Oscillator
    iii. External and Internal Interrupt Sources
    iv. Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, and Standby
12. I/O and Packages
    i. 23 Programmable I/O Lines
    ii. 28-lead PDIP, 32-lead TQFP, and 32-pad QFN/MLF
13. Operating Voltages
    i. 2.7 - 5.5V
14. Speed Grades
    i. 0 - 16MHz
15. Power Consumption at 4MHz, 3V, 25°C
    i. Active: 3.6mA

ii. Idle Mode: 1.0mA
iii. Power-down Mode: 0.5µA

The table 3.1 shows a basic comparison between different microcontroller families-

Table 3.1- Microcontroller families' comparison

	8051	**PIC**	**AVR**
SPEED	Slow	Moderate	Fast
MEMORY	Small	Large	Large
ARCHITECTURE	CISC	RISC	RISC
ADCs	Not Present	In-built	In-Built
TIMERS	In-built	In-built	In-built
PWM CHANNELS	Not Present	In-built	In-Built

The most important feature of ATmega8 is its high speed. Majority of AVR instructions are executed in a single execution cycle making the microcontroller 4 times faster than PICs. The power consumed is much lesser and the microcontroller can be operated in different power saving modes as it performs single cycle executions, allowing 1 million instructions being executed per cycle. The high speed, in-built ADCs and low power consumption makes ATmega8 an ideal microcontroller for this project.

3.5 SIM300 GSM Modem

The Android based Home Automation System uses GSM to send/receive SMS containing the status information and control commands. The user can use his/her smartphone to send/receive SMS. The circuit however cannot use a smartphone, which is why a GSM module with Sim card slot and an antenna is used. The GSM modem receives SMSs from the user when the system is in GSM mode to control the connected appliances. The modem also transmits pre-programmed messages to a registered mobile number if any of the connected sensors (motion or gas sensor) detects a reading.

SIM 300 is a tri-band GSM/GPRS engine that operates on frequencies EGSM (Extended-GSM) 900 MHz, DCS (Digital Cellular System) 1800 MHz and PCS (Personal Communication Service) 1900 MHz. SIM300 provides GPRS multi-slot class 10 capability and support the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4 (Simcom, 2005). Sim300 GSM module utilized here comprises of a TTL (transistor-transistor logic) interface and a RS232 interface. The TTL interface permits us to specifically connect with a microcontroller while the RS232 interface incorporates a MAX232 IC to empower correspondence with the PC. It additionally comprises of a signal, reception apparatus and SIM space. Sim300 in this application is utilized as a DCE (Data Circuit-ending Equipment) and PC as a DTE (Data Terminal Equipment) (Simcom, 2005).

Figure 3.4- SIM300 GSM modem (EMsys, 2011)

SIM 300 and numerous other devices that requires machine to machine communication utilizes Hayes attention commands also known as AT commands to communicate with a host (PC or microcontroller). The commands originated from the Hayes smart modems developed in 1990s. The command set starts with AT command, which is used to indicate the attention from the modem. The commands used for this project and their respective system responses are explained in the Chapter 5.

3.6 HC-05 Bluetooth Module

Developed for transparent wireless serial connection setup, HC-05 is an easy to use Serial Port Profile module. A serial port Bluetooth is a fully qualified version 2.0 Bluetooth with enhanced data rate (EDR) and 300Mbps modulation with a complete 2.4 GHz radio transceiver and baseband (ITead Studio, 2010). As per the specifications provided by the manufacturer the Bluetooth module uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and AFH (Adaptive Frequency Hopping Feature) and has a device footprint as small as 12.7mmx27mm (ITead Studio, 2010).

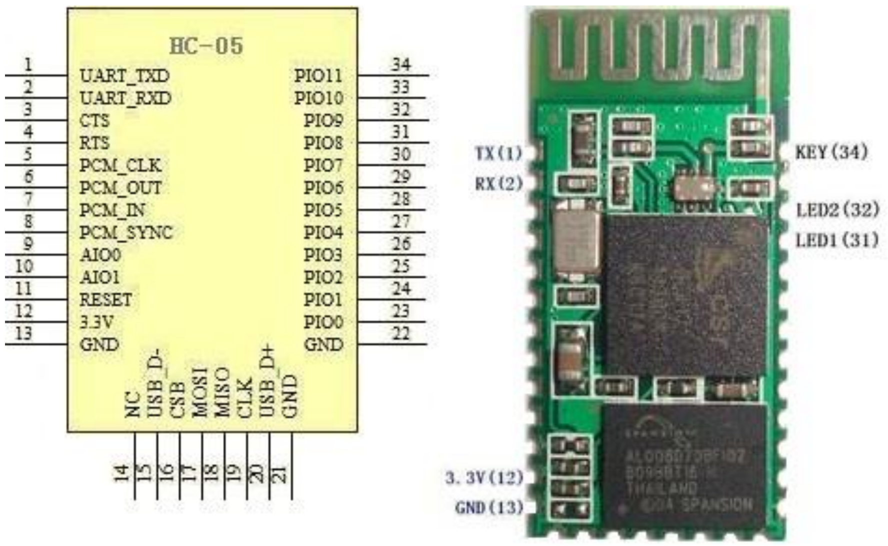


Figure 3.5- HC-05 Bluetooth module (Marchi, 2015)

The Bluetooth module allows the home automation system to connect with the smartphone over a Bluetooth communication channel while being operated in slave mode. The typical hardware and software specifications followed by different manufacturers are-

Hardware Features (ITead Studio, 2010)

- Typical -80dBm sensitivity
- Up to +4dBm RF transmit power
- Low Power 1.8V Operation ,1.8 to 3.6V I/O
- PIO control
- UART interface with programmable baud rate
- With integrated antenna
- With edge connector

Software Features (ITead Studio, 2010)

- Default Baud rate: 38400, Data bits:8, Stop bit:1,Parity:No parity, Data control: has. Supported baud rate: 9600,19200,38400,57600,115200,230400,460800.
- Given a rising pulse in PIO0, device will be disconnected.
- Status instruction port PIO1: low-disconnected, high-connected;
- PIO10 and PIO11 can be connected to red and blue led separately. When master and slave are paired, red and blue led blinks 1time/2s in interval, while disconnected only blue led blinks 2times/s.
- Auto-connect to the last device on power as default.
- Permit pairing device to connect as default.
- Auto-pairing PINCODE:"0000" as default
- Auto-reconnect in 30 min when disconnected as a result of beyond the range of connection.

The Bluetooth module uses the same AT commands as the GSM modem to establish communications with a host. The figure 3.6 shows a list of some common AT commands.

AT COMMAND LISTING

	COMMAND	FUNCTION
1	AT	Test UART Connection
2	AT+RESET	Reset Device
3	AT+VERSION	Querry firmware version
4	AT+ORGL	Restore settings to Factory Defaults
5	AT+ADDR	Query Device Bluetooth Address
6	AT+NAME	Query/Set Device Name
7	AT+RNAME	Query Remote Bluetooth Device's Name
8	AT+ROLE	Query/Set Device Role
9	AT+CLASS	Query/Set Class of Device CoD
10	AT+IAC	Query/Set Inquire Access Code
11	AT+INQM	Query/Set Inquire Access Mode
12	AT+PSWD	Query/Set Pairing Passkey
13	AT+UART	Query/Set UART parameter
14	AT+CMODE	Query/Set Connection Mode
15	AT+BIND	Query/Set Binding Bluetooth Address
16	AT+POLAR	Query/Set LED Output Polarity
17	AT+PIO	Set/Reset a User I/O pin
18	AT+MPIO	Set/Reset multiple User I/O pin
19	AT+MPIO?	Query User I/O pin
20	AT+IPSCAN	Query/Set Scanning Parameters
21	AT+SNIFF	Query/Set SNIFF Energy Savings Parameters
22	AT+SENM	Query/Set Security & Encryption Modes
23	AT+RMSAD	Delete Authenticated Device from List
24	AT+FSAD	Find Device from Authenticated Device List
25	AT+ADCN	Query Total Number of Device from Authenticated Device List
26	AT+MRAD	Query Most Recently Used Authenticated Device
27	AT+STATE	Query Current Status of the Device
28	AT+INIT	Initialize SPP Profile
29	AT+INQ	Query Nearby Discoverable Devices
30	AT+INQC	Cancel Search for Discoverable Devices
31	AT+PAIR	Device Pairing
32	AT+LINK	Connect to a Remote Device
33	AT+DISC	Disconnect from a Remote Device
34	AT+ENSNIFF	Enter Energy Saving mode
35	AT+EXSNIFF	Exit Energy Saving mode

ERROR CODES

ERROR CODE	VERBOSE
0	Command Error/Invalid Command
1	Results in default value
2	PSKEY write error
3	Device name is too long (>32 characters)
4	No device name specified (0 lenght)
5	Bluetooth address NAP is too long
6	Bluetooth address UAP is too long
7	Bluetooth address LAP is too long
8	PIO map not specified (0 lenght)
9	Invalid PIO port Number entered
A	Device Class not specified (0 lenght)
B	Device Class too long
C	Inquire Access Code not Specified (0 lenght)
D	Inquire Access Code too long
E	Invalid Iquire Access Code entered
F	Pairing Password not specified (0 lenght)
10	Pairing Password too long (> 16 characters)
11	Invalid Role entered
12	Invalid Baud Rate entered
13	Invalid Stop Bit entered
14	Invalid Parity Bit entered
15	No device in the Pairing List
16	SPP not initialized
17	SPP already initialized
18	Invalid Inquiry Mode
19	Inquiry Timeout occured
1A	Invalid/zero lenght address entered
1B	Invalid Security Mode entered
1C	Invalid Encryption Mode entered

Figure 3.6- Common AT commands used by HC-05 Bluetooth

3.7 HC-SR-501 PIR Motion Sensor

A passive infrared sensor (PIR sensor) is an electronic sensor used to measure infrared (IR) radiation from the objects in its field of view. The most common application of PIR sensors is PIR-based motion detectors. The sensors are small in size, inexpensive, low-power, easy to use and immune to ageing. The core of the PIR consists of a set of two solid state sensors made of natural or artificial pyroelectric materials like Gallium Nitride (GaN), Caesium Nitrate ($CsNO_3$), polyvinyl fluorides, etc. The pair of the sensor units are connected to a differential amplifier as opposite inputs. This setting allows the PIR measurements to cancel each other out in order to remove the average temperature of the field of view from the electrical signal. This will prevent any increase in IR energy across the entire sensor from triggering the device. This allows the device to resist false triggering due to events like flash of light or a field-wide illumination.

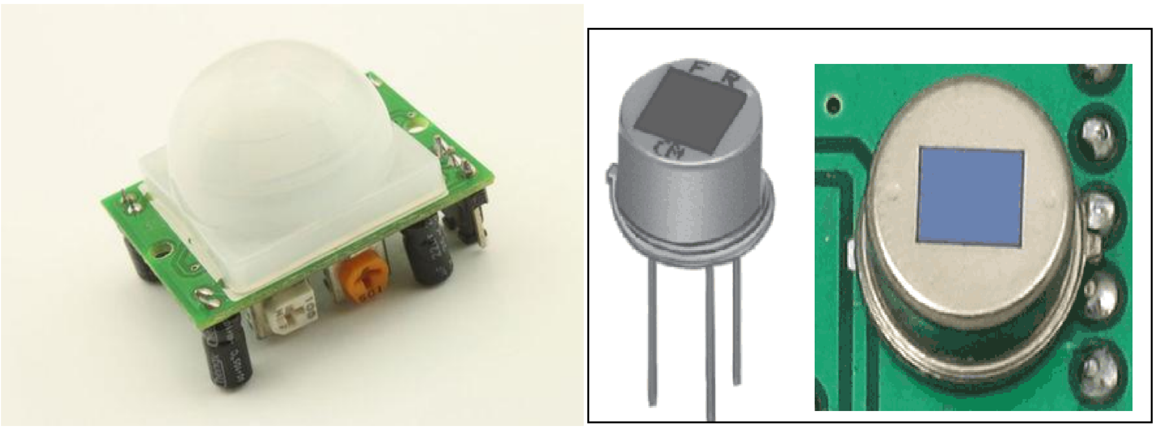


Figure 3.7- HC SR 501 Module and the IR sensor on-board

HC SR 501 comes with features like sensitivity adjustments & trigger delay. The specifications are as follows (PIR Motion Sensor Module:DYP-ME003, 2015)-

- Voltage: 5V – 20V ◦ Power Consumption: 65mA
- TTL output: 3.3V, 0V
- Lock time: 0.2 sec
- Trigger methods: L – disable repeat trigger, H enable repeat trigger
- Sensing range: less than 120 degree, within 7 meters
- Temperature: – 15 ~ +70
- Dimension: 32*24 mm, distance between screw 28mm, M2, Lens dimension in diameter: 23mm

3.8 MQ-6 Gas Sensor

MQ6 is a liquefied petroleum gas (LPG) sensor, used for sensing LPG which is primarily composed of mostly propane and butane, concentrations in the air. The MQ-6 has a detection range between 200 to 10000ppm (Agarkar, 2013).

The sensor operating temperatures ranges from -10 to 50°C, it consumes less than 150 mA at 5 V. The sensor has a high sensitivity and fast response time. The sensor's output is an analog resistance and it is suitable for detecting- LPG, Isobutane, Propane, LNG, Cigarette Smoke (Probots, 2014).

Specifications-

- Parameter Value Unit
- Target Gas iso-butane, Propane, LPG
- Detection Range 100 to 10000 PPM (part per millions)
- Output Voltage Range 0 to 5 VDC
- Working Voltage 5 VDC
- Current Consumption ≤180 mA
- Warmup Time 10 Minutes
- Calibrated Gas 1000ppm iso-butane
- Response Time ≤10s Seconds
- Resume Time ≤30s Seconds
- Standard Working Condition Temperature:-10 to 65 deg C. Humidity: ≤95%RH
- Storage Condition Temperature: -20-70 deg C Hum: ≤ 70%RH

Features-

- High sensitivity to CH_4 and Natural gas
- Fast response
- Stable and long life
- 3 pin interlock connector
- Continuous analog output
- Low cost and compact size

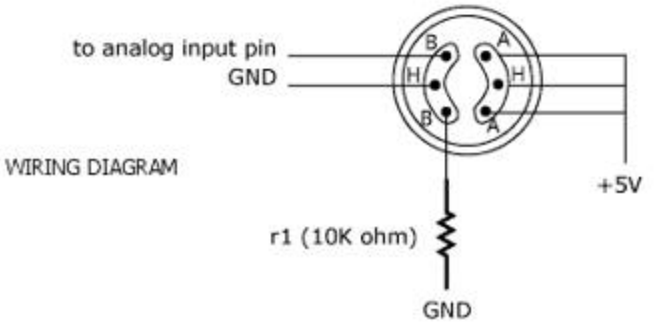
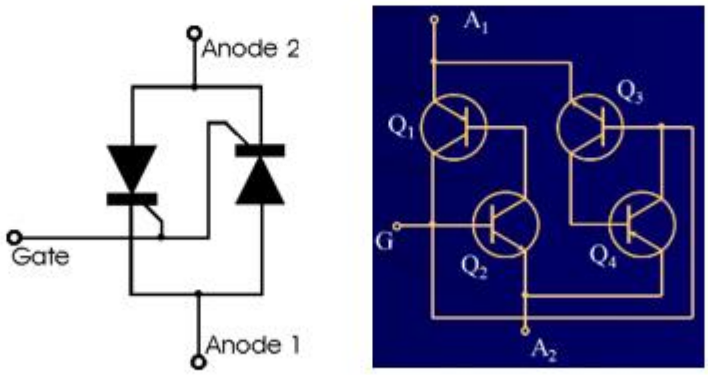


Figure 3.8- MQ-6 gas sensor and pin diagram

3.9 BT136 Triacs

A triac (TRIode AC) is a bi-directional, multi-layered, three terminal device, used extensively in AC power circuits. A triac behaves as two thyristors connected in anti-parallel fashion with a single gate terminal as shown in figure 3.9 (a), or four equivalent transistors as shown in figure 3.9 (b).



(a) (b)

Figure 3.9- (a) Thyristor equivalent circuit, (b) Transistor equivalent circuit

The device can be triggered by either a positive or negative voltage between the gate and one of the two terminals A1 or A2. Either of the terminals can act as anode or a cathode. When the gate is open, the triac will block both polarities of the voltage applied across A1 and A2, if the magnitude of the voltage is less than the breakover voltage of the device. The characteristics of triac are same as that of a thyristor, except that thyristor conducts only in forward direction but triac can conduct in both directions (Jain, 2014).

BT 136 are glass passivated triacs designed to be used for applications with high bidirectional transients and blocking voltage capacity. Some applications include- motor control, industrial and domestic lighting and static switching. The hardware and circuit symbol of a BT136 is shown in the figure 3.10. In this project, the BT136 gate is triggered by the microcontroller to switch on or off the connected loads. MOC3021 opto-isolators are used along with the triacs to provide electrical isolation between the electronic circuitry and the AC loads. Hence the triacs along with the opto-isolators work as solid state relays.

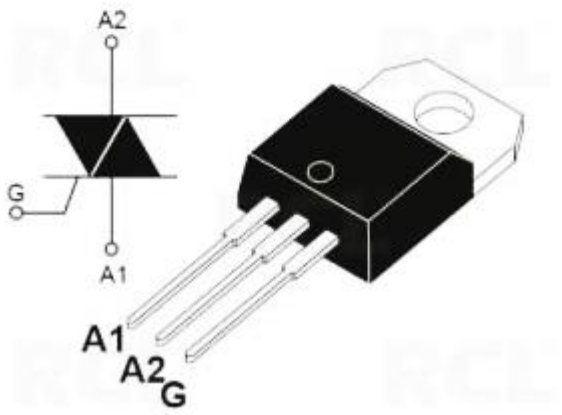


Figure 3.10- Hardware and circuit symbol for BT136

The static characteristics of BT136 are described in the table 3.2 (Philips Semiconductors, 1997)-

Table 3.2- Static Characteristics of BT136

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP	MAX.			UNIT
Igt	Gate Trigger Current	V_D = 12 V; I_T= 0.1 A						
		T2+ G+	-	5	35	25	50	mA
		T2+ G-	-	8	35	25	50	mA
		T2- G-	-	11	35	25	50	mA
		T2- G+	-	30	70	70	100	mA
I_L	Latching Current	V_D = 12V; I_T= 0.1 A						
		T2+ G+	-	7	20	20	30	mA
		T2+ G-	-	16	30	30	45	mA
		T2- G-	-	5	20	20	30	mA
		T2- G+	-	7	30	30	45	mA
I_H	Holding Current	V_D = 12V; I_T= 0.1 A	-	5	15	15	30	mA
V_T	On state voltage	I_T = 5A	-	1.4	1.7			V
V_{GT}	Gate Trigger Voltage	V_D = 12V; I_T= 0.1 A V_D = 400V; I_T= 0.1A	- 0.25	0.7 0.4	1.5 -			V V
I_D	Off-state leakage current	$V_D = V_{DRM(Max)}$ T_j = 125 °C	-	0.1	0.5			mA

3.10 Comparison between Triacs and Relays

The system design proposed during the Final Year Project 1 incorporated electromechanical relays to control the electrical appliances. However, at the time of implementation electromechanical relays caused certain problems.

- Due to a physical opening and closing mechanism EMRs often arced when they interrupt current, this resulted in a short circuited condition.
- EMRs require periodic maintenance and testing which is difficult and time consuming.
- The relay operation is affected due to the components aging, dust and pollution which might cause spurious trips.
- The switching is slow as the operational speed of the relay depends on the mechanical inertia.
- The relays occupy a larger space on the PCB.

The solid state relay provides a much faster switching as there are no moving components involved, no sparking between contacts and no problem of component ageing. SSRs provide complete electrical isolation to the electronics components as shown in the figure 3.11. Another advantage of using SSRs is that it opens the AC circuit only at the point of zero load current; as triacs are thyristors, they maintain circuit continuity even after the led is switched off till the AC current falls below the holding current (DigiKey, 2011).

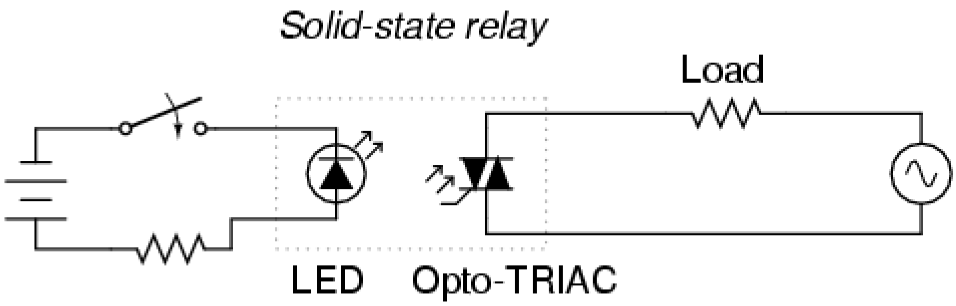


Figure 3.11- Solid state relay with opto-isolator and triac (DigiKey, 2011)

3.11 Summary

A detailed analysis about the flow of processes involved in the project along with the characteristics of the components used has been discussed in this chapter. The software subsystem is comprised of the programming and simulation software which will used to program and test the operation of the hardware components. The hardware components including the sensors, communication modules and triac will be separately configured and combined together to work as a single system.

CHAPTER 4

CIRCUIT DESIGN AND OPERATION

4.1 Introduction

The Home Automation System consists of several different sub-systems like sensors, communication modules, microcontroller and triac switching circuitry. The circuit design is carried out in four phases: schematic capture, programming, printed circuit board (PCB) design and hardware implementation. The schematic capture and the printed circuit board are designed using the Altium Designer 14, an electronic design package used for PCB, FPGA and embedded system design. Altium Designer has an extensive electronics component library along with respective PCB footprint of each component. The system design process is illustrated by the following diagram.

The processes involved in schematics layout, programming, PCB design and hardware implementation are discussed in details in the following sections and the next chapter provides the details about simulation results and system analysis.

4.2 Schematics Layout

The first task involved in schematics capture is to design a power source to provide the Vcc and ground required by the peripherals. The circuit is powered by the standard 230V 50Hz domestic supply; hence a transformer is used to step down the high voltage which is further converted into DC by a bridge rectifier.

The other subsystems of the home automation circuit include-

- Multiplexer: To connect Bluetooth and GSM with ATmega8 USART
- 16x2 LCD: To display text
- Switching circuit: BT136 triacs to switch on/off electrical appliances
- Sensors: MQ-6 gas sensor and PIR motion sensor

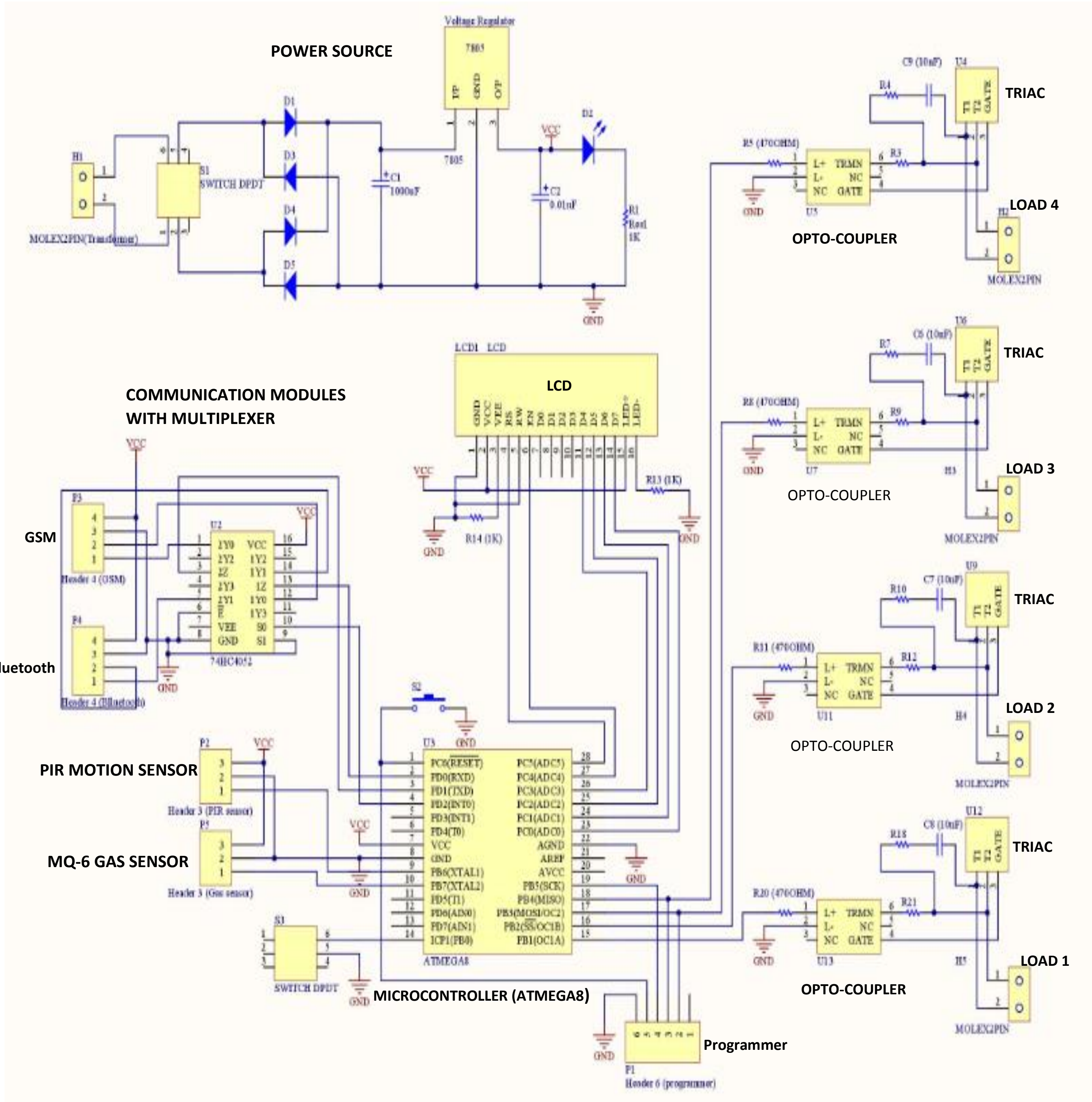


Figure 4.1-Circuit diagram

The complete circuit diagram for the designed Home Automation System is shown in Figure 4.1. The microcontroller is the processing unit which interacts with communication modules, sensors, LCD and triacs. ATmega8 processes the input commands from the user and controls the output relatively. It also processes the signals from sensors and notifies the user if an anomaly is detected through SMS. The pin configuration and connections for ATmega8 are defined in table 4.1.

Table 4.1- ATmega8 pin configuration

PIN NO.	PIN DESIGNATION	CONNECTED PERIPHERAL	INPUT/OUTPUT STATUS
1	PC6/RESET	Push Button S2	INPUT
2	PD0/RXD	Mux Common I/O 1Z	INPUT
3	PD1/TXD	Mux Common I/O 2Z	OUTPUT
4	PD2/INT0	Mux Select S0	OUTPUT
5	PD3/INT1	NC	NC
6	PD4/XCK/T0	NC	NC
7	VCC	Power Source VCC	-
8	GND	Ground	-
9	PB6/XTAL1	Motion Sensor Output	INPUT
10	PB7/XTAL2	Gas Sensor Output	INPUT
11	PD5/T1	NC	-
12	PD6/AIN0	NC	-
13	PD7/AIN1	NC	-
14	PB0/ICP1	DPDT Switch S3	INPUT
15	PC5/ADC5	LCD RS	OUTPUT
16	PC4/ADC4	LCD EN	OUTPUT
17	PC3/ADC3	LCD D4	OUTPUT
18	PC2/ADC2	LCD D5	OUTPUT
19	PC1/ADC1	LCD D6	OUTPUT
20	PC0/ADC0	LCD D7	OUTPUT
21	AGND	Ground	-

22	AREF	NC	-
23	AVCC	NC	-
24	PB5/SCK	Header 6 (Pin 4)	INPUT
25	PB4/MISO	Header 6 (Pin 3)/ Optocoupler U5	INPUT/OUTPUT
26	PB3/MOSI	Header 6 (Pin 2)/ Optocoupler U7	INPUT/OUTPUT
27	PB2/SS	Optocoupler U11	OUTPUT
28	PB1/OC1A	Optocoupler U13	OUTPUT

4.3 Programming

Once the circuit layout is complete, the microcontroller can be programmed according to the connections specified in the circuit diagram. The AVR ATmega8 is programmed using Embedded C programming, a high level C programming platform for embedded systems design and development.

The program specifies the input and output ports of the microcontroller depending on the connections made in the circuit diagram. There are 3 I/O ports in ATmega8 – port B, port C and port D, each with 8 I/O pins. The table 4.1 provides a complete pin configuration for ATmega8 used in this project.

Atmel AVR Studio 7.0 allows the user to write, modify and compile an embedded C program. The following are the steps involved in creating a new project and writing code in

AVR Studio: Start AVR Studio 7.0 → New Project → GCC C Executable Project → Name: FYP → Device Selection: ATmega8 → Finish.

Figure 4.2 shows the AVR Studio 7.0 text editor window with the embedded C program.

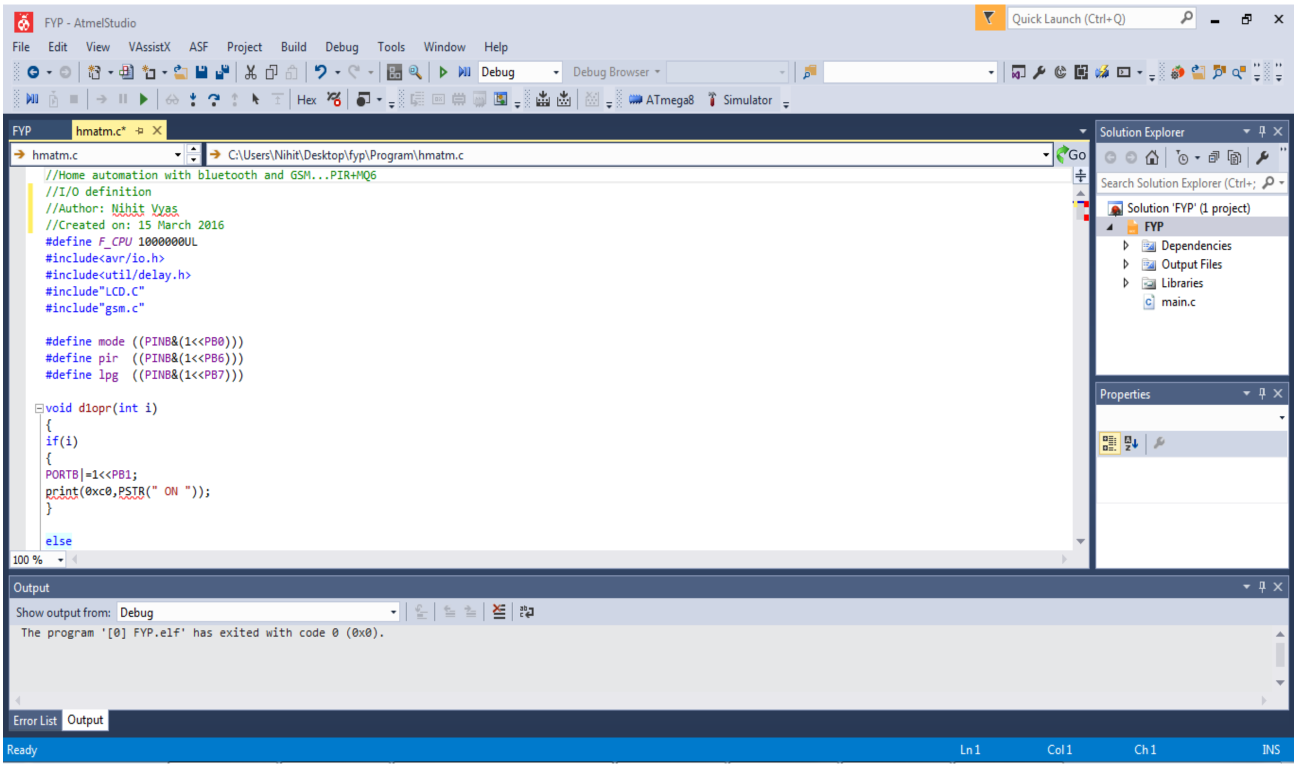


Figure 4.2- AVR Studio text editor

Note: For complete C program refer to Appendix 1.

4.3.1 Compilation and Burning

The completed program is compiled using the AVR Studio Compiler. A successful build and compilation generates the hex file which stores the machine language equivalent of the C program. To burn the program into the microcontroller an In-Serial Programmer circuit is used. A sample programmer circuit is shown in the figure 4.3.

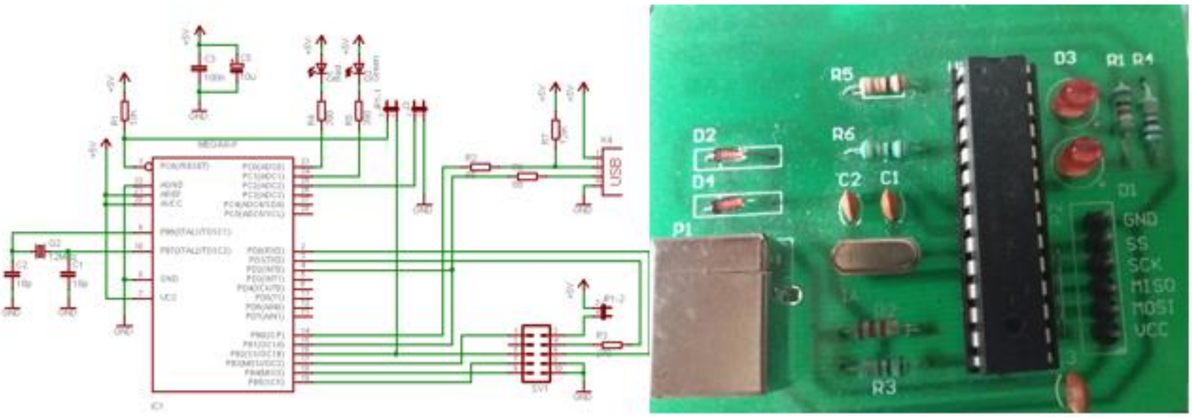


Figure 4.3- AVR ATmega8 programmer

The next requirement is a burner tool: a software used for flash burning. In this project I have used ProgISP burner tool by Zhifeng Software.Inc to burn the FYP.hex file into the microcontroller.

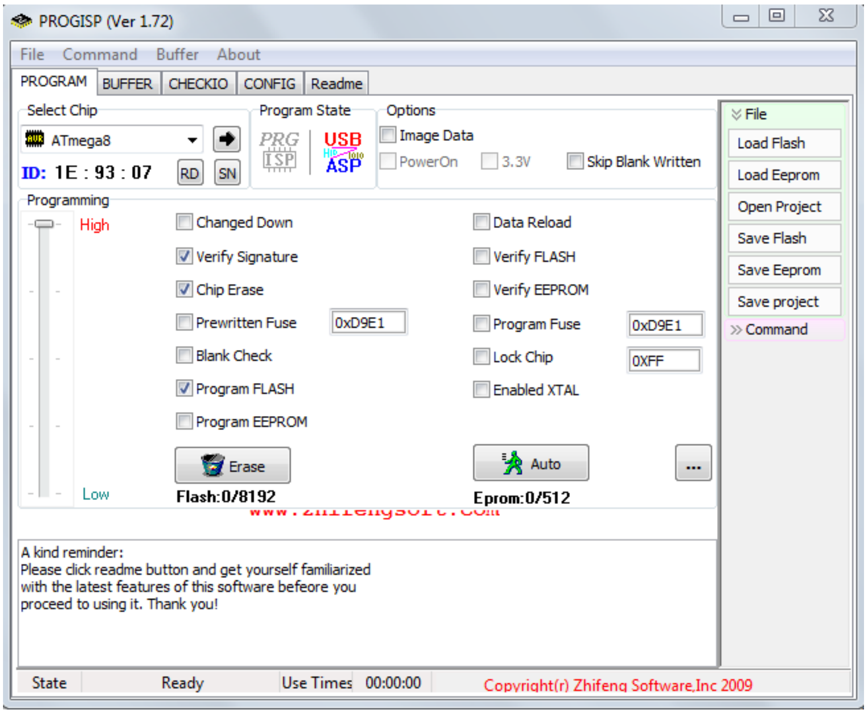


Figure 4.4- ProgISP burner tool

Flash burning process-Connect programmer to PC by USB cable → Open ProgISP → Select Chip: ATmega8 → Open Project: FYP.hex → Load Flash.

4.4 Printed Circuit Board Design

Once the schematic layout is complete, the PCB for the circuit can be designed. In Altium Designer, a new PCB file is added to the project. The blank PCB design file is shown in figure 4.5.

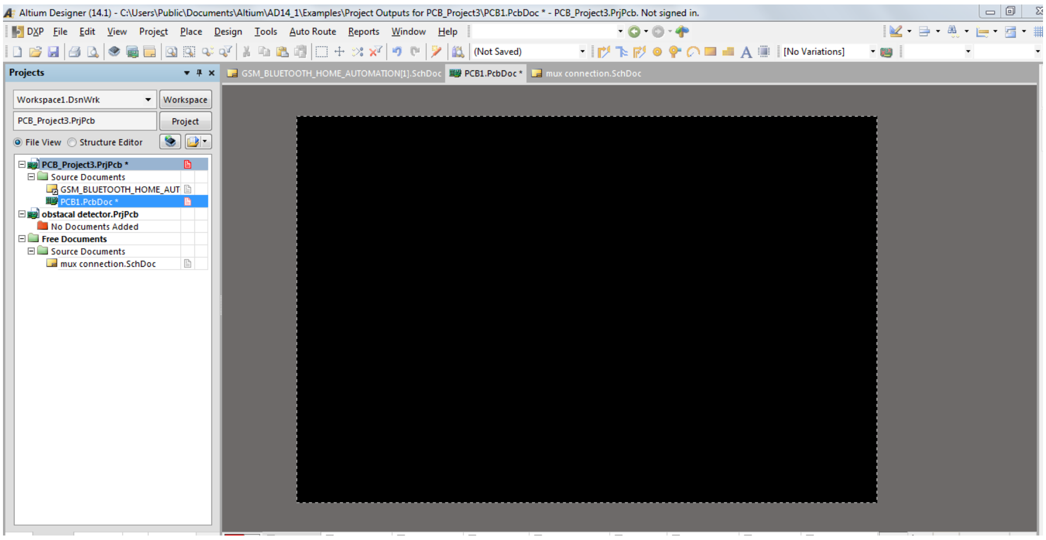


Figure 4.5- Blank PCB file

The PCB file imports the device footprints from the schematics layout. Each component used in the schematic layout has an inbuilt PCB footprint in the Altium Library. After the footprints are imported, they are connected as per the schematics diagram using the copper layer connections and the polygon plane is used to fill the copper area. The blue lines represent the copper tracks on the PCB.

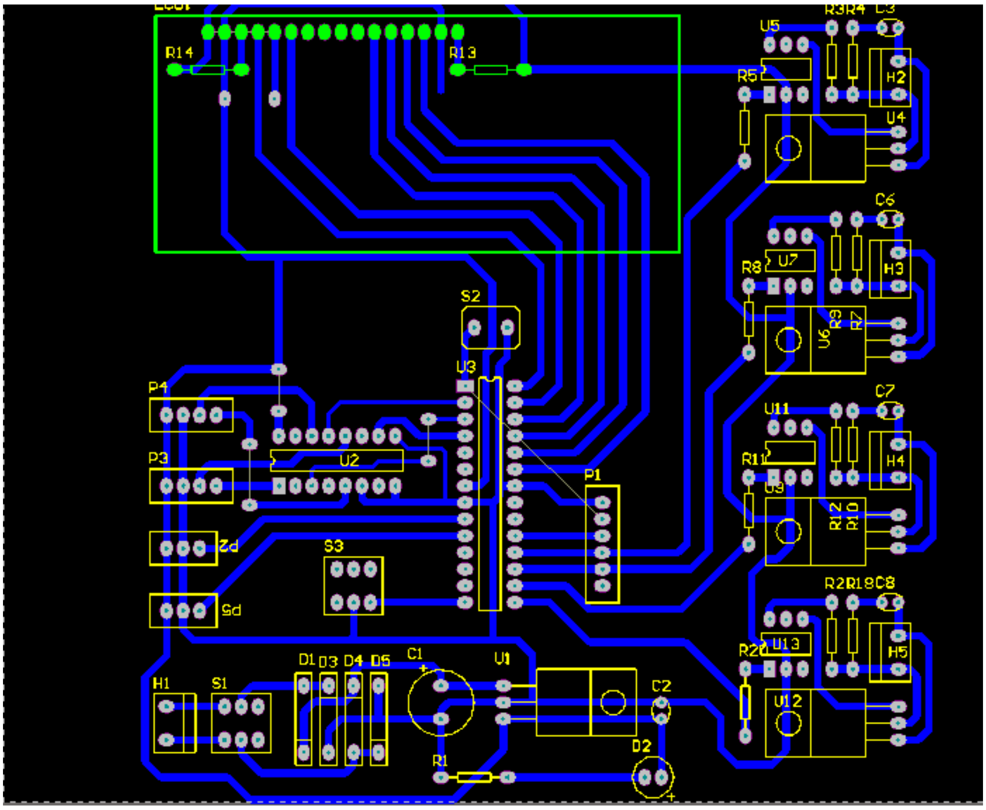


Figure 4.6- PCB footprints connection

The figure 4.7 shows the complete single layer PCB layout of the home automation circuit.

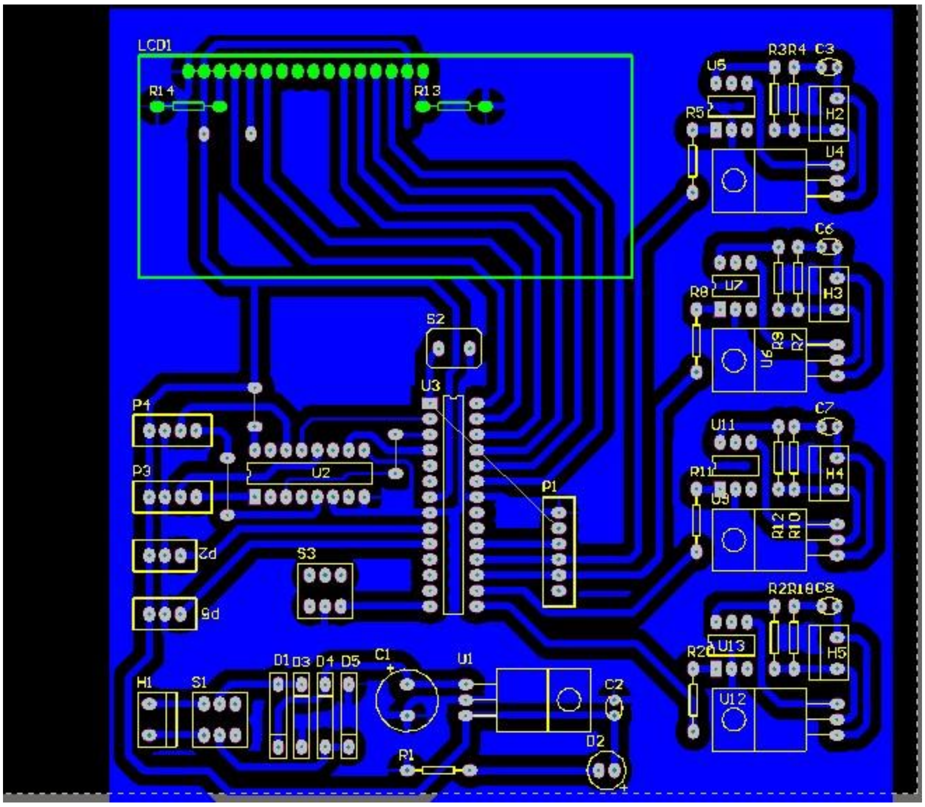


Figure 4.7- Completed single layered PCB layout

The PCB layout is converted into a PDF file to obtain the printable version of the layout.

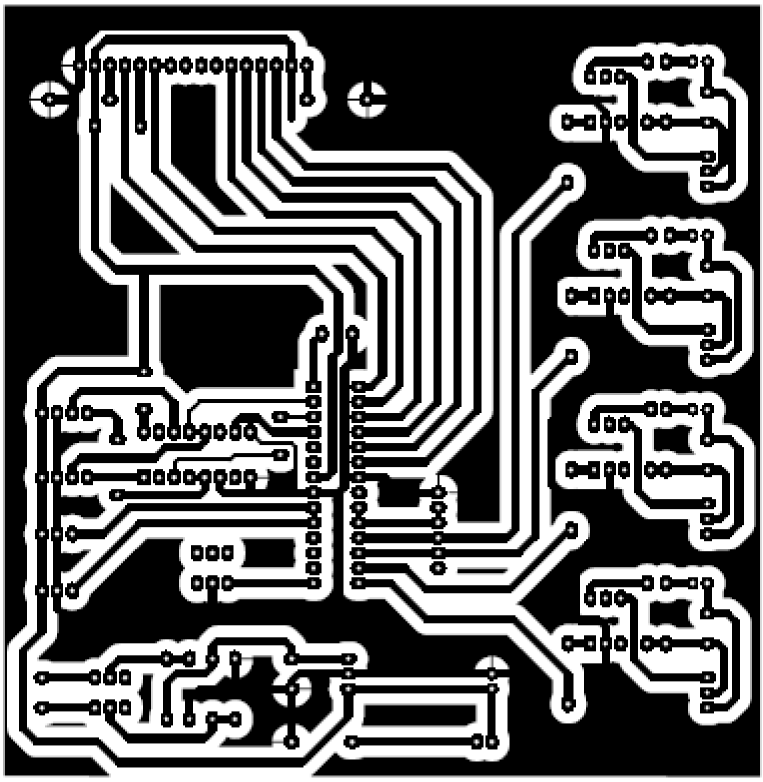


Figure 4.8- Black and white PCB layout

4.5 Hardware Implementation

The most interesting part of the design process is the hardware implementation where the PCB for the project is designed and the hardware components are connected. The hardware implementation involved the following steps-

1) **Circuit Board Printing:** A copper board is cut according to the size of the PCB layout and the copper is thoroughly rubbed with steel wool to remove the oxidation layer.

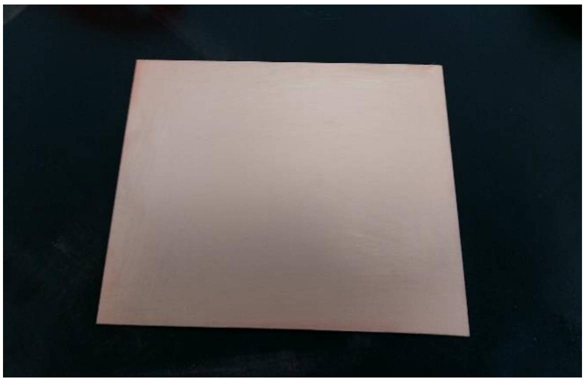


Figure 4.9- Blank copper board

A laser printout of the PCB is taken on a glossy paper and the printed side is placed on the copper board and packed gently. The board is now ironed for 8-10 minutes till the ink on the paper is transferred to the copper board.

Figure 4.10- Ironing the copper board

2) **Etching:** Once the layout is printed on the copper board, the PCB is dipped into the etching solution of ferric chloride ($FeCl_3$) and warm water for 15-20 minutes. After the 20-minute duration, the PCB is removed from the solution and washed with cold water. Thereafter, the copper remains only in the area covered in ink. The ink is removed by rubbing the board with steel wool and the board is ready for soldering.

Figure 4.11-PCB Etching

3) **Soldering the components:** The PCB is now drilled on the pads using a 1mm drill bit. The drilling is done carefully to prevent the copper pads from breaking. The components are placed in the drilled holes and soldered.

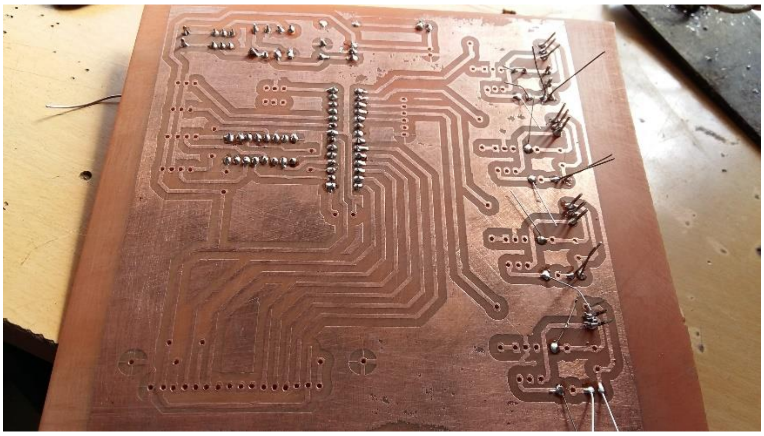


Figure 4.12- Drilling and soldering

The final circuit with all the components soldered is shown in the figure 4.13.

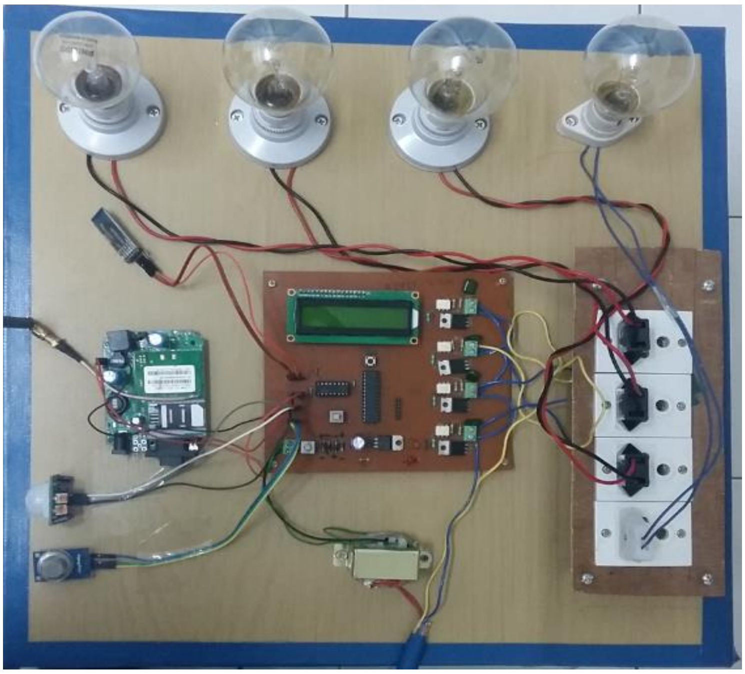


Figure 4.13- Completed design of home automation system

4.6 System Operation

The system operation is explained by the operational flow chart in figure 4.14. Once the system is on it performs the following functions-

1) Configures SIM300 GSM Modem
2) Selects operating mode (GSM or Bluetooth) based on the state of DPDT switch
3) Displays the current mode on LCD
4) Displays the load (electrical appliance) status: On/Off
5) The connected appliances can be controlled remotely via SMS or Bluetooth depending upon the current mode of operation
6) Regardless of the current mode of operation, if any of the sensor's state changes from low to high (stimulus detected), the microcontroller triggers an alert SMS which is delivered to the configured mobile phone.

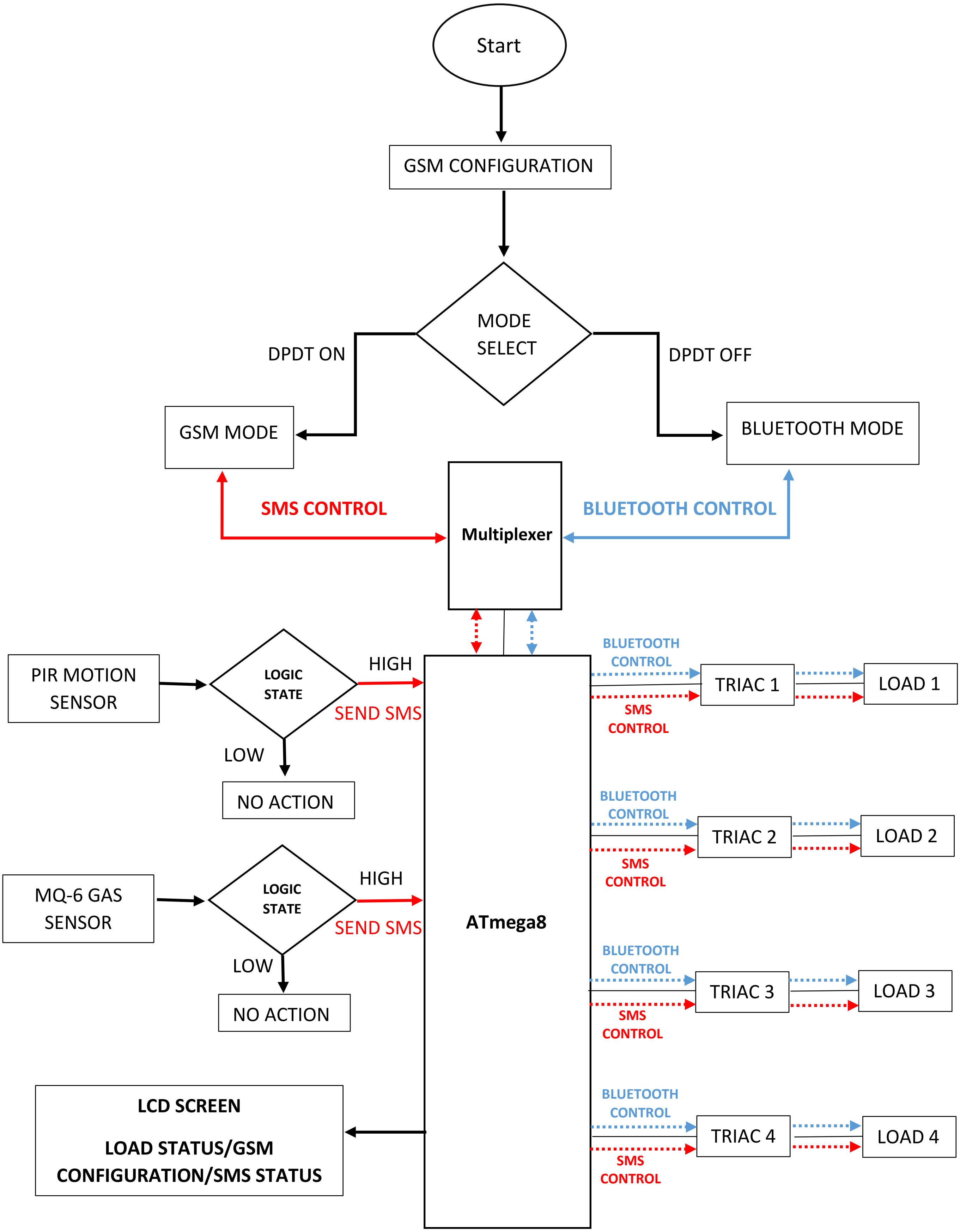


Figure 4.14- Operational flow chart of home automation system

4.7 Summary

The four phases (schematics layout, programming, PCB design, and hardware implementation) of the system design has been discussed in this chapter. It is important that the PCB etching should be carried out in proper laboratory conditions while wearing protective gear (lab coat and gloves) to prevent the chemicals to come in contact with skin as they can cause burn or skin injury. Also during soldering, reasonable precaution must be exercised to ensure solder fumes are not inhaled as it is injurious to respiratory health.

The system operates in Bluetooth mode and GSM mode depending upon the user's choice. When in Bluetooth mode a smartphone app with a Bluetooth SPP terminal can be used to control the electrical appliances. The Bluetooth mode also enables the user to connect with a voice recognition application or an external voice recognition device which can encode and transmit voice commands to the designed system, allowing the user to control the devices with voice. The GSM mode provides a worldwide connectivity and a user can send SMS text to control the appliances. It is also used to receive SMS whenever the connected sensors sense a stimulus.

CHAPTER 5

RESULTS AND ANALYSIS

5.1 Introduction

The Home Automation System consists of following sub-systems or modules-

- Power Source
- 74HC4052 Analog Multiplexer/De-Multiplexer
- AVR Atmega8 Microcontroller
- SIM300 GSM Modem
- HC-05 Bluetooth Module
- HC SR 501 PIR Motion Sensor
- MQ-6 Gas Sensor
- MOC3021 Opto-Coupler and BT136 Triac switch
- 16x2 LCD Screen

This chapter provides a detailed functional analysis and simulation results for the different modules used in this project. The circuit simulations are carried out in National Instruments Multisim 13 Student Version, which is a schematic capture and simulation program. Multisim is popularly used in electronics and electrical engineering design industry, academic projects and SPICE simulations.

5.2 Power Source

The power source for the circuit consists of a 9-0-9 transformer which is used to step down 230V to 9V. As mentioned in the circuit design, the bridge rectifier converts AC to DC which is further regulated to a stable 5V by LM7805 Voltage Regulator IC. The DC output of the rectifier is oscillating and has a high ripple factor. Hence a capacitor filter is used to maintain a proper voltage supply into the load circuit.

There are four steps involved in the power supply circuit design-

a) AC Step Down
b) Rectification
c) Filtering
d) Voltage Regulation

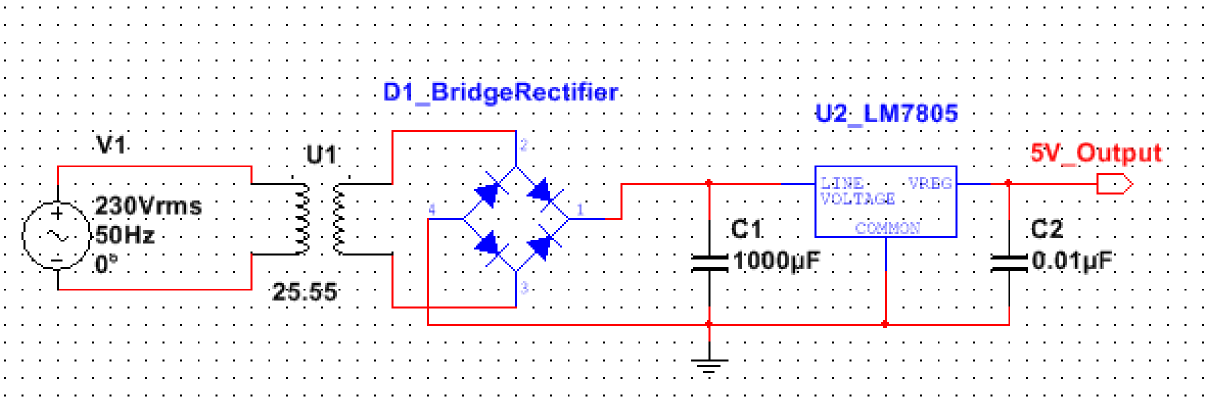


Figure 5.1-Power supply circuit.

The bridge rectifier output is shown in the following transient analysis graph (Figure 5.2).

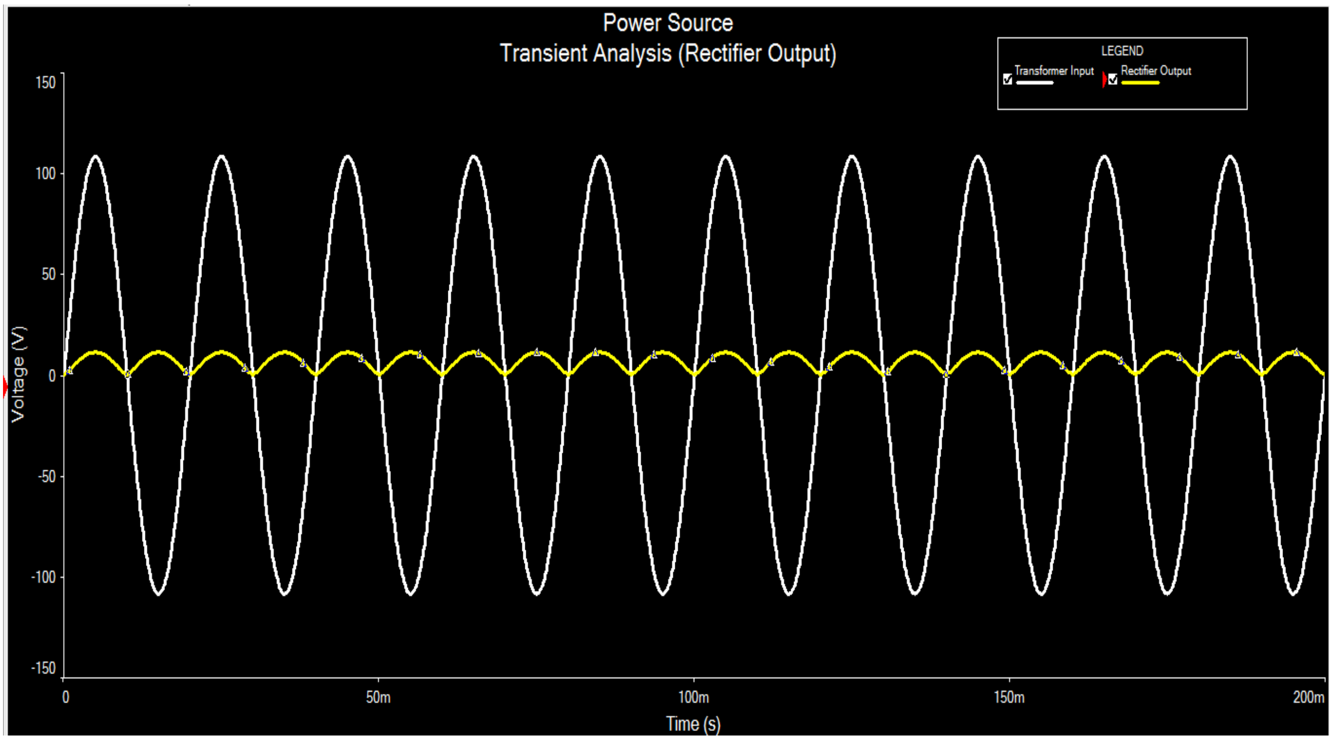


Figure 5.2-Full Wave Bridge Rectifier Output

$V_{RMS} = 9V$

$V_{pp} = V_{RMS}\sqrt{2} = 12.72V$

As can be observed, the rectifier output is oscillating DC with a high ripple factor. Hence ripple filter is used to obtain stable DC output.

To find capacitor value-

$C = \frac{It}{V}$ Where, I = Maximum output current of the transformer = 500mA, t = 10ms

Conversion of 50Hz AC to DC results in a wave frequency of 2x50= 100Hz as one pulse is converted into 2.

For f=100Hz t=1/100= 10ms

V= Peak Voltage – Voltage to the regulator

Minimum voltage needed by LM7805 regulator is 2V greater than the regulated voltage, i.e 5V+2V= 7V

9-0-9 is the RMS value of the transformer, hence the peak voltage Vpeak= $9\sqrt{2}$ = 12.72V.

For each half wave, 2 diodes will be forward biased hence a voltage drop of 1.4V (0.7V per diode is observed). Also, when the capacitor discharges into load the voltage drop across the regulator is 7V.

Therefore $V = 12.72 - 1.4 - 7 = 4.33V$

$$C = \frac{It}{V} = \frac{500mA * 10ms}{4.33} = 1154\text{uF}$$

The following graph shows the rectified output with a ripple filter capacitor of 1000uF.

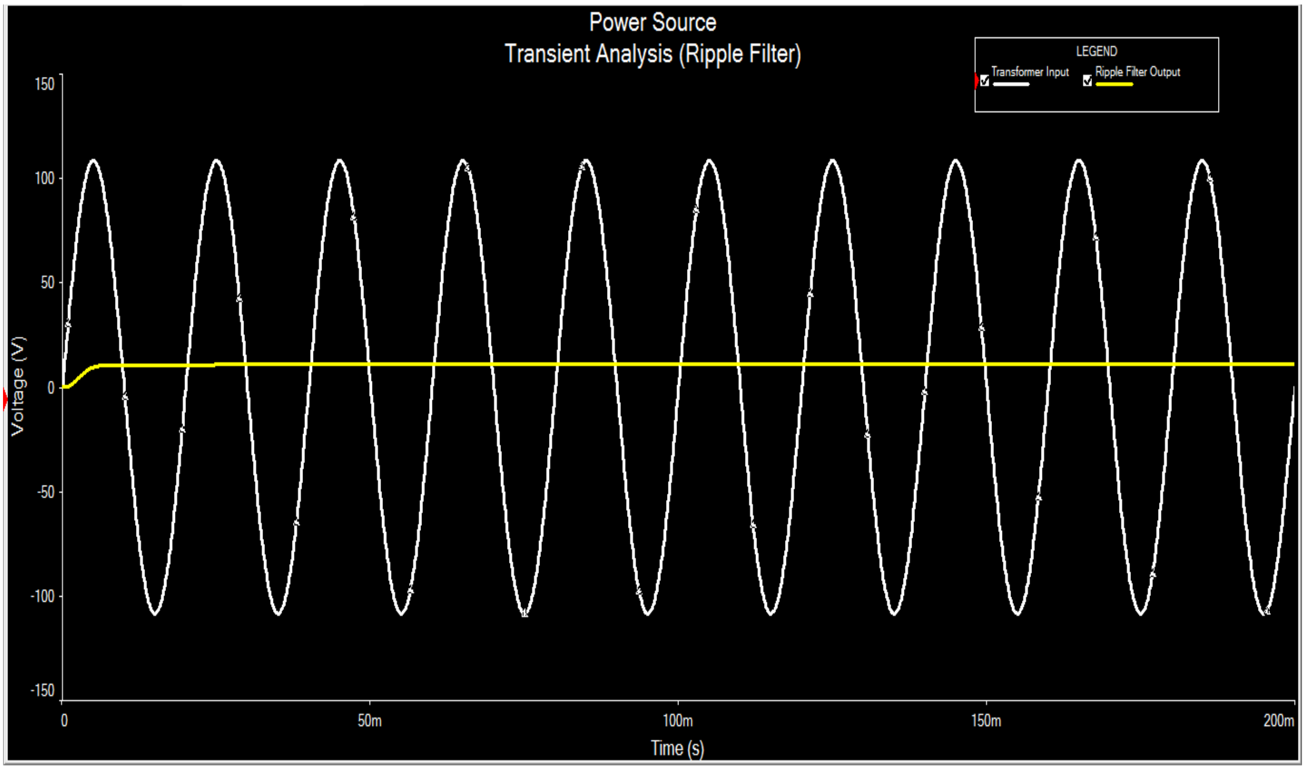


Figure 5.3- Ripple filter output

The ripple filter yields a stable 7V DC output. This is further fed into the LM7805 Voltage Regulator which reduces the voltage to 5V DC.

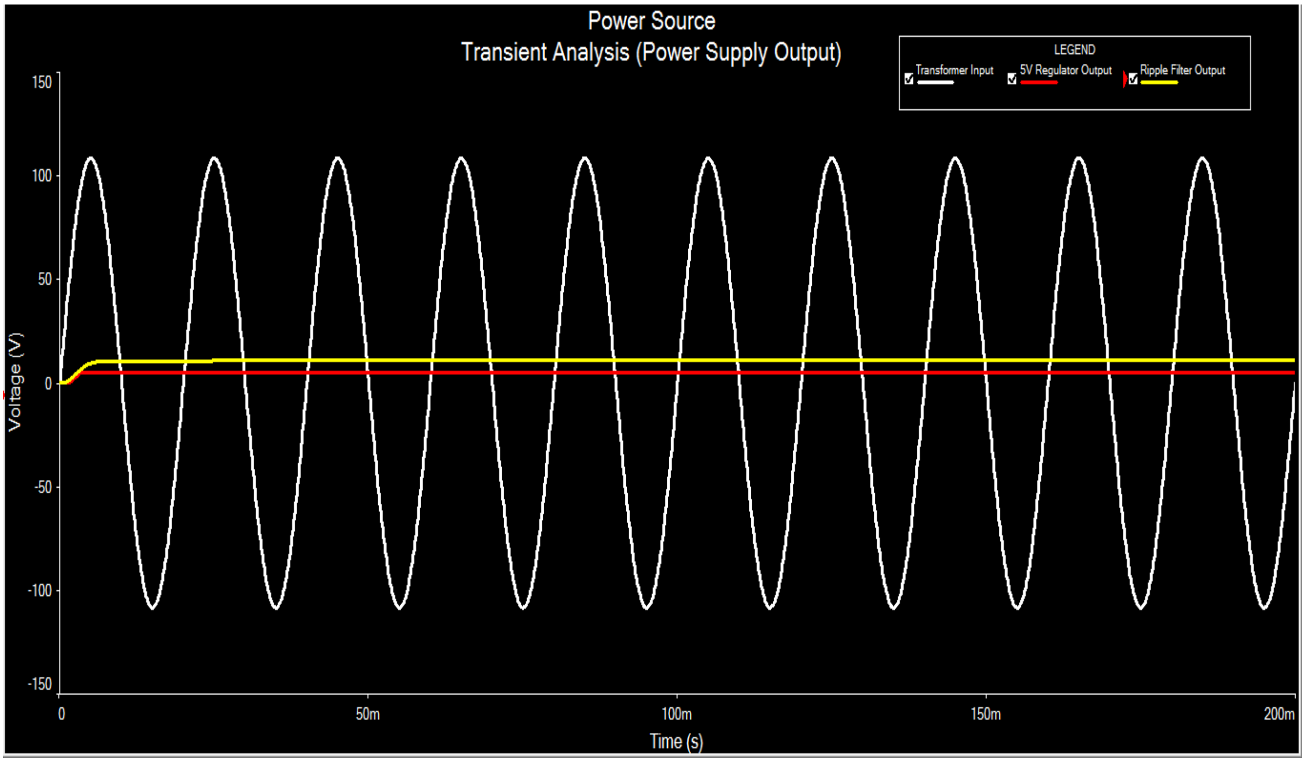


Figure 5.4- Power supply output

5.3 74HC4052 Multiplexer/De-multiplexer

The Atmega8 microcontroller has a single USART (Universal Synchronous Asynchronous Receiver and Transmitter) i.e one pair of transmitter and receiver pins (RXD-Pin 2 and TXD Pin-3), thus in order to connect more than one communication modules with the USART, a 74HC4052 analog multiplexer/de-multiplexer is used.

74HC4052 is a high speed Si-gate CMOS device that operates as dual 4-channel analog multiplexer and demultiplexer with common select logic (Philips, 2004) which is used to interface the Bluetooth (HC 05) and GSM (SIM300) modules with the microcontroller. There are four independent input/output pins (nY0 to nY3) along with a common input/output pin (nZ). Inputs S0 and S1 are used as common channel select logic along with an active low enable Ē. Voltage tolerance (Vcc) lies between 2V to 10V and Vcc-V_{EE} should not increase more than 10V (Philips, 2004).

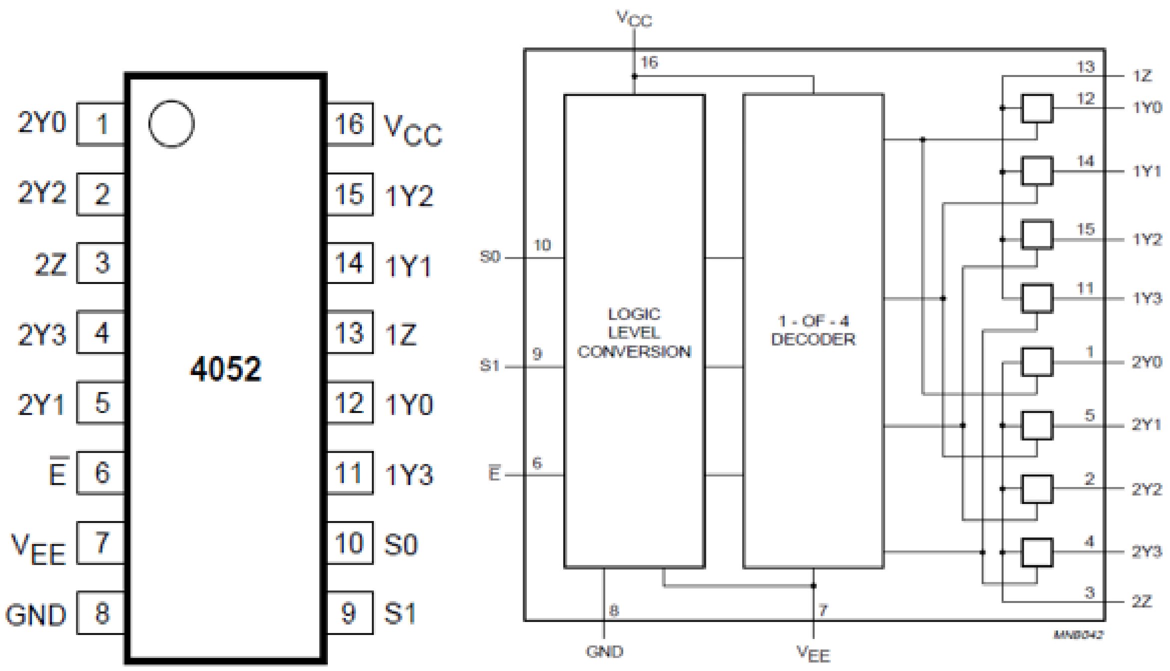


Figure 5.5- 74HC4052 Pinout and Functional Diagram (Philips, 2004).

Table 5.1 shows the logical operation of 74HC4502 along with enable Ē and select inputs S0 and S1.

Table 5.1- 74HC4052 Mux Truth Table

INPUT			CHANNEL BETWEEN
Ē	**S1**	**S0**	
0	0	0	nY0 and nZ
0	0	1	nY1 and nZ
0	1	0	nY2 and nZ
0	1	1	nY3 and nZ
1	X	X	None

Source: (Philips, 2004) 74HC4052 Datasheet

The figure 5.6 shows the connections between the Atmega8 USART and the communication modules through 74HC4052 IC.

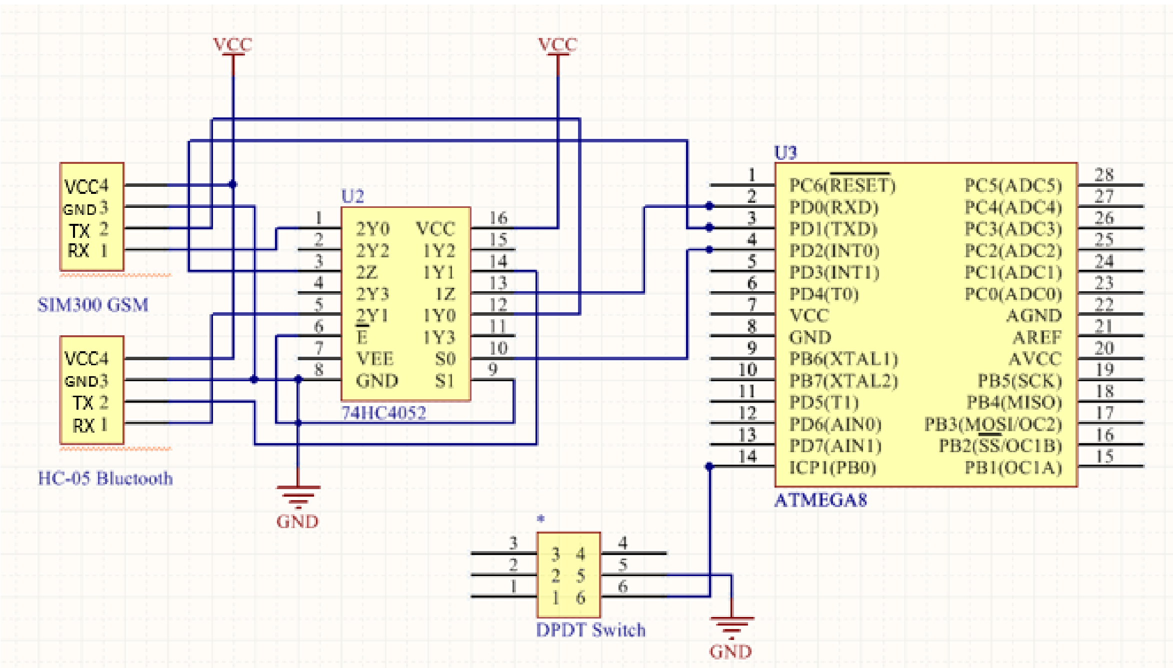


Figure 5.6- Bluetooth and GSM connection with ATmega8-USART

The DPDT push button is used to toggle between GSM and Bluetooth mode. The logic 0 on Pin14 of microcontroller (DPDT Push-On state) yields a select logic S1=0 and S0=0 in 4052, which establishes a channel between 1Y0-1Z and 2Y0-2Z (Table 5.2). The channel 1Y0-1Z connects the GSM Pin2 (GSM-TX) to the microcontroller Pin2 (USART-RXD) and the channel 2Y0-2Z connects GSM Pin1 (GSM-RX) to microcontroller Pin3 (USART-TXD). This allows the microcontroller USART to receive/transmit command signals (in the form of SMS) through the SIM300 GSM Modem hence the system operates in the GSM/SMS mode.

The Push-Off state of the DPDT switch provides a logic 1 on the Pin14 (Port B) of the microcontroller resulting in the select logic S1=0 and S0=1, establishing channel between 1Y1-1Z and 2Y1-2Z (Table 5.2) connecting the Bluetooth Transmitter (BT Pin2) to the UART Receiver (microcontroller Pin2) and Bluetooth Receiver (BT Pin1) to the USART Transmitter (microcontroller Pin3) respectively. This allows the UART to receive/transmit command signals through the HC-05 Bluetooth module and hence the system operates in Bluetooth mode.

Table 5.2- 74HC4052 Functional Logic

<table>
<tr><th colspan="3">INPUT</th><th rowspan="2">CHANNEL</th><th rowspan="2">CONNCETION BETWEEN</th></tr>
<tr><th>$\bar{E}$</th><th>S1</th><th>S0</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1Y0-1Z(O/P) & 2Y0-2Z(I/P)</td><td>(GSM TX – USART RXD) and (GSM RX – USART TXD)</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>1Y1-1Z(O/P)</td><td>(BT TX – USART RX)</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>Not Used</td><td>–</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>Not Used</td><td>–</td></tr>
<tr><td>1</td><td>X</td><td>X</td><td>None</td><td>None</td></tr>
</table>

Note: Though the select logic S1=0, S0=1 can establish the channel 2Y1-2Z allowing the connection between Bluetooth receiver and UART transmitter, this channel however is not used in this project. Sometimes it is possible that the user can lose the Bluetooth connection due to increased distance or lack of phone battery. In such a case it is important to ensure that the user is notified of a gas leak or an unwanted motion. Therefore the code for the microcontroller is written in order to utilize the Pin 2Z of 4052 as a common input for the SIM 300 transmitter at all times. This is done in order to enable the system to send SMS to the user whenever the motion sensor or the gas sensor is active regardless the current mode of operation. This means even if the system is in the Bluetooth mode, the user will still receive SMS from the GSM modem if any of the sensor detects an anomaly.

5.4 AVR Atmega8 Microcontroller

The AVR (Advanced Virtual RISC) ATmega8 follows the RISC (Reduced Instruction Set Computing) architecture that allows the device to run faster through the use of reduced number of machine level instructions (Barnett, O'Cull, & Cox, Embedded C Programming and Atmel AVR 2E, 2007). In this project, the AVR ATmega8 microcontroller is used to operate the communication peripherals (GSM and Bluetooth Module), sensors, LCD screen and triac triggering to switch on/off electrical appliances.

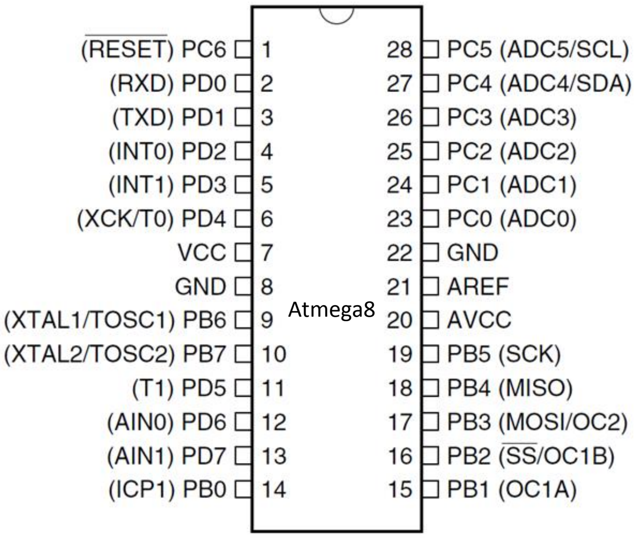


Figure 5.7- AVR ATmega8 Pinout (Atmel Corporation, 2015)

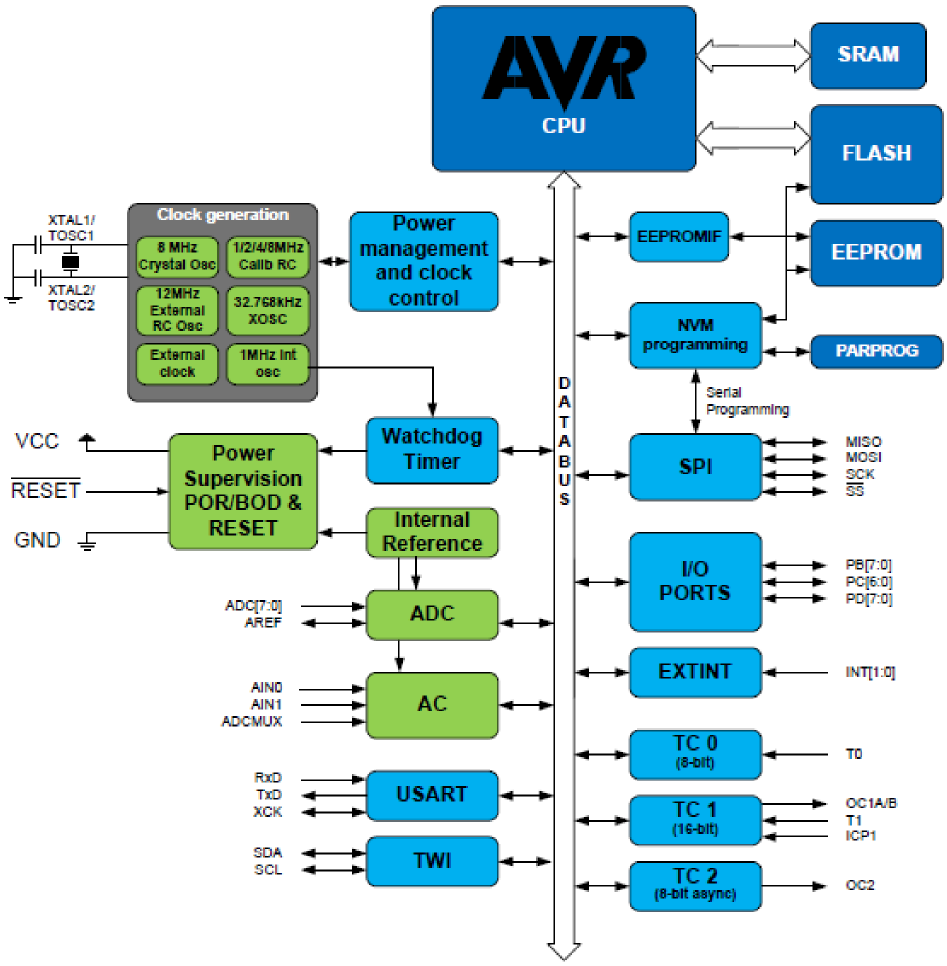


Figure 5.8- AVR ATmega8 Block Diagram (Atmel Corporation, 2015)

5.4.1 Defining I/O

The microcontroller is programmed using Embedded C language which consists of specialized C libraries for embedded system development. The ATmega8 dual-in-line package consists of 28 pins with three 8 bit input/output ports namely PORTB, PORTC and PORTD, with 8 I/O pins each (Atmel Corporation, 2015).

The following code is written to define the system I/O and importing the required libraries-

```
#define F_CPU 1000000UL // defines the CPU frequency (using the internal clock) to 1MHz
#include<avr/io.h>
#include<util/delay.h>
#include"LCD.C"
#include"gsm.c"

#define mode ((PINB&(1<<PB0)))
#define pir  ((PINB&(1<<PB6)))
#define lpg  ((PINB&(1<<PB7)))
```

The following header files are used to import libraries-

- Avr/io.h : Contains the IO definitions for the microcontroller specified by the compiler command line switch
- Util/delay.h : Provides the delay between successive code execution
- LCD.C : C library for 16x2 LCD screen
- GSM.C : C library to configure GSM modem

The three initially defined variables are-

- Mode : Stores the logic value on Pin14 (PB0), used to toggle between GSM and Bluetooth mode
- Pir: Defines Pin PB6 (Pin9) as input pin for the PIR sensor output
- Lpg: Defines Pin PB7 (Pin10) as input pin for LPG sensor output

5.4.2 Interfacing SIM300 GSM Modem

The SIM300 GSM modem allows the users to stay connected with their houses through GSM from anywhere in the world. SIM300 is a triband GSM modem that operates in 900MHz, 1800MHz and 1900MHz bands. It uses Hayes commands or AT commands (AT stands for attention!) to send SMS, make calls and access GPRS. In this project, SIM300 is used to receive SMS commands to turn on/off electrical appliances. It also sends SMS to the user if a sensor reading goes high. The connection between SIM300 and ATmega8 via 74HC4052 multiplexer is shown in figure 5.6

Figure 5.9- SIM300 GSM modem (EMsys, 2011)

The AT Commands used for this project to configure the SIM300 and their functions are –

Table 5.3- AT configuration commands for SIM300

COMMAND	DESCRIPTION	EXPECTED RESPONSE
AT	Used to test the condition of the modem and check if the system is functional or not.	\r\nOK\r\n or an \r\nERROR\r\n in case of error.
ATE0	Disables echo. Prevents modem to echo commands received from DTE.	OK 1 = echo on 0 = echo off
AT+CPIN?	To check if any password is required or not.	• READY : no further entry needed • SIM PIN : equipment waiting for pin • SIM PUK : equipment waiting for

		puk
AT+CREG?	To check weather network is available or not.	OK (CONNECTED) : registered on network +CME ERROR: error related to equipment functionality
AT+CMGF=1	To select input and output format of messages.	0 = PDU (Protocol Data Unit) mode 1 = Text mode
AT+CMGD=1	Range of SMS on SIm card to be deleted.	OK (DONE) CMS ERROR (FAILED): in case of error related to equipment functionality

Please refer to Appendix 1 for the full program to configure GSM modem and display the obtained response.

In order to prevent any unauthorised person to send/receive messages, the user has to send a one-time SMS with the string- *MOB(authorised mobile number)# to the GSM modem. By doing this, only the authorised mobile number will be able to send/receive system messages. The Defining SMS Mode subroutine of the program defines the GSM mode LCD display, authorized mobile phone to send/receive SMS and SMS instruction commands to control the electrical devices connected to the system.
For full code please refer to Appendix 1.

Table 5.4 gives the detailed set of SMS commands and their respective system response-

Table 5.4- SMS commands for GSM mode and respective system response

SMS COMMAND	SYSTEM RESPONSE
*light on#	D1 (light) On
*light off#	D1 (light) Off
*fan on#	D2 (fan) On
*fan off#	D2 (fan) Off
*motor on#	D3 (motor) On
*motor off#	D3 (motor) Off
*heater on#	D4 (heater) On
*heater off#	D4 (heater) Off

It should be noted that the electrical devices mentioned here (light, fan, motor and heater) are arbitrary. The SMS commands controls the electrical sockets through BT136 Triacs which has 250V tolerance which means any electrical appliance below 250V operating voltage can be connected and the command can be changed accordingly. The system also sends SMS notifications to the user whenever the PIR or Gas sensor reading goes high. The sensor and their respective notification messages are presented in table 5.5.

Table 5.5- Sensors and their respective notifications

SENSOR	**SMS NOTIFICATION**
PIR Motion Sensor (HC SR 501)	SOMEBODY ENTERD IN YOUR AREA
LPG Gas Leakage Sensor (MQ-6)	GAS LEAKAGE DETECTED

Once again, the notification commands are arbitrary and can be changed according to the type of sensor connected.

5.4.3 Interfacing HC-05 Bluetooth Module

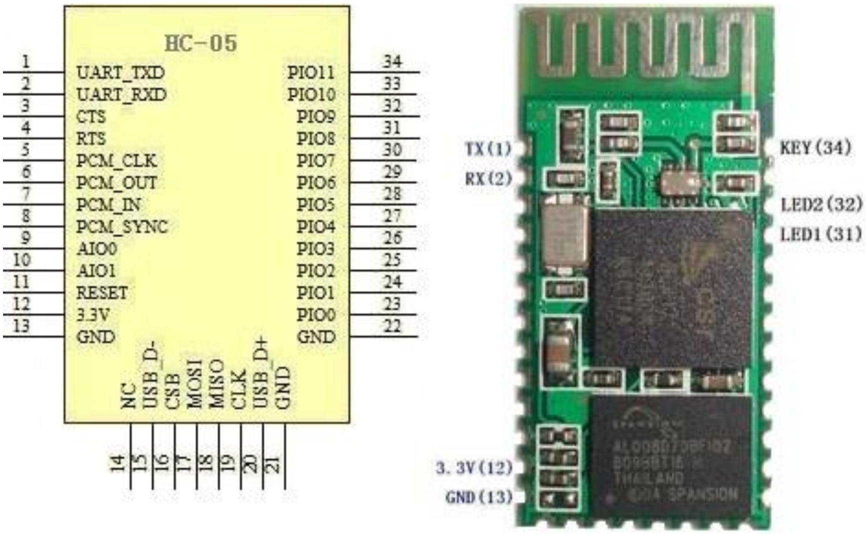


Figure 5.10- HC-05 Bluetooth module (Marchi, 2015)

When in the Bluetooth mode (Mux select logic S0=1, S1=0), the ATmega8 microcontroller communicates with the smartphone using HC 05 Bluetooth module in slave mode. The Bluetooth module uses the Serial Port Profile/Protocol to set up virtual serial ports and connect two Bluetooth enabled devices. In this particular application, the smartphone acts as the Initiator (device that initiates the connection) and the HC-05 acts as the acceptor. The following figure shows the OSI layers protocols for the Serial Port Profile where Baseband, LMP and RFComm are layer 1,2 and 3 Bluetooth protocols-

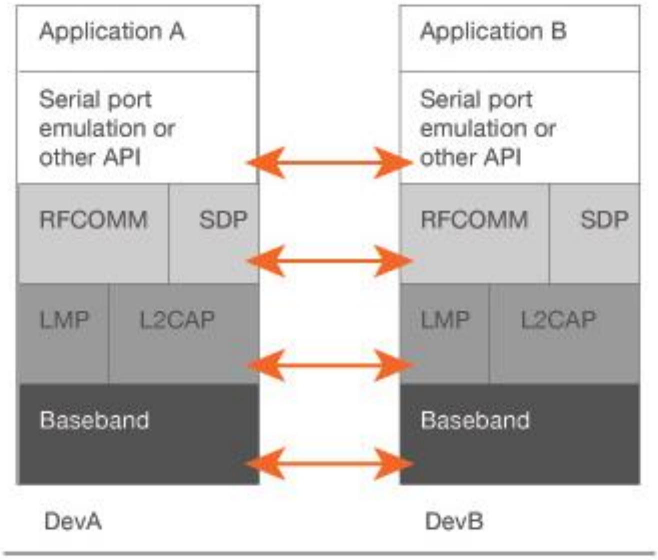
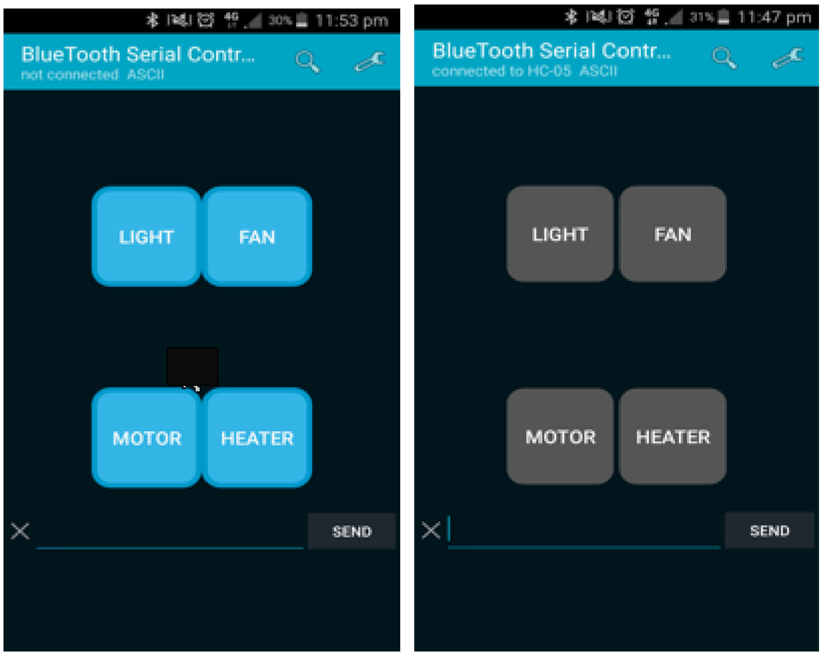


Figure 5.11- OSI layer protocols for SPP (Bluetooth Inc, 2015)

When in Bluetooth mode, the user has the facility to provide input commands through a smartphone app or via a voice recognition system. In this project a Bluetooth SPP app is used to configure an Android GUI with buttons to control the electrical appliances. The app allows the user to connect to a Bluetooth device and the buttons transmits a predefined command over the Bluetooth SPP channel. The app is modifiable and can be configured according to the types and number of devices connected. The figure 5.12 shows the proposed home automation GUI for Android phones.



A) B)

Figure 5.12- Bluetooth control for the home automation system. A) All on B) All off

In order to simplify the interaction with the system in Bluetooth mode, the user can send the control commands through an open source Voice Recognition System like Google's or Microsoft Cortana. For the demonstration purpose, the home automation system is connected via Bluetooth to a demo app called Android Meets Robot. The Android Meets Robot app is designed to allow a user to communicate with an embedded system.

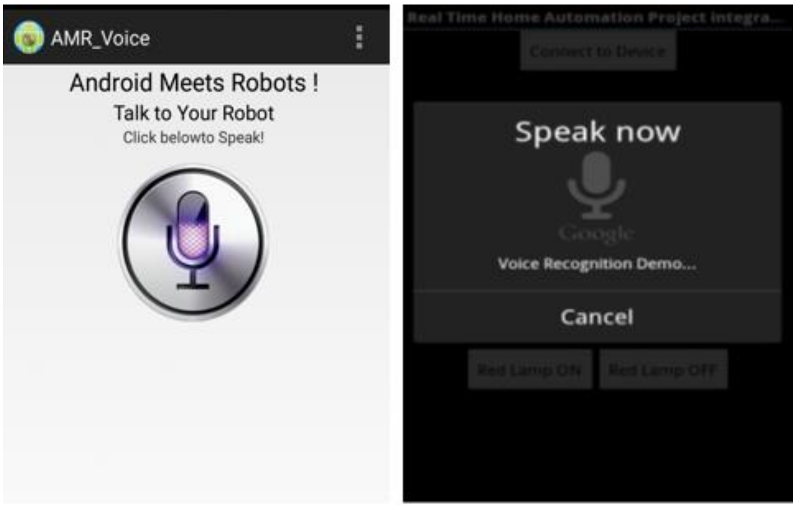


Figure 5.13- AMR app with Google Voice Recognition

The Bluetooth mode follows the similar command set and respective system response as the GSM mode.

Table 5.6- System response for voice command

VOICE COMMAND	APP RESPONSE (OVER BLUETOOTH CHANNEL)	SYSTEM RESPONSE
light on	*light on#	D1 (light) On
light off	*light off#	D1 (light) Off
fan on	*fan on#	D2 (fan) On
fan off	*fan off#	D2 (fan) Off
motor on	*motor on#	D3 (motor) On
motor off	*motor off#	D3 (motor) Off
heater on	*heater on#	D4 (heater) On
heater off	*heater off#	D4 (heater) Off

Instead of using a smartphone, a user can install **Amazon Echo Dot** (Amazon.com Inc, 2016), a small hands-free voice controlled device with far-field voice recognition system, in various locations throughout a house, to capture voice commands and control house appliances. Echo Dot can connect to the designed home automation system via Bluetooth and can hear the user from even a far-off distance through an in-built microphone array.

Figure 5.14- Amazon Echo Dot (Amazon.com Inc, 2016)

5.4.4 HC-SR-501 PIR Motion Sensor

Security systems have always been an integrated part of advanced home automation systems. The HC-SR-501 PIR sensor is used in this project to ensure domestic security through motion detection. During night or at times when the premises are vacant, the motion sensor module can be switched on to ensure the user can be notified if any unauthorized motion is detected in order to prevent burglaries and break-ins.

The PIR sensor is connected to the digital pin 9 (PB6) of ATmega8. The connection schematic is shown in the following figure-

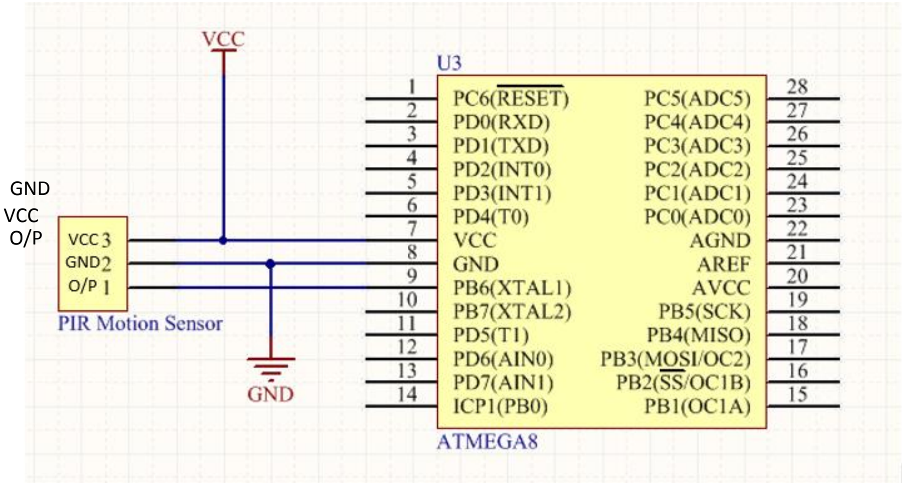


Figure 5.15- PIR sensor interface with ATmega8

Operation

The Pin 9 of microcontroller is configured as an input pin. It takes the input from the sensor and triggers the SIM300 module to send alert message to the user.

The PIR motion sensor module contains a pyroelectric sensor to detect levels of IR radiation. The pyroelectric sensor is constructed with two IR sensor blocks made of crystalline material which generates surface charge when exposed to heat in form of infrared radiation (Yun & Lee, 2014). A typical configuration and drive circuitry, provided by the manufacturer for the HC SR-501 module is shown in the following figure-

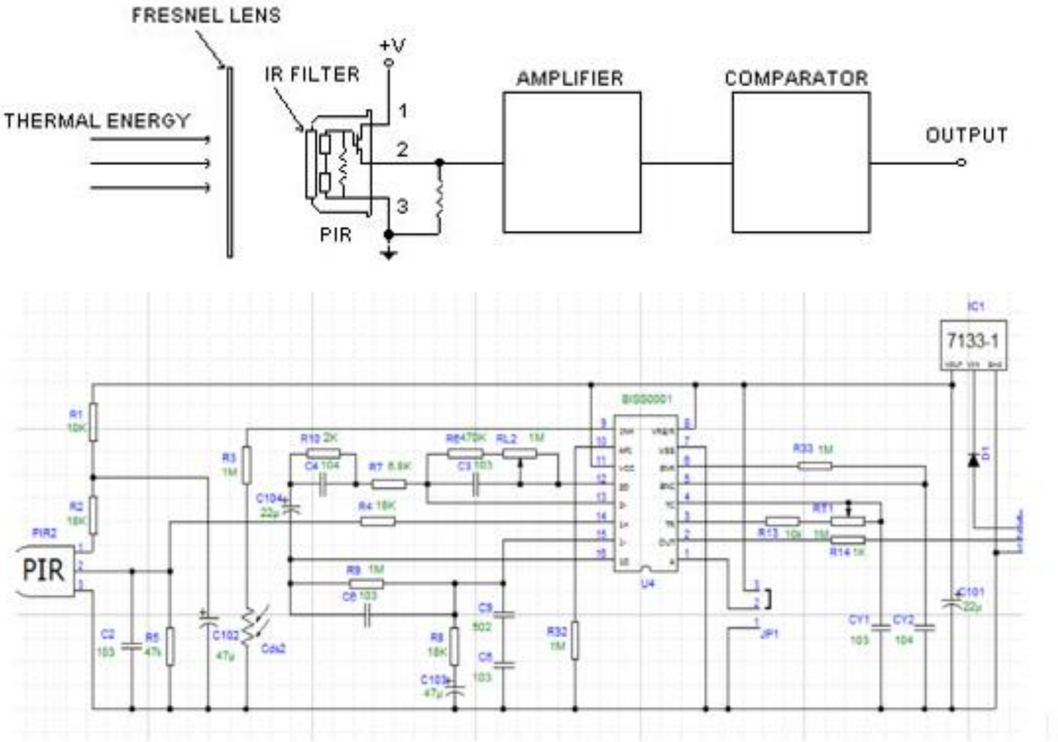


Figure 5.16- HC SR 501 module configuration and drive circuitry

A Fresnel lens is used to increase the sensing range of the pyroelectric sensor. As shown in figure 5.17**,** a Fresnel lens focuses a wider range of IR radiation onto the sensor.

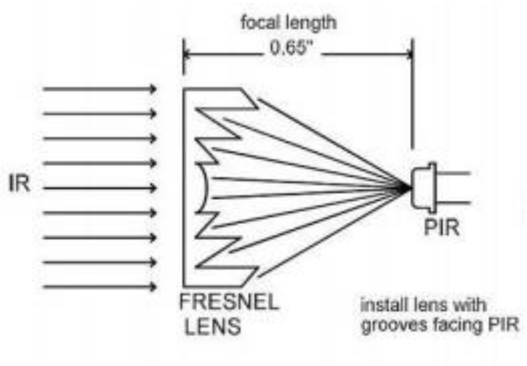


Figure 5.17- Fresnel lens used to focus IR radiation (Yun & Lee, 2014*)*

The analog reading of the sensor vary according to the distance of the detected object. For this project to measure the variation in output voltage of the sensor, a test object was placed at different distances and the respective output voltage was measured. The following graph shows the different analog voltage readings of the pyroelectric sensor, with the Fresnel lens, acquired by placing an object at different distances.

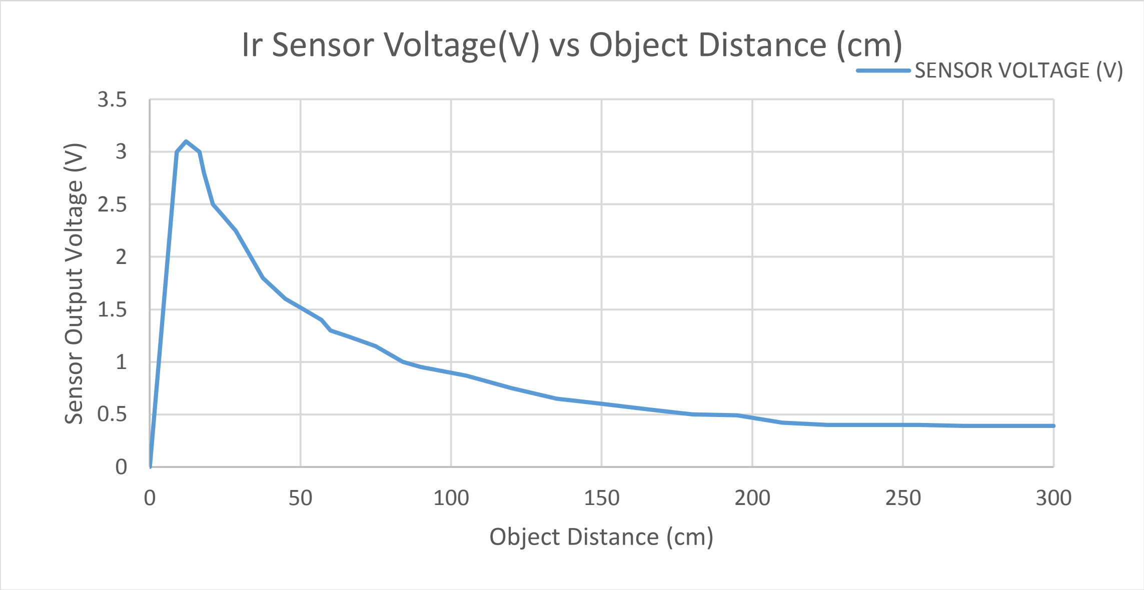


Figure 5.18- PIR sensor voltage vs object distance

It can be observed that the output voltage decreases as the distance of the object increases. The BISS0001 IC used in the HC-SR-501 module is a high performance sensor signal processor with variable sensitivity that works with an op-amp based comparator (Adafruit, 2012). When a warm body is intercepted by any one of the detecting IR block, it generates a positive differential voltage between the two blocks. When the intercepted body moves out of the range, a negative differential change is generated and this causes BISS0001 to generate an output pulse.

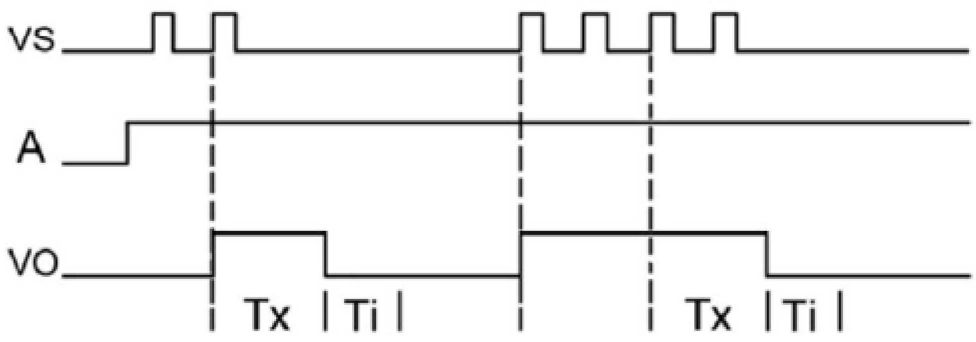


Figure 5.19- PIR sensor waveform (Pereira, 2015)

In this project the sensor works in the Retriggerable mode which allows the sensor to re-trigger the output pulse every time an object is detected. In figure 9, the signal Vs represents the sensor reading whenever an object is detected, A is the selected mode (in this case Retriggerable) and Vo shows the output voltage and control signal. Once Vo= High, the ATmega8 delivers the AT+CMGS command to SIM300 to send text alert to the user. The PIR sensor can parallelly be connected to a siren circuit in order to trigger an alarm if a motion is detected.

5.4.5 MQ-6 Gas Sensor

MQ-6 is highly sensitive to LPG, Isobutane, methane, propane, natural gas, alcohol and cigarette smoke. The LPG gas explosions in a domestic or commercial environment can be catastrophic and cause significant damage to life and property. The MQ-6 sensor integrated with the home automation system notifies the user of a gas leak as small as 200 ppm (Parts per Million). The internal schematics of the MQ-6 sensor are shown in the following figure-

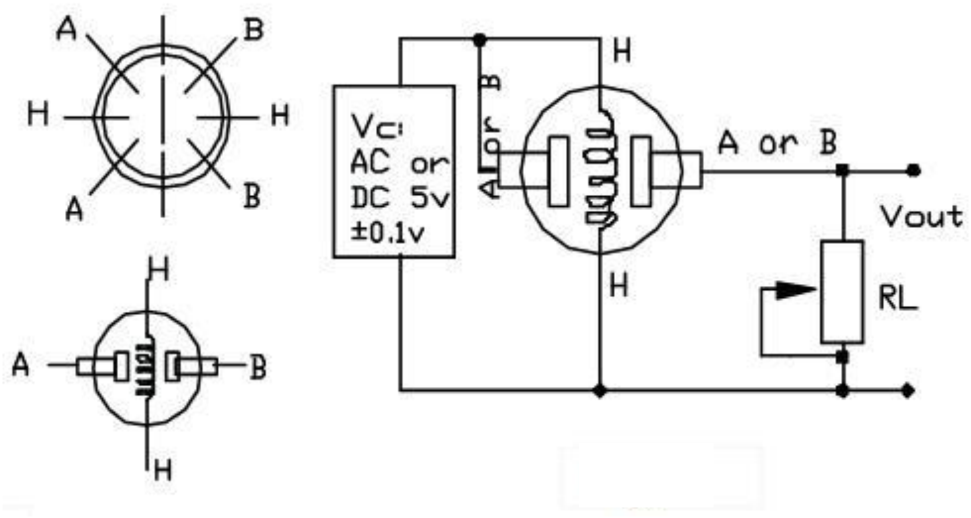


Figure 5.20- MQ-6 internal schematics (Mohankumar, 2012)

When powered by the Vcc, the coil is heated in approximately 20 seconds. The sensing material in MQ-6 is a **Tin DiOxide** semiconductor, which is heated up using a copper wire coil with 5V. Once the sensing material comes in contact with gas particles, it generates a surface charge leaving positive charge in space charge layer (Mohankumar, 2012).

The gas sensor output is connected to the Pin 10 (PORT B, pin7). The connection of MQ-6 with ATmega8 is show in the following diagram-

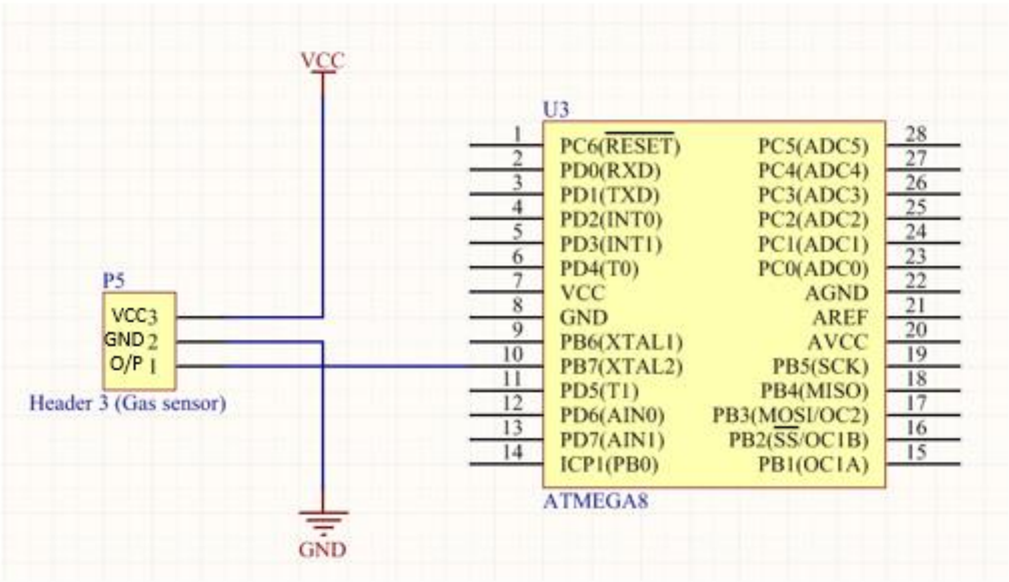


Figure 5.21- MQ-6 connection with ATmega8

Figure 5.21 shows the typical sensitivity characteristics of MQ-6 for several gasses. Ro is the sensor resistance at 1000ppm of LPG in clean air and Rs is the sensor resistance at various concentrations of gasses.

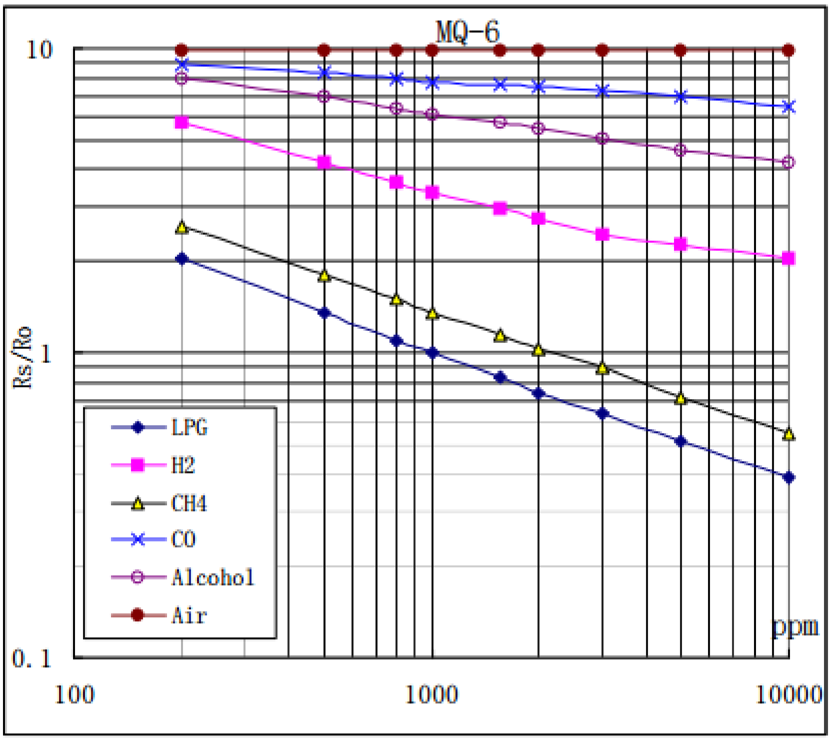


Figure 5.22- Sensitivity characteristics of MQ-6 (Hanwei Sensors, 2012)

The system response when MQ-6 detects a gas leak or smoke, is given in table 5.2. Figure 5.23 shows the LCD display for gas detection and the received notification in the user's mobile phone.

Figure 5.23- LCD display and received SMS in case of gas leak

5.4.6 Switching Circuitry MOC3021 Opto-couplers and Bt136 Triacs

The initial circuit design proposed during the Final Year Project 1, utilised electromechanical relays to switch on or off connected appliances. However, it was observed that relays are prone to reverse current which can flow through the coil back to the electronic circuitry (in this case the microcontroller). This poses a risk of damaging the microcontroller. Also, overheating of the relay coil can result in a short circuit and causes the tripping of the miniature circuit breakers used in the domestic power supplies.

In order to prevent the shortcomings of electromechanical relays, the switching circuitry design is upgraded with MOC3021 Opto-Isolator and BT136 triacs. The following are the advantages of using opto-couplers and triacs over electromechanical relays-

- The triacs are noise free (unlike relays), can handle voltage up to 400V
- Allows triggering in all four quadrant
- Opto-couplers provide a complete electrical isolation between the electrical subsystem and the electronic components of the circuit preventing any damage due to reverse current
- There is no electromagnetic induction due to switching sparks/arc
- Instead of only switching on/off, triacs can be used to dim lights or control the speed of a DC motor. Triacs and opto-couplers are smaller in size and occupy much lesser space on the PCB as compared to relays

For purpose of demonstration, four sets of triac switches are used in this project and thereby four devices can be connected. The switching circuitry with opto-coupler and triac is shown in the figure 5.24.

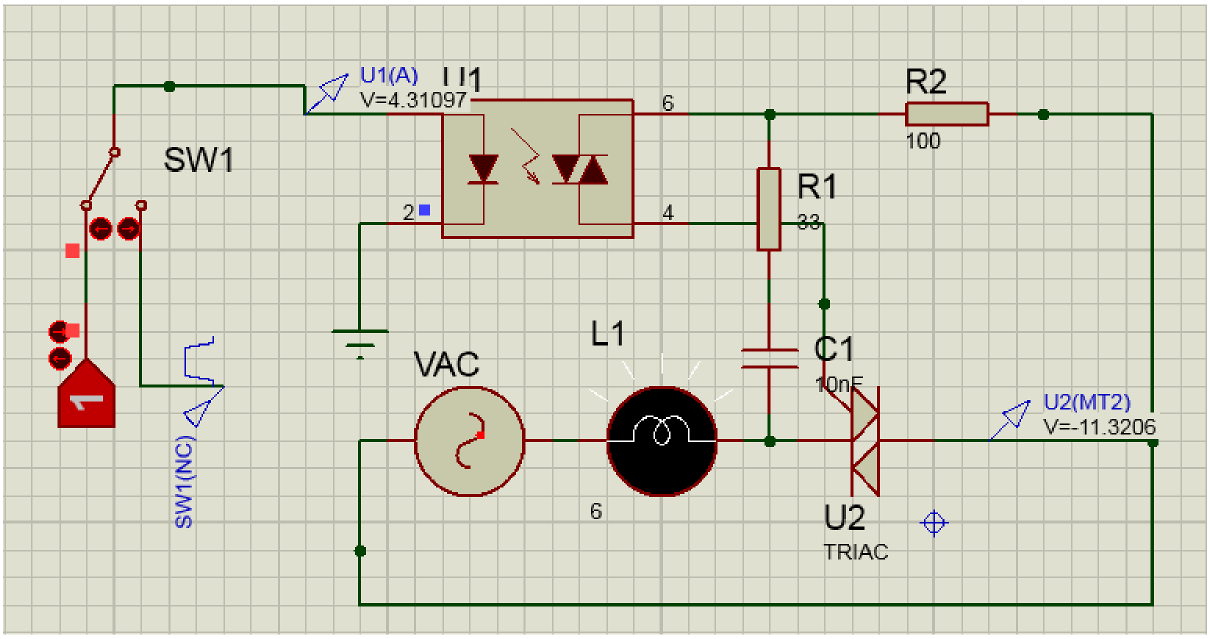


Figure 5.24- Opt-coupler and triac switch (ON State)

The logic toggle state 1 represents the HIGH output (5V) from the microcontroller. During this stage, the LED inside the MOC3021 is on, allowing the opto-diac to conduct. The output of MOC3021 triggers the BT136 triac gate and completes the circuit between VAC and the connected device (Bulb L1).

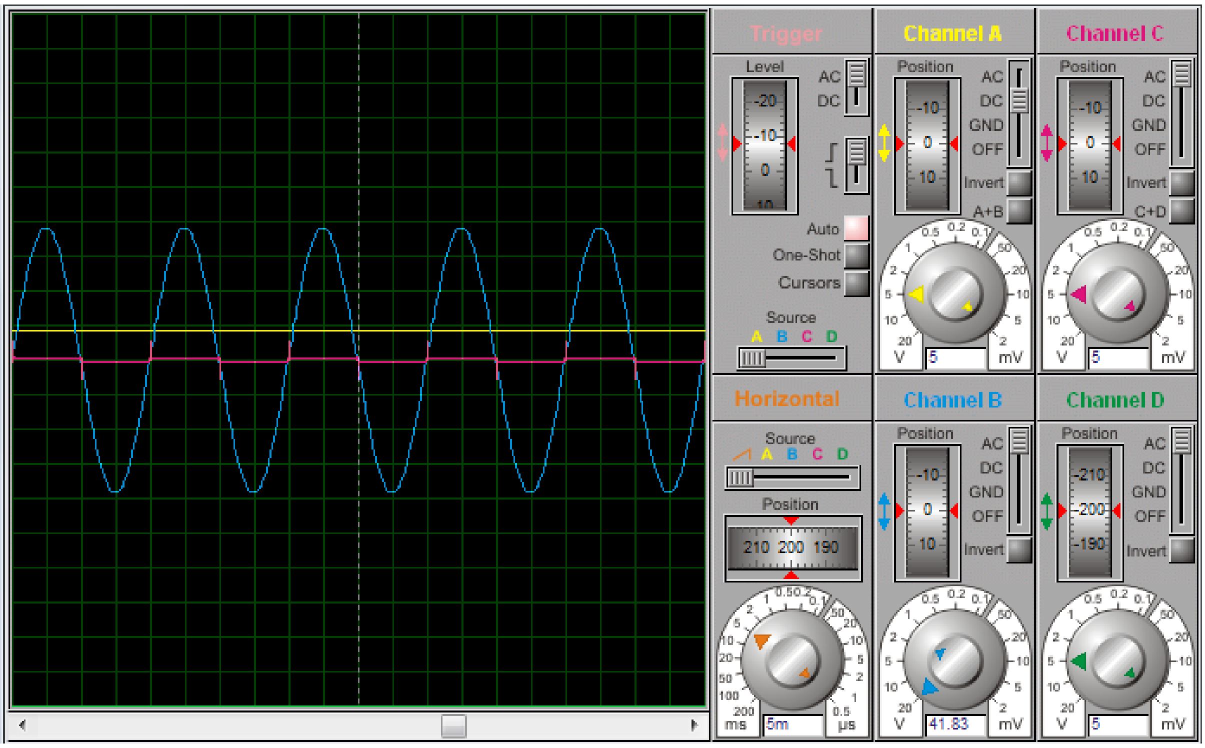


Figure 5.25- Resulting waveform

Table 5.7- Oscilloscope reading

PARAMETER	CHANNEL	VALUE
Microcontroller output	A (Yellow)	4.74 V
Voltage across Bulb	B (Blue)	162 V

A logic state 0 would render the device off as shown in figure 5.26-

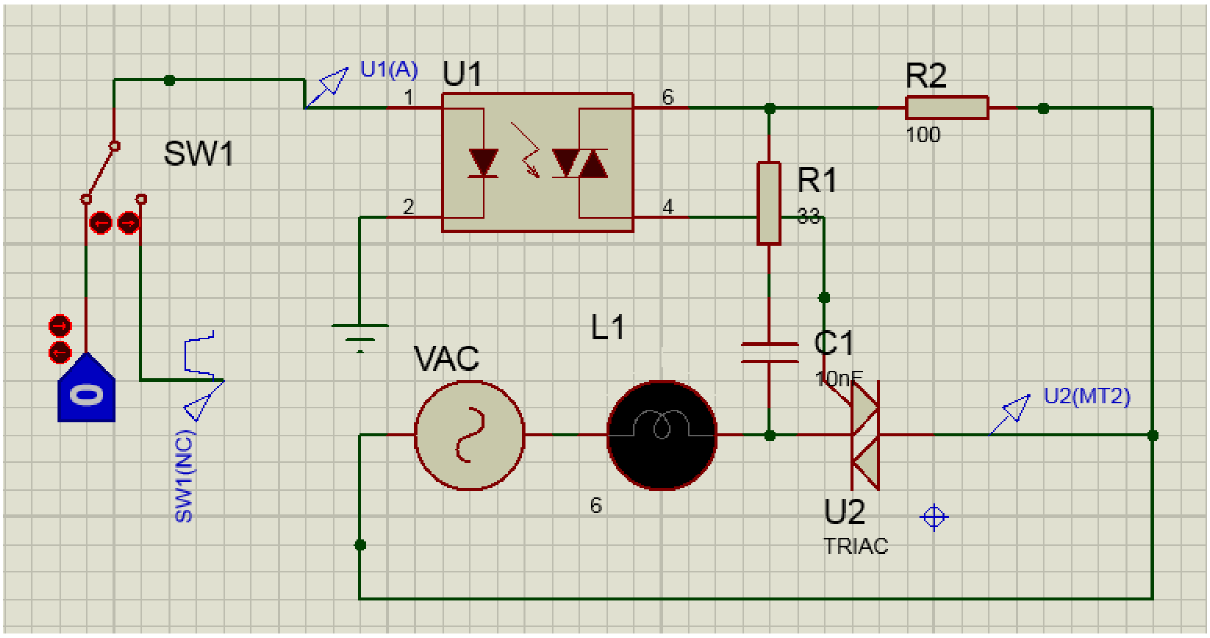


Figure 5.26- Opto-coupler and triac switch (OFF State)

Resistor R1 and capacitor C1 forms the snubber network. An RC snubber circuit is used to improve triac immunity against fast voltage transients due to critical rate rise of commutation off-state voltage dV/dt (ST Microelectronics, 2010). The RC snubber dampens the energy of parasitic resistance or capacitance found in inductive loads like fans preventing the triac from triggering spontaneously.

5.4.7 LCD Interfacing

A 16x2 LCD screen is used in this project to display the various variables related to the home automation system (like active mode, device status, input/output commands, sensor status). A 16x2 LCD consists of two lines with 16 characters each. This means the LCD can display 16 characters per line (Vitek, 2014).

Figure 5.27- 16x2 LCD Display

To store the command instructions and the data to be displayed, the LCD screen uses Command/Instruction Register and a Data Register respectively. Command instructions are used to carry out predefined tasks like initializing, clearing the screen, setting the cursor position, controlling display etc. These instructions are stored in the Command/Instruction Register whereas the Data Register stores the ASCII value of the data to be displayed.

The address distribution in the LCD data register is given by the table 5.7. The addresses in the row one ranges from 0x80 to 0x8F, whereas the row two addresses ranges from 0xC0 to 0xCF.

Table 5.8- 16x2 LCD address distribution

LCD Row1	80	81	82	83	84	85	86	87	88	89	8A	8B	8C	8D	8E	8F
LCD Row2	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	CA	CB	CC	CD	CE	CF

The LCD display is a 16 pin hardware with 2 pins as anode and cathode of the background LED. The remaining 14 pins are software controlled. The following table provides the detailed pin configuration of the LCD screen-

Table 5.9- LCD pin configuration

PIN NO.	NAME	DESCRIPTION
Pin 1	VSS	Power supply (GND)
Pin 2	VCC	Power supply (+5V)
Pin 3	VEE	Contrast adjust
Pin 4	RS (Register Select)	0 = Instruction input 1 = Data input
Pin 5	R/W (Read/Write)	0 = Write to LCD module 1 = Read from LCD module
Pin 6	EN (Enable)	Enable signal
Pin 7	D0	Data bus line 0 (LSB)
Pin 8	D1	Data bus line 1
Pin 9	D2	Data bus line 2
Pin 10	D3	Data bus line 3
Pin 11	D4	Data bus line 4
Pin 12	D5	Data bus line 5
Pin 13	D6	Data bus line 6
Pin 14	D7	Data bus line 7 (MSB)

The ATmega8 is programmed to display the status of GSM configuration, active mode (Bluetooth or GSM), device status (on/off), input commands received and output commands being transmitted.

Once the system is on, the microcontroller runs the AT commands to configure the GSM modem, the status strings are displayed on LCD as follows-

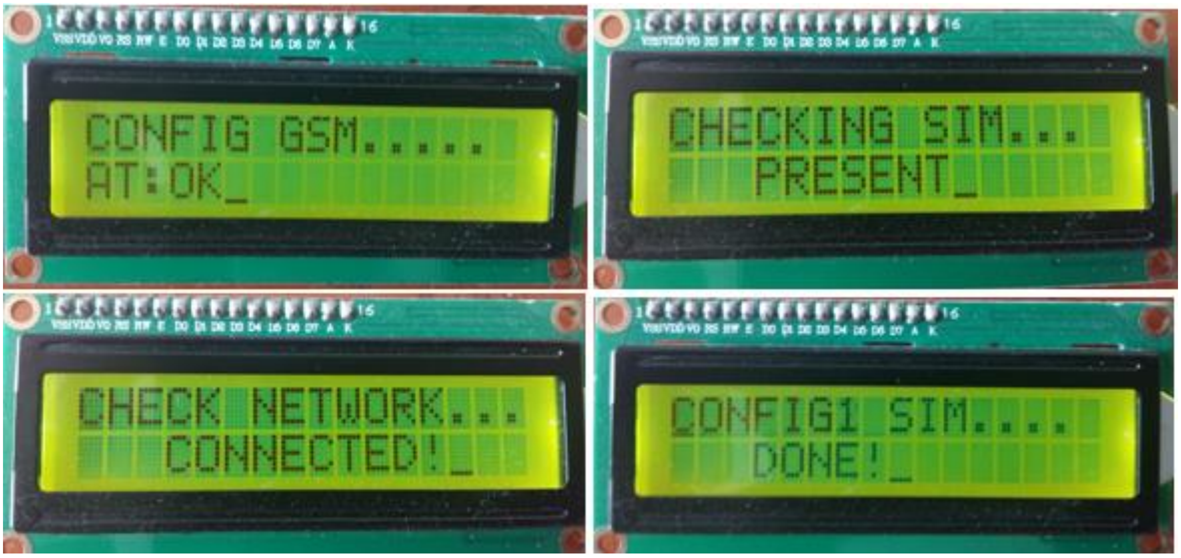


Figure 5.28- LCD Display for GSM Configuration

Once the system has configured the GSM modem, the microcontroller displays the status of the connected electrical appliances/devices D1, D2, D3 and D4 on the LCD.

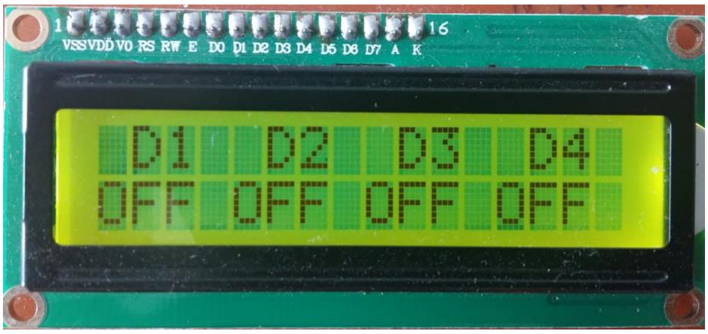


Figure 5.29- Device Status Display.

The LCD screen is also used to display the string “SENDING MSG (SENSOR)” in case the PIR or LPG sensor detects an anomaly.

Figure 5.30- LCD display for sending message

5.5 Summary

This chapter discussed the results and operation of various subsystems of the home automation system. As most of the components used have an average voltage tolerance between 3V-25V, the power source was designed to convert AC to DC and supply stable 5V DC input to the system. The IC 74HC4052 has been used to multiplex the Bluetooth and GSM modems with the microcontroller USART port and a DPDT switch has been installed to toggle between the two modes. The DPDT switch can be replaced with a software based switching between the modes mechanism through which the users can select the modes using their smartphones. The high performance, low power consumption, high instruction execution speed and RISC architecture of the AVR ATmega8 makes it an ideal microcontroller for this project and hence the different sensors, LCD screen, and triac switches are controlled by the I/O ports of the microcontroller.

CHAPTER 6

RECOMMENDATIONS AND CONCLUSION

6.1 Overview

This project introduced the design and implementation of a low cost home automation system with basic control and security features. Due to the low cost of construction and ease of design, the system can easily be mass produced and its standardised software and hardware specifications makes it compatible to all domestic environments. With the rapid development in technology, providing households with a basic low cost system with automation and security features can mark a big step in achieving the goal of smart cities in countries like India and Malaysia. The designed system can easily be integrated with advanced digital personal assistants and smart home systems like Google Home, broadening the prospects for further development. An updated design with advanced microcontrollers or microprocessors like ATmega1280, Intel C2738 and ARM Cortex, with more number of I/O pins and multiple USARTs can be used to control dozens of electrical appliances and other domestic variables like temperature and lighting.

6.2 Future Scope

There are numerous possible applications for this system and its upgrades, some of which are discussed here.

1. **Industrial Automation:** An evolved version of the proposed design can be implemented at the industrial level providing automation in factories and workshops. The Industrial Bluetooth or the long range Bluetooth can provide a range from 400m to 1km and can be well suited for automation devices in serial, fieldbus and industrial Ethernet networks (DigiKey European Editors, 2013). According to DigiKey,

industrial Bluetooth can be used for providing a flexible user interface for machines to handle data direction from sensors to links to an established wired network such as fieldbus or Highway Addressable Remote Transducer (DigiKey European Editors, 2013) used for transmission and reception of digital in smart devices and monitoring systems.

The automation system proposed in this project can be linked with industrial Bluetooth for applications like industrial valve control, process control, assets and environmental management. The latest version of Bluetooth called the Bluetooth 5, announced on 16th June 2016 by Bluetooth SIG is expected to quadruple the speed of the current Bluetooth 4.2 and increase the size of data packets making it possible to transmit larger amount of information and work more efficiently in applications like voice recognition and control (Cunningham, 2016).

2. **Web Based Home Automation:** A web based home automation system would allow the user to access and control their household parameters through internet. A web interface would provide the user up to date real time information about the variables like temperature, lighting etc. The 4G standard based video monitoring system incorporating a closed circuit camera will facilitate real time streaming video feed which can be accessed by the user on a secured web portal anywhere in the world. Using the web based automation system, a direct link to emergency services like 911 can be established which can help the emergency service to respond to an emergency quickly and efficiently. For example, a notification is delivered to the user and the emergency service at the same time if a fire is detected, or the live video feed during a burglary can be streamed to the police.

3. **Automated Lighting:** A lighting control system by Javier Castro and James Psota of MIT uses a facial recognition algorithm to determine the presence of the owner and turning on the lights. The system can be instructed to control the intensity of the lighting allowing the user to increase or decrease the brightness. The proposed home automation in this project can incorporate dimmers which can create pre-programmed lighting patterns and ambience.

4. **Integrating with Amazon Echo:** Controlled by Amazon's voice command engine Alexa, Amazon Echo can accept input through voice recognition, convert into text

and transmit the string to the microcontroller which will compare the command with the pre-programmed strings. If the voice command matches the text string stored in the microcontroller, any the connected appliance can be controlled. The advantage of using Alexa is that it is an interactive personal digital assistant which can be integrated with all the existing smart gadgets, works as a music player, consists of a seven microphone array with noise cancellation and enhanced reception range.

5. **Internet of Things:** An IOT based home automation system aims to develop a network of connected peripherals such as sensors and controllers which allow user to control the home appliances and store the data on a cloud. The designed system can be upgraded to an IOT based system by using Intel Galileo which has an in-built Wifi card that allows the board to act as a web server (Sagar & Kusuma, 2015). A wireless array of sensors and other peripherals will reduce the need to wired connectivity allowing the entire system to operate wirelessly.

6.3 Conclusion

The proposed objectives for the "Imperium" Home Automation System project have been successfully accomplished. The designed system has been tested and found to be operating as desired. The system successfully operates in both GSM and Bluetooth mode allowing the user to choose from either to control the electrical appliances. The sensors are set to be sensitive to stimuli and provide accurate input to the microcontroller. The system is ready to be implemented within a domestic/official environment.

During the past decade, the development of high speed wireless communications, 3G and 4G Internet, Wi-Fi, Wi-Max, Internet of Things and a cornucopia of other communication and computing technologies have seismically improved the way we communicate and connect ourselves to people and the world. These developments have paved the way for a global proliferation of Domotics and systems like "Imperium" can play an important role in the world wide initiative of building Smart Cities and Smart Nations. The total cost for the design of the proposed system ranges between RM 450 - RM 500, which is very much cheaper than the home automation systems currently available in developing countries. Easy to design, upgrade, operate and produce on large scale, a system like "Imperium" can be an attractive and affordable choice for customers willing to implement automation for their households. Providing a range of functionalities like voice/gesture control, baby monitor, automatic pet feeder, automatic cooking system, all accompanied by an intelligent personal digital assistant (like Amazon's Alexa), the potential upgrades of the designed system, mentioned in the previous section, can prove to be a milestone for the modern day consumer electronics and housing industry. With in-built safety and security systems, a large number of accidents can be avoided, loss of life and property can be prevented, and households can be made safer and more secure than ever before. The rapidly developing fields of Artificial Intelligence and Quantum Computing will soon be able to establish a stronghold as control systems for Domotics, creating intelligent systems which can be adaptive and self-customizable, successfully eliminating the need for human intervention and revolutionizing our perception of a domestic environment.

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APPENDIX 1- ATmega8 C PROGRAM

```
//Home automation with bluetooth and GSM...PIR+MQ6
//I/O definition
#define F_CPU 1000000UL
#include<avr/io.h>
#include<util/delay.h>
#include"LCD.C"
#include"gsm.c"
#define mode ((PINB&(1<<PB0)))
#define pir  ((PINB&(1<<PB6)))
#define lpg  ((PINB&(1<<PB7)))
void d1opr(int i)
{
if(i)
{
PORTB|=1<<PB1;
print(0xc0,PSTR(" ON "));
}
else
{
PORTB&=~(1<<PB1);
print(0xc0,PSTR("OFF "));
}
}
void d2opr(int i)
{
//Device status on LCD
if(i)
{
PORTB|=1<<PB2;
print(0xc4,PSTR(" ON "));
```

```
}
else
{
PORTB&=~(1<<PB2);
print(0xc4,PSTR("OFF "));
}
}
void d3opr(int i)
{
if(i)
{
PORTB|=1<<PB3;
print(0xc8,PSTR(" ON "));
}
else
{
PORTB&=~(1<<PB3);
print(0xc8,PSTR("OFF "));
}
}
void d4opr(int i)
{
if(i)
{
PORTB|=1<<PB4;
print(0xcc,PSTR(" ON "));
}
else
{
PORTB&=~(1<<PB4);
print(0xcc,PSTR("OFF "));
}
```

```
}
void main(void)
{
int d1=0,d2=0,d3=0,d4=0;
int stpir=0, stlpg=0;
char fg=0;
/////////////////PORT CONFIGURATION//////////////
DDRC=0xff;
DDRB=0x3e;
PORTB|=(1<<PB0)|(1<<PB6)|(1<<PB7);
DDRD|=1<<PD2;
PORTD|=(1<<PD6)|(1<<PD7)|(1<<PD0)|(1<<PD1);
lcmd(0x02);
lcmd(0x28);
lcmd(0x0e);
lcmd(0x01);
UART_init();

///////////////// GSM CONFIGURATION ////////////////////

print(0x80,PSTR("CONFIG GSM....."));
print(0xc0,PSTR("AT:"));
////////////// AT //////////////////
AT:
fg=cmdrpl("AT\r\n","OK");
if(fg)
print(0xc3,PSTR("OK"));
else
{
print(0xc3,PSTR("ERROR"));
goto AT;
}
```

```
gsm;
rtxstr(PSTR("ATE0\r\n"));
_delay_ms(1000);
/////////////SIM CONFIGURATION/////////////////
lcmd(0x01);
print(0x80,PSTR("CHECKING SIM..."));
fg=cmdrpl("AT+CPIN?\r\n","READY");
if(fg)
print(0xc3,PSTR("PRESENT"));
else
{
print(0xc0,PSTR("NOT PRESENT!"));
}
_delay_ms(1000);
/////////////NETWORK CONFIGURATION////////////////////
lcmd(0x01);
print(0x80,PSTR("CHECK NETWORK..."));
fg=cmdrpl("AT+CREG?\r\n","+CREG: 0,1");
if(fg)
print(0xc3,PSTR("CONNECTED!"));
else
{
print(0xc0,PSTR("NOT CONNECTED!"));
}
_delay_ms(1000);
//////////////configuration///////////////
lcmd(0x01);
print(0x80,PSTR("CONFIG1 SIM...."));
fg=cmdrpl("AT+CMGF=1\r\n","OK");
if(fg)
print(0xc3,PSTR("DONE!"));
else
```

```
{
print(0xc3,PSTR("FAILED!"));
}
_delay_ms(500);
lcmd(0x01);
print(0x80,PSTR("CONFIG2 SIM...."));
fg=cmdrpl("AT+CMGD=1\r\n","OK");
if(fg)
print(0xc3,PSTR("DONE!"));
else
{
print(0xc3,PSTR("FAILED!"));
}
_delay_ms(500);
///////////////////////////PRIMARY/DEFAULT DISPLAY//////////////////////////////
if(mode)
{
lcmd(0x01);
print(0x80,PSTR("  VOICE MODE    "));
print(0xc0,PSTR("SPEAK UR COMMAND"));
_delay_ms(500);
lcmd(0x01);
print(0x80,PSTR(" D1  D2  D3  D4 "));
blt;
st=0;
bclr();
while(1)
{
        d1opr(d1);
        d2opr(d2);
        d3opr(d3);
        d4opr(d4);
```

```
blt;
        if(st==1)
        {
        lcmd(0x01);
bprint(0x80,buff);
        _delay_ms(1000);
        if(match(buff,"*light on#"))
        d1=1;
        else if(match(buff,"*light off#"))
        d1=0;
 else if(match(buff,"*light of#"))
        d1=0;

        else if(match(buff,"*fan on#"))
        d2=1;

        else if(match(buff,"*fan off#"))
        d2=0;

        else if(match(buff,"*fan of#"))
        d2=0;

        else if(match(buff,"*motor on#"))
        d3=1;

        else if(match(buff,"*motor off#"))
        d3=0;

        else if(match(buff,"*motor of#"))
        d3=0;

        else if(match(buff,"*heater on#"))
```

```
            d4=1;

            else if(match(buff,"*heater off#"))
            d4=0;

            else if(match(buff,"*heater of#"))
            d4=0;

            st=0;
            bclr();
    print(0x80,PSTR(" D1  D2  D3  D4 "));
            }
if( (pir)&&(stpir==0) )
{
lcmd(0x01);
print(0x80,PSTR("SENDING MSG PIR!"));
fg=sendmsg("SOMEBODY ENTERD IN YOUR AREA");
if(fg)
print(0xc3,PSTR("SUCCESS!"));
else
print(0xc3,PSTR("FAILED!!"));
stpir=1;
_delay_ms(500);
lcmd(0x01);
print(0x80,PSTR(" D1  D2  D3  D4 "));
}
if( (!pir)&&(stpir==1) )
stpir=0;
if( (lpg)&&(stlpg==0) )
{
lcmd(0x01);
print(0x80,PSTR("SENDING MSG LPG!"));
```

```
fg=sendmsg("GAS LEAKAGE DETECTED");
if(fg)
print(0xc3,PSTR("SUCCESS!"));
else
print(0xc3,PSTR("FAILED!!"));
stlpg=1;
_delay_ms(500);
lcmd(0x01);
print(0x80,PSTR(" D1  D2  D3  D4 "));
}
if( (!lpg)&&(stlpg==1) )
stlpg=0;
}
}
/////////###############///DEFINING SMS MODE/////////////////////////////////////////
else
{
print(0x80,PSTR("   SMS MODE    "));
print(0xc0,PSTR("SMS UR COMMANDS"));
_delay_ms(1000);
lcmd(0x01);
print(0x80,PSTR(" D1  D2  D3  D4 "));
while(1)
{
d1opr(d1);   //DEVICE 1 OPERATION
d2opr(d2);   //DEVICE 2 OPERATION
d3opr(d3);   //DEVICE 3 OPERATION
d4opr(d4);   //DEVICE 4 OPERATION
   gsm;
         if(st==1)
         {
   fg=match(buff,"+CMTI:");
```

```
    if(fg)
    {   print(0x8f,PSTR("*"));
fg=rdmsg();
if(fg)
            {
             print(0x8f,PSTR("#"));
            ldmsg();
if(match(buff,"MOB"))
      svmob();

            else if(match(buff,"light on"))
            d1=1;

            else if(match(buff,"light off"))
            d1=0;

            else if(match(buff,"fan on"))
            d2=1;

            else if(match(buff,"fan off"))
            d2=0;

            else if(match(buff,"motor on"))
            d3=1;

            else if(match(buff,"motor off"))
            d3=0;

            else if(match(buff,"heater on"))
            d4=1;

            else if(match(buff,"heater off"))
```

```
                d4=0;
                }
        }
   print(0x8f,PSTR(" "));
        st=0;
        bclr();
        }
if( (pir)&&(stpir==0) )
{
lcmd(0x01);
print(0x80,PSTR("SENDING MSG PIR!"));
fg=sendmsg("SOMEBODY ENTERD IN YOUR AREA");
if(fg)
print(0xc3,PSTR("SUCCESS!"));
else
print(0xc3,PSTR("FAILED!!"));
stpir=1;
_delay_ms(500);
lcmd(0x01);
print(0x80,PSTR(" D1  D2  D3  D4 "));
}
if( (!pir)&&(stpir==1) )
stpir=0;
if( (lpg)&&(stlpg==0) )
{
lcmd(0x01);
print(0x80,PSTR("SENDING MSG LPG!"));
fg=sendmsg("GAS LEAKAGE DETECTED");
if(fg)
print(0xc3,PSTR("SUCCESS!"));
else
print(0xc3,PSTR("FAILED!!"));
```

```
stlpg=1;
_delay_ms(500);
lcmd(0x01);
print(0x80,PSTR(" D1  D2  D3  D4 "));
}
if( (!lpg)&&(stlpg==1) )
stlpg=0;
}//while
}// else
}
```

APPENDIX 2- PROJECT SCHEDULE GANTT CHART

Schedule for Final Year Project I (September 2015 – January 2016)

		Week Number													
No.	Task Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Concept	■													
2	Literature Research		■	■	■										
3	Design					■	■								
4	Analytical Work						■	■	■						
5	Simulation						■	■	■						
6	Prototyping									■	■				
7	Improvement										■	■			
8	Report Writing												■	■	
9	Presentation														■

Schedule for Final Year Project II (February 2016 – June 2016)

		Week Number													
No.	Task Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature Research	■	■	■	■										
2	Design Update			■	■	■									
3	Programming			■	■	■	■	■							
4	Simulation						■	■	■						
5	Improvement (Design/Program)								■	■					
6	PCB Design & Hardware Implementation										■	■			
7	Report Writing										■	■	■	■	
8	Presentation														■