**A Dissertation on**

# WIRELESS SENSOR NETWORK BASED CONTROLLING AND MONITORING OF HOME APPLIANCES USING ZIGBEE

*Submitted in the partial fulfillment of the requirements of the degree of*

**MASTER OF TECHNOLOGY**

**In**

**CONTROL & INSTRUMENTATION**

By

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2K15/C&I/05

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# CERTIFICATE

This is to certify that the Major project -II report **WIRELESS SENSOR NETWORK BASED CONTROLLING AND MONITORING OF HOME APPLIANCES USING ZIGBEE** is a bonafide work carried out by **Mr. Ankit Kumar Garg** bearing Roll No. **2K15/C&I/05**, a student of Delhi Technological University in partial fulfillment of the requirements for the award of Degree in **Master of Technology** in "**Control& Instrumentation Engineering**".

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# Candidate Declaration

I, hereby declare that the work which is being presented in this thesis entitled **Wireless Sensor Network Based Controlling and Monitoring of Home Appliances using Zigbee** is my own work carried out under the guidance of Mrs. Bhavnesh Jaint, Assistant Professor, Department of Electrical Engineering, Delhi Technological University.

I further declare that the matter embodied in this thesis has not been submitted for the award of any other degree or diploma.

Date: Ankit Kumar Garg

Place: New Delhi 2K15/C&I/05

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# ABSTRACT

Zigbee technology is used in wireless communication. It works over 802.15 standards for monitoring and controlling the devices. Zigbee is designed for smart home automation. Zigbee provides low cost and low power connectivity. It also enables self-organization and self-healing networks. For industry Zigbee is used for remote monitoring and automated manufacturing. The design and development of a smart monitoring and controlling system for household electrical appliances in real time has been reported here. The system principally monitors electrical parameters of household appliances such as voltage and current and subsequently calculates the power consumed. The novelty of this system is the implementation of the controlling mechanism of appliances in different ways. The developed system is a low-cost, compact, and flexible in operation and thus can save electricity expense of the consumers. The prototype has been extensively tested in real-life situations and experimental results are very encouraging.

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# CHAPTER 1

# INTRODUCTION

Due to requirement of human society inventions mostly appear. The advancement in digital technology was started in the 21st century. The mainly enhancement in digital technology is in the field of intelligently controlling and monitoring of different appliances and events. The Wireless Sensor Network consist of wireless sensors and networks which is used to controlling and monitoring of low size smart homes to big size-structure house automation, a children toy to huge engineering assembly machineries, an universal space research center to a college research laboratory and health care services. The wireless sensor technology enables us to reduce the complexity to transmitted wires transmission and installment of sensors, actuators and controllers. Due to wireless technology innovation, the cost and connection time for a large number of sensors installations in a city is significantly reduced. There are many types of wireless channel communication in which according to requirement and application we can create wireless sensor network.

## 1.1 Wireless sensor network based automation

The leading applications of wireless sensor network are house monitoring and automation where a number of mixed sensors are installed to find out different actions of users, Power supply as well as battery; both can be used in wireless sensor network. The power source selection depends on the position of environment and access of power for application like temperature sensing outside the house. In a Primary (consumable) battery, lifetime is decided by sampling rate of data and sending power while external energy source is used for energy gathering applications so it is free from the primary battery usage. In wireless sensor network, many nodes are included with sensors, actuators, controllers, and Radio frequency chips for communication without wire. IEEE 802.15.4 standard is the first international standard for WSNs. It was implemented in 2003 [1]. A limitation of IEEE 802.15.4 standard is that, it defines only two lower layers (PHY and MAC) for RF communication purpose. The networking method for the upper layers is not described.

ZigBee communication protocol IEEE 802.15 was standardized by ZigBee Alliance and its Mesh network along with IPv6. Encryption, verification of network nodes and an effective and modern routing that leads to mesh networking topology is proposed the upper layer enhancement. ZigBee is mainly desired by WSNs designers with only Mesh topology, although mesh topology is moderately complex, ZigBee provides wonderful specification for urban environment wireless sensor network and short range. ZigBee IEEE 802.15.4 standards work on the license free Medical, scientific, medical, industrial(ISM) frequency band.

IOTs (Internet of Things) is the one of the very advance addition in the wireless sensor network base home automation Positive remote control and monitoring are suitable by the worldwide connectivity and distributed brainpower of the IOTs with WSN. In a period of IOTs, No. of connected devices and equipment with IOT are increasing as time is increasing above 12.5 billion devices were connected in 2010. Cisco expects that there will be fifty billion devices by 2020.

The WWW services is used from a smart house view point to connect households, objects, mainly electrical and electronic appliances, sensors and actuators by internet of things (IOT). The equipment and things are intelligently and quickly interlocked to each other to improvement accepting of wireless communication and new customs between a things as well as person.

These traditions and understanding create a view for gadgets close in the shrewd home encompassing to begin the joint effort and assemble altogether different areas. A situation that gets from our regular action and necessities, for example, when we get up in the morning, how much time we rest, and to what extent we sit in front of the TV, can respond to a tenant's conduct to advance their riches and wellbeing. For instance, an occupant rose late in the morning and in light of the fact that he was in rush to get the metro to the work environment, he/she neglected to kill the Air adapted and just watched this in the wake of achieving the working environment. Presently from an out of reach separate, through an IOT-based brilliant home framework, he/she can control the Air conditioned.

The interests to create and outline the smart house are; enhancing extravagance, openly living, security, wellbeing, and successful use of power. The name

'shrewd home' is perfect for a home domain outfitted with cutting edge innovation that grants control and observing of its tenants, and improvements free living through wellbeing foreseeing in view of behavioral plan era and identification. To discover the issues and difficulties of the real execution of keen home watching, we need to know present and progressing research here. A scope of brilliant home frameworks for encompassing helped living has been anticipated and grown, however there are, similarly few houses that utilization savvy advancements. One of the center purposes behind this is the enlargement and shifted plan necessities connected with various spaces of homes.

These areas are control, diversion, private interchanges, and living spaces. Aware Home Research Initiative (AHRI) at GIT (Georgia Institute of Technology) [2], CASAS (The Center for Advanced Studies in Adaptive Systems) at Washington State University [3], AgingMo at University of Missouri [4], PlaceLab at MIT [5] and Smart home Lab at Iowa State University [6, 7], are checking the activity of everyday living, enhancing the solace, and making setting mindful relative circumstances through heterogeneous sensor position, and these sensor units contain cameras too. These are instructive research ventures. From a group perspective, the utilization of the camera is an immediate infringement of mystery for seeing in a shrewd home condition. At a similar moment, the video playing by the camera is in fact troublesome. Examination and checking over video stream are simple; however it requires real storage room on the server. The server proposed at home is a neighborhood home entryway server, which has restricted accumulation and capacity memory. There are different distinctive assembling enormous building brilliant home offices accessible; Electronic House by McDonough, in New York, Toyota dream house in Japan, W.S at Stuttgart, and Crystal House by Hung, at Taichung, Taiwan, House R128 by Intgeniere, in Germany which have focused on vitality protection objectives and maintainability, and solace and offer accommodation through the mental aptitude of nature [8].

Microsystems, implantable, and wearable that can be introduced over the body territory organize for instance the Apple watch are realistic nowadays. These gadgets are worn by the installed or individual in the home environment to bolster somebody for wellbeing administrations. Many activities including the use of flag helped wearable gadgets are proceeding in various research labs Senswear Armband by Body Media Inc. [9], Smart Shirt [10], and PROETEX extend by CSEM focus [11],

Life Shirt by Vivo metrics [12] are wearable gear to quantify ECG. Other research has focused on fall location utilizing wearable sensors [13] in view of accelerometers. A man experiencing disease can utilize these gadgets as a feature of a social insurance approach; however some person who is wellbeing may not value wearing.

Numerous analysts have effectively executed shrewd home structures in view of remote correspondence innovation, yet fusing remote with IOTs has astonishing potential in keen home zones. Most research of IOT-based savvy homes is in the beginning stage, and not many research trainings include viable execution [14]. IOT-based savvy structures offer us responsive encompassing and remote contact examination of home vibe; however they can play out this when the execution of IOTs is finished through powerful database administration [15]. Likewise, the practically savvy home assignments are done methodically in light of the suspicions from test bed controlled conditions, which might be entirely unexpected from a genuine situation where an inhabitant lives customary life independent of sensor hub establishment.

The intelligent home condition requests action energy about day by day life from raw sensor information, and these raw informational indexes are sporadic and complex to scramble into predefined circumstances. Indeed, even in the wake of programming this raw information, it is truly hard to recognize diverse conduct in light of the fact that these informational collections are on various sense modalities and inspecting rate. These sensor modalities and diverse time make glitches amid condition definition. It is very simple to make behavioral plans from just occurrence informational indexes; however it might raise a false ready.

### 1.2 Overview of Zigbee

ZigBee is mostly used in industries for wireless mesh networking standard for interface instrumentation, control systems and sensors. Internet of things has called ZigBee specification for communication in a wireless personal area network (WPAN). ZigBee is a global, open, reliable, packet-based protocol designed to provide an easy-to-use architecture for secure, low power wireless networks. Low data wireless networking standard is used in IEEE 802.15.4 and ZigBee for elimination of bulky and costly wiring in control application of industries. Control equipment of process or flow can be

installed anywhere and still communicate with system. Its position can be changed because network is not bothered about the physical location of sensors or valves.

ZigBee is used in which application domain where low data rate, low power and low duty cycle requirement devices. Fig 1 shows below example of ZigBee network.

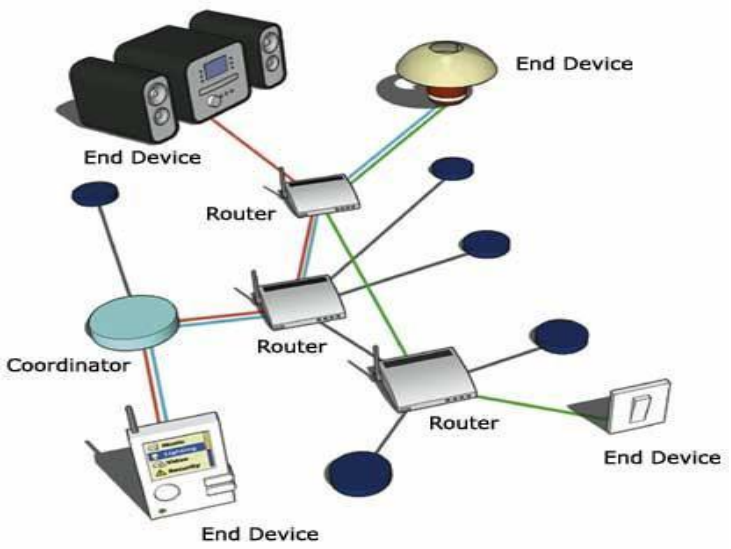


Figure 1.1 Diagram of ZigBee Network

ZigBee is familiar as the global sensor/control network standard. It is aimed to provide the following features:

- Implementation simple, Power consumption low
- Batteries life is excellent (many months to years)
- It can be operate in many different modes and position depending upon your power requirements and latency such as hold, sniff, park, active etc.; IEEE 802.15.4 / ZigBee has sleep or active (receive / transmit).

**Cost wise low (maintenance, device, and installation)**

Users have to spend less money in installation cost, maintenance and device cost. ZigBee devices consumes less batteries so it can be used many months to years using primary cells (cost wise low) without any charging device (easy installation and low cost). Simplicity of ZigBee's permits for in-built configuration and provides low maintenance due to redundancy of network devices.

**Per network High density of nodes**

In ZigBee's, we use IEEE 802.15.4 standard which uses two lower layers, MAC and PHY, permits networks to handle any number of devices. It is crucial for huge sensor arrays and control network.

**Global implementation, Simple protocol**

Bluetooth's or 802.11's protocol code stack is estimated to be about 4$^{th}$ times of ZigBee's. So it is very small protocol code size compare to Bluetooth. ZigBee has been adopted IEEE 802.15.4 PHY and designed for the 915 MHz band in N America, Australia, etc; the 868 MHz band in Europe, and the 2.4 GHz band is now accepted as a global band recognized in almost all countries.

## 1.3 **Wireless Communication**

In all the wireless communication systems have the Transmitter, Receiver, Antenna and path between the receiver and the transmitter. The transmitter feeds a signal of encoded data modulated into RF waves into the antenna. The antenna radiates the signal through the air where it is picked up by the antenna of the receiver. The receiver demodulates the RF waves back into the encoded data stream sent by the transmitter.

### 1.3.1 Network Types for Wireless

In wireless communication many number of different types of networks used. Network types are normally defined by location and size.

#### 1.3.1.1 Wireless Personal Area Network (WPAN)

WPAN is meant small area like an individual workspace or a private home. For over a short distance communication, WPAN is used. The specifications do not block longer ranges being accomplished with the exchange off of a lower information rate.

In WPANs, the key concept is Ad-hoc networking. Devices are allowed to be part of the network temporarily; it can leave and join at will. It is worked well for mobile devices like laptops, phones and PDAs.

### 1.3.1.2 Wireless local area networks (WLAN)

WLANs are meant to span a comparatively small area, for example: a building, house, or a school campus. In WLANs costs come down and standards improve so it is becoming more prevalent. A wired local area network (LAN) can be replaced with a WLAN, its access point coupled to a Local Area Network technology like Ethernet. A popular protocol 802.11 is for WLAN, also popular as Wi-Fi.

### 1.3.1.3 Wireless wide area network (WWAN)

A WWAN is meant to span a big area, like a state, country and city. It makes use of satellite dishes and radio waves to transfer data as well as telephone lines.

### 1.3.2 Wireless Network Topologies

The IEEE 802.15.4 and ZigBee specifications supported the network topologies. The topology of a network defines how the nodes are coupled, either logically or physically. The flow of data between the nodes is mapped by the logical topology. Physical topology is a geometrical shape resulting from the physical links from node to node, as per the figure given below.

Peer-to-peer and star topologies are supported by IEEE 802.15.4. Star and two kinds of peer-to-peer topologies, mesh and cluster tree are supported by the ZigBee specification. ZigBee-compliant devices are sometimes specified as supporting point-to-multipoint and point-to-point topologies

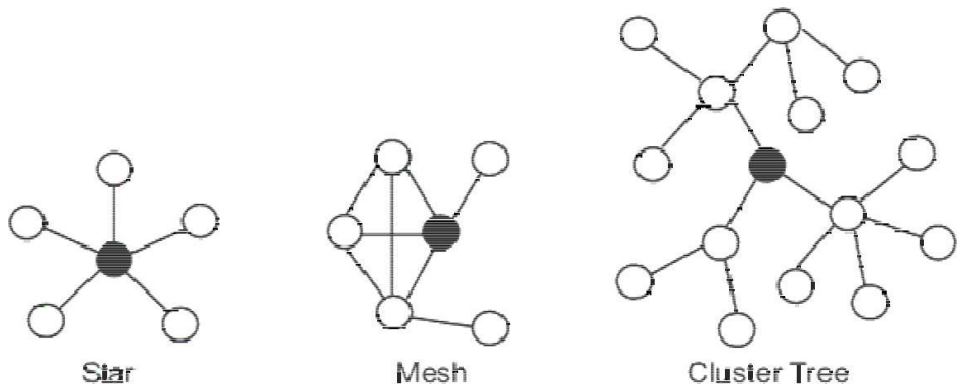


Figure 1.2 ZigBee Network Topology

### 1.3.3 Wireless Standards

Table 1.1 Comparison of different Wireless Standards

| **Wireless Parameters** | **ZigBee** | **Bluetooth** | **Wi Fi** |
|---|---|---|---|
| Frequency Band | 2.4 GHz | 2.4 GHz | 2.4 GHz |
| Range | Indoors: up to 30 m Outdoors (line of sight): up to 100 m | 9 m | 75 to 90 m |
| Physical/MAC layer | IEEE 802.15.4 | IEEE 802.15.1 | IEEE 802.11b |
| Current consumption | 25-35 mA (Tx mode) 3 mA (Standby mode) | 60 mA (Tx mode) | 400 mA (Tx mode) 20 mA (Standby mode) |
| Raw data rate | 250 Kbps | 1 Mbps | 11 Mbps |
| Typical network join Time | 30 ms typically | >3 sec | variable, 1 sec typically |
| Interference avoidance method | DSSS (direct-sequence spread spectrum) | FHSS (frequency-Hopping Spread spectrum) | DSSS (direct-sequence spread spectrum) |
| Protocol stack size | 32 KB & 4 KB (for limited function end devices) | 250 KB | 1 MB |

# CHAPTER 2

# LITERATURE REVIEW

The system explained in [16] [17] [18] provides different ways to control home appliance such as the Global System Mobile, Zigbee, Bluetooth and internet. The real time measurements and monitoring provides the important information that can be utilized for the automation system. Any monitoring parameter change occurs in the device, it can be control real time. Personal computer or other electronic device is used to send the information to the main control server. The main server recognizes the related information and sends the commands to the related electronic device. In this way the home appliance can be control and monitor.

## 2.1 GSM based Home Automation System

Global System for mobile communication provides connection in a remote place where internet connectivity is poor. The microcontroller PIC16F887 is used to control the home appliances [19]. The microcontroller used the Global System for mobile communication network to control the Home appliances. It is a short message service based system. Global System for mobile communication is used because it provides highly secure communication and high coverage area. The short message service codes are used to control the related home appliance. Control commands can be provide through the Global System for Mobile communication and particular home appliance can be controlled. The device sends the message to the user through the short message service. The working of this system is based on the short message service. There is no user interface that the user can use to control the device .The control commands depends on the network connectivity and sometimes delay may occur. The system does not have any feedback system to track the device continuously.

The detailed information given of the system [20] is a Machine to Machine system and communication occurs through the Global System for Mobile communication. GSM has option for machine to machine communication which include the Dual Tone Multi frequency, Short Message Service and General Packet Radio Service. This system uses the Short Message Service and Attention commands. The personal computer is used as a center for commands. A Global System for Mobile

communication dial-up and communication system embedded in the personal computer. The programming language Visual C++ is used for implementation. The personal computer extracts the coded information and receives the appropriate commands via the Short Message Service and performed action required. This system can be programmed as per the requirements of the home appliance. This system also has the capability to control the mechanical appliances through the different sensors. There is no feedback to the user for any information. The system totally controlled by the personal computer and the computer active all time. This system is not real time control system. The server at the home is based on the Short Message Service / General Packet Radio Service mobile cell module and controller [21]. This can be used by the user to monitor and control the different home appliance at the home by using the Java enabled cell phone. The paper described the detailed design and implementation of attention modem driver, the interface with mobile phone is user-friendly and easy to control the desired commands. They transmit the command and receive the feedback from the system as the Short Message Service strings. For Hardware implementation Atmel microcontroller is used, and connected with a serial port interface RS232.The relevant data is store in the EEPROM memory. The authentication system based on the password. The message sent contain the password which is insure that the message come from the valid source. The main disadvantage of this system it is mostly relies on the Short Message Service and it is not very fast. A system based on Global System for mobile communication via Short Message Service is used to control the home appliance. Controller board from Arduino is used to interface the home appliances. The board used different peripheral drivers and solid state relays to achieve this interfacing. Smart phone is main user interface device. App Inventor visual programming tool is used to develop the interface and other tool to deploy the App. The App is used to generate Short Message Service based on the user requirements and send to the Global System for Mobile communications attached to the Arduino. This method is used to control the home appliances. The whole system reliability depends on the Short Message Service and the interface preprogrammed and cannot be customized based on the devices.

A voice operated control system is proposed [22] that will used to enable or disable the home appliance remotely. The basic communication is through the Global System for Mobile communication. An Android operating system based mobile phone is used to get the voice command and convert them into the text and this text message is

sent via Short Message Service to another phone through the Global System for Mobile communication network.

This is sent via Short Message Service to other mobile phone by the Global System for Mobile communication. The Module is connected to microchip Microcontroller of the PIC16F877A family. The Microcontroller decodes the commands and performs the right action. The electrical circuit controlled with a different system to provide the isolation to the load from the control circuit.

The user received an alert message through the feedback regarding the command. Voice command feature makes it universally accessible. However the usage of Short Message Service makes it unreliable. It required two mobile phone, one with user and another in proximity to the controller can lead to the extra charges.

The complete system utilized [23] the Global System for Mobile communication network and all peripheral controlled by the Microcontroller of AVR. The system is based on the short message service. The client provides the commands .These are sent via Short Message Service. The system uses standard code and microcontroller can easily process. Global System for Mobile communication system is connected to the AVR. Instruction sent by the via Short Message Service it receive easily. This will receive the instruction that is sent. Attention instructions are used to exchange with the modulator and demodulator. AVR give command to main drive network to manage the home application instrument as required. This network has wireless potentials from very wide area. It is very difficult to function in specified fixed time.

A microcontroller with Global System for Mobile communication [24] can be used a home automatic control system. Global System for Mobile communication modulator and demodulator receive instruction from the mobile phone via GSM network. This instruction is changed to written message and fed to the Microcontroller with a serial interface bus. These instructions are recognize by the control unit and the appropriate action was taken. The main difficulty of this network is that it requires outside power requirements. It is not able to manage different home application instrument simultaneously.

**2.2 Bluetooth Based Home Automation**

Bluetooth technology [25] and cellular phone is used in the system. Low price and coded communication, efficient communication is the main feature of the Bluetooth technology. The whole system is used an Ardunio Bluetooth board. Cell phone interface programming language main candidate is python. The Input output pins of the Bluetooth board and switch are used for connecting with the instruments which are required to be managed. The Bluetooth technology is highly secure and key coded to provide surety that the network system is protected and used with authorize person. The Bluetooth has cover very small distance of 11 to 110 meters, 2400MHz wide span of frequency and very high speed up to 2.9Mega bits per seconds. The main beauty of the python app is portability. It is high speed and cheap network. There is a debugging network that can used to find the difficulty in the electronic network. A closed loop network will update state of circuit after every variation in the main signal. The disadvantage with compare to Bluetooth is that it required a very much time to find and access devices in its nearby range. It does not provide any idea to save the energy. Within time specified access cannot possible. The devices cannot access in the wide area the access range is small because limitation due to the Bluetooth range.

The application of the Bluetooth technology is to manage and control the home application instruments [26]. The Personnel computer that is interface via Universal Serial Bus to the Bluetooth card, sensing network and a PWM circuit. Sensing network and actuators are used to manage the electronic network. Various instructions communicate with the interface module through the Bluetooth technology. The Bluetooth device has the capability to scan and easily recognize the other devices. It has capability to find the status of the device functionality. The network also has a lighting sensor that can illuminates on lights when outside light is not sufficient and sensing for the temperature sensor also available. The main disadvantage has very limited range of operation and 10 meters only. The development cost of the system is in the normal range.

### 2.3 Phone Based Home Automation

The detailed given of the some network system allow the system that can be used to general framework for home appliance control. It enables a network for a stylish house that has provision for control, wiring and a general connection. This will manage by the already established network for the home appliances.

Power point control using wireless technology hardware detailed given [27]. The main job of this network to manage the power of all devices and instruments at very far place. The instructions are sending through the telephone lines. The control action is a decision based network and developed completely by the hardware. It reduces the price incurred with controllers. Dual tone Multi frequency transmitter and receiver is connected with MOSFET device to control the supply of the power. It is practically designed with not visible signals and alternating current technique.

A home application network has the DTMF technique provide by the telephones lines [28]. This system comprises the three main parts. Dual Tone Multi Frequency receiver and the ring detector are the first components. Input output connected unit is the $2^{nd}$ part. Personal computer is the $3^{rd}$ part which provides the online access. The decoding and the authentication of the desired user is done by the Personal computer. Verified user can used the key pad to control the Devices as required. Stepper motor example considers here. The system has main benefit of coded and have standardization of the international level. Dual Tone Multi Frequency tones are the same all over the world. But this system has disadvantage that the quantity of home application instruments is restricts by the keys in the keyboard. The number of keys in the general mobile phones has only the 12.

### 2.4 ZigBee Based Home Automation

The ZigBee Home application appliances can be used without wire technology [29]. Voice recognition and controller system is used for this aim. Mike provides the voice instruction. The instruction provides by the mike and compared with already store instruction in the memory and then processed. The receiver receives the instruction through the microcontroller and the ZigBee network. The receiver unit has other PIC microcontroller that can process the instruction. The respected home application instruments can be controlled by using the solid state relays. The small communication range is the main drawback of the system. From the far away locations it is very difficult to wireless access. The smoke detector is added in this has the extra advantage. When smoke is sense, it give the message to the user at given mobile number.

## 2.5 Wireless Control Systems

The stand-alone application of the wireless network can be used present in the office or at the home and form an integrating network. It combines various technologies to perform the particular task combined technology as Wi-Fi and Bluetooth. The user use transparent network of the device with universal plug and play capability. Open Service Gateway Interface is use to make the system. Different networking technologies are used to interface all home application appliances. Web browsers are used for user application layer. Home application appliance can be controlled using the Voice based instruction. Very advance quality is used such as devices search and device interface. Linux operating system platform is used to implement all this system. Intelligent control modules can also add and this feature incorporated in this system. Knowledge capturing and pattern recognition are also main feature of this system. Standard protocol is used for the interoperability with universal plug and play capability. Interoperability is the main advantage of this given system. Dynamic discovery of the service is the main feature of the system. Many services can be share buy using this system. Wi-Fi communication technology [30] and Arduino board is used in this system. Light and temperature sensor can also be used to control the home application appliances. This can be set to control the home appliances depending on the conditions. The system uses an Android operating system smart phone to communicate with a home personal computer those servers as a server. The PC is used to control the Ardunio board. The Graphical User Interface is developed using MATLAB programming language. The internet can be used to communicate with the personal computer. Wi-Fi can be also used to Internet access. However, this extension is not implemented in the system. Wireless access through has the main benefit of the system. The main disadvantage the personal computer required to be left on all the time.

## 2.6 Mixed Type

Home application appliance automatic control is obtained [31] with a combined of Global System for Mobile communication, ZigBee technologies and Bluetooth. Android operating is used for the user application. Voice input of the user maps it to a set of textual instruction. These instructions transmit through short message service different mobile at home. PIC controller received the instruction through the Bluetooth technology. It is named as the remote access unit. ZigBee transceiver

receives the instruction from the remote control unit. This transfers these instructions through ZigBee to the main controller. The Micro controller decodes the instructions and takes the necessary action. It has feedback connection to retransmit the information through ZigBee. This complete network system is usable and provides wireless access. The use of multiple controllers and technologies the system cost may increase.

A detailed of different technologies that can be applied to home application appliance automation is done [32].It provides the basic idea how modern technology networking applied for the home appliance application. Various internet protocols are used for standardization of home automation. The abbreviation of the UPnP is plug and play capabilities. The documents describes the use of Global System for Mobile communication networks as a backup facility, primary user interface is a web based application. The home network connectivity can be ensuring by using Technologies like Wi-Fi and X-10 protocols.

A different alternative for home application appliance automation [33] added with Global System for Mobile communication and ZigBee. It uses Short Message Service to send instructions from the long distance to the home application mobile. In the case of any doubt activity, the system use of Global System for Mobile communication to send SMS alert or automated calls to the user. Implementation of the hardware using T290 I mobile phone set, Atmega128 Microcontroller unit, ZigBee EM357 module. The Controller unit will deal with both the ZigBee and Global System for Mobile communication networks. ZigBee system is used to communicate with the Microcontroller unit. C programming language is used to implement the whole system. All home applications appliances are controlled by the relays. The Relays highly isolated from the control section due to the ZigBee network. The main benefit of the network low cost and user friendliness. The added feature of this system is it provides very good home security. It is not come in the real time operating system category.

Different non-conventional network for home application appliance automation [34] are easily obtained. An addition of Global System for Mobile communication and a FPGA system. This is due to the dynamic programming capability Field Programmable Gate Array which can be programmed with user requirements. It has small cost as a microcontroller. This reduces over all the costs of these systems. The field programmable Gate Array is connected with GSM Modulator and Demodulator.

The modulator and demodulator is used share the information with the devices. The Field programmable Gate Array takes the logical decision to control of devices. A Universal Asynchronous Transmitter /Receiver are used to allow the interfacing between the Global System for Mobile communication and the Field Programmable Gate Array. The real time operating system main benefit used in the systems. They provides high secure as they are hard wired and cannot be attacked by malicious intent. They can also add or subtract features as required by the user.

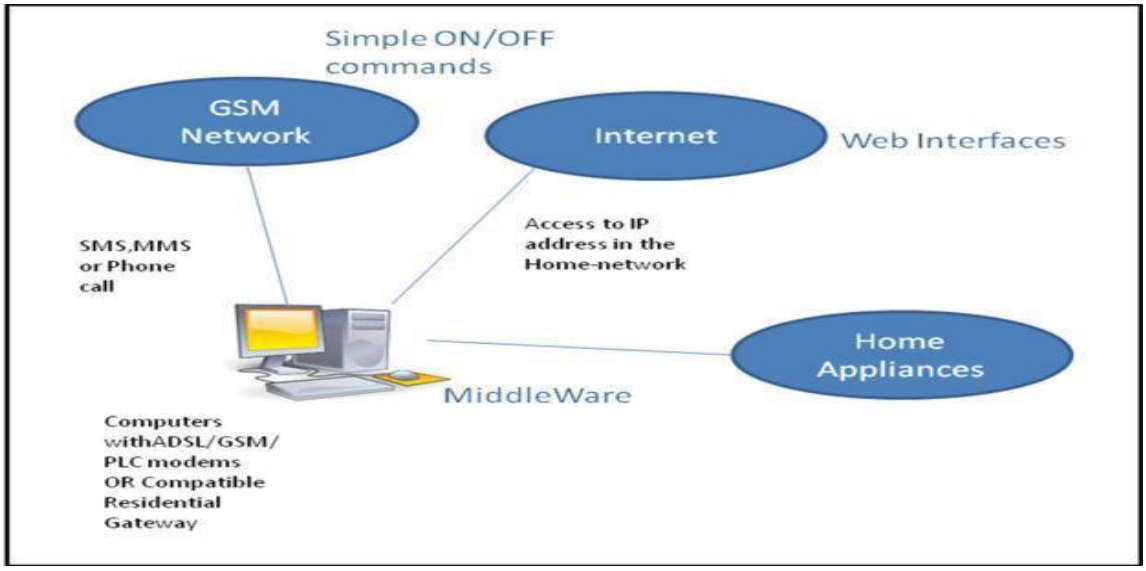


Fig 2.1 Mixed typed automation

Table 2.1 Consolidated comparison report of all systems

| **System** | **Primary Communication** | **Remote access** | **Number of devices** | **Speed** | **Real Time** |
|---|---|---|---|---|---|
| Global System for Mobile Communication | Short Message Service Message | Access from anywhere in the world | Unlimited | Slow due to delivery issue | No |
| Bluetooth | Bluetooth and Attention commands | Restricted to Bluetooth range 10 meters | Unlimited | Fast due to proximity | Yes |
| Phone based | Phone lines | Anywhere with a phone line | 12 due to 12 freq of Dual Tone Multi Frequency | Fast | No |
| Zigbee | Zigbee and Attention commands | Around 10 meter | Unlimited | Fast | Yes |

| | | | | | |
|---|---|---|---|---|---|
| Wireless | Radio infrared or Other waves | Depending on range and spectrum of waves used | Unlimited | Slow due to interference | Yes |

There is a merit and demerit of the entire above different network explained. Some common features all system has which we have studied. All these system have basic communication technology. The benefit & disadvantage of the network derive from this underlying technology. The entire network has different control circuit to interface with the electrical appliance. There has to be a same instruction network that will be used to issue instruction to the control the different logic circuits. The user interface is important feature of the system. This defines how user controls the system. This affects the utilization of the system. All system has the coded lock system that only authorized person an access the system. The most general types of methodologies seen from the above surveyed systems are Global System for Mobile Communication, Bluetooth, based, wireless and combinations of these.

# CHAPTER 3

## SYSTEM ARCHITECTURE

The system has been designed for the Control of connected household appliances and measurement of their electrical parameters remotely. Salient features to the system are the easiness of modeling, setup, and user friendly. Electrical power consumption of various appliances in a house along with drawn current and supply voltage is the key parameter. Fig. 1 demonstrates the operational explanation of the designed and developed system to control apparatuses in view of the consumer prerequisites and monitor electrical parameters.

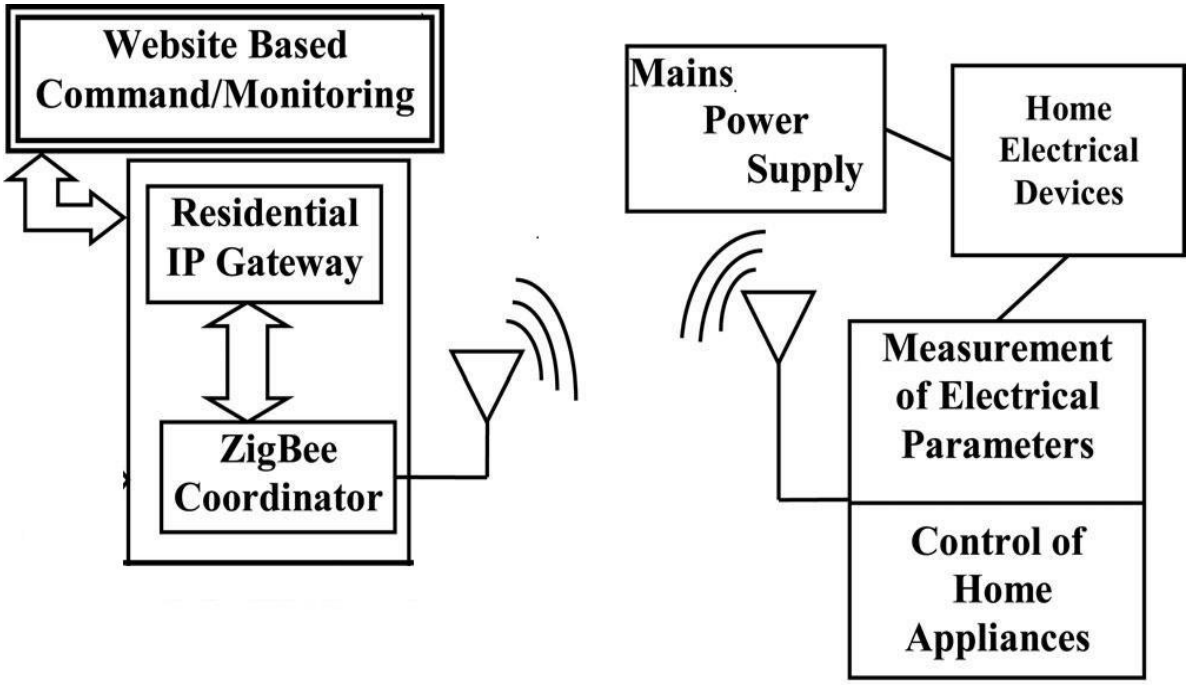


Fig 3.1 Functional Block Diagram of the System

The electrical parameters of home appliances have been measured by interfacing with fabricated sensing modules. The functional details of the design and development of the sensing modules are explained in the following sections.

- Master Unit
- Slave unit

The output signals from the sensors are integrated and connected to Microcontroller and ZigBee module for transmitting electrical parameters data wirelessly. The ZigBee modules and microcontroller are interfaced with various sensing devices and inter-connected in the form of mesh topology to have reliable data reception at a centralized ZigBee coordinator. The maximum distance between the adjacent ZigBee nodes is less than 10 m, and through hopping technique of the mesh topology, reliable sensor fusion data has been performed.

The complete hardware system has been developed in two parts, Master unit and Slave unit.

## 3.1 Master Unit

Block diagram of Master unit is shown in Fig 3.2. It shows that Microcontroller ATMega 328 based on Audrino Uno has been interfaced with Wi Fi Module, Zigbee Module through level shifter. SD card Module, RTC Module and LCD have been also interfaced with the Microcontroller.

### 3.1.1 Working of Master unit

ATMega 328 Microcontroller is main controlling device which communicate with Wi Fi Module, Zigbee Module through level shifter, SD card Module, RTC Module and LCD. It generates and receives the command to /from the unit.

Wi Fi is a wireless communication medium which is password protected and it gets connected through internet if Password and user ID is matched. After connecting to internet, Wi Fi communicates with Microcontroller and User1 (Website Based).

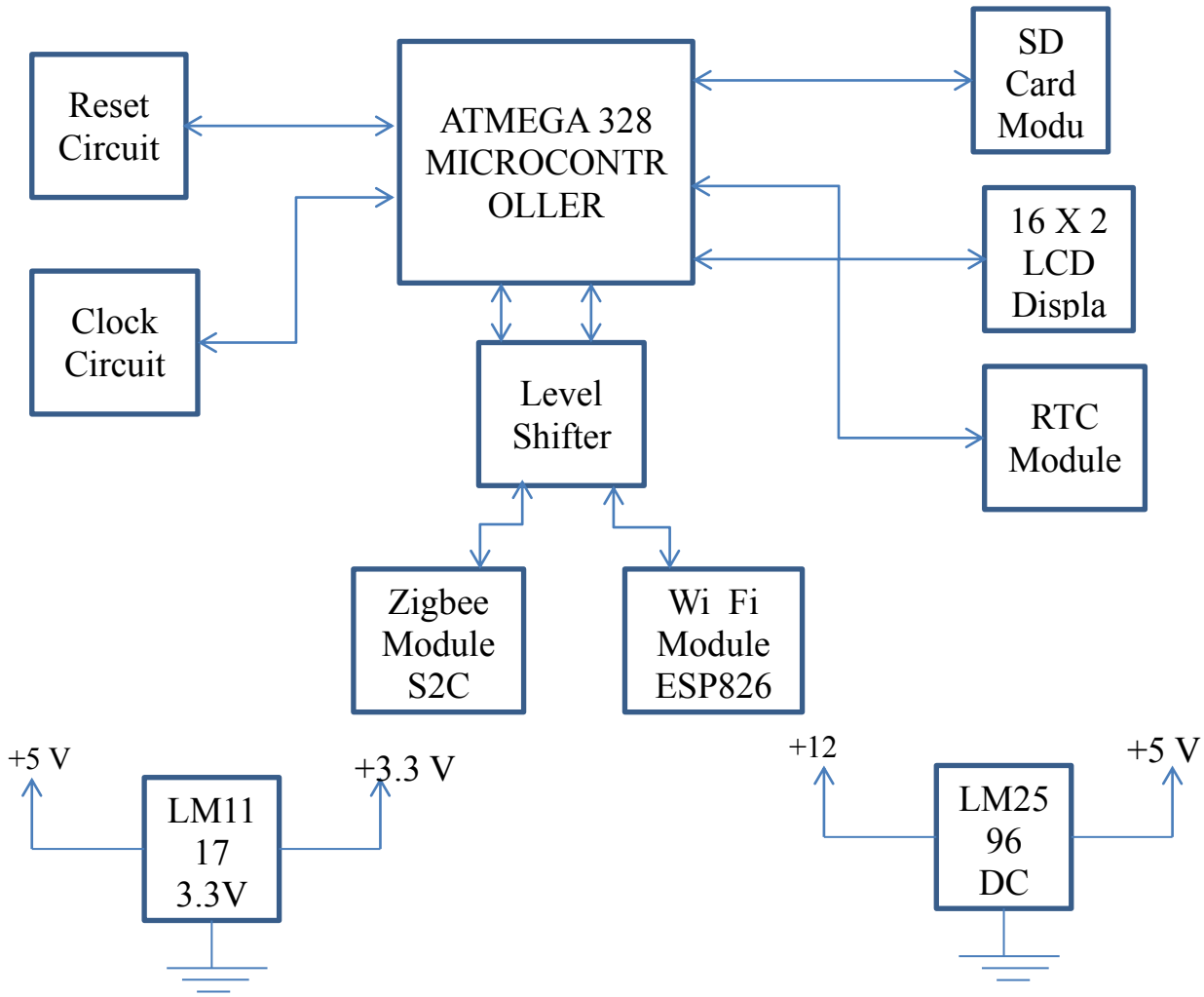


Fig 3.2 Block Diagram of Master Unit

Wi Fi, ZigBee and Microcontrollers works on different voltage levels. Therefore Level shifter is used to convert one voltage level into other compatible voltage level.

Coordinator ZigBee Module communicates with Master Microcontroller and Slave ZigBee module.

SD card module stores the Data like voltage, current and Power of each connected device with slave unit. The time stamping is required to know the timing of each log. So Real time clock (RTC) is used to generate time stamping for the each log.

Present status of device (ON/OFF), voltage, current and power of each device are displayed on the Liquid crystal display (LCD). The status of devices is showed in the form of 0 or 1 on the LCD. 0 indicates device is OFF and 1 shows device is ON.

LM2596 & LM1117 voltage regulator are used to generate fixed 5V & 3.3V supply respectively. 5 Volt is used in microcontroller, Level shifter, RTC, SD and LCD module. 3.3 volt is used to operate ZigBee, Level Shifter and WI Fi module.

## 3.2 Slave Unit

Block diagram of the Slave unit is shown below. Microcontroller has been interfaced with voltage sensor, current sensor, switching circuit, ZigBee module, Temperature sensor, Power cutoff circuit.

### 3.2.1 Working of Slave unit

In slave unit, Microcontroller is main controlling device which communicate with voltage sensor, current sensor, switching circuit, ZigBee module, Temperature sensor, and Power cutoff circuit. It generates and receives the command to /from the unit.

In Voltage sensor, step down transformer converts 220V into 12V, this voltage passed through voltage divider circuit. This analog signal is converted into digital signal by the ADC. Microcontroller senses this digital signal. The sense voltage is displayed on the LCD of Master unit.

Current sensors (ACS712) are placed in series of Loads. The one point of current sensors is also interfaced with Microcontroller and Microcontroller senses the value of all the current sensors. The sense current of each device is displayed on the LCD of Master unit.

Temperature sensor (LM35) is used to measure the temperature of Slave unit area. It is also displayed on the LCD of Master unit.

In switching circuit, Solid state Relay is used to ON/OFF the devices. Microcontroller sends a signal to SSR for switching purpose. SSR consist of Opto coupler and the Triac.

Slave Zigbee Module communicates with Slave Microcontroller and Coordinator Zigbee module. It receive the sense voltage, sense current, sense temperature and status of each device from the slave microcontroller. It also receives the

On/OFF instruction from the coordinator ZigBee. It sends the received slave microcontroller data to coordinator ZigBee and Coordinator ZigBee data to slave Microcontroller.

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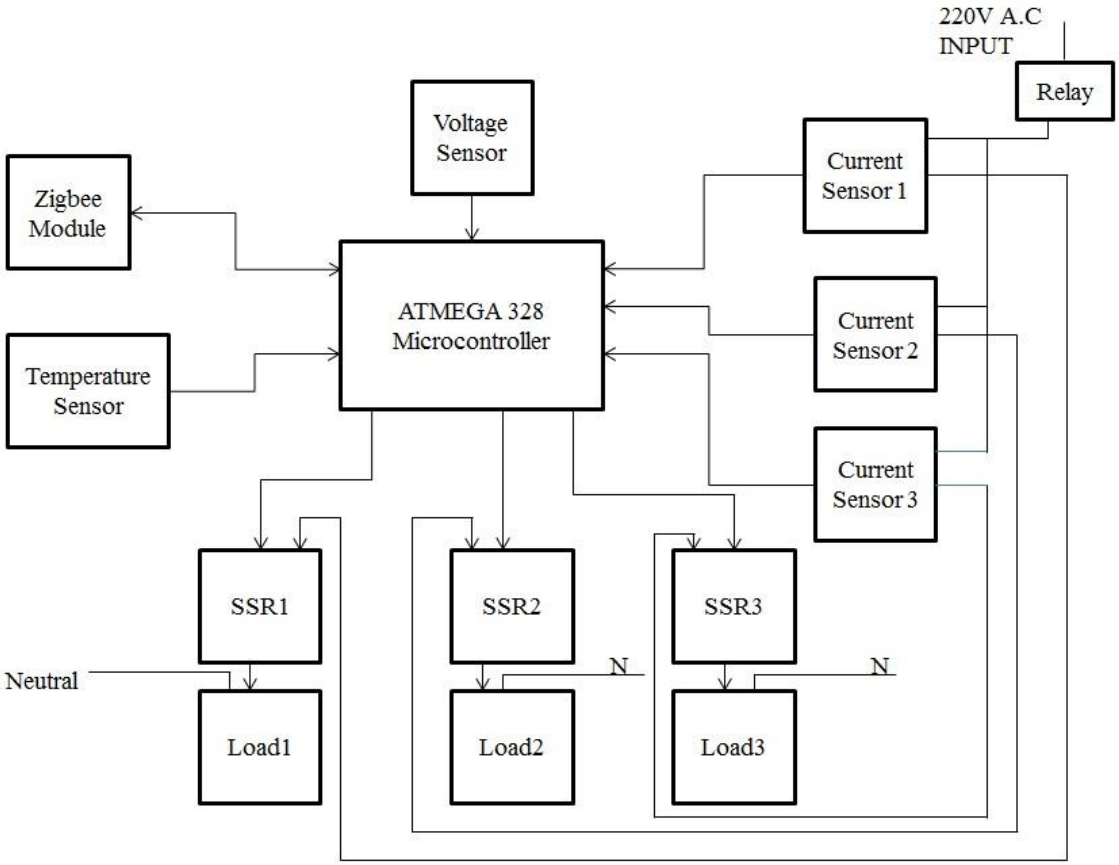


Fig 3.3 Block Diagram of Slave Unit

LM7805 & LM1117 voltage regulator are used to generate fixed 5V & 3.3V supply respectively. 5 Volt DC is required to operate the microcontroller, current sensor and Solid State Relay. 3.3 Volt DC is used to operate the slave ZigBee

### 3.3 Working of complete system

The three Web pages were also developed for complete operation of the system. The web page name is User / Admin login page, User web page and Admin web page. In starting Login user ID and Password entered in the web login page. User web page will open after authentication of user ID and password. In user web page first we check the status of the connected devices. Than user press the ON switch of a device

one, then command through MQTT reaches to Wi Fi module, if Wi Fi module is connected to authorize internet connection than Wi Fi forward this command to Microcontroller, which sends a signal to Coordinator Zigbee module (Master), coordinator Zigbee further sends command to Slave Zigbee, Slave Zigbee send a command to Slave microcontroller, the microcontroller generates a trigger command to Solid State Relay, and device1 will activate. Voltage sensor and current sensor interfaced with slave microcontroller, Slave microcontroller senses the voltage and current and sends to slave Zigbee, slave zigbee send status of devices, voltage and current to the master controller, it sends all these signals to LCD. LCD will display status of devices, voltage, current and power of each device. The sensed data also displayed on the user web page for monitoring and control the devices.

A SD card is used to store information that comes from Master microcontroller. The stored data is used to data analysis for Load Management and other uses.

A scheme has been setup where the system figures out the peak hour of electricity usage and it accordingly controls power consumption at home by switching off the un-important appliances. The system is connected to the mains (220- 240 V, 50 Hz) through monitoring circuit.

### 3.4 Measurement of Electrical Parameters

#### 3.4.1 Voltage measurement

The input **(**230–240 V) of ac input supply is stepped down to 12 V RMS ac signal. The stepped down voltage is then rectified and to get a ripple free dc voltage, the rectified voltage is passed through a Capacitor filter. Once the dc signal is obtained it is given to a voltage divider circuit and the voltage divider circuit brings down the voltage to the level of microcontroller level voltage. The details can also be observed in the schematic of slave unit figure too.

Analog input channel of microcontroller is now provided with the output signal that is obtained Microcontroller. It is important to note that this voltage is linearly proportional to input voltage. The scaling of the signal is found through voltage divider and transformer step down ratio. The actual voltage is thus

$$\text{Voltage}_{(actual)} = \text{Voltage}_{(voltage\text{-}measured)} * m1 \text{----------(1)}$$

Where, proportionality factor = m1

### 3.4.2 Current measurement

ACS712 current sensor is used to sense the current. Compact size and fully encapsulated PCB mounting are the main features of this sensor. Schematic of slave unit in Figure shows the circuit for current measurement. Everything is similar to the voltage measurement discussed above except for the fact that here we are using two different current sensor and both have different ranges one is between 0 to 5 ampere and the other's range is between 0 to 20 ampere. It is also important to note that the circuit has filter that reduces the noise.

For Current,

$$I_{(actual)} = V_{(voltage\text{-}measured)} * m2 \text{----------(2)}$$

Where, scaling factor is m2. Different values of m2 should be used for two different current sensors. It is important to note that 1st sensor is used for appliances with a combined power rating of 1000 Watt. And the 2nd sensor is used for appliances with power rating between 0 to 4000 Watts. We intend to provide outlets of two different loads at same sensing node that is why we have used two different sensors.

### 3.4.3 Power Measurement

The power of a single-phase ac circuit is calculated is by multiplying RMS voltage and RMS current by the power factor. Power factor is cos (the phase angle of voltage and current).

$$P_{(Actual)} = V_{(RMS)} * I_{(RMS)} * Cosx \text{----------(3)}$$

Whether the connected load is capacitive, inductive or even purely resistive the output signal of the current sensors depends on the type of the connected devices.

The problem is we don't actually get pure sinusoid from domestic appliance for different loading condition. Plus, elimination of Noise is not always a trivial job. And also it is difficult to measure zero-crossing for some of the appliances.

To calculate the power accurately correction factor can be used. Where, correction factor is equal to actual power divided by measured power. For power measurement of some load correction factor is required. A graph can be plotted between calculated power and the actual power to get the correction factor.

The system has been tested on many household electrical appliances and the results that were achieved are shown in the result sections. The 0 to 5 % error for all measured parameters. It can be seen that maximum error for household appliance is less than 5%. And hence for such low error percentage correction factor is not required.

### 3.5 Control of Electrical Appliances at Home

Our system is unique from other similar literature because of its feature of controlling. To give flexibility to consumer in controlling the device triac-BT139 along with intelligent Metering system has been used for switching device on/off. The user can turn the device off and on three different ways:

#### 3.5.1 Automatic

Our system can be programmed in such a way that it can automatically scrap webpage of electricity distributor of the particular user to get the tariff rate of electricity. And the system has the capability of deciding the peak hour and accordingly it will switch off or switch on the connected device, giving user some sort of automation.

#### 3.5.2 Manual

The user is provided with a manual control of system. A OFF/ON switch is directly provided to user to control the system at his/her own wish. This actually gives power to user to actually bypass the automatic control. Our system is designed in such a way that a manual command will always override the automatic command. .

#### 3.5.3 Controlling Remotely

Users can remotely control the system from a remote location. It can be controlled from a webpage or even from an app. This is pretty useful for users who often forget to switch off their electric appliances before stepping out of home. The

webpage will show the user about the current status of appliance and the user can turn the appliance on or off from the webpage.

### 3.6 Data Storage

Information such as time, source address & channel and sense data are stored in database. Every time a packet is received a row gets added to the table. Hence samples gets arranged by sensor node, time and sensor channel.

C language has been used here for programming packet transformations and data transmission. And for packet reception and data storage also we have used “C” language. However PHP Script and Java Scripts is used for Web interface.

# CHAPTER 4

# HARDWARE DESIGN

The complete system has been designed and developed hardware wise in two units, called Master and Slave unit. The Hardware used in the Master and Slave unit has been described below:

## 4.1 Hardware Components Used in Master and Slave Unit

- AVR ATMega328 Microcontroller working on Arduino UNO Platform
- Wi Fi Module - ESP 8266
- ZigBee Module 2C
- DC-DC Converter - LM 2596
- Voltage Regulator - LM 7805 & LM 1117
- Triac with optocoupler - BT139
- Current Sensor - ACS712
- Micro SD card Module
- RTC - DS 1307 module
- Level Shifter
- 16 x 2 LCD MATRIX
- Temperature sensor - LM 35

## 4.2 Microcontroller (ATmega328/P)

The Atmel ATmega328/P is an 8-bit Microcontroller. It is CMOS based low power microcontroller. It is designed and developed based on Reduced Instruction Set Complex architecture. It can execute powerful instruction in a single clock cycle.it has 32 general purpose register, all are 8 bit register. The throughput is 20 MIPS at 20 MHz. It has 2 cycle multiplier on the chip. In System self-programmable flash program is 32 bytes. It has Electrical Erasable Programmable Read only Memory and Internal Static Random Access Memory, 1Kbytes and 2Kbytes respectively. It has 3 Timer/counters in which two Timer/counter is 8bits and one Timer/counter is 8 bits. It works on +5V DC. The input voltage range limits is 6 – 20 V but input voltage recommended is 7-12V. It

has Digital input/output Pin is 14 and Analog input Pin is 6. DC current per input/output is 40 mA. Its clock speed is 16 MHz.

Arduino is free electronics prototyping platform based on easy to use software and hardware.it has the capability of sensing the surrounding by receiving input data from numerous sensors and it can reflect output using control motors, lights, and actuators. The microcontroller has been programmed with the help of Arduino programming language and the Arduino development environment. Anybody can build the board or it can be bought, the software and CAD files are free.

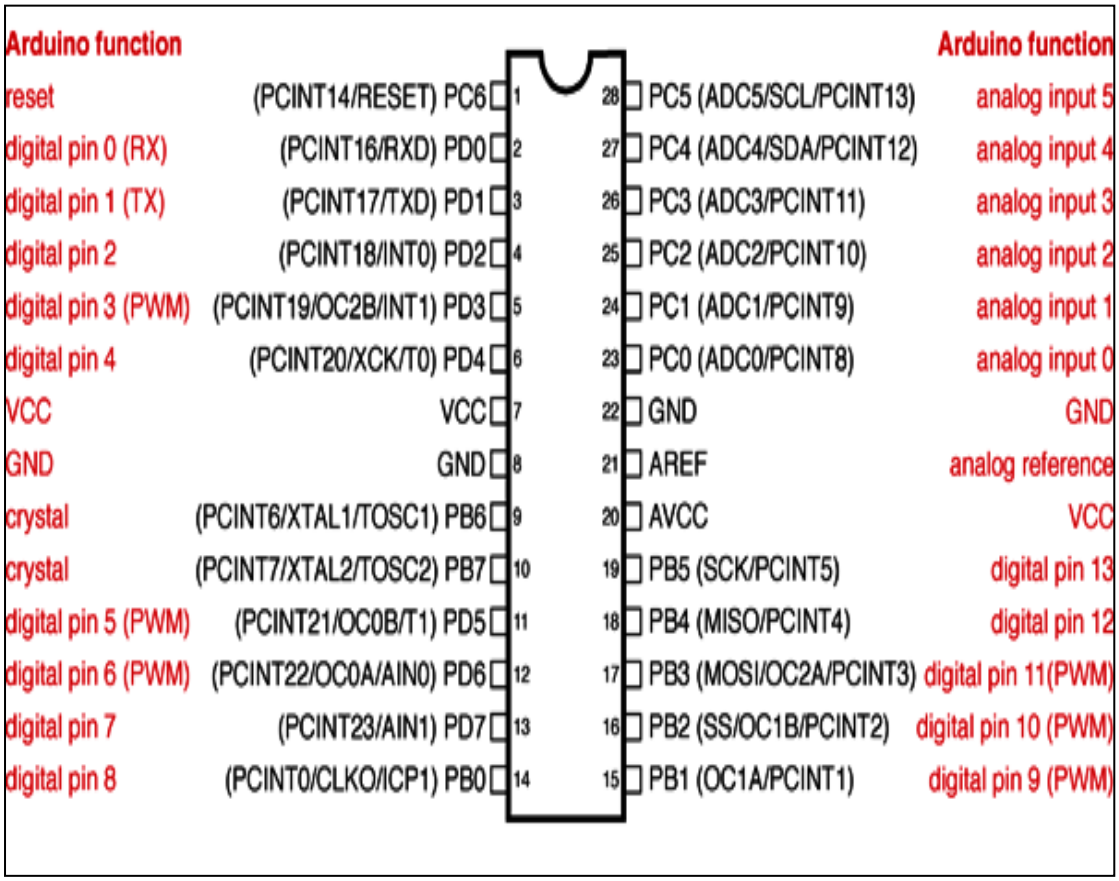


Fig. 4.1 Pin Diagram of the UNO along with mapping of Atmega328 pins

### 4.3 ZigBee Module

The ZigBee Series 2 OEM RF Modules were engineered to operate within the ZigBee protocol and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between remote devices. The modules operate within the ISM 2.4 GHz frequency band.

**Table 4.1 Specifications of the ZigBee Series 2 OEM RF Module**

| **Specification** | **ZigBee Series 2** |
|---|---|
| Performance | |
| Indoor/Urban Range | up to 133 ft. (40 m) |
| Outdoor RF line-of-sight Range | up to 400 ft. (120 m) |
| Transmit Power Output<br><br>(software selectable) | 2mW (+3dBm) |
| RF Data Rate | 250,000 bps |
| Serial Interface Data Rate<br><br>(software selectable) | 1200 - 230400 bps<br>(non-standard baud rates also supported) |
| Receiver Sensitivity | -95 dBm (1% packet error rate) |
| Power Requirements | |
| Supply Voltage | 2.8 – 3.4 V |
| Operating Current (Transmit) | 40mA (@ 3.3 V) |
| Operating Current (Receive) | 40mA (@ 3.3 V) |
| Power-down Current | < 1 uA @ 25$^{o}$C |
| General | |
| Operating Frequency Band | ISM 2.4 GHz |
| Dimensions | 0.960” x 1.087” (2.438cm x 2.761cm) |
| Operating Temperature | -40 to 85$^{o}$ C (industrial) |
| Antenna Options | Integrated Whip, Chip, RPSMA, or U.FL Connector |

| | |
|---|---|
| Networking & Security | |
| Supported Network Topologies | Point-to-point, Point-to-multipoint, Peer-to-peer & Mesh |
| Number of Channels<br><br>(software selectable) | 16 Direct Sequence Channels |
| Addressing Options | PAN ID and Addresses, Cluster IDs and Endpoints (optional) |

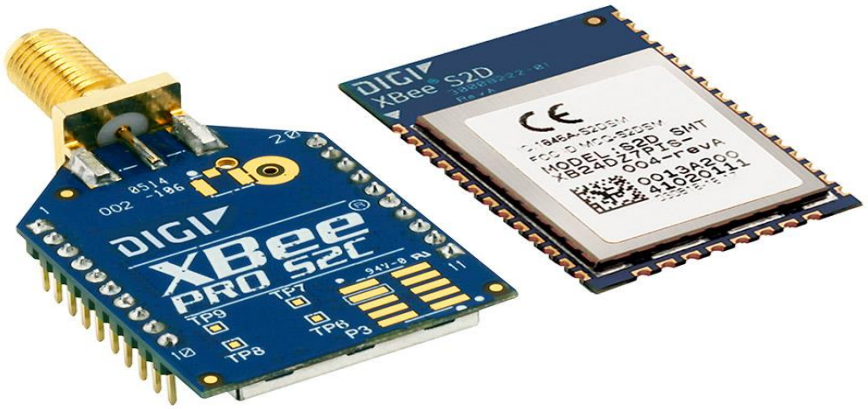


Fig4.2 ZigBee Module (Model S2C)

**4.4 WI - FI (ESP8266)**

ESP8266 is a smaller sizes Wi Fi module. It is 32-bit Microcontroller unit, low power. It has 10-bit ADC Integrated, TCP/IP protocol stack Integrated. It supports antenna diversity. It supports 80 MHz & 160 MHz Clock speed. The IEEE802.11 b/g/n standard is used in this module. This module can be used as a separate network controller or the add on modules in existing network. It is wireless, system on chip (SOC) module with high integration. It is designed for power and space limitation mobile platform designers. It gives incredible capacity to implant Wi-Fi abilities inside different frameworks, or to work as an independent application, with the most reduced cost, and insignificant space necessity.

ESP8266 offers an entire and independent Wi-Fi organizing arrangement; it can be utilized to have the application or to offload Wi-Fi organizing capacities from another application processor.

At the point when ESP8266EX has the application, it boots up straight forwardly from an outer blaze. In has incorporated store to enhance the execution of the framework in such applications.

### 4.5.1 Step-Down Switching Regulator (LM 2596)

The LM2596 is a step down switching regulator, monolithic integrated circuit. It is also called buck converter. It is suitable for easy and convenient design of step down switching regulator. It can drive up to 3.0 Ampere load current with excellent line and load regulation. The desired output can be adjusted by variable potentiometer. This device is accessible in movable output form and it is inside repaid to limit the quantity of outer components to streamline the power supply design. Because LM2596 converter is a SMPS supply (switch−mode control supply), its effectiveness is essentially higher in examination with prominent three−terminal linear regulators, particularly with higher input voltages.

The LM2596 works at an switch frequency of 150 kHz in this way permitting smaller size filter component than what might be required with lower frequency switch regulator. Accessible in a standard 5 lead TO 220 bundle with a few diverse lead twist choices and D2PAK surface mount bundle.

### 4.5.2 Fixed 3.3 Voltage regulator (AMS 1117)

The AMS1117 arrangement of movable and settled voltage controllers are intended to give up to 1 Ampere output current and to work down to 1Volt I/P to O/P differential. The dropout voltage of the device is ensured most extreme 1.3V, diminishing at bring down load currents.

The AMS1117 devices are pin compatible with other three-terminal SCSI controllers and are offered in the position of safety surface mount SOT-223 bundle, in the 8L SOIC bundle and in the TO-252 (DPAK) plastic bundle.

### 4.5.3 Fixed 5V Voltage Regulator (LM 7805)

7805 is a voltage controller Integrated circuit. It is an individual from 78xx arrangement of settled straight voltage controller ICs. The voltage source in a circuit may have variances and would not give the settled voltage yield. The voltage controller IC keeps up the yield voltage at a steady esteem. The xx in 78xx demonstrates the settled output voltage it is intended to give. 7805 gives +5V managed control supply.

Capacitors of appropriate values can be associated at input and output pins relying on the particular voltage levels.

### 4.6 Triac Module (MOC3061 BT139 600V 16A)

Single Channel Triac Module has the capacity to control AC related applications with Arduino, PIC or Any other microcontroller. There are one/two directs as specified in the thing portrayal and single/both channels can be utilized all the while. In this module Triac is operated through opto coupler MOC3061.

## 4.7 Current Sensor (ACS712)

The ACS712 is a current sensor. It can sense AC or DC current accurately in commercial industrial and communication applications. User can use and implement this sensor easily. The main uses include load detection and motor control management, SMPS, and overcurrent fault protection.

The gadget comprises of a low-offset, exact, direct Hall sensor circuit with a copper conduction way situated close to the surface of the die. Connected current moving through this copper conduction way produces an attractive field which is detected by the incorporated Hall IC and changed over into a corresponding voltage. Gadget precision is upgraded through the nearby vicinity of the attractive flag to the Hall transducer. An exact, relative voltage is given by the low-offset, chopper-balanced out Bi CMOS Hall IC, which is customized for exactness in the wake of bundling.

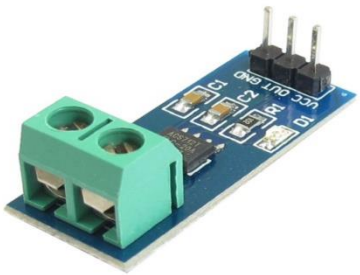


Fig 4.3 ACS 712 current sensor Module

**Features of current sensors**

It is small-noise analog signal path. Filter pin is used to set the device bandwidth. The O/p rise time is 5 microseconds in respect to step input current. The

bandwidth is 80 KHz. Its operate on +5 V DC and minimum isolation voltage is 2.1 KVRMS. The output voltage proportional to AC or DC currents. The output sensitivity is from 66 to 185 mV/A.

## 4.8 Micro Storage Device Breakout Board

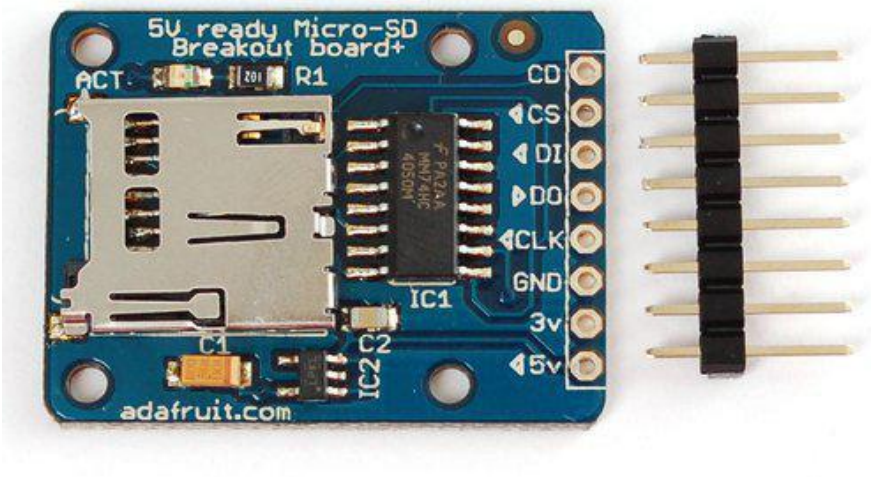


Fig 4.4 Micro Storage breakout board of Arduino

The micro SD adapter is used to store the data of the events. It is designed for ease of use. **5V** to 5V, **GND** to ground, **DI** to pin 11, **DO** to pin 12,and **CS** to pin, 10**,CLK** to pin 13 for connection with Arduino.

- 5V &3V regulator offers 150mA onboard for power-hungry cards.
- 3V level shifting is used so can use e on either 5V or 3V systems.
- Level shifting chip is used instead of resistors: minimize problems, and fast read/write access.
- 3 or 4 pins (digital) is used to read and write, storage is 2GB.
- LED is glow when read and write operation carried out.
- SD card can be inserted or removed easily by Push-push sock.
- It can be used in bread board on in PCB.

### 4.9 Real Time Clock (DS1307)

The DS 1307 is serial real time clock which is full binary-coded decimal (BCD), calendar / clock plus 56 bytes of NV SRAM, low-power. Data and address are sending serially through two wires, bi-directional bus. The calendar / clock provides hours, minutes, seconds, date, month, day, and year information. The month end date is adjusted automatically for months with fewer than 31 days, including for leap year

corrections. The clock can set in either the 12-hour or 24-hour format with A.M/P.M indicator. The RTC can sense power failure and switch to battery supply automatically.

**Features of RTC**

- RTC (Real-time clock) counts sec, min, hrs, month date, month, week day, and year.
- NV (Nonvolatile) Random Access Memory for data storage (56-byte)
- Square wave output signal Programmable
- Serial interface with Two-wire
- Power failure detection and automatic switching
- Operating temperature range for industry from -40 to +85 degree Celsius
- With oscillator running, Consumes less than 500nano Ampere in battery backup mode
- SOIC or DIP in 8-pin

### 4.10 Liquid Crystal Display (LCD)

Fig 4.5 Liquid Crystal Display

Electronic display module is used for displaying Data, it is called Liquid Crystal Display (LCD). It is used in many applications. A LCD display of 16x2 is very common module and it is used in various circuit and devices. These types of modules are chosen over multi segment LED and seven segments display. It is easily programmable, no limitations displaying special character, animation, cheap and so on.

There are two such lines by which 16 characters per line can be displayed in a 16x2 LCD. Command and Data register are used in this LCD. For insert a special command into the LCD, Command register is used. For insert a Data into LCD, Data register is used. Like move to line one character, setting up the cursor, clear screen etc.

## 4.11 LEVEL SHIFTER

Use this module to connect two devices of different digital voltage levels. For example: connecting an Arduino (5V device) to an ESP8266 (3.3V device).

For Level shifter module operation, two power supplies is required, high and low voltage source. HV pin of level shifter is connected with high voltage and LV pin of shifter is connected with low voltage supply. Both Ground pin of ( LV & HV) shifter is connected with supply ground . for example if we have to connect the Microcontroller(+5V signal) and Wi Fi (ESP8266) (3.3V signal) with level shifter than HV pin of shifter is connected with +5V and LV pin is connected with +3.3V.Ground pin is connected with supply ground. Connect the signal pin from the microcontroller to level shifter HV1 pin and connect the signal pin of Wi Fi to level shifter LV1 pin.

**Specifications of Level Shifter**

- Power from two (high and low)voltage sources; low voltage to the LV pin and high voltage goes to the HV pin
- Convert 4 pins on the low side to 4 pins on the high side or vice versa
- Pinout labeled on modules
- Breadboard compatible
- I2C signal capable

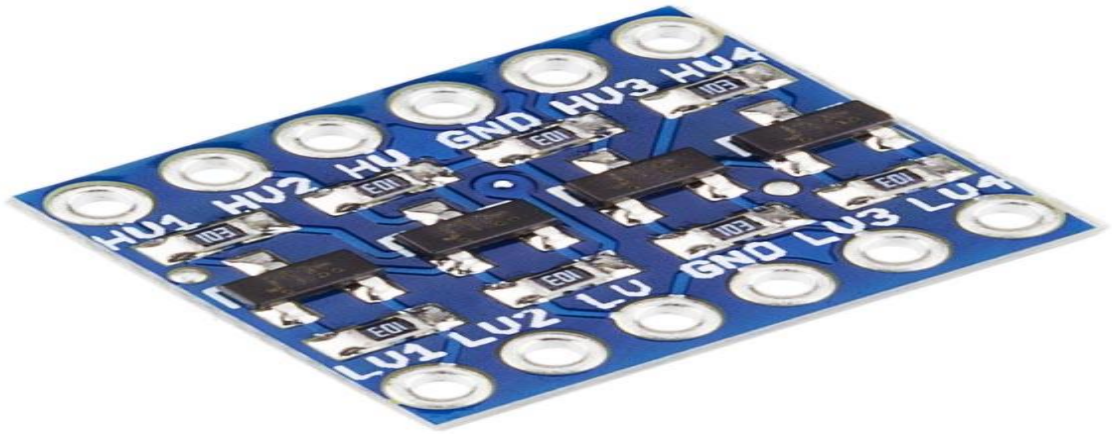


Fig 4.6 Level Shifter

## 4.12 Temperature Sensor (LM 35)

For temperature measurement, LM35 IC is used in the slave module. The LM35 series are very accurate temperature sensors. Its output voltage is directory proportional to $^{o}$C temperature. The LM35 has a very important characteristics that its output comes in directly degree Celsius, while many other temperature sensors, output

comes in Kelvin. In case of Kelvin output, user has to subtract large constant voltage from its output voltage to get useful centigrade scaling. The LM 35 is a factory calibrated IC. So it does not require any calibration externally. At room temperature ±1⁄4˚C accuracy and at −55 to +150˚C temperature range ±3⁄4˚C is get. The LM35 is precise inherent calibration, low output impedance, and linear output creates interfacing to control circuitry especially easy or readout. It operates with single power supplies. It can operate with plus or minus power supply. The current draw 60 µA from supply. The LM35 can operate −55˚ to +150˚C temperature range, while the LM35C can operate for a −40˚ to +110˚C range.

**Features of temperature sensors**

- Accuracy 0.5˚C
- + 10.0 mV/˚C Linear scale factor
- Very useful for distant applications
- −55˚ to +150˚C Rated for full range
- 4 to 30 volts Operating voltage
- Due to wafer-level trimming Low cost
- Less than current drain 60 µA

# CHAPTER 5

# WORKFLOW

The entire project is developed into 2 major sections (**Master and Slave**) and we have planned the development of the system accordingly.

## 5.1 Master Section

In Master Unit, Many components are used like Power Module, Microcontroller, Wi-Fi, Liquid Crystal Display (LCD), Real Time Clock (RTC), SD Module and Level Shifter. All the components have been mounted and soldered as per circuit diagram. All the components have been interfaced with each other as per schematic of Master Unit as shown in Fig 5.1. The detailed description of work carried out is as given below:

### 5.1.1 Power Supply requirement and its Design

In master section of the complete module we need two different power supplies (5V and 3.3 V). 5 V has been used for microcontroller, Real Time Clock module, SD module, LCD and LM 1117.

Power supply of 3.3 V has been used for Wi-Fi module, Zigbee Module and Level Shifter. LM 2596 Step down Power Module DC-DC converter is used for generating fixed 5V. The range of input voltage is 4.2 - 40V and output voltage is 1.25V - 7V, which are continuously adjustable. The input voltage must 1V higher than output voltage.

LM 1117 low drop out Voltage Regulator IC is used for generating fixed 3.3V. In this IC, three pins are used for Input, Output and Ground. 5V is applied at input and fixed 3.3V is received at output of the regulator.

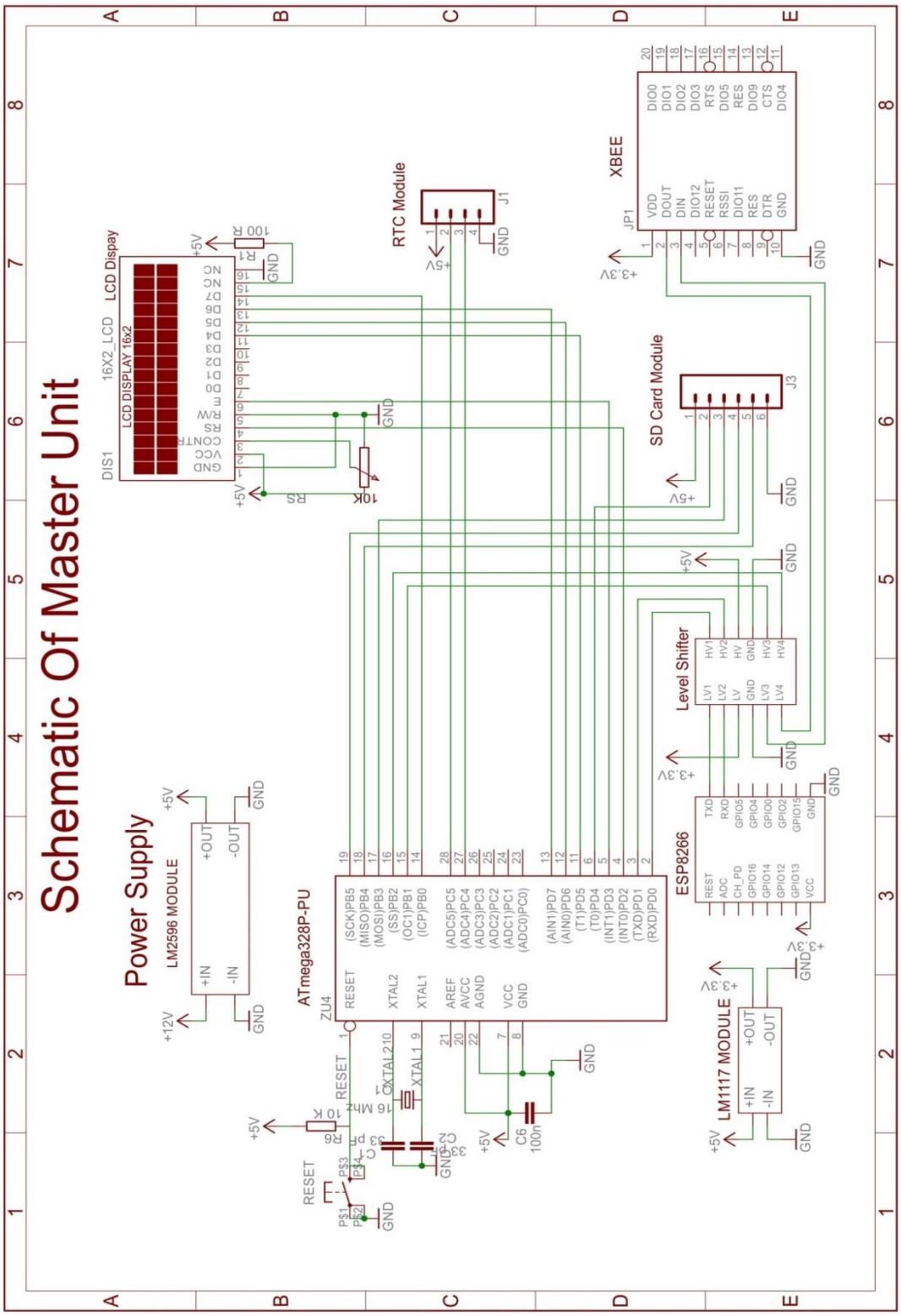


Figure 5.1 Schematic of Master Unit

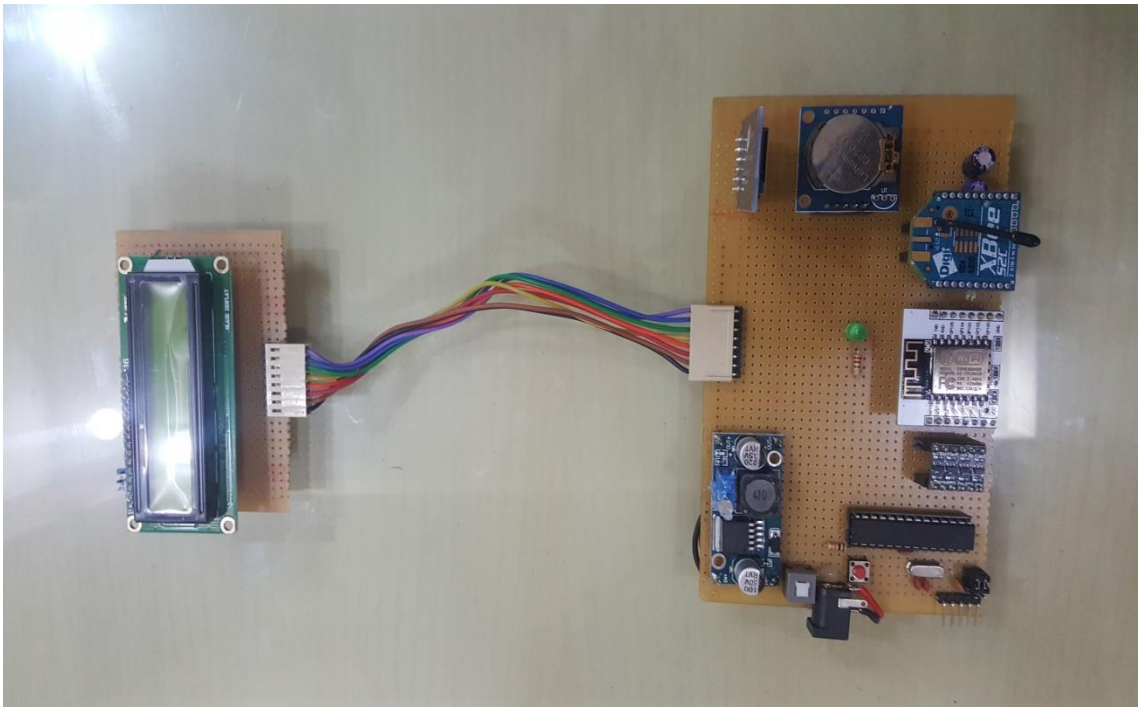

Figure 5.2 Hardware of Master Unit

The following procedure has been adopted for generation and verification of 5V and 3.3 V fixed voltage.

1. Power Regulator Module LM 2596 was mounted and soldered on the PCB of Master Unit.
2. 12 V DC adapter has been connected with LM2596 Module, after that the output voltage is measured using Digital Multimeter.
3. Potentiometer was adjusted to get output voltage of 5 volts.
4. Potentiometer was fixed for so that output remains unchanged during the operation.
5. LM 1117 IC has been mounted and soldered.
6. DC supply of 5V has been applied at Input Pin (output of LM2596 Module) of the LM1117 IC and Ground pin is grounded. Output voltage of 3.3 volts was obtained at the Output pin of IC which was further used to operate the Wi fi, Zigbee and Level shifter.

### 5.1.2 Interfacing of Microcontroller (ATmega 328P)

ATmega Microcontroller has been used in the master and slave unit of the module. In master unit, basic Arduino platform was used for the functioning of the microcontroller. Minimum circuit which is required for the functioning of the Microcontroller (ATmega 328) includes crystal oscillator circuit and Reset circuit. The Microcontroller is a 28 Pin IC which has an internal clock generation circuit but for more accuracy external clock generation circuit has been used. Reset function is also a critical and important feature of the microcontroller which is useful under various operations.

The following procedure has been followed for the implementation of the basic circuit of Arduino/Microcontroller:

1. ATmega 328P Microcontroller IC base has been mounted and soldered.
2. The detailed pin diagram of Microcontroller is shown in figure5.1. Crystal oscillator of 16 MHz has been mounted and soldered between the Pin no. 9 & 10.
3. Two capacitors of 33 pF have been mounted and soldered at pin no 9 & 10. One end of capacitors was grounded.
4. At the Reset Pin no 1, 10 KΩ Resistance and reset switch were mounted and soldered.
5. 5V and Ground was also provided to Reset and Oscillator circuit.
6. 5V DC was applied at Pin no. 7 & 20 and Pin no. 8 & 22 were Grounded.

### 5.1.3 Interfacing of Liquid Crystal Display (LCD)

During the operation of the system we have to display various parameters like Voltage, Current, Power, status of all the connected appliances and Temperature. A 16 x 2 LCD has been used for displaying these parameters. LCD is interfaced with Microcontroller. In this LCD two lines are available for 16 characters. Microcontroller sends a Data to LCD for displaying Voltage, Current, Power, Status of device connected and Temperature.

The following procedure has been used to interface LCD with Microcontroller.

1. LCD has been mounted and soldered as per schematic.
2. The pin details of the LCD are shown in figure 5.1. 5V DC was applied on Pin no. 1 and pin no 2 was Grounded.
3. Pin no.3 is used for contrast. Contrast can be adjusted using 10 KΩ variables Resistance.
4. For back light of LCD, 100KΩ Resistance is connected at pin no. 15 and provides 5V DC.
5. Pin no. 4,6,11,12,13,14 of LCD has been connected with Pin no. 4, 5, 14,28,27,26 of Microcontroller.

### 5.1.4 Interfacing of Wi Fi Module (ESP 8266)

The internet connectivity is necessary for the Master module which has been established through Wi Fi. The Wi Fi Module was selected and it was programmed separately to connect to a particular SSID/Password. It was further integrated with the system. This Wi Fi module works on 2.4 GHz. It requires 3.3 V DC for operation of Wi Fi module. It is 16 Pin Module which has been mounted on IC base. Only 4 Pins were used for the operation (Vcc, Ground, Tx & Rx ).

The following procedure has been used to interface Wi Fi with Microcontroller.

1. Wi Fi has been mounted and soldered as per schematic.
2. 3.3 Volt has been connected At Pin no. 8.
3. Pin no. 16 has been grounded.
4. Pin no 9 (Tx) & 10 (Rx) of Wi Fi was connected with LV1 & LV 2 of Level Shifter.
5. HV1 & HV2 of Level Shifter has been connected with Pin no. 2 (Rx) & 3 (Tx) of Microcontroller.

### 5.1.5 Interfacing of Zig Bee Module (S2C)

It is 20 Pin IC modules which is mounted on IC base. It is work on 3.3V DC supply. Only 4 Pins of this module have been used for Data transfer and for providing the voltage to the module. It communicates with the Microcontroller. A level shifter is used to interface between the two hardware operating on different supply voltage. In our

case Microcontroller and Xbee operates on different voltage levels of 5V and 3.3V respectively. Xbee was selected and programmed to communicate with the Microcontroller and Slave ZigBeee. ZigBee was configured as per the system requirements.

The following procedure has been used to interface ZigBee with Microcontroller.

1. ZigBee Module stand has been mounted and soldered as per schematic.
2. 3.3 V DC was connected to Pin no. 1.
3. Pin no. 10 was Grounded.
4. Pin no 2 ($D_{out}$) & 3 ($D_{in}$) of ZigBee were connected with LV3 & LV 4 of Level Shifter.
5. HV3 & HV4 of Level Shifter was connected with Pin no. 15 & 16 of the Microcontroller.

### 5.1.6 Interfacing of Level Shifter

Level shifter is used to convert voltage level of 3.3V into 5V and vice versa. Microcontroller, Wi-Fi and ZigBee operates on different voltage levels. For the communication of Wi Fi and ZigBee with Microcontroller, level shifter is required. In this Level Shifter only two modules can be connected for communication.

The following procedure has been followed to interface Xbee, Wi-Fi with Microcontroller using level shifter.

1. Level Shifter Module has been mounted and soldered as per schematic.
2. 3.3V was connected At LV.
3. 5V has been connected At HV.
4. Ground has been connected to respective LV & HV Gnd.
5. LV1 & LV2 was connected with Wi Fi module. HV1 & HV2 were connected with the Microcontroller.
6. LV1 & LV2 was connected with Wi Fi module. HV1 & HV2 were connected with Microcontroller.
7. LV3 & LV4 were connected with Xbee module. HV3 & HV4 were connected with the Microcontroller.

### 5.1.7 Interfacing of Real Time Clock (RTC) & Storage Device (SD) Module

In our system we have to store the events with their real time instants, to achieve the same RTC and SD Card were added to create a log. Real time clock is required to know the actual time and date of the event.

The following procedure has been followed to interface SD & RTC module with Microcontroller.

1. RTC & SD module were mounted and soldered as per schematic.
2. 5V DC and Ground were provided as per the pin details.
3. Pin no.2 & 3 of SD were connected with Pin no. 28 & 27 of Microcontroller respectively.

## 5.2 SLAVE SECTION

In Slave Unit also, number of components were used like Power supply, Triac module with opto coupler, Microcontroller, Current sensor, voltage sensor, LCD and Xbee module. All these components were mounted and soldered as per schematic of slave unit in Fig 5.3. The description of work done is as given below:

### 5.2.1 Interfacing of Power Supply

Power supply was designed as per the current and voltage requirements. Various supplies 5V/3.3V were generated using a transformer and rectifier using different regulators.

In master section we have used two power supply 5V and 3.3V. Power supply of 5 V has been used for microcontroller, Relay module, Current sensor and LM 1117 . Power supply of 3.3 V has been used for ZigBee Module.

LM 1117 low drop out Voltage Regulator IC was used for generating fixed 3.3V. In this IC, three pins are used for Input, Output and Ground. A DC supply of 5V was applied at input and fixed 3.3V Output was obtained.

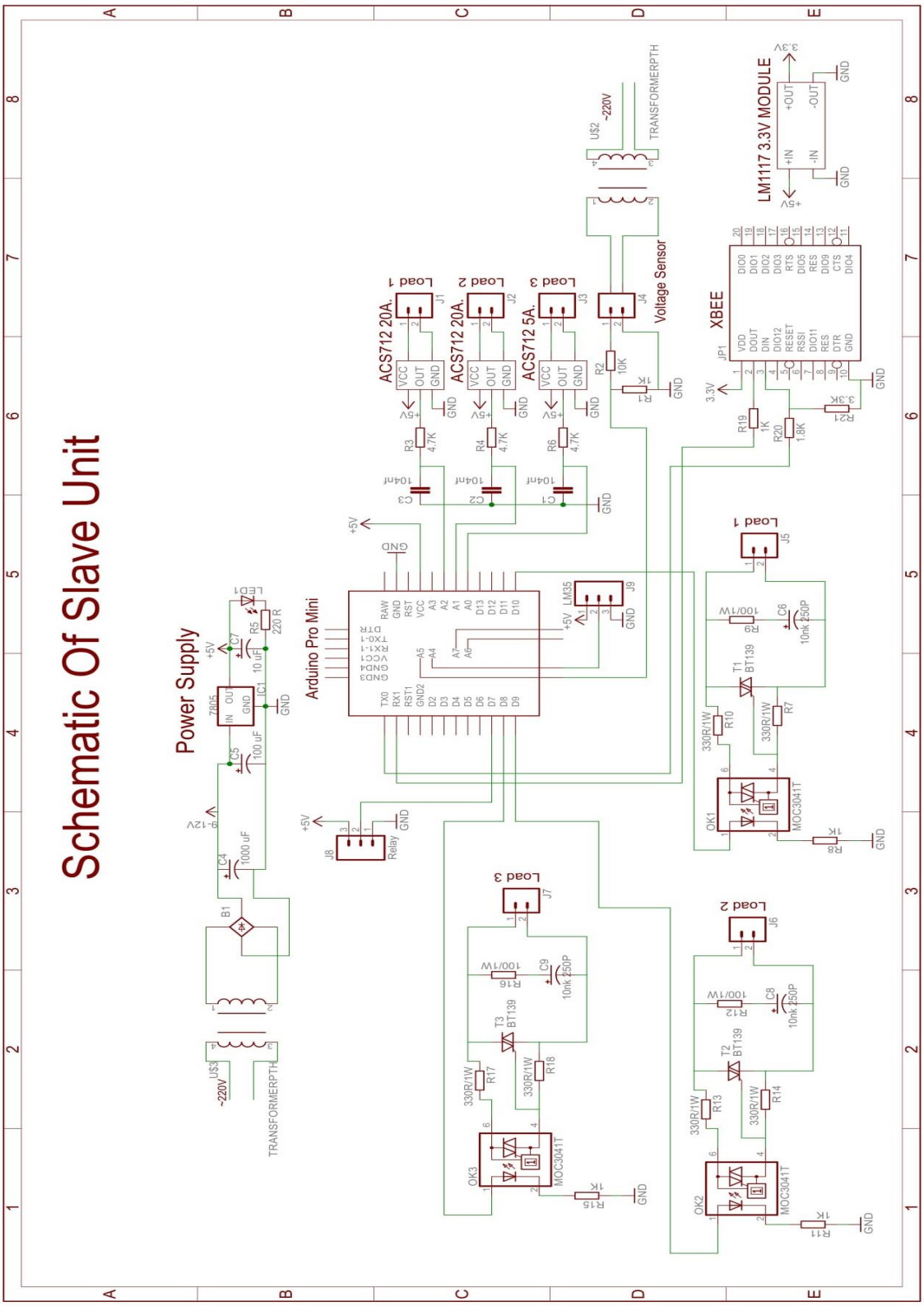


Figure 5.3 Schematic of Slave Unit

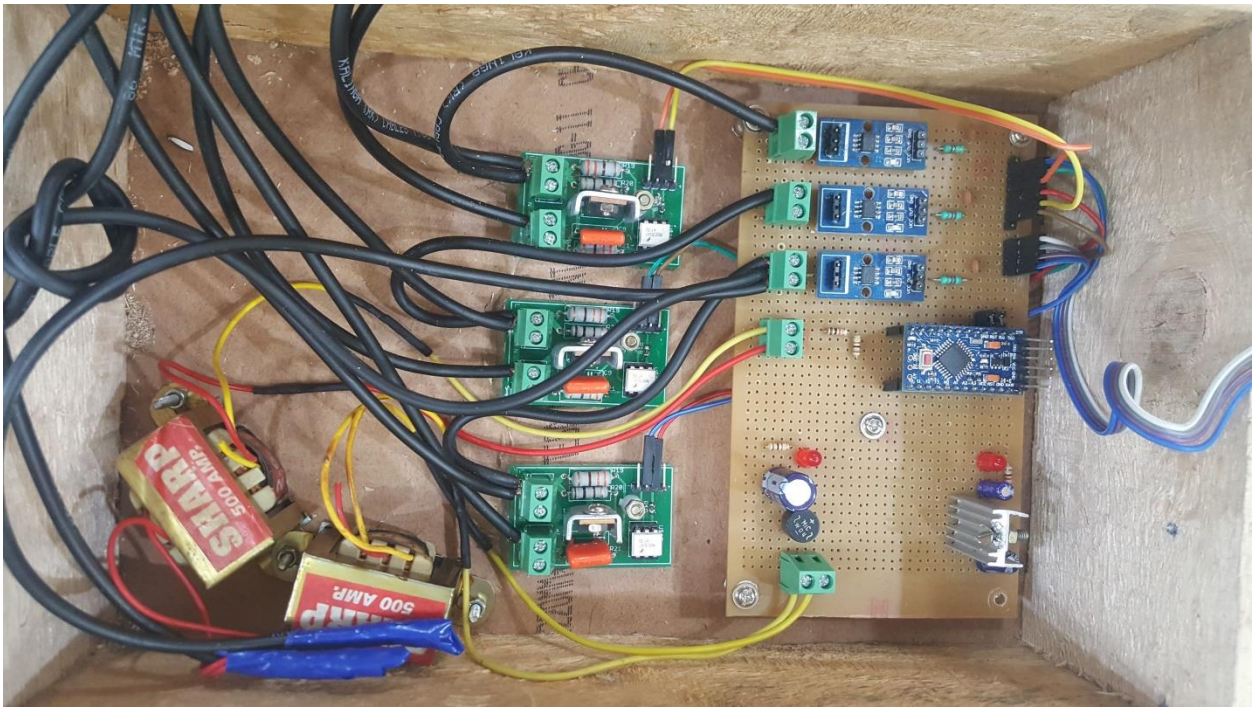


Figure 5.4 Hardware of Slave Unit

The following procedure has been used for generating 5V and 3.3 V fixed voltage.

1. 12 V step down transformer was used to convert 240V AC into 12V AC.
2. Bridge rectifier has been mounted and soldered to convert 12 V AC into 12V DC.
3. Filter circuit has been mounted and soldered to filter out the noise/ripples.
4. LM7805 Voltage Regulator IC was mounted and soldered to convert 12V DC into fixed 5V DC.
5. LED has been mounted with 220Ω series resistor to indicate power supply is available.
6. LM 1117 IC was mounted and soldered.
7. 5V DC is applied at the Input Pin (output of 7805 IC) and Ground pin was grounded. 3.3V DC was obtained At output pin of the IC.

### 5.2.3 Interfacing of Voltage Sensor

Input voltage is also one of the parameter which is to be monitored. In voltage sensor, the input voltage is measured and displayed at the LCD and web page. For this purpose a 12V transformer converts 240V AC voltage into 12V AC which is fed to the voltage divider circuit. The output of voltage divider is fed to the microcontroller. Microcontroller senses this voltage. Using appropriate multiplication factor the actual input voltage is monitored on the display.

The following procedure has been used for sensing the input voltage:

1. 12V transformer was mounted. Output of the transformer was fed to voltage divider circuit.
2. Voltage divider circuit was designed and the desired components were soldered. 10KΩ and 1KΩ Resistance were used.
3. The output of voltage divider was fed to microcontroller. Microcontroller has inbuilt ADC to sense the voltage.
4. Sensed voltage by Microcontroller is displayed at LCD with incorporating appropriate multiplication factor. This voltage is also displayed at the web page.

### 5.2.4 Interfacing of Current Sensor

Load Current is also one of the parameter which is to be monitored. ACS712 is a current sensor which is used to measure the load current. To measure the current of each appliance, each load was connected via an invasive current sensor (ACS712) and its value was measured using ADC of the Microcontroller.

The following procedure has been adopted for measuring the load current:

1. Current sensors of two different ratings were used (5A and 20A).
2. ACS712 current sensor was placed in line with the load.
3. The output of current sensor is in millivolt range which is fed to ADC of Microcontroller.
4. In the 5A current sensor, 1A current corresponds to 185mV and so on.
5. In the 20A current sensor, 1A current corresponds to 100mV and so on.

6. These respective mV values are sensed with the microcontroller. For displaying the actual Load current these are multiplied with their appropriate multiplication factor.
7. Actual Load current value is displayed on the LCD of Master unit and web page.

### 5.2.5 Interfacing of Switching Circuit

For switching On/OFF to the connected appliance, switching circuit was implemented using Solid State Relays based on TRIAC BT139 and opto coupler ( MOC 3041). Once the switching has been tested, we added Sockets with the switches for demonstrating the switching of loads properly.

The following procedure has been used for measuring load current.

1. Three Switching circuits were placed before the loads.
2. The inputs of optocoupler (MOC 3041) were connected through microcontroller D8, D9, and D10.
3. Microcontroller gives the command to optocoupler, which triggers the Triac.
4. After this operation the main supply extended to the load.

### 5.2.6 Interfacing of Zig Bee Module (S2C)

It is 20 Pin IC module which is mounted on IC base. It is work on 3.3V DC supply. Only 4 Pins of this module have been used for Data transfer and for providing the voltage to the module. It communicates with the Microcontroller. A level shifter is used to interface between the two hardware operating on different supply voltage. In our case Microcontroller and ZigBee operates on different voltage levels of 5V and 3.3V respectively. ZigBee was selected and programmed to communicate with the Microcontroller and Slave ZigBee. ZigBee was configured as per the system requirements. Zigbee was connected and its communication was verified by sending some data from master and switching LED’s.

The following procedure has been used to interface ZigBee with Microcontroller.

**1.** ZigBee Module was mounted and soldered as per schematic.

2. 3.3 V DC was connected at Pin no. 1.
3. Pin no. 10 was Grounded.
4. Pin no 2(Dout) & 3(Din) of Xbeeis were connected to Rx & Tx of the Microcontroller.
5. Din is connected with voltage divider circuit which was designed to get the appropriate range of output for Zigbee. This has been done because Zigbee works at 3.3 volt but the Microcontroller Rx signal is at 5V level.

### 5.2.7 Interfacing of Temperature sensor (LM35)

Temperature is also one of the parameter which is to be monitored. LM35 is a precision temperature sensor with its output voltage proportional to the temperature (in $^{o}$C). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, temperature can be measured more accurately than with a thermistor. It also possess low self-heating and does not cause more than 0.1 $^{o}$C temperature rise in still air. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in response to every $^{o}$C rise/fall in the ambient temperature, i.e., its scale factor is 0.01V/ $^{o}$C.

The following procedure has been used to interface Temperature sensor with Microcontroller.

1. Pin no. 1 was connected with 5V DC.
2. Pin no. 3 was connected with Ground.
3. Pin no 2 was connected with ADC of microcontroller (A4).
4. Temperature is displayed on LCD of Master Unit .Temperature was measured as per given in data sheet 10 mV per °C.

### 5.2.8 Interfacing of Cut off Circuit

In case of any emergency or such requirement, if we have to switch of the all appliances there is an option for doing the same. This can be done by switching off the supply of slave circuit. Relay has been used to cut off the supply of slave switching unit and the cut off signal is generated by the Master unit.

The following procedure has been used to interface cut off circuit with Microcontroller.

1. Pin no. 3 was connected with 5V DC.
2. Pin no. 1 was Grounded.
3. Pin no 2 was connected with microcontroller (D7).
4. Master unit generates the cut off signal, Slave controller receives the signal through the Zigbee communication.
5. Slave Microcontroller send signal to relay. Relay will be activate and supplies will be interrupted.

### 5.3 Development of Web pages

For remotely control and monitor of electrical appliances, the three web pages have been developed using HTML, Java script, PHP. Login Web page has been developed for secure login in the internet for user and Admin. For login, user name and password is required. The Fig 5.5 has been given below for login the user or Admin.


Figure 5.5 Login Page of user

In the above figure user name and password is entered. Here two pages were developed for Appliance user and Admin. Appliance user can control and monitor the all appliances which are connected through the developed Slave system. But admin can only monitor and ON or OFF the all appliances at a time in emergency condition.

After entering the correct user name and password, the new page will open like given below. In this Page has been shown that three electrical appliances can be operated remotely. We also measure the voltage, current and power of each appliance and Temperature of Slave unit. Three status symbol has been also given in this page. Every status symbol represents its corresponding appliance condition. Here status symbol colour is blue, which indicate Master unit is not connected with internet. So we can not operate or monitor the appliances until master unit is not connected with the internet. When Master unit is connected with internet the colour of status symbol will change Red or Green. Red indicates particular appliance is OFF. Green indicates particular appliance is ON condition.

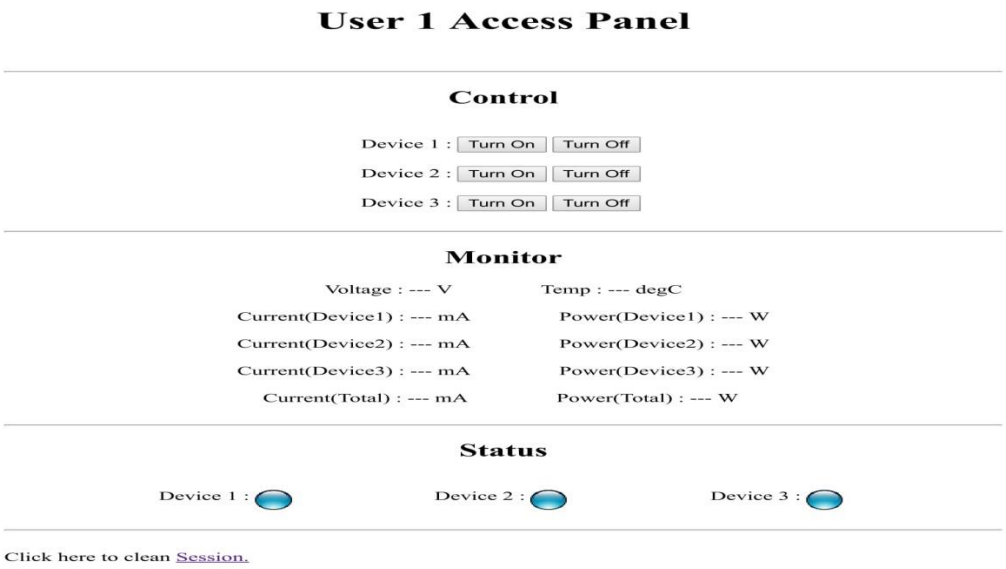


Figure 5.6 Webpage of Monitor and Control of Devices

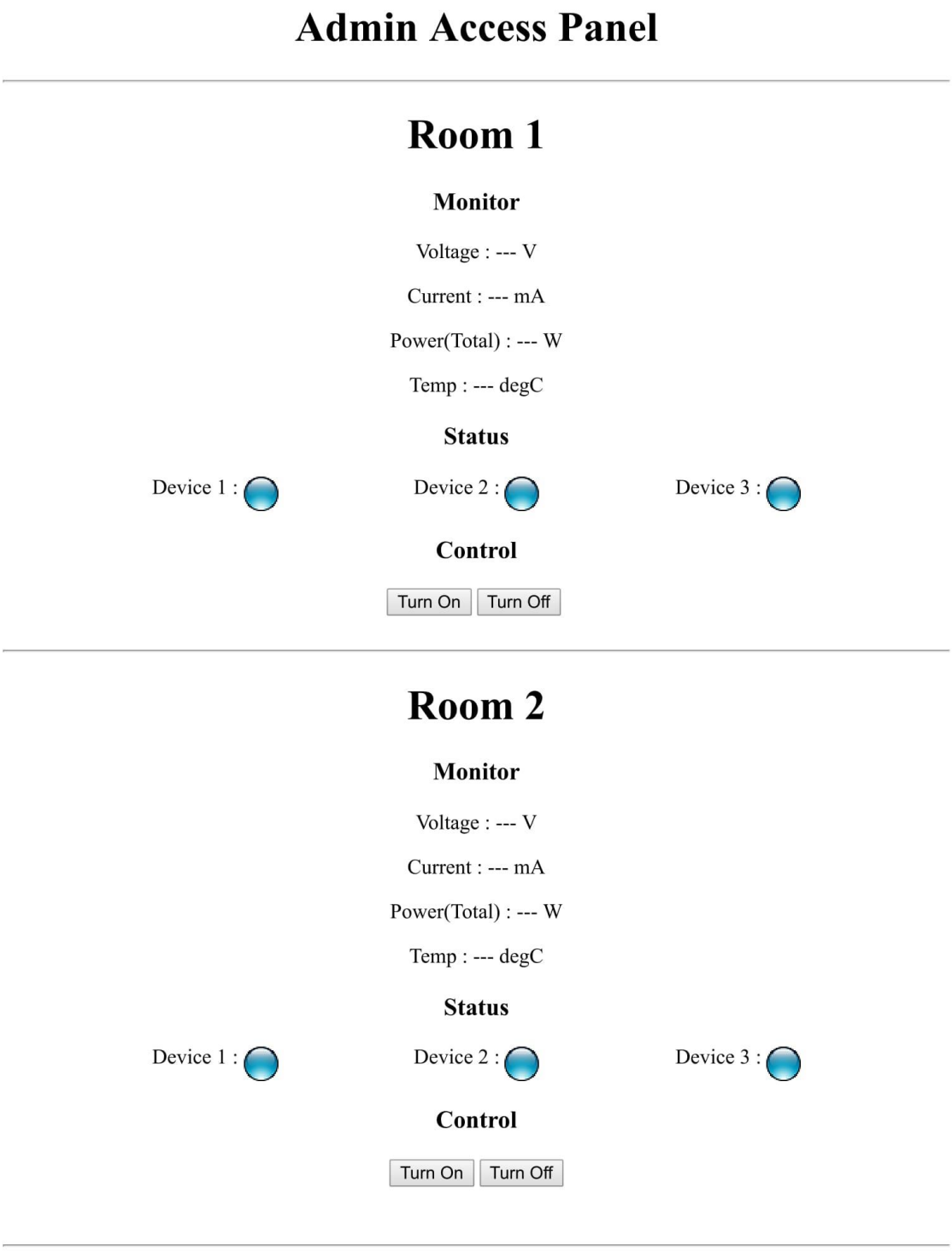


Figure 5.7 Webpage of Admin

In the above Fig 5.7 Admin page has been shown. It comes after entering the Admin user name and the related password. In this page total voltage, current, Power of all appliances and Temperature of Slave unit is monitored. Here we can also

check the status of each device by the colour. Blue colour means Master unit is not connected with the internet. Red colour shows that appliance in OFF condition. While Green colour of status shows device in ON condition.  Here Admin can OFF or ON the all the devices in the emergency or as per requirement.

# CHAPTER 6

## RESULT

The system designed here is best suited for home. We have tested our system on loads like Air Conditioner, Geyser, television, refrigerator, water kettle, toasters, microwave oven etc. However any number of electrical appliances can be put as load provided each load is below 4000 W.

Air-conditioner operation and Monitoring of electrical parameters was tested using developed system has been shown in Figure 6.1.

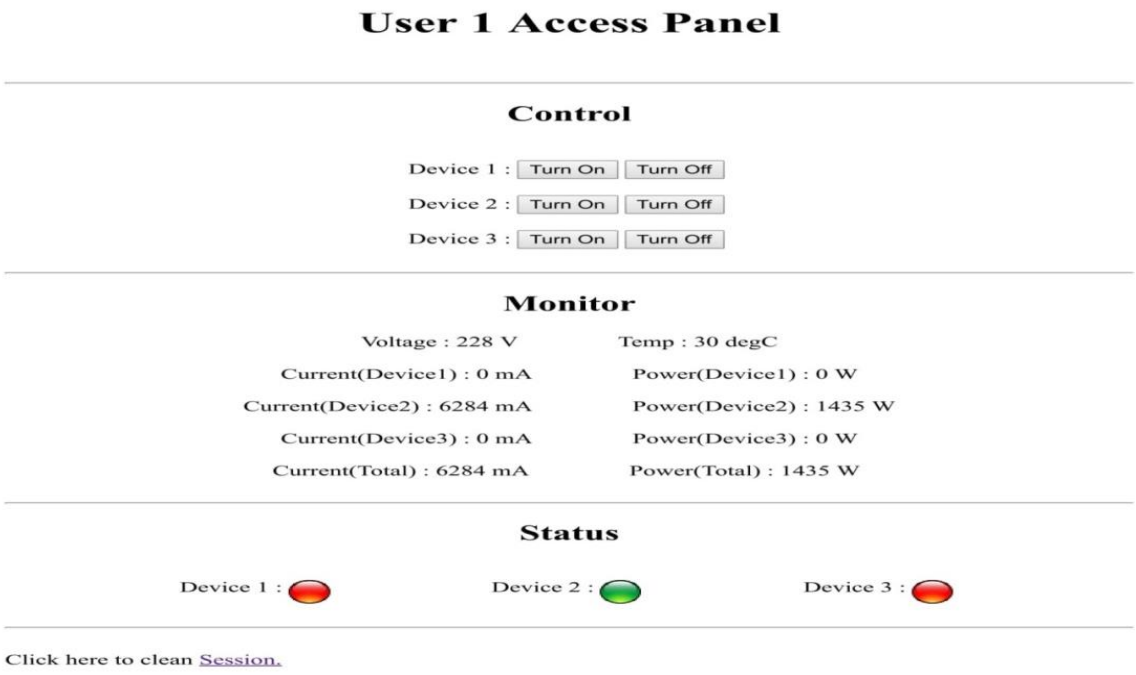


Fig 6.1 Controlling and Monitoring of Air Conditioner

The AC was connected to Device 2 position. The AC was operated remotely through internet (webpage). When AC operated, the status of Device 2 will change from Red to Green. The web page also shows the input voltage 228 Volt, Current drawn by AC 6.284 Ampere and power consumption 1435 Watt. This also shows the temperature of slave unit.

Electric Iron operation and Monitoring of electrical parameters was tested using developed system has been shown in Fig 6.2.

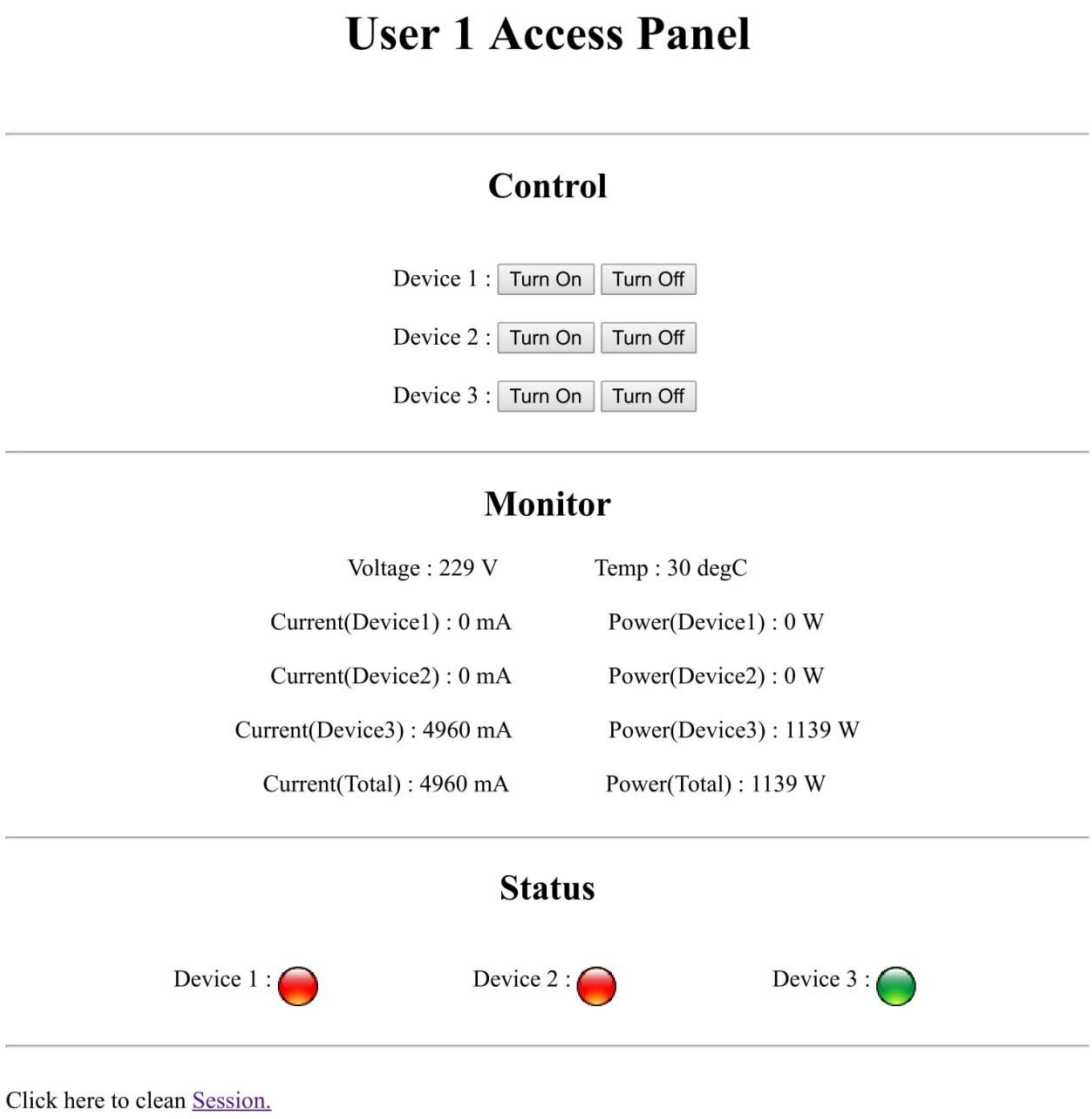


Fig 6.2 Controlling and Monitoring of Electric Iron

The Electric Iron was connected to Device 3 position. The Iron was operated remotely through internet (webpage). When Iron operated, the status of Device 3 will change from Red to Green. The web page also shows the input voltage 229 Volt, Current drawn by AC 4.96 Ampere and power consumption 1139 Watt. This also shows the temperature of slave unit.

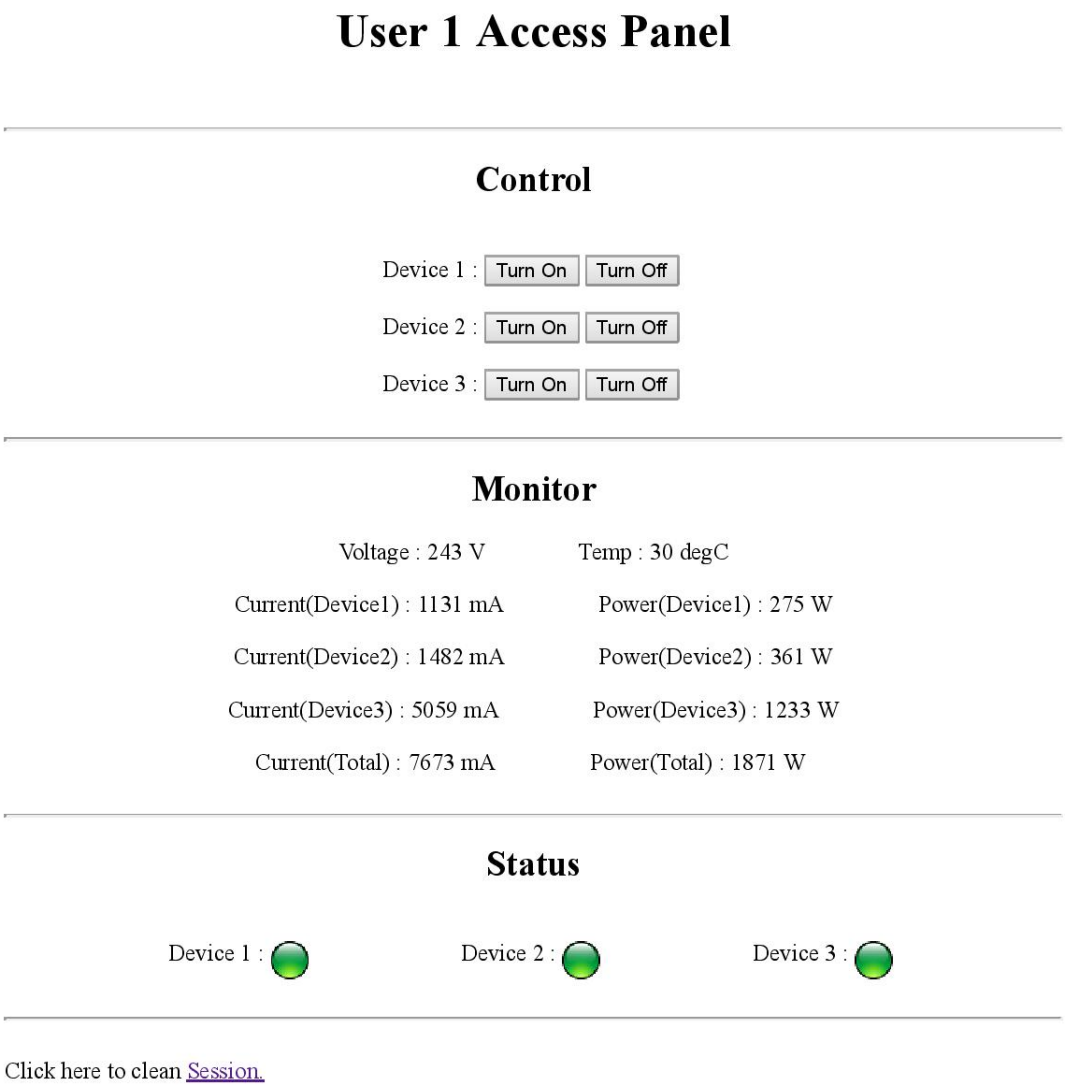


Fig 6.3 Controlling and Monitoring of Three Devices

Three Devices were connected with the developed system for controlling and monitoring of electrical parameters of Water cooler, Freeze and Electric Iron. All the three devices connected respectively at Device 1, Device 2 and Device 3. All the devices were operated remotely through internet (webpage). When Device 1 (Water Cooler) operated the status of Device 1 will change from Red to Green. The web page also shows the input voltage 243 Volt, Current drawn by Water cooler 1.131 Ampere and power consumption 275 Watt. This also shows the temperature of slave unit. When Device 2 (Freeze) operated the status of Device 2 will change from Red to Green. The web page also shows the Current drawn by Freeze 1.482 Ampere and power

consumption 361 Watt. When Device 3 (Iron) operated the status of Device 3 will change from Red to Green. The web page also shows the Current drawn by Iron 4.96 Ampere and power consumption 1233Watt. The total Current and Power of all devices were 7.673 Ampere and 1871 Watt respectively.

To log time we have used SD card module. Electrical or Electronics appliances generate lots of data. These data correspond to power consumption by different appliances. These data need to be stored for further use and processing so these are stored in SD card and are available for users to manipulate. Users can manipulate these data through Webpage through graphic user interface. Information about different parameters like Temperature, current and voltage is shown to users in a very easy to understand manner, using GUI.

The sensors pick the data and it calculates the value of Temperature, Current and Voltage. These values are converted to digital form and are passed on to Coordinator. Then the job of computer starts, its job is to get the data from Wi-Fi and manipulate the data in some way so that it can calculate the actual power that is being consumed by the appliances. It is also worthwhile to note that we have used C programming to process our data.

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# CHAPTER 7

## CONCUSION AND FUTURE SCOPE

An intelligent system that faithfully monitors and controls electrical appliance, at home, for intelligent buildings has been developed.

A continuous watch on electrical appliances can be kept through a website. And just by extension of these ideas, we can keep a watch on the entire building. Our aim here is to come up with an optimized solution that minimizes electricity consumption during peak hours.

The sensor systems are computerized with user friendly User Interface, keeping heterogeneity in users in mind. We aim to see user's reaction towards this intelligent system. We also aim to list possible advantages and disadvantages.

Our system has been faithfully monitoring and controlling appliances remotely for last one month. It is very user friendly and can easily be handled by beginner users.

In future, this framework will be part of user's day to day life. People will be aware of possible power wastage. A possible ranking system can be framed which will rank users in terms of smart energy usages.

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