

ENHANCED PLC BASED HOME AUTOMATION SYSTEM

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in Electrical and Electronics Engineering

By

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **SHASHANK UKEY**(Reg. No. 37140078) and **KSHITIZ TYAGI** (Reg. No. 37140048) who carried out the project entitled "**ENHANCED PLCC BASED HOME AUTOMATION SYSTEM**" under our supervision from December 2020 to April 2021.

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DECLARATION

We **SHASHANK UKEY** (Reg. No. 37140078) and **KSHITIZ TYAGI**(Reg. No. 37040048) hereby declare that the Project Report entitled “**ENHANCED PLCC BASED HOME AUTOMATION SYSTEM**” done by us under the guidance of **DR. D. GODWIN IMMANUEL** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering.

DATE:16-03-2021

PLACE:CHENNAI

The image shows two handwritten signatures in black ink. The signature on the left is 'Shashank' and the signature on the right is 'Kshitiz Tyagi'.

SIGNATURE OF THE CANDIDATES

ACKNOWLEDGEMENT

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TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	i
	LIST OF FIGURES	ii
	LIST OF TABLES	iv
	LIST OF ABBREVIATION	v
1	INTRODUCTION	1
	1.1 General Introduction	1
	1.2 Scope of Project	2
	1.3 Motivation for the project	2
	1.4 Aim of the project	3
	1.5 Advantages & disadvantages	3
2	LITERATURE SURVEY	4
	2.1 Traditional System	4
	2.2 Problems with existing system	7
3	PROJECT PROPOSAL	8
	3.1 Basic Block Diagram	8
	3.2 What is PLC	9
	3.3 Our Implementation	9
	3.4 Features	10
	3.5 Goals	11
	3.5.1 Major steps to be taken	11
	3.5.1 Benefits to the client by our Established goal	12
	3.6 Uniqueness	12

	3.6.1 Simplicity	12
	3.6.2 Usability	12
	3.6.3 Affordability	12
	3.6.4 Efficiency	13
	3.6.5 Ease of repair	13
4	SIMULATION	14
	4.1 Proteus simulation	14
	4.2 Algorithm	19
	4.3 Arduino program	20
5	HARDWARE WORKING AND DESCRIPTION	23
	5.1 Hardware diagram	23
	5.2 Working and Explanation	24
	5.2.1 Control and monitoring circuit	24
	5.2.2 Relay circuit and appliances	25
	5.2.3 Circuit Connections	27
	5.3 Physical model	28
	5.4 Hardware modules used	32
	5.4.1 KQ330 module	32
	5.4.2 Arduino uno	34
	5.4.3 Optocoupler relay	37
	5.4.4 LCD module	38
	5.4.5 ACS-712 module	40
	5.4.6 ZMPT 101 module	41
	5.4.7 USB to TTL converter	42
6	SUMMARY AND CONCLUSION	43
	REFERENCES	44

ABSTRACT

Our project is the contemporary technology of Power line carrier communication. This technology provides substantial improvement over the existing methods. Thus it is our aim to demonstrate the working of PLCC to create the necessary awareness in order to boost the implementation of this technology. One of the biggest applications is PLCC in home network provides local home network that is that can be used to communicate between devices and enable the services system integration. There are various application at home with the help of PLCC like sharing internet home control, games, distributed video. The key feature of PLCC is without installing new wire in our houses we can use the existing wire and we can use it efficiently. The PLCC network must attain importance to guarantee several security requirements to realize the multiple envisioned scenarios. Automation is important part of our life and it reduces the dependency of human in various what places and involves the use of Technology effectively and reduces the time and effort of human. Automation also reduces the peak power consumption by enabling people to turn off auto turn on appliances at their will. With advancement of Technology automation can be done remotely and can be used by any person. Automation uses different electronic equipment to control different parameters off the process.

Energy is the main concern of every country and the main concern of engineers from all around the world is to save electricity. Technology enables people to be more energy conscious and automation has them to have a real-life status and a monitoring system on the energy consumed by enabling them to work closely with technology. With the help of remote control of appliances, it enables to user to facilitate a constant power supply by wearing price of energy and different time like day and night. With help of with the help of technology we can easily save a lot of electricity. The earlier PLC based system on telephone lines. Remote based system for home automation using a personal computer can be used in existing automation system which have a lot of limitations. The drawback of current automation system is that it requires rewiring or reconnecting every appliance in a central unit. . But due to the urgent need the security aspects of PLC network are not well studied. PLCC can be the next big thing in automation. The concept of no new wire can be in a place where rewiring can be a very hard thing.

LIST OF FIGURES

FIGURE	TITLE	PAGE
NO.		NO.
3.1	Block diagram	8
4.1	Simulation in on state	15
4.2	Simulation with lamp 1 off	16
4.3	Simulation with lamp 1 on solar	17
4.4	Simulation with motor on and off	18
4.5	Flow chart of Algorithm	19
5.1	Complete circuit diagram	23
5.2	Arduino Modules	24
5.3	Appliance-Lamp	25
5.4	Appliance-Induction motor	26
5.5	Model receiving side	29
5.6	Model transmitting side	30
5.7	Model transmitting side connected to USB	30
5.8	TeraTerm software	31
5.9	Plcc module	32
5.10	Plcc module pin	33
5.11	Arduino uno	34
5.12	Relay	37

5.13	LCD	38
5.14	ACS712 pin diagram	40
5.15	ACS712 module	41
5.16	ZMPT101b	41
5.17	USB to TTL	42

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO
4.1	Components used in simulation	14
5.1	Components used in physical model	28
5.2	Arduino uno Pin description	36
5.3	LCD Pin description	39

LIST OF ABBRRVIATIONS

PLCC	-	Power line carrier communication
RXD	-	Receiving
TXD	-	Transmitting
PV	-	Photo voltaic
V	-	Voltage
A	-	Ampere
AC	-	Alternate Current
DC	-	Direct Current
LED	–	Light emitting Diode
RTP	-	Real Time Pricing
IOT	-	Internet of Things
TTL	–	Transistor Transistor Logic
USB	–	Universal Serial Bus.
SPI	-	Serial peripheral Interface
SSB	-	Single Side Band

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Power line carrier communication is used in power station to protect the power line and communicate between two stations. The communication between two stations is done by two different PLC channel in a single line. In PLCC the Wave Trap are installed in R and B phase of transmission line. Phase two phase respond to two channels of PLCC. There are three code used in each channel code A, code B and code C. Code A and B are used for carrier signal and code C is used for direct trip signal. The majority of PLCs are modular and they allow the user to add various functionality like analog and discrete control. PID and position control. It also provides serial communication and high-speednet working. When compared to other technologies in the same era PLC is easier to implement and troubleshoot it is more reliable. It is more cost efficient and more versatile.

Different part of PLC are power supply, CPU, input and output card. PLCC gets its modular design by different electrical connection between all the separate components. Proprietary Communication protocols are being used by many PLC manufacturers so that input and output can securely communicate with CPU. The data in PLCC is mixed with radio frequency and then it is amplified. After amplification it is injected into the high voltage power line. The injection of data is done by suitable coupling capacitor. Long conductors are used which is parallel to the ground to guide the carrier waves in the transmission line. Point to point communication between two ends is done by SSB Trans receiver. PLCC provides a different and effective approach towards home automation and with the increasing advancement in the field of semiconductors and microchips making integrated system on chips module the support PLCC is becoming very cheap. Making modular and ergonomic devices that have PLCC inbuilt in them is easier now then ever, the main purpose of our project is to make the general public aware of the PLCC technology and to bring to light the various advantages of using this technology and thus PLCC should be considered as a next big thing in world of automation.

1.2 SCOPE OF PROJECT

In this demonstrative project with the application of PLCC as a transmitter and receiver that enables the user to have a control over any range of appliances. As well as taking a better approach on existing home automation system and providing fast response, better security, connectivity and range. With this approach no new wiring has to be provided in household. The existing house wirings are used in order to communicate with different appliances. The interaction and control is done with a help of Arduino. Along with all these a power monitoring system is added to the system to have a better monitoring over the instantaneous power that is being used by the appliances. This approach enables us to use an alternative power source such as solar or battery to which the user can switch the supply to on the fly based on the data received from the monitoring instruments, for example if there are some light in the house that are turned on all the time then the user can switch such devices to the alternate source of power. Such task can also be automated using ai implementation, where the program will automatically determine which appliances are consuming more energy on daily basis and switch them to the alternate power supply automatically.

1.3 MOTIVATION FOR THE PROJECT

The main approach of this project is to give an option to user to have an alternative technology when it comes to home automation and it can be easy for the user to choose between a suitable technology according to its need and it can be very helpful for a user who has been facing a lot of drawback when considered the tradition technology and maybe an alternative like PLCC can actually be suitable and very helpful in order to make an effective system and can be used by a large number of people and be used to automate things without the limitations of the traditional home automation system. Along with this a proper setup for power management has been installed, It enables the user to take decision accordingly and switch between different power supplies according to his wish.

1.4 AIM OF THE PROJECT

The main aim of this project is to show that PLCC is a more effective and a better alternative when it comes to the home automation system. The approach of no new wires in the system can be a very big thing when it comes to the home automation. When we talk about traditional system and its drawback it seems like it is very expensive and the appliances used to it is modified according to that system but in case of PLCC there is no need to change any wiring at your home and it can be directly applied to the system and a single pair of transmission and receiver module can be used to automate the whole house using the existing wiring technology and thus it can be seen that In some aspects of automation PLCC can be better than the wireless based system because it has various advantages like high responsiveness, low latency, good connectivity, less moving parts, easy assembly, no need wirings needed.

Thus, with our project we are going to demonstrate the various advantages of PLCC system which are one step ahead of wireless based traditional system.

1.5 ADVANTAGES AND APPLICATION OF PROPOSED TECHNIQUE

1. An Immediate and fast response from appliances.
2. Loss of command signal is minimal.
3. Versatile and a large range of connectivity with different appliances.
4. No new wires are used in home automation
5. A better connectivity range with appliances
6. Better security than existing home automation system.

CHAPTER 2

LITERATURE SURVEY

2.1 TRADITIONAL SYSTEM

The current system of home automation is mostly dependent on the wireless system that is mostly based on Wi-Fi. This System enables the user to control appliances wirelessly and with ease of control at touch it modernizes the use of appliances and can easily replace the switch system with any mobile device. The use of personalized user interface in various kind of applications can increase the user experience. With the help of various sensors and actuators this system can be easily be enhanced and can be used to sense the moisture and humidity of the room and according to the sensor data the appliances can be easily controlled to have an optimum humidity and temperature.

This system can be easily used to have an energy management system. The sensors can be applied in this system to measure the energy consumption of appliances and when the energy comes up a threshold value the sensors can be actuate some appliances to work on lower power consumption medium and thus can be easily used to conserve and manage electricity.

This system enables the user to control and manage everything with the touch of a finger. With advancement of technology there is advancement in this area of home automation. With new technology more and more functionality added to the wireless home automation. The wireless technology can be connected with a cloud and the data which has been recorded can be easily be captured in cloud and easily accessible from around the world.

The security at home can be also installed in this system. Any video camera can be installed and the footage captured by the camera can be easily be transferred to cloud so even if the security camera is removed the footage is saved in the cloud and it can be easily accessed. With the help of internet, a better control and response of the system can be achieved.

Wi-Fi signals usually operate in the range of 2GHz to 5GHz giving them a penetration range of 15m to 35m through open air, but considering the walls and steels used in constructions this penetration drops significantly. But modern system uses various signaling techniques and high-power transmissions to try and overcome this problem. Wifi routers running 24/7 consume around 60-70 Watts that's the same as a fan. Thus running an elaborate and complex system is extremely power consuming.

As mentioned in the 2015 base paper by Satish Palaniappan the wireless network home automation system the cost to procure multiple router setup to provide strong wireless connection to all devices is more than 200% of the whole project, and more over the paper states that the proprietary software development is required to provide proper connectivity and ensure seamless communication.

The 2008 publication by Yuan, X., Archer, R.L., Xu, J. and Yu, H. on the visualization tool for wireless network shows the actual range and penetration of wifi signals is depend on multiple factors which drastically decrease the wifi performance even though the wifi signal is strong.

PLCC based home automation and energy monitoring system is one of the many form of home automation system but using power line carrier communication in home automation. This kind of system will have a different approach towards automation and will help to overcome the previous draw backs of the other system Even though home automation system is being considered by various university and they are taking their own new and innovative approach towards it. As can be seen a paper by Ravi Kishore Kodali and Vishal Jain on IoT Based Smart Security and Home Automation System, it has been seen that in their approach they have taken internet as their medium of alert for their security system as well as they have used wireless medium to connect between different.

It is an impressive approach and it should be considered that when used it will perform effectively but it may have some drawbacks. The few of the drawback is that when the system is connected to internet it is vulnerable to the virus and bugs

that can alter with security of the system. The wireless medium makes the communication between devices a little bit tricky as the number of devices when increased it may cause loss of latency and increase the response time of the system.

And when considering a different approach by Karthick, Stalin, PrithiviRajan, Iourdhu Shelton, Anitha Thulasi. In their paper IOT BASED SMART ENERGY METER BY USING PLCC they have taken the existing power line as their mode of communication between the appliances and this can be very interesting approach towards the home automation and it is the base of our project too.

The use of PLCC manages to improve the security of the system and it also manages to improve the time taken to communicate between different appliances and the communication does not get effected by large distances because it uses power lines as a medium of communication. And thus many functionality can be easily added to have a better efficiency of the system like monitoring the energy consumption and it can be used by the user in order to have a closer look in the energy consumption of the house and by applying this we can easily make this system a very different and considerable approach in home automation. When considering a larger area there should not be loss of signal and the security of data will also place a vital role in this area. Although when used PLCC for communication there is less loss of signal in larger area as the communication is directly be done through the power lines and no other system is used. Whereas when it comes to security PLCC have a better security too as it does not uses internet so the chance of getting your system expose to the World Wide Web it is contained to your home and your system is isolated from outside world. Based on the analysis on the above base papers many problems and inconsistencies were found in the traditional system which hinder the users on the ergonomic side as connectivity issues persist even if expensive and high-end connectivity hardware and technologies are implemented. Thus in the below section we will explore the problems with the traditional system and provide a tentative solution the root cause of the problem.

2.2 PROBLEMS WITH THE EXISTING SYSTEM

The disadvantages of this Wi-Fi based system can be very devastating when applied in a larger area. The one of the major disadvantages of the system is that the range of the system. The Wi-Fi has an approximate RANGE OF 10 meters and when the distance becomes more there is decrease in latency of the system and eventually the system disconnects.

From this we conclude that the distance place a major role in the Wi-Fi based system and it cannot be applied to a building that requires a connectivity of devices at a distance that is more than 10 meters. Now from this we can see that when we are planning to apply the wireless based system in a big building like a corporate office or Hospitals we need to apply many Wi-Fi modules that will cost way expensive and along with that the amount will be not worth it for automation. And along with that the more the number of devices connected to the same router the less will be the response for the devices and larger the number of devices the more will be the delay in transfer of data from one appliance to another.

This project is an attempt to explore other technology for home automation. The use of PLCC in home automation can be a very effective. The PLCC removed the drawback of distance when it comes to connectivity of issue and thus it can be seen that the response of appliances does not vary according to the number of appliances added in the system. The response of the system is totally dependent on the transmission line of home. Generic wi-fi systems are also affected by cross interference from other devices and appliances which lead to constant disconnection issues. The PLCC uses the power line as the transmitting medium thus it does not get affected by any hindrance of other signals and provide a way better connectivity response and easy installation with respect to the Wi-Fi based system. On the power consumption side since there is no exchange of complex instruction regarding authentication and protocols ,no complex high power consumption routers are required.

CHAPTER 3

PROJECT PROPOSAL

3.1 BASIC BLOCK DIAGRAM OF ENHANCED PLCC BASED HOME AUTOMATION

Below in fig 3.1 is the basic outline of the circuitry of the projects. The relays and lamps (appliances) can be increased as per the user demands.

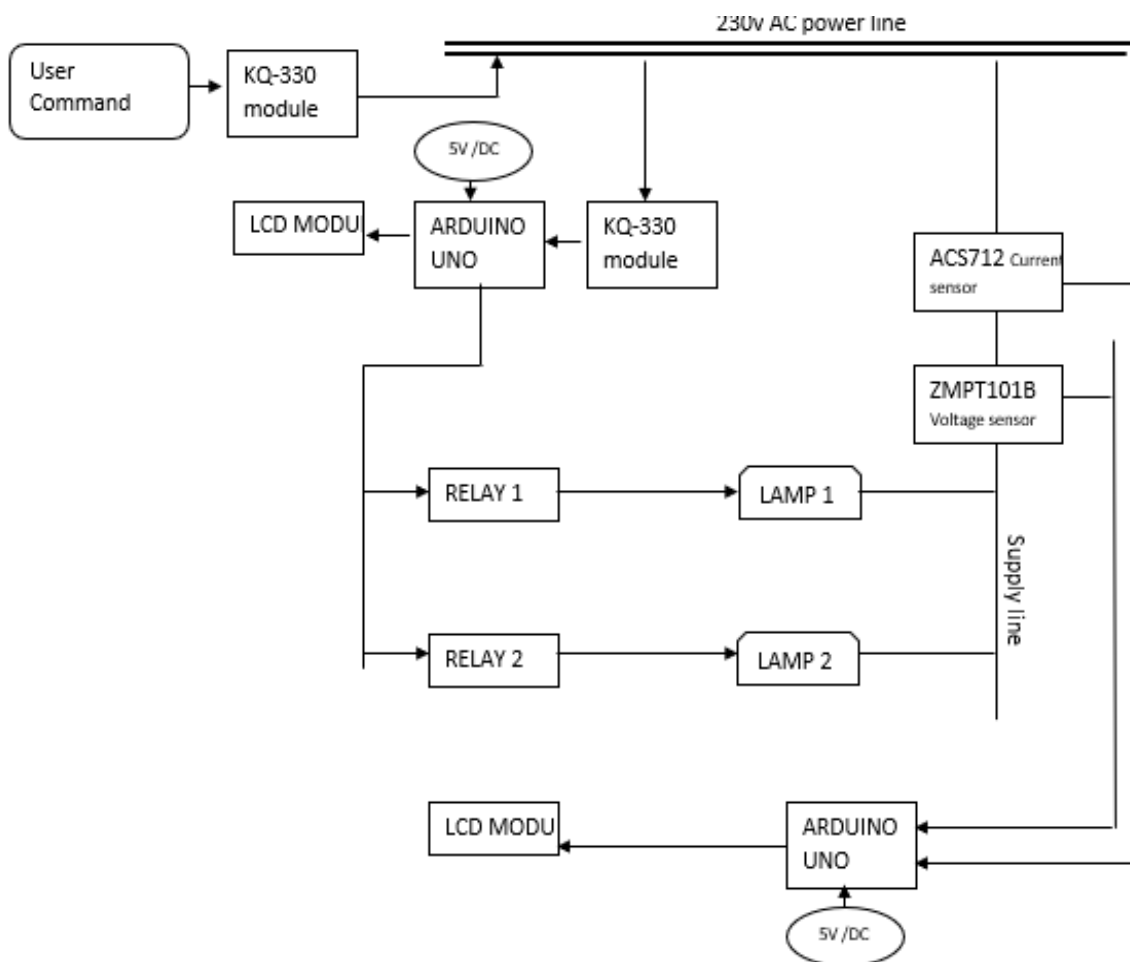


Fig. 3.1 Block diagram

3.2 WHAT IS PLCC

PLCC is the short form for power line carrier communication. This technology is widely implemented in the field of power transmissions and distribution. Power carrying conductors are used to transmit communication signals along side with power by using proper modulation techniques, this helps to create a robust isolated communication network of power systems. Relay control between various stations and emergency communication in case of failure of conventional communication is done through PLCC. Devices like Wave traps are installed at each end to capture the high frequency(150-300kHz) PLCC signals which are then decoded by the modems.

3.3 OUR IMPLEMENTATION

In our project we utilize the modulation techniques used in commercial PLCC to do the same in house hold wirings to provide the user with intuitive control of the appliances. This is a step ahead of the conventional automation technique as the main media of communication between the device is wired so the latency of communication is substantially reduced and performance is significantly increased.

In case of wireless communication the construction and spacing of the building significantly impacts the connectivity strength. Thus utilizing a wired medium of communication gives us a tremendous advantage.

We use PLCC module in connection with Arduino board and relays which are connected to the appliances. The Arduino board acts as the central unit along with the PLCC module which acts as the modem. The PLCC module transmits the command over the house wiring which are received by the receiving side PLCC module and sent to the Arduino board which in turn operates the relay to control the appliances.

3.4 FEATURES

Using PLCC over the conventional methods provides plethora of features to the user some of which are mentioned below:

1. High fidelity communication.
2. Low latency communication.
3. Less power consuming circuit design.
4. Exceptional modularity and versatility.
5. Ease of expansion of system over time.
6. Ease of planning and implementation of system.
7. Cheaper repair and maintenance.

All of the above features are the courtesy of using PLCC over the traditional wireless system .Implementation of PLCC for home automation has fled under the radar for many years as manufacturing of SOCs capable of conduction PLCC communication over large period of time without malfunctioning has proved very expensive. But now with the advancement in the field of semiconductor manufacturing making such PLCC module at a n affordable price for the consumer has become possible and thus the main feature of our project is to bring awareness about the use of this technology so that the people can benefit form it.

Another main feature is the substantially less power consumption as compared to the traditional wifi system. As traditional wifi system uses multiple connection and authentication protocols to interconnect the network, the complexityof the circuitry increases , thus increasing the power consumption. This is no the case with PLCC as interconnection already exists and only communication needs to happen.

3.5 GOAL

The most vital goal of automation is to make the user life simpler and it should be a major step towards the saving of time of user. The important thing is that for each smart automation project, they are distinct. Automation can be a major step when taken in a right way. There are a large number of ways to automate any building or home. But every area has its own requirement and the same automation technique will not be able to satisfy all the user requirements so intern we should know what the user want before implementing any automation system. When considering a small house the loss will be small for applying a wrong automation system but when talking about a large corporate building the same system cannot be use. We must inaugurate the system by having some question in our mind which are:-

- Is the system easy to install by the user or technician?
- Is the automation system is efficient for the building?
- Is the vigilance essential?
- Is the monitoring system should have specific access use only or not?
- Which type of appliances is the user going to automate and monitor?

3.5.1 Major steps to be taken

We need to have a step by step smaller goal in order to get our major goal. We need to have a proper blueprint in order to make any system. And the automation to be done should be efficient for that building.

- Controlling all the appliances.
- Monitoring all the load's power consumption.
- Calculation of instantaneous Voltage and current.
- Providing a single switch between two different power sources.
- Scheduling some load power consumption excides peak value.

3.5.2 Benefits to the client by our Established Goal

The main concern of this project is to make the life of the user easy and make the system user friendly and more ergonomic and generate necessary awareness about the advantages of using PLCC over traditional system. This can be done by

- Faster response of the system.
- A sense of uniqueness and personalization.
- Timely Monitoring of the system.
- Future reference of demands and investigation

3.6 UNIQUENESS

3.6.1 Simplicity

Simplicity is a significant consideration, although it is difficult to accomplish. However, it is enormously complex and quite convoluted to be resolute in our interfaces. Automation is the main focus, along with generating green energy through PV sell this implies the automation system does smart switching between solar and source power supply. Providing more robust and reliable at the same time more simple method is our main goal.

3.6.2 Usability

The system should be easy to use and it should be easy to implement. The system should not be manufactured in such a way that it is hard to implement by the user. In addition to that the system should have structural and functional benefits over the other system. In case of a fault the system should be easily rectifiable and the parts should be easily replaceable. The system uses a very modular equipment that can be easily replaced.

3.6.3 Affordability

The system manufactured should not cost hundreds of thousands of bucks. As the system is mostly going to be used in house so it should be in the price range of people. There are other major steps that can be taken in order to minimize the cost of consumption. By using the LED based lighting system that will reduce the cost of system. The home improvement path was completely viable based on electronics and engineering hence the path short listed.

3.6.4 Efficiency

Energy consumption is the significant aspect of home automation. The efficiency of the system can be increased with the LED based system and thus it can be seen that this system that the alternate power system can be used to increase the efficiency. After automation we be focusing on generate green energy to save energy consumption from main grid and as well as nature. The generating green energy power will work on the basic components. In such manner we save extra energy consumption cost and nature.

3.6.5 Easy repair

The PLCC based home automation system uses equipment that uses low voltage and thus the chance of getting into a fault is very less. The use of modular equipment in the system makes it easy to repair and make it less vulnerable to faults occurring in power line. The parts are easily replaceable when fault occurs. The system is exchangeable with a conventional electrical installation without changing the cabling.

CHAPTER 4

SIMULATION

4.1 PROTEUS SIMULATION

The project has been Simulated in the Proteus 8.0 program,a virtual terminal has been programmed to demonstrate the working of The PLCC module.

Table 4.1 components used in simulation

<u>COMPONENTS</u>	<u>QUANTITY</u>
ARDUINO UNO	2
LCD Display	2
ACS712	4
ZMPT101B	1
REALY 5v	8
VIRTUAL TERMINAL	1
LAMP	2
AC MOTOR	2
RESISTORS 10K	2
RESISTORS 470	2
RESISTORS 220	4
AC SINE GENERATOR 230V	4
PULSE GENERATOR 50HZ	2
1N4007	2
LED YELLOW	2
CAPACITOR 120u	1
BC547	2
SOALR PANEL	1

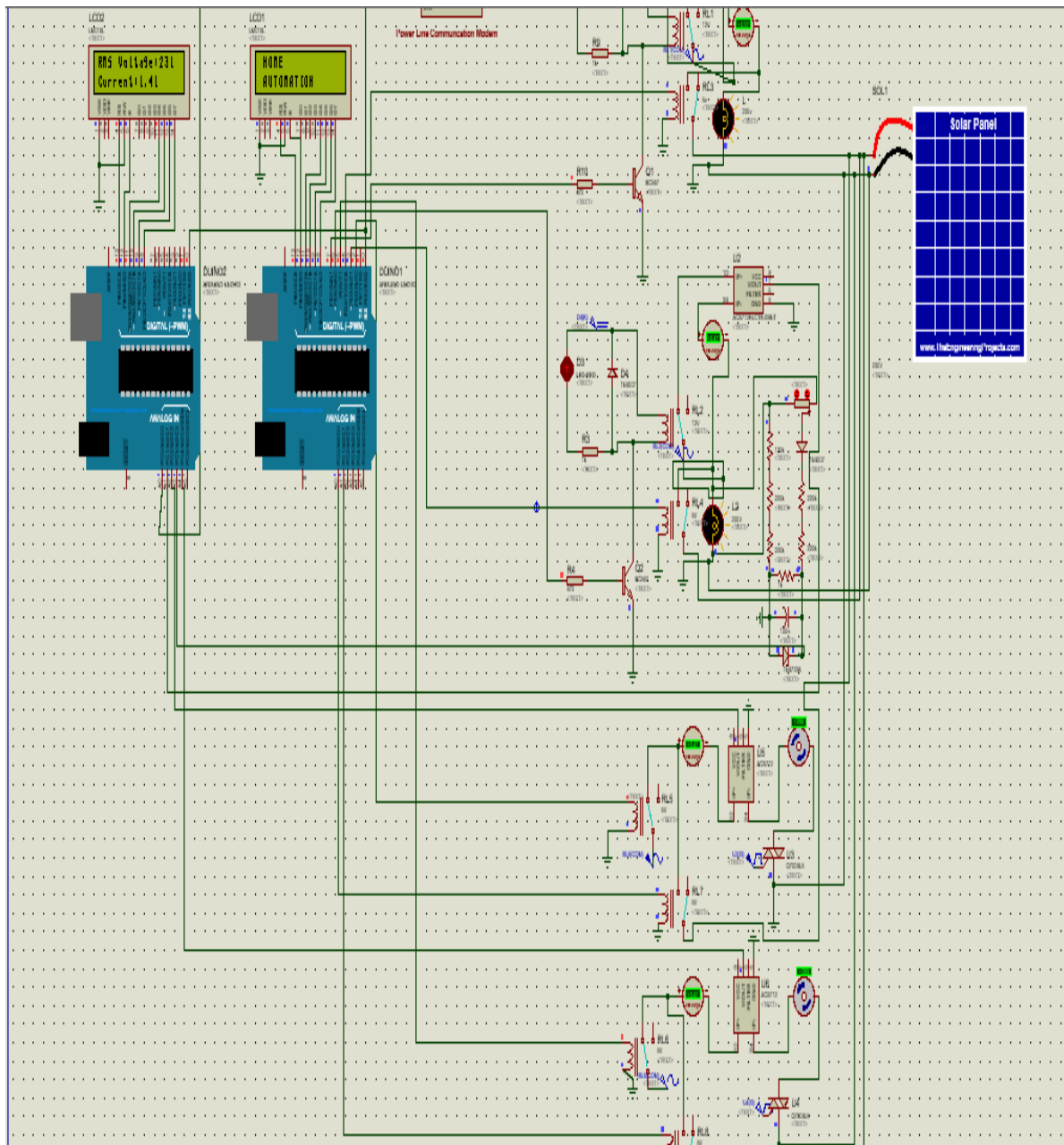


Fig. 4.1 Simulation in on state

The above diagram Fig 4.1 shows the lamp 1 in on state simulation using proteus simulation.

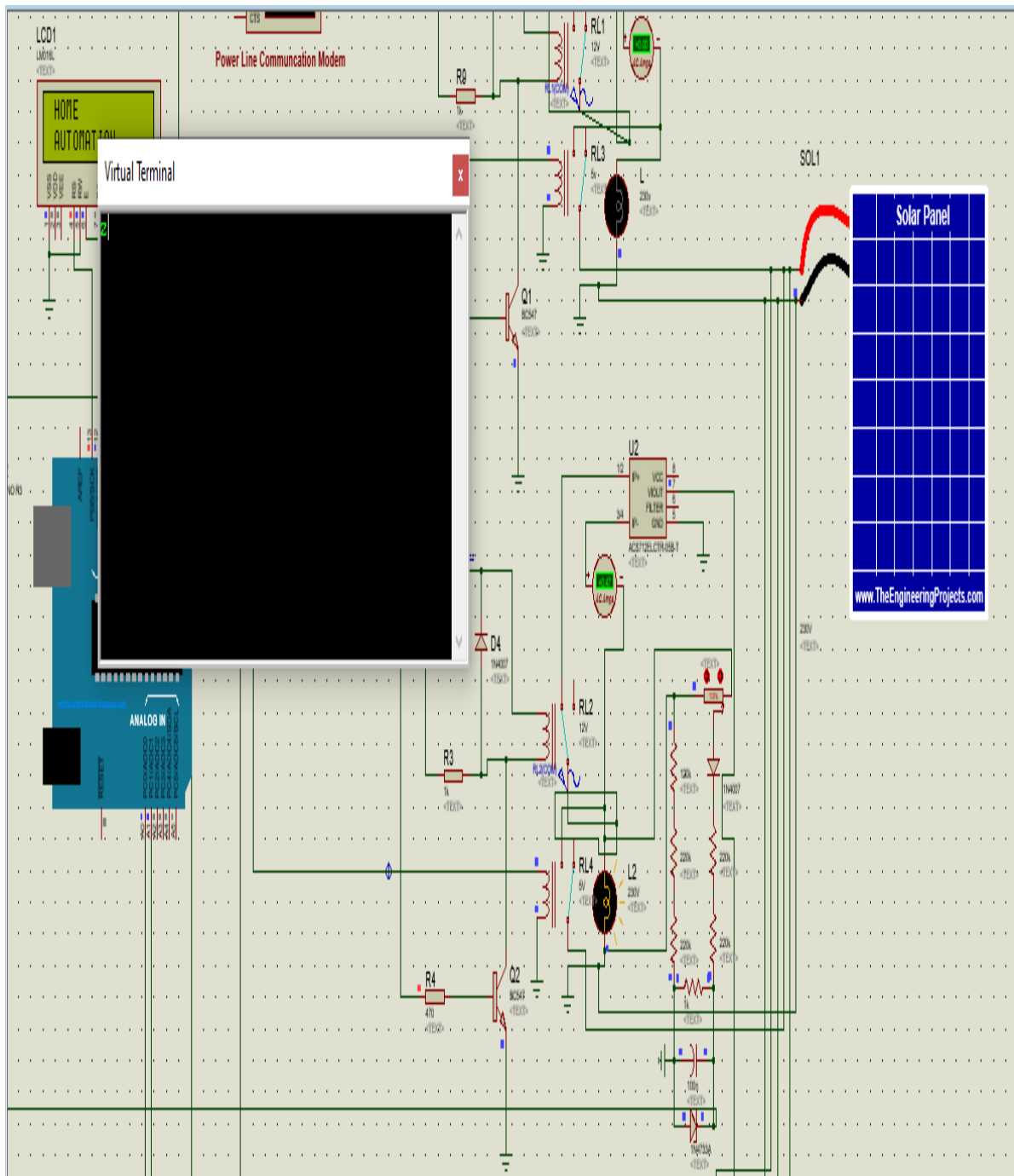


Fig. 4.2 Simulation with lamp 1 off

The above diagram Fig. 4.2 shows the Lamp 1 in off state simulation using proteus simulation.

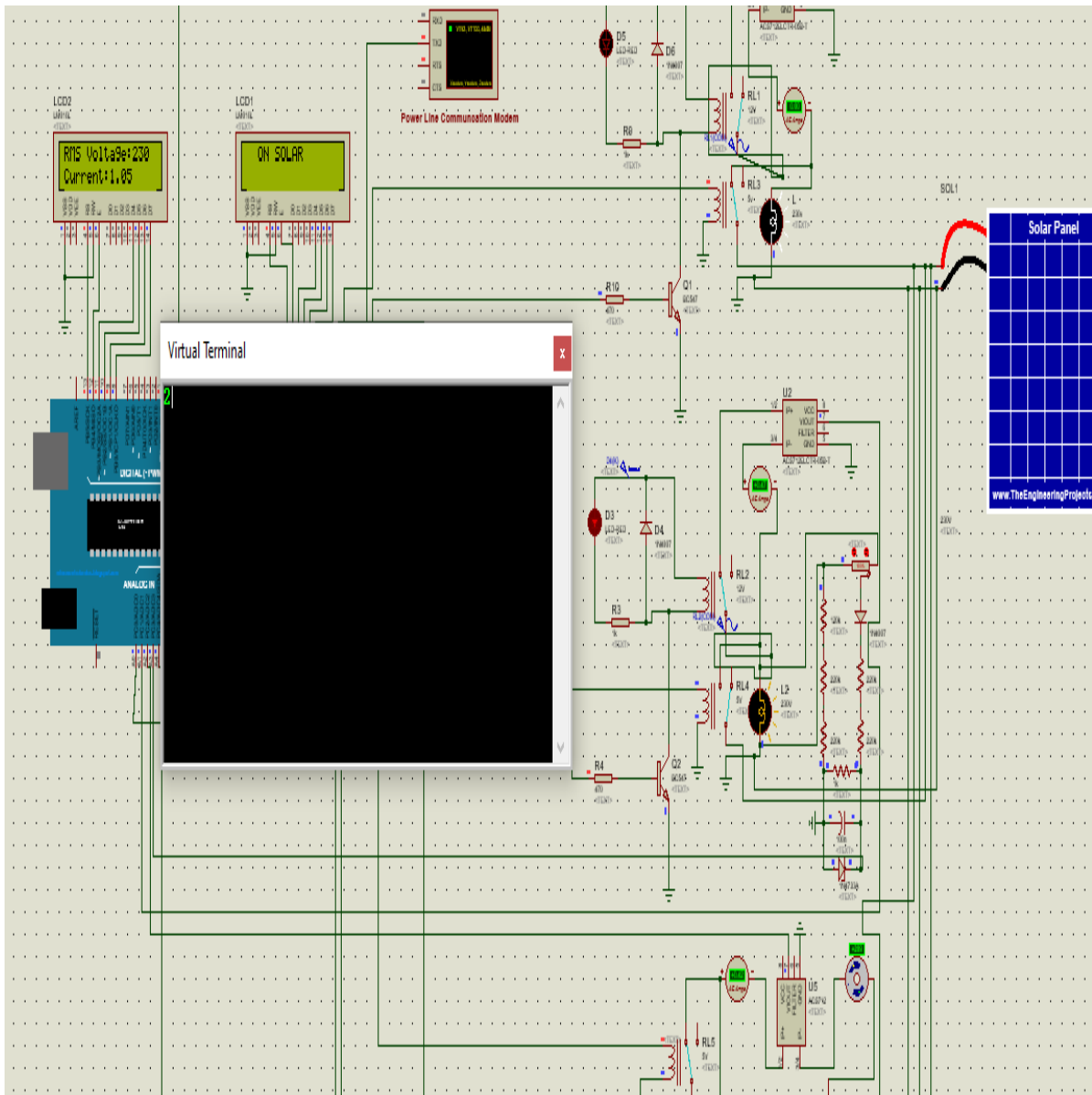


Fig. 4.3 Simulation with lamp 1 on solar

The above diagram Fig. 4.3 shows the lamp 1 on solar power supply simulation using proteus simulation.

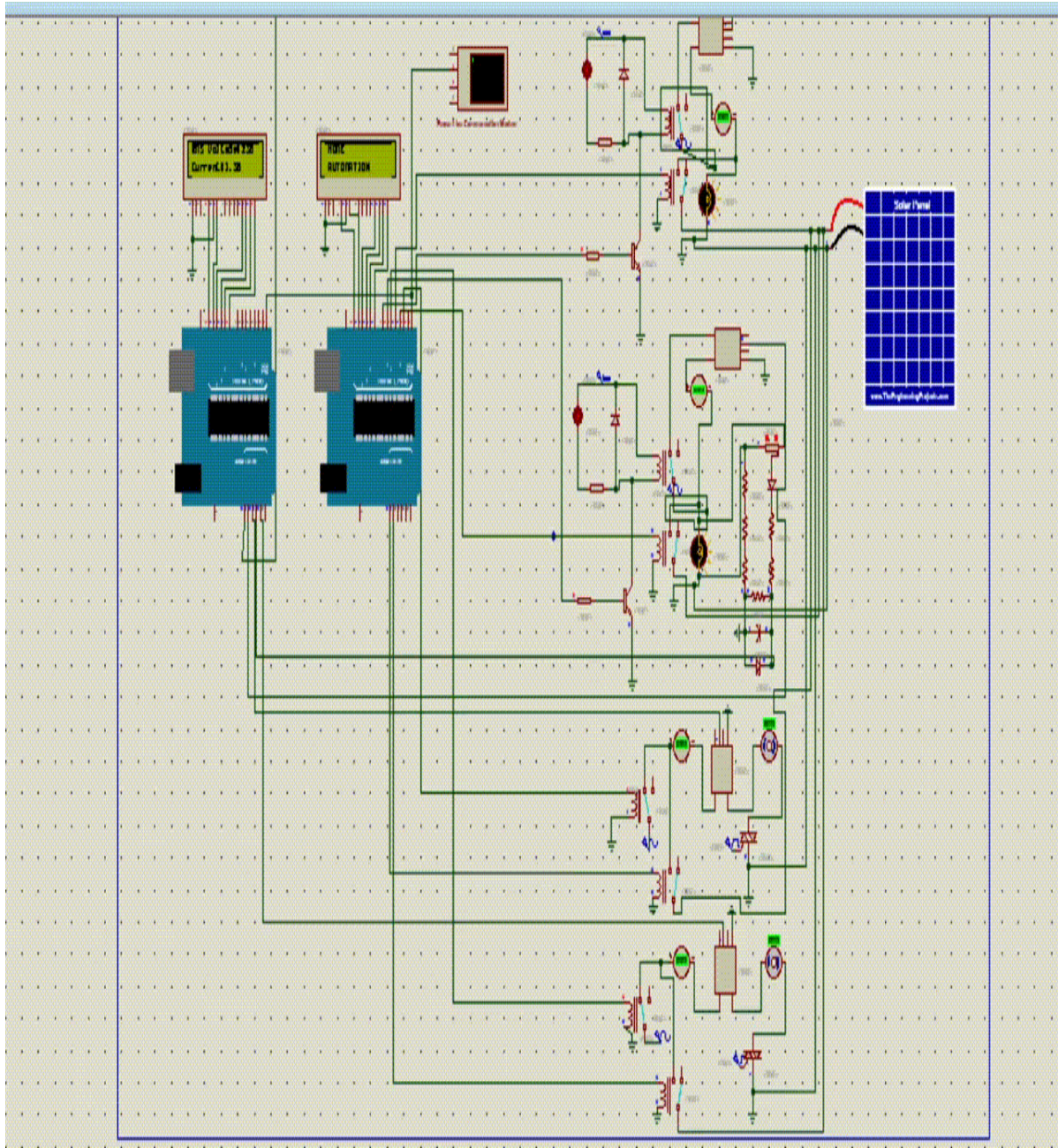


Fig. 4.4 Simulation with motor on and off

The above diagram Fig. 4.4 shows the motors simulation using proteus simulation.

4.2 FLOWCHART

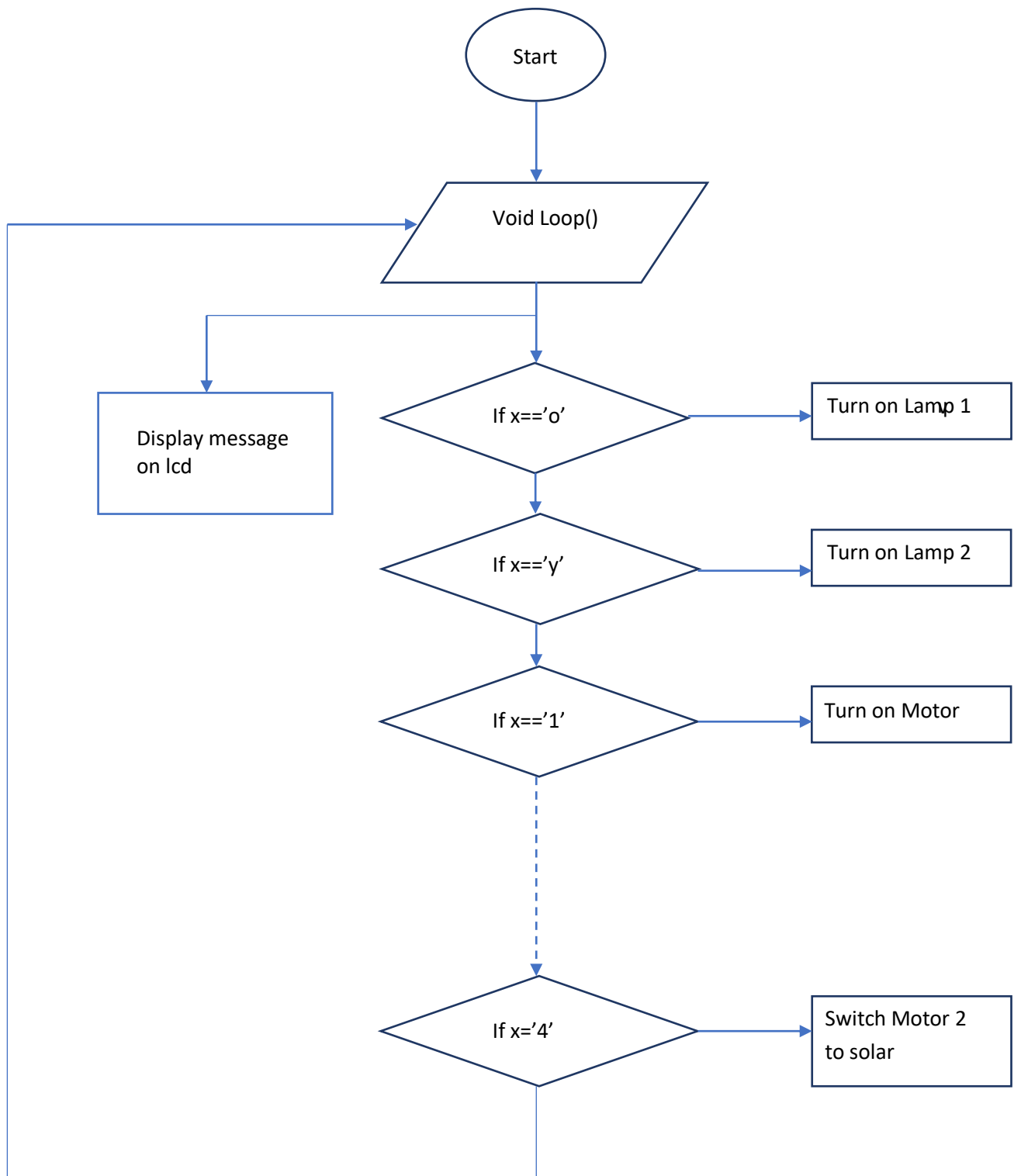


Fig 4.5 Flow chart of Algorithm

4.3 ARDUINO PROGRAM FOR CONTROLLING ARDUINO

```
#include <LiquidCrystal.h>

// initialize the library by associating any needed LCD interface pin

// with the arduino pin number it is connected to

LiquidCrystal lcd(13, 12, 11, 10, 9, 8); // Creates an LC
object. Parameters: (rs, enable, d4, d5, d6, d7)

int ADC1_PIN = A4;

int ADC1_VAL;

int ADC2_PIN = A2;

int ADC2_VAL;

int ADC3_PIN = A3;

int ADC3_VAL;

int ADC4_PIN = A1;

int ADC4_VAL;

int ADC5_PIN = A0;

int ADC5_VAL;

void setup() {

    // set up the LCD's number of columns and rows:

    lcd.begin(16, 2);

    Serial.begin(9600);

    // Print a message to the LCD.

    pinMode(7,OUTPUT);

    pinMode(6,OUTPUT);

    pinMode(4,OUTPUT);

    pinMode(3,OUTPUT);

    pinMode(2,OUTPUT);

    pinMode(5,OUTPUT);

    pinMode(A0,OUTPUT);

    pinMode(A1,OUTPUT);

    lcd.print(" WELCOME ");

    delay(1000);

    lcd.clear();

    lcd.print(" POWER LINE ");

    lcd.setCursor(0, 1);

    lcd.print(" COMMUNICATION ");

    delay(1000);

    digitalWrite(7,HIGH);

    digitalWrite(6,HIGH);

    digitalWrite(2,HIGH);

    digitalWrite(5,HIGH);

    lcd.clear();

    lcd.setCursor(0, 0);

    lcd.print(" HOME ");

    lcd.setCursor(0, 1);

    lcd.print(" AUTOMATION ");

}

void loop() {

    String readString;

    String Q;

    while (Serial.available()){

        delay(10);

        if(Serial.available()>0){

            char c = Serial.read();

            if (isControl(c)){

                break;

            }

            readString += c;

        }

    }
```

```
lcd.setCursor(0, 0);
```

```
Q = readString;
```

```
delay(10);
```

```
if (Q=="o"){
```

```
lcd.clear();
```

```
lcd.setCursor(0, 0);
```

```
lcd.print(" ON SOURCE ");
```

```
digitalWrite(6,HIGH);
```

```
digitalWrite(3,LOW);
```

```
}
```

```
if (Q=="t"){
```

```
digitalWrite(6,LOW);
```

```
}
```

```
if (Q=="y"){
```

```
lcd.clear();
```

```
lcd.setCursor(0, 0);
```

```
lcd.print(" ON SOURCE ");
```

```
digitalWrite(7,HIGH);
```

```
digitalWrite(4,LOW);
```

```
}
```

```
if (Q=="z"){
```

```
digitalWrite(7,LOW);
```

```
}
```

```
if (Q=="1"){
```

```
lcd.clear();
```

```
lcd.setCursor(0, 0);
```

```
lcd.print(" ON SOLAR ");
```

```
digitalWrite(6,LOW);
```

```
digitalWrite(3,HIGH);
```

```
}
```

```
if (Q=="2"){
```

```
lcd.clear();
```

```
lcd.setCursor(0, 0);
```

```
lcd.print(" ON SOLAR ");
```

```
digitalWrite(7,LOW);
```

```
digitalWrite(4,HIGH);
```

```
}
```

```
if (Q=="m"){
```

```
lcd.clear();
```

```
lcd.setCursor(0, 0);
```

```
lcd.print(" ON SOURCE ");
```

```
digitalWrite(2,HIGH);
```

```
digitalWrite(A0,LOW);
```

```
}
```

```
if (Q=="n"){
```

```
digitalWrite(2,LOW);
```

```
}
```

```

    if (Q=="b"){
        lcd.clear();

        lcd.setCursor(0, 0);

        lcd.print(" ON SOURCE ");

        digitalWrite(5,HIGH);

        digitalWrite(A1,LOW);

    }

    if (Q=="v"){

        digitalWrite(5,LOW);

    }

    if (Q=="3"){

        lcd.clear();

        lcd.setCursor(0, 0);

        lcd.print(" ON SOLAR ");

        digitalWrite(2,LOW);

        digitalWrite(A0,HIGH);

    }

    if (Q=="4"){

        lcd.clear();

        lcd.setCursor(0, 0);

        lcd.print(" ON SOLAR ");

        digitalWrite(5,LOW);

        digitalWrite(A1,HIGH);

    }

}

```

CHAPTER 5

HARDWARE WORKING AND DESCRIPTION

5.1 HARDWARE DIAGRAM

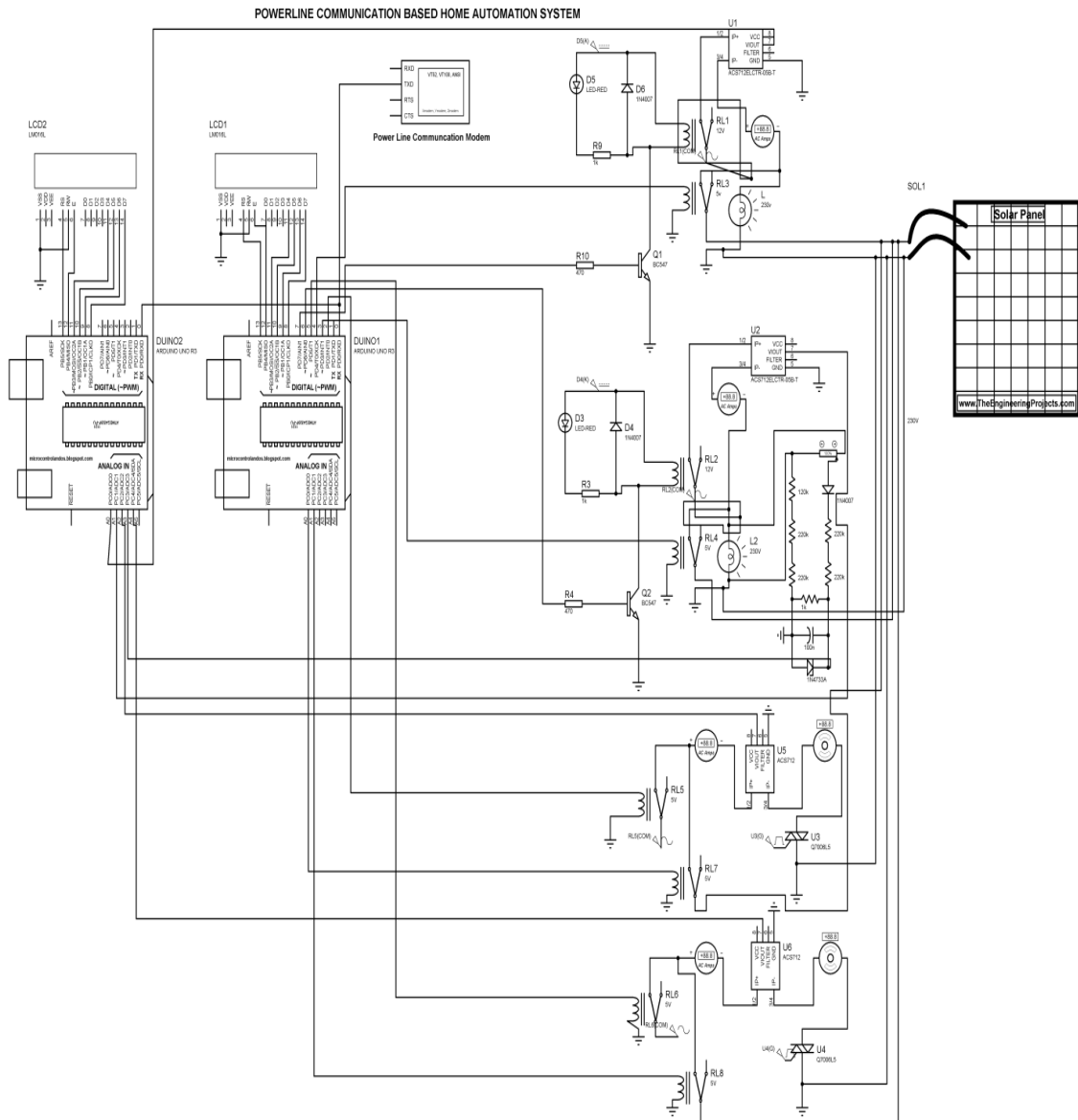


Fig.5.1 Complete circuit diagram

5.2 WORKING AND EXPLANATION

From the above diagram (fig 5.1) we can see the basic as well as the hardware diagram of the project. The process starts from the transmission side, in this side we have a PLCC module i.e. KQ330. This module is used as to transmit the control signal into the power lines of our house. This PLCC module uses serial mode of communication to transfer the control signals. The other end is the receiving side that consists of another PLCC Module i.e. KQ330 and it receives the signal that is being transmitted in the power lines. This receiving PLCC module sends the control signal to Arduino which gives the enable and disable signal to the relay which is directly connected to the home appliances and this enables the user to control the appliances via PLCC. Along with this an additional relay can be used to add more than one power source can be installed via a relay and can be switched when needed. The additional energy monitoring system enables the user to monitor the instantaneous value of voltage, current and power. This is done via the current sensor and voltage sensor that are directly connected to the appliances and can easily send the sensor data to Arduino which enables the user to view the exact values of instantaneous values of current, voltage and power.

5.2.1 Control and Monitoring circuit

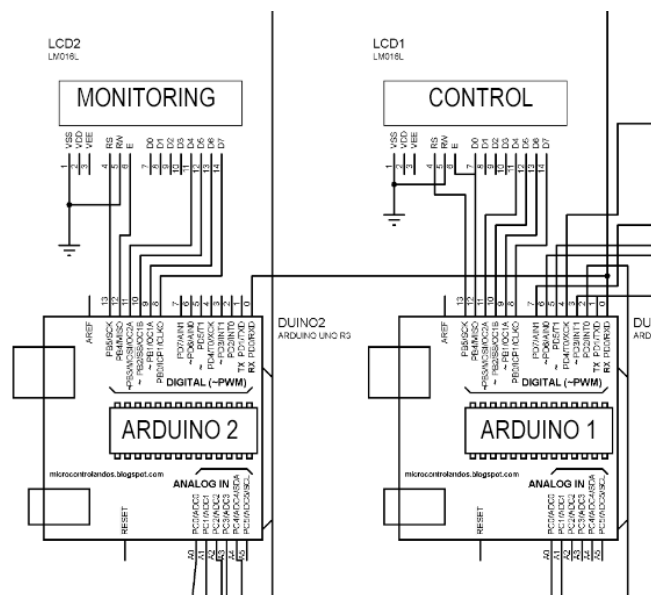


Fig. 5.2 Arduino Modules

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signal to

5.2.2 Relay circuit and Appliances

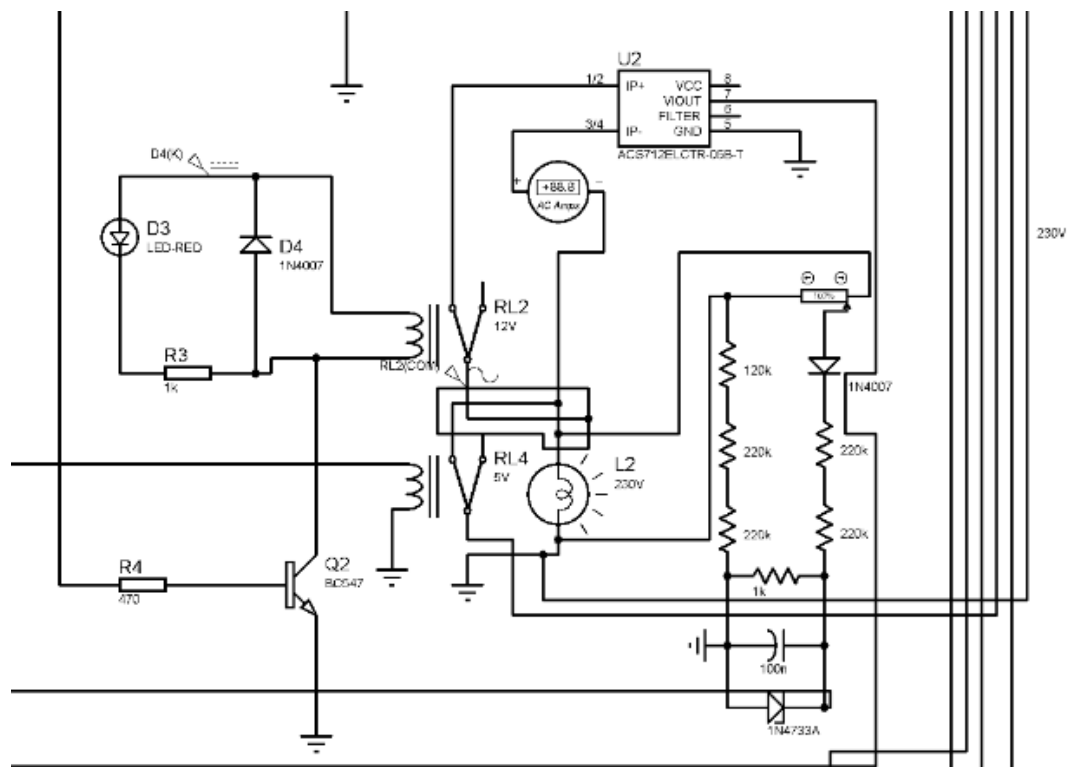


Fig. 5.3 Appliance-Lamp

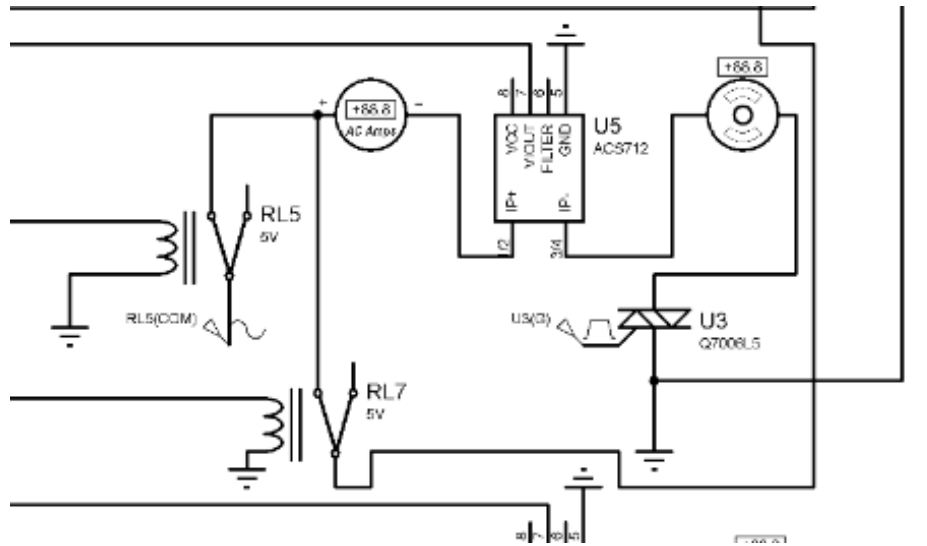


Fig. 5.4 Appliance-Induction motor

The above two diagrams (fig 5.4) show 2 sample appliances that are connected the supply alamp(fig 5.3) and an induction motor representing a fan. ACS712 current sensor is connected in series with the both appliances to measure and a ZMPT101B voltage sensor is used in parallel to measure the voltage. Each of the two appliance is connected to two relays. The lamp in figure 3 is connected to two relays R2 and R4. The relay R2 is connected to normal 230V Ac power supply and Relay R4 is connected the alternate power supply which is a solar panel in our case. Similarly, the Induction motor is connected to the relays R5 and R7 which are connected the 230V Ac supply and alternate power supply respectively. When the power supply is switched on the relays R2 and R5 receive the ON state command form the Arduino and the lamp turns on and the motor starts rotating, now both the appliances are on the source power supply, but once the Arduino receives the switch supply command, for example is the user wants to switch the supply of the lamp then relay R2 will turn off and relay R4 will turn on immediately switching the power supply to the solar panel. This action may also happen automatically if the Arduino is programed to measure the watt consumption of the appliances and is made to switch them to an alternate supply at a certain time in the day or after a certain amount of power consumption.

5.2.3 Circuit Connections

The analog Pins Arduino 1(fig 5.2) are used as data pins to control relay R7 and R8 (Fig 5.1). The Arduino Uno has the ability to multipurpose the various pins using Wire.h header library which allows us to use all the interface pins as data pins. Analog Pins of Arduino 2(fig 5.3) from A0-A5 are connected to the various current and voltage sensors of the appliances. Using all the analog pins of an Arduino uno simultaneously uses a lot of power thus Arduino 2 must be powered from a separate adaptor power supply, USB power from a laptop or a battery-based power source can't be used to power it when the Arduino is operated in this particular way.

Relay R1 and Relay R3 are connected to Lamp 1 (fig 5.3) R1 controls the connection of the lamp through the source supply. Relay R3 controls the power switching from solar power to source power and vice-versa. Relay R2 and Relay R4 are connected to Lamp 2 (fig 5.1) R2 controls the connection of the lamp through the source supply. Relay R4 controls the power switching from solar power to source power and vice-versa.

Relay R5 and Relay R7 are connected to motor 1 (fig 5.4) R5 controls the connection of the motor through the source supply. Relay R7 controls the power switching from solar power to source power and vice-versa. Relay R8 and Relay R6 are connected to motor 2 (fig 5.1) R8 controls the connection of the motor through the source supply. Relay R6 controls the power switching from solar power to source power and vice-versa.

Current Sensors U1, U2 and U6, U7 are connected to Lamp1,2 and Motor 2,3 respectively. The ACS712 current sensor uses Hall effect to measure the current precisely. The volage sensor ZMPT101B is connected in parallel to the main supply line as the voltage level doesn't fluctuate too much for individual appliances. 5V Relays are connected to the Arduino based on the Arduino pin out. Higher and more standard 12 V relay can also be used with the Arduino along with a pullup resistor and npn transistor.

5.3 PHYSICAL MODEL

The physical model of the project uses a USB to TTL converter to send the command to transmitting PLCC module and both the transmitting and receiving PLCC modules are connected to the power sockets.

Components used in the physical model: -

Table 5.1 component list for physical model

COMPONENTS	QUANTITY
ARDUINO UNO	2
LCD Display	2
ACS712	1
ZMPT101B	1
REALY 5v	2
LAMP	2
PLCC MODULE	2
USB TO TTL	1
I2C	2
JUMPER CABLES	FEW
CAPACITOR 120u	1

Software call TeraTerm was also use to take input form the keyboard and convert it into serial 8-bit data to send it over to the PLCC. The command goes from the computer to the usb to ttl convertor and to the PLCC transmitting side then over to the power line and to the receiving side.

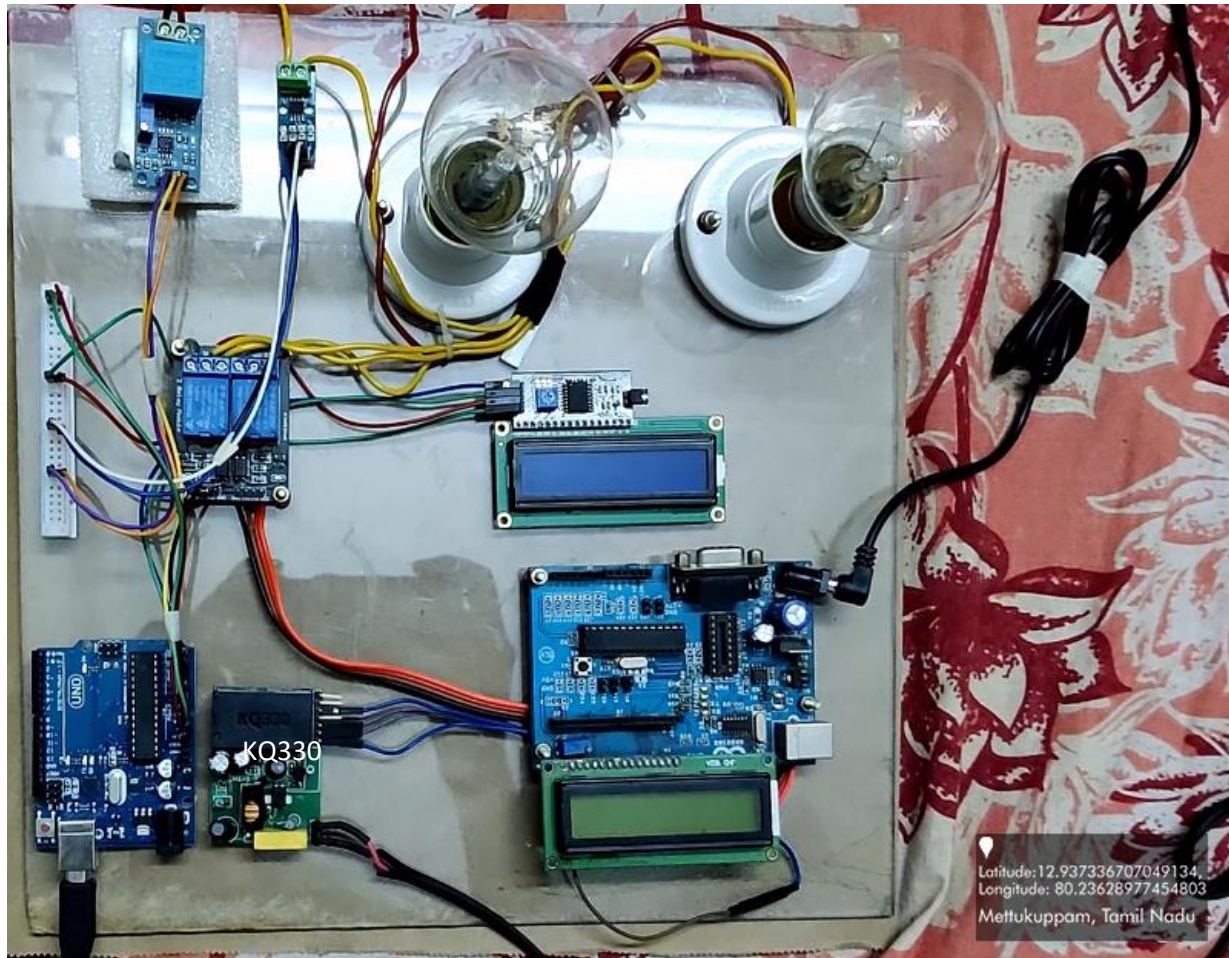


Fig. 5.5 Model receiving side

The physical model (fig 5.5) above displays the receiving side PLCC module along with the controlling Arduino boards and the two lamps, acs712 and zmpt101b sensor. The KQ330 plcc module is connected the Arduino form one end and the other end is connected the power outlet. When the power is turned on both the bulbs are in on state and based on the command signal the bulbs turn on and off.



Fig. 5.6 Model transmitting side

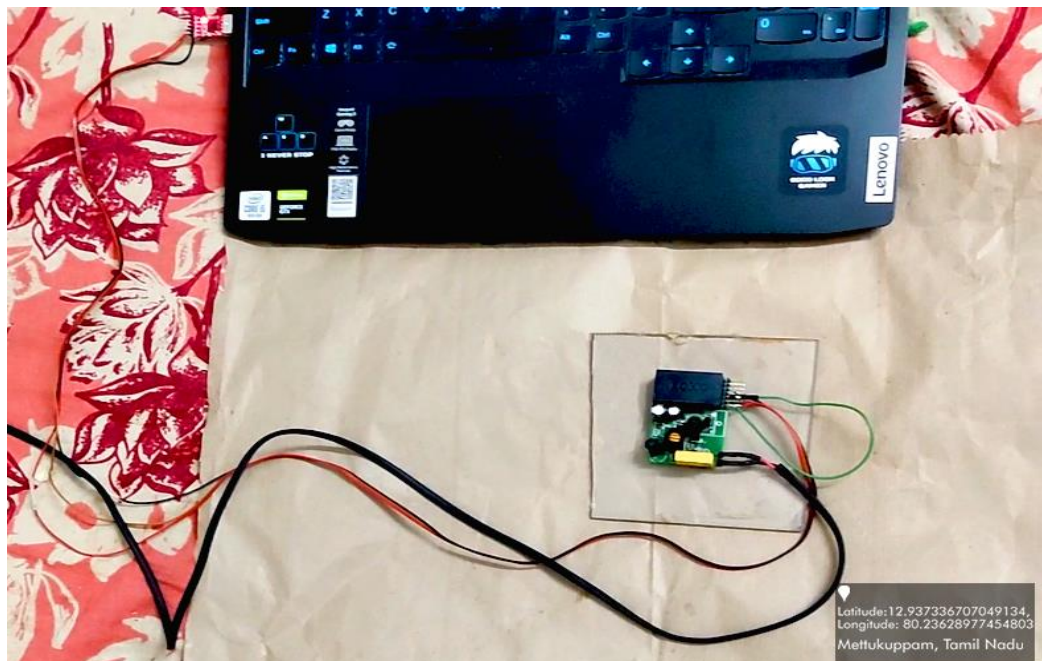


Fig. 5.7 Model transmitting side connected to USB

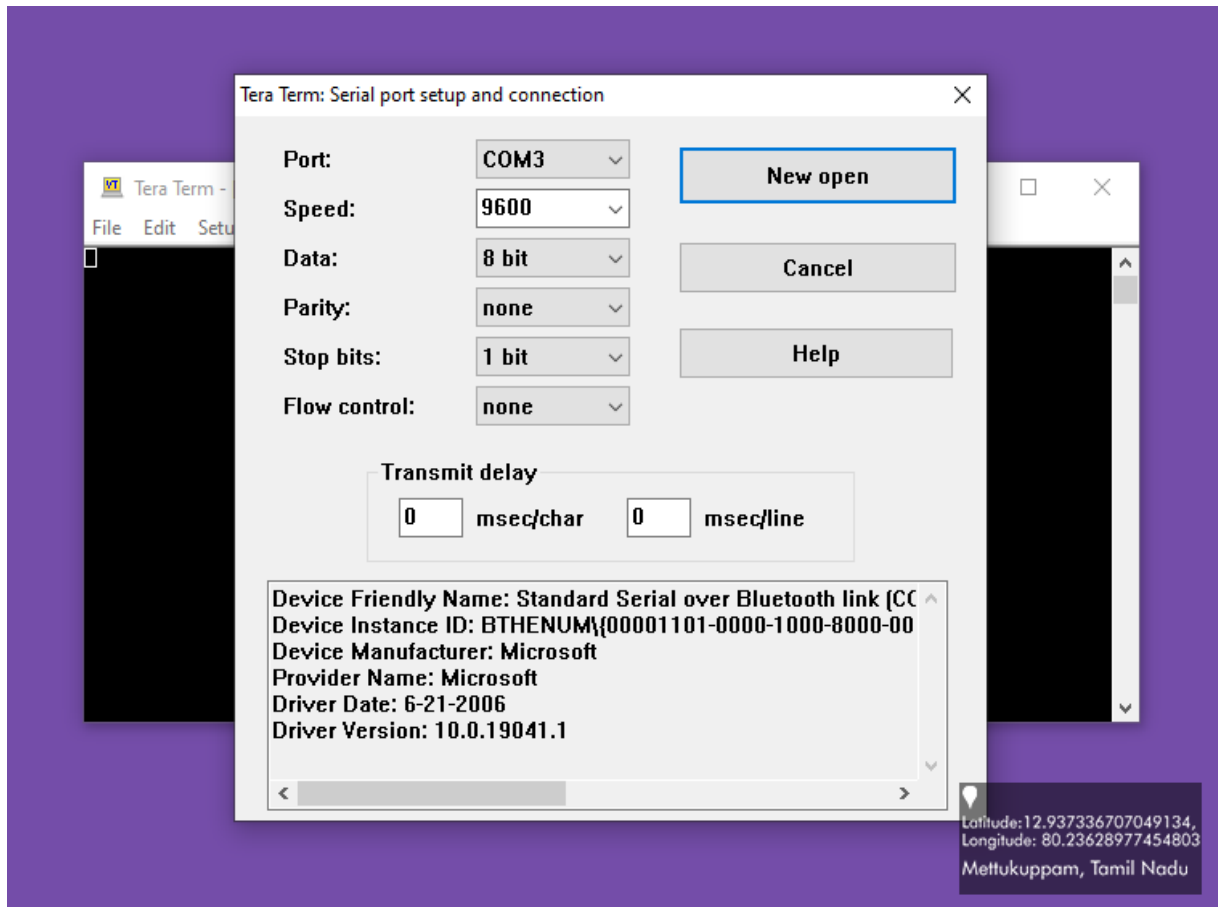


Fig. 5.8 TeraTerm software

The above picture (fig 5.8) shows the TeraTerm software that is used to convert the keyboard inputs into serial communication data. The baud rate is set to 9600bps which is the same as KQ330 models baud rate. The data is transmitted as 8-bit serial data with no parity bit and 1 stop bit, which is set as per the specifications of the KQ330. Not using the proper baud rate will lead to overlap and interference of the data and may lead to loss of command signals and erratic behavior of the system.

The Differential Code Shift Keying (DCSK) method which is implemented by the KQ330 uses 1 parity bit, as the command signals, we send are simple Boolean operations rather than complex mathematical instruction, so using complex error detection method will only slow down the communication process.

5.4 HARDWARE MODULES USED

5.4.1 PLCC Module KQ-330

KQ-330 is a small footprint superior single-pin nine utilizing the zero-carrier knowledge transceiver module (Fig 5.9). is intended for 220V AC on the sturdy interference, sturdy attenuation, the gap necessities of the atmosphere, the reliable transmission of knowledge and above all the planning and development of high value carrier module. It is employed for metering, street, intelligent home, fire, and alternative building management applications got to transmit knowledge to the facility line.

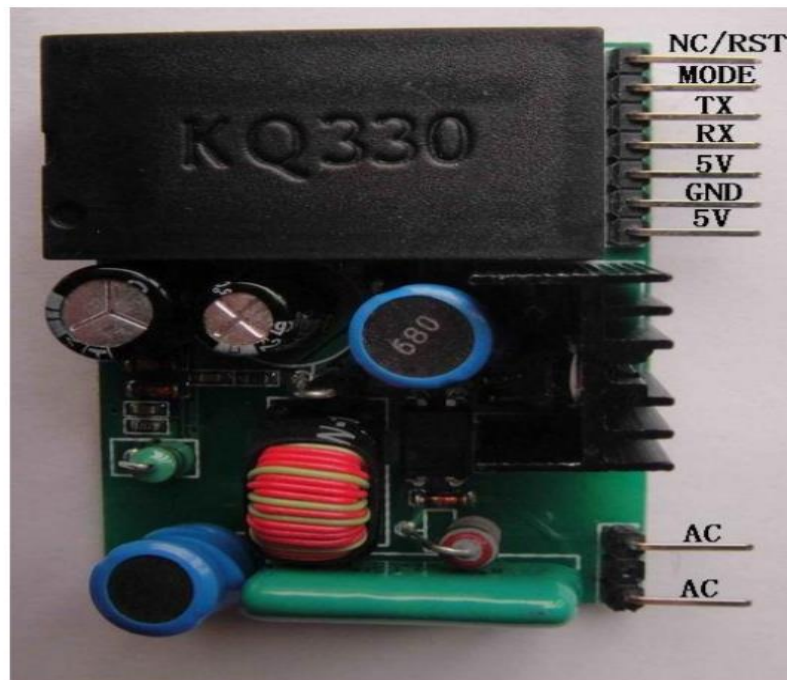


Fig. 5.9 KQ330

KQ-330F is a unified module implemented in carrier plate peripheral applications, there is no need of various coupling elements, it is directly coupled to alternating current 220Volts use.

1. Dimensions of 53 by 38 by 17 mm (L × D × H), single lead pin with 2 feet to 220V AC power non-directional (1 foot, 2 feet spacing 2X0.1 inches), 2 feet, 3 feet spacing of 1.1 inches, 0.1 inches spacing between each of the remaining pins.
2. The working frequency of 120 to 135KHZ, the baud rate of interface is 9600bps. The real worldbaud rate 100bps with 250 byte buffers.

3. Temperature range: -25 °C to + 70 °C Humidity less than 90%
4. Power supply: ≤11mA when transmitting: DC + 5V when receiving ≤300mA.

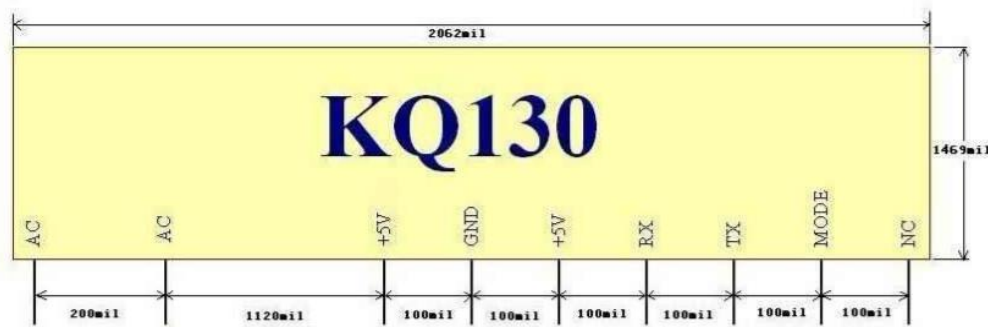


Fig. 5.10 KQ330 Pin diagram

PIN description:

1Pin-AC: Fire wire (or neutral) AC voltage 220V

2Pin-AC: AC 220V line voltage zero (or FireWire)

3Pin- + 5Volts: + 5Volts power transmission (260mA), data can be received if a single vacant reduce power consumption

4Pin-GND: Ground digital circuit

5Pin- + 5V: + 5V working power 11mA

6Pin-RX: TTL level into a data carrier, then MCU TXD, Hi-Zinput cannot besuspended

7Pin-TX: Transistor Transistorlogic(T.T.L) level, a data carrier, and then the microcontroller receiving pin.

8Pin-MODE: mode selection, floating or connected to five volt is high, low ground

9Pin-NC / RST: reset pin (active low) mode is used only when switching frequently at work. If the feature is not required, the pin should be left open.

KQ330 MODULE DIFFERENCES: -

KQ-130F is meant for AC 220V / 110V, 50HZ / 60HZ sturdy AC module design based on the principle of zero carrier transmission scheme, the transmission power upper city with good effect, distance and so on. Data to be transmitted over AC power, the carrier rate frequency is 50HZ with 100BPS, 60HZ with 120BPS software can be optimized for desired bit transmission

KQ-130E is integrated carrier module, and transmitting data irrespective of the zero point. After carrier demodulation digital filtering done to improve its anti-interference ability of the data carrier, the lower the rate the better.

KQ-130E can run at standard 220V DC voltage for carrier communication, such as: 220V, 110V, DC voltage, and the like in the communication carrier power failure. KQ-130E Is the highest rate 400BPS. Communication can choose 100BPS improve anti-jamming capability, but also 100BPS of KQ-100E communication effect on AC power than a lot of KQ-130F poor.

5.4.2 Arduino Uno

Arduino(Fig 5.11) is an open-source free for all hardware developed by AtMeL company ,it facilitates user community that designs and manufactures single-board microcontrollers for building iot projects. Its hardware products are licensed under a CC-BY-SA license, the software is licensed under General public license permitting the manufacture of Arduino boards and software distribution by anyone. This also allows for free development and improvement of the existing board

Arduino board designs use various microprocessors and controllers. The boards are implemented with sets of digital(12) and analog(4) input/output (I/O) pins that can be used to interface various expansion boards or breadboards (for prototyping) and other components and sensors. The boards feature serial communications pins, including Universal Serial Bus (USB) on a fewmodels that are also used for uploading programs to the Arduino flash memory. The microcontrollers can be programmed using the C/ C++ languages other languages

can be included using libraries or using a standard API which is also known as the "Arduino language". In addition to using conventional compiler frameworks, the Arduino software provides an integrated development environment (IDE) and a command line interface tool called Arduino-clipse developed using Go.

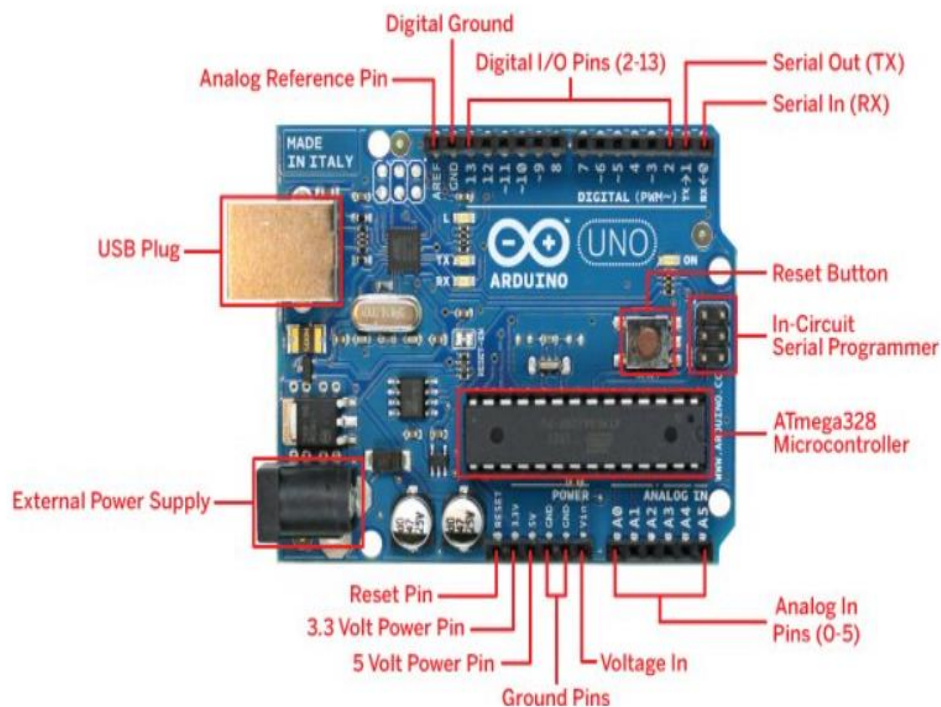


Fig. 5.11 Arduino uno

The Arduino project was initiated in 2005 as a tool for electronics enthusiasts at the Interaction Design Institute in Italy, with a goal to provide a economic and simple way for novices and professionals to create devices and mini projects that interact with their surrounding using sensors and actuators. General examples of such devices intended for beginner hobbyists include simple robots, thermostats and motion detectors.

Table 5.2 Arduino uno Pin

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

Arduino uno has enable many electronics enthusiast to pursue their dreams at affordable costs. Releases of Arduino boards brought about a mass revolution in

the field of DIY electronics projects and has to many a new innovations. This has also led the consumers to pursue the independent development of prototyping boars for example ESP32 or ESP8266 and many others. The ATMEGA chip int heart of Arduino enables it to stay UpToDate with the fast changes in the software implementations.

5.4.3 Opto-Coupler Relay

An opt-coupler (short for optical isolator) Fig(5.12)is a semiconductor-based device that allows the flow of an electrical signal to be transmitted in between two electrically isolated circuits. Two parts that are used in an opt coupler are,an Light Emitting Diode that emits infrared light and a photosensitive sensor that detects light coming from the LED. Both the parts are contained within a secure box with pins provided for connectivity. The input part of the circuit takes the incoming signal, the signal may be AC or DC in nature, and uses the signal to turn on the LED.



Fig. 5.12 Relay

A relay on the other hand is an electromagnetic mechanical switch operated by a small current that controls a much larger current. A relay is an electrically operated switch that can be turned on or off, letting the current go through it or not, and can be controlled with low voltages and signals, for example the five volts

provided by the Arduino Uno VCC pins. Controlling a relay module with the Arduino is as simple as controlling other output as we'll see later on.

The opto-coupler relay module has two channels (each channel is represented by a blue cube). There are models with one, four and eight channels base on the user's requirement. This module is connected with 5V, which is appropriate for the Arduino uno. There are various other relay modules that are powered using 3.3Volts, which are ideal for ESP32 board or ESP8266 board , and other microcontrollers.

5.4.4 L.C. D Module

An L.C.D(Liquid Crystal Display)Fig(5.13) is an electronic display module that uses liquid crystal to produce a visible mono-color image. The 16×2 Grid L.C.D display is a very rudimentary module commonly used in DIY projects and circuits. The 16×2 Grid translates to a display 16 characters per line with 2 such lines. In this L.C.D each character is displayed in a 5×7 pixel matrix grid with blue back light and black contrast.

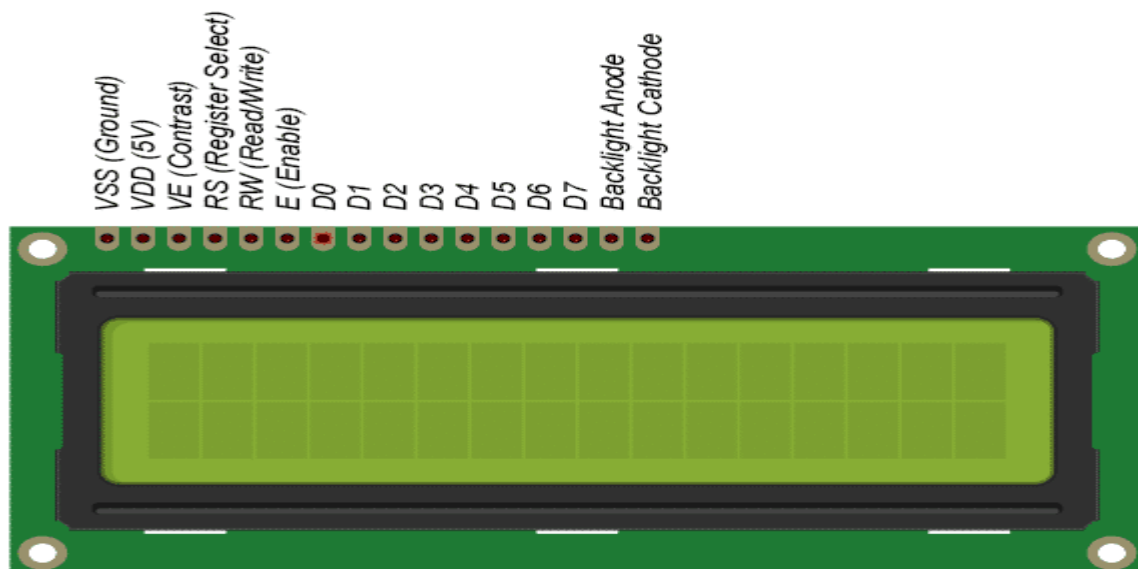


Fig. 5.13 LCD display module

Table 5.3 LCD Pin Description

Pin No.	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; the best way is to use a variable resistor potentiometer. The output of the potentiometer is connected to this pin. Rotate the potentiometer knob forward and backwards to adjust the LCD contrast.	Vo / VEE
4	Selects command register when low, and data register when high	RS (Register Select)
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given; Extra voltage push is required to execute the instruction and EN(enable) signal is used for this purpose. Usually, we set en=0, when we want to execute the instruction we make it high en=1 for some milliseconds. After this we again make it ground that is, en=0.	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight VCC (5V)	Led+
16	Backlight Ground (0V)	Led

5.4.5 ACS-712 Current sensor

Hall Effect Sensors are transducer type sensors that are used to convert change in magnetic fields into electrical signals for further electronic circuit processing. Typically, current sensors use the Hall Effect to convert current signals into voltage outputs. Principle of Hall effect is that the electrons from an electric current flow through a magnetic field plate. The field then causes the electrons to deflect to one side of the plate and produce a voltage potential between the two plates. The difference in voltage from the sides of the plate is the output of the Hall sensor.

ACS-712(Fig 5.14) is a current measuring sensor that can work on both AC and DC inputs. This sensor operates at five Volts and produces a corresponding analog voltage output proportional to the measured current. This tool consists of a series of Hall sensors with copper lines.

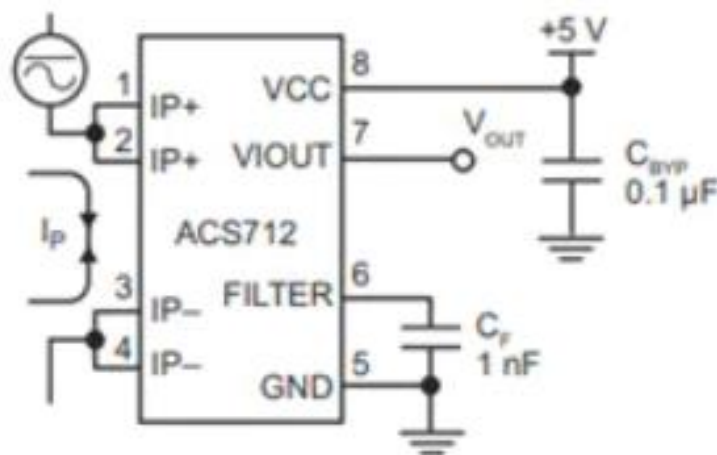


Fig. 5.14 ACS-712 Pin

This current sensor has an output voltage of max $V_{CC} \times 0.5 = 2.5$ volts at the input current 0A and a 5V VCC power supply. There are 3 types based on the readable current range, 5A, ± 20 A, and ± 30 A with output sensitivity of each type of 185mV / A, 100mV / A, respectively.



Fig. 5.15 AC712

5.4.6 Voltage sensor ZNPT-101

ZMPT101B AC(fig 5.16) Single-Phase voltage measuring module is based on a precise ZMPT101B voltage Transformer. ZMPT101B(Fig 5.16) AC Voltage measuring is the best utilized for the purpose of the small projects and prototyping, where we are required to measure the precise AC voltage with a voltage step-down transformer. This is a perfect choice to measure the AC voltage using Arduino and similar microcontrollers which utilize an open-source platform. In various electrical projects, engineers have to deal with measurements with few basic requirements like High isolation, Wider Range, High precision, Good accuracy.

The sensor utilizes Onboard precision miniature voltage step-down transformer, The active phase AC output voltage step-down transformer module. Onboard precision op-amp circuit, the sensors utilizes signal sampling and appropriate compensation techniques for precise functioning and measurements. Modules can be used to perform measurements within range of 250Volts AC voltage, the corresponding analog output can be calibrated. It is brand new, good quality high performance.



Fig. 5.16 ZMPT101B

5.4.7 USB TO RS232/485/TTL

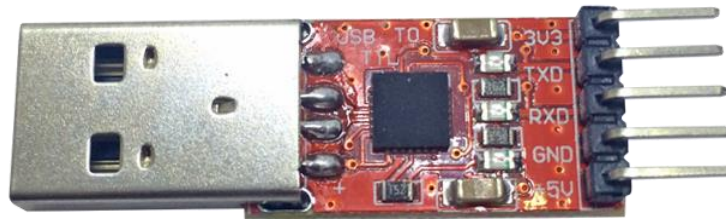


Fig. 5.17 ZPT101B

This is an industrial Universal Serial Bus(fig 5.17) to RS232-485/TTL isolated converter with original FT232RL IC inside. It has embedded protection circuits such as power isolation, analog to digitalmagnetic isolation, and T.V.S diode, etc. What's more, the USB TO RS232-485/TTL(Fig 5.17) comes with an aluminum alloyalcad enclosure, making it sturdy and rigid to work.

Features of the Converter module

Single-chip USB to Serial synchronous-asynchronous data transfer interface.

- Fully Compliant with USB Specification v2.0 (Full-Speed).
- UHCI/OHCI (USB1.1), EHCI (USB 2.0), xHCI (USB 3.0) Host Controller Compatible.
- Integrated USB 1.1 Transceiver and 5V to 3.3V Regulator.
- Integrated 96MHz clock generator (No external crystal required).
- Supports USB to RS232 Serial UART Interface.

CHAPTER 6

SUMMARY & CONCLUSION

PLCC can be a major step in world of home automation. In the upcoming days this technology has a huge impact in the field of automation and internet of things. The system was tested using a Power Line transmitter and two receivers connected to appliances kept at different locations but within the same electric network. The appliances were controlled by sending specific commands to trigger the relays which were the switch link in the circuit. The signals do not get transmitted through the MCB so the signals sent from one house don't interfere with that of the neighbor's. The response to commands time sent by the control interface had a lag of 0.6 to 1 second. Thus it can be considered that PLCC is a better alternative in home automation.

The scope of future work in this technology is tremendous as multiple IoT modules can be conformed together to make the system more versatile and effective. Moreover, the automotive industry and similar institutions had to face a great challenge in its transition from mechanical engineering towards mechatronic products. In the last ongoing decades, the power line carrier communication technology has received substantial amount of attention and spans several applications both in indoor, outdoor and intra-vehicle data communications. And in the past few years ethernet over powerline has gained tremendous traction in the field of IoT leading to mass manufacturing of PLCC modules making such modules more affordable for common people and students. Going forward in future making technologies more integrated and robust is the way to go and implementing automation in the house wiring itself rather than using multiple routers provides impeccable robustness to the system increasing its reliability and also at the same time reducing the overall expenditure of the automation network. The advancements in the field of SOCs and microelectronics have made manufacturing of dedicated PLCC modules with all the peripherals included very cheap, thus reducing the overall cost as compared to traditional Wi-Fi routers systems. Thus PLCC based home automation can be considered as a viable alternative to the traditional systems.

REFERENCES

- [1] AnithaThulasi UG Scholar Electrical and Electronics DMI College of Engineering, Chennai, Tamil Nadu.Assistant Professor Electrical and Electronics DMI College of Engineering, Chennai, Tamilnadu. IOT BASED SMART ENERGY METER BY USING PLCC.
- [2] Asadullah.U and A. Raza, "An overview of home automation systems," 2016 2nd International Conference on Robotics and Artificial Intelligence (ICRAI), Rawalpindi, Pakistan, 2016, pp. 27-31, doi: 10.1109/ICRAI.2016.7791223.
- [3] Hrasnica.T, AbdelfattehHaidine, Ralf Lehnert, "Broadband Power line Communications: Network Design", Wiley Publications, August 2004, ISBN: 978-0-470-85741-0.
- [4] Ravi Kishore Kodali, Vishal Jain, Suvadeep Bose and Lakshmi Boppana Department of Electronics and Communications Engineering National Institute of Technology, Warangal. IoT Based Smart Security and Home Automation.
- [5] Satish Palaniappan ,IndiaNaren T Kesh CSE, SSN College of Engineering, Anna University, Chennai, India Home Automation Systems - A StudyInternational Journal of Computer Applications (0975 – 8887) Volume 116 – No. 11, April 2015.
- [6] Shwehdi, M.H.; Khan, A.Z. "A power line data communication interface using spread spectrum technology in home automation," Power Delivery, IEEE Transactions on, vol.11, no.3, pp.1232-1237, Jul 1996 doi: 10.1109/61.517476.
- [7] Yuan, X., Archer, R.L., Xu, J. and Yu, H. (2008). A Visualization Tool forWireless Network Attacks. Journal of Education, Informatics and Cybernetics.
- [8] Power line Communications and its applications Conference Paper · May 2008 DOI: 10.1109/ISPLC.2008.4510400 · Source: IEEE Explore
- [9] Yitran-ltd.com - IT800D documentation.
- [10] <https://www.arduino.cc/en/main/documentation>

- [11] <https://www.sparkfun.com/datasheets/BreakoutBoards/0712.pdf>
- [12] <https://www.nxp.com/docs/en/application-note/AN10216.pdf>
- [13] http://www.zeming-e.com/file/0_2013_10_18_093344.pdf
- [14] <https://www.mikrocontroller.net/attachment/423733/document.pdf>
- [15] <https://components101.com/microcontrollers/arduino-uno>
- [16] <https://datasheetpdf.com/pdf/570845/AllegroMicroSystems/ACS712/1>
- [17] <https://www.futurlec.com/LED/LCD16X2.shtml>
- [18] <https://aricom.it/zmpt101b-esp32.html>
- [19] https://c44f5d406df450f4a66b-1b94a87d576253d9446df0a9ca62e142.ssl.cf2.rackcdn.com/2018/02/PLCC_DS293.pdf
- [20] <https://ttssh2.osdn.jp/manual/4/en/macro/command/index.html>