NORTHERN ILLINOIS UNIVERSITY

Home Control and Monitoring
A Thesis Submitted to the

University Honors Program

In Partial Fulfillment of the

Requirements of the Baccalaureate Degree

With Upper Division Honors

Department Of

Electrical Engineering
By

Sagar Shah
DeKalb, Illinois

12/08/2017

University Honors Program

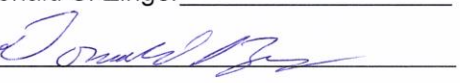
Capstone Approval Page

Capstone Title

Home Control and Monitoring

Student Name ___Sagar Shah_____

Faculty Supervisor _____Dr. Donald S. Zinger_____

Faculty Approval Signature 

Department of _Electrical Engineering_____

Date of Approval ____12/08/2017_____

HONORS THESIS ABSTRACT

Home automation has rapidly growing at present. People need comfort and convenience. In this paper, I give an overview of the home automation through power line communication (PLC) technology. This paper presents an overview of the research, methods, applications, standards and some of the critical features of the power line communication. Powerline communication is one of the most emerging home network technology that allows consumers to use their already existing powerline wires to connect home appliances to each other and the Internet. The PLC channel is discussed. Noise in power line communication and impulsive Gaussian noise are showed in this paper.

HONORS THESIS ABSTRACT
THESIS SUBMISSION FORM

AUTHOR: SAGAR SHAH

THESIS TITLE: HOME CONTROL AND MONITORING

ADVISOR: DR. DONALD S. ZINGER

ADVISOR'S DEPARTMENT: ELECTRICAL ENGINEERING

DISCIPLINE: POWER ELECTRONICS AND COMMUNICATION TECHNOLOGIES

YEAR: 2017

PAGE LENGTH:

BIBLIOGRAPHY:

ILLUSTRATED:

PUBLISHED (YES OR NO): NO

LIST PUBLICATION:

COPIES AVAILABLE (HARD COPY, MICROFILM, DISKETTE):

ABSTRACT (100-200 WORDS): Home automation has rapidly growing at present. People need comfort and convenience. In this paper, I give an overview of the home automation through power line communication (PLC) technology. This paper presents an overview of the research, methods, applications, standards and some of the critical features of the power line communication. Powerline communication is one of the most emerging home network technology that allows consumers to use their already existing powerline wires to connect home appliances to each other and the Internet. The PLC channel is discussed.

INDEX

1. PROBLEM STATEMENT

1.1 Need

One could say the market is completely saturated with all sorts of home automation devices. However, using powerline communication to do the task of automation gets rid of the reliance on wireless technologies. Bluetooth has a very short range whereas Wi-Fi can only have so many connected devices at a time limiting your overall capabilities. With powerline communication, you could have a single transmitter connected to Wi-Fi and use your phone to control every device over one single wireless connection as opposed to having every single device connected to wireless as the current market trend shows. For example, there are plenty of devices to help with deaf people answering the door. Now a PLC network could flash all the lights in the entire house on and off at the press of the doorbell. The other devices that already use flashes of light to alert the hearing impaired only provide one function to the user and it's limited to where you plug it in. With a PLC network, all installed lights can flash on and off at the press of a button can also be dimmed automatically and manually. That same network can be used for a multitude of other things from automatically watering your grass through a sprinkler system to notifying you why your power bill is so high this month. There is a hefty need in tethering all the individual automation technologies together into a single system.

1.2 Objective

The goal of the project is to design and implement an array of transmitters and receivers into a powerline communication network in order to control and monitor via receptacle sub-circuits. This network will be capable of both automatic and manual controlling/monitoring. The network will communicate will be capable of multiple input multiple output (MIMO) communication.

1.3 Research survey and patent research

“Figure 1.1 illustrates the evolution of the PLC technology by identifying some early patents, specific application domains and international standards along with a timeline. The origins of PLC can be traced back to the late 1800s and again in the early 1990s. Patents and consider remote meter reading via PLC The first description of remote load management using PLC, or so-called ripple control, is given in (we note that mentions the slightly earlier patent submission). These ripple control systems (RCS) were developed further in the 1930s and at a larger scale in the 1950s to establish unidirectional communication for load management and other control functions in the power distribution grid. RCS use high-power and narrowband PLC signals. The signal frequencies are between 125 Hz and 3 kHz so that signals can pass through the distribution transformers and reach consumers. Before the widespread use of PLC via ripple control in the distribution domain, power line voice communication over medium-voltage and high-voltage transmission lines became popular in the 1920s [1]”.

Figure 1.1 Illustration of evaluation of PLC technology [1]

Light dimming is based on adjusting the voltage which gets to the lamp. Light dimming has been possible for many decades by using adjustable power resistors and flexible transformers. Those methods have been used in movie theatres, stages, and other public places. The problem of those light controlling ways have been that they are big, expensive, have reduced efficiency, and they are hard to control from one location. In this project, we used light dimmers work by varying the "duty cycle" (on and range between off and on,) of the full AC voltage that is applied to the lights being controlled. For example, if the voltage is applied for only half of each AC cycle, the light bulb will appear to be much less bright than when it gets the full AC voltage because it gets less power to heat the filament. With the logic program and sensors use the brightness knob setting to determine at what point in each voltage cycle to switch the light on and off or a rang. As powerline communication is still a somewhat new area, few standards have been established, especially for broadband applications. Powerline Communication is found to be one of the cheapest and easiest communication techniques, and electronic companies are looking forward to its applications in home automation, automatic energy reading, broadband, etc. It is the project we propose a PLC modem, which is cost-efficient and easy to implement. And low voltage narrowband powerline communication for PLC Modem. The proposed PLC modem design transmit and receive data for application such as controlling home equipment's, meter reading, etc. PLC Modem is the heart of Powerline communication. The primary task of PLC Modem is signal preparation and conversion for its transmission over power line as well as a signal reception. This project is based on data transmission over the power line. The power line modem uses the power line cable as the communication medium. It is convenient as it eliminates the need to lay additional cables. The modem at the transmission end modulates the signal from data terminal through TDA5051 interface onto the carrier signal in the power line. At the receiving end, the modem recovers the data from the power line carrier signal by demodulation and sends the data to data terminals through the TDA5051 interface. Once the data signal has been generated, it needs to be placed on the powerline by coupling network or circuits. The idea is to superimpose the data signal onto the 110 V, 60 Hz power waveform, and extract it afterward at the receiving end.

2. REQUIREMENT SPECIFICATIONS

The system will be able to read commands from the host or pc and captured to the control box via a serial connection to the PC COM port. These commands will specify whether certain lights or appliances in the house must be turned on or off and at what times these must occur. Commands to the devices will be sent via the 120V/240V AC (alternating current) powerline circuitry in the house and received by each appliance controller.

Light bulbs will be controlled by a unit that will plug directly into the light bulb socket and will allow a light bulb to be plugged into it. Other units will plug into a wall socket and will provide a 3-point socket for any appliance to be switched by plugging the appliance into the unit.

Marketing requirements	Engineering Requirements	Justification
Access	System needs to have a host or internet to access	Based on the design system will communicate or in active mode when it has the proper access
Voltage	System should not exceed 120V-240V	Based on AC power line voltages.
Control Box	Needed to support manual and automatic control	System has full home control and energy efficient light dimming
Noise Level	System should not exceed 80 dB noise level in the power line	More than 80 dB noise will cause power line communication chip to communicate with data lost
Comfortable	Receptacle should not exceed 2 lb.	More weight may cause minor damage to the circuit

Accurate	System will not communicate more than 32 receptacles	It will decrease the system accuracy
Energy Efficient	System should check monitoring data	That way the system will keep track of power and energy
Cost	System should not exceed $200	Based on the cost of competing products
Ease of use	System will have a single controller to operate everything	That way consumer will have the more robust control from one device.
Safety	System should use GFCI outlets. System should auto disconnect in case of overvoltage	Based on the NEMA standards
Consumer Friendly	System will operate in the noisy power lines.	Based on the capability of the chip to suppress noise levels.
Feedback	System will check feedback constantly. Also, the dimming sensor values every 20 times per minutes	Based on the reaction time on the dimmable LEDs.
Space	System should not exceed the double the size of receptacles	Based on the circuit space and hardware implementation

3.0 THE DESIGN

3.1 System overview

The system will be able to read commands from the user and captured to the control box via PC. These commands will specify whether certain lights or appliances in the house must be turned on or work by some percentage or off and at what times these must occur. Commands to the devices will be sent via the 120 V AC (alternating current) power line circuits (transmitter and receiver) in the house and received by each appliance controller. Interactive units will provide feedback from sensors attached to them for example a light sensor to indicate night or day or the amount of incandescent -bright- to provide for the automation aspect of the project, the goal is to develop user-friendly interactive system that allows the user to specify or auto mode when the house appliances must be switched, using one or more of the following criteria:

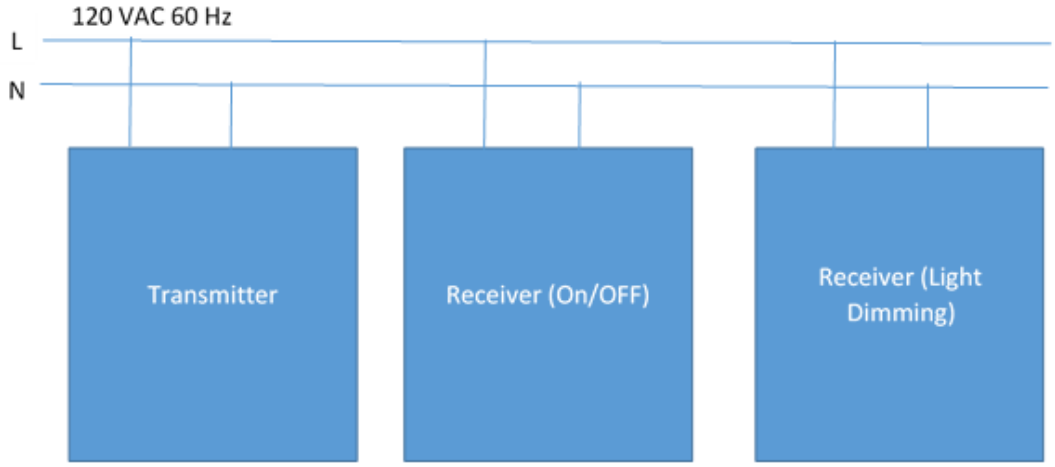


Figure 2 System functionality block diagram

3.2 System modules

- Microcontroller
- Monitor
- Light sensor for light dimming
- Security
- Outside Units

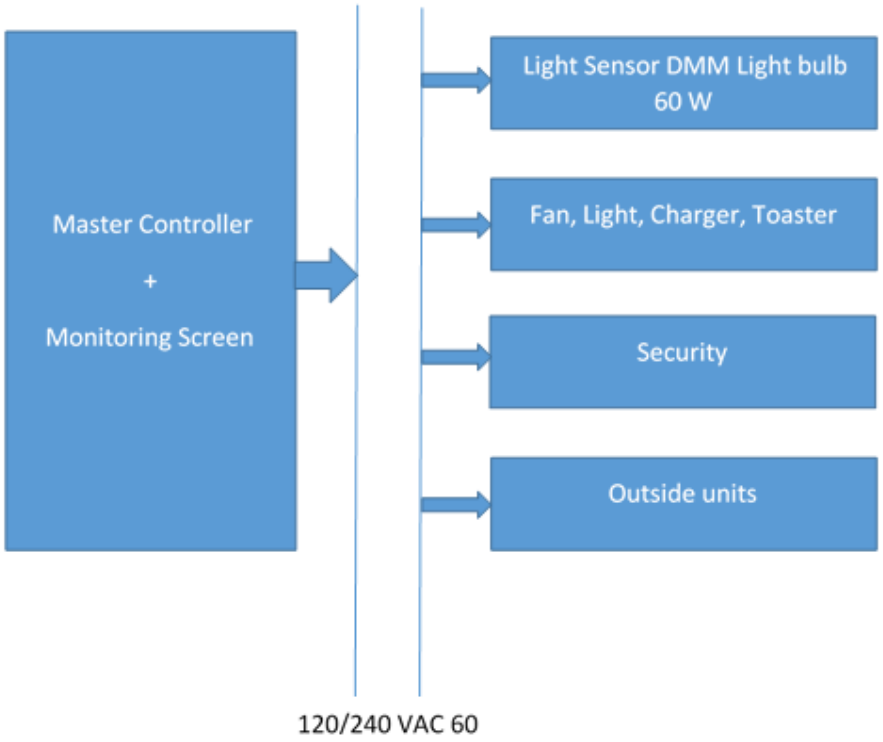


Figure 3 System modules

3.3 Protocol

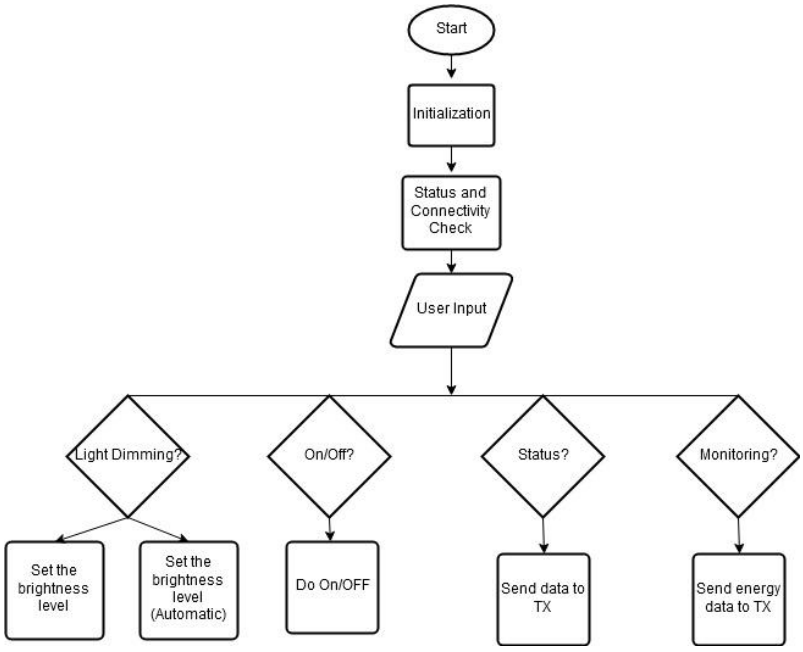


Figure 4 Flow chart- System protocol

The powerline home automation system comprises of the following parts:

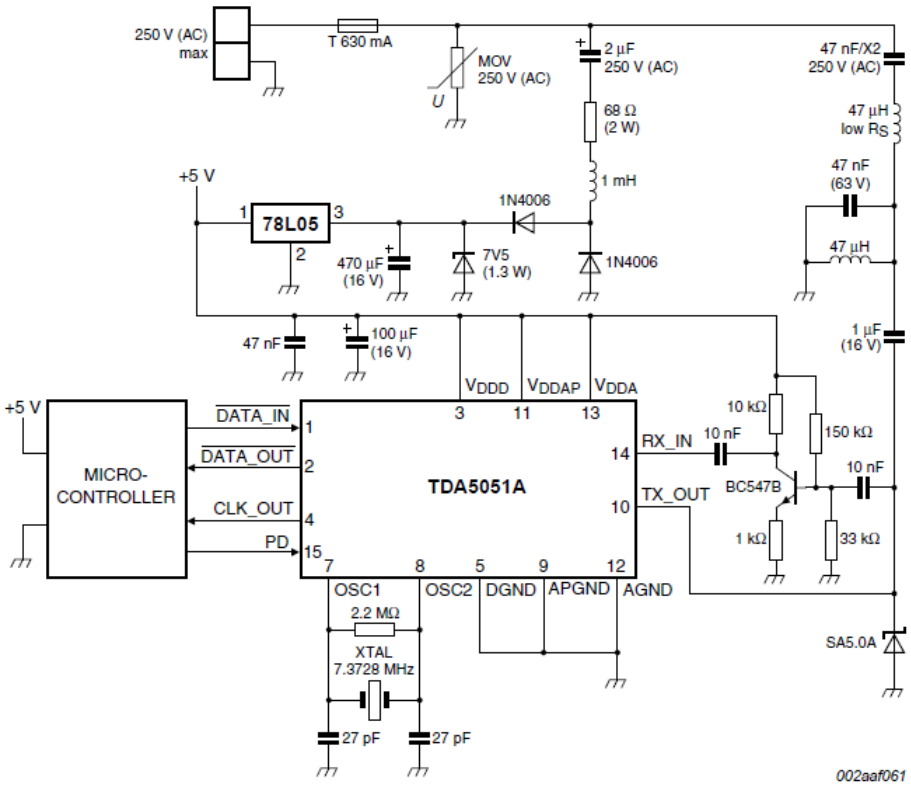
- A host or pc to program that interprets the instructions and issues commands to the master unit,

- The serial interface between the computer and the master unit,
- A master unit microcontroller that encodes and times the instructions to be sent across the network,
- A signal modulator/demodulator chip,
- A line filter that isolates the high voltage 120 V/ 240 V, 60 Hz carrier from the rest of the circuitry and couples the signal onto the powerline,
- Another microcontroller that resides in the slave modules, decoding the instructions and controls the slave function,
- The slave function module, which is one of the following:
    - A power switching module to switch an appliance on or off,
    - A light sensor to report on the ambient light, compatible with automatic light dimming
    - A simple illustrative monitoring system, which can be interfaced to a larger existing system.
- The module power supplies.

Each of the above parts will be briefly discussed:

Master microcontroller

At the heart of the master unit lies an Arduino microcontroller. It has a built-in serial interface module that is used to communicate via the computer and with other devices on the network. The communication settings used with other units are also 1200 bits/second, odd parity and 1 stop bit. Then serial data stream from the host is multiplexed between the computer and the powerline using a TDA5051A PLC chip, wired as a dual multiplexer/demultiplexer. The microcontroller adds an error control CRC code to the message and issues it to the network.



f_{cr} = 115.2 kHz for XTAL = 7.3728 MHz standard crystal.

Figure 5 Transmitter schematic [2]

Modulation

The modulation technique chosen is ASK (Amplitude Shift Keying) and the serial data train is modulated using an NXP TDA5051 ASK modulator/demodulator chip. Considering the noise and attenuation properties of the powerline the most suitable carrier frequency is 125 kHz. A binary 1 corresponds to a burst of a sine carrier at 125 kHz, and a binary 0 causes no signal to be placed on the line.

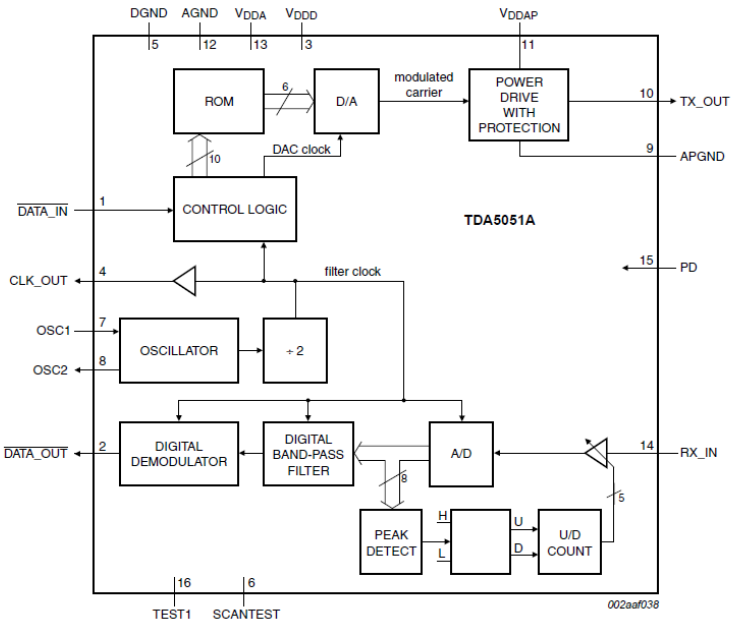


Figure 6 TDA5051A chip modules [2]

Line filter and line coupling

The line filter is a passive LC filter, designed to filter out the 120 V 60 Hz to below 80 dB, while allowing the 125 kHz carrier to pass with attenuation of no more than 2 dB. The output of the modulator is connected to the input port of the filter and the live and neutral connections of the powerline are connected to the output port of the filter.

Coupling circuit design

In this coupling circuit, a double LC bandpass filter is used to provide efficient rejection 60Hz signal (high pass) and anti-aliasing (low pass) for digital filter without any adjustment or tunable from the components. A unidirectional transient suppressor (SA5.0A, D1) is connected across the TXOUT and RXIN to protect from overvoltage. It also protects the TXOUT from negative transient voltage which also might damage the circuit output amplifier.

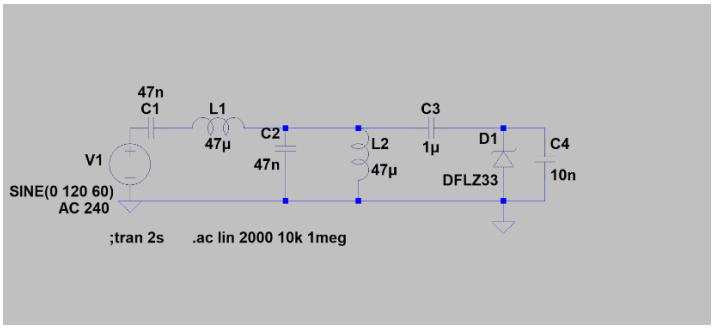
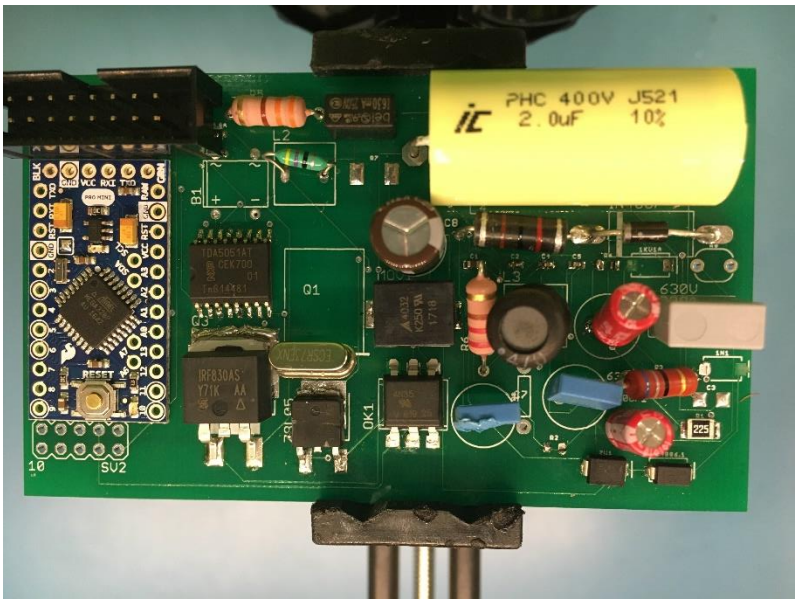


Figure 7 Coupling circuit

Slave microcontroller

The microcontroller used in the slave modules is the Arduino pro mini. The serial functions are implemented in software as well as the encoding and decoding of the instructions received. Each slave module on the network receives all the instructions sent by the master controller and compares its own unique network id with that in the instruction word id field and only executes the instruction upon a match. When the instruction matches code in the slave microcontroller will perform the actions or tasks.



Light sensor and light dimming

The light sensor unit uses an LDR (Light Dependent Resistor) to detect the ambient light level. The LDR forms part of a 2-resistor voltage divider between 5 volt and ground. The resulting voltage is compared to a fixed voltage produced by another voltage divider containing a potentiometer and a resistor, using an operational amplifier. The output of the amplifier is fed to the microcontroller as the sensor signal.

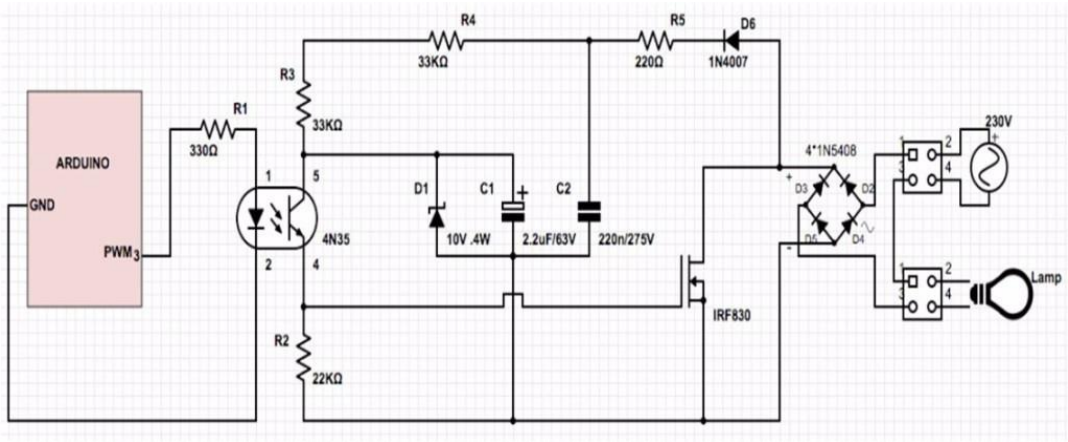


Figure 8 Light dimming circuit [3]

Power supply

This AC power supply circuit will be fed in with 120VAC and eventually step down and converted to 5VDC with the help of voltage regulator and few components act as half wave rectifier. In this power supply, it consists of primary and secondary protection. Secondary protection consists of the metal oxide varistor (MOV), rated at 240VAC for the power line operation. This MOV (Metal Oxide Varistor) will be able to limit the overvoltage spikes which might damage Capacitor (C1). Whereas a primary protection includes an extra fast fuse connected before the MOV, this is to overcome the long and severe overvoltage, so that the fuse will be destroyed before the MOV.

Capacitor (C1) is used to discharge high voltage, whereas to R1 & L1 is connected before the rectifier to prevent current surge during power up. And with D2 and C2 in place, it provides a minimum voltage 28VDC before entering the voltage regulator. Which will eventually generate a +5VDC source after going through a voltage regulator.

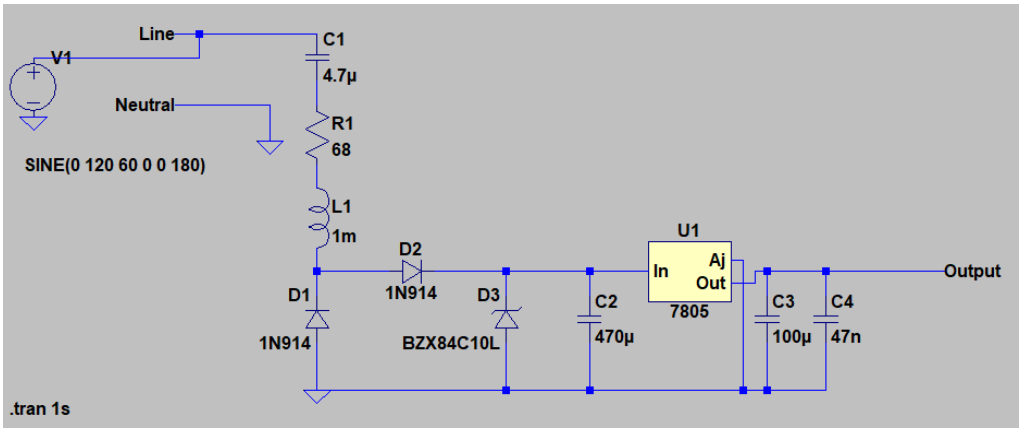


Figure 9 Power Supply

4. DESIGN VERIFICATION AND TESTING

TDA5051A chip testing

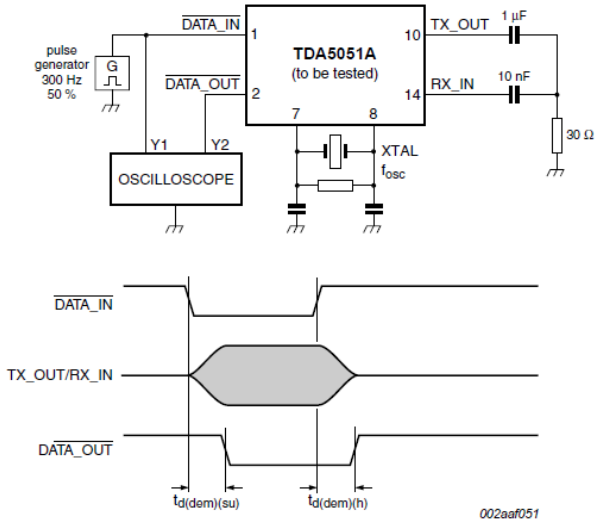


Figure 10 Chip test reference [2]

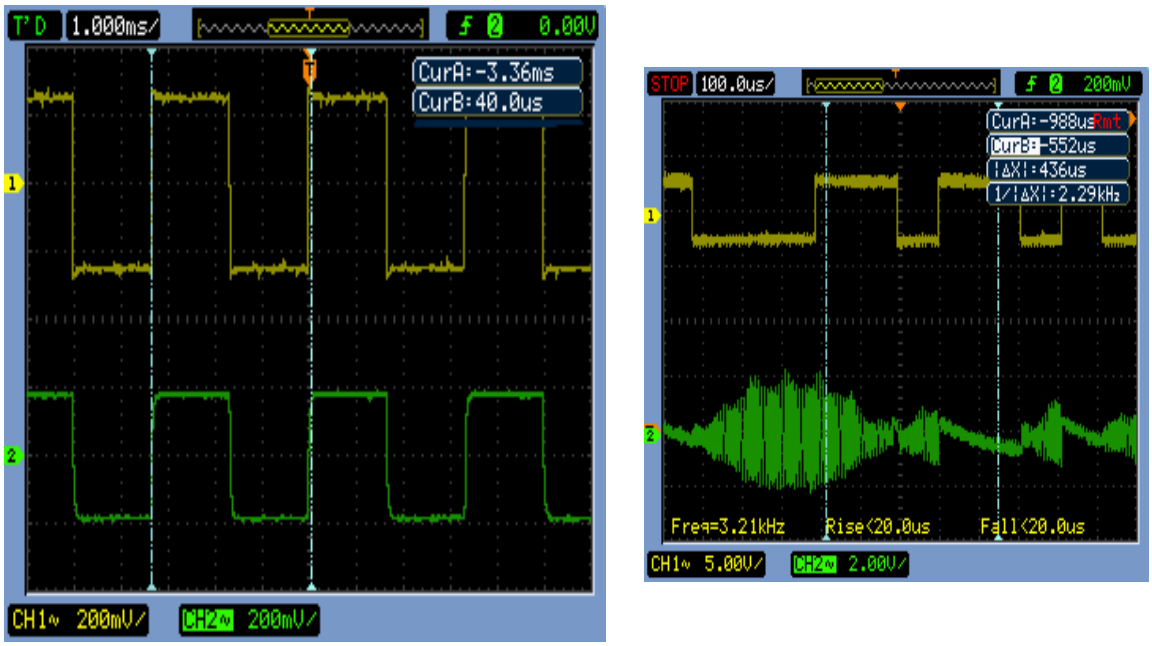


Figure 11 Frequency testing

Communication test

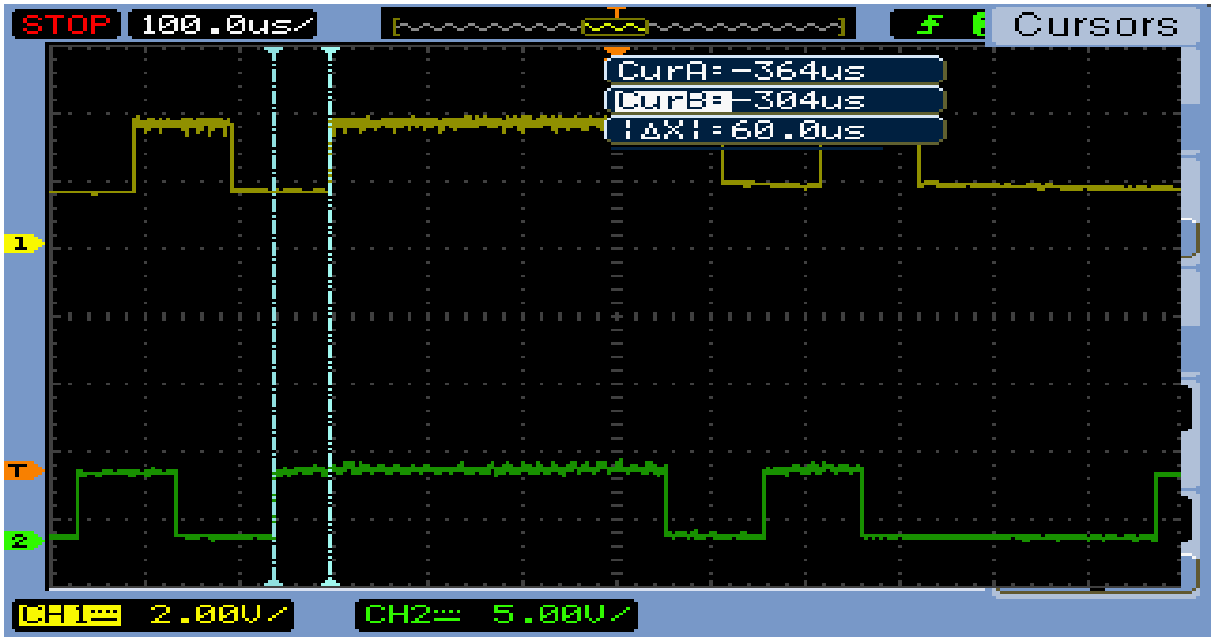
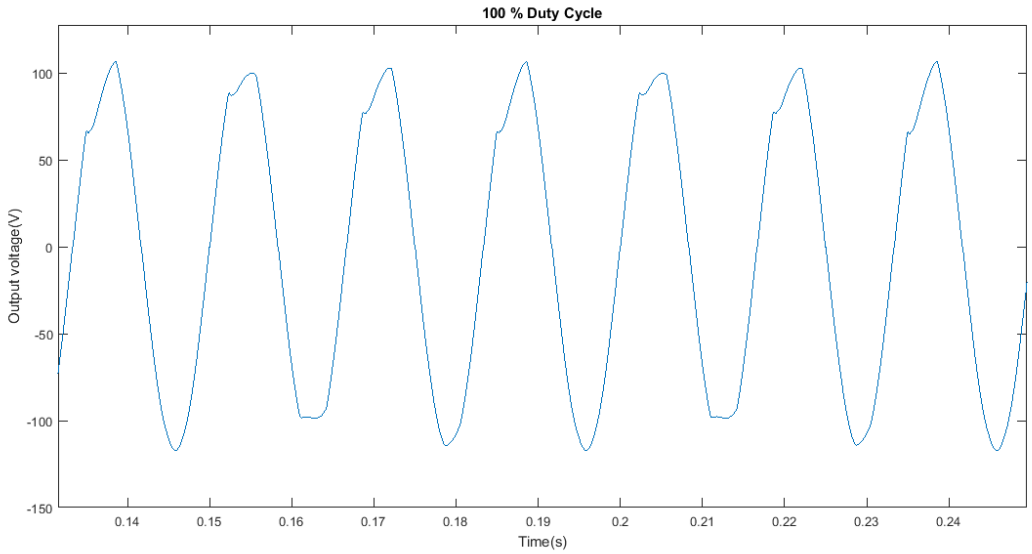
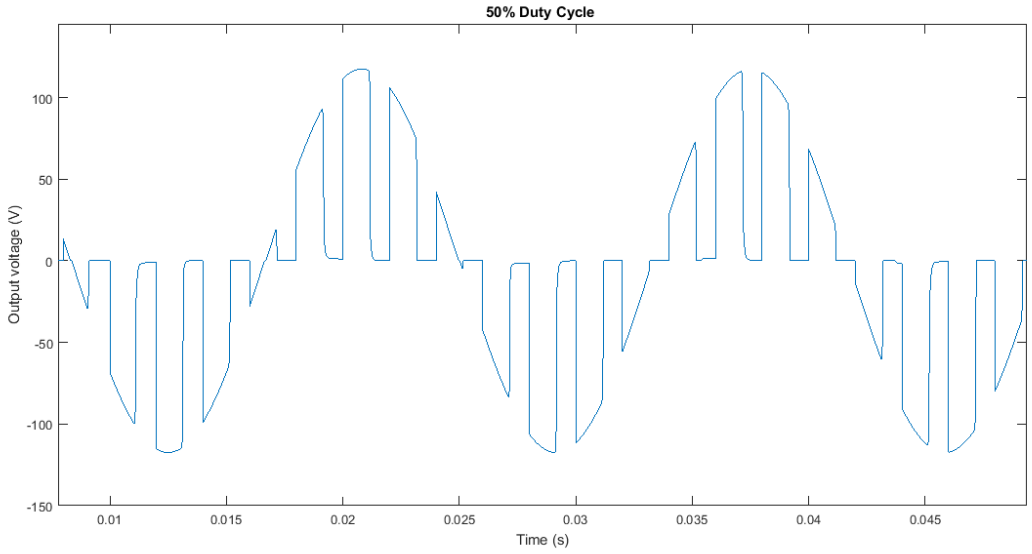


Figure 12 Data testing with 1.5 m wire

Light Dimming Test Data





5. FAILURE MODE & EFFECTS ANALYSIS

The purpose of the failure mode and effects analysis is to find potential causes and effects of failures within the *Home Control & Monitoring* System.

There are two types of causes of failure. One being direct which is due to the physical process and the other is indirect which is due to outside interference such as environment or human error.

This helps to find out which specifically which process or component of the system is causing an error or failure in the system. This also helps with taking precautions for future trials and taking recommended actions to prevent failure in the future.

There are three criteria to score, Occurrence, Severity and Detection. For Occurrence, a value is given between 1 to 10, with 10, it is the most extremely high possibility of failure. For Severity, a value is given between 1 to 10, with 10 being the most critical of system damage/failure. For Detection, a value is given between 1 to 10 with 1 being the most easily detectable cause and 10 being the most difficult detection. After all criteria have been scored, the product of these three values is the Risk Priority Number. The RPN basically ranks the modes. The higher the number the more attention that mode will need for prevention of failure and thus improvements can be made.

FAILURE MODE AND EFFECTS ANALYSIS

Project	Home Control and Monitoring
Model:	Demo
Core Team:	Naveed Siddiqui, Mutwakil Elsidig, Sagar Shah, Steven Keeley

Circuit Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	RPN
Circuit ground	Short circuit	system failure	10	failure to properly isolate	1	GFCI	1	10
Noise reduction	Bad signal	improper in communication	3	bad TDA5051a	4	Isolate devices from each other	2	24
data Communication	Wrong data signal	Large delay	3	powerline channel interference	5	Good conductuctors	2	30
Monitoring	defective sensors	Monitoring Failure	6	bad current transformer	2	Device testing	2	24
coupling circuit	failure of circuit	No PLC communication	7	capacitor blowout	1	use rated capacitors	1	7
Power supply	power outage	sytem doesn't work	7	Power supply company	1	unavoidable	1	7
light dimming	flickering	annoyance	1	programming and unstable power supply,	7	robust control	1	7
circuit breaker	melt metal contact	no communication	8	a short circuit	1	Quality circuit breaker	1	8
microcontroller	defective pins	communication gap	6	receiving over rated signals	2	Simulate before implementation	10	120
Feedback	no reference point	hard to track monitoring	5	powerline channel interference	6	short time in between feedback check	2	60

CONCLUSION

Power line communication home automation is a technique that allows the exchange of data using electric power line network that is presented in every building. In this, I came to know about the application, advantages, and disadvantages of power line communication technology and understood some basic idea of the standards, noise, channel, and applications. I hope this project gives an overall basic understanding of the topic concisely and quickly to the reader in the power line communication. In this, I find PLC is an attractive research area many studies are still necessary to be better understand and improve the overall performance of power line for high data transmission. And to make communication very easy and cost-effective for home automation.

REFERENCES

[1] Lutz Lampe, Andrea M. Tonello, and Theo G. Swart, "*Power Line Communications-principles, standards and applications from multimedia to smart grid*" © 2016, John Wiley & Sons, Ltd.

[2]2017. [Online]. Available: https://www.nxp.com/docs/en/data-sheet/TDA5051A.pdf. [Accessed: 26- Oct- 2017].

[3]"How to Make an Arduino Powered Lamp Dimmer | DIY Hacking", *DIY Hacking*, 2017. [Online]. Available: https://diyhacking.com/arduino-lamp-dimmer/. [Accessed: 26- Oct- 2017].

[4] P. Bertoldi, B. Hirl, N. Labanca, "*Energy efficiency status report*", Joint Res. Center Inst. Energy Transport, May 2014, [online] Available: http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/energy-efficiency-status-report-2012.pdf.

[5] D. Shahgoshtasbi, M. M. Jamshidi, "*A new intelligent neuro-fuzzy paradigm for energy-efficient homes*", IEEE Syst. J., vol. 8, no. 2, pp. 664-673, Jun. 2014.

[6] J. Lagorse, M. G. Simoes, A. Miraoui, "*A multiagent fuzzy-logic-based energy management of hybrid systems*", IEEE Trans. Ind. Appl., vol. 45, no. 6, pp. 2123-2129, Nov./Dec. 2009

[7] Light dimming circuits by Tomi Engdahi 1997-2000

[8] A.Alheraish, "*Design and Imlementation of Home Automation System*", 2004 IEEE transaction on consumer electronic, vol. 50(4) pp 1000-1092.

[9] BaKi Koyuncu "*PC Remote Control of Appliance by using Telephoneline*" 1995, Linglong Dai, Jian Fu,Jun Wang "*LDPC coded TDS-OFDM for PLC*" 2010 IEEE ,Journals & magazines volume 15 issue 3 pp 312-318