

**CELL PHONE CONTROLLED HOME ELECTRICAL APPLIANCES**  
**(Home Automation with Power Line Carrier Technology)**

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**A project report submitted in partial fulfilment of the  
requirements for the award of the degree of  
Bachelor (Hons.) of Electrical and Electronic Engineering**

**Faculty of Engineering and Science  
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**May 2011**

## DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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Specially dedicated to  
my beloved grandmother, mother and father

## **ACKNOWLEDGEMENTS**

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Lim Yun Seng for his invaluable advice, guidance and his enormous patience throughout the development of the research. Besides that, I would also like to express my appreciation to Dr. Lo Fook Loong for his guidance on the telecommunication part of the project.

In addition, I would also like to express my gratitude to my loving parent and friends who had helped and given me encouragement on the project. I would also like to express my thankfulness to my project partner, Teo Che Shen who always gives his full cooperation.

Without these people, the project wouldn't be able to complete.

## **CELL PHONE CONTROLLED HOME ELECTRICAL APPLIANCES**

### **ABSTRACT**

GSM based home automation system is an electrical and communication system designed to control home appliances using cell-phone and GSM modem. In this project, an old GSM cell-phone is implemented as a GSM modem. This is because GSM cell-phone is cheaper compared to a GSM modem and the budget for this project is limited.

The chosen GSM cell-phone is Sony Ericsson K700i. This phone is chosen because it is cheap and easily found. Besides, it is also easy to implement due to the phone data transmission pins is outside the phone. AT Command is used as the communication medium between GSM modem and microcontroller.

For the home automation part, Power Line Communication (PLC) technology is implemented. The main purpose of implementing PLC technology is that it doesn't require any extra cabling because it uses the existing electrical line system in the house. X-10 standard is used to send control messages on power line and the communication medium between appliances. X-10 standard is chosen because it is more flexible, more understandable, and more common among others.

The microcontroller that used to control the PLC modem and home appliances is PIC16F877. PIC is used to detect zero-crossings and 120 KHz X-10 carrier signal on the line. A MAX232 is used in the communication between microcontroller and computer. Power line carrier modem is used as a translator to make data communication on the electrical line as the electrical line is an analog environment while the microcontroller is digital environment. In this study, 2 types

of power line carrier modem is discussed which are TDA5051A and ST7537HS1. TDA5051A uses ASK modulation technique while ST7537HS1 uses FSK modulation technique.

An isolation transformer is used at the AC power source due to safety purpose. Besides, it is also to protect the powered device from the power source by isolating them.



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**LIST OF SYMBOLS / ABBREVIATIONS**

AC	Alternating Current
ADC	Analogue to Digital Converter
AGC	Automatic Gain Control
ASK	Amplitude Shift Keying
DAC	Digital to Analogue Converter
DC	Direct Current
FSK	Frequency Shift Keying
GSM	Global System for Mobile Communication
HF	High Frequency
IC	Integrated Circuit
I/O	Input/ Output
IR	Infrared
LED	Light-Emitting Diode
MOV	Metal Oxide Varistor
PCB	Printed Circuit Board
PIC	Peripheral Interface Controller
PLC	Power Line Communication
RAM	Random Access Memory
SCI	Serial Communication Interface
SMS	Short Messaging Service
SNR	Signal to Noise Ratio
SPI	Serial Peripheral Interface
TDMA	Time Division Multiple Access
UART	Universal Asynchronous Receive/ Transmit
VR	Variable Resistor



## CHAPTER 1

### INTRODUCTION

#### 1.1 Introduction

Nowadays, people's expectations in their life quality are increasing as the technology is improving rapidly. People need an affordable smart system that can make their lives easier, more comfortable, and offer more safety. GSM based Home Automation System is an electrical and electronic system designed to control home appliances with a mobile phone. The 2 main technologies applied in the system are GSM and PLC. GSM stands for Global System for Mobile Communication and PLC stands for Power Line Communication. In this study, Sony Ericsson K700i is chosen as the GSM phone that receives command and transfers it to controller.

Due to rapidly advancing of mobile communication technology and widely availability make it possible to incorporate mobile technology into home automation systems. AT command is used as communication between GSM phone and microcontroller by passing through a serial interface RS232 with the help of its driver.

The most common used standards in Smart Home Automation design are such as X10, CEBUS, and LonWorks. X10 standard is the most popular and the most commonly used in home automation design. This is mainly because of the standard doesn't require any extra cabling for the system installation as it uses the existing electrical line in the house.

The backbones of the study are the control circuits which consist of the microcontrollers and integrated modems. The modem is used to send and receive X10 codes on the electrical line by converting the signal types. The control circuits can be divided in two parts which are master unit and slave units. Master unit is connected to the GSM phone to receive command. User can control appliances connected to slave unit when command is received.

## **1.2 Aims and Objectives**

The objective of this project is to build a GSM based Home Automation System using a GSM phone, Microcontrollers, PLC modems, and isolation transformer. Besides that, it is also to learn and apply the GSM and PLC technology in the system. Apart from that, the project is also carried out to learn on the power line insulation.

## **1.3 Task Distribution**

The project is assigned to me with a partner due to time consuming. I will be focusing on the Home Automation with Power Line Communication part while my partner, Teo Che Shen will be focusing on the GSM communication part. Hence, the study will be focusing on Home Automation in this report.

## **1.4 Scopes of Project**

Several scopes proposed in my part of project are:

- i) To design and fabricate a transmitter and a receiver modules using PLC modem TDA5051A.
- ii) To design control circuits using PIC16F877A.

- iii) To design power line insulation interface with the circuits.
- iv) To design a network protocol for power line communication.
- v) To design an ultrasonic transceiver as switch.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Global System for Mobile Communication (GSM)



Figure 2.1: GSM Logo

GSM is the most popular and widely used digital mobile telephony system in the world. According to GSM world, it is now used by over 1.5 billion people all over the world. Hence, the ubiquity of GSM enables international roaming arrangements between mobile phone operators and provides their subscribers the use of the phone in many parts of the world. Besides that, GSM is considered a second generation (2G) cell phone system as both the signalling and speech channels are digital which differs from the previous technology.

**Table 2.1: History of GSM**

<b>Year</b>	<b>GSM Development</b>
1982	European Conference of Postal and Telecommunications Administrations (CEPT) created the <a href="#">Groupe Spécial Mobile</a> (GSM) to develop a standard for mobile telephone system in Europe.
1987	Memorandum of understanding was signed by 13 countries in Europe to develop a common cell phone system.
1989	GSM responsibility was transferred to ETSI.
1990	Phase I of GSM specifications was published.
1991	The first GSM network was launched in Finland.
1993	Over 1 million subscribers were using GSM phone networks.

GSM also found a low-cost implementation of the SMS, short message service, which has since been supported on other cellular phone standards as well. For example, the worldwide emergency telephone number feature (112) is included.

GSM uses narrowband Time Division Multiple Access (TDMA) for voice and Short Messaging Service (SMS). TDMA is a technology used in digital mobile phone communication that divides each cellular channel into 3 time slots to increase the amount of data that can be carried. GSM digitizes and compresses data, then sends it down a channel with 2 other user data in its own time slot.

## 2.2 Sony Ericsson K700i



Figure 2.2: Sony Ericsson K700i

Sony Ericsson K700i is chosen as the GSM modem in this project due to its low price and availability in the market. Besides, the main reason is that the data pinout of the phone is designed to be outside the phone. Hence, it is easier to retrieve data from the phone since the microcontroller needs to read the text message as command from the phone. The following diagram shows the pinout of Sony Ericsson K700i.

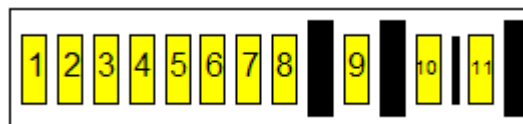


Figure 2.3: Connector Pinout of SE K700i

Pin 4 and pin 5 are data-in (Rx) and data-out (Tx) pins respectively. Hence, these two pins are connected to the microcontroller to transmit and receive data (command) where microcontroller will operate based on the command received.

### **2.3 Power Line Communication (PLC)**

Power Line Communication or Power Line Carrier (PLC) is basically a technology that enables narrow or broad band speeds through power lines by varies advanced modulation technology. It is based on the principal of controlling each unit or specifically each electrical device connected to an electrical socket with the existing power line in the house. In this project, the main purpose of developing power line communication is because this technology doesn't require extra cabling. It only uses the existing power cable in the house. Hence, the owner of the house doesn't have to restructure their cabling system which is very inconvenient and costly.

Basically, all PLC systems work by impress a modulated carrier signal on the wiring system either by ASK or FSK modulation. Different types of PLC system use different frequency bands, depending on the power wiring used. Data rates over a PLC system vary widely. Thus, low frequency carriers impressed on high voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per second.

Electrical line system is an analog environment due to the AC (alternating current) nature. Hence, in order to make data communication on the electrical line, a translator unit is required. A modem is used as the translator unit in this project due to the ability to modulate the digital data to analog at sender side and demodulate it digital at receiver side as desired. There are a few integrated modems which can be used in home automation system that available in the market such as TDA5051A (Philips), ST7537 (ST Microelectronics), LM1893 (National Semiconductor), and PLM-24.

## 2.4 X10 Technology

X10 technology is probably the most inexpensive technology used in home automation. It was developed in 1975 by Pico Electronics of Glenrothes, Scotland which designed in order to allow remote control of home devices and appliances. It also was the first general purpose domotic (home automation) network technology and still widely available all over the world.

X10 is an international and open industry communication standard protocol used to communicate among electronic devices for home automation. It works across home power lines with extremely low bandwidth. With X10, electronic devices that plugged into the wall socket can communicate with each other. It primarily uses power line wiring for signalling and control, where the signals involve short radio frequency (RF) bursts representing digital information. X10 remains popular in home automation purpose with millions of units in use worldwide although some other higher bandwidth alternatives exist including KNX, BACnet, and Lon Works.

X10 communicates between transmitter and receiver by sending and receiving signals across the power line wiring. The transmissions are synchronized when there is zero crossing point of the AC power line. The existing power line wiring is used to send digital data between X10 devices. The digital data which encoded onto a 120 kHz carrier is transmitted during the zero crossings of the 50 Hz AC power source. For instance, 1 bit of data is transmitted at each zero crossings of AC waveform. Besides that, it is also desirable to block X10 signals from leaving the local area so that the X10 signals in one house do not interfere with the X10 signals from neighbouring house. This can be solved by implementing inductive filters to attenuate X10 signals coming into or going out of the local area.



### 2.4.1 X10 Protocol

In home automation system, all the control units must use the same language to communicate with each other. X10 protocol is the language used for the control units to communicate. It basically uses Power Line Communication technology. The following diagram shows an example of X10 signal.

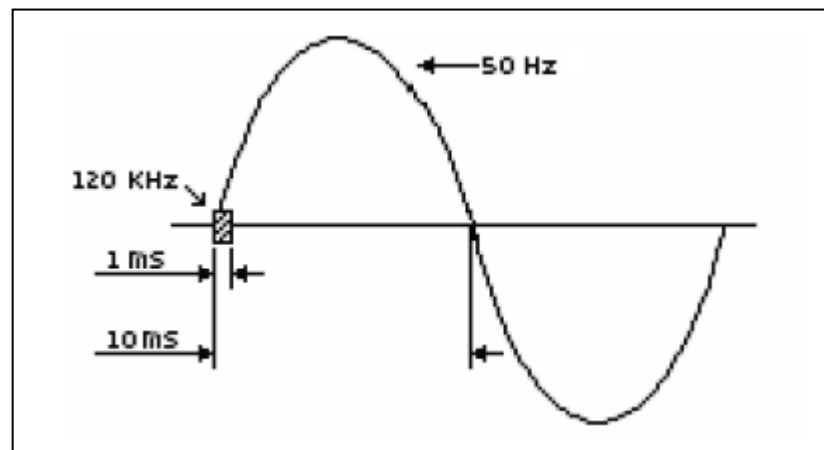


Figure 2.4: X10 signal

Refer to X10 signal in figure 1.4, a 120kHz 1ms burst is generated as the 50Hz power line voltage is zero. Note that the 50Hz sinusoidal wave becomes zero 100 times per second which means a hundred bursts is generated in 1 second. These bursts are used for binary coding for data transmission. Two bursts are needed to transmit 1 bit of data which means it can transmit 50 bits per second. However, a basic X10 message only consists of 13 bits. It is separated into 4 parts. First 4 bits are start code which is standardized to be “1110”. The following 4 bits are house code and the next 4 bits are either unit code or function code depends on the last code. The last bit will decide the preceding 4 bits are unit code or function code. If it is zero the preceding code is unit code, and if it is one then the preceding code is function code. All the units in the system will receive the unit code in the beginning of the message. However, only the unit with the correct unit code receives the rest of the message. The following figure shows the standardized X10 codes.

HOUSE CODES					KEY CODES					
	H1	H2	H4	H8		D1	D2	D4	D8	D16
A	0	1	1	0	1	0	1	1	0	0
B	1	1	1	0	2	1	1	1	0	0
C	0	0	1	0	3	0	0	1	0	0
D	1	0	1	0	4	1	0	1	0	0
E	0	0	0	1	5	0	0	0	1	0
F	1	0	0	1	6	1	0	0	1	0
G	0	1	0	1	7	0	1	0	1	0
H	1	1	0	1	8	1	1	0	1	0
I	0	1	1	1	9	0	1	1	1	0
J	1	1	1	1	10	1	1	1	1	0
K	0	0	1	1	11	0	0	1	1	0
L	1	0	1	1	12	1	0	1	1	0
M	0	0	0	0	13	0	0	0	0	0
N	1	0	0	0	14	1	0	0	0	0
O	0	1	0	0	15	0	1	0	0	0
P	1	1	0	0	16	1	1	0	0	0
All Units Off						0	0	0	0	1
All Lights On						0	0	0	1	1
On						0	0	1	0	1
Off						0	0	1	1	1
Dim						0	1	0	0	1
Bright						0	1	0	1	1
All Lights Off						0	1	1	0	1
Extended Code						0	1	1	1	1
Hail Request						1	0	0	0	1
Hail Acknowledge						1	0	0	1	1
Pre-Set Dim						1	0	1	X	1
Extended Data (analog)						1	1	0	0	1
Status-on						1	1	0	1	1
Status-off						1	1	1	0	1
Status Request						1	1	1	1	1

Figure 2.5: X10 Codes

As mentioned previously, two zero crossings (or 2 bursts) are required for the 1 bit of data transmission. This is because in X10 protocol, each bit is sent as complementary bit pair which means “0” is sent as “01” and “1” is sent as “10”. Therefore, a binary “1” was defined as the presence of a pulse and immediately followed by the absence of a pulse. While a binary “0” was defined as the absence of a pulse and immediately followed by the presence of a pulse. For example, to send a house code B(1110), “10101001” is sent. The following diagram shows an example of binary “1” and “0” data respectively.

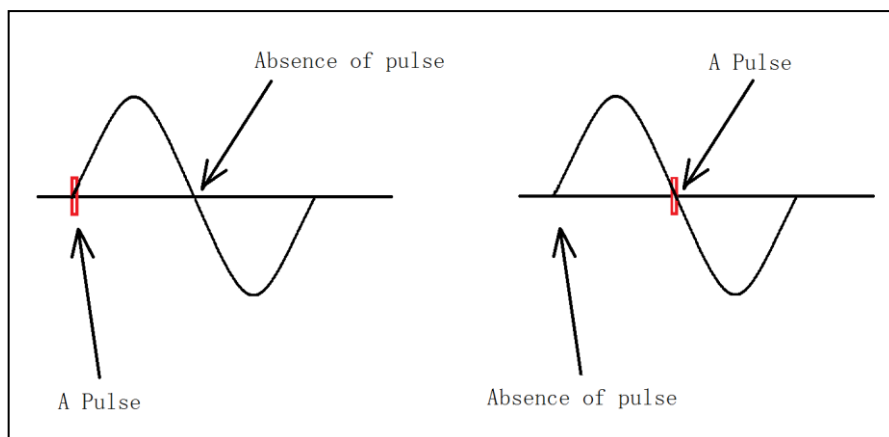


Figure 2.6: Example of Binary 1 and 0 X10 Codes

In order to provide a predictable start point, every data frame should always begin with at least 6 leading clear zero crossings and ends with another 6 clear zero crossings before another data frame. 6 zero crossings are equivalent to 3 sinusoidal wave cycle. Hence, the 6 leading clear zero crossings are followed by the start code (1110) as mentioned. The first 4 nibbles is then sent as house code with “A”, “B”, “C” code and etc. as shown in figure 1.5. X10 protocol calls for every data frame to be transmitted twice for the purposes of redundancy, reliability and to accommodate line repeaters. This condition can be seen in the following diagram.

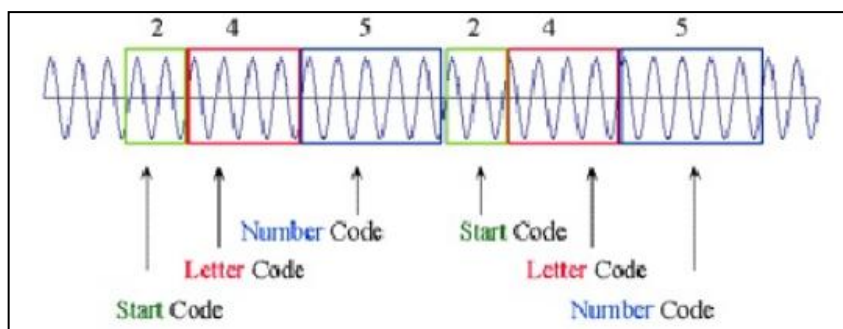


Figure 2.7: The Standard X10 Data Frame is Routinely Sent Twice

However, whenever the data changes from one address to another address, from an address to a command, or from a command to another command, the data frames must be separated by at least 6 clear zero crossings. The 6 clear zero crossings can reset the shift registers. As the receiver finished process the unit codes, it is ready to receive a command or function codes. Hence, the X10 protocol is sent in 2 messages. The first message tells which unit is controlled while the second message tells the function to do on the unit controlled. The messages sent to control a unit are shown in the following block diagram.

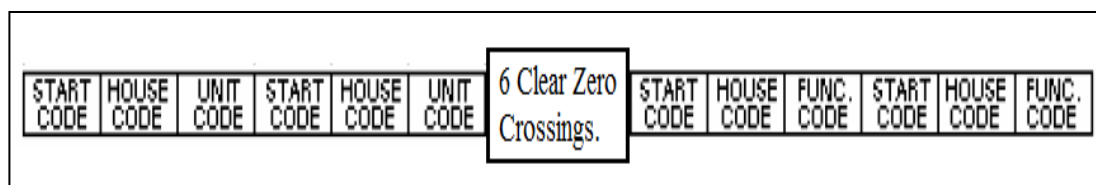


Figure 2.8: Complete X10 Command

The frequency of the electrical line in Malaysia is 50Hz which consists of 50 sinus cycle per second. Whereas the standard X10 message is formed of 50 sinus cycle, hence X10 message is sent in 1 second duration. Of course, some commands take even less time. For instance, when sending an “All-Lights-On” command, no address needs to be sent since the command refers to all lights. Hence, it could take less than 1 second.

## 2.5 Amplitude Shift Keying (ASK)

Amplitude shift keying or ASK is basically a form of modulation that represents digital data as variations in the amplitude of a carrier wave. In the context of digital communication, ASK is a modulation process which imparts to a sinusoid two or more discrete amplitude levels. Binary data modulation with ASK technique is shown below.

$$a(t) = \begin{cases} A \cos(2\pi ft), & \text{Binary 1} \\ 0, & \text{Binary 0} \end{cases} \quad (1.1)$$

This means that in this modulation technique, the amplitude of the carrier signal is representing data for binary 1 while the “0” of the modulation signal is representing data for binary 0. The following figure shows an example of the ASK signal that representing data ‘00110100010’.

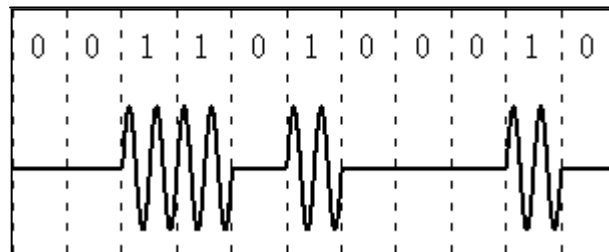


Figure 2.9: Amplitude Shift Keying

This modulation method is used in PLC modem TDA5051a.

## 2.6 Frequency Shift Keying (FSK)

FSK is also known as frequency shift modulation and frequency shift signalling. It is a method to transmit digital signals through discrete frequency changes of a carrier wave. The digital signal is converted into a specific frequency or tone in order to transmit it over wire or wireless media. The following diagram shows an example of signal modulation using FSK concept.

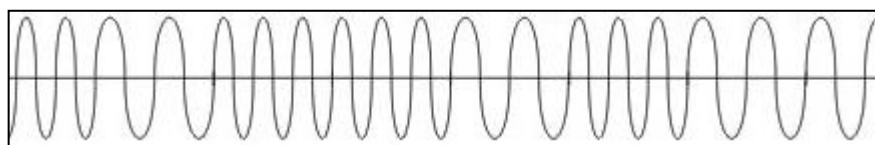


Figure 2.10: Frequency shift Keying

FSK has several advantages over ASK due to the fact that the carrier of FSK has a constant amplitude. Hence, it is immunity to rapid fading, non-linearity, and adjacent channel interference. Besides, lesser error found in FSK compared to ASK. For these reasons, FSK is more preferable for stable purpose. A modem is used to convert the binary or digital data from a microcontroller to FSK for transmission over telephone lines, cables, optical fibre, or wireless media. The modem also converts incoming FSK signals to digital low and high states, which the microcontroller can “understand”. This modulation method is used in PLC modem ST7537HS1.

## CHAPTER 3

### METHODOLOGY

#### 3.1 General Description of the System

In general, the system consists of two main parts which are phone-to-phone GSM transmission and home automation with power line communication. The user will send a command in text messages with his mobile phone to the GSM modem (GSM phone). The GSM modem will transfer the commands to microcontroller through serial interface. After that, the microcontroller at the master unit will transfer the command signals in X10 standard to the power line with the help of PLC (Power Line Carrier) modem. The PLC modem is applied to convert the digital data from microcontroller to analog signals since the electrical line is analog environment. Next, the modems at the slave unit will observe the line continuously, and the microcontroller will determine whether the signal received belongs to the particular unit or not. The owner of the signal will receive the command and do the function user wants. The following diagram shows the system's general structure.

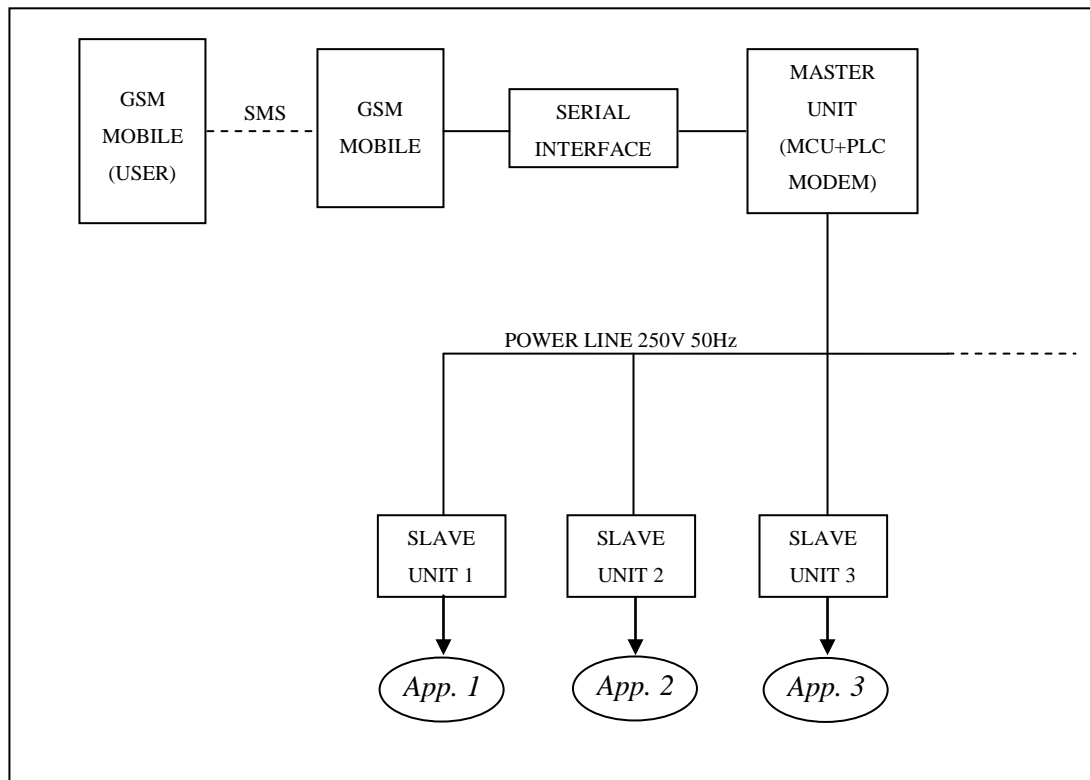


Figure 3.1: System's General Structure

In X10 protocol, there are 16 house codes and 16 unit codes. Hence, in total 256 units or appliances can be controlled with these codes. Slave units are set to desired house and unit code by switches. Apart from that, there is a small system risk when communicating on power lines which is the control signals can pass to neighbor's electrical system. However, the data signals are weakened by the distance and the electric meter to a level under threshold of the modem. An alternative is to use different house codes for different houses. Besides that, signal attenuator and blocking coupler are use to reduce the problem.

At the power source, an isolation transformer is implemented as power line insulation. It is mainly for safety purpose and circuit protection.



### **3.2 Microcontroller**

A microcontroller (MCU) is a basic part of computer on a single integrated circuit (IC) that contains a processor core, programmable input/output peripherals, and memory (RAM). It is designed mainly for embedded applications which in contrast to the microprocessors used in personal computers.

Microcontrollers are usually found in automatically controlled devices such as appliances, toys, remote controls, radios, television, and many similar areas. It is preferred due to its speed, small size, internal time, interrupt control, and re-programmable flash memory properties. Among the choices, PIC (Peripheral Interface Controller) is the most popular and common used MCU produced by Microchip. It has simple and small sized instruction set because it is produced with RISC (Reduced Instruction Set Computer) architecture.

In this project, PIC16F877 and PIC16F628 are chosen to operate in master and slave units respectively. They are chosen based on the properties needed such as number of input and output pin, RAM capacity, number of internal timer, and etc for construction of circuits. The main purpose of implementing microcontroller is to detect zero-crossings and the 120kHz X10 data bursts on the 50Hz AC electrical line.

### 3.2.1 PIC16F877A

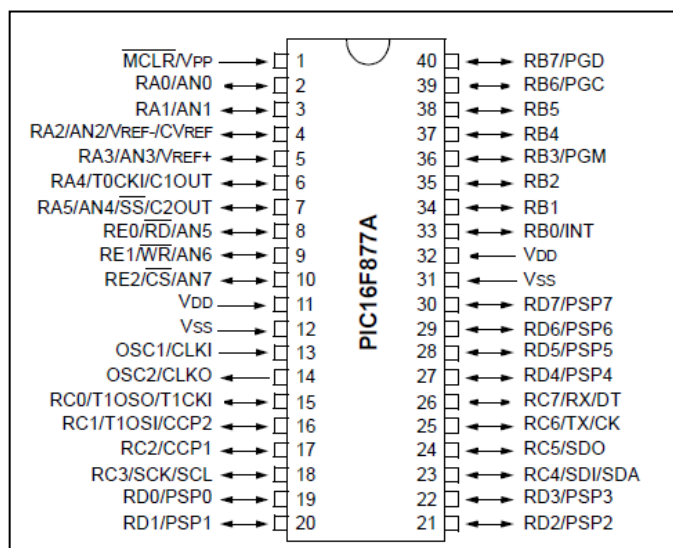


Figure 3.2: Pin Diagram of PIC16F877A

PIC16F877A is chosen to be used in the master unit mainly because more I/O port is needed compared to slave units where uses PIC16F628. There are five I/O port in PIC16f877A including port A, B, C, D, and E. It can communicate with GSM modem with pin 25 (TX) and pin 26 (RX) which is bit 6 and 7 of Port C. TX pin is to send message to GSM modem while RX pin is to read message command from GSM modem. Port C is an 8 bit bidirectional port. Based on the datasheet, TX pin is a USART asynchronous transmit pin while RX pin is a USART asynchronous receive pin. USART stands for Universal Synchronous Asynchronous Receiver and Transmitter. It is sometimes refer to as Serial Communications Interface (SCI). In this case, it is used in asynchronous mode. The most common use of the USART in asynchronous mode is to communicate to a PC serial port using the RS232 protocol. However, a driver is always needed to interface to RS232 voltage level where in the most commonly used is MAX232 chip.

Hence, for device testing purpose, PIC16F877A is connected to COM port of PC with RS232 through MAX232 driver. This can be described in the following diagram.

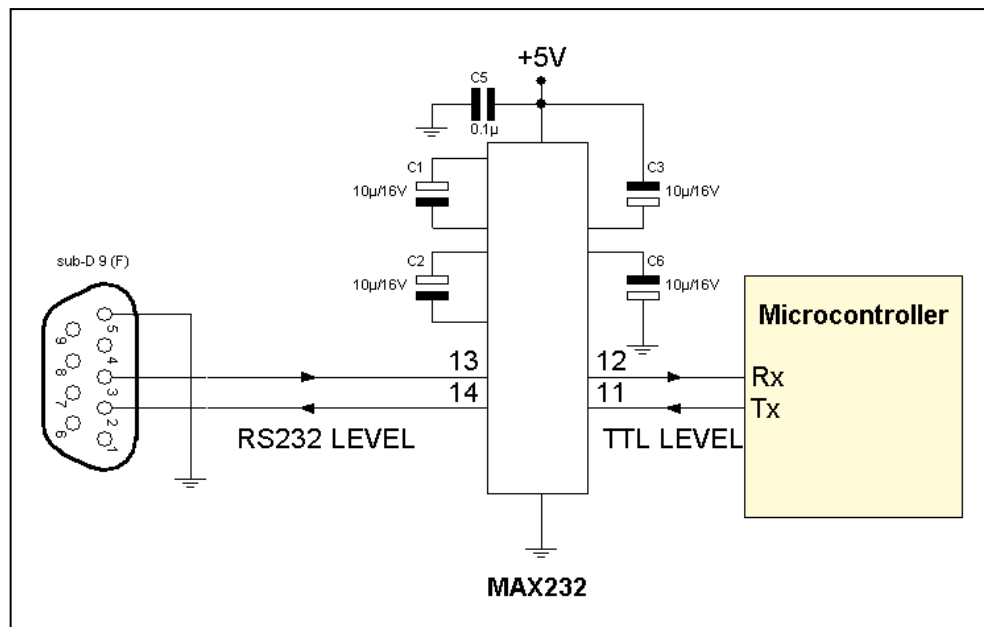


Figure 3.3: MAX232 as RS232 Driver

Note than pin 11 and pin 12 are TTL input and output pins while pin 13 and pin 14 are RS232 input and output pins.

The PIC16F877 at master units will send a command signals in a packet through X10 standard to the electrical line with the help of the modem. Modem will convert the digital data from microcontroller to analog signals to transmit over the electrical line which is analog based.

### 3.2.2 PIC16F628

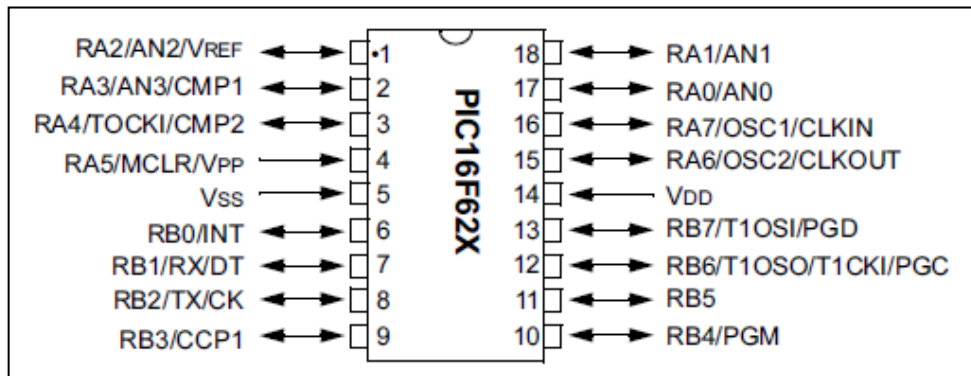


Figure 3.4: Pin Diagram of PIC16F628

PIC16F628 is chosen as the slave units' microcontroller due to its less complexity compared to PIC16F877. It is also a low cost with high performance CMOS microcontroller. Besides that, it has enhanced the core features, 8-level deep stack, and multiple internal and external interrupt sources. A total of 35 instruction sets are available (reduced instruction set). Additionally, the PIC16F628 devices have special features to reduce external components, thus reducing system cost and power consumption.

There are only two I/O ports in this MCU which are Port A and Port B. Some pins for these I/O ports are multiplexed with an interchange purpose for the peripheral features on the device. Hence, when the peripheral is enabled, that pin may not be used as a general purpose I/O pin.

The PIC16F628 is used at the slave units to determine whether the command received from master unit is belongs to them or not. Once the command is verified, the PIC will do the function according to the command received.

### 3.3 MAX232

MAX232 is an integrated circuit (IC) that translates signals from an RS232 serial port to signals suitable for use in TTL (Transistor-transistor Logic) compatible digital logic circuits. It is very commonly used to convert signals from microcontroller to RS232 serial port. At the RS232 side, the driver provides the desired voltage level which is approximately 7.5V from 5V supply and external capacitors. On the other side, it will reduce the RS232 inputs which usually around 25V to a standard 5V in TTL levels. The following diagram shows the pin configuration of MAX232.

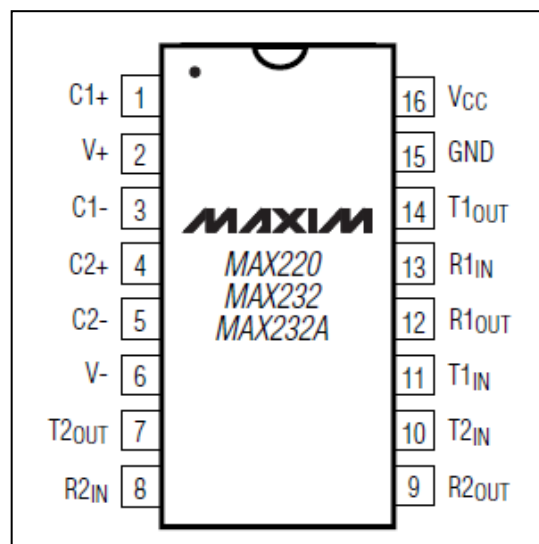


Figure 3.5: Pin Diagram of MAX232

**Table 3.1: Pin Description of MAX232**

<b>Pin</b>	<b>Symbol</b>	<b>Description</b>
1	C1+	Capacitor 1 +
2	V+	Voltage +
3	C1-	Capacitor 1 -
4	C2+	Capacitor 2 +
5	C2-	Capacitor 2 -
6	V-	Voltage -
7	T2 <sub>OUT</sub>	RS232 Outputs
8	R2 <sub>IN</sub>	RS232 Inputs
9	R2 <sub>OUT</sub>	TTL/CMOS Outputs
10	T2 <sub>IN</sub>	TTL/CMOS Inputs
11	T1 <sub>IN</sub>	TTL/CMOS Inputs
12	R1 <sub>OUT</sub>	TTL/CMOS Outputs
13	R1 <sub>IN</sub>	RS232 Inputs
14	T1 <sub>OUT</sub>	RS232 Outputs
15	GND	Ground
16	V <sub>CC</sub>	Voltage Supply

### **3.4 Power Line Carrier Modem**

As mentioned before, there are a few types of power line carrier modem available in the market such as TDA5051A (Philips), ST7537HS1 (ST Microelectronics), LM1893 (National Semiconductor), and PLM-24. Each of the modem has different features but basically doing similar things.

#### **3.4.1 TDA5051A**

TDA5051A is one of the most popular PLC modem IC in the market because it has small size which can reduce the space used to build the circuit. Besides, it uses less external electronic components which make the development of the circuit less complicated. Furthermore, it also has lower price compare to other PLC modem in the market. The maker of this modem IC is Philips and NXP Semiconductors. NXP Semiconductors is established in year 2006 and is formerly a division of Philips.

TDA5051A is a 16 pin integrated modem which generally designed to control home electrical appliances by supplying data transmission on the electrical line. It uses minimum 600 baud and maximum 1200 baud data transmission rate. A single 5V supply is needed to operate this modem IC. One of the benefits of this modem IC is that it works in full duplex mode which means it is able to send and receive data.

This modem IC is specifically devoted to ASK (Amplitude Shift Keying) transmission by means of the existing home power supply network. There are several features and benefits of TDA5051A modem IC. It has full digital carrier generation and shaping ability which means it can generate and shape a medium that carry the digital signals. Besides, it has build-in Automatic Gain Control (AGC) at the receiver input of the modem. AGC is an adaptive system that can automatically adjust the gain to an appropriate level for a range of input signal levels when an average output signal is fed back. For example, the AGC can effectively reduce the amplitude if the signal is strong and raises it when it is weaker. Furthermore, it can easily compliance

with EN50065-1 which developed by CENELEC work shop with simple coupling network.

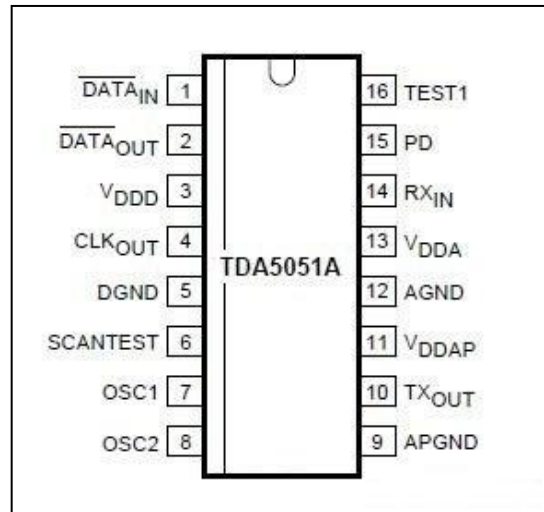


Figure 3.6: Pin Diagram of TDA5051A

The diagram above shows the pin configuration of TDA5051A modem IC. As shown in the diagram, the modem IC consists of 16 pin. Each pin has different functions and purposes. The following table describes the function of each pin from pin 1 to pin 16.

Table 3.2: Pin Description of TDA5051A

Pin	Symbol	Description
1	$\overline{\text{DATA\_IN}}$	Digital data input (active LOW)
2	$\overline{\text{DATA\_OUT}}$	Digital data output (active LOW)
3	$V_{\text{DDD}}$	Digital supply voltage
4	$\text{CLK\_OUT}$	Clock output
5	DGND	Digital ground
6	SCANTEST	Test input (LOW in application)
7	OSC1	Oscillator input
8	OSC2	Oscillator output
9	APGND	Analog ground for power amplifier
10	TX_OUT	Analog signal output



11	V <sub>DDAP</sub>	Analog supply voltage for power amplifier
12	AGND	Analog ground
13	V <sub>DDA</sub>	Analog supply voltage
14	RX_IN	Analog signal input
15	PD	Power-down input (active HIGH)
16	TEST1	Test input (HIGH in application)

DATA\_IN pin is where the digital data is received from microcontroller. The pin is active LOW meaning a burst is generated on the line (pin TX\_OUT) when DATA\_IN pin is LOW. Pin TX\_OUT will stay in high-impedance state as long as the device is not transmitting signals. Hence, pin TX\_OUT is in a high-impedance state as long as DATA\_IN pin is HIGH. The PD pin or pin 15 is connected to microcontroller. It is active HIGH which means the power consumption minimum when pin PD is HIGH. This will eventually disable all the functions in the modem IC except clock generation. The following table shows the relationship between DATA\_IN, TX\_OUT and PD (Power Down) pin.

**Table 3.3: Relationship between  $\overline{\text{DATA\_IN}}$  and TX\_OUT**

PD	DATA_IN	TX_OUT
1	X	High-impedance
0	1	High-impedance
0	0	Active with DC offset

X= don't care.

When PD pin is HIGH, DATA\_IN pin will not be able to process any data received from microcontroller. Hence, the TX\_OUT will stay in high-impedance state as long as PD pin is HIGH. Active with DC offset meaning the waveform has unequal amounts of signal in the positive and negative domain. The following diagram shows an example of waveform describing the relationship between DATA\_IN and TX\_OUT.

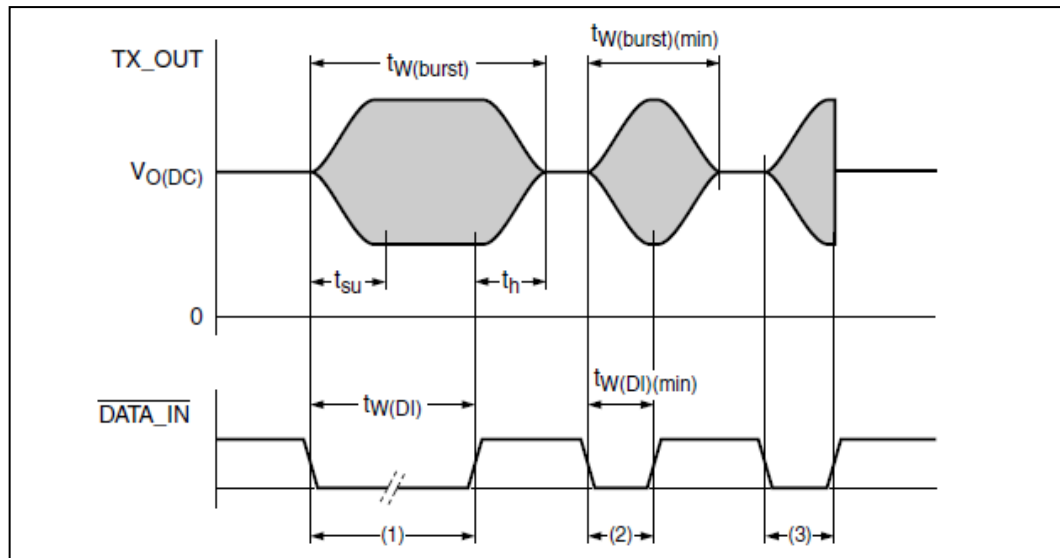


Figure 3.7: Relationship between  $\overline{\text{DATA\_IN}}$  and TX\_OUT

**Table 3.4: Description of Parameters**

Symbol	Parameter	Unit
$t_{W(\text{burst})}$	Burst time of $V_{O(\text{DC})}$ signal	s
$t_{\text{SU}}$	Demodulation set up time	s
$t_{\text{h}}$	Demodulation hold time	s

When DATA\_IN changes from HIGH to LOW, there is a demodulation set up time  $t_{\text{SU}}$  needed for the  $V_{O(\text{DC})}$  to change from LOW to HIGH. On the other hand, when DATA\_IN changes from LOW to HIGH, there is also demodulation hold time  $t_{\text{h}}$  needed for  $V_{O(\text{DC})}$  to change from HIGH to LOW.

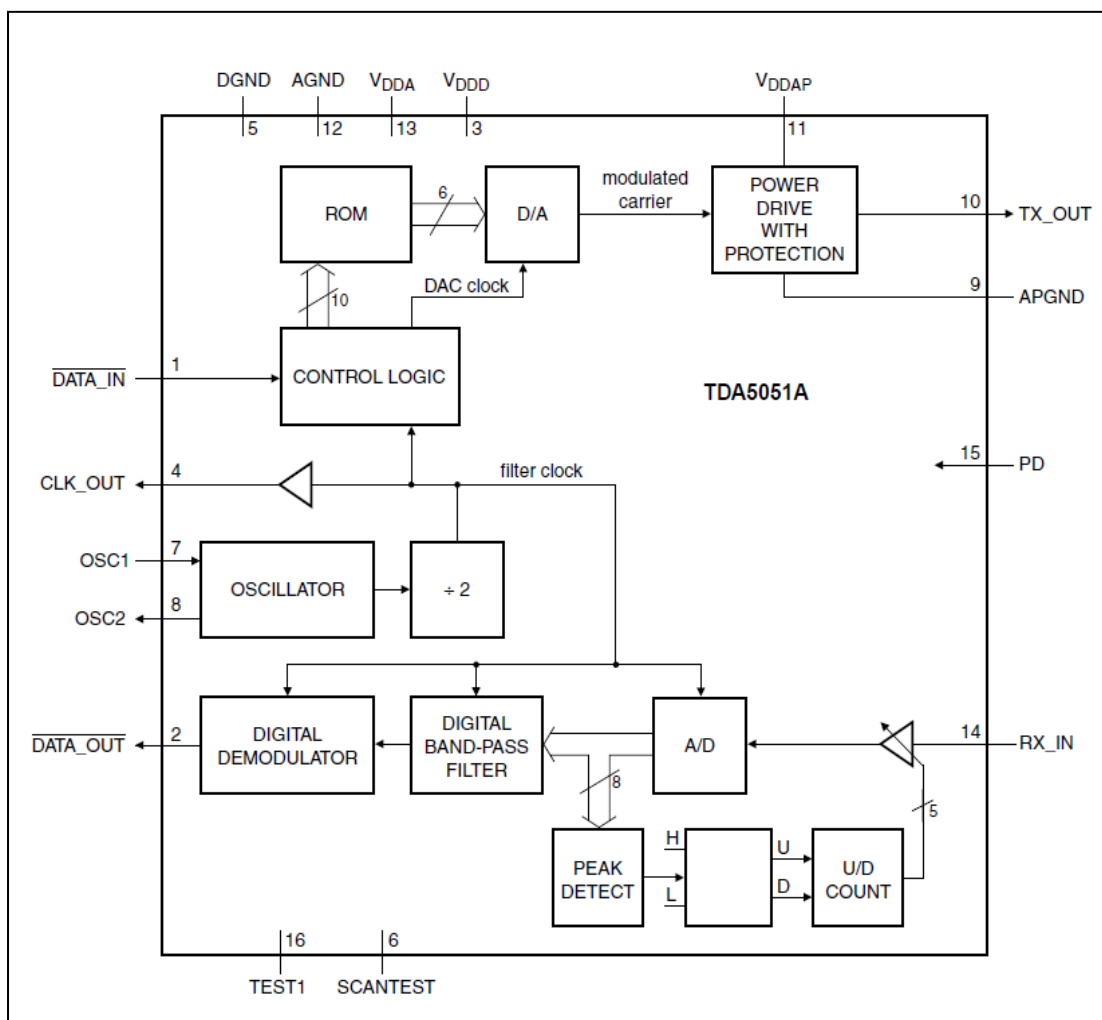


Figure 3.8: Block diagram of TDA5051A

TDA5051A has a digital band-pass filter, an 8 bit analog-to-digital (ADC) converter, a 6 bit digital-to-analog (DAC) converter, a digital demodulator, an automatic gain control (AGC) at signal input, an oscillator and over load protection at signal output. TX\_OUT and RX\_IN pin are analog input and output used for communication with power line which is an analog environment. On the other hand, DATA\_IN and DATA\_OUT pin are used to communicate with microcontroller which uses digital signal. Hence, ADC and DAC are built in TDA5051A so that microcontroller can communicate with the power line. Next, a crystal is connected to OSC1 and OSC2 pins of the modems. CLK\_OUT pin will output a frequency value equal to  $\frac{1}{2}$  of the crystal value. This frequency value is connected to the microcontroller which will then use it. TEST1 and SCANTEST pin is only used for



generated on the TX\_OUT pin as DATA\_IN pin is LOW. The carrier frequency is generated by scanning the ROM memory under the control of the microcontroller clock or the reference frequency provided by the on-chip oscillator. The data modulation is applied through pin DATA\_IN and then smoothly applied by specific digital circuits to the carrier (shaping). In order to provide a maximum signal level of 122dB $\mu$ V (RMS) at the output, the DAC and the power stage are set. From the application diagram, a decoupling capacitor is connected to the output of the power stage (TX\_OUT) because there is always a DC level of 0.5V<sub>DD</sub> at the pin even when the device is not transmitting. Besides that, this can also protect the pin against overvoltage and negative transient signals. The zener diode SA5.0A is served as a transient voltage suppressor in the circuit. Transient voltage suppressor (TVS) is designed to react to sudden or momentary overvoltage conditions. It is to protect electronics against overvoltage.

In reception mode, an input signal is received by the modem at RX\_IN pin. It is applied to a wide range input amplifier with AGC (-6dB to +30dB). This can basically improve the noise performance and adjust the signal level which will ensure a maximum sensitivity of the ADC. Refer to the block diagram in figure 2.4, an 8-bit ADC is performed, then followed by digital band-pass-filter, and finally goes to digital demodulator. After digital demodulation, the baseband data signal is made available after pulse shaping. For the same reasons as with pin TX\_OUT, the RX\_IN pin also has to be protected and DC decoupled. Besides that, an efficient 50Hz rejection filter is also required at this input due to high sensitivity. This can be done by the LC coupling network shown in the application circuit in figure 3.9. In this mode, the DATA\_OUT pin remains LOW as long as a burst is received.

### 3.5 Coupling With the Power Line

A coupling network is necessary as the interface between the power line and the low voltage TX\_OUT and RX\_IN pins of the PLC modem for protection. There are 2 options to couple with the power line depending on the situation and cost. For low cost applications, when the power line insulation is not required, a double LC band-pass filter can be used, providing efficiency without any adjustment or tuneable components. On the other hand, if power line insulation is compulsory, a HF (High Frequency) Transformer can be considered.

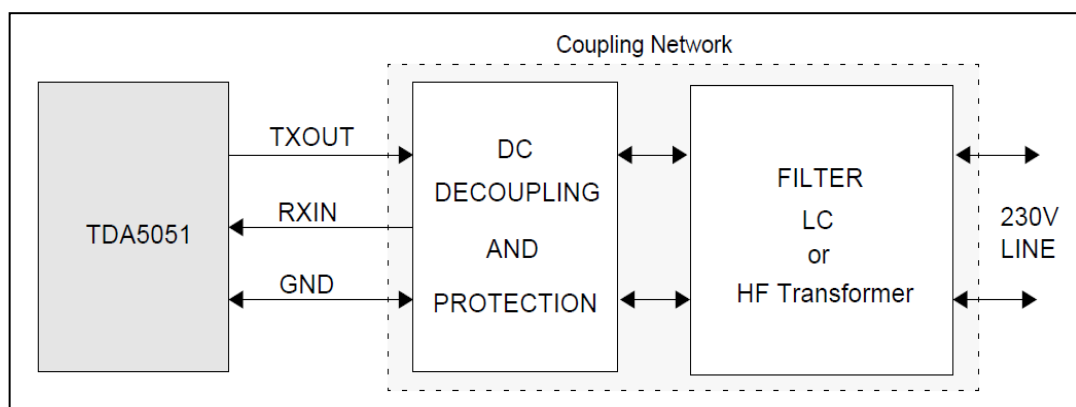


Figure 3.10: Coupling With the Power Line

For safety purpose and to protect the circuit from the high voltage AC power source, the implementation of HF isolation transformer is necessary. Isolation transformer is a transformer used to transfer voltage power from an AC power source to some devices by isolating the powered device from the power source. The electronic components used in this project are quite costly for example the PLC modem, hence a good isolation is mandatory. Apart from the power line insulation, the transformer also has to realize the appropriate filtering in transmission and reception mode.

### 3.5.1 Low Cost Coupling Network

Low cost coupling network is used in this project since our budget is limited. On the other hand, using low cost coupling network can also decrease the cost of the product. Coupling network acts as an efficient 50Hz rejection filter and an anti-aliasing filter for the internal digital processing. Figure 3.11 shows the basic form of the coupling circuit.

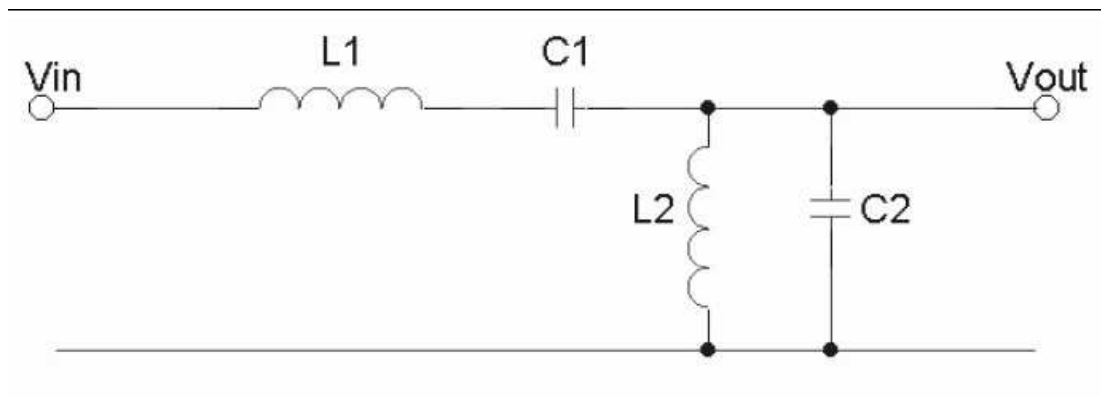


Figure 3.11: Basic Form of LC Coupling Circuit

The LC filter is tuned to match the chosen carrier frequency. The carrier frequency is chosen to be approximately 115.2 kHz. The following formula is used to tune the desired carrier frequency:

$$F_c = \frac{1}{2\pi \cdot \sqrt{L_1 \cdot C_1}} = \frac{1}{2\pi \cdot \sqrt{L_2 \cdot C_2}} = \frac{F_{osc}}{64}$$

Hence, the values of L1 and L2 are set as 47μH and C1 and C2 are set as 47nF. Figure 3.12 shows the low cost coupling diagram recommended by NXP Semiconductors.

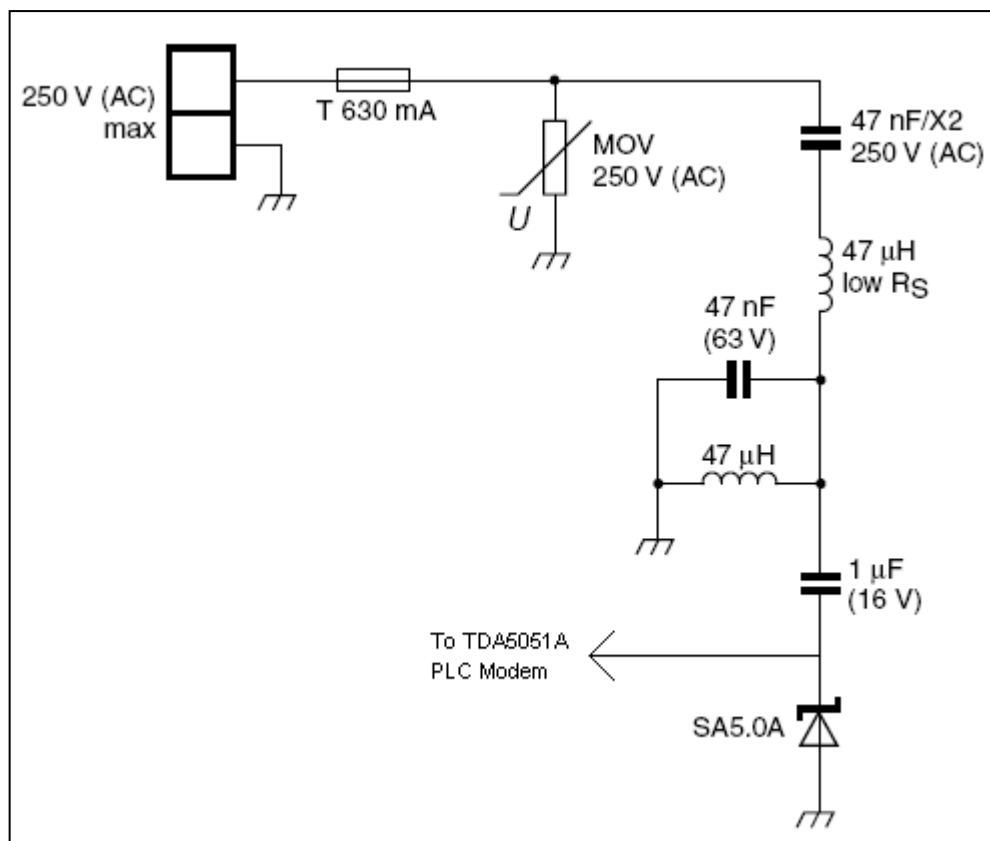


Figure 3.12: Low Cost Coupling Network

The fuse value is set as 630mA so that the current drain in the circuit never exceeds 630mA (over current). The fuse will burn once the current goes more than 630mA. MOV or Metal Oxide Varistor is an electronic component with a “diode-like” nonlinear current-voltage characteristic. It is used to protect the application circuit against excessive transient voltages. When overvoltage occurred, the varistor will be triggered and shunt the current created by high voltage away from sensitive components. The main purpose of the fuse and varistor is to protect the TDA5051A PLC modem. This is because the modem is a very sensitive device. Moreover, the modem is quite costly and not easily found in the market. Besides fuse and MOV, transient voltage suppressor (SA5.0A) is also used to protect the TDA5051A modem. It is used to protect sensitive electronic components from voltage spikes induced on connected wires. It is a clamping device that will suppress all the overvoltage above its breakdown voltage.



### 3.5.2 TOKO T1002

TOKO T1002 is a HF Transformer that is suggested to use in the application for power line insulation. It has one primary and two secondary windings with the ratio of 4:1. In order for the transformer to work correctly, it has to be tuned with a tuning screw to the desired carrier frequency. Besides, an external capacitor  $C_t$  which can be placed on the serial connection of the two secondary windings is required, as shown is the following diagram.

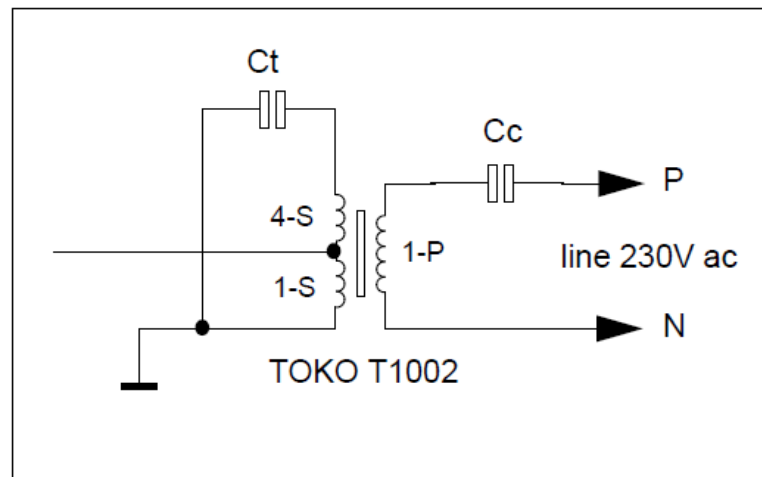


Figure 3.13: Tuning of TOKO T1002

To calculate the capacitance value  $C_t$ :

Inductance of 1 turn winding,  $L_1 = 9\mu\text{H}$

Inductance of 4 turns winding,  $L_4 = 150\mu\text{H}$

Equivalent Inductance,  $L_{EQU} = L_1 + L_4 + 2M$  where  $M = 0.7 \times \sqrt{L_1 \times L_4}$

Carrier Frequency,  $F_C = \frac{1}{2\pi \times \sqrt{(L_{EQU} \times C_t)}}$

The value of  $C_t$  can be easily calculated for a given carrier frequency  $F_c$ . Another X2 type capacitor  $C_c$  (470nF) is used to couple with the power line as shown in the following diagram.

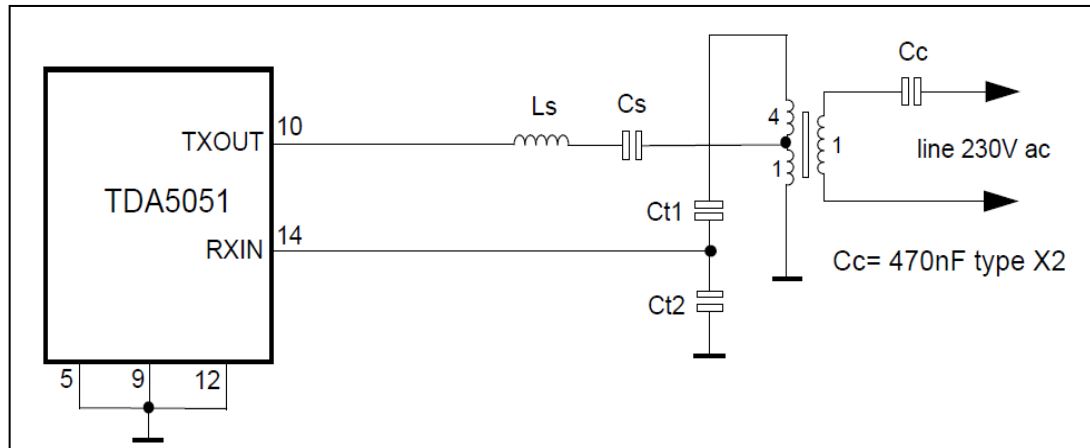


Figure 3.14: Coupling with TOKO T1002

### 3.6 Power Supply Unit

To drive the modem TDA5051A and PIC microcontroller, 5V power supply is needed. At testing stage, this 5V power supply is not necessary since the testing can be done with the power supply in lab. Figure 3.15 shows the 5V DC power supply circuit from 230V AC.

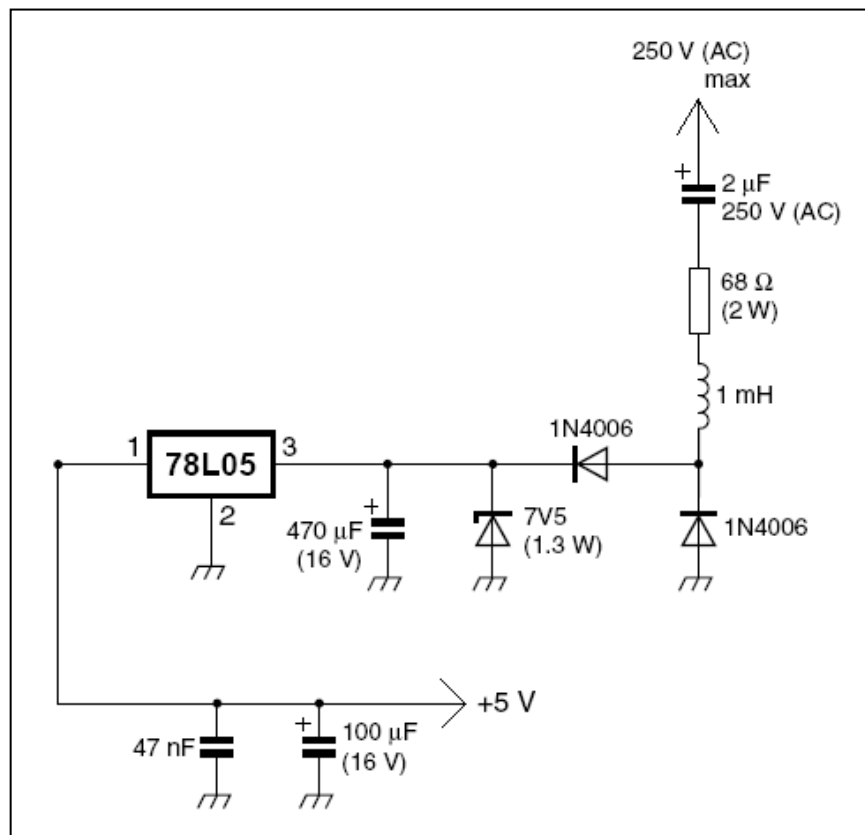


Figure 3.15: Power Supply Circuit Diagram

This power supply circuit is one of the most popular types of non-insulated power supply. It uses the 50Hz impedance of capacitor 2 μF (250VAC) to supply a full-wave rectifier (1N4006) and a DC capacitor, followed by a linear +5V regulator (78L05). Voltage regulator is used to maintain a constant voltage level. To comply with the standards, a 1mH inductor with an extra 68Ω resistor is used. Capacitors after the voltage regulator are used to reduce the ripple voltage to increase the stability and accuracy.

### 3.7 Relay Unit

At the end of the receiver circuit, after the microcontroller unit, a relay circuit is needed to supply voltage to appliances. The relay will be triggered on by a transistor which acts as a switch to increase its stability. Figure 3.16 shows a general circuit of the relay unit.

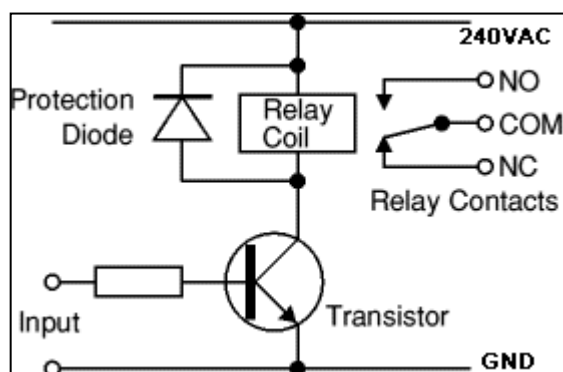


Figure 3.16: General Relay Circuit

The transistor is acting as a switch to turn on the relay unit. The input to turn on the transistor is 5V from the output pin of microcontroller. This means when the microcontroller receives a command to switch on the appliance, it will supply 5V to the transistor to turn on the transistor. As the transistor is on, the relay which built at the collector of transistor will be triggered on. The relay contacts will go from NC (Normally closed) to NO (Normally On). Hence, the 240VAC will be supplied to the appliance that connected to the NO pin of the relay. A diode is connected in parallel with the relay in order to protect the relay circuit. The testing of relay circuit will be shown in chapter 4.

### 3.8 Universal Asynchronous Receiver/ Transmitter (UART)

UART is usually used for serial communications over a computer or peripheral device serial port. Hence, to transmit an 8-bit serial data from microcontroller, UART function of the PIC16F877A is implemented. Pin 25 (TX) and pin 26 (RX) of PIC16F877A is used as UART transmit (TX) and receive (RX) pins.

Every character sent via UART is framed. Figure 3.17 shows the framing of each character. The start bit of each character is sent as low logic, a configurable number of data bits which usually 7 or 8 bits, and finally a high logic stop bit. The start bit tells the receiver that a new character is coming. The stop bit tells the receiver that the character sending is completed.



Figure 3.17: Character Framing

To make sure the operation of transmit and receive is working properly, both transmitting and receiving UARTs must be set for the same bit speed, character length and the stop bit.

### 3.9 Ultrasonic Transceiver



Figure 3.18: Ultrasonic Transceiver

Sound with frequency more than 20 kHz cannot be heard by human beings. This sound is called ultrasonic sound. Ultrasonic transceiver generates high frequency sound waves and evaluates the echo which is then received back by the sensor. This technology is very popular to apply in medicine and industry use. In medicine, it is used to make pictures of different parts of human body since the transducer can be passed over the surface of body. In industry, it is used mainly to detect the presence of targets in automated factories and process plants. In this project, it is used in home automation as ultrasonic switch. Besides, it is also used in security system as sensors.

### 3.9.1 Ultrasonic Transmitter

Ultrasonic transmitter can generate ultrasonic wave of frequency between 40 to 50 kHz. The signal sent from ultrasonic transmitter is to turn on the relay connected to the receiver. When the relay is activated, it can switch on or off the appliances connected to the relay. Figure 3.19 shows the application circuit of the ultrasonic transmitter.

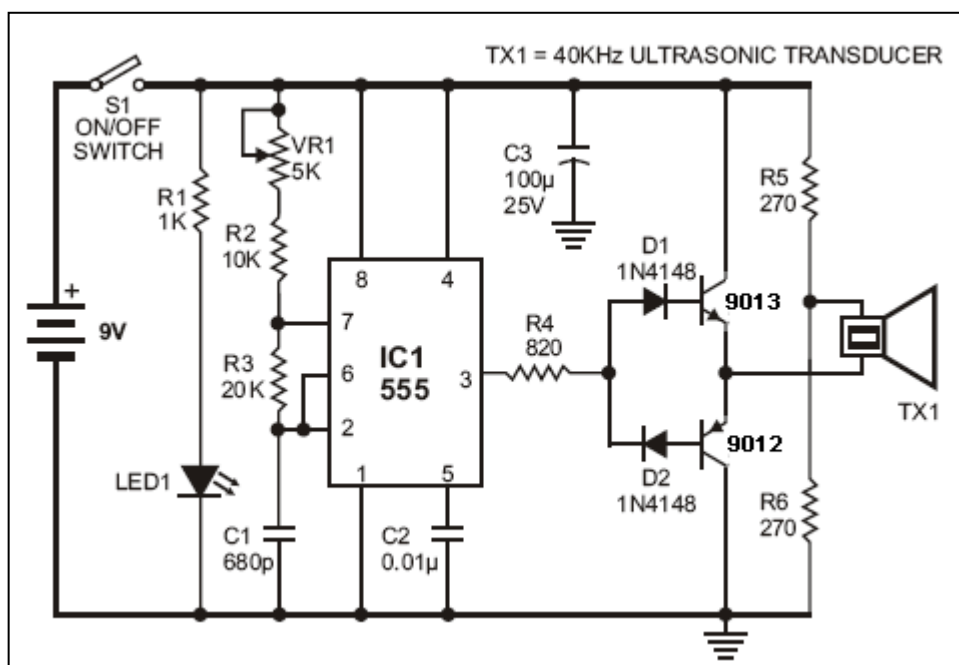


Figure 3.19: Ultrasonic Transmitter

The on-off switch S1 is connected to the output of another relay that is turned on by a microcontroller. For example, when the user send a message from his cell phone to GSM modem to turn on a device, the GSM modem will send the data message to microcontroller, microcontroller will turn on the relay accordingly using output port, and finally the relay will turn on the on-off switch of the ultrasonic transmitter.

As shown in figure 3.17, a 9V dc source is needed to drive the circuit. It is supplied by a 9V adapter from power source. The IC1 555 is an astable multivibrator or oscillator which provides frequency oscillates at 40 to 50 kHz. Variable resistor

VR1 is used to adjust the frequency of the ultrasound generated varies from 40 to 50 kHz. The two transistors are amplifiers to amplify the ultrasonic wave so that it is stronger and able to transmit longer.

### 3.9.2 Ultrasonic Receiver

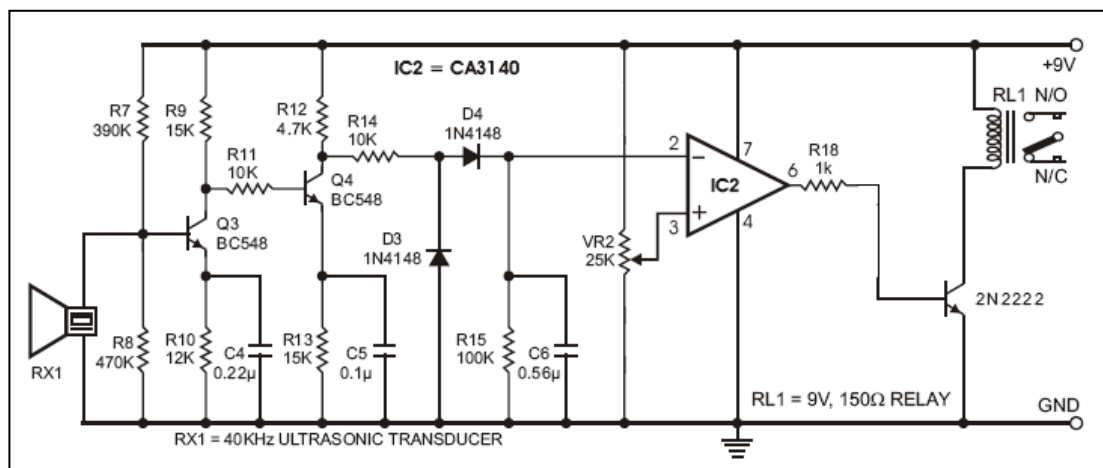


Figure 3.20: Ultrasonic Receiver

Ultrasonic receiver is used to sense the ultrasonic sound and switch on a relay. The two transistors BC648 is used to amplify the ultrasonic wave received. There is also a rectifier stage provided by the two diodes 1N4148. CA3140 is an operational amplifier operating in inverting mode. Output of the op-amp is connected to the relay through a complimentary relay drive stage.

As the ultrasonic wave received by the receiver, it is converted into electrical variations (AC) with the same frequency. The signal is then amplified by transistor T3 and T4. These signals are then rectified and filtered become DC voltage. The DC voltage is then supplied to inverting pin of the op-amp CA3140. The variable resistor VR2 is used to determine the threshold value of the ultrasonic sound received by receiver for the operation of relay. When transistor 2n2222 is triggered on by the op-amp, it will actuate the relay which can control any electrical appliances.



### 3.10 Printed Circuit Board (PCB)

Printed circuit board is a non-conductive substrate with conductive pathways or tracks used to mechanically support and electrically connect electronic components. The main reason to fabricate PCB and build circuit on that is to stabilize the circuit. Circuit is not stable when connected using breadboard. Besides, building circuit on breadboard consume more space compare to PCB. In addition, PCB is inexpensive and highly reliable.

#### 3.10.1 PCB Fabrication

Before fabricate a circuit on PCB, a PCB layout of the circuit must be prepared. There are a few software available on the Web that can be used to draw the PCB layout. DipTrace is the software used to draw the PCB layout because it is free and available on the Web. The software is very convenient to use as any components can be found in it.

There are a few rules that must be followed when drawing PCB layout. When sketching the conductive track, it should not be 90 °to prevent short circuit. The track for the IC pin should be drawn longer so that it is easier to solder. Figure 3.21 shows the PCB layout of the Power Line Carrier modem TDA5051A. The modem is a surface mount device so it has to be directly soldered on the PCB. Figure 3.22 shows the photo of the modem soldered on the PCB.

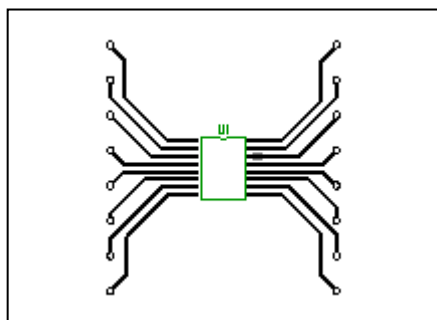


Figure 3.21: PCB layout of TDA5051A

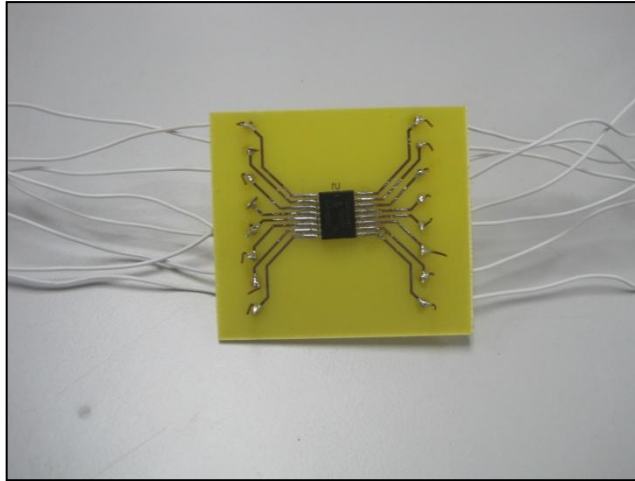


Figure 3.22: TDA5051A Soldered on PCB

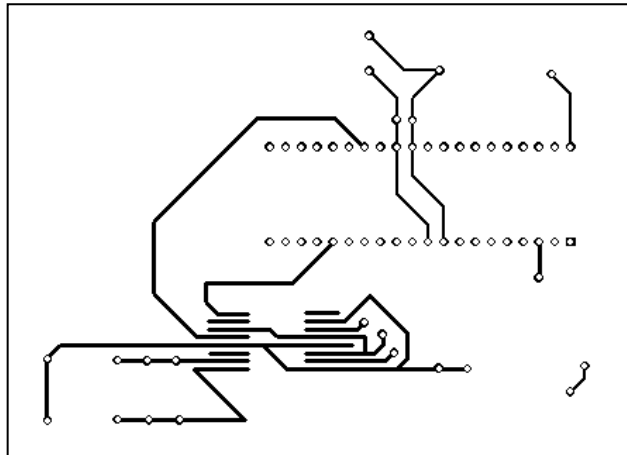


Figure 3.23: PCB of PLC Modem and PIC16F877A Circuit

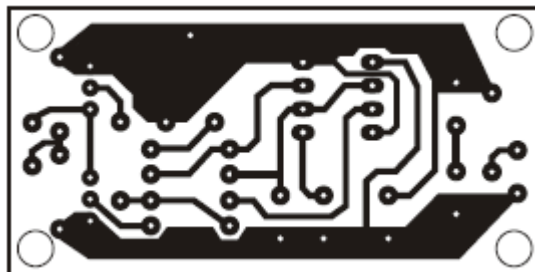


Figure 3.24: PCB layout of Ultrasonic Transmitter

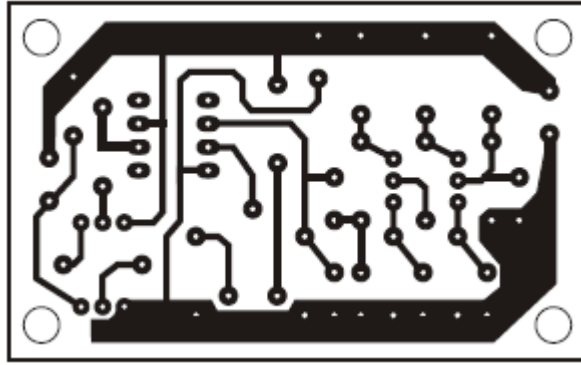


Figure 3.25: PCB layout of Ultrasonic Receiver

## CHAPTER 4

### RESULTS AND DISCUSSIONS

#### 4.1 Testing of TDA5051A (Transmission Mode)

Before apply the PLC modem into the complete circuit, to make sure it is working accordingly, it must be tested. Figure 4.1 shows the schematic used to test the transmission mode of the TDA5051A.

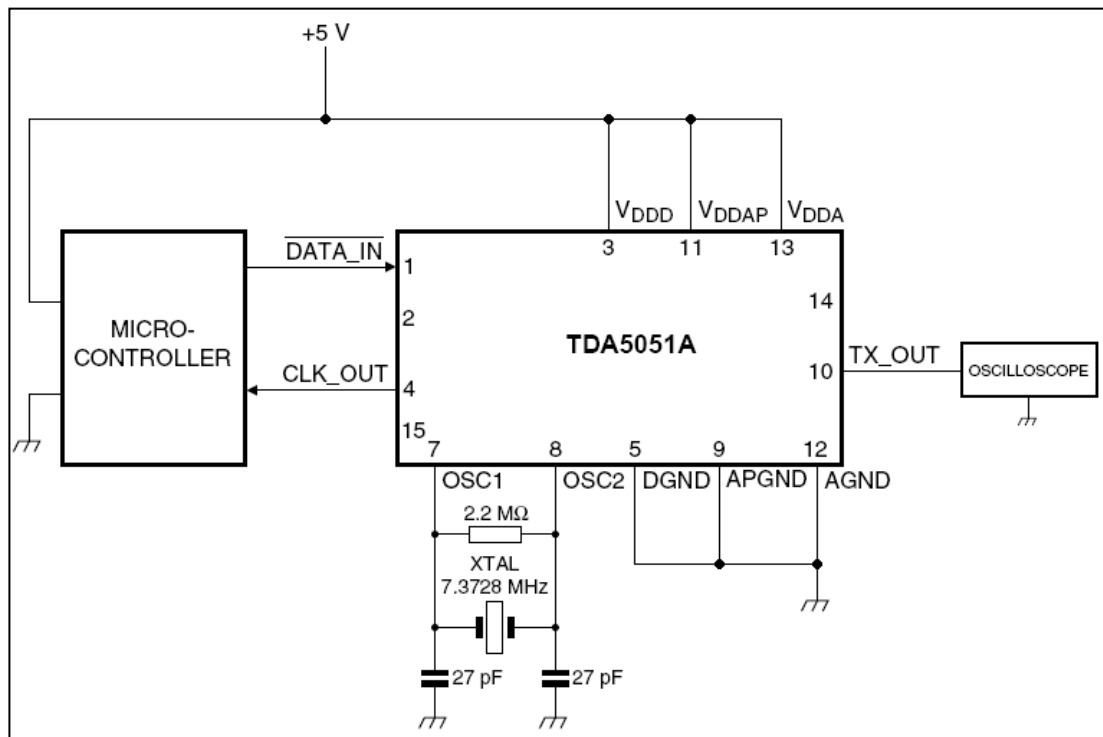


Figure 4.1: Testing Circuit of TDA5051A Transmission Mode

The microcontroller PIC16F877 is driven by the external oscillator circuit of the tda5051a modem. It doesn't require separate oscillator circuit to drive the PIC. PICKIT2 (PIC burner) is used to burn a program code into the microcontroller. A testing code is written to send a series of 8-bit binary data using UART function of microcontroller. As discussed before in chapter 3, the data input (DATA\_IN) is active LOW where a burst is generated when the DATA\_IN pin is LOW. Figure 4.2 shows the relationship between the DATA\_IN and TX\_OUT displayed on the oscilloscope. The signal 1 on top is the digital signal at DATA\_IN while signal 2 at the bottom is the output signal at TX\_OUT.

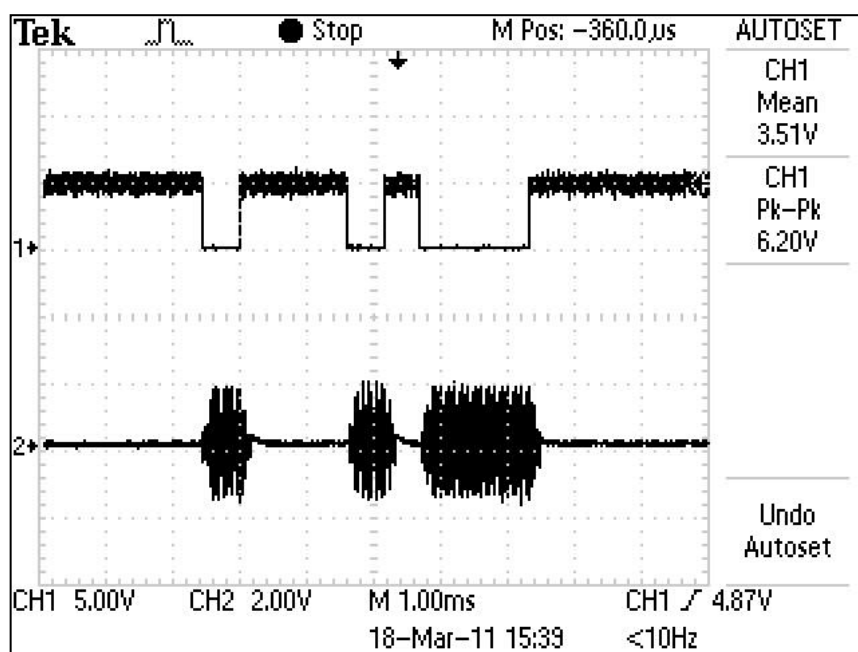


Figure 4.2: Relationship between DATA\_IN and TX\_OUT of TDA5051A

As shown in the waveform 1 in figure 4.2, the 8-bit binary data sent from the microcontroller is "00010111" with the stop bit "01". The data is read from right to left from oscilloscope. The digital signal from microcontroller went through Amplitude Shift Keying (ASK) modulation in the TDA5051A modem and converted into modulated signal which is shown in waveform 2 in figure 4.2. This is so that the data can be transmitted through electrical system by superimposing the modulated signal (burst) on the electrical signal. The signal is modulated when the input signal (DATA\_IN) is zero because it is active low.

[illegible]

Figure 4.3: Communication between Transmitter and Receiver

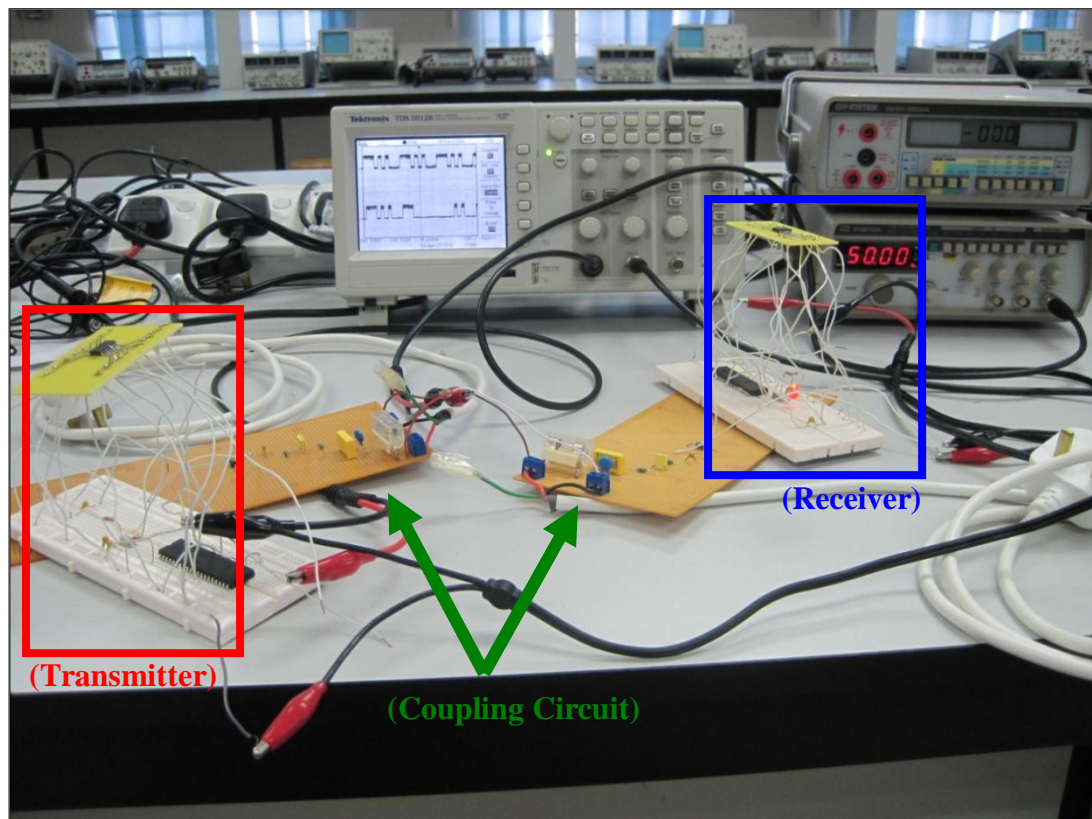


Figure 4.4: Photo of the Complete Testing Circuit

At the middle of the transmitter and receiver, a 22Vac (50Hz) signal is supplied from signal generator acting as the lower voltage version of the real life 230Vac (50Hz) environment. This is to check whether the AC signal will affect the transmission of the modulated signal. The coupling circuit is soldered on stripboard because the breadboard cannot sustain high voltages. Figure 4.4 shows the coupling circuit soldered on stripboard together with the power plug that connects to the power source.

The coupling and filter circuit successfully filter out the 50Hz signal from signal generator and only passed the desired modulated data signal. The LED at the receiver is turned on when it receives the desired data. Figure 4.5 shows the input waveform at transmitter and output waveform at receiver.

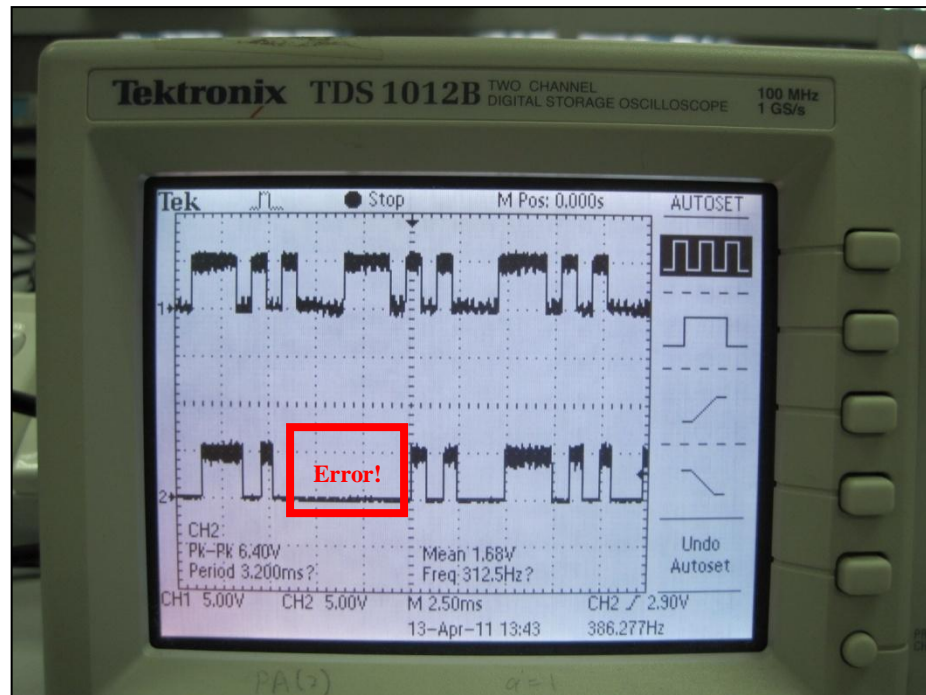


Figure 4.5: Input Waveform at Transmitter and Output Waveform at Receiver.

Waveform number 1 on top is the input waveform supplied by the microcontroller while waveform number 2 at the bottom is the output waveform that supplied into the microcontroller at the receiver side. The data sent from the microcontroller at transmitter is '1110001'. The data is sent repeatedly so that the receiver can receive the desired data correctly. As shown in the figure 4.5, there is error occur at the receiving data where part of it is lost. This shows that when the data transmit from transmitter and goes all the way through the power line and circuits, it will somehow get disturb and lost.

Due to this reason, the receiver may receives error data and hence not able to function accordingly. Hence, a more stable way is introduced to replace the power line communication which is ultrasonic transceiver which was theoretically discussed in section 3.9 previously.







Figure 4.7: Ultrasonic Switch to turn on and off a Relay

The ultrasonic sound is able to transmit and receive in a distance of approximately 30cm. The transmission distance can still be increased. However, as the distance increased, the transmission will get more easily disturbed by the environment because the signal becomes weaker.

The receiver circuit is tested with relay and connected to an extension plug to see the result. When 9V is supplied to the transmitter circuit, the relay at the receiver is triggered and the appliances connected to the relay is switched on.

Hence, the concept is actually same as the power line communication where power line carrier modem transmits data through existing power line while ultrasonic switch transmit signal through air.

#### **4.4 Comparison between PLC and Ultrasonic Transceiver**

Other alternatives can be implemented to replace the power line communication home automation. Ultrasonic switch is a lower cost and easier method for home automation. The concept of implementing ultrasonic switch is similar with power line communication where the user doesn't have to re-wire their house's electrical system. However, the transmission distance of the controller is shorter compared to power line communication method which only reaches approximately 30cm.

This implementation is pure hardware, hence no software is required. This means no data is transmit through ultrasonic wave. Another drawback of ultrasonic switch is that one set of ultrasonic transmitter and receiver is required for each appliance under controlled. The power line communication only needs one transmitter with several receivers because the receiver can recognize which data to be received. Moreover, the ultrasonic wave is highly directional where the ultrasonic transmitter has to place towards ultrasonic receiver for proper functioning.

Another drawback of implementing PLC transceiver is the sensitivity of PLC modem TDA5051A. TDA5051A is a surface mount device (SMD) where it has to be soldered on a PCB (Printed Circuit Board) before connected to the application circuit. The process of soldering it on PCB is not easy because it is very small and the pin leg is very near to each other. One TDA5051A was accidentally burnt in the process of soldering.

Both power line carrier and ultrasonic transceiver could get disturbed by environment. For power line carrier, the data might be lost when it passed through the power line. For ultrasonic switch, it might get disturbed by the condition of the environment between transmitter and receiver. There are pros and cons for both the systems.

## 4.5 Software Implementation

As discussed previously in chapter 3 section 3.2, Microchip PIC16F877A is implemented as the main controller unit. Coding is developed in High-tech C language. MPLAB version 8.5 is used to write and simulate the codes. There are a lot of programming languages in writing codes. We have chosen to use high tech C programming language since we learnt it before and quite familiar with it. When the codes written are ready to use, PICKIT2 is used to burn the codes into the microcontroller. The microcontroller that now contains data will be functioning accordingly. Figure 4.8 shows the PICKIT2 that is used to burn the source code into the microcontroller.

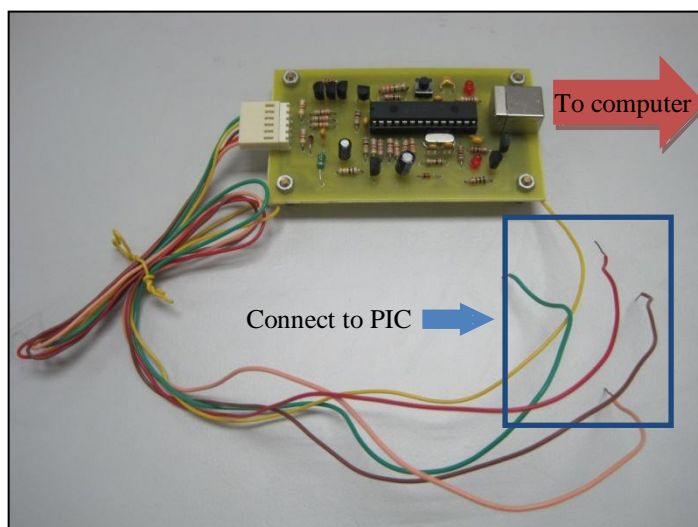


Figure 4.8: PICKIT2 as Program Burner

The setting for the crystal frequency in the program is very important and must be carefully done. This is due to an external oscillator circuit is used to drive the microcontroller in this project. Refer to figure 4.1, the oscillator circuit at TDA5051A will send a clock signal to the microcontroller. The crystal frequency used for the TDA5051A is 7.3728 MHz. However, when the clock signal passed through the TDA5051A, it is divided by 2. The block diagram in figure 3.8 shows the internal process of the TDA5051A that divide the clock signal by 2. Hence, the actual crystal frequency setting in the program is divided by 2 as well.

$$\text{Crystal frequency} = \frac{7.3728}{2} \text{ MHz} = 3686400 \text{ Hz} \quad (4.1)$$

Besides the setting of the crystal frequency, the setting for SPBRG value must be synchronize with the crystal frequency. SPBRG is the baud rate generator register in the microcontroller. The following equation is used to calculate the SPBRG value in low speed asynchronous mode.

$$\text{Baud rate} = \frac{F_{osc}}{64 (X + 1)} \quad (4.2)$$

where

$F_{osc}$  = Oscillator frequency, Hz

$X$  = Value in SPBRG (0 to 255)

Referring to the data sheet of the TDA5051A, the data baud rate is 1200. The crystal frequency is calculated in equation 4.1 which is 3686400 Hz. Hence the SPBRG value can be calculated by modifying the equation 4.2.

$$X = \frac{3686400}{64 (1200)} - 1 = 47 \quad (4.3)$$

SPBRG value of the program is set as 47 with BRGH = 0 to indicate low speed UART communication.

During testing stage, an LED is connected at the output port RB5 of PIC16F877A to indicate the data has been successfully sent and received.

#### 4.5.1 Program Flow Chart

There are two microcontrollers at the transmitter side. One is for the GSM modem while another one is to transmit data. The two programs cannot be combined because one PIC16F877 can only support one UART function when both the GSM communication and power line communication also implementing UART function. Moreover, there is only a pair of TX and RX pin for each PIC. Hence, two PICs are used at the transmitter side.

When a message is sent to the GSM modem for example “Switch on device 1”, the first microcontroller will retrieve the command from GSM modem using UART function. It will then send a signal “1” to the input port of second microcontroller using normal input/ output port. When the second microcontroller receives the signal, it will send out data to the power line using UART function. When the data is sent, the microcontroller will turn on LED at output port RB5 to indicate that the data has been sent. The program will be repeated after that. Figure 4.9 shows the program flow chart of the second microcontroller. The first microcontroller is handled by my partner who is working on the GSM controller.

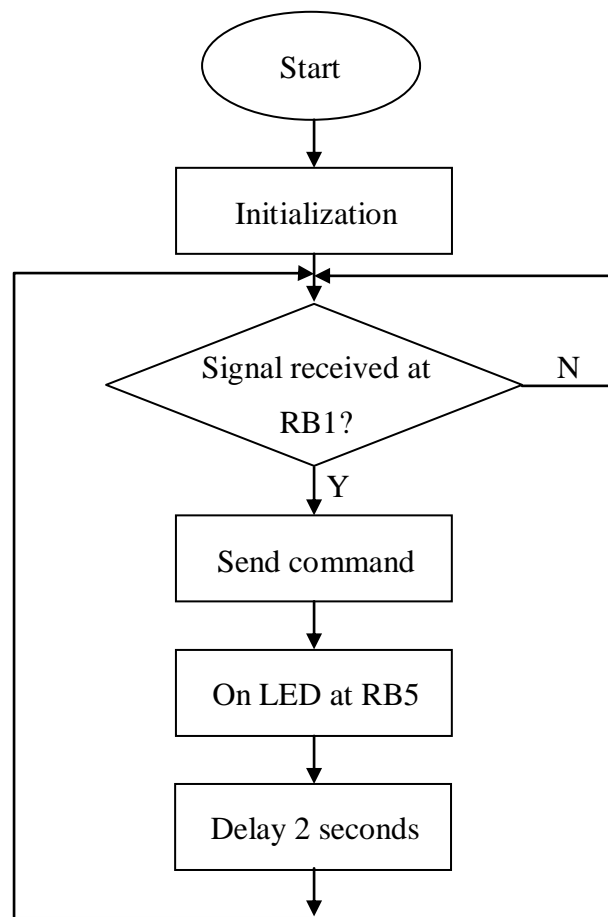


Figure 4.9: Program Flow Chart for Second Microcontroller (Transmitter)

At the receiver side, the microcontroller will be waiting for the command data signal. When the command data is received, it will check whether the received data is correct or not. If it is matched, a signal will be sent through output port RB5 to turn on the relay which connected to appliances. Figure 4.10 shows the program flow chart of the microcontroller at receiver side.

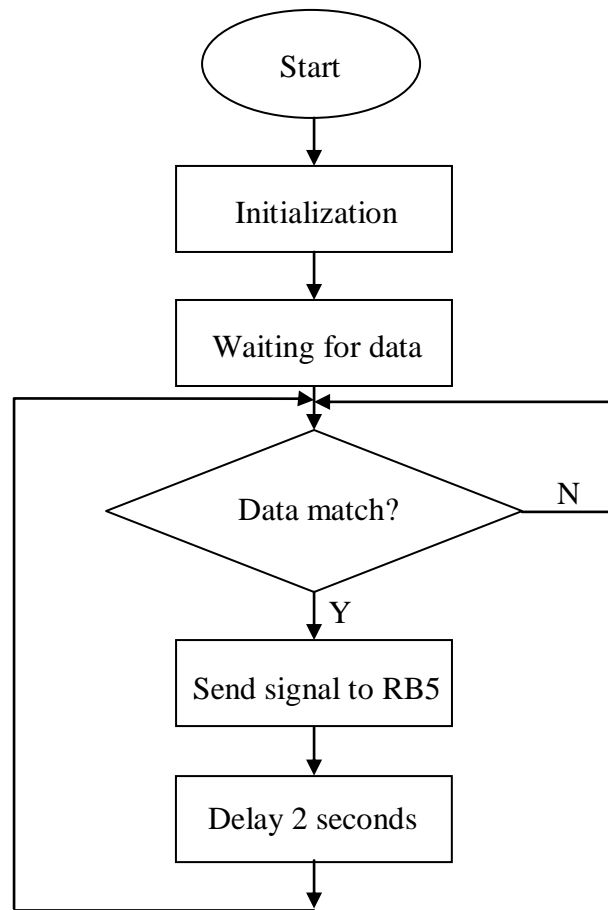


Figure 4.10: Program Flow Chart for Receiver Microcontroller



## 4.6 Designing Network Protocol

In order for the devices to communicate with each other, a machine language or network protocol is needed. Previously in chapter 2 section 2.4.1, X10 protocol is discussed. By understanding and referring to the X10 protocol, a simpler network protocol can be designed. Network protocol is designed using simplex multimode concept. To make it simple, there will be only one way communication where the data is only sent from transmitter to receiver.

By implementing UART function, the serial data is sent in a maximum of 8-bit data frame. Figure 4.11 shows an example of 8-bit data used to turn on the relay connected to output port RB5 of receiver microcontroller. Normally open output of the relay is connected to the appliances. Hence, when the receiver microcontroller receives the data, a signal is sent to RB5 to turn on the relay, the normally open will closed and the appliance is switched on.

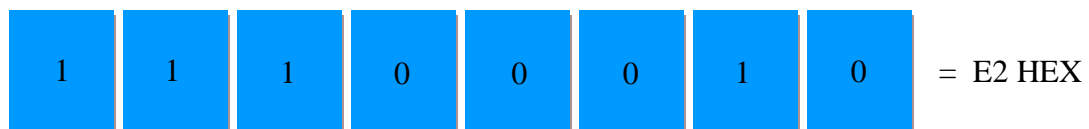


Figure 4.11: Serial Data to Turn on Relay at Output Port RB5 of receiver

To turn off the relay at RB5 of receiver microcontroller, a signal “0” is sent to output port RB5. A different data must be received by the receiver microcontroller before it can send a “0” to the RB5 to turn off the relay. Any hexadecimal number from 0 to FF can be used as the data to turn off the relay. Figure 4.12 shows the 8-bit data command used to turn off the relay at RB5 of receiver.

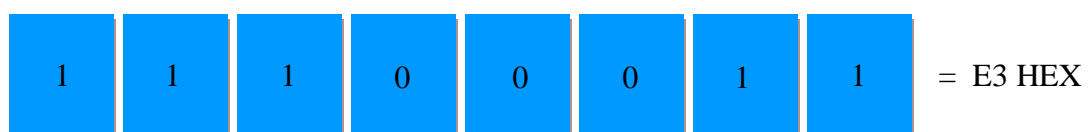


Figure 4.12: Serial Data to Turn off Relay at Output Port RB5 of receiver

## CHAPTER 5

### CONCLUSION AND RECOMMENDATIONS

#### 5.1 Future Recommendations

Power Line Carrier modem TDA5051A is implemented in this project to modulate and demodulate signals in ASK (Amplitude Shift Keying) modulation technique so that data can be transferred through power line. There are other PLC modems in the market that using FSK (Frequency Shift Keying) modulation technique to modulate the digital data. As discussed previously in chapter 4 section 4.2, some of the data is lost when it transmit through the line. Hence, the TDA5051A modem is not stable enough that causes data lost because of ASK modulation technique.

FSK power line modem works better than ASK in the sense of stabilization because the carrier has constant amplitude. Hence, it is immunity to non-linearities, immunity to adjacent channel interference, and the ability to work in small SNR environments. This is due to the effect of exchanging SNR for bandwidth. Due to these reasons, for further research, it is recommended to replace the ASK power line modem to FSK power line modem for example ST7540.

Apart from that, as discussed before, two microcontrollers are needed at the power line transmitter side because both GSM and PLC need UART function but one microcontroller only provide one set of UART function and pin. This will increase the cost of the product as one PIC16f877A cost around RM18. Hence, for further research, Serial Peripheral Interface (SPI) function of the PIC16F877A should be implemented at the PLC side to send data. SPI also allows 8-bit of data to be

synchronously transmitted and received simultaneously. Hence, by implementing SPI, one microcontroller at transmitter is sufficient to do both jobs. The reason SPI is not implemented in this project is because our knowledge on SPI is very limited.

As for the ultrasonic switch, to improve the sensitivity and the distance of transmission, a set of better or higher quality ultrasonic transducer can be used. The ultrasonic transducer used in the project is low quality type from China. Due to the limited cost of project, expensive ultrasonic transducer is not affordable.

Other than that, power consumption is another issue of ultrasonic switch. Ultrasonic switch is kind of energy hungry. Infrared (IR) can be an alternative to replace ultrasonic switch. Infrared switch consume less energy which is energy saving and is cheaper compare to ultrasonic switch.

## **5.2 Conclusion**

The power line communication system for home automation has been successfully developed. However, there is error occur in the system due to the sensitivity of the PLC modem and the disturbance in the electrical line. Hence, its reliability is low. The main purpose of implementing power line communication is because it doesn't require installing new wiring system because the data can be transmitted through existing power line system. With the same concept, ultrasonic switch is developed to replace the PLC system with better stability.

Ultrasonic switch for home automation is successfully developed and is able to switch on and off electrical appliances. However, improvement can be done so that the transmission distance can be longer. Better quality ultrasonic transducer can be implemented to increase the stability.

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## **APPENDICES**

### **APPENDIX A: Source Code for PLC Transmitter**

```

//=====
=====
//=====INCLUDE=====
#include<pic.h>

//=====CONFIGURATION=====
__CONFIG (0x3F31);

#define      send1      RB5
#define _XTAL_FREQ 3686400

//=====FUNCTION PTOTOTYPE=====
void uart_send(unsigned char data);
void long_delay(unsigned short i);

//=====MAIN FUNCTION=====
void main()
{
//initialization
char uart_scode1 =0b1110010;
char uart_scode2 =0b1110011;

unsigned char data[6],dat;
unsigned short i;
TRISB5      =      0;
TRISC6      =      0;
TRISC7      =      1;
PORTB       =      0;
PORTC       =      0;
SPBRG       =      47;
BRGH =      0;
TXEN =      1;
TX9  =      0;
RX9  =      0;

```

```

SPEN =    1;
CREN =    0;

send1=0;

while(1)
{

if(RB1==1){
uart_send(uart_scode1);
send1 =1;
__delay_ms(2000);    //delay for 2 seconds
}

if(RB2==1){
uart_send(uart_scode2);
send1 =1;
__delay_ms(2000);    //delay for 2 seconds
}

}

//=====UART SEND FUNCTION=====

void uart_send(unsigned char data)
{
    while(TXIF==0);    //only send the new data after
    TXREG=data;        //the previous data finish sent
}

```

## APPENDIX B: Source Code for PLC Receiver



```

//=====
=====
//=====INCLUDE=====
#include<pic.h>

//=====CONFIGURATION=====
__CONFIG (0x3F31);

#define      receive      RB5

#define _XTAL_FREQ 3686400

//=====FUNCTION PTOTOTYPE=====
unsigned char uart_rec(void);
void long_delay(unsigned short i);

//=====MAIN FUNCTION=====

void main()
{
//Initialization
unsigned char data[6],dat;
unsigned short i;
TRISB5      =      0;
TRISC6      =      0;
TRISC7      =      1;
PORTB       =      0;
PORTC       =      0;
SPBRG       =      47;
BRGH        =      0;
TXEN        =      1;
TX9         =      0;
RX9         =      0;
SPEN        =      1;

```

```

CREN      =      1;

receive =      0;

while(1)
{

dat=uart_rec();

if(dat==0b11100010){
    receive =1;
}

else if(dat==0b11100011){
    receive =0;
}

}

}

//=====UART RECEIVE FUNCTION=====

unsigned char uart_rec(void) //receive uart value
{
    unsigned char rec_data;
    while(RCIF==0);          //wait for data
    rec_data = RCREG;
    return rec_data;         //return the received data
}

```

## APPENDIX C: NXP TDA5051A Datasheet