

ELECTRONIC TOKEN SYSTEM USING RF TECHNOLOGY

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*Specially dedicated to
my beloved family and friends...*

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ABSTRACT

In recent years, both wired and wireless communications have been developed. Various types of wireless communication devices have been introduced in the market such as Zigbee, Bluetooth, infrared and EnOcean. From short distance wireless communication devices to long distance communication devices are being widely used in electronic field today. In wired communication devices, the usage of Universal Serial Bus (USB) has overcome the usage of serial ports. This project is concerned with the implementation of frequency modulation (FM) wireless communication in electronic token. Radio frequency (RF) technology particularly is being used for its minimum circuit complexity and low cost. It takes designing and building the electronic token and interface with the personal computer (PC) through USB. USB is used because there is lesser usage of serial ports nowadays especially in lap tops. Most of the electronic devices use USB because its application is universal. A graphical user interface (GUI) is developed for control and display purposes. This project has proved a success in building an effective token system using low cost wireless communication device.

ABSTRAK

Pada masa kini, sistem komunikasi berwayar dan tanpa wayar telah berkembang luas. Terdapat pelbagai bentuk sistem komunikasi tanpa wayar di pasaran seperti Zigbee, Bluetooth, infrared dan EnOcean. Sistem komunikasi tanpa wayar yang berjarak dekat dan berjarak jauh digunakan secara meluas di dalam bidang elektronik. Penggunaan bas sesiri universal (USB) lebih meluas berbanding penggunaan liang sesiri dalam sistem komunikasi berwayar. Projek ini menitikberatkan penggunaan sistem komunikasi modulasi frekuensi (FM) tanpa wayar di dalam token elektronik. Teknologi frekuensi radio (RF) digunakan secara khususnya kerana litarnya yang ringkas dan harga yang agak rendah. Projek ini melibatkan pembinaan token elektronik dan diantaramukakan dengan komputer peribadi melalui USB. USB digunakan kerana penggunaan liang sesiri dalam sistem komunikasi semakin rendah terutamanya dalam komputer riba. Antaramuka pengguna grafik juga dibangunkan untuk tujuan mengawal dan paparan. Projek ini telah membuktikan kejayaan dalam menghasilkan sistem token yang efektif menggunakan sistem komunikasi tanpa wayar dengan harga yang rendah.

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LIST OF NOTATIONS

SYMBOLS

V	Volts
mA	milliampere
MHz	Mega Hertz
uA	microampere
cm	centimetre
Ω	Ohm
“	Inch

ABBREVIATIONS

LED	Light Emitting Diode
CMOS	Complementary Metal-Oxide-Semiconductor
IRQ	Interrupt Request
CCS	Custom Computer Services

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The majority of electronic control devices in use today are embedded with microcontrollers (computer-on-a-chip). Microcontrollers are developed from microprocessors. Before microcontrollers exist in the market, microprocessors were mainly used in electronic control devices. In recent years, priority is given to microcontrollers because it has built-in Random Access Memory (RAM), Read Only Memory (ROM), Electrical Erasable Programmable Read Only Memory (EEPROM), input and output ports and also other useful features such as timers, analog to digital converter (ADC), pulse width modulation (PWM), serial port interface, synchronous and asynchronous. By reducing the size, cost and power consumption compared to a design using a separate microprocessor, memory and input/output devices, microcontrollers make it economical to electronically control devices. The internally built-in features depend on the version and manufacturer of the microcontroller. Programmable Intelligent Computer (PIC) is a family of Harvard architecture microcontroller made by Microchip Technology and MC68HC11 is a Von Neumann architecture microcontroller made by Motorola is among of the commonly used microcontroller in electronic control devices today.

In addition to the features stated, some microcontrollers even introduce design enhancements that make devices in the microcontrollers incorporate a fully features Universal Serial Bus (USB) communications module. PIC18F4550 is a

suitable microcontroller for the USB communications module that is compliant with USB Specification Revision 2.0. The module supports both low speed and high speed communication for all supported data types.

Communication system is a very important aspect of life in today's world. Communication system has developed from wired to wireless communication system. It is even possible to control a computer using a Bluetooth device rather than the typical wired mouse. Although wireless communication is being widely developed, the need of the earlier wireless devices such as radio frequency (RF) is still in need. RF is used mainly because it is a low cost device, low circuit complexity and a moderate length of transmitter and receiver.

1.2 Problem Statement

In today's dynamic world, queuing up at places like food courts, banks and post offices remains as a source of time waste. Although numbering system is applied, it is poor in the sense of time management as the client has to be in the area to make sure he doesn't miss his turn. Through the implementation of this project, one could actually use the time for a good purpose and could go to places nearby. This project requires high knowledge in wireless communication, serial communication and the usage of graphical user interface (GUI).

1.3 Design Objectives

The overall aim of this project is to build a wireless electronic token system controlled by the host's personal computer to save customer's time in food courts, banks and post offices.

The objectives of this project are:

- i) To build electronic token system using radio frequency (RF) technology.
- ii) To develop a Graphical User Interface (GUI) for electronic token system using Microsoft Visual C#.
- iii) To build a Universal Serial Bus (USB) device with a PIC18F4550.

1.4 Scope of Project

The scopes of this project are:

- i) To build a low cost electronic token using the low end radio frequency (RF) technology to save customers' time.
- ii) A graphical user interface (GUI) will be developed in order to place control options for the electronic token system.
- iii) The communication between personal computer (PC) and the electronic token is through Universal Serial Bus (USB).

1.5 Thesis Overview

The remaining chapters of this thesis are outlined as follows:

Chapter 2 outlines the literature review done for the development and implementations of the system. It gives a brief review about the current numbering system, Universal Serial Bus (USB) and radio frequency (RF) wireless transmitter and receiver module.

Chapter 3 includes the description of the electronic token hardware and USB port interface implemented in this project. It briefly describes the physical structure of the whole project. It also provides the information about the software which are C embedded high level language and graphical user interface (GUI) developed in this project. It describes the functionality of the software in controlling the device.

Chapter 4 explains the testing done for each sub module and also finally the whole integrated system. This is important to demonstrate modular development of a complex circuit.

Chapters 5 summarize the overall project design and its future development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Designing and building an electronic token requires high knowledge of wireless communication, communication protocol, interfacing Universal Serial Bus (USB) and others. This chapter focuses on the methodologies of the system design that have been implemented in the final system.

2.2 Current System

2.2.1 Current Food Courts' and Fast Food Center's System

Current food courts' system in Malaysia for example Jaya Jusco shopping complex food court and fast food centers (e.g. Kentucky Fried Chicken restaurant):

- i) After ordering food, the customers will receive a bill.
- ii) Then they have to go to another cash counter to pay the bill.
- iii) After that the customers have to wait at the area until their food is ready.

Pros:

- The bill and receipt given by the owner is cheap as it is made of paper and ink.
- This system is also easy because the owner just need to print out the bill and receipt.

Cons:

- The customers will be wasting time while waiting for the food in the food court.
- The customers also will be tired of waiting especially when they buy food after work.

2.2.2 Current Banks and Post Offices' System

Numbering system is applied at banks and post offices in Malaysia.

- i) Clients will have to press the button on the numbering machine and a number will be printed out.
- ii) The clients have to wait until their turn comes according to the number.

Pros:

- The number printed out is cheap as it is also made of paper and ink.

Cons:

- The clients will be wasting time at one place waiting for their turn although they need to go to other places nearby.

Figure 2.1 shows the current numbered ticket used in Maybank, Malaysia.



Figure 2.1: Numbering Ticket Used in Maybank, Malaysia

2.3 Universal Serial Bus (USB)

2.3.1 Description

Anyone who has been around PC's for any length of time realizes that one built-in problem is the scarcity of serial or communication ports. When IBM first designed the PC, they decided that no one would ever need more than two serial ports at a time. (Just like the idea that 640K of RAM would always be more than necessary.) So the PC was designed with four serial ports, but only two were available simultaneously. That was because they assigned only two interrupts (IRQs) to the four ports. With the PC-DOS or MS-DOS operating system, this scheme worked, to a degree.

Another problem with serial ports was a decided lack of speed. In serial ports data is sent one bit at a time. The first ports were limited to 9600 bits per second. The newer ports can handle 115K bits per second. That's a lot faster, but, still not fast enough.

Using a single cable, a USB port will allow you to connect your monitor, a keyboard, mouse, drawing tablet, modem, scanner, joystick, printer(s), telephone, to your computer. This is done by daisy-chaining each component or connecting to a multiple port box. In fact, you can link up to 127 devices to a single port on your computer, provided the total length of the connection is not longer than 15 feet.

Another advantage of the USB is SPEED. The USB has two data speeds. It uses 1.5 million bits per second for slow devices like keyboards, mice and joysticks. It has 12 million bits per second speed for monitors, printers, scanners, modems, removable drives, etc. [1]

2.3.2 The USB Process

When the host powers up, it queries all of the devices connected to the bus and assigns each one an address. This process is called enumeration devices are also enumerated when they connect to the bus. The host also finds out from each device what type of data transfer it wishes to perform:

- Interrupt
 - A device like a mouse or a keyboard, which will be sending very little data, would choose the interrupt mode.
- Bulk
 - A device like a printer, which receives data in one big packet, uses the bulk transfer mode. A block of data is sent to the printer (in 64-byte chunks) and verified to make sure it is correct.
- Isochronous
 - A streaming device (such as speakers) uses the isochronous mode. Data streams between the device and the host in real-time, and there is no error correction.

The host can also send commands or query parameters with control packets. As devices are enumerated, the host is keeping track of the total bandwidth that all of the isochronous and interrupt devices are requesting. They can consume up to 90 percent of the 480 Mbps of bandwidth that is available. After 90 percent is used up, the host denies access to any other isochronous or interrupt devices. Control packets and packets for bulk transfers use any bandwidth left over (at least 10 percent).

The Universal Serial Bus divides the available bandwidth into frames, and the host controls the frames. Frames contain 1,500 bytes, and a new frame starts every millisecond. During a frame, isochronous and interrupt devices get a slot so they are guaranteed the bandwidth they need. Bulk and control transfers use whatever space is left. The technical links at the end of the article contain lots of detail if you would like to learn more. [2]

2.4 RF Transmitter and Receiver

Synchronizing:

Obviously, for an RF link the receiver has to lock on to the transmitted signal. When not receiving a valid signal, some receiver modules increase their sensitivity. The output then randomly switches high and low. If you are looking for a particular bit sequence to indicate valid data, you don't want the receiver to receive a few 'bits' of noise just before you transmit a valid code, or the received data will be shifted out of sequence (e.g. transmitting first bit when the Rx is looking for third). Probably the easiest and least software intensive way around this is to turn the transmitter on (normally by pulling data pin high) for several bits before the code is transmitted, then off again. This drops the sensitivity back down to an appropriate level for the transmitted signal. By making the combined on and off time longer than the code sequence the receiver is looking for, it will then be looking for the beginning of the code again before you transmit. [3] Figure 2.2 is a simple block diagram of basic communication system.

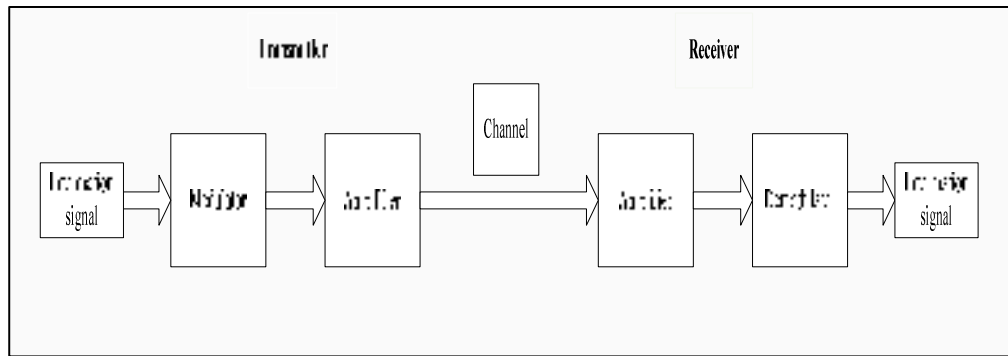


Figure 2.2: Block Diagram of Basic Communication System

2.5 Communication Protocol

Generally there are two types of communication protocol that is acknowledged and unacknowledged protocol.

Unacknowledged protocol is mostly used when transmitting brief blocks of data. The speed of transmitting data using unacknowledged protocol is high. Thus the real-time data are updated. Although fast, the lost data is unable to be recovered.

Acknowledged protocol is used to transmit several data in blocks. This is because in acknowledged protocol first the receiver will determine whether it receives the correct data. For example Manufacturer Identification Code to ensure message security between the transmitter and receiver and Send-Receiver Acknowledgement techniques where every communication initiated by the transmitter is acknowledged by its intended receiver. By applying acknowledged protocol, the receiver would be able to ensure that the data it receives is the data it requests. Furthermore data lost or damaged could be detected and retrieved again.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Generally, this project needs a lot of literature review on wireless communication, serial communication and the usage of graphical user interface (GUI). It is to enhance the knowledge about the connection, function, and the description of each electronic component. This knowledge is implemented to design the electronic token. This chapter briefly describes the methodology of the whole project. Later, in this chapter, the physical structure and hardware design of this project will be described in detail. This chapter also provides the information about the software, C embedded and GUI developed in this project. Figure 3.1 shows the block diagram of the electronic token. Figure 3.2 illustrates the methodology flow chart of electronic token system.

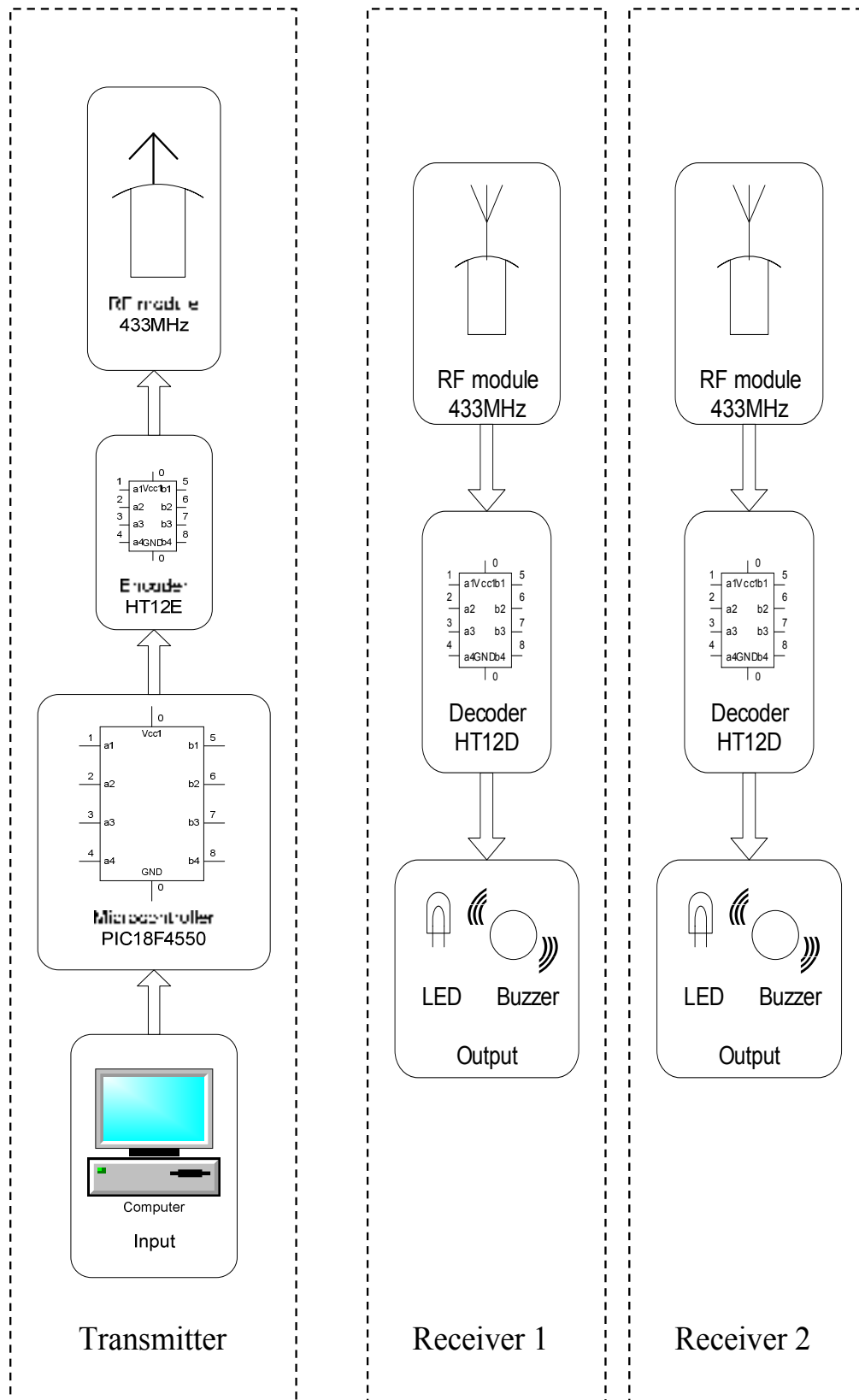


Figure 3.1: Block Diagram of Communication System in Electronic Token

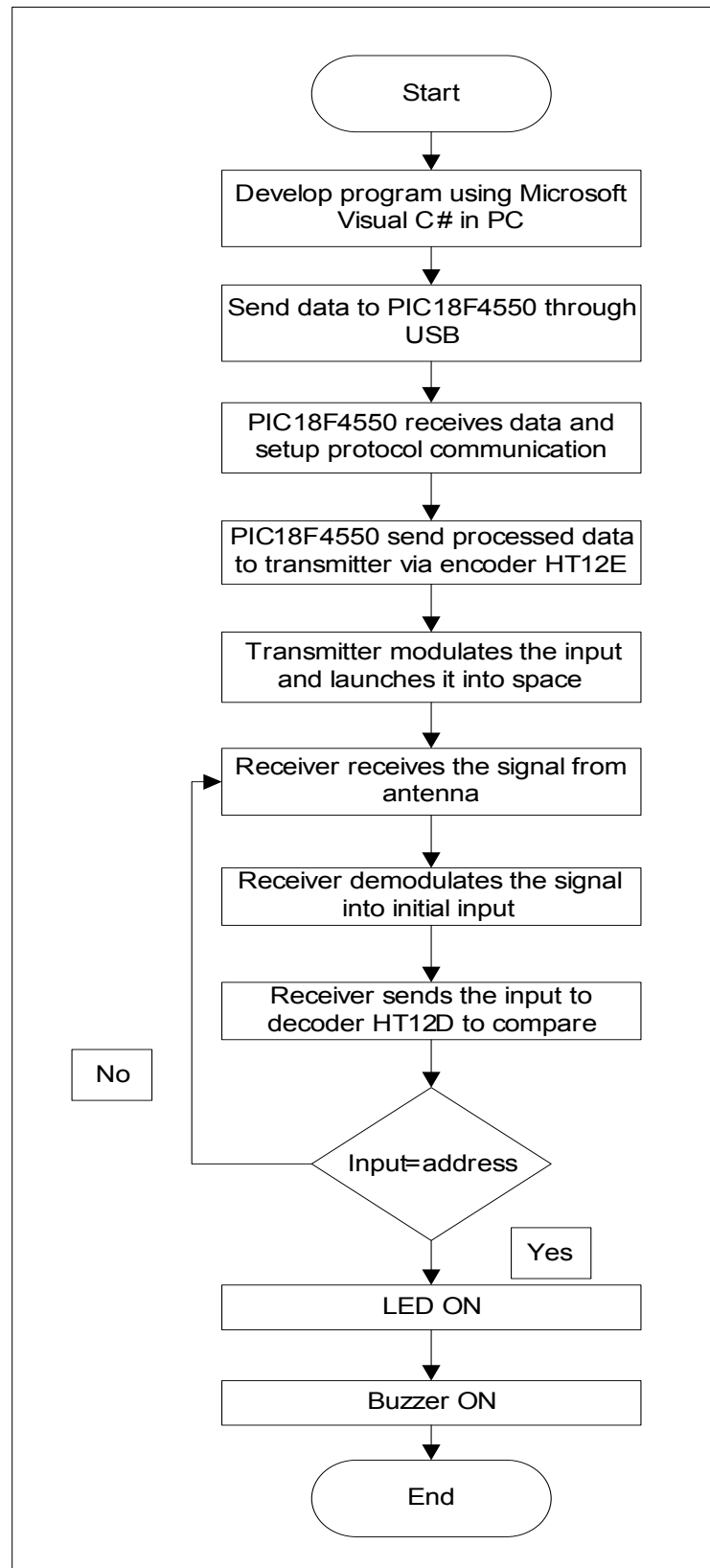


Figure 3.2: Process Flow Chart

The electronic token is a simple device where the LED and Buzzer on when the correct signal are sent and received. This means that the clients are being called. So one can move around while waiting for their turn to arrive. This device is also affordable for the average income restaurateur and shop owners.

The software that will be used to control the input and display purpose will be Microsoft Visual C#, because it is simple, modern and for general purposes. The purpose of using Microsoft Visual C# is to develop Graphical User Interface (GUI). A GUI is a graphical user interface to a computer.

The input from a personal computer (PC) will be sent to PIC 18F4550 through Universal Serial Bus (USB). USB is used nowadays because there is lesser usage of serial ports. Most of the electronic devices use USB because its application is universal. The PIC 18F4550 will be programmed using C embedded. PIC 18F4550 will set up a protocol with the input sent. Protocol technique will be set up in order to achieve secure and error free communications. For example Manufacturer Identification Code to ensure message security between the transmitter and receiver and Send-Receiver Acknowledgement techniques where every communication initiated by the transmitter is acknowledged by its intended receiver. This means the token will only function when the address register in encoder of the transmitter is similar to the address register in the decoder of the receiver.

The output of PIC 18F4550 will be sent to the frequency modulation (FM) transmitter through encoder HT12E. The transmitter modulates the output into an FM radio signal which can then be picked up by the FM receiver. The antenna at the transmitter site will launch the FM radio signal into space.

At the receiver site, the antenna will receive as many signals as possible. The signals will then be sent to the FM receiver. The receiver receives its input from the antenna, uses an electronic filter to separate wanted radio signals from all other signals picked up by the antenna, amplifies it to the level suitable for further

processing and finally converts it through a demodulator and decodes the signal into the original data.

The output of the FM receiver will be sent to the decoder HT12E. So the decoder will compare its address register with the address register of the encoder. If the data matches, the output will be sent to the token so that the LED and Buzzer on. If it doesn't match, the decoder prepares to receive other signals from the receiver.

3.2 Hardware Design

The electronic token requires a microcontroller to process the data received from personal computer (PC) and to send it to the encoder. The PC is connected to the electronic token through Universal Serial Bus (USB). For these reasons, microcontroller which is compatible with USB is the best microcontroller to be used in this project. Figure 3.3 shows the picture of PIC18F4550 microcontroller.

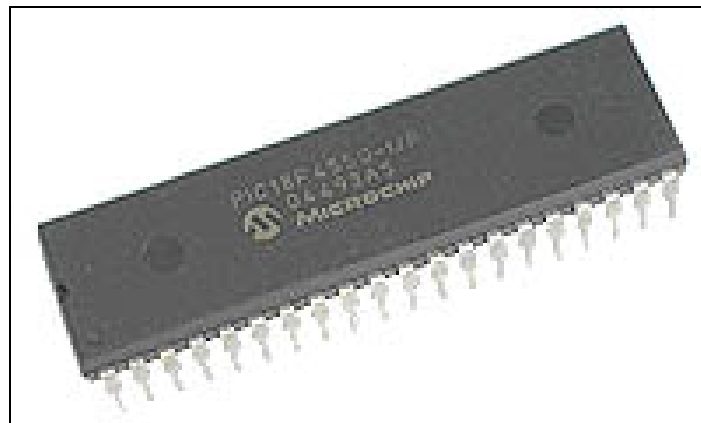


Figure 3.3: PIC18F4550 Microcontroller

3.2.1 PIC18F4550 Pin Assignments

The microcontroller has to perform for Universal Serial Bus (USB) function and data handling function to receive and transmit data with the personal computer (PC) and the encoder.

For each specific function, specific ports and pins are assigned to suit the requirements. Table 3.1 describes in detail the microcontroller pin assignments for every function of the electronic token.

Table 3.1: PIC18F4550 Pin Assignments

	Function	Pin Assignment	Pin Type
USB	Reset	VPP	Power
	Clock	OSC1 OSC2	Input
	LED	RA1	Output
		VREF-	
	Interrupt	INT0 INT1 INT2	Input
	Voltage Regulator	VUSB	Output
	USB	D- D+	Input
Data Management (Encoder)	Data Out	RC0 RC1	Output
	Data In	RD0...RD7	Input

3.2.2 Universal Serial Bus (USB) Module

As expressed earlier, USB is used to connect and interface personal computer (PC) with the PIC18F4550 microcontroller. PIC18F4550 is powered from the USB. The microcontroller can also be powered from external source. When the board is powered from the USB, the power budget is 5V/100mA and the circuit should not exceed this power. Figure 3.4 shows the USB connection circuit. D+ and D- is the main connection to USB and PIC18F4550 has supplied specific pins assigned as D+ and D-. VUSB pin is the internal USB 3.3V voltage regulator.

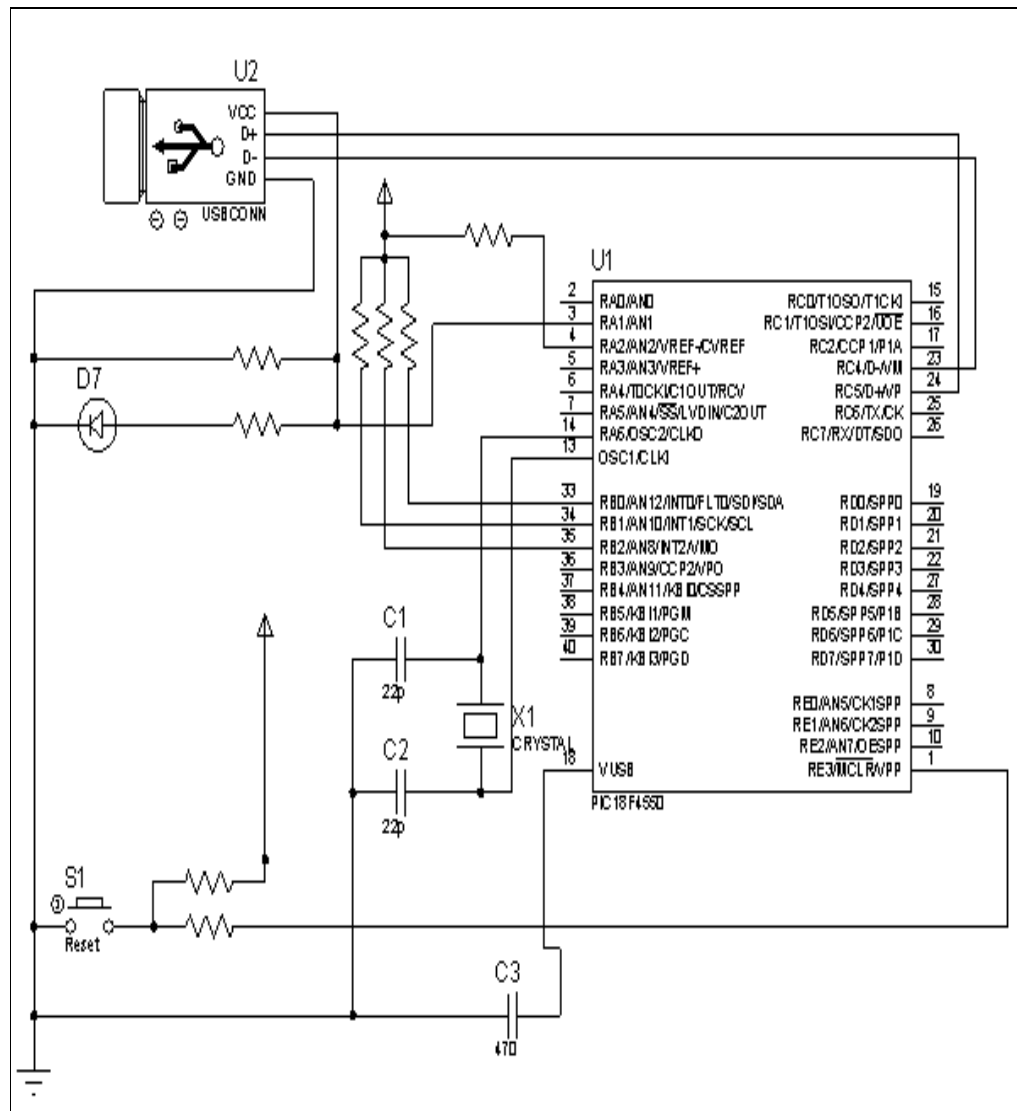


Figure 3.4: USB Connection Circuit

The RESET circuit consists of connection to VPP pin at PIC18F4550, two resistors with value of $10K\Omega$ each and RESET push button.

The oscillator circuit is made with 20 MHz crystal oscillator. Thus the PIC18F4550 runs at maximum performance.

3.2.3 FM Wireless System Modules

This module consists of four components which are the encoder, decoder, transmitter and receiver modules. The components are arranged as shown in Figure 3.5. Figure 3.6 shows the circuit of transmitter module which consists of encoder and transmitter while figure 3.7 shows the circuit of receiver module which consists of decoder and receiver.

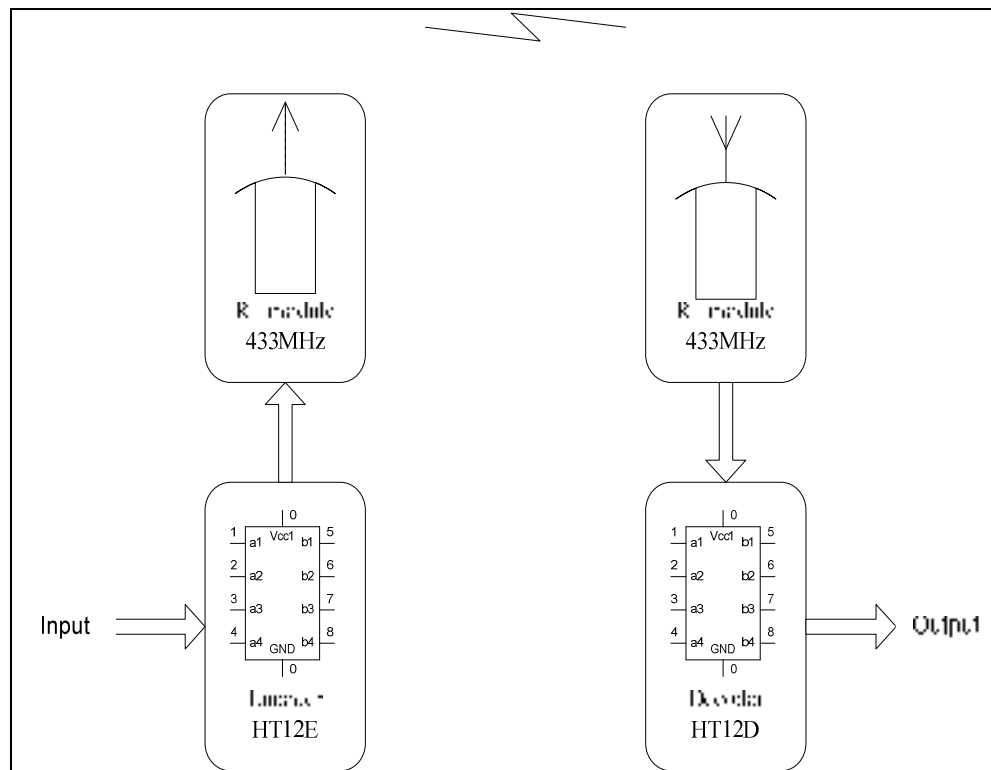


Figure3.5: FM Wireless as Communication Medium

In order to transmit data to a specific receiver, both the encoder and decoder must have the same address. The transmitter and receiver module used in this project operates at frequency of 433MHz. Following are the description of each component for this module.

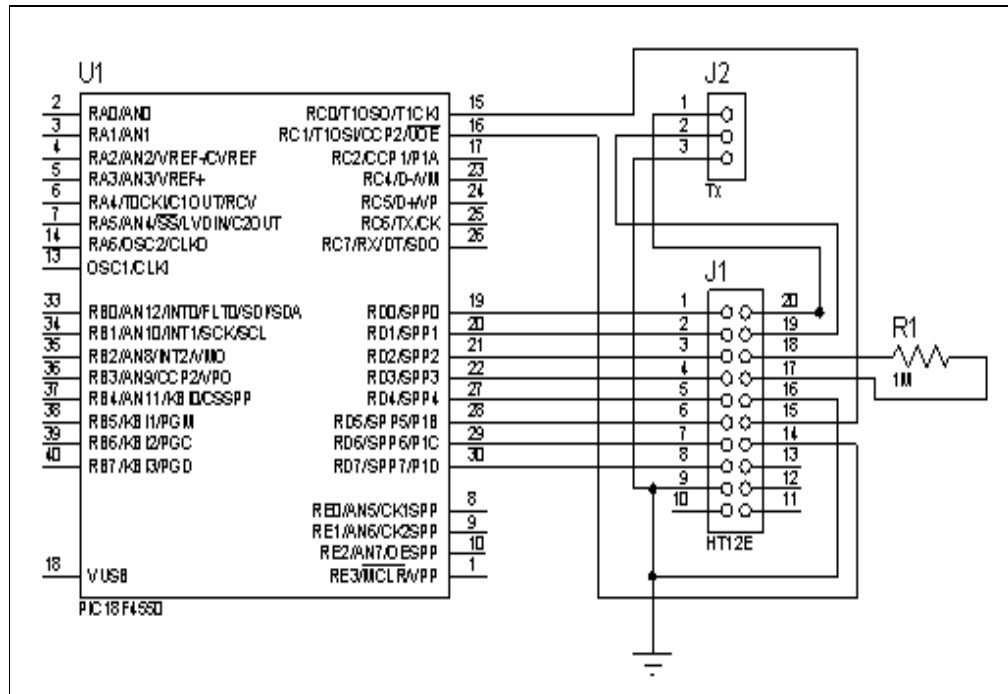


Figure 3.6: Transmitter Module Circuit

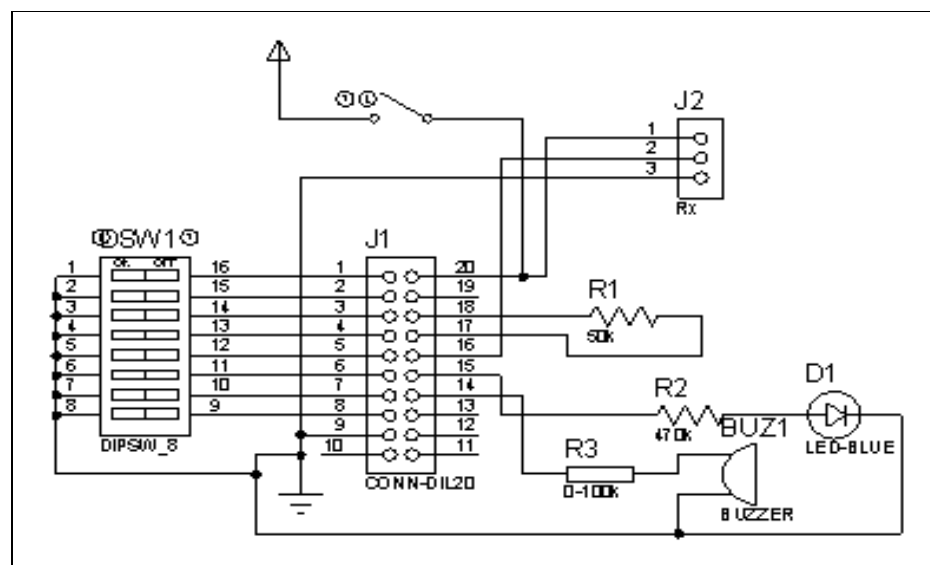


Figure 3.7: Receiver Module Circuit

3.2.3.1 Encoder

The encoder used in this project is HT12E manufactured by HOTLEK. This encoder has 8-bit address and 4-bit data pins.

The encoder is used to send 8-bit address and 4-bit data in order to identify to which receiver it should receive. This encoder is chosen, due to its ability of transmitting 12-bit data. The preset address and current data will be encoded and sent together once the transmit enable pin is triggered low.

Other features such as it operates on low power, high noise immunity because of CMOS technology, low standby current, built-in oscillator and data code has positive polarity and requires minimal external components. On the other hand, the input pins used for addressing and data purpose can be externally set to VSS (logic LOW) or left open (logic HIGH).

The encoder begins a 4-word transmission cycle when the transmission enable pin triggered low. This cycle repeats as long as the transmission enable pin is held low. Once the transmission enable pin returns high, the encoder output completes its final cycle and then stops as shown in figure 3.8 below.

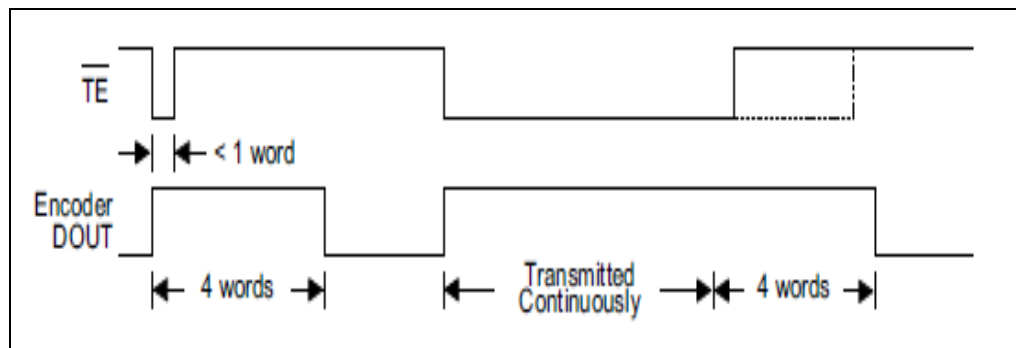


Figure 3.8: Timing Diagram for HT12E

The status of each address and data pin can be individually preset to logic HIGH or LOW. If the transmission enable signal is low, the encoder transmits the current address set and the current data serially in the order A0 to AD11.

During information transmission, these bits are transmitted with a preceding synchronization bit. If the trigger signal is not applied, the chip enters the standby mode and consumes a reduced current of less than 1uA for a supply voltage of 5V.

For this project, byte for the address and data pins is received from personal computer (PC). As a byte only contains 8-bits, 6-bits are used to preset the address pin and the other 2-bits are used as the data pins. So in this project only 8-bits are used to preset address and data pins. The other 2-bits for addressing pin are always set HIGH. This is due to safety reasons. The transmission enable pin also is always set to LOW.

3.2.3.2 Decoder

The decoder used in this project is HT12D manufactured by HOTLEK. This decoder has 8-bit address and 4-bit data pins.

This decoder provides various combinations of addresses and data pins in different packages to pair with encoder HT12E. The decoder receives 8-bit address and 2-bit data from the transmitter and compares with the address and data set in the decoder itself. If the address pins are same, the data pins will be HIGH. For this project the address pins are preset using DIP switch.

The output of the valid transmission (VT) pin is HIGH only when the transmission is valid. Otherwise it is always LOW.

3.2.3.3 Transmitter Module

Radio frequency (RF) transmitter FMTX1-433 is used in this project. The frequency used by the transmitter is 433Hz. The low cost RF transmitter can be used to transmit signal up to 100meters. The antenna design, working environment and supply voltage will seriously impact the effective distance. 5V is supplied to transmitter although 3-12V can be supplied as the power supply from the personal computer (PC) is only 5V. The DATA pin in transmitter is connected to the DATA pin at the encoder. It is to send the data from the encoder to the transmitter to be transmitted.

3.2.3.4 Receiver Module

Radio frequency (RF) receiver FMRX1-433 is used in this project. It is used to be compatible with the RF transmitter FMTX1-433. The frequency used by the receiver is also 433Hz. The low cost RF receiver is used to receive RF signal from the transmitter at 433Hz. Super regeneration design ensure sensitive to weak signals. An antenna is also required for receiver. The DATA pin in receiver is connected to the DATA pin at the decoder. It is to send the data received from the transmitter to the decoder to be compared. 5V is supplied from the batteries.

3.2.3.5 Antenna Design

One factor that impacts the distance of transmission and receiving is the antenna design. The space around the antenna is important as the antenna itself. The antenna can be made by rolling a wire into spring shape. The thicker the wire the better the antenna will be. The length of the antenna plays an important role. As transmitter and receiver with frequency 433Hz are used in this project, the suitable antenna length will be 18cm.

3.3 Software Development

Two programs are used in this project which is C embedded to program PIC18F4550 and graphical user interface (GUI). Following will be the explanation about the programming language and GUI.

3.3.1 PIC18F4550 Programming Language Setup Tools

The program for the electronic token is developed using C embedded high level language. There are two stages to program the PIC18F4550 which are writing and compiling the program and loading the program into the PIC18F4550.

3.3.1.1 Writing and Compiling

CCS C [4] compiler is the software used to write and compile the program. Figure 3.9 shows the layout of the CCS C compiler. After writing the program using C embedded language, compilation has to be done by just clicking on the Compile button. Compiling will produce the hex file which will be used to program the microcontroller.

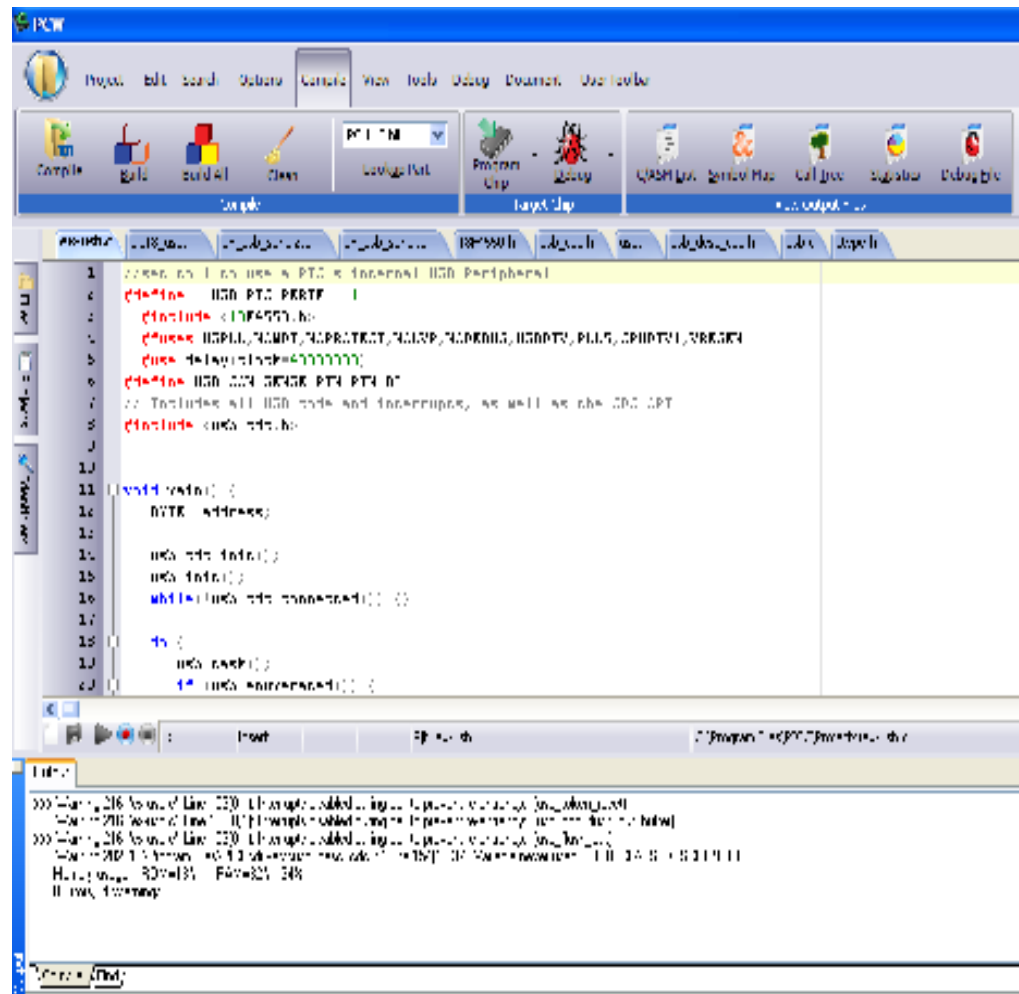


Figure 3.9: CCS C Compiler

3.3.1.2 Programming the PIC18F4550

PICKit 2 v2.40 [5] is the software used to load the program into PIC18F4550. USB ICSP PIC Programmer is the tool to load the program into the microcontroller. Figure 3.10 shows the USB ICSP PIC Programmer tool.

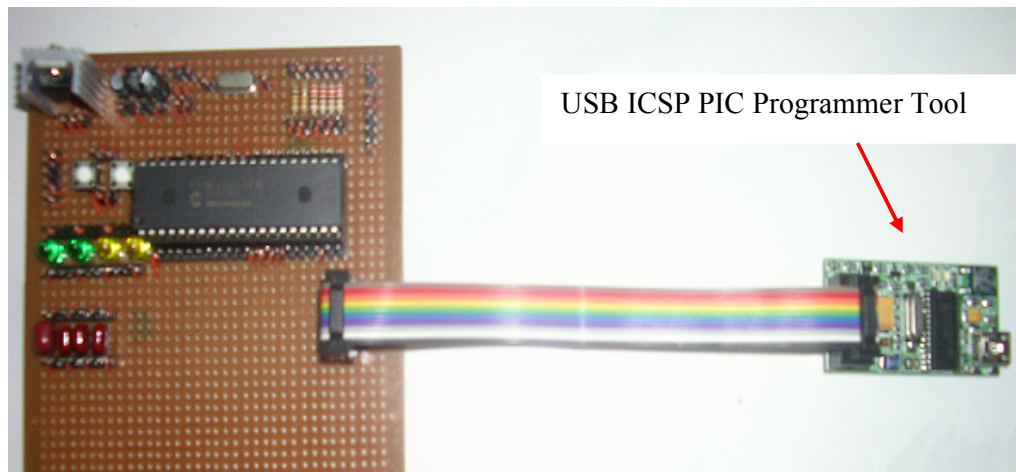


Figure 3.10: USB ICSP PIC Programmer Tool

After installing the hardware and software, the USB ICSP PIC Programmer tool is used with PICKit 2 v2.40 programming software to load the program into the PIC18F4550.

The programmer tool is connected to microcontroller and personal computer (PC). By running the PICKit 2 software, the programmer will be able to automatically detect the PIC from connected target and display it in the *Device Configuration* window as show in figure 3.11.

Hex file is then imported. After Hex file has been successfully imported, the PIC18F4550 is programmed by clicking on *Write*. The PIC will be erased and programmed with the new Hex code imported. The operation status will be displayed on the *Status window* and the *Status window* and *Status bar* will turn green after the writing is successful as shown in figure 3.12.

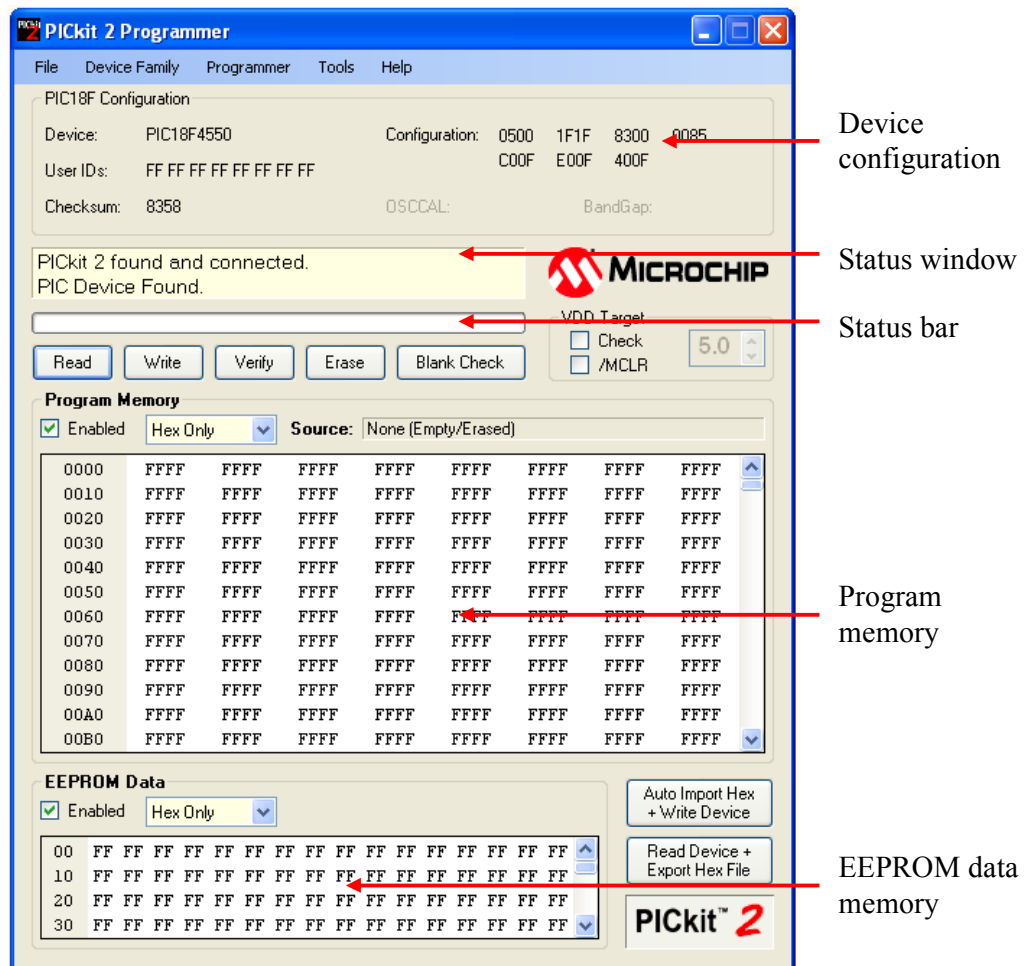


Figure 3.11: PICkit 2 Software Layout

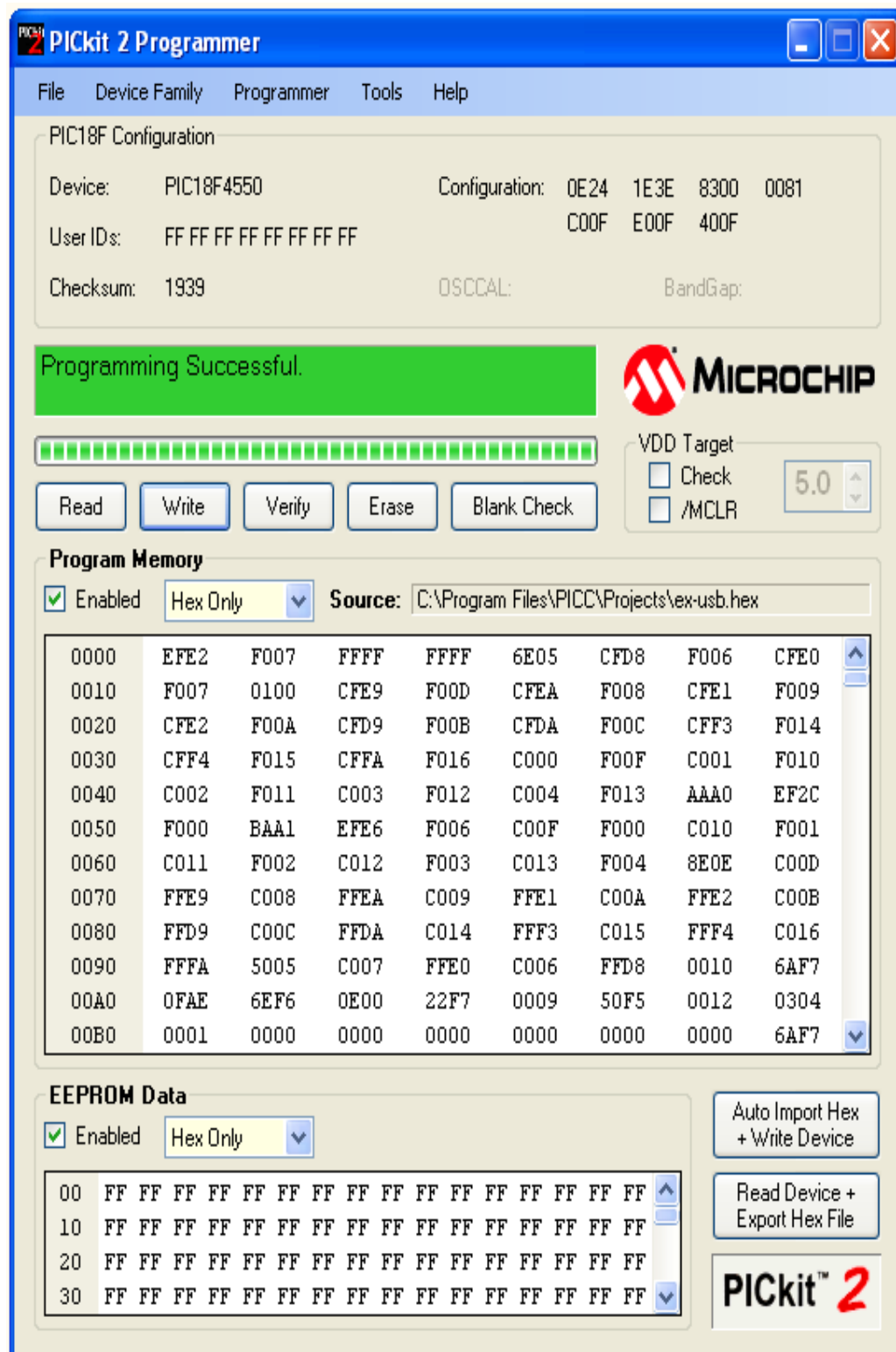


Figure 3.12: PICkit 2 Software Layout after Successful Programming

3.3.2 PIC18F4550 Programming Language

The program begins with the initialization of PIC18F4550's Universal Serial Bus (USB) port. Then it receives data sent by the personal computer (PC) in byte form to process. Figure 3.13 shows the flowchart of the program.

Firstly bit 7 and bit 6 will be tested either the bits are HIGH or LOW. Then output pin C1 and C0 will be set HIGH or LOW according to the bits respectively. After that, both bits are cleared and sets output pin D7 and D6 as LOW.

Secondly bits 5 till 0 will be tested. Then output pins D5 till D0 will be set HIGH or LOW according to bits 5 till 0 respectively.

This data is needed to set the address and data in the encoder. The program loops continuously.

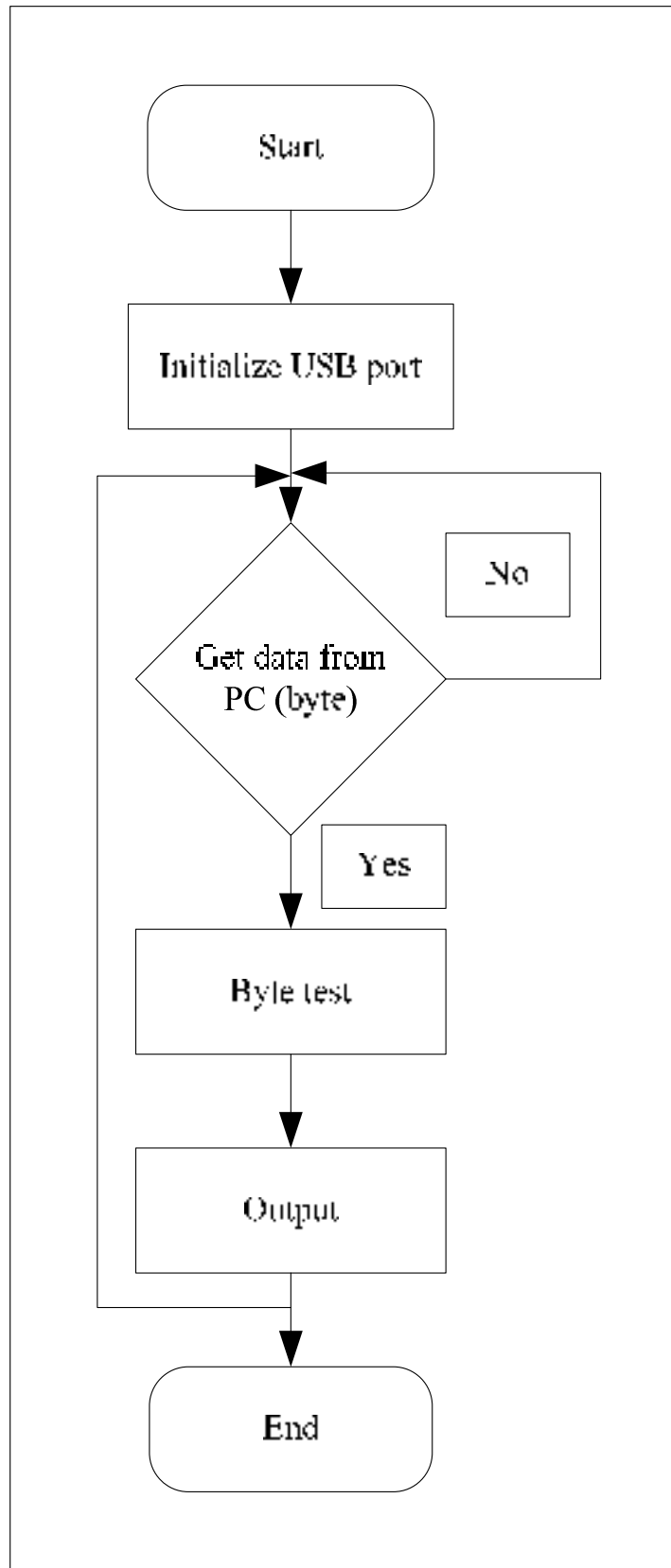


Figure 3.13: Flowchart of Programming Language

3.3.3 The Graphical User Interface (GUI)

The GUI is developed under Microsoft Visual C# 2005 environments. Microsoft Visual C# 2005 is user friendly capable of accessing input / output ports of the personal computer (PC) especially the Universal Serial Bus (USB) port. This GUI contains more functions compared to other GUIs and simple to understand. Figure 3.14 is the layout of the GUI.

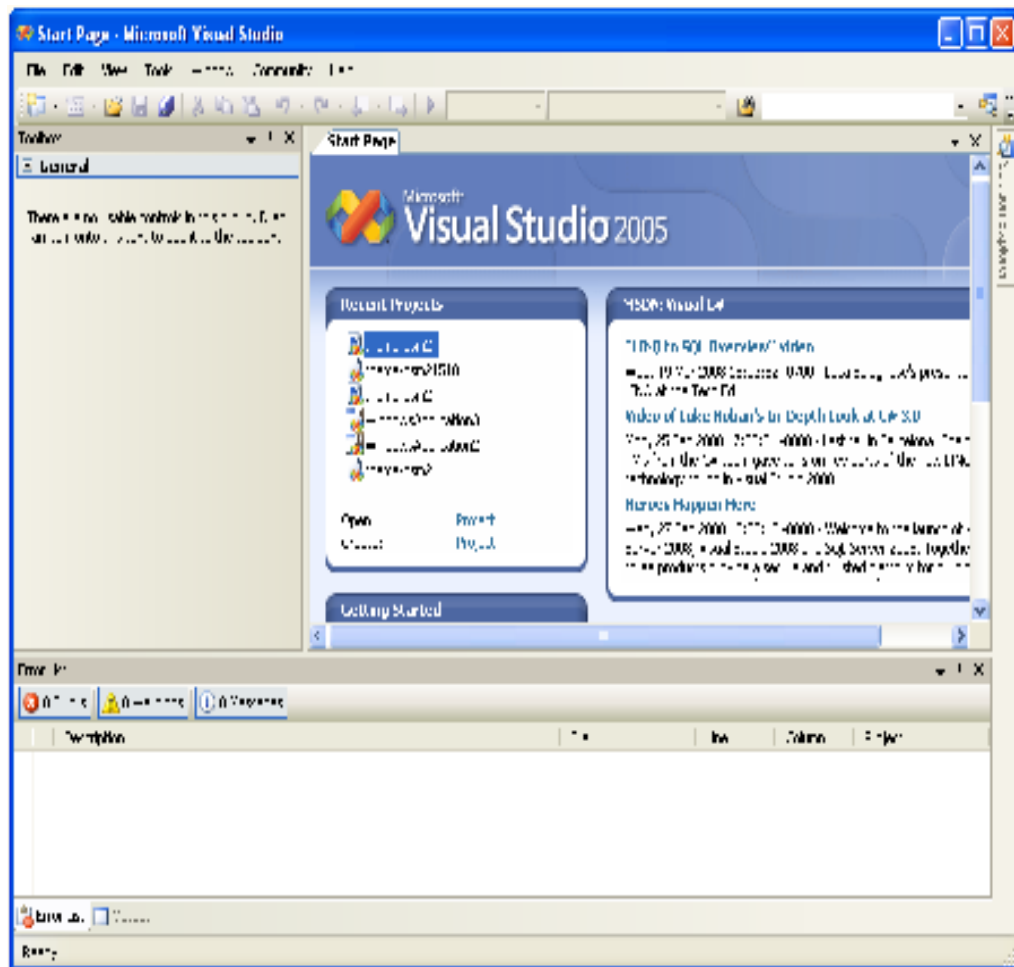


Figure 3.14: The GUI Layout

3.3.3.1 The GUI Development

The Universal Serial Bus (USB) port is accessed through the graphical user interface (GUI) by just placing the serial port icon into the design form. Then to initialize the serial port, the following code is written

```
serialPort1.Open ();
```

The GUI is designed in tab form to ease the application. In *registration* tab, radio buttons are used so that the user can select an item from menu option. By clicking the *save* button, the customer's name, order and device number will be saved in grid format at *control* tab. *New order* button will delete customer's name so that new order can be entered. *Exit* button functions to exit from the whole system.

In *control* tab, the *device number* and outputs either *LED* or *Buzzer* can be chosen. By clicking *send* button, the data in byte form will be sent to PIC18F4550 through USB. Figure 3.15 shows the flowchart of GUI.

About us tab contains the details of my supervisor, Mr. Zamri Ibrahim and me.

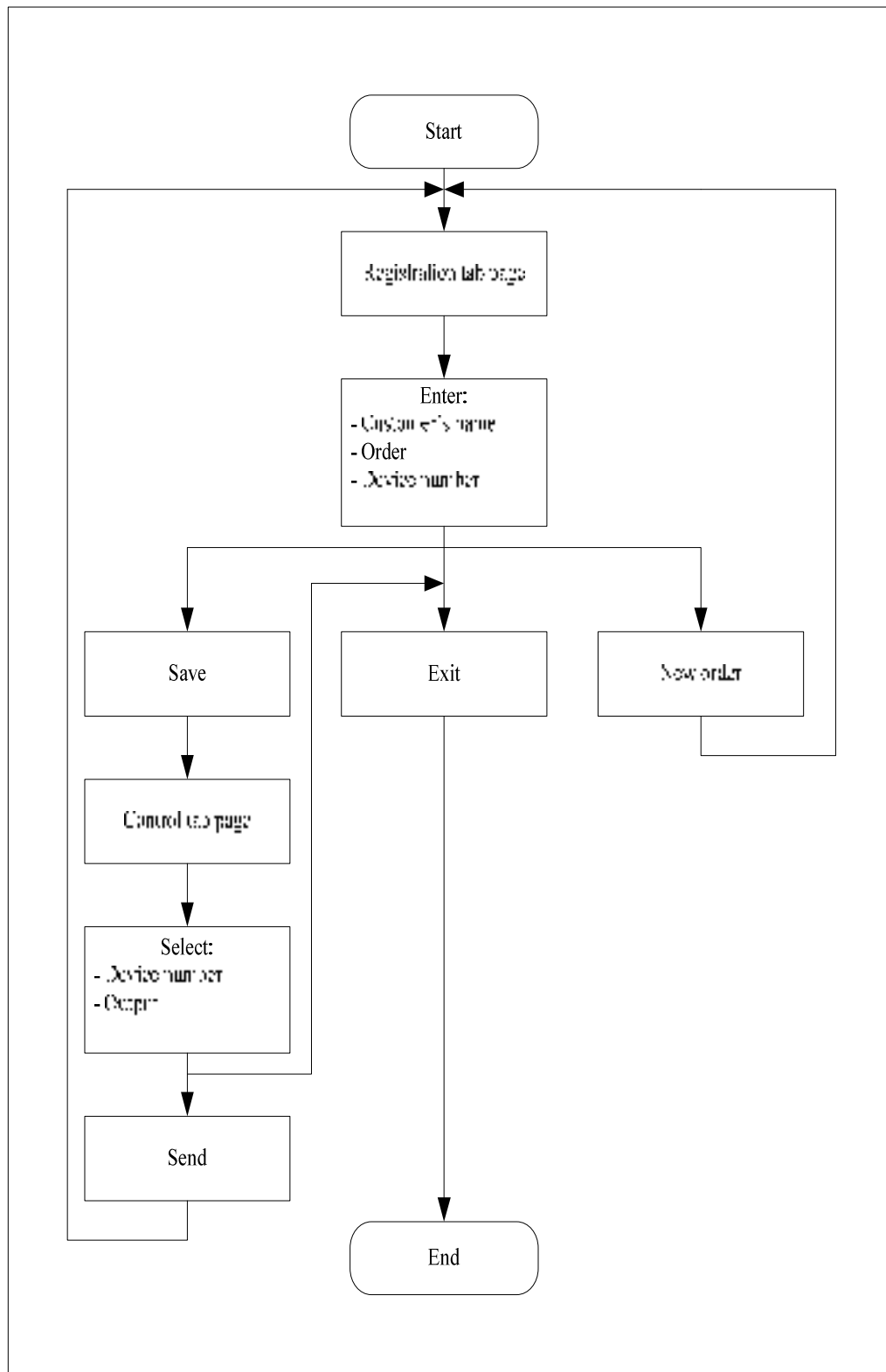


Figure 3.15: Flowchart of GUI

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The important part of this project is to conduct various tests on the developed system. This is to ensure each module in the system functions well before integration of all modules. The modules tested are Universal Serial Bus (USB) module and the frequency modulation (FM) wireless module.

4.2 Universal Serial Bus (USB) Module Test

The USB module test is carried out to test whether the personal computer (PC) could detect the module as an USB device. It detects and the device in PC is installed as Com Port. When HyperTerminal window is opened, data is sent to on the LED and the LED on. This shows the functionality of this module.

4.3 Frequency Modulation (FM) Module Test

The FM wireless module test is carried out to discover the functionality of encoder and decoder and also the distance of transmission. Firstly the transmission of data via a wire as a medium is tested. Then replacing the wired medium with FM wireless transmission module is tested

4.3.1 Encoder and Decoder Test

The encoder and decoder were tested in pair as shown in figure 4.1. The D_{out} pin of encoder HT12E is connected directly to the D_{in} pin of decoder HT12D. The address pin, AD0 till AD7 of HT12E and HT12D are connected to DIP switch. The data pin AD8 till AD11 of HT12E also is connected to DIP switch. LED is connected to D8 till D13 of HT12D through resistors.

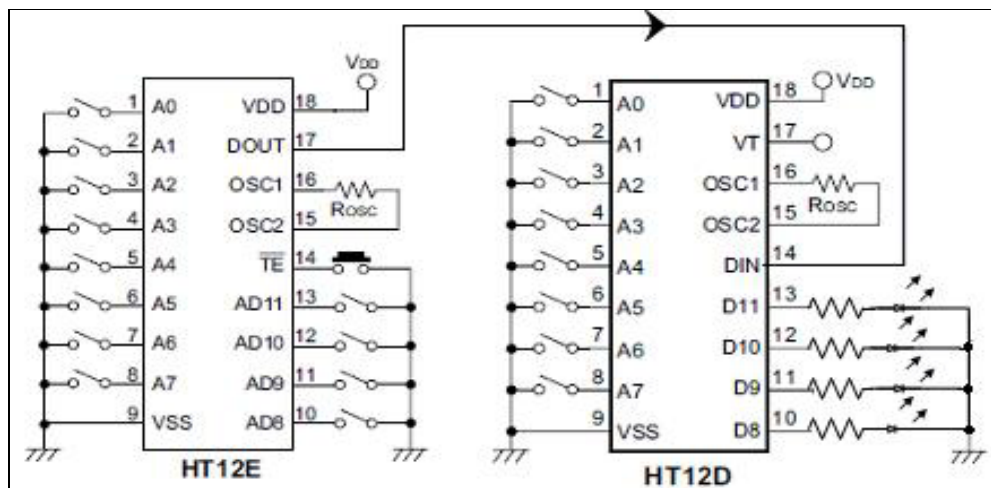


Figure 4.1: Encoder and Decoder Test Circuit

This module is tested with different addresses. The LEDs at decoder on according to the output pins if same address is set at both encoder and decoder. The VT pin goes HIGH whenever the /TE is pressed. VT goes LOW when /TE is HIGH. If different addresses are set, the decoder holds the previous data latched as it could not update to the latest data sent by the encoder.

4.3.2 Transmitter and Receiver Test

The direct wire connection from D_{out} to D_{in} is replaced with frequency modulation (FM) wireless transmitter and receiver modules as shown in figure 4.2.

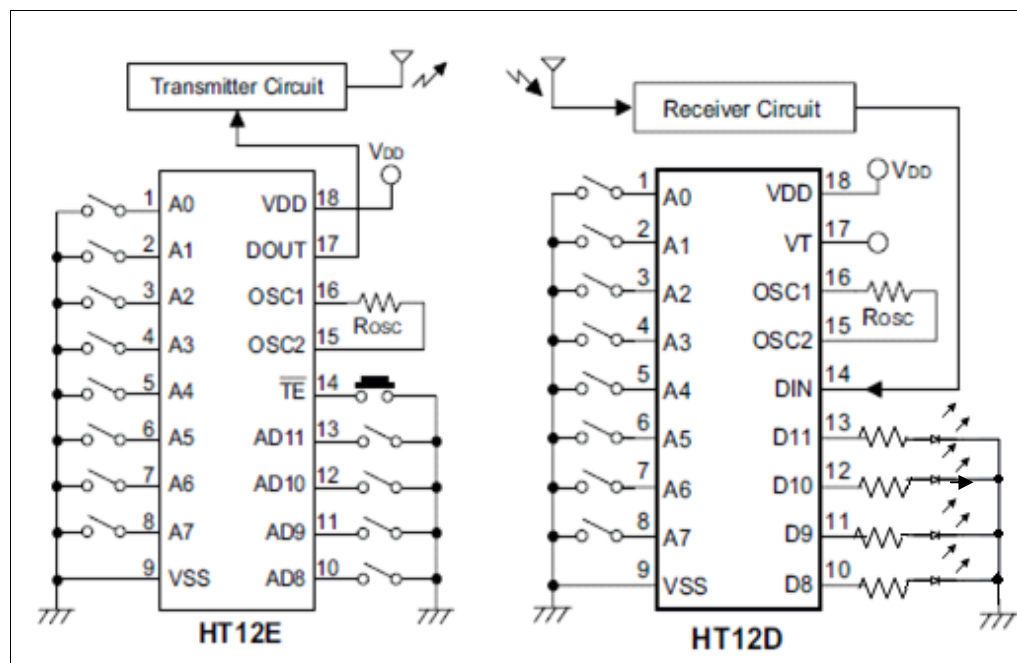
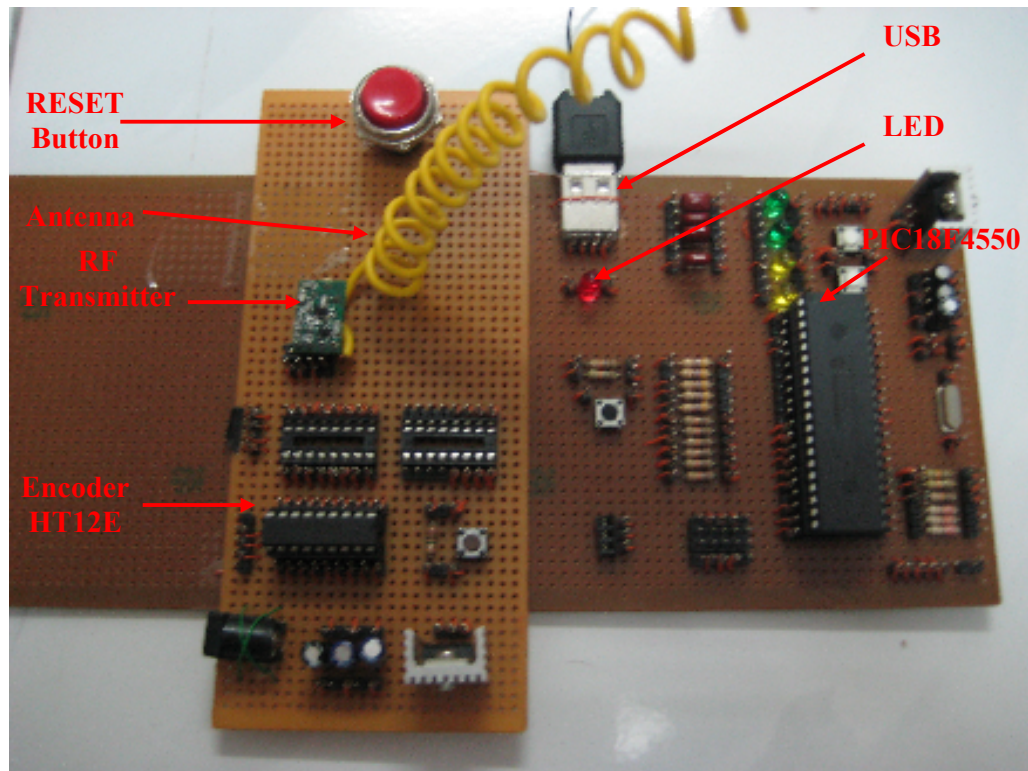


Figure 4.2: FM Wireless Module

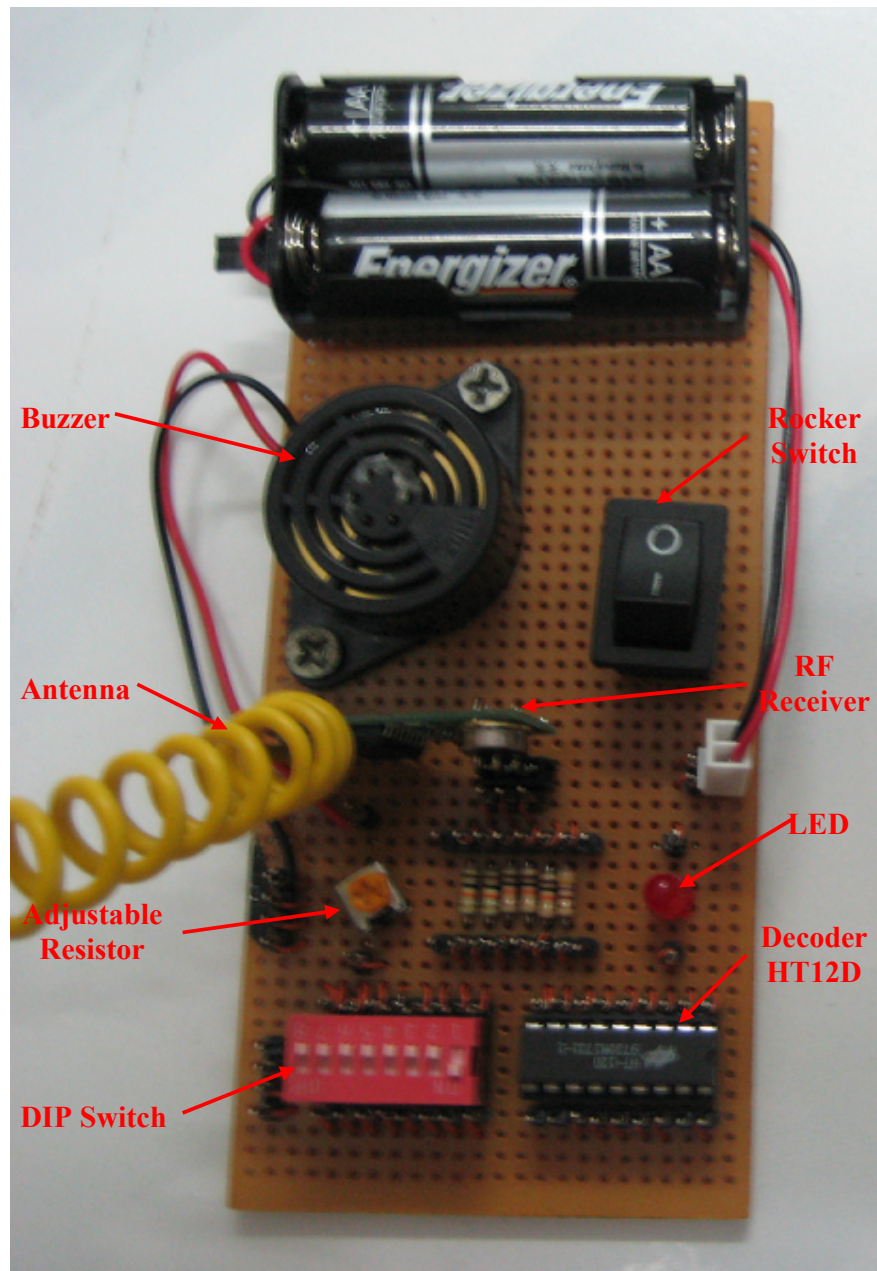
The antenna used is a wire rolled into spring shape adjusted to a length of 18cm as stated in the data sheet. When tested, the distance achieved is approximately 42meters.

4.4 Integrated System Test

During this test, the receiver is placed around 40 to 50 meters away from the transmitter in an open area and close area. The test is successfully conducted in open area although the output of the receiver does not on in a close area due to radio frequency (RF) transmission limitations. Figure 4.3(a) and figure 4.3(b) shows the complete integrated system of the electronic token.



(a)



(b)

Figure 4.3: Integrated System of the Electronic Token (a) Electronic Token: Host (b) Electronic Token: Client

4.5 The GUI Layout

The following figures show the result layout of graphical user interface (GUI). Figure 4.4 shows tab page registration. Figure 4.5 shows the tab page control and figure 4.6 shows tab page about us.



Figure 4.4: Registration Tab Page


Registration Control About Us

No	CustomerName	DeviceNum	Order
1	thama	7	BeveragesRM1.20
2	ashvaany	63	Fresh JuiceRM2.00
3	yanthi	24	Soft DrinksRM1.50

Device Number: ☒ Buzzer On ☒ LED On

Figure 4.5: Control Tab Page

Registration Control About Us

 Thamayanthi Thangavelu
Final Year Project(PSM)-Student
Universiti Malaysia Pahang
Hp No. : 017-5026943

Reference:


 Mr. Mohd Zamri Bin Ibrahim
Final Year Project(PSM)-Supervisor
Universiti Malaysia Pahang
Hp No. : 012-9204243

Figure 4.6: About Us Tab Page

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project has successfully developed an electronic token system using radio frequency (RF) technology. The electronic token is built using PIC18F4550 along with encoder, decoder and Universal Serial Port (USB).

Communication is established through USB using communication protocol. The graphical user interface (GUI) enables the operator to control the electronic token and acquire data to select the particular receiver and output. As for data transfer, it proves that acknowledged protocol communication provides the best data communication reliability.

In addition the analysis and results reveals that the use of electronic token will improve the numbering system applied in banks, food courts, post offices and other places. The electronic token saves time and it is low cost. This device also can be categorized as user friendly by applying the suitable GUI.

5.2 Future Recommendations

Although this project, an electronic token system using radio frequency (RF) technology has been successfully demonstrated, few recommendations and suggestions could be followed and applied for future improvement.

- Add external voltage to the transmitter to extend the range of transmission. Universal Serial Bus (USB) port only provides 5V power supply from personal computer (PC) but transmitter could operate with 3-12V of power supply.
- Amplifier circuit to boost the transmission signal.
- Replace wrapping wire with printed circuit board (PCB) to reduce the size of the electronic token. PCBs are rugged, inexpensive and can be highly reliable. PCBs are much cheaper and faster for high volume production.
- Development on battery monitoring application to always update the host about the battery level of the receiver.
- Development of database system for graphical user interface (GUI) for wider and user friendly application.

5.3 Costing and Commercialization

5.3.1 Costing

Table 5.1 and table 5.2 shows the expenses for this project.

Table 5.1: Host Components' Cost

No.	Component	Specification	Estimate Cost / unit (RM)	Quantity	Estimate Cost (RM)
1	PCB header	40 ways	0.80	6	4.80
2	IC base	40 pin	0.50	1	0.50
3	IC base	18 pin	0.20	1	0.20
4	Crystal	20MHz	1.50	1	1.50
5	LED	Red	0.15	1	0.15
6	Reset switch	4 pins	0.60	2	1.20
7	Doughnut board	10" x 4"	5.00	1	5.00
8	Capacitor	22pF	0.08	2	0.16
9	Capacitor	470F	0.15	1	0.15
10	Resistor	470Ω	0.05	1	0.05
11	Resistor	10kΩ	0.05	7	0.35
12	Resistor	1MΩ	0.05	1	0.05
13	RF transmitter	433MHz	25.00	1	25.00
14	PIC18F4550	40 pins	40.00	1	40.00
15	HT12E	18 pins	4.50	1	4.50
16	Wire	Single core	0.40	1/2	0.20
17	USB port		0.50	1	0.50
TOTAL ESTIMATED COST (RM)					84.61

Table 5.2: Client Components' Cost

No.	Component	Specification	Estimate Cost / unit (RM)	Quantity	Estimate Cost (RM)
1	PCB header	40 ways	0.80	2	1.60
2	IC base	16 pin	0.15	1	0.15
3	IC base	18 pin	0.20	1	0.20
4	LED	Red	0.15	1	0.15
5	HT12D	18 pins	4.50	1	4.50
6	DIP switch	8 ways	3.50	1	3.50
7	Doughnut board	6" x 2.5"	1.60	1	1.60
8	Variable resistor	10k Ω	0.50	1	0.50
9	Rocker switch	2 pins	1.50	1	1.50
10	Resistor	470 Ω	0.05	1	0.05
11	Resistor	10k Ω	0.05	5	0.25
12	Buzzer	3-12V	4.00	1	4.00
13	RF receiver	433MHz	35.00	1	35.00
14	AA battery holder	2 x 1.5V	5.00	1	5.00
15	AA battery	1.5V	2.50	2	5.00
16	Wire	Single core	0.40	1/2	0.20
TOTAL ESTIMATED COST (RM)					63.20

5.3.2 Commercial Potentialities

Electronic token can be commercialized because it can be easily integrated in any application requiring time and cost saving system. Electronic token is cost saving is proved by the calculation above. Electronic token can be implemented in:

- Banks
- Food courts
- Post offices

Figure 5.1 shows the overview of electronic token implementation.

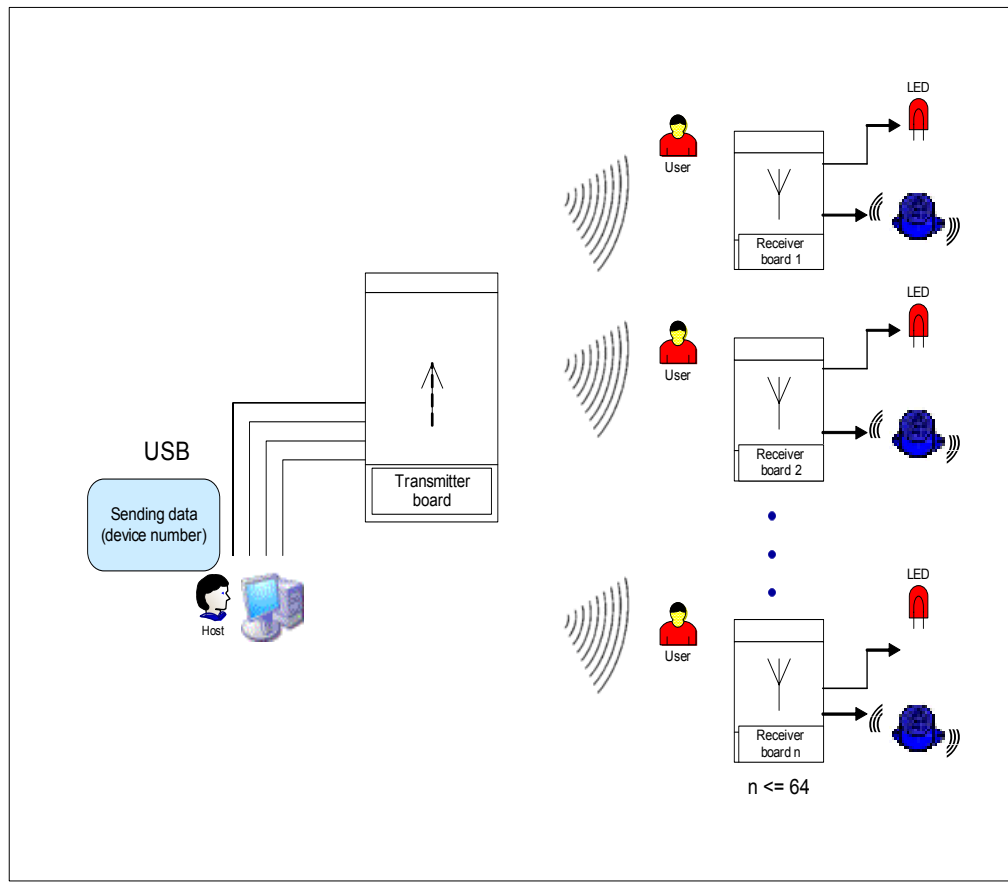


Figure 5.1: Implementation of Electronic Token

REFERENCES

1. Brian K. Lewis (1998). *The Universal Serial Bus*, Sarasota Personal Computer Users Group, Inc.
2. Marshall Brain. *The USB Process*
<http://computer.howstuffworks.com/usb3.htm>
3. B.T.Kelly (2004). *RF Transmitter & Receiver Tips*, btKelly@tpg.com.au
4. CCS, Inc.
<http://www.ccsinfo.com/>
5. Microchip Technology Inc.
<http://www.microchip.com/>
6. Wayne Tomasi (2004). *Electronic Communications Systems: Fundamentals Through Advanced*. 5th ed. Singapore: Prentice Hall.
7. John Rogers and Calvin Plett (2003). *Radio Frequency Integrated Circuit Design*. Artech House Publishing Company.
8. Muhammad Ali Mazidi, Rolin D. McKinlay and Danny Causey (2008). *PIC Microcontroller and Embedded Systems: Using Assembly and C for PIC18*. Upper Saddle River, NJ: Prentice Hall.
9. Stephen Randy Davis and Chuck Sphar (2006). *C# 2005 for Dummies*. Hoboken, NJ: Wiley Publications.

10. Harvey M. Deitel, Paul J. Deitel, Tim Hoey and Cheryl H. Yaeger (2004). *Simply C#: An Application – Driven Tutorial Approach*. Upper Saddle River, NJ: Pearson / Prentice Hall.

APPENDICES

APPENDIX A1

APPENDIX A1

Electronic Token Code Listings

```
//set to 2 to use a PIC's internal USB Peripheral
#define __USB_PIC_PERIF__ 2
#include <18F4550.h>
#fuses HSPLL, NOWDT, NOPROTECT, NODEBUG,
PLL5, VREGEN
#use delay (clock=20000000)
#define USB_CON_SENSE_PIN PIN_B8
// Includes all USB code and interrupts, as well as the CDC API

void main() {

    usb_cdc_init();

    while (!usb_cdc_connected()) {}

    do {
        usb_task();

        printf(usb_cdc_putc, "Device 2call");

        if (bit_test (address, 7))
        {
            output_high (PIN_C0);
```

```
}  
else  
{  
output_low (PIN_C0);  
}  
if (bit_test (address, 6))  
{  
output_high (PIN_C1);  
}  
else  
{  
output_low (PIN_C1);  
}
```

```
if (bit_test (address, 5))  
{  
output_low (PIN_D5);  
}  
else  
{  
output_high (PIN_D5);  
}  
if (bit_test (address, 4))  
{  
output_low (PIN_D4);  
}  
else
```

```
{  
    output_high (PIN_D4);  
}  
if (bit_test (address, 3))  
{  
    output_low (PIN_D3);  
}  
else  
{  
    output_high (PIN_D3);  
}  
if (bit_test (address, 2))  
{  
    output_low (PIN_D2);  
}  
else  
{  
    output_high (PIN_D2);  
}  
if (bit_test (address, 1))  
{  
    output_low (PIN_D1);  
}  
else  
{  
    output_high (PIN_D1);  
}  
if (bit_test (address, 0))  
{  
    output_low (PIN_D0);  
}  
else
```



```
        {  
            output_high (PIN_D0);  
        }  
    }  
}  
} while (TRUE);  
}
```

APPENDIX A2

APPENDIX A2

Microsoft Visual C # 2005 GUI Source Codes

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Text;
using System.IO.Ports;
using System.Windows.Forms;

namespace thama_psm2
{
    public partial class Form1 : Form
    {

        public Form1()
        {
            InitializeComponent();
        }

        private void button3_Click(object sender, EventArgs e)
        {
            if (radioButton1.Checked == true)
            {
                textBox4.Text = label1.Text + radioButton1.Text;
            }

            else if (radioButton2.Checked == true)
            {
                textBox4.Text = label2.Text + radioButton2.Text;
            }

            else if (radioButton3.Checked == true)
            {
                textBox4.Text = label3.Text + radioButton3.Text;
            }

            comboBox2.Items[comboBox2.SelectedIndex].
```

```

ToString(), textBox4.Text));

private void button5_Click(object sender, EventArgs e)
{
    if (checkBox1.Checked == true)
    {
        if (checkBox2.Checked == true)
        {
            textBox6.Text = Convert.ToString (Num1 +
            uiDecimal = Convert.ToUInt32(textBox6.Text);
            serialPort1.Write(textBox2.Text);
        }
        else if (checkBox2.Checked == false)
        {
            serialPort1.Write(textBox2.Text);
        }
    }
    else if (checkBox1.Checked == false)
    {
        if (checkBox2.Checked == true)
        {

            textBox6.Text = Convert.ToString (Num3 +
            serialPort1.Write(textBox2.Text);
        }
        else if (checkBox2.Checked == false)
        {
            serialPort1.Write(textBox2.Text);
        }
    }
}

private void button6_Click(object sender, EventArgs e)
{
    textBox3.Text = "";
}

private void grid_CellContentClick(object sender,
DataGridViewCellEventArgs e)
{
}

private void grid_CellDoubleClick(object sender,
DataGridViewCellEventArgs e)
{
}

private void button4_Click_1(object sender,
EventArgs e)

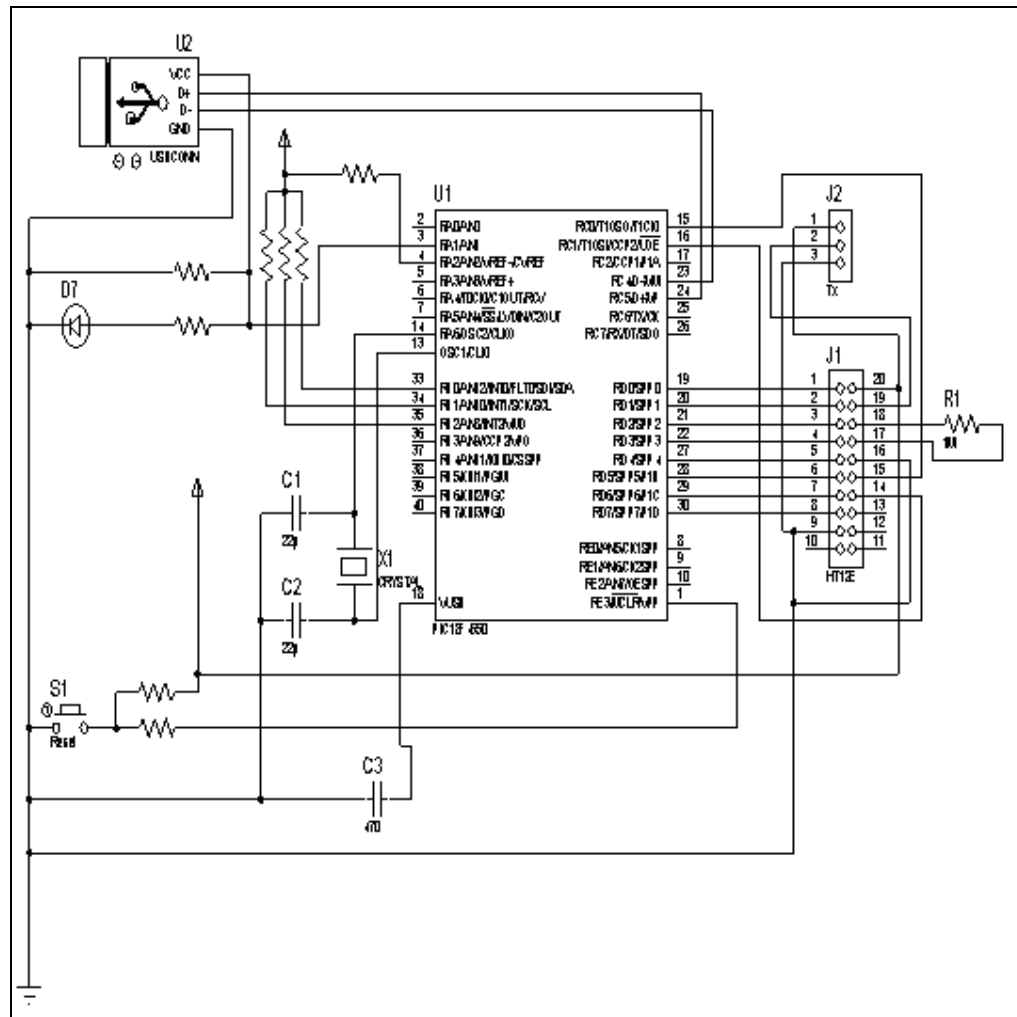
```

```
        {  
            me.Close();  
        }  
  
        private void button7_Click_1(object sender,  
            EventArgs e)  
        {  
            me.Close();  
        }  
    }  
}
```

APPENDIX B1

APPENDIX B1

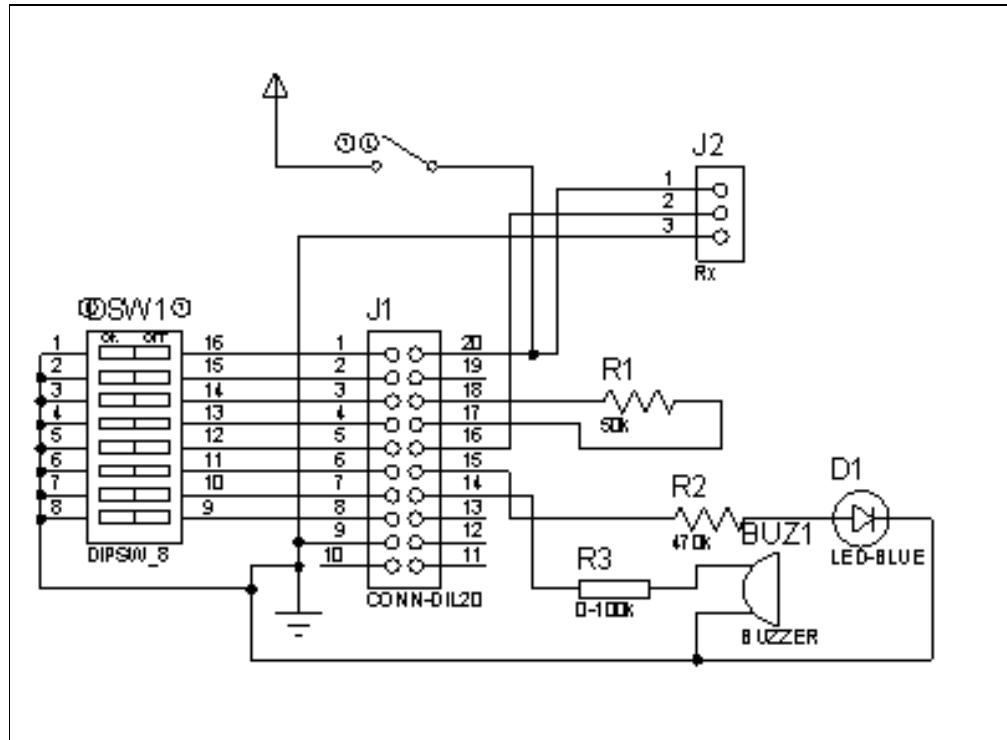
Electronic Token Schematic Diagram – Host



APPENDIX B2

APPENDIX B2

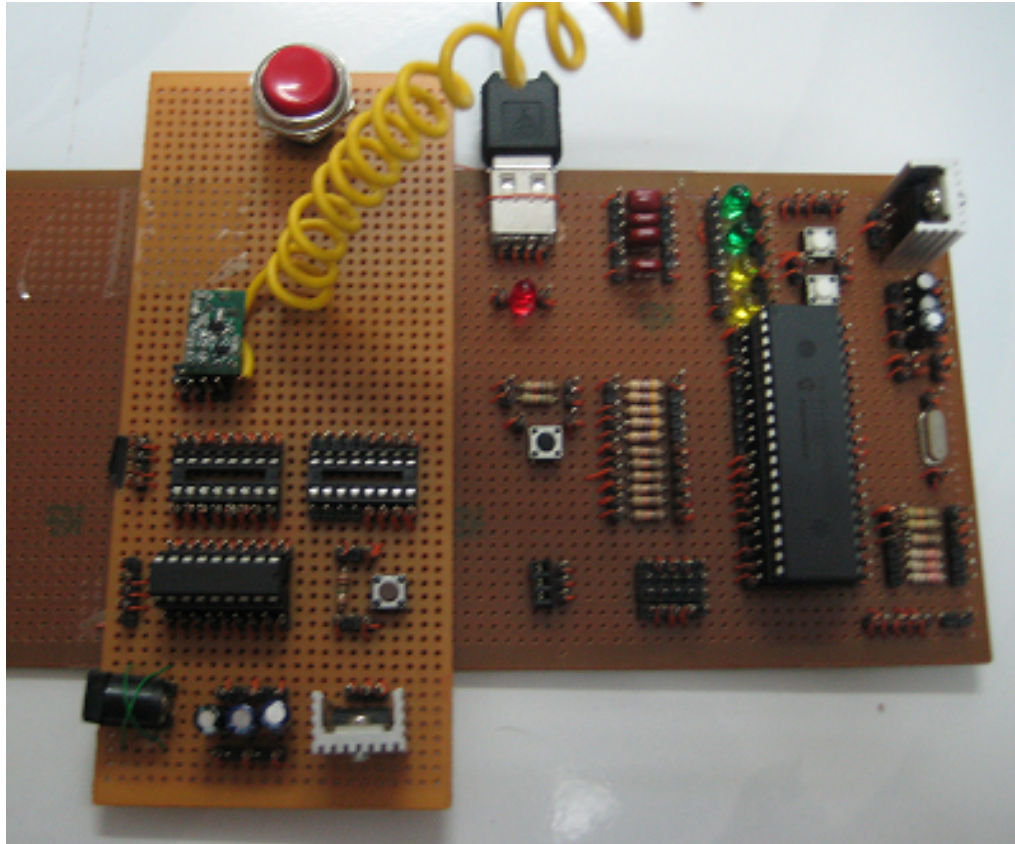
Electronic Token Schematic Diagram – Client



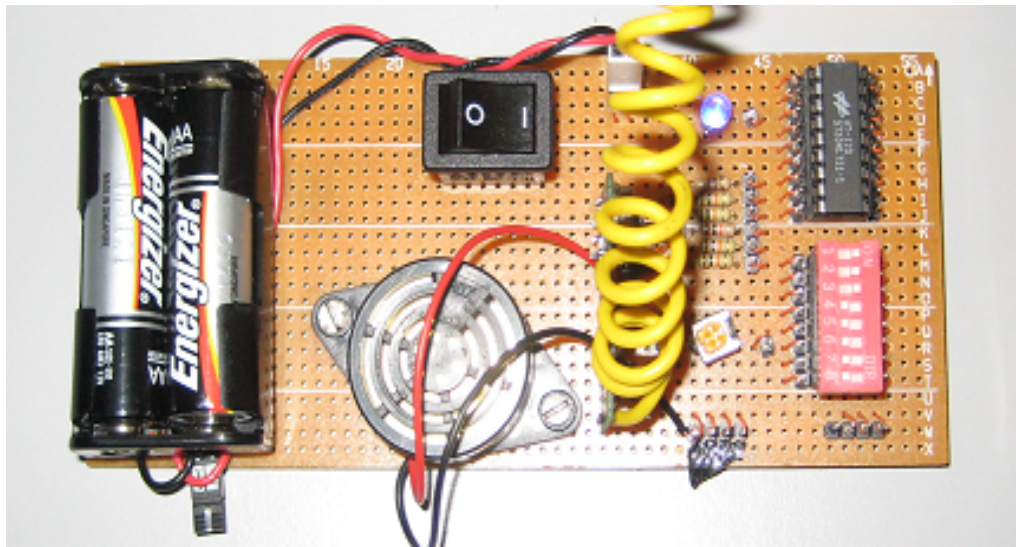
APPENDIX C

APPENDIX C

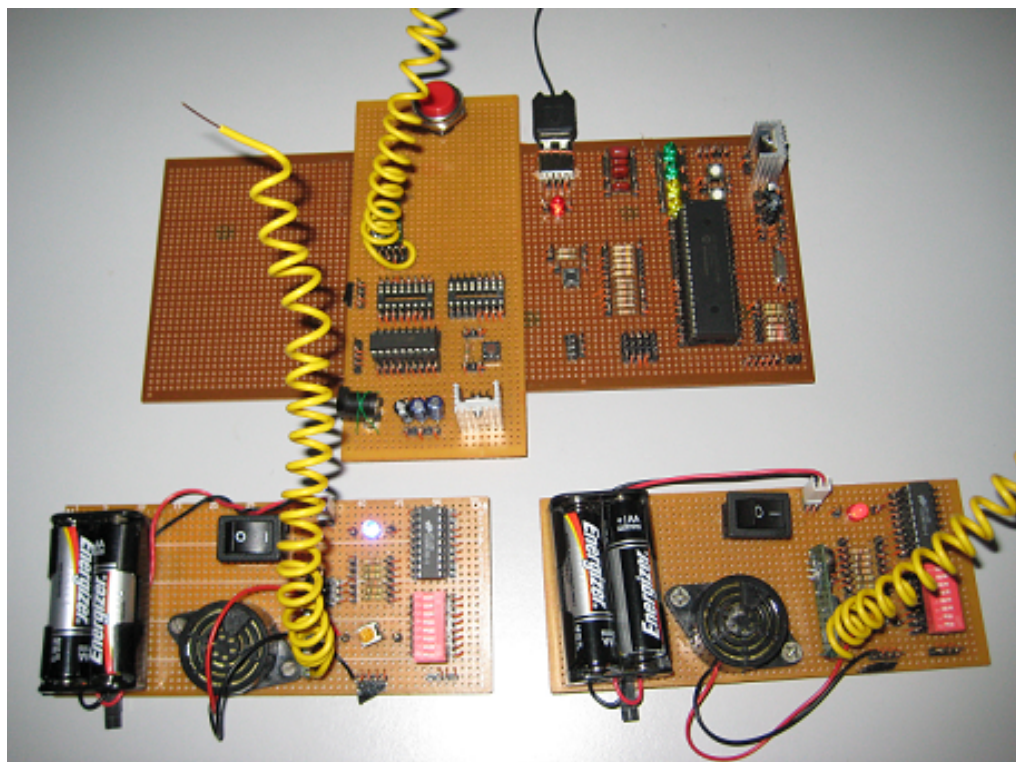
Photos of Electronic Token



Transmitter : Host



Receiver : Client



Integrated Electronic Token System

APPENDIX D

APPENDIX D

Datasheets

PIC18F4550 – Flash 40-pin High Performance Microcontroller with USB

Photograph



Features

Low-Power Features

- RUN: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 μ A typical
- Sleep mode currents down to 0.1 μ A typical
- Timer1 Oscillator: 1.1 μ A, 32 kHz, 2V
- Watchdog Timer: 2.1 μ A typical, 32 kHz, 2V
- Two-Speed Oscillator Start-up

Peripheral Features

- High current sink/source 25 mA/25 mA
- Three external interrupt
- Enhanced Capture/ Compare/ PWM (ECCP) module
- Compatible 10-bit, up to 13-channels Analog-to-Digital Converter module (A/D)
- Capture 16-bit, max. resolution 6.25 ns
- Compare 16-bit, max. resolution 100 ns
- Dual analog comparators

Special Microcontroller Features

- Priority levels for interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Priority levels for interrupts
- 100,000 erase/write cycle Enhanced FLASH program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory
- Wide operating voltage range: 2.0V to 5.5V
- Single supply 5V In-circuit Serial Programming via two pins
- In-Circuit Debug (ICD) via two pins

Oscillators

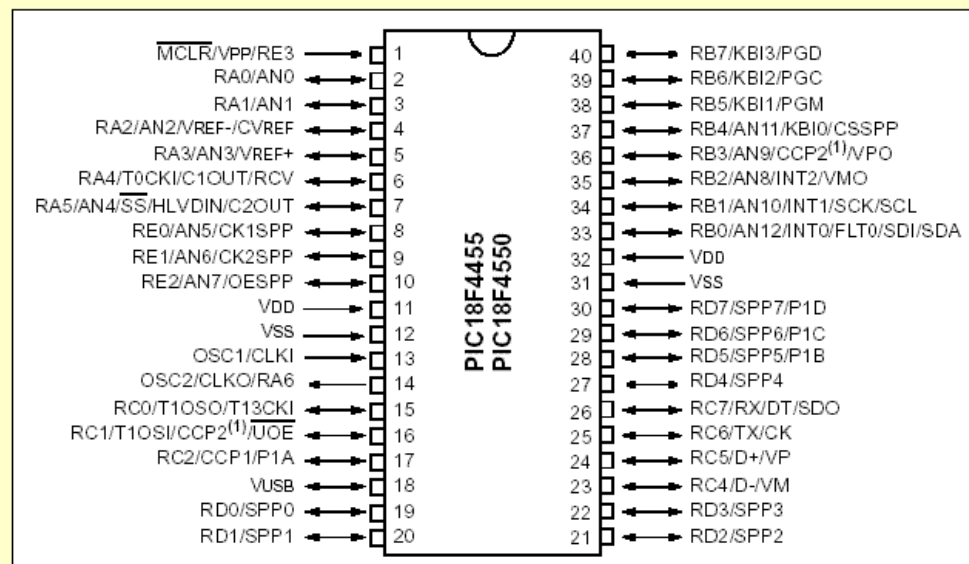
- Four Crystal modes
- Two external Clock modes, up to 48 MHz
- 8 user-selectable frequencies
- Secondary oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor

Pin Description	
Pin Number	Description
1	MCLR/VPP
2	RA0/AN0
3	RA1/AN1
4	RA2/AN2/VREF-/CVREF
5	RA3/AN3/VREF+
6	RA4/T0CKI/C1OUT/C2OUT
7	RA5/AN4/SS/HLVDIN/C2OUT
8	RE0/AN5/CK1SPP
9	RE1/AN6/CK2SPP
10	RE2/AN7/OESPP
11	VDD
12	VSS
13	OSC1/CLKI
14	OSC2/CLKO/RA6
15	RC0/T1OSO/T13CKI
16	RC1/T1OSI/CCP2/UOE
17	RC2/CCP1/P1A
18	VUSB
19	RD0/SPP0
20	RD1/SPP1
21	RD2/SPP2
22	RD3/SPP3
23	RC4/D-/VM
24	RC5/D+/VP
25	RC6/TX/CK
26	RC7/RX/DT/SDO
27	RD4/SPP4
28	RD5/SPP5/P1B
29	RD6/SPP6/P1C
30	RD7/SPP7/P1D

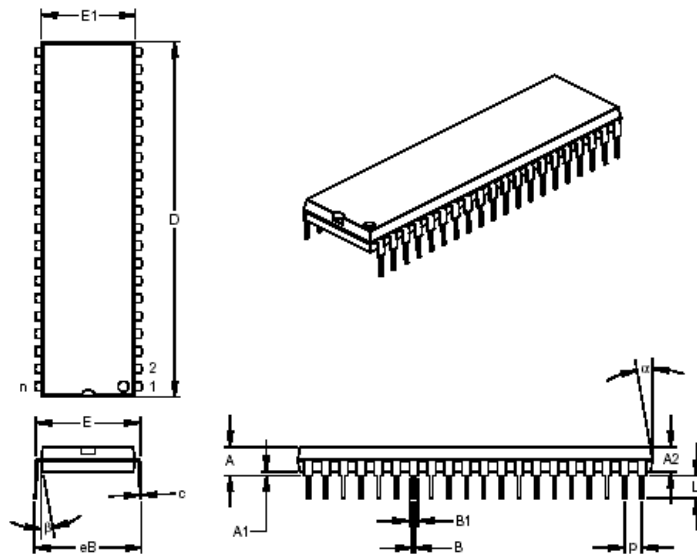
32	VDD
33	RB0/AN12/INT0/SDI/SDA
34	RB1/AN10/INT1/SCK/SCL
35	RB2/AN8/INT2/VMO

32	VDD
33	RB0/AN12/INT0/SDI/SDA
34	RB1/AN10/INT1/SCK/SCL
35	RB2/AN8/INT2/VMO
36	RB3/AN9/CCP2/VPO
37	RB4/AN11/KBI0/CSSPP
38	RB5/KBI1/PGM
39	RB6/KBI2/PGC
40	RB7/KBI3/PGD

Pin Layout



Dimensional Drawing



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		40			40	
Pitch	P		.100			2.54	
Top to Seating Plane	A	.160	.175	.190	4.06	4.45	4.83
Molded Package Thickness	A2	.140	.150	.160	3.56	3.81	4.06
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.595	.600	.625	15.11	15.24	15.88
Molded Package Width	E1	.530	.545	.660	13.46	13.84	14.22
Overall Length	D	2.045	2.058	2.065	51.94	52.26	52.45
Tip to Seating Plane	L	.120	.130	.135	3.05	3.30	3.43
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.030	.060	.070	0.76	1.27	1.78
Lower Lead Width	B	.014	.018	.022	0.36	0.46	0.56
Overall Row Spacing	§ eB	.620	.660	.680	15.75	16.51	17.27
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

* Controlling Parameter

§ Significant Characteristic

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-011

Drawing No. C04-016