

Development of Electrical Appliance Controlling System using Bluetooth Technology

M. Shafanizam, Y. Z. Arief, Z. Adzis

Abstract—The use of electronic controllers for controlling electrical home appliances can be found widely around the world especially in the developed countries. By time, wireless technology such as infrared light communication. This wireless technology is widely commercialized and can be found almost anywhere. Though appealing, it still has a weakness due to the use of infrared light as data transmission medium. When there are objects blocking the infrared receiver, the process of controlling those electrical appliances becomes difficult due to the point-to-point or line-of-sight communication mode. From this situation, came the idea to create a wireless electronics control system utilizing Bluetooth technology for data transfer and control of electrical appliances. PIC 16F877A microcontroller acts as a “brain” for this system in executing the tasks and operations according to the user’s wish. This system’s Graphical User Interface (GUI) is developed using Microsoft Visual Basic Express to enable the user to control and understand the system in controlling electrical appliances easily.

Index Terms—Bluetooth, Graphical user interface (GUI), Microsoft visual basic express, PIC Microcontroller.

I. INTRODUCTION

Rapid development of electronics has brought many benefits in our daily lives. Tasks have been made easier; thanks to the aid of electronic devices that was developed and invented to ease our daily lives. In the past, most of the appliances like fan, lamps and so on are connected to their controllers or switches through wires or cables. Then, the infrared controller is utilized as the improvement for controlling those appliances. Currently, we can see many of such appliances in the market with the different designs and brands. Since then the wireless technology has started to be used widely in the electrical appliance’s control method. We noticed that the infrared (IrDA) is a point-to-point communication type. If there are things blocking the infrared receiver, we cannot control the appliances. Then, another wireless technology was developed which is Bluetooth technology to overcome that problem. Hence, the Bluetooth technology was implemented in order to ease the control appliances without any interruption. Many related research works utilizing Bluetooth technology for home appliance controlling system have been reported during this decade [1-4]. Most of those works based on mobile phone operation system. In this project, we utilized personal computer for electrical appliance controlling system.

In this project, a system that uses the application of

wireless Bluetooth as data transfer medium is being built. “Bluetooth Appliances Control System” is a development to further enhance the infrared remote control systems.

Generally, this system is related on how to control any objects like appliances and machines. A Personal Area Network (PAN) would be created in order to control the appliances. This PAN uses the Bluetooth as the medium of communication. Nowadays, almost every equipment and machine has their own control method in order to run or operate them. This method of controlling through Bluetooth can in particular be implemented in high voltage equipments. Ozone water treatment is an example that needs high voltage supply and high voltage circuit breaker. In ozone water treatment, initial process is the molecule of Ozone; O_2 must be isolated or separated to become atom O- by injecting the high voltage power supply. So, the manual control is improved to Bluetooth wireless technology replacing cables in order to inject the high voltage.

The main objective for this project is to design and develop a system for electrical appliances which is easier and simple to control. Using a laptop and Bluetooth as the medium of data transfer to the custom designed of appliances, the user can simply switch on or off those appliances on the laptop to switch the appliances on or off. Another objective is to control the electrical appliances at the certain distance using wireless without having to manually switch those electrical appliances on or off. This system is suitable to be used in room, lecture halls, laboratories, offices and hotels.

II. DEVELOPMENT OF OPERATION SYSTEM

The development of this project is divided into two main parts; the first part is the development in the laptop or computer as the controller for this project. The second part is the development of a Bluetooth server unit where the function that is selected by the user would be received. The second part of development has three subsets which would be the Bluetooth component, the PIC 16F877A microcontroller unit and the relay circuit. Windows application shall be used as the background operating system to develop a graphical user interface (GUI) for the system. Microsoft’s Visual Basic Express Edition is used as GUI application for the Bluetooth system. The computer would receive input from the user through the GUI that will be developed which will then process the input data and transfer it to the display unit using Bluetooth connection [5].

The receiver (a Bluetooth server) that is connected to the appliance will receive the input data that was sent by the computer and then would transfer it to the microcontroller. The input received by the microcontroller would be characters that are coded in the ASCII code. Those ASCII codes need to be the same characters with the ASCII code that one already programmed into microcontroller. Thus, the microcontroller would produce the output according to the user's wish. Fig. 1 shows the flow diagram of the system which explains in general how the system operates.

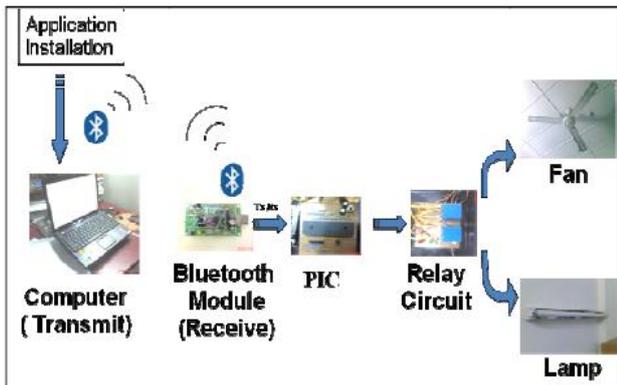


Fig. 1 Flow Diagram of Developed System.

III. HARDWARE DEVELOPMENT

A. Bluetooth Module

Diagram in Fig. 2 shows the steps taken in developing the hardware. It started off with information searching or literature study followed by acquiring the components needed, and then circuit design to the component soldering on the strip board. The main problem in the hardware development is the circuit design for the whole system. They are the Bluetooth module, the microcontroller PIC 16F877A board and finally the voltage regulator circuit. The KC21 Bluetooth is a wireless communication Bluetooth chip that is assembled and ready to be used. This module is equipped with internal antenna which is graded as a 2nd Class Bluetooth chip. The operational range for this module is up to 10 meters and needs a power input of 3.3 volts (DC) to make it functional. It has 14 slots (input/output) for general purpose and can support point to point Bluetooth connection and point to multipoint Bluetooth connection. Fig. 3 shows the pins that are on the KC21 Bluetooth chip [5].

The main component in the Bluetooth circuit is the Bluetooth module produced by KCWirefree; model KC21 that plays the primary role in this circuit. The Bluetooth device circuit has 3 resistors and two capacitors that act as the supporting components for this Bluetooth Module circuit [5]. This KC21 module Bluetooth needs a power supply of DC 3.3 volts to be in operational condition. As it is shown in Fig. 4, pin numbers 3, 23 and 24 are connected to the power supply of 3.3 volts. The two pins that play the main role of transferring data that is received from the microcontroller are pin 6 (TXD) and pin 8 (RXD).

Pin TXD on module Bluetooth KC21 will be connected to pin RX2 on the microcontroller PIC 16F877A unit, and pin RXD on the Bluetooth module KC21 will then be connected to pin TX2 on the microcontroller. The cross connection is made between the pins which is specialized for communication between the Bluetooth module and PIC 16F877A.

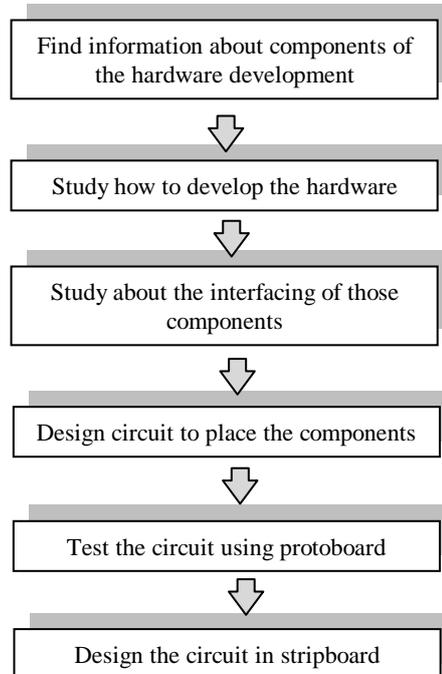


Fig. 2 Flowchart of Hardware Development.

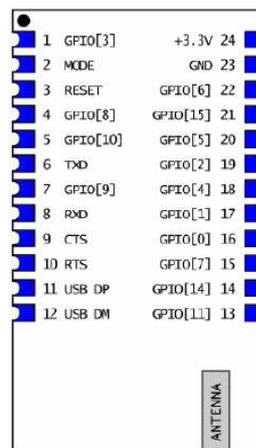


Fig. 3 Bluetooth KC21 Pins. [9]

B. Microcontroller

A microcontroller can be classified as a single chip computer, because all of the basic integral things that a computer needs are being provided in a single chip. The microcontroller is designed to function similar to a basic personal computer. One of its most important ability is the fact that it can store and run a program. Other than that it has a CPU (Central Processing Unit), ROM (Read Only Memory), EEPROM (Electrical Erasable Programmable Read Only Memory), I/O line (Input/Output), parallel and

serial socket, timer and some microcontroller. It even has a built in analog to digital converter.

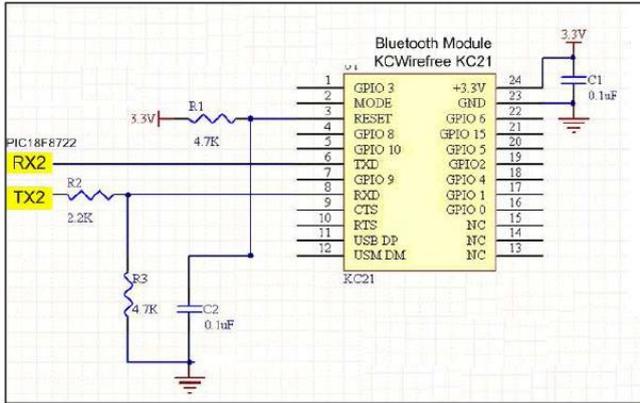


Fig. 4 Bluetooth KC21 circuit [10]

In this project the PIC 16F877A microcontroller was chosen. It is an 8 bit chips and the simple one microcontroller. The entire PIC family microcontroller has an RISC processing architecture which is built of high performance. The PIC has a large number of registers thus it makes programming easier and it also enhances its performance. The advantage of the PIC 16F877A is that it can reduce the use of external components. This indirectly saves costs and also enhances its reliability as external components are more exposed to wear and tear [5]. This chip operates at the speed of DC clock input 20MHz and each instruction cycles takes about DC 200 nanoseconds.

Another advantage of this microcontroller is that it has a Flash Program Memory and it also has an EEPROM data that has the ability to rewrite the program that has already been written in the EEPROM. This microcontroller contains 256 bytes EEPROM Data and this Flash Program Memory enables the user to erase and write the program up to a thousand times. While the EEPROM enables the user to erase and write programs in it up to a massive 1 million times. This shows that the program can be updated and edited without the need to remove the microcontroller from its socket. Fig. 5 shows the pins schematic for the PIC 16F877A. This type of PIC has up to 40 pins. The other pins are used for clock, timer, power input, interrupt and earth/ground. This microcontroller uses a Harvard architecture where the program and data transfer is done by different memories. This is because the PIC memory is divided into two main parts which is the data memory and program memory. Different bus lines are used to enable both of this memory to communicate with one another. Apart from the advantage of the Harvard architecture is that both of the busses can be used simultaneously in the same clock cycle.

In this architecture memory management is divided into two as follows [1].

- 1) Memory data
- 2) Program memory or Flash Program Memory

Fig. 6 shows the block diagram for the internal architecture of PIC 16F877A microcontroller. Referring to the figure, there are three main blocks in the internal

architecture of the microcontroller [5].

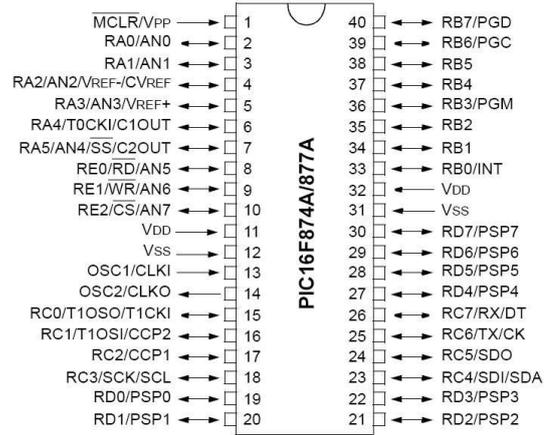


Fig. 5 PIC 16F877A Pin Configuration [8].

Those three main blocks are

- 1) Flash Program Memory
- 2) Random Access Memory
- 3) Electrical Erasable Programmable Read Only Memory

The first part in the internal architecture of the PIC 16F877A microcontroller is the Flash program memory. The Flash program memory is used to store programs. The advantage is that it can be reprogrammed up to a thousand times. The program that is stored in here will not be erased when the power is cut off.

The second part of the internal architecture of the microcontroller is the file register for the RAM (Random Access Memory). The size of this register is 368 bytes, the data inside it will be erased once the power supply is cut off but it has no limitation to the number of times it can be rewritten [5]. This memory is divided into two sections:

- 1) Special Function Registers (SFR)
- 2) General Purpose Register (GPR)

The third section of the internal architecture of this microcontroller is the EEPROM. This microcontroller has 128 or 256 bytes of data EEPROM with an address range from 00h to FFh. The program that has been written into it will not be erased when the power supply is cut off and it can be erased and rewritten up to a million times [5].

The memory data for EEPROM can be written and read during normal operations which are in the range where VDD is full. This memory is not directly mapped into the register files but indirectly addressed to the SFR (Special Function Register) [5]. Four types of SFR used for reading and writing memories are as follows.

- 1) EECON1
- 2) EECON2
- 3) EEDATA
- 4) EEADR

EECON 1 is the control register for the EEPROM while EECON2 is the protection writing register for the EEPROM. EEDATA provides the space to store data that has the size of 8 bits. EEADR meanwhile is the address marker for the EEPROM.

EEPROM data memory allows read and write bytes. If the written bytes are activated then it will automatically erase the old location and thus installs new data. This technique is known as the erase first old data before entering the new data. The writing period is controlled by an on chip timer and it changes according to the voltage, temperature and differs from chip to chip. For components that have a classified code, the CPU can still continue the process of reading and writing in its EEPROM memory [5].

it would enable the programmed that has been burned into the microcontroller to be reset.

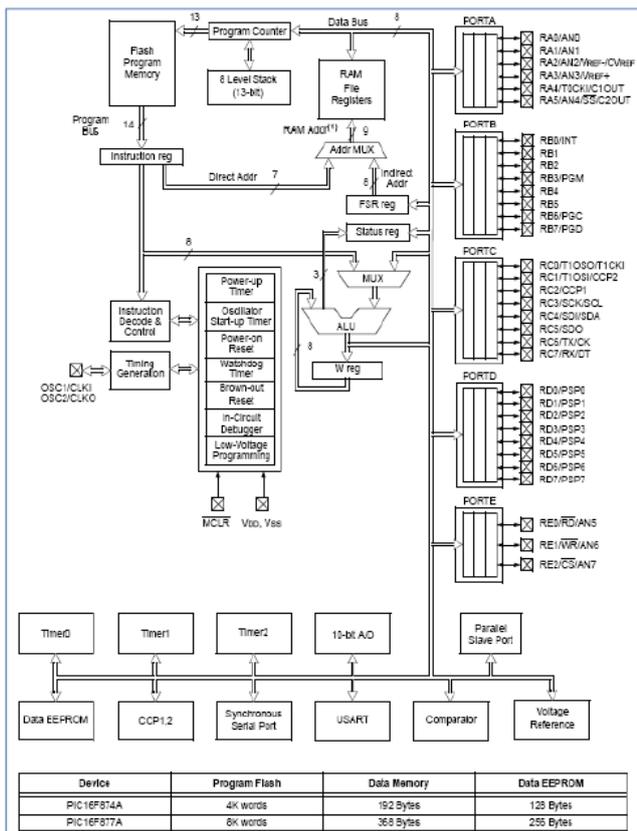


Fig. 6 PIC 16F877A Block Diagram [8].

Fig. 7 shows the complete circuit of PIC 16F877A microcontroller circuit. The complete circuit consists of one PIC 16F877A microcontroller chip, a rest circuit, an oscillator circuit, and also a capacitor. Referring to the figure, signal from pin RXD and TXD on the module Bluetooth circuit will be connected to pin TX2 and RX2 on the G port of the PIC microcontroller which is also pin 6 and 7. PIC microcontroller would then read and process the data to identify the display text that was inserted by the user. All of the codes for the display process has been programmed initially and stored in the PIC memory bank [5]. In the PIC 16F877A microcontroller connection as shown in Fig. 7 several sensitive pins needs to be treated with great care in order to avoid misconnections which might damage the PIC. The VDD pins are connected to a regulated power supply of 5 volts. The incoming 5 volts are generated by using the LM 7805 chip which is also a built in integrated voltage regulator. VSS on the other hand would be connected to earth [5]. Connection for the MCLR pin or RESET pin is vital for

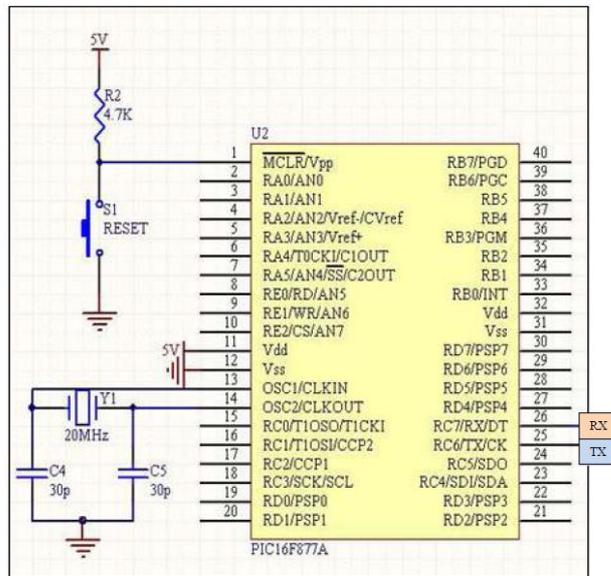


Fig. 7 PIC 16F877A Microcontroller Circuit [6].

This pin is an active-low pin thus it is connected to a high logic switch (5 volts) so that it will be in open circuit mode. If the user needs to reset the push on button will cut off the 5 volts supply thus an active low is connected to the pin thus resetting the program. The reset button circuit is also shown in Fig. 7 [5]. OCS1pin is connected to the 20 MHz crystal to generate the E clock signal. The signal will be generated continuously at the rate for 1/4 of the frequency of the signal, since the crystal that is used in this project is 20 MHz, hence [5]:

$$1E\text{-clock} = 20\text{MHz}/4 = 5 \text{ MHz}$$

$$1\text{clock cycle} = 1/5\text{MHz} = 0.2\mu\text{s}$$

The oscillating circuit in this project is also shown in the Fig. 7. RX and TX pins are connected to the Bluetooth module KC21. These pins are necessary for data transaction between the Bluetooth and the microcontroller [5]. The data that is received by the Bluetooth server from the laptop in this system will be transferred to the microcontroller using these two pins.

C. Relay

In this project, the relay is to make isolation between the lower outputs of microcontroller (5VDC) and the higher output of the appliances voltage source (240VAC). The SPDT relays that are used are just only SRD 5VDC. Fig. 8 shows the picture of relay SRD 5VDC which is used in this project. Relay consists of five pins which are Positive Coil Pin, Negative/ Ground Coil Pin, Normally Open (NO), Normally Close (NC), and Common (C). Figs. 9 and 10 show the connection of the relay to the electrical appliances and other components. Pins NO for both relay are connected to the lamp and fan respectively.



Fig. 8 Relay SRD 5VDC. [10]

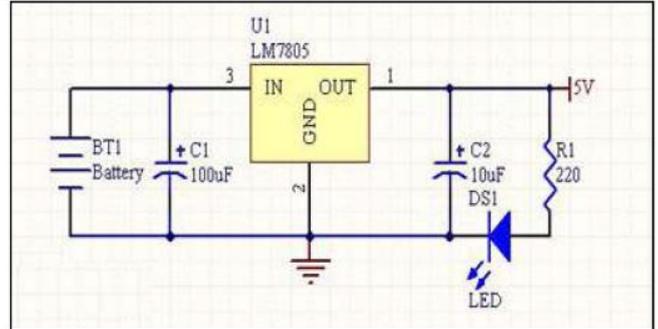


Fig. 11 5 V Voltage Regulator Circuit [10].

D. Voltage Regulator

In this project, there are two voltage regulator circuits that are designed for an output for 5 volts and for a 3.3 volt output. The PIC 16F877A microcontroller needs an input of regulated DC 5 volts to operate while the Bluetooth KCWirefree module KC21 needs an input of regulated 2.2 volts DC to operate [5]. The LM7805-5 volt voltage regulator circuit is used to get the regulated stable 5V DC output. The connections for the LM7805 voltage regulator can be seen in Fig. 11. For the output regulated voltage of 3.3 volts the REG104FA-3.3KTTT is used as shown in Fig. 12 [5].

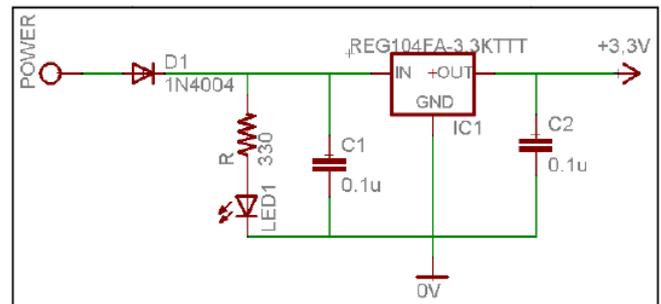


Fig. 12 3.3 V Voltage Regulator Circuit [5].

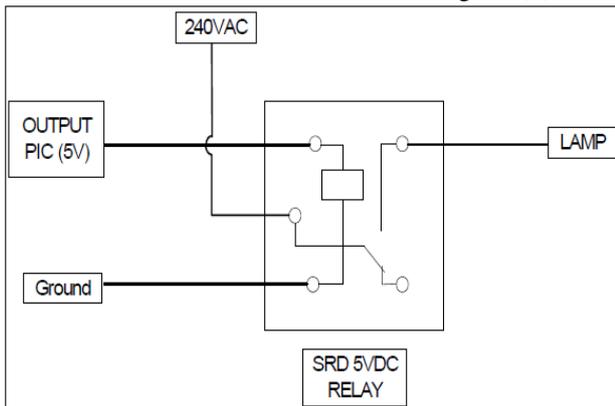


Fig. 9 Relay Connection for Lamp

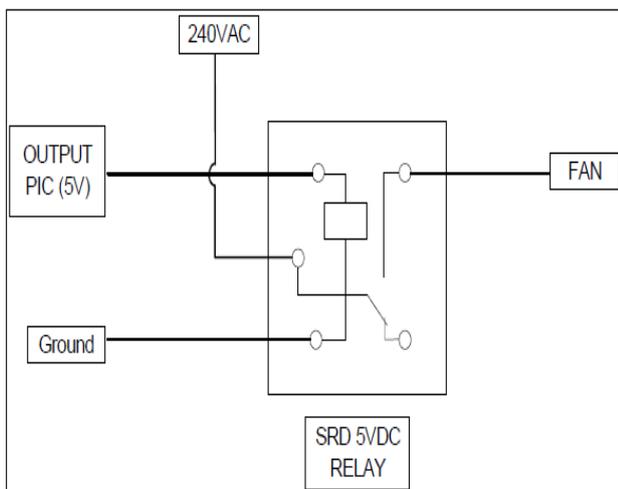


Fig. 10 Relay connection for fan

The input voltage for both of this regulator chip must be at least 8 volts. Apart from getting a stable 5V and 3.3V regulated voltage, these voltage regulator IC can be used to cut down the risk or component damage due to excessive current and voltage coming from an unstable power supply. The LM 7805 and REG104FA-3.3KTTT is equipped with suitable heat sinks to dissipate excessive heat that is generated during the regulation process thus cutting down significantly the risk of having the regulating IC's damaged [5].

IV. SOFTWARE DEVELOPMENT

To enable the system (hardware) running, the microcontroller needs to be programmed first. This is because the PIC 16F877A microcontroller acts as the control panel that would control all the operation in the display system. The output "ON" and "OFF" of the appliances also depends on the PIC programming. The software development process for the whole project can be divided into two main sections. The first is the development process in programming the C language for the PIC 16F877A and the second section is the development process for the Graphic User Interface (GUI) design for the system. In order to program the PIC 16F877A microcontroller work, two software which are used in this project namely Micro Software and WinPic800. To develop the GUI, Microsoft Visual Basic Express Edition is used. This software is used to design the whole GUI system.

A. Visual Basic Express

Generally, Visual Basic is one of the computer's programming languages that enable communication with computers. Visual Basic is also known as a development tool that can be used by programmers to create any application especially for the windows operating system (OS) [7].

In this project, Microsoft Visual Basic Express is used to develop the GUI. All of the interface design which includes the programming, control buttons and other peripherals is done using this software. Microsoft visual basic express has one very important feature that is needed in the development for the GUI system, namely Microsoft Serial Port. Serial Port uses active-X technology creates a serial data communication platform for the hardware and computer that will be used by the GUI. Serial Port can hold both process of data transaction serially whether it is transmitting data or receiving it. Through this function the data inserted by the user on the GUI can be compiled and sent to the project hardware through the serial port of the computer [5].

B. MicroC software

Before the program that was written in C language is downloaded into the EEPROM of the PIC microcontroller, firstly needs to be compiled into a hex file. These hex files is a machine code that the microcontroller can understand thus to upload the program into the EEPROM the assembly language must be changed into hex files using WinPic800 software. The microC software serves as a platform to further enhance the usage of their PIC microcontrollers. This software is pretty simply and the complex programming can be done here depending on the creativity of the programmer [5].

C. WinPic800 software

To enable the written program to stay permanently in the internal EEPROM of PIC 16F877A, special software is needed. The software is called WinPic800. The Serial Communication Interface (SCI) is still used in the data transaction from the computer to the PIC 16F877A. The user needs to key in the name of the file that needs to be compiled using microC software.

One of the most basic things that one must do when using this software to upload the program into the PIC 16F877A microcontrollers is to ensure that the communication port on the computer and the microcontroller circuit is securely connected. This WinPic800 software will then detect if there is communication between the computer and the microcontroller. Once confirmed, the next step is to set the starting address and the end address of the EEPROM to be used [5]. The EEPROM needs to be fully erased first before any program can be downloaded into it. This is to avoid any clashes and error during the process of downloading the program into the EEPROM. Once the downloading process is done, the microcontroller is ready to be connected to the components that it needs to operate and run the program that is written in the EEPROM [5]. Fig. 13 shows the front page of Win Pic800 software

D. Graphic User Interface

The graphical user interface (GUI) is a very important section of this project because through this interface, the system displays the entire function controller. The users only need to click the button that is located in the GUI in order to switch “ON” or “OFF” the lamp and fan of the developed model. Fig. 14 shows the GUI for this system. On the GUI system as shown in Fig. 4, there are three main parts, namely Baud Rate, Com Port Enabled, and Function Button “ON” and “OFF”. Not forgetting the buttons that is setting the Com Port for security reason ‘Com Port Setting’. This system use Com Port number 4 and Baud rate is about 115.2 kbps. The “ON” button will send the signal to the Bluetooth server and this server would switch “ON” the lamp or fan according to the user, while vice-versa for the “OFF” button . The Bluetooth server would switch “OFF” the lamp or fan after this server receive the signal from “OFF” button.

The extra functions; OFF Delay 5s and OFF Delay 10s are used in order to make the delay time in switching off the lamp or fan. In other words, if user would like to switch off the lamp after 5s, so he or she just only clicks on this button. In this project, the delay button is set to be 5s and 10s but at the real world, this function more reliable by setting about 5 minutes and above.

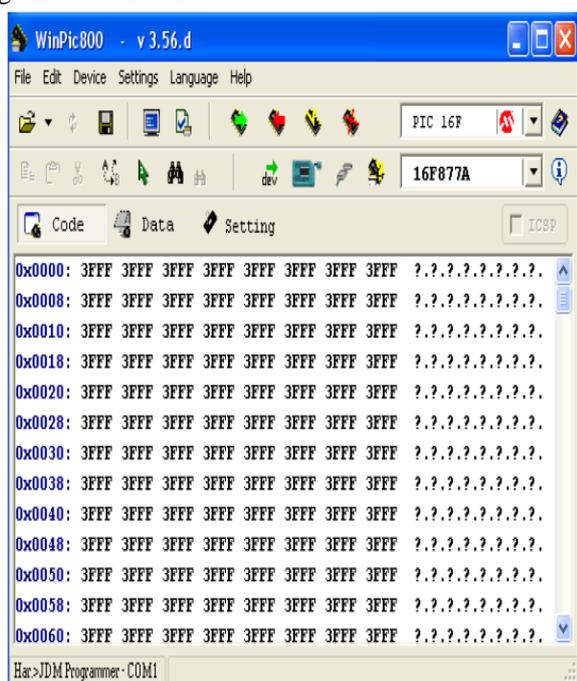


Fig. 13 Winpic800 Software

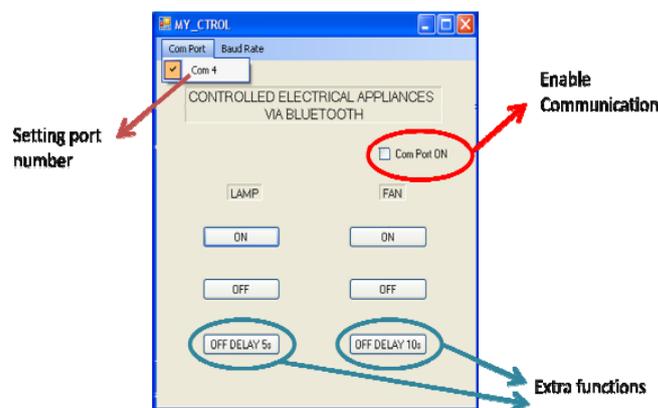


Fig. 14 The Graphical User Interface (GUI) of this project

V. MODEL OF ELECTRICAL APPLIANCES, SYSTEM DEVELOPMENT, AND TESTING

The electrical appliances, such as 240 VAC lamp and fan are modelled as 12 VDC lamp and fan in this project. This model is used in order to make the development, testing and troubleshooting simpler. Actually, the Bluetooth module in this project is capable to connect to the 240 VAC when used with a relay that can support the 240 VAC source at its Normally Open (NO) pin. Fig. 15 shows the appliances model developed in this project.

A. Bluetooth server

The Bluetooth server is another important part instead of Graphic User Interface (GUI). This server act as the “brain” of the system which receives the signal from computer or laptop and then it acts according to the user’s wish. This server has three important parts which are the Bluetooth module, PIC16F877A and relay connection to the appliances. Figs 16, 17, and 18 show the physical figure of the Bluetooth server.

B. System Testing

Once the design process has been completed and both the hardware and software development is done the project moves onto the next phase. In this phase this is where testing is being done to assess the result of this project and to analyze whether the project had achieved the objectives. The testing process covers all the system designed and explained in previous chapters starting from software testing to hardware testing.

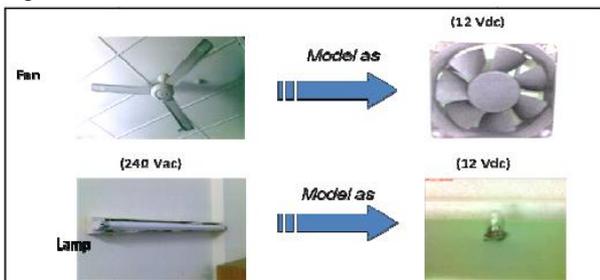


Fig. 15 Model of appliances

The testing process includes all of the circuits that were designed such as the module KC21 circuit, PIC 16F877A microcontroller circuit, relay connection and the voltage regulator. Software testing process involves running the GUI that was developed using Microsoft Visual Basic Express. The GUI will be tested by analyzing whether it operates according what the system needs. Software testing usually involves whether the hardware operates according what the software tells it to do. The microcontroller programming that was written in C language is also tested in order to eliminate any possible bugs that may create problems when the whole system runs [5].

These testing process are done in phases so that it would be easier to detect problems and troubleshoot easier. Once completed, it is time to test the system as a whole. This final phase will determine whether this project succeeds. In this phase the testing is done by assuming that a user is going to

use the system and whether the lamp or fan can be switch “ON” or “OFF”.

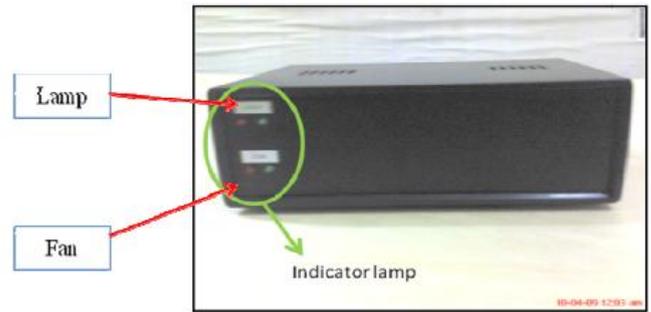


Fig. 16 Front view of Bluetooth server

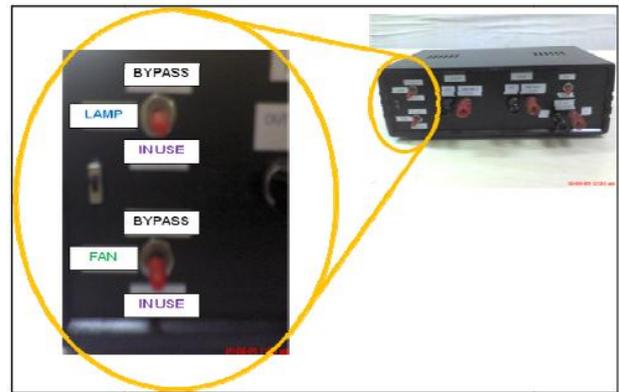


Fig. 17 Rear view of Bluetooth server

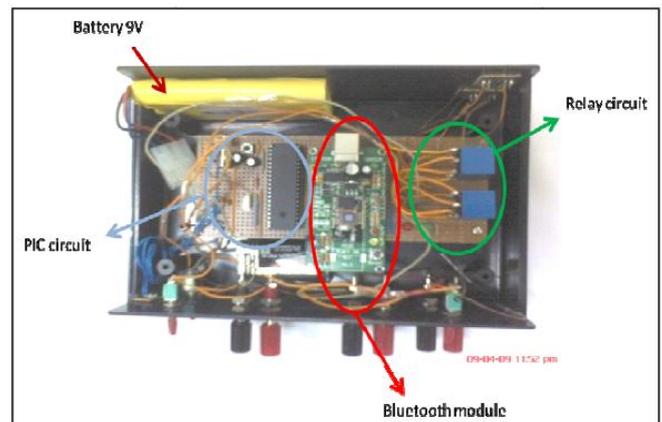


Fig. 18 Inside view of the Bluetooth server

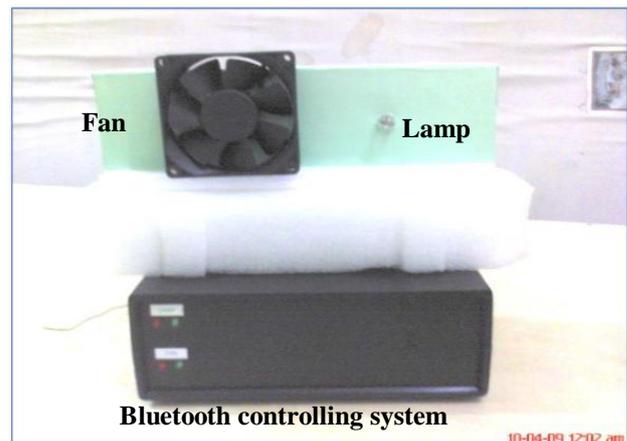


Fig. 19 The Complete Bluetooth Controlling System

After going through several phases of design, development and testing, finally the Bluetooth Appliances Control System has been successfully built and completed. This system can be operated at a radius of up to 20 meters. Fig. 19 shows the picture of the whole system which includes Bluetooth server and model of electrical appliances.

VI. CONCLUSION

The Bluetooth controlling system has been successfully built and has met the objectives. The final testing and troubleshooting phase shows that the overall scope of project has been achieved although with the existence small errors. This project covers the design, development and the testing process in a very satisfactory manner which applies to all of the engineering knowledge, techniques, skills and ethics. During the development of this project, a lot of energy, effort, and time and brain power has been spent in the designing phase. The whole system works very well which includes the Bluetooth server design, the development of the interface between microcontroller and Bluetooth module, the troubleshooting and merging between the software and hardware, the development of the GUI and also the C language programming for microcontroller. The data transactions for this project also work well and are reliable. However, the delay time does not function well as the Bluetooth chip did not operate at its optimum performance due to some requirement of the Bluetooth module not fulfilled during testing.

As an improvement, the Bluetooth chip could also be upgraded by replacing it with a much more reliable Bluetooth chip (and more expensive) so that it can further stabilize the data transaction between the computer and the system. Currently the KC21 Bluetooth chip is a class 2 Bluetooth (20 meters communication) and the system could use an upgrade of a class 1 Bluetooth chip which is can communicate within 100 meters. Apart from that the system can further be enhanced by developing it for controlling more appliances instead of two appliances due to the capabilities of the PIC 16F877A has 28 pins that can be declared as output. Besides, nowadays there are other microcontroller types or brands in the market that has many pins that can be used as output.

Last but not least, it can be improved by making the Bluetooth server able to read the value and data of certain parameters such as temperature, level of voltage, current, etc, and then send those values or data to the computer for the user information.

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