OBSTACLE DETECTION FOR A SPEECH-CONTROLLED DC MOTOR OPERATED WHEELCHAIR WITH ELEVATION SYSTEM

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APPROVAL SHEET

This is to certify that I have supervised the preparation of and read the thesis paper prepared by **Lloyd Edwinson S. Arellano, Darryll Jade E. Arias, Francis Mark Adriane G. Luna, and Aljon C. Santillan,** entitled **OBSTACLE DETECTION FOR A SPEECH-CONTROLLED DC MOTOR OPERATED WHEELCHAIR WITH ELEVATION SYSTEM** and that the said paper has been submitted for final examination by the Oral Examination Committee.

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Abstract

Nowadays, most handicapped people who suffer mobility problem primarily depend on using wheelchairs and most of these wheelchairs are already automated. The designs are made in response to the condition of the target user. Considering the users who already lost the ability to use their hands, the researchers of this paper believe that implementing a speech control mechanism and incorporating sensors to the wheelchair will give solution to this problem. It is also believed that to improve its functionality, a lifting mechanism should be considered to allow the user to move up by himself into elevated platforms. As a result, an obstacle detection for a speech controlled dc-operated wheelchair with elevation system is considered in this paper. The wheelchair will use voice module that will process the user input speech command and a microcontroller to control the movement of the wheelchair in response to the user input command. Proximity sensors will also be used to create a system wherein obstacle detection mechanism is present. Lastly, for the elevation system the wheelchair will be incorporated by an electric car jack that will allow itself to lift into the elevated platform.

Keywords: Voice module, Electric car jack, PIC microcontroller, DC motors,Proximity Sensors

Chapter 1

INTRODUCTION

Wheelchairs are one of the commonly used devices for assisting human mobility. It was invented as a solution to the mobility problems of paralytic people. Most of these people are those who suffer serious cases and totally lost their mobility. An ordinary wheelchair is a big help to them but still needs another person for assistance.

Nowadays, there are various types of wheelchairs that already exist. Some of the innovations made the manually operated wheel chair into an automated system. The most common type of automated wheelchair is the one controlled through buttons and joysticks. Other designs implement some advance technology such as wireless application and voice recognition to improve the existing wheelchair designs. These wheelchairs are generally prescribed for those people who experience difficulty in using manual wheelchair due to arm and other disabling conditions. The condition of the user indicates the type of electronic wheelchair to be used. For some cases, when the user lacks coordination with his finger, hand controlled wheelchair would not be advisable. Other means of controls must be implemented for the convenience of the patient.

Although there are a lot of studies regarding the improvement of a wheelchair, most of these are concentrating on the application of easier manual control or voice recognition alone and do not give more concern on the safety of the users. Most of them do not have the ability to elevate the wheelchair and thus make it less reliable when the user goes to different places alone.

This study aims to design an obstacle detection mechanism for a speech controlled wheelchair with elevation to improve safety of users. The specific objectives of this study are the following: a) To design an obstacle detection mechanism using proximity sensors b) To specify possible obstacles that the wheelchair can detect c) To determine the effectiveness of proximity sensors when used for obstacle detection.

With the completion of this study, people who are having problems with mobility will have fewer worries when it comes to their safety in using a wheelchair. They will also have the benefit of using a speech recognition wheelchair that would allow them to manipulate the direction where they would like to go and can elevate themselves to a certain level without using physical strength.

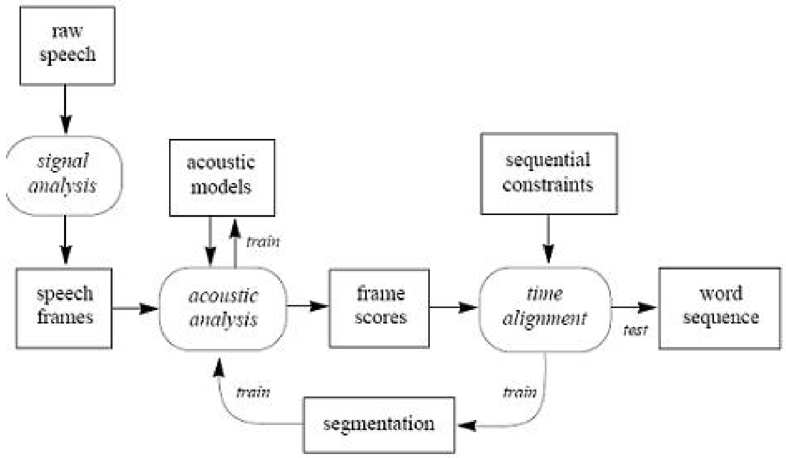
The obstacle detection mechanism comprises of proximity sensors that can be activated to avoid accidents like falling down from a gutter and hitting a wall. Speech recognition technology is applied to the wheelchair. There will be a headset to be worn by the user to serve as his medium of control for the device. There are also 2 emergency buttons; one for stop and another one for enabling and disabling the obstacle detection system. The wheelchair will consist of 7 commands, namely, move forward, move backward, move left, move right, stop, move up (to elevate), and move down. The headset will receive voice command from the user to determine the movement of the wheelchair and even allow it to be elevated upon command. For instance, the user says “move-forward”, the voice command will trigger the forward movement of the device. Similarly, there will be another voice command for the wheelchair to turn either to the right or left direction and to elevate or not. The input command from the headset will be transmitted to the microcontroller through wires. The microcontroller will be responsible in processing the input from the user. DC motors will be applied on the wheel chair as well as relay drivers. The DC motors will serve as the main machine in moving the device. The power will then be supplied by batteries. On the other hand, the relay drivers will be used to supply enough power to the motors. The microcontroller itself is not capable of providing the needed power of the motors. The use of wheelchair is limited due to the source of power which is a battery. The wheelchair can only perform one movement operation at a time and has a stable speed. People who are mute cannot use the wheelchair. The wheelchair has a limit on how high it can elevate and is mostly used only for sidewalk banks. The design cannot elevate on stairs due to simultaneous elevation. The obstacle mechanism can only detect large obstacle like walls and can also detect near falling off platform. When the obstacle detection system detects an obstacle it will then make the wheelchair to immediately stop automatically. To enable the elevation, the user must first disable the obstacle mechanism.

CHAPTER 2
REVIEW OF RELATED LITERATURE

For the past decades, evolution of ways to improve technology that will support people with mobility problems has been given a lot of attention. Because of the latest trend of technology, people were able to communicate with machines through programs. Speech is a natural mode of communication for people and with the use of the latest technology, people have created speech recognition programs.

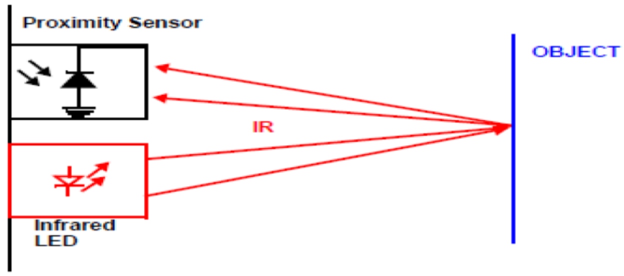
Speech Recognition

Speech recognition, often called automatic speech recognition, is the process by which a computer recognizes what a person says. Speech recognition is the ability of a machine or program to identify words and phrases in spoken language and convert them to a machine-readable format. However, rudimentary speech recognition software has a limited vocabulary of words and phrases and may only identify them if they are spoken very clearly. More sophisticated software has the ability to accept natural speech. Speech recognition applications include call routing, speech-to-text, voice dialling, and voice search. Speech recognition software has two primary components. The first piece, called the acoustic model*,* analyzes the sounds of the voice and converts them to phonemes, the basic elements of speech. The second major component of speech recognition software is the language model which analyzes the content of the speech. It compares the combinations of phonemes to the words in its digital dictionary (Miastkowski, 2000). The structure of a standard speech recognition system is illustrated in the figure below:



Infrared Proximity Sensor

Infrared proximity switches work by sending out beams of invisible infrared light. A photodetector on the proximity switch detects any reflections of this light. These reflections allow infrared proximity switches to determine whether there is an object nearby. Proximity switches with just a light source and photodiode are susceptible to false readings due to background light. Thus, more complex switches modulate the transmitted light at a specific frequency and have receivers which only respond to that frequency. Proximity sensor captures the reflected infrared signal. The proximity readout is linearly proportional to the captured infrared-light signal intensity and inversely proportional to the square of the distance (Luo & Schmitz, 2009).



Different types of proximity sensors can be used but Infrared Proximity sensors would be the best choice because of their sensitivity.

Direct Current (DC) Motors

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion. At a simplistic level, using DC motors is pretty straightforward; put power in, and get rotary motion out (Seale, 2003). DC motors are used on the design as a source of power in elevation and movement of the wheelchair.

Related Studies

Battery Assisted Wheel Chair

This research deals with series hybrid combination of manual and battery powered wheelchair. The control scheme used is simpler than other hybrid wheelchairs. It includes the sensor less control of the speed. Battery assisted wheelchair (BAW) which is operated by a DC motor and has less number of components in its hardware. Effort made by rider is reduced considerably. The control scheme also includes the dead man's switch feature. Speed loop is provided for the smooth variation of the speed. The current limit is governed by peak current mode control (Rahulanker & Ramanarayanan, 2006).

Voice Controlled Automation System

This paper discusses speech recognition and its application in control mechanism. Speech recognition can be used to automate many tasks that usually require hands-on human interaction, such as recognizing simple spoken commands to perform something like turning on lights or shutting a door or driving a motor. Despite these breakthroughs, however, current efforts are still far away from a 1000/0 recognition of natural human speech. Therefore, the project is considered but it involves processing of a speech signal in any form as a challenging and rewarding one. In this paper, a block diagram was used to show the sequence on how speech will be processed.

Pattern matching was also discussed and was stated that the comparison of two speech signals is nothing but basically their pattern matching. The speech signal can be represented as the set of numbers representing certain features of the speech that is to be described. For further processing, it is useful to construct a vector out of these numbers by assigning each measured value to one component of the vector. It is also stated that an uttered voice can differ from a stored template due to interference, noise, and other magnitude distortions which corrupt the input signal and can make it sound different from the reference signal. Also, unexpected pauses, unusually fast or slow speaking styles, and other changes in speed can randomly shift the position of the input relative to the template. The same person can utter the same word in slightly different ways each time. The person can pause, speak faster, speak slower, or emphasize certain syllables. These differences are called intra-speaker differences. The differences between the same words uttered by the different speakers or different words uttered by same speaker or different speakers are called inter-speaker differences. These differences are large as compared to intra speaker differences (Haleem, 2008).

A Survey and Experimental Evaluation of Proximity Sensors for Space Robotics

The paper provides an overview selection process for proximity sensors for manipulator collision avoidance. Five categories of sensors have been considered for this use in space operations: intensity of reflection, triangulation, time of flight, capacitive, and inductive. From these categories, the most promising commercial and mature laboratory prototype sensors have been selected and tested. After reviewing the selection process and the experimental results, conclusions are drawn about which sensors are best and why. The report has detailed the selection of proximity sensors for manipulator collision avoidance. In this paper proximity sensors were tested and their capabilities were known. Optical intensity of reflection sensors are probably the most widely available in the number of manufacturers, the number of models, and the ranges of operation. Many of these sensors have adjustable ranges, which are set by turning a potentiometer on the sensor housing. Therefore, the ranges listed for some sensors may not be attainable by one sensor setting (Volpe & Ivlev, 1994).

Switchgear control apparatus and relays for alternating-current circuits

The paper stated that control relays are a standard practice for a correct design and it is very important to lay-out such relays in the circuit. With this, the system depends on the proper action of relays because this will take a large part on the success of the operation of circuit. Implementing relays to control a circuit requires that the circuit must be controlled by only one signal. Multiple relays can be activated at the same time, thus a different operation must be done with single activated relay; different combinations can have different operations. In the article, relays are used to control the alternating currents of a switchgear control apparatus. The relay here has a single moving element which moves under the action of the currents. The team also stated that if the circuit is in breakdown, the overload on the single overloaded phase must be much greater than before for the relay to operate. This means that if the circuit has no relays the overloading will occur simultaneously on each of the operation phases but if relays are installed, this overloading will only occur in only one phase, thus make the circuit safe for more damage that it will take from breakdown (Garrard, 2010).

Obstacle Avoidance Fuzzy System for Mobile Robot with IR Sensors

The paper deals with the navigation problem of mobile robots in an unknown indoor environment with the use of infrared sensors. In this paper, the robot has the ability to plan motion and to navigate autonomously avoiding any type of obstacles. This is a reactive strategy and is completely based on sensory information. This gives the idea that infrared sensors can be used as proximity sensors for an obstacle detection mechanism. It has been stated in the article that infrared detectors have built-in optical filters that allow very little light which is the main idea of detecting an obstacle whether it is physically present or not.

By using infrared sensors, a program can be designed for obstacle detection and thus allow the possibility of creating a machine that would be used for collision avoidance. This article proves that a collision free navigation system is possible in a machine that uses infrared sensors and is programmed in the most appropriate way they should be.

Chapter 3

OBSTACLE DETECTION FOR A SPEECH-CONTROLLED DC MOTOR OPERATED WHEELCHAIR WITH ELEVATION SYSTEM

Abstract

A speech-controlled dc motor operated wheel chair with proximity sensors as an obstacle detection is proposed in this paper. The user can control the wheel chair through speech command and is capable of moving forward, turning either to the left or right direction and can climb up elevated surfaces.

Introduction

Most automated wheelchairs nowadays implement advance technology in their designs. Some designs implement different medium of control like buttons, joysticks and wireless technology to make wheelchair more convenient to use. But in some cases, these existing designs are not enough to give solution for the mobility of people who suffer extreme case of disability. Some of these people have already lost the functionality of their arm. In such cases, where buttons, joysticks and other arm-controlled medium are not anymore applicable, a speech controlled wheelchair can be used. Additional safety features will also be needed to ensure the safety of the user. The combination of a speech controlled wheelchair and proximity sensor would allow the user to move independently without worrying about his safety.

Methodology

The study is divided into 3 major parts. The first part is all about the implementation of speech control to a dc operated wheelchair. The next part is designing the elevation system for the wheel chair. And the last part, which is the core of the study, is all about the development of obstacle detection mechanism.

Figure 3.1 below shows the conceptual framework of the study. The figure shows the process in designing the speech controlled dc operated wheelchair with an obstacle detection mechanism.

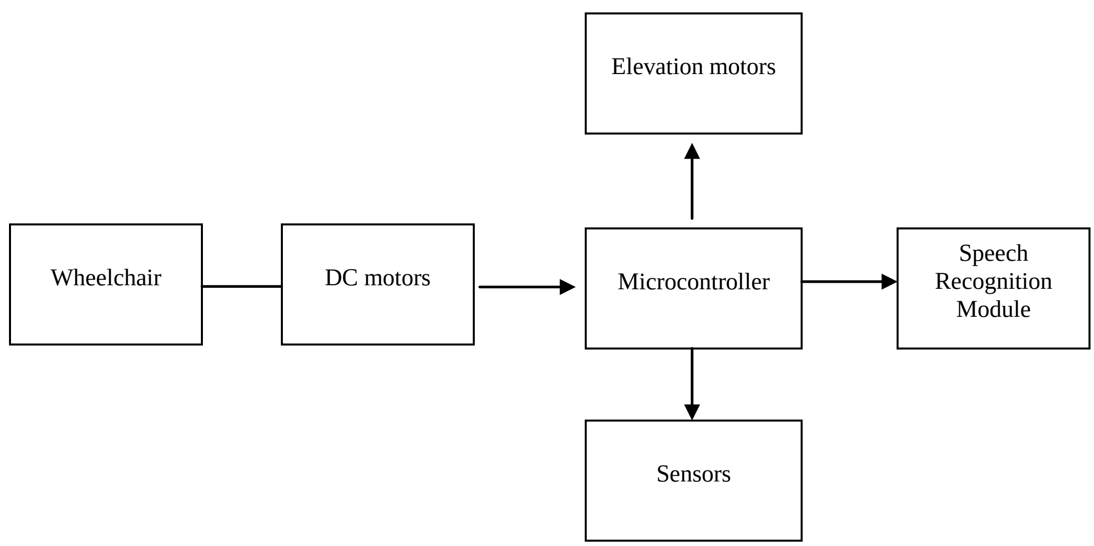


Fig 3.1 Conceptual Framework of the study

The design process starts by incorporating DC motors to the manually operated wheel chair. This DC motors will be responsible for the movement of the wheelchair. There will be 4 DC motors to be applied. Each wheel at the back will have its own motor to operate and another 2 motors for the elevation process. These motors will be controlled by the microcontroller. In this study, the researchers will use a PIC16F877A microcontroller. This microcontroller will control the movement of the motors depending on the input it receives. The input will come from the speech recognition module. Each wheelchair movement has a corresponding speech command. The last process is the integration of proximity sensors on the wheelchair. The proximity sensors will serve as the medium in detecting obstacle in the wheelchair's movement.

Figure 3.2 shows the methodology block of the study.

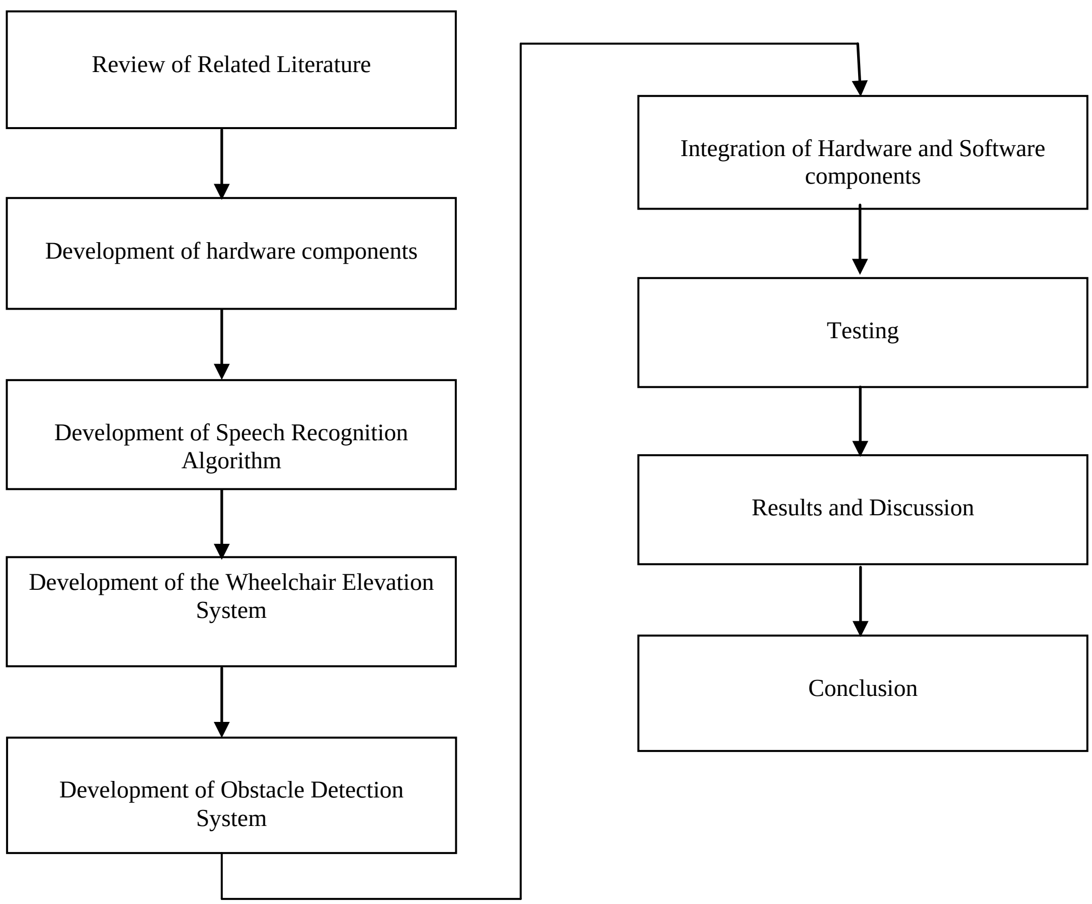
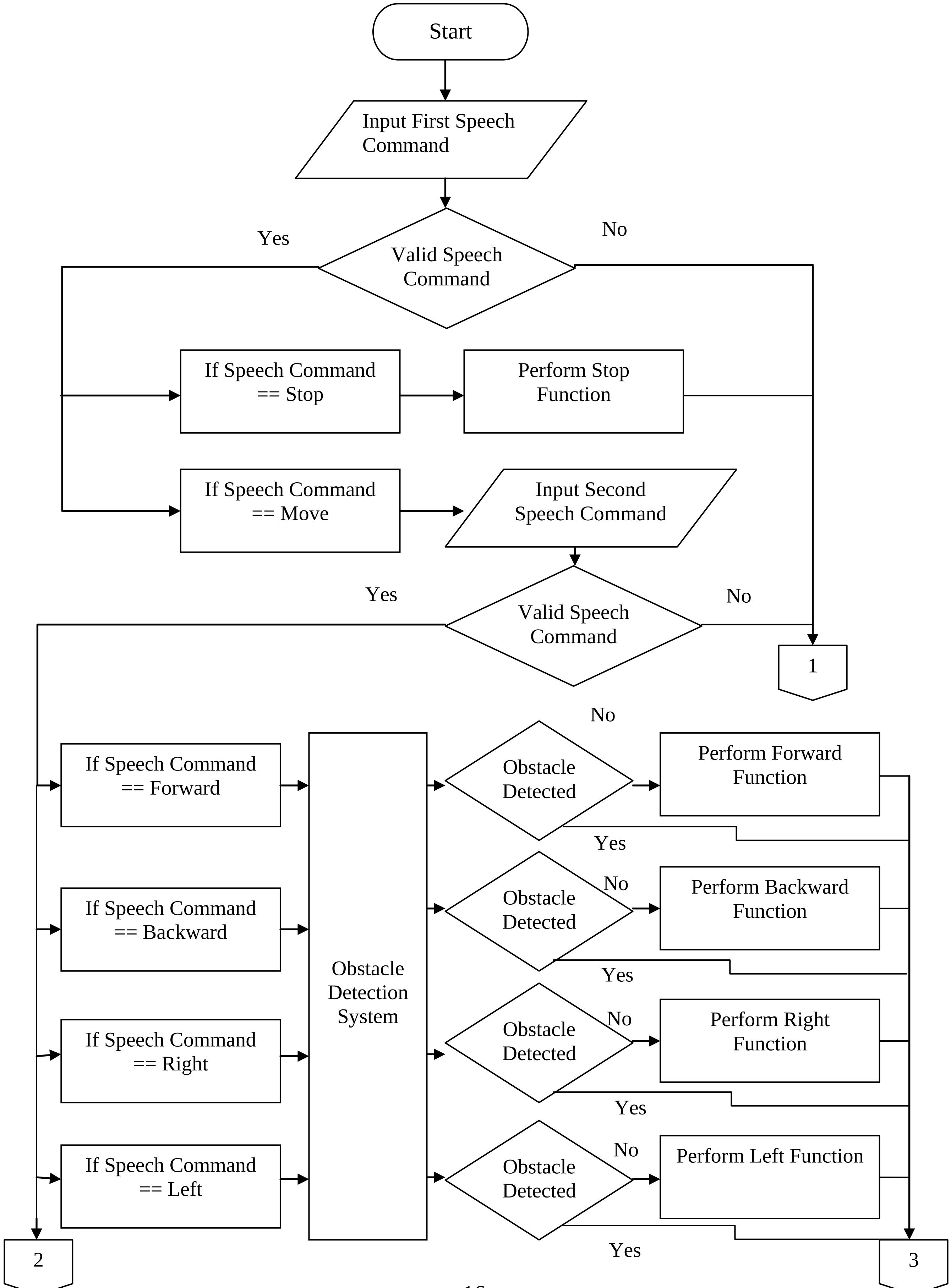


Fig 3.2 Methodology Block

The first step the researchers must do is to do a review of related literatures about the study. Through this, the researchers will be able to determine the needed materials as well as the necessary steps in designing the device. After the review of related literatures, the researcher will develop the hardware components. This includes the integration of the basic hardware parts such as the DC motors, electric car jack, relays, microcontroller, battery and speech recognition module. Then the next step is to develop the speech recognition module algorithm.

Figure 3.3 shows the speech recognition module flowchart and algorithm. It describes the flow of program to be designed for the speech recognition module.


Start
Input First Speech Command
Valid Speech Command
Yes
No
If Speech Command == Stop
Perform Stop Function
If Speech Command == Move
Input Second Speech Command
Valid Speech Command
Yes
No
1
If Speech Command == Forward
If Speech Command == Backward
If Speech Command == Right
If Speech Command == Left
Obstacle Detection System
Obstacle Detected
No
Yes
Perform Forward Function
Obstacle Detected
No
Yes
Perform Backward Function
Obstacle Detected
No
Yes
Perform Right Function
Obstacle Detected
No
Yes
Perform Left Function
2
3

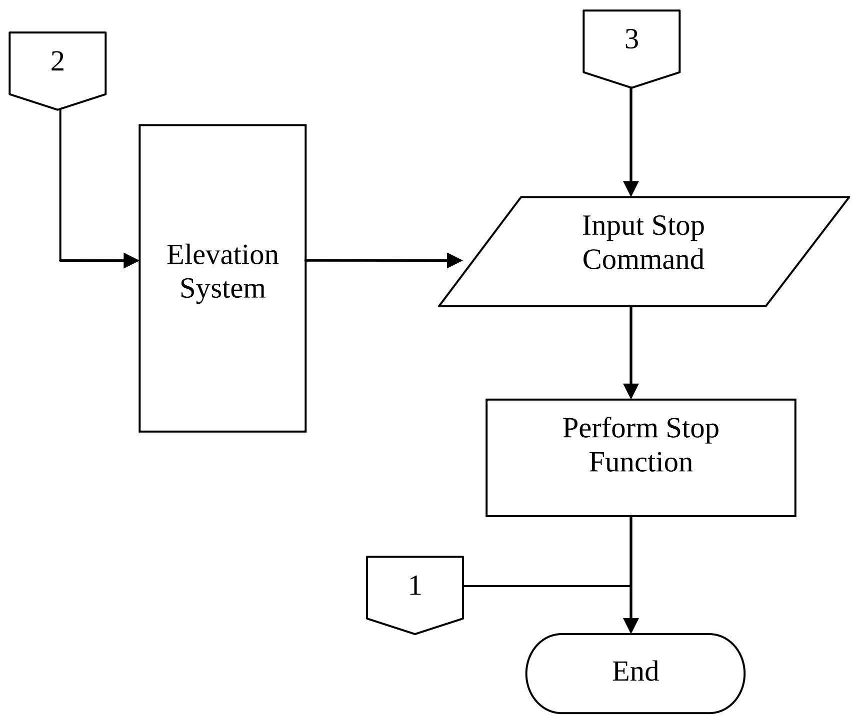


Fig 3.3.A Speech Recognition Module Flowchart

```
Start
    get First Speech Command
    If Speech Command is Valid
        Switch (First Speech Command)
        Case "Stop":
                Perform Stop Function; Break;
        Case: "Move"
                Input Second Speech Command
                If Speech Command is Valid
                        Switch (Second Speech Command)
                                Case "Forward":
                                        Call Obstacle Detection System;
                                        If Obstacle is considerable
                                        else
                                                Perform Forward Function;
                                        Break;
                                Case "Backward":
                                        Call Obstacle Detection System;
```

```
                    If Obstacle is considerable
                    else
                            Perform Backward Function;
                    Break;
            Case "Left":
                    Call Obstacle Detection System;
                    If Obstacle is considerable
                    else
                            Perform Left Function;
                    Break;
            Case "Right":
                    Call Obstacle Detection System;
                    If Obstacle is considerable
                    else
                            Perform Forward Function;
                    Break;
            Default:
                    Call Elevation System Function;
    Get Stop Input Command
    Perform Stop Command
End
```

Fig 3.3.B Speech Recognition Algorithm

First, the speech recognition will accept a first degree command of move or stop. When the command is Stop, it will perform the stop function that instantly stops the current function of the wheelchair. While when the command is Move, it will wait for a second degree command such as forward, backward, left, right, up and down. Forward, Backward, Left and Right commands will trigger the obstacle detection system while Up and Down commands will affect the elevation system. Other commands that are not included in the given sets of command are voided.

After designing the algorithm for the speech recognition module, the implementation of the elevation system is next. This includes integrating the other 2 DC motors to the wheelchair. One motor will be responsible for lifting the wheelchair while the other one is for the forward movement of the wheelchair while being elevated.

Figure 3.4 below shows the algorithm for the elevation mechanism of the wheelchair. First, there will be an input speech command from the user. The input speech command will be verified if it is for elevating the wheelchair or for moving it down". If the command falls either for these commands, that specific command will be executed. If it is invalid, the microcontroller will do nothing.

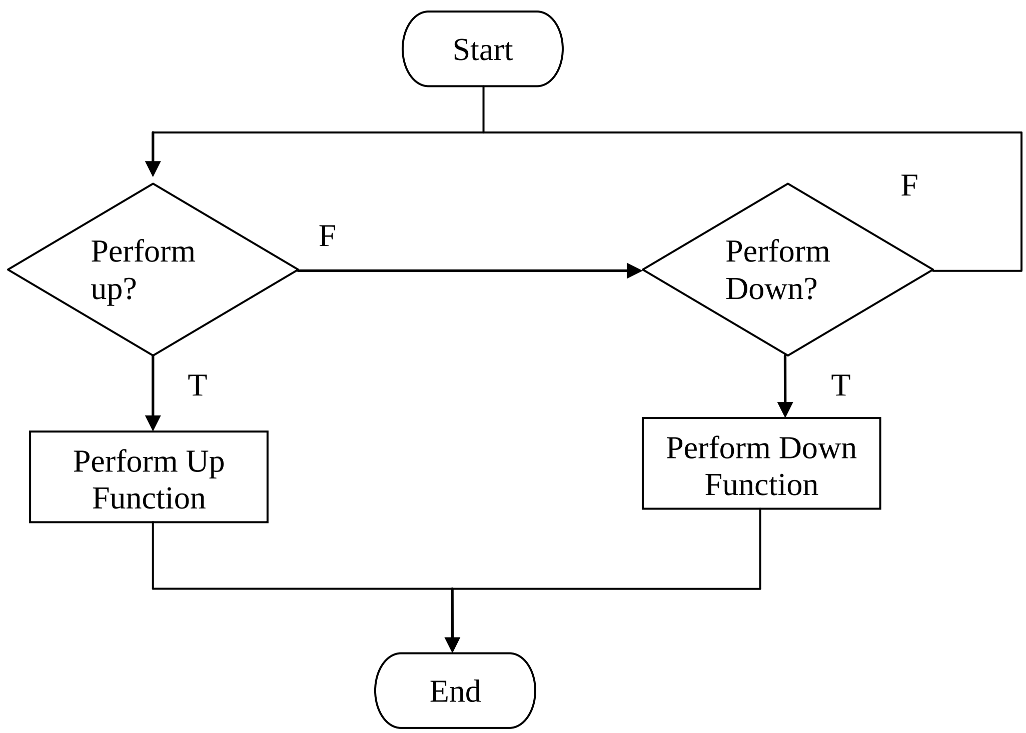


Fig 3.4.A Elevation System Flowchart

```
Start
        If Operation is Up
                Perform Up Function
        Else
                Perform Down Function
Return
```

Fig 3.4.B Elevation System Algorithm

When the speech recognition module and elevation system algorithm are finished, the next thing to design is the mechanism for obstacle detection of the wheelchair. In this part, the speech controlled wheel chair will be integrated with proximity sensors. There will be proximity sensors to be attached at the front and back of the wheelchair. There will also be another set of proximity sensors at the bottom of the wheelchair. This is for detecting dangerous places such as stairs, cliffs and etc. The flowchart and algorithm for the obstacle detection are described respectively below

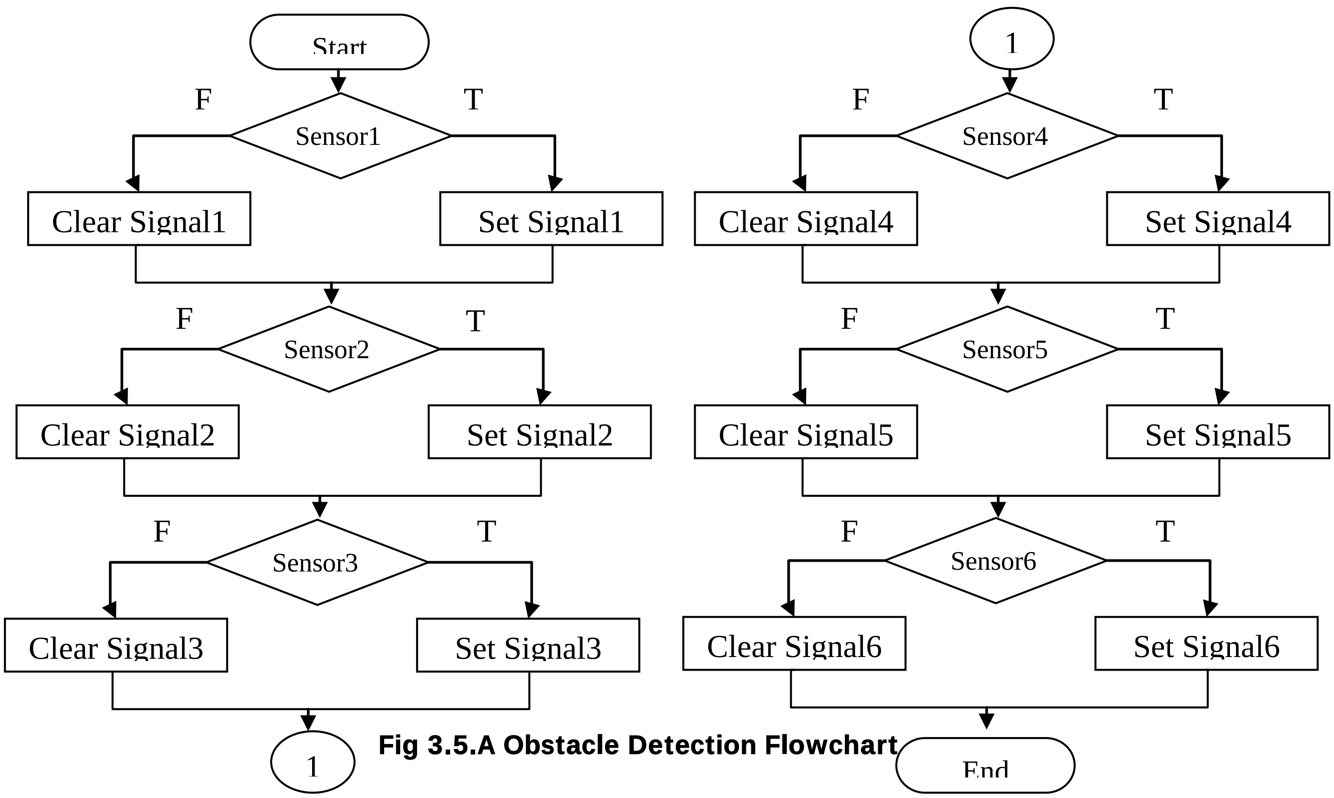


Fig 3.5.A Obstacle Detection Flowchart

```
Start
        If Sensor1 Detects an Obstacle
                Set Signal1
        Else
                Clear Signal1
        If Sensor2 Detects an Obstacle
                Set Signal2
        Else
                Clear Signal2
        If Sensor3 Detects an Obstacle
                Set Signal3
        Else
                Clear Signal3
        If Sensor4 Detects an Obstacle
                Set Signal4
        Else
                Clear Signal4
        If Sensor5 Detects an Obstacle
                Set Signal5
        Else
                Clear Signal5
        If Sensor6 Detects an Obstacle
                Set Signal6
        Else
                Clear Signa6
Return
```

Fig 3.5.B Obstacle Detection Algorithm

First, there will be a speech command input from the user. Then after receiving an input voice command from the user, there will be continuous checking of obstacles in that specific direction in relation to the inputted voice commands. If there is an obstacle, there will be no operation, but if there is no obstacle detected, then the command will be executed.

The next step is to integrate the hardware with the software components. The algorithm for the speech recognition module, the elevation mechanism algorithm and the obstacle detection algorithm, will be programmed to the microcontroller in interfacing the hardware to the software.

Testing and Interpretation of Results

In order to further support the study, testing will be performed after the process of integrating the software and hardware is done. There will be four types of test that will be performed in measuring the performance of the design.

Test on the effectiveness of the front and back proximity sensors

The first test focuses in measuring the effectiveness of the front and back sensors in obstacle detection. The purpose of this test is to determine if the proximity sensor is effective in detecting the obstacle to avoid collision. In this test, four of the wheelchair's movement command will be tested upon the obstacles located at varying locations as described in Table 3.5. Upon encountering an obstacle, the wheelchair will disable the movement command used with respect to the location of the obstacle.

The procedures to be performed for this test are described below.

Procedure:

1.) The four movement commands namely "move forward", "move backward", "move left" and "move right" will be put to test while obstacles are placed on different location as specified in Table 3.5
2.) The movement command that will not be done in response to the detection of an obstacle will be marked as "disabled" and others will be marked as "working".
3.) Results will be obtained and recorded at the given table.

Table 3.5 Test of effectiveness of the front and back proximity sensors

Location of obstacle	Forward Command	Backward Command	Turn Left Command	Turn Right Command
1.) Front	Disabled	Working	Working	Working
2.) Back	Working	Disabled	Working	Working
3.) Left	Working	Working	Disabled	Working
4.) Right	Working	Working	Working	Disabled
5.) Front and Left	Disabled	Working	Disabled	Working
6.) Front and Right	Disabled	Working	Working	Disabled
7.) Front and Back	Disabled	Disabled	Working	Working
8.) Back and Right	Working	Disabled	Working	Disabled

9.) Back and Left	Working	Disabled	Disabled	Working
10.) Left and Right	Working	Working	Disabled	Disabled
11.) All direction	Disabled	Disabled	Disabled	Disabled

As shown, Table 3.5 shows that the design is successful in disabling the movement of the wheelchair upon encountering an obstacle. All of the wheelchair's movement commands tested show independent behavior in response to the obstacle detected. As shown in the table, the obstacle detected at the front will not affect the functionality of the other movements like move back, move left and move right.

Test on the effectiveness of the bottom proximity sensors

After performing the first test, the next test will be performed. This test focuses in measuring the effectiveness of the bottom sensors. The purpose of this test is to determine if the proximity sensors is effective in detecting continuous surface which will help in avoiding accidents like falling from stairs and etc. Similar to the first test, the four movement command will be tested upon discontinuous surface (stairs, gutter etc.) at varying locations. Upon encountering no floor surface, the wheelchair will disable the movement command used with respect to the location of the discontinuous surface.

The set of procedures to be performed for this test is described below.

Procedure:

1.) The four movement command namely "move forward", "move backward", "move left" and "move right" will be put to test with the position of the discontinuous path on different positions.

2.) The movement command that will not be done in response to the detection of an obstacle will be marked as "disabled" and others will be marked as "working".

3.) Results will be obtained and recorded at the given table.

Table 3.6 Test of effectiveness of the bottom proximity sensors

Location of discontinuous path	Forward Command	Backward Command	Turn Left Command	Turn Right Command
1.) Front	Disabled	Working	Working	Working
2.) Right	Working	Working	Working	Disabled
3.) Left	Working	Working	Disabled	Working
4.) Front and Right	Working	Working	Working	Disabled
5.) Front and Left	Disabled	Working	Disabled	Working
6.) Right and Left	Working	Working	Disabled	Disabled

Table 3.6 shows that the wheelchair is completely successful at disabling the movement command upon encountering a discontinuous path. Results shown in Table 3.6 show the same response in relation to the results shown in Table 3.5. The disablement of each command is independent to other

commands. On the other hand, some of the limitations that had been observed during the implementation of test is that the discontinuous path cannot be detected when it is located at the back.

Measurement of distance in obstacle detection

The next test to be performed is to measure the distance at which the wheelchair can detect obstacles. The purpose of this test is to determine at how far the wheelchair will disable its movement upon encountering an obstacle. The data obtain would help in determining if the wheelchair is disabling the commands accurately in the distance specified by the designers.

The procedures to be performed for this test are described below.

Procedure:

1.) The four movement command namely “move forward”, “move backward”, “move left” and “move right” will be put to test with an obstacle placed at varying distance from the wheelchair.
2.) Upon stopping of the wheelchair in doing the movement command, the distance of the wheelchair will be measured from the obstacle.
3.) Results will be obtained and recorded at the given table.

Table 3.7 Measurement of distance in obstacle detection

Distance of obstacle	Distance at which Forward Command is disabled	Distance at which Backward Command is disabled	Distance at which Turn Left Command is disabled	Distance at which Turn Right Command is disabled
1.) 0.2 m	0.2m	0.2m	0.2m	0.2m
2.) 0.4 m	0.4 m	0.4 m	0.4 m	0.4 m
3.) 0.6 m	0.6 m	0.6 m	0.6 m	0.6 m
4.) 0.8 m	0.8 m	0.8 m	0.8 m	0.8 m
5.) 1.0 m	0.8 m	0.8 m	0.8 m	0.8 m
6.) 1.2 m	0.8 m	0.8 m	0.8 m	0.8 m
7.) 1.4 m	0.8 m	0.8 m	0.8 m	0.8 m

Table 3.7 shows the results in testing the obstacle detection of the wheelchair at varying distances. Results show that at a range of less than or equal to 0.8 meters (distance ≤ 0.8m), the wheelchair would disable the movement command. When the distance of the obstacle is greater than 0.8m, the wheelchair will continue its forward or backward movement until it reaches 0.8 meters from the obstacle. The same goes in performing the move left and right command. The wheelchair will continue to rotate when the distance of the obstacle is not on the range of detection of the wheelchair.

Measurement of the response time in performing the movement command

The next test focuses in determining the response time of the wheelchair. The purpose of this is to identify the time interval at which the wheelchair will perform the movement command specified by the user.

The set of procedures to be performed for this test is described below.

Procedure:

1.) All of the wheelchair’s speech commands will be tested by the researcher.

2.) The researcher will measure the time interval upon the glowing of the orange LED button up to the time the wheelchair started to perform the command.

3.) Results will be obtained and recorded at the given table.

Table 3.8 Measurement of the response time in performing the movement command

Speech Command	Response Time
1.) Move Forward	0.593 sec
2.) Move Left	0.597 sec
3.) Move Right	0.6 sec
4.) Move Up	0.593 sec
5.) Move Down	0.595 sec
6.) Move Backward	0.6 sec
7.) Stop	0.595 sec

Table 3.8. shows the results of the test in measuring the response time in performing the speech command. Based form the results, the time interval in performing the speech commands is approximately 0.6 sec.

Determination of the obstacles that can be detected

The last part of the test focuses in determining the possible obstacle that the wheelchair can detect. This test covers all the proximity sensors including those installed at the bottom of the wheelchair. The purpose of this test is to determine the limitations as well as the capabilities of the wheelchair in obstacle detection. In this test, those obstacles specified at Table 3.8 that can be detected will be marked as “success” while those cannot be detected will be mark as “failed”

The set of procedures to be performed for this test is described below.

Procedure:

1.) The wheelchair’s obstacle detection will be tested for 5 consecutive trials for each obstacles specified in Table 3.7.
2.) Results will be obtained and recorded at the given table.
3.) Upon obtaining the results in each trial of the given types of elevated platforms, the percentage of success will be computed. Computing for the percentage of success is described by the formula below:

$$\frac{\text{Total number of succes trial}}{\text{Total number of trials performed}} \text{ X } 100\%$$

The percentage of success for each type of obstacle will determine if the wheelchair is either capable or not capable of detecting that specific obstacle. Obstacles with a percentage of success lower than 80% will be considered to be an object

Table 3.9.A Determination of the obstacles that can be detected by front and back sensors

Obstacles	**Front and Back Proximity Sensors**					
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Percentage of Success (%)**
Solid Objects						
1.) Gate	Success	Success	Success	Success	Success	100%
2.) Wall	Success	Success	Success	Success	Success	100%
3.) Human	Success	Success	Success	Success	Success	100%
4.) Lamp Post	Failed	Success	Failed	Failed	Success	40%
5.) School Table	Success	Success	Success	Success	Success	100%
6.) School Chair	Success	Success	Success	Failed	Success	80%
Translucent/Glass/Light passing Objects						
1.) Mirror	Success	Failed	Failed	Success	Success	60%
2.) Sliding Glass Door	Success	Success	Failed	Success	Success	80%
3.) Curtains	Success	Success	Success	Success	Success	100%
4.) Stainless Roof	Success	Success	Success	Success	Success	100%
Colored Obstacles (Wall)						
1.) Red colored obstacle	Success	Success	Success	Success	Success	100%
2.) Yellow colored obstacle	Success	Success	Success	Success	Success	100%
3.) White colored obstacle	Success	Success	Success	Success	Success	100%
4.) Brown colored obstacle	Success	Success	Success	Success	Success	100%
5.) Blue colored obstacle	Success	Success	Success	Success	Success	100%

Table 3.9.B Determination of the obstacles that can be detected by bottom sensors

Obstacles	Bottom Proximity Sensors					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Percentage of Success (%)
1.) Stairs	Success	Success	Success	Success	Success	100%
2.) Gutter	Success	Success	Success	Success	Success	100%
3.) Man Hole	Success	Success	Success	Success	Success	100%
4.) Pothole	Success	Success	Failed	Success	Failed	80%
5.) Inclined Plane	Failed	Failed	Failed	Failed	Failed	0%

Table 3.8.A shows the results of the test in detecting various types of obstacles. Based from the results, the wheelchair is able to easily detect an object with wide and large area. On the other hand, a thin object like the lamp post shows lower percentage of success compared to other obstacles. Also based from the results, reflective objects are not easily detected by the proximity sensors. And in terms of the color of the obstacles, the obstacle detection of the system is not much affected by color of the obstacle. The obstacle detection of that specific object (even with varying color) shows high percentage of success in terms of detection.

Table 3.8.B shows the result in detecting discontinuous paths. Based from the results, the wheelchair is able to detect steep surfaces as described in the table. Movement commands are still working at shallow discontinuous surfaces such as an inclined plane is not considered as an obstacle.

Chapter 4

CONCLUSION

In this paper, a hardware design of obstacle detection of a speech control with elevation system is presented. This design is intended mainly for the use of handicapped persons especially those who have lost their ability in using their arms and to insure that the user will be safe while using the hardware design. The design is guided by a main objective and specific objectives. The main objective is met. The device is able to detect the given specific obstacles mentioned in the objectives and tests. The obstacle detection system of the device consists of six infrared sensors. The sensors will be controlled by the PIC 16F877A. The two pair of sensors will be responsible for detecting hindrance objects while the other pair of sensors will be detecting if the wheelchair will encounter situation wherein it will fall.

In terms of obstacle detection, the design has successfully met this objective. The hardware design is able to detect obstacles using infrared proximity. The pair of sensors at the front and back of the wheelchair detects at a range of distance ≤ 0.8m form the obstacle thus, preventing the wheelchair from possible collisions. Upon detection of the obstacle, the wheelchair will halt its movement operation. That specific movement command will be disabled until such time that there is no obstacle detected. The same goes to the bottom sensors. The movement of the wheelchair will continue until such time that the sensors do not detect the floor. Upon encountering discontinuous path, that specific movement commands with will be disabled.

Another objective of the study is to determine the possible objects that the wheelchair can detect. Based on the results, the wheelchair is able to detect wide and large obstacles. Thin objects are sometimes not detected due to the position of the sensors which are located at the arm of the wheelchair. Reflective objects also show lower detection especially in bright environments. In terms of the obstacle colour, the capability of infrared proximity sensors in obstacle detection are not much affected. In terms of the bottom sensors detection, the wheelchair is able to detect steep surfaces.

To summarize it all, the obstacle detection of the wheelchair helps improve the safety of the user. The wheelchair is able to automatically stop upon encountering an obstacle which will help in preventing collisions. It is also able to detect discontinuous surfaces which will help the user to prevent accidents like falling into the stairs and etc. There is also an emergency stop button installed to stop the wheelchair movement in case of emergency.

Some of the limitations of the wheelchair design are:

1.) Wheelchair cannot detect discontinuous surface at the back of the wheelchair

2.) Obstacle detection does not work accurately at extremely bright environment.

Chapter 5

RECOMMENDATION

Some modifications can be made to improve the design prototype in order to please the user and receive a positive feedback. The recommendations are as follows:

1. Addition of possible obstacles it can detect by installing additional sensors at the blind spot of the wheelchair specifically at the middle front and middle back.
2. Provide an LCD display that would inform the user how high the system has elevated and at the same time show the battery level.
3. Improve the speech recognition system by using noise filters.
4. Installation of backrest and seat cushion for the users comfort.
5. Improve the maximum weight limit by installing supports at the bottom of the wheelchair.
6. Improve the maximum height limit the wheelchair can elevate.
7. Change the location of the bottom proximity sensors that will enable the wheelchair to stop at long distance from the discontinuous surface.
8. Add a feature that will enable the wheelchair to be moved manually in instance that the wheelchair can no longer move.

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Appendix A. User’s Manual

This part of the paper describes the important things on how to effectively use the speech controlled dc-motor operated wheelchair with elevation system. Also included in this part of the paper are the safety precautions to be followed by the user.

The following procedures below are the basic steps in operating the wheelchair:

1. Attached the power supply clips to their respective polarity in the battery.
2. Turn on the power button of the microphone and wait for it to be ready. (The green LED indicator will blink when the microphone is ready to accept input.)
3. Input a voice command (either “move” or”stop”).
4. Wait for the green LED indicator to glow. If the green LED glows, proceed to step 5 else go back to step 3. The green LED will glow if the command input is valid.
5. If the first word input is “move” then proceed to step 6 else repeat step 3.
6. Input the second voice command (“forward”, ”backward”, ”left”, “right”, “up”, “down”). An orange LED will glow once the second input word is recognize else go back to step 3.
7. Wait for the wheelchair’s output and proceed to step 3.

In order to further understand how the wheelchair operates, a summary of the wheelchair’s function is described by the table below

Table 4. Summary of the movement operation of the speech controlled dc-motor operated wheelchair with elevation system.

First Word Command + Second Word Command	Wheelchair's Response
Move + Forward	The wheelchair will continuously move forward
Move + Backward	The wheelchair will continuously move backward
Move + Left	The wheelchair will continuously turn counter-clockwise (rotate left)
Move + Right	The wheelchair will continuously turn clockwise (rotate right)
Move + Up	The wheelchair will lift its front wheels.
Move + Down	The wheelchair will land its front wheels
Stop	The wheelchair stops from moving

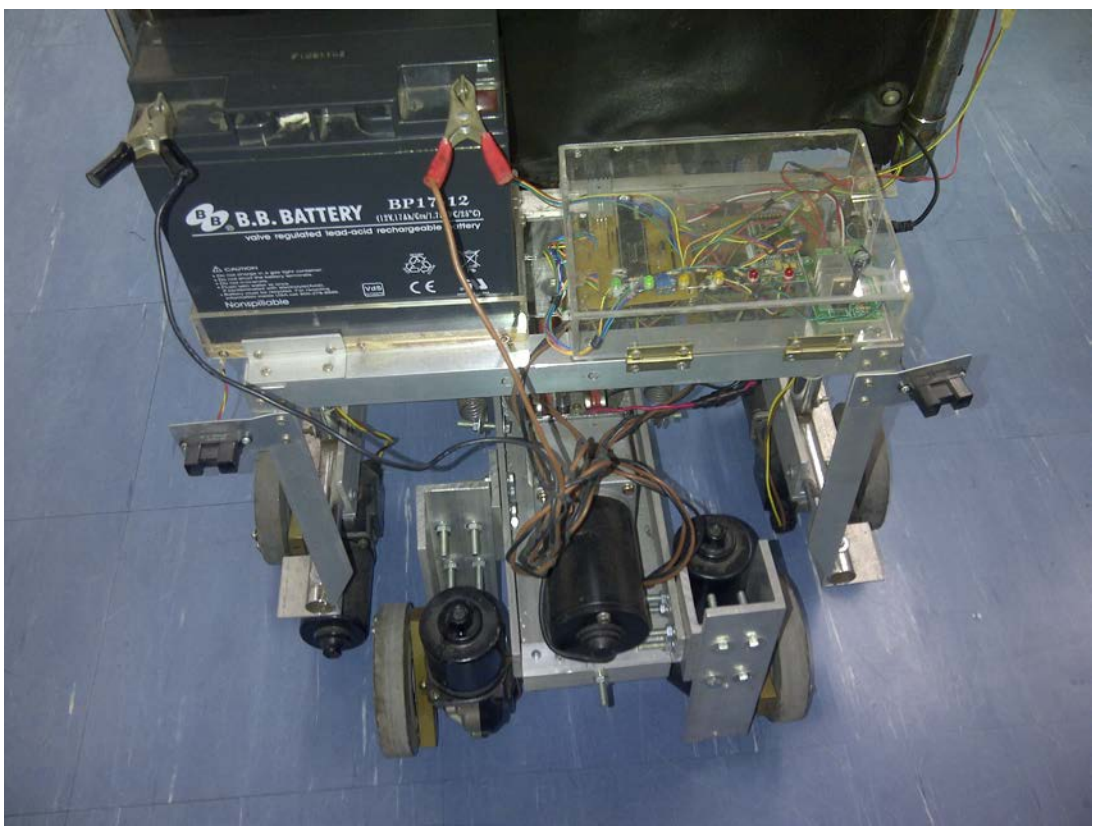
Safety switch- use to as an emergency stop for the wheelchair's movement. It is located at the front of the right arm of the wheelchair.

And for the safety precautions in using the design, the information below will give the user the necessary precautions to be followed to prevent damaging the wheelchair as well as to prevent accidents.

Safety precautions:

1. Always remove the power supply clip from the battery if the wheelchair is not in used.
2. Always ensure that the power supply clips are correctly attached to the polarity of the battery. (RED-Positive; BLACK-Negative)
3. As much as possible, turn off the microphone if the wheelchair is not in used.
4. Remember to always have a hand to the safety switch.

Appendix B. Pictures of Prototype


B.B. BATTERY

Appendix C. Program Listing

```
;**********************************************************************
***
;            filename:      VoiceChair04.asm
             processor      16F877A
             include        <P16F877A.inc>
  __config  _HS_OSC & _WDT_OFF & _PWRTE_ON & _LVP_OFF & _BODEN_OFF
& _CP_ALL
;**********************************************************************
***********
;                 Variable Declaration
Voice_Var     equu    H'20'          ;
                                     ;
SWA_New       equ    H'30'           ;
SWA_Prev      equ    H'31'           ;
SWE_New       equ    H'32'           ;
SWE_Prev      equ    H'33'           ;
                                     ;
LED1_Tmr      equ    H'40'           ;
LED2_Tmr      equ    H'41'           ;
                                     ;
Sensor        equ    H'42'           ;
                                     ;
ADC0          equ    H'50'           ;
ADC1          equ    H'51'           ;
ADC2          equ    H'52'           ;
ADC3          equ    H'53'           ;
ADC4          equ    H'54'           ;
ADC5          equ    H'55'           ;
ADC6          equ    H'56'           ;
ADC7          equ    H'57'           ;
ADC_Sel       equ    H'5A'           ;
                                     ;
is_data       equ    H'60'           ;
rx_data       equ    H'61'           ;
tx_data       equ    H'62'           ;
                                     ;
I             equ    H'70'           ;
J             equ    H'71'           ;
                                     ;
Temp1         equ    H'78'           ;
```

```
Temp2        equ    H'79'          ;
Temp3        equ    H'7A'          ;
Temp4        equ    H'7B'          ;
W_TEMP       equ    H'7C'          ;
STAT_TEMP    equ    H'7D'          ;
;*****************************************************************
***********
;           Reset Vector Starts at Address 0x0000.
;*****************************************************************
***********
            org    0x0000          ; start of reset vector.
            goto   Initialize      ;
                                   ;
            org    0x0004          ; start of interrupt service routine.
            goto   ISR_routine     ;
;*****************************************************************
***********
;           Initialization Routine.
;*****************************************************************
***********
Initialize:  clrf   TMR0           ; Clear TMR0
            clrf   INTCON          ; Disable Interrupts and clear T0IF
            bcf    STATUS,RP1      ;
            bsf    STATUS,RP0      ; Select Bank 1
            movlw  B'11000011'     ;
            movwf  OPTION_REG      ; prescaler of 1:16
                                   ;
            movlw  B'00000001'     ;Set PortA and PortE all Analog RA3= +Vref
            movwf  ADCON1          ; Left Justified
                                   ;
            movlw  B'11111111'     ;       0=OUT 1=IN
            movwf  TRISA           ; Port A. 11xx xxxx:TTL
                                   ;
            movlw  B'00000000'     ;       0=OUT 1=IN
            movwf  TRISB           ; Port B. xxxx xxxx:TTL
                                   ;
            movlw  B'11001111'     ;       0=OUT 1=IN
            movwf  TRISC           ; Port C. xxxx xxxx:schmitt
                                   ;
            movlw  B'00000000'     ;       0=OUT 1=IN
            movwf  TRISD           ; Port D. xxxx xxxx:schmitt
                                   ;
            movlw  B'00000111'     ;       0=OUT 1=IN
            movwf  TRISE           ; Port E. xxxx xxxx:schmitt
```

```
                    ;
     bcf    STATUS,RP0        ; Select Bank 0
                    ;
     call   Init_Var          ;
     call   Init_UART         ;
     call   Init_VR           ;
;*********************************************************************
***********
;        Main Program Starts Here.
;*********************************************************************
***********
Main:     call   VR_Recognize     ;
     goto   Main              ;
;*********************************************************************
***********
;        The Interrupt Service Routine.
;*********************************************************************
***********
ISR_routine:  nop                 ; Save Registers
                    ;
     retfie               ; Return from Interrupt.
;*********************************************************************
***********
Init_Var:    clrf   PORTB           ;
     clrf   PORTC             ;
     clrf   PORTD             ;
     clrf   tx_data           ;
     clrf   LED1_Tmr          ;
     clrf   LED2_Tmr          ;
     movf   PORTA,W           ;
     movwf  SWA_New           ;
     movwf  SWA_Prev          ;
     movf   PORTE,W           ;
     movwf  SWE_New           ;
     movwf  SWE_Prev          ;
     movlw  B'10000001'       ;
     movwf  ADCON0            ;
     clrf   ADC_Sel           ;
     clrf   ADC0              ;
     clrf   ADC1              ;
     clrf   ADC2              ;
     clrf   ADC3              ;
     clrf   ADC4              ;
     clrf   ADC5              ;
```

```
        clrf   ADC6             ;
        clrf   ADC7             ;
        clrf   Sensor           ;
        return                  ;
;*************************************************************
***********
; Voice Recognition
;===========================================================
====================
; Constant Declaration
;===========================================================
====================
; Protocol Command                  ;
CMD_BREAK     equ    "b"              ; abort recog or ping
CMD_SLEEP     equ    "s"              ; go to power down
CMD_KNOB      equ    "k"              ; set si knob <1>
CMD_LEVEL     equ    "v"              ; set sd level <1>
CMD_LANGUAGE  equu   "l"              ; set si language <1>
CMD_TIMEOUT   equ    "o"              ; set timeout <1>
CMD_RECOG_SI  equ    "i"              ; do si recog from ws <1>
CMD_RECOG_SD  equ    "d"              ; do sd recog at group <1> (0 = trigger
mixed si/sd)
;===========================================================
====================
; Protocol Status                   ;
STS_AWAKEN    equ    "w"              ; back from power down mode
STS_ERROR     equ    "e"              ; signal error code <1-2>
STS_INVALID   equ    "v"              ; invalid command or argument
STS_TIMEOUT   equ    "t"              ; timeout expired
STS_INTERR    equ    "i"              ; back from aborted recognition (see 'break')
STS_SUCCESS   equ    "o"              ; no errors status
STS_RESULT    equ    "r"              ; recognised sd command <1> - training
similar to sd <1>
STS_SIMILAR   equ    "s"              ; recognised si <1> (in mixed si/sd) -
training similar to si <1>
;===========================================================
====================
; Protocol arguments are in the range 0x40 (-1) TO 0x60 (+31) inclusive
ARG_MIN       equ    H'40'            ; 0x40 = 64 (ascii '@')
ARG_MAX       equ    H'60'            ; 0x60 = 96 (ascii '"')
ARG_ZERO      equ    H'41'            ; 0x41 = 65 (ascii 'A')
ARG_ACK       equ    H'20'            ; 0x20 = 32 (ascii ' ')  'TO READ more status
arguments
```

```
;============================================================
====================
; Wordset                              ;
WST          equ    D'0'              ; wordset trigger
WS1          equ    D'1'              ; Wordset 1 commands
WS2          equ    D'2'              ; Wordset 2 actions
WS3          equ    D'3'              ; Wordset 3 numbers
;============================================================
====================
;Wordset Commands                      ;
WS1_Action    equ    D'0'              ;
WS1_Move      equ    D'1'              ;
WS1_Turn      equ    D'2'              ;
WS1_Run       equ    D'3'              ;
WS1_Look      equ    D'4'              ;
WS1_Attack    equ    D'5'              ;
WS1_Stop      equ    D'6'              ;
WS1_Hello     equ    D'7'              ;
                                       ;
WS2_Left      equ    D'0'              ;
WS2_Right     equ    D'1'              ;
WS2_Up        equ    D'2'              ;
WS2_Down      equ    D'3'              ;
WS2_Forward   equ    D'4'              ;
WS2_Backward  equ    D'5'              ;
                                       ;
WS3_Zero      equ    D'0'              ;
WS3_One       equ    D'1'              ;
WS3_Two       equ    D'2'              ;
WS3_Three     equ    D'3'              ;
WS3_Four      equ    D'4'              ;
WS3_Five      equ    D'5'              ;
WS3_Six       equ    D'6'              ;
WS3_Seven     equ    D'7'              ;
WS3_Eight     equ    D'8'              ;
WS3_Nine      equ    D'9'              ;
WS3_Ten       equ    D'10'             ;
                                       ;
WS_Timeout    equ    D'254'            ;
WS_Error      equ    D'255'            ;
;============================================================
====================
; Voice Recognition Variable
```

```
;==================================================
====================
VCountLo      equ    Voice_Var +D'0'   ;
VCountHi      equ    Voice_Var +D'1'   ;
VRA           equ    Voice_Var +D'2'   ;
VRA1          equ    Voice_Var +D'3'   ;
VRLED         equ    Voice_Var +D'4'   ;
WS            equ    Voice_Var +D'5'   ;
RXC           equ    Voice_Var +D'6'   ;
RXC_PREV      equ    Voice_Var +D'7'   ;
VR_RecgWait   equ    Voice_Var +D'8'   ;
;==================================================
====================
Init_VR:      clrf   VCountLo          ;
          clrf   VCountHi          ;
          clrf   RXC               ;
          clrf   RXC_PREV          ;
                                   ;
          call   VR_Wakeup         ; Wake Up Voice Module
          call   VR_SetLanguage    ;
          call   VR_SetTimeout     ;
                                   ;
          movlw  D'1'              ;
          movwf  WS                ;
                                   ;
          return                   ;
;==================================================
====================
VR_Wakeup:    movlw  CMD_BREAK         ;
          movwf  tx_data           ;
          call   Send_tx           ;
          clrf   VCountHi          ;
          clrf   VCountLo          ;
          call   Get_rx            ;
          movlw  STS_SUCCESS       ; IF VRA <> STS_SUCCESS THEN GOTO
VR_Wakeup
          subwf  VRA,W             ;
          btfss  STATUS,Z          ;
          goto   VR_Wakeup         ;
          call   Delay             ;
          return                   ;
;==================================================
====================
VR_SetLanguage:                    ;
```

```
            movlw  CMD_LANGUAGE       ;
            movwf  tx_data            ;
            call   Send_tx            ;
            movlw  D'0'               ; english language
            addlw  ARG_ZERO           ;
            movwf  tx_data            ;
            call   Send_tx            ;
            movlw  D'100'             ;
            movwf  VCountHi           ;
VR_LangLoop: clrf  VCountLo           ;
            call   Get_rx             ;
            movlw  STS_SUCCESS        ; IF VRA = STS_SUCCESS
            subwf  VRA,W              ;
            btfss  STATUS,Z           ;
            goto   VR_LangLoop        ;
            call   Delay              ;
            return                    ;
;=====================================================
=====================
VR_SetTimeout:                        ;
            movlw  CMD_TIMEOUT        ;
            movwf  tx_data            ;
            call   Send_tx            ;
            movlw  D'3'               ; 3 second
            addlw  ARG_ZERO           ;
            movwf  tx_data            ;
            call   Send_tx            ;
            movlw  D'100'             ;
            movwf  VCountHi           ;
VR_SetTLoop: clrf  VCountLo           ;
            call   Get_rx             ;
            movlw  STS_SUCCESS        ; IF VRA = STS_SUCCESS THEN
            subwf  VRA,W              ;
            btfss  STATUS,Z           ;
            goto   VR_SetTLoop        ;
            call   Delay              ;
            return                    ;
;=====================================================
=====================
VR_Recognize:                         ;
            movlw  D'250'             ;
            movwf  LED1_Tmr           ;
                                      ;
Chk_WS:     movlw  D'1'               ;
```

```
            subwf  WS,W             ;
            btfss  STATUS,C         ;
            goto   WS_1             ;
                                ;
            movlw  D'3'             ;
            subwf  WS,W             ;
            btfss  STATUS,C         ;
            goto   Chk_WSDone       ;
                                ;
WS_1:       movlw  D'1'             ;
            movwf  WS               ;
Chk_WSDone: nop                     ;
                                ;
            movlw  CMD_RECOG_SI     ;
            movwf  tx_data          ;
            call   Send_tx          ;
            movf   WS,W             ;
            addlw  ARG_ZERO         ;
            movwf  tx_data          ;
            call   Send_tx          ;
                                ;
            movlw  D'250'           ;
            movwf  VCountHi         ;
            clrf   VCountLo         ;
            call   Get_rx           ;
                                ;
            movlw  STS_SIMILAR      ; IF VRA = STS_SIMILAR
            subwf  VRA,W            ;
            btfss  STATUS,Z         ;
            goto   VR_RecgErr       ;
                                ;
            movlw  ARG_ACK          ;
            movwf  tx_data          ;
            call   Send_tx          ;
                                ;
            clrf   VCountHi         ;
            clrf   VCountLo         ;
            call   Get_rx           ;
                                ;
            movlw  ARG_MAX          ;
            subwf  VRA,W            ;
            btfsc  STATUS,C         ;
            goto   VR_RecgErr       ;
            movlw  ARG_ZERO         ;
```

```
            subwf  VRA,W            ;
            btfss  STATUS,C         ;
            goto   VR_RecgErr       ;
            movwf  I                ;
            incf   I,F              ;
                                    ;
Chk_WS1:    movlw  D'1'             ;
            subwf  WS,W             ;
            btfss  STATUS,Z         ;
            goto   VR_RecgOut       ;
                                    ;
Chk_WS1Stop: movlw D'7'             ;
            subwf  I,W              ;
            btfss  STATUS,Z         ;
            goto   Chk_WS1StopX     ;
            clrf   I                ;
            goto   VR_RecgOut       ;
Chk_WS1StopX: nop                   ;
                                    ;
Chk_WS1Move: movlw D'2'             ;
            subwf  I,W              ;
            btfss  STATUS,Z         ;
            goto   Chk_WS1MoveX     ;
            movlw  D'2'             ;
            movwf  WS               ;
            movlw  D'250'           ;
            movwf  LED2_Tmr         ;
Chk_WS1MoveX: nop                   ;
                                    ;
            goto   VR_RecgDone      ;
                                    ;
VR_RecgOut: movlw  D'1'             ;
            movwf  WS               ;
            movlw  D'250'           ;
            movwf  LED2_Tmr         ;
                                    ;
VR_Recg0:   movlw  D'0'             ;
            subwf  I,W              ;
            btfsc  STATUS,Z         ;
            call   Move_Stop        ;
                                    ;
VR_Recg1:   movlw  D'1'             ;
            subwf  I,W              ;
            btfsc  STATUS,Z         ;
```

```
            call   Turn_Left          ;
                                  ;
VR_Recg2:     movlw  D'2'             ;
            subwf  I,W                ;
            btfsc  STATUS,Z           ;
            call   Turn_Right         ;
                                  ;
VR_Recg3:     movlw  D'3'             ;
            subwf  I,W                ;
            btfsc  STATUS,Z           ;
            call   Move_UP            ;
                                  ;
VR_Recg4:     movlw  D'4'             ;
            subwf  I,W                ;
            btfsc  STATUS,Z           ;
            call   Move_Down          ;
                                  ;
VR_Recg5:     movlw  D'5'             ;
            subwf  I,W                ;
            btfsc  STATUS,Z           ;
            call   Move_FWD           ;
                                  ;
VR_Recg6:     movlw  D'6'             ;
            subwf  I,W                ;
            btfsc  STATUS,Z           ;
            call   Move_BAK           ;
                                  ;
            goto   VR_RecgDone        ;
                                  ;
VR_RecgErr:   movlw  D'1'             ;
            movwf  WS                 ;
                                  ;
VR_RecgDone:  call   Short_Delay      ;
                                  ;
            return                ;
;====================================================
====================
Send_tx:      bsf    STATUS,RP0       ;
            btfss  TXSTA,TRMT         ; (1) if Transmit is Done
            goto   $-1                ;
            bcf    STATUS,RP0         ;
            btfss  PIR1,TXIF          ;
            goto   $-1                ; wait for transmitter interrupt flag
            movf   tx_data,W          ;
```

```
        movwf  TXREG            ; load data to be sent...
        call   Short_Delay      ;
        return                  ;
;=========================================================
====================
Get_rx:     clrf   VRA              ;
        call   Short_Delay      ;
        incf   VCountLo,F       ;
        movlw  D'250'           ;
        subwf  VCountLo,W       ;
        btfss  STATUS,C         ;
        goto   Get_rx1          ;
        clrf   VCountLo         ;
        decf   VCountHi,F       ;
        movf   VCountHi,W       ;
        btfsc  STATUS,Z         ;
        goto   Get_rxDone       ;
Get_rx1:    call   ser_in           ; get UART input into W and rx_data
        btfss  is_data,0        ;
        goto   Get_rx           ; Check until
        movf   rx_data,W        ;
        movwf  VRA              ;
Get_rxDone:   return                ;
;=========================================================
====================
Do_LED1:    movf   LED1_Tmr,W       ;
        btfsc  STATUS,Z         ;
        goto   Do_LED1OFF       ;
        bsf    PORTC,4          ;
        decf   LED1_Tmr,F       ;
        goto   Do_LED1Done      ;
                                ;
Do_LED1OFF:   movlw  D'2'           ;
        subwf  WS,W             ;
        btfss  STATUS,Z         ;
        bcf    PORTC,4          ;
        movlw  D'2'             ;
        subwf  WS,W             ;
        btfsc  STATUS,Z         ;
        bsf    PORTC,4          ;
Do_LED1Done:  return                ;
;=========================================================
====================
Do_LED2:    movf   LED2_Tmr,W       ;
```

```
          btfsc  STATUS,Z          ;
          goto   Do_LED2OFF        ;
          bsf    PORTC,5           ;
          decf   LED2_Tmr,F        ;
          goto   Do_LED2Done       ;
Do_LED2OFF:   bcf    PORTC,5       ;
Do_LED2Done:  return               ;
;==============================================================================
Read_ADC:     bsf    ADCON0,0      ;
          bsf    ADCON0,7          ;
          nop                      ;
          bsf    ADCON0,2          ;
          nop                      ;
          btfsc  ADCON0,2          ;
          goto   $-1               ;
                                   ;
Read_ADC0:    movlw  D'0'          ; RA0
          subwf  ADC_Sel,W         ; Left Front Sensor
          btfss  STATUS,Z          ;
          goto   Read_ADC0X        ;
          movf   ADRESH,W          ;
          movwf  ADC0              ;
                                   ;
          clrf   Temp1             ;
          movlw  D'80'             ; 75cm equivalent
          subwf  ADC0,W            ;
          btfsc  STATUS,C          ;
          bsf    Temp1,0           ;
          btfsc  Temp1,0           ;
          call   Move_Stop         ;
          btfsc  Temp1,0           ;
          bsf    PORTD,0           ;
          btfss  Temp1,0           ;
          bcf    PORTD,0           ;
                                   ;
Read_ADC0X:   nop                  ;
                                   ;
Read_ADC1:    movlw  D'1'          ; RA1
          subwf  ADC_Sel,W         ; Right Front Sensor
          btfss  STATUS,Z          ;
          goto   Read_ADC1X        ;
          movf   ADRESH,W          ;
          movwf  ADC1              ;
```

```
                        ;
          clrf   Temp1           ;
          movlw  D'80'           ; 75cm equivalent
          subwf  ADC1,W            ;
          btfsc  STATUS,C          ;
          bsf    Temp1,0          ;
;          btfsc  Temp1,0          ;
;          call   Move_Stop        ;
          btfsc  Temp1,0          ;
          bsf    PORTD,1          ;
          btfss  Temp1,0          ;
          bcf    PORTD,1          ;
                        ;
Read_ADC1X:   nop                 ;
                        ;
Read_ADC2:    movlw  D'2'           ; RA2
          subwf  ADC_Sel,W         ;
          btfss  STATUS,Z          ;
          goto   Read_ADC2X        ;
          movf   ADRESH,W          ;
          movwf  ADC2              ;
Read_ADC2X:   nop                 ;
                        ;
Read_ADC3:    movlw  D'3'           ; RA3
          subwf  ADC_Sel,W         ;
          btfss  STATUS,Z          ;
          goto   Read_ADC3X        ;
          movf   ADRESH,W          ;
          movwf  ADC3              ;
Read_ADC3X:   nop                 ;
                        ;
Read_ADC4:    movlw  D'4'           ; RA5
          subwf  ADC_Sel,W         ; Left Back Sensor
          btfss  STATUS,Z          ;
          goto   Read_ADC4X        ;
          movf   ADRESH,W          ;
          movwf  ADC4              ;
                        ;
          clrf   Temp1           ;
          movlw  D'80'           ; 75cm equivalent
          subwf  ADC4,W            ;
          btfsc  STATUS,C          ;
          bsf    Temp1,0          ;
;          btfsc  Temp1,0          ;
```

```
;               call   Move_Stop         ;
              btfsc  Temp1,0            ;
              bsf    PORTD,2            ;
              btfss  Temp1,0            ;
              bcf    PORTD,2            ;
                                 ;
Read_ADC4X:   nop                      ;
                                 ;
Read_ADC5:    movlw  D'5'              ; RE0
              subwf  ADC_Sel,W         ; Right Back Sensor
              btfss  STATUS,Z          ;
              goto   Read_ADC5X        ;
              movf   ADRESH,W          ;
              movwf  ADC5              ;
                                 ;
              clrf   Temp1             ;
              movlw  D'80'             ; 75cm equivalent
              subwf  ADC5,W            ;
              btfsc  STATUS,C          ;
              bsf    Temp1,0           ;
;               btfsc  Temp1,0           ;
;               call   Move_Stop         ;
              btfsc  Temp1,0            ;
              bsf    PORTD,3            ;
              btfss  Temp1,0            ;
              bcf    PORTD,3            ;
                                 ;
Read_ADC5X:   nop                      ;
                                 ;
Read_ADC6:    movlw  D'6'              ; RE1
              subwf  ADC_Sel,W         ; Left Floor Sensor
              btfss  STATUS,Z          ;
              goto   Read_ADC6X        ;
              movf   ADRESH,W          ;
              movwf  ADC6              ;
                                 ;
              clrf   Temp1             ;
;               movlw  D'60'             ; 85cm equivalent
              movlw  D'50'             ; ??cm equivalent
              subwf  ADC6,W            ;
              btfss  STATUS,C          ;
              bsf    Temp1,0           ;
;               btfsc  Temp1,0           ;
;               call   Move_Stop         ;
```

```
            btfsc  Temp1,0           ;
            bsf    PORTD,4           ;
            btfss  Temp1,0           ;
            bcf    PORTD,4           ;
                                     ;
Read_ADC6X:  nop                     ;
                                     ;
Read_ADC7:   movlw  D'7'             ; RE2
            subwf  ADC_Sel,W         ; Right Floor Sensor
            btfss  STATUS,Z          ;
            goto   Read_ADC7X        ;
            movf   ADRESH,W          ;
            movwf  ADC7              ;
                                     ;
            clrf   Temp1             ;
;           movlw  D'60'             ; 85cm equivalent
            movlw  D'50'             ; ??cm equivalent
            subwf  ADC7,W            ;
            btfss  STATUS,C          ;
;           bsf    Temp1,0           ;
;           btfsc  Temp1,0           ;
            call   Move_Stop         ;
            btfsc  Temp1,0           ;
            bsf    PORTD,5           ;
            btfss  Temp1,0           ;
            bcf    PORTD,5           ;
                                     ;
Read_ADC7X:  nop                     ;
                                     ;

            movf   PORTD,W           ;
            andlw  B'00111111'       ;
            movwf  Sensor            ;
                                     ;

            incf   ADC_Sel,F         ;
            movlw  D'8'              ;
            subwf  ADC_Sel,W         ;
            btfsc  STATUS,C          ;
            clrf   ADC_Sel           ;
                                     ;
Sel_ADC0:    movlw  D'0'             ;
            subwf  ADC_Sel,W         ;
            btfss  STATUS,Z          ;
```

```
            goto   Sel_ADC0X         ;
            movlw  B'10000001'       ;
            movwf  ADCON0            ;
Sel_ADC0X:    nop                    ;
                                ;
Sel_ADC1:     movlw  D'1'            ;
            subwf  ADC_Sel,W         ;
            btfss  STATUS,Z          ;
            goto   Sel_ADC1X         ;
            movlw  B'10001001'       ;
            movwf  ADCON0            ;
Sel_ADC1X:    nop                    ;
                                ;
Sel_ADC2:     movlw  D'2'            ;
            subwf  ADC_Sel,W         ;
            btfss  STATUS,Z          ;
            goto   Sel_ADC2X         ;
            movlw  B'10010001'       ;
            movwf  ADCON0            ;
Sel_ADC2X:    nop                    ;
                                ;
Sel_ADC3:     movlw  D'3'            ;
            subwf  ADC_Sel,W         ;
            btfss  STATUS,Z          ;
            goto   Sel_ADC3X         ;
            movlw  B'10011001'       ;
            movwf  ADCON0            ;
Sel_ADC3X:    nop                    ;
                                ;
Sel_ADC4:     movlw  D'4'            ;
            subwf  ADC_Sel,W         ;
            btfss  STATUS,Z          ;
            goto   Sel_ADC4X         ;
            movlw  B'10100001'       ;
            movwf  ADCON0            ;
Sel_ADC4X:    nop                    ;
                                ;
Sel_ADC5:     movlw  D'5'            ;
            subwf  ADC_Sel,W         ;
            btfss  STATUS,Z          ;
            goto   Sel_ADC5X         ;
            movlw  B'10101001'       ;
            movwf  ADCON0            ;
Sel_ADC5X:    nop                    ;
```

```
                        ;
Sel_ADC6:    movlw  D'6'            ;
             subwf  ADC_Sel,W       ;
             btfss  STATUS,Z        ;
             goto   Sel_ADC6X       ;
             movlw  B'10110001'     ;
             movwf  ADCON0          ;
Sel_ADC6X:   nop                    ;
                        ;
Sel_ADC7:    movlw  D'7'            ;
             subwf  ADC_Sel,W       ;
             btfss  STATUS,Z        ;
             goto   Sel_ADC7X       ;
             movlw  B'10111001'     ;
             movwf  ADCON0          ;
Sel_ADC7X:   nop                    ;
                        ;
Read_ADCX:   return                 ;
;=====================================================
====================
Read_SW:     movf   PORTA,W         ;
             movwf  SWA_New         ;
                        ;
Chk_SWA4:    btfsc  SWA_New,4       ;
             goto   Chk_SWA4Done    ;
             call   Move_Stop       ;
Chk_SWA4Done: nop                   ;
                        ;
;Chk_SWA0:   btfsc  SWA_New,0       ;
;            goto   Chk_SWA0Done    ;
;            call   Move_Stop       ;
;Chk_SWA0Done: nop                  ;
;                       ;
;Chk_SWA1:   btfsc  SWA_New,1       ;
;            goto   Chk_SWA1Done    ;
;            btfss  SWA_Prev,1      ;
;            goto   Chk_SWA1Done    ;
;            call   Move_FWD        ;
;Chk_SWA1Done: nop                  ;
;                       ;
;Chk_SWA2:   btfsc  SWA_New,2       ;
;            goto   Chk_SWA2Done    ;
;            btfss  SWA_Prev,2      ;
;            goto   Chk_SWA2Done    ;
```

```
;               call    Turn_Right          ;
;Chk_SWA2Done: nop                          ;
;                                   ;
;Chk_SWA3:      btfsc   SWA_New,3           ;
;               goto    Chk_SWA3Done        ;
;               btfss   SWA_Prev,3          ;
;               goto    Chk_SWA3Done        ;
;               call    Turn_Left           ;
;Chk_SWA3Done: nop                          ;
;                                   ;
;Chk_SWA4:      btfsc   SWA_New,4           ;
;               goto    Chk_SWA4Done        ;
;               btfss   SWA_Prev,4          ;
;               goto    Chk_SWA4Done        ;
;               call    Move_BAK            ;
;Chk_SWA4Done: nop                          ;
;                                   ;
;Chk_SWA5:      btfsc   SWA_New,5           ;
;               goto    Chk_SWA5Done        ;
;               btfss   SWA_Prev,5          ;
;               goto    Chk_SWA5Done        ;
;               call    Move_Down           ;
;Chk_SWA5Done: nop                          ;
;                                   ;
;Chk_SWE0:      btfsc   SWE_New,0           ;
;               goto    Chk_SWE0Done        ;
;               btfss   SWE_Prev,0          ;
;               goto    Chk_SWE0Done        ;
;               call    Move_UP             ;
;Chk_SWE0Done: nop                          ;
                                    ;

Chk_FWD:        movf    PORTB,W             ;
                andlw   H'0F'               ;
                sublw   B'00000101'         ;
                btfss   STATUS,Z            ;
                goto    Chk_FWDX            ;
                btfsc   Sensor,0            ;Left Front
                call    Move_Stop           ;
                btfsc   Sensor,1            ;Right Front
                call    Move_Stop           ;
                btfsc   Sensor,4            ;Left Floor
                call    Move_Stop           ;
                btfsc   Sensor,5            ;Right Floor
```

```
            call   Move_Stop         ;
Chk_FWDX:     nop                    ;
                                 ;
Chk_BAK:      movf   PORTB,W          ;
            andlw  H'0F'             ;
            sublw  B'00001010'       ;
            btfss  STATUS,Z          ;
            goto   Chk_BAKX          ;
            btfsc  Sensor,2          ;Left Back
            call   Move_Stop         ;
            btfsc  Sensor,3          ;Right Back
            call   Move_Stop         ;
Chk_BAKX:     nop                    ;
                                 ;
Chk_Left:     movf   PORTB,W          ;
            andlw  H'0F'             ;
            sublw  B'00000110'       ;
            btfss  STATUS,Z          ;
            goto   Chk_LeftX         ;
            btfsc  Sensor,0          ;Left Front
            call   Move_Stop         ;
            btfsc  Sensor,4          ;Left Floor
            call   Move_Stop         ;
Chk_LeftX:    nop                    ;
                                 ;
Chk_Right:    movf   PORTB,W          ;
            andlw  H'0F'             ;
            sublw  B'00001001'       ;
            btfss  STATUS,Z          ;
            goto   Chk_RightX        ;
            btfsc  Sensor,1          ;Right Front
            call   Move_Stop         ;
            btfsc  Sensor,5          ;Right Floor
            call   Move_Stop         ;
Chk_RightX:   nop                    ;
                                 ;
            movf   SWA_New,W         ;
            movwf  SWA_Prev          ;
            movf   SWE_New,W         ;
            movwf  SWE_Prev          ;
            return                 ;
;===========================================
====================
Move_Stop:    bcf    PORTB,0          ;
```

```
        bcf    PORTB,1          ;
        bcf    PORTB,2          ;
        bcf    PORTB,3          ;
        bcf    PORTB,4          ;
        bcf    PORTB,5          ;
        bcf    PORTB,6          ;
        bcf    PORTB,7          ;
        call   Relay_Delay      ;
        return                  ;
                                ;
Move_FWD:   bcf    PORTB,1      ;
        bcf    PORTB,3          ;
        bcf    PORTB,7          ;
        call   Relay_Delay      ; 76543210
        bsf    PORTB,0          ; 01  0101
        bsf    PORTB,2          ;
        bsf    PORTB,6          ;
        return                  ;
                                ;
Move_BAK:   bcf    PORTB,0      ;
        bcf    PORTB,2          ;
        bcf    PORTB,6          ;
        call   Relay_Delay      ; 76543210
        bsf    PORTB,1          ; 10  1010
        bsf    PORTB,3          ;
        bsf    PORTB,7          ;
        return                  ;
                                ;
Move_Left:  bcf    PORTB,1      ;
        bcf    PORTB,2          ;
        bcf    PORTB,3          ;
        bcf    PORTB,6          ;
        bcf    PORTB,7          ;
        call   Relay_Delay      ; 76543210
        bsf    PORTB,2          ; 00  0100
        return                  ;
                                ;
Move_Right: bcf    PORTB,0      ;
        bcf    PORTB,1          ;
        bcf    PORTB,3          ;
        bcf    PORTB,6          ;
        bcf    PORTB,7          ;
        call   Relay_Delay      ; 76543210
        bsf    PORTB,0          ;
```

```
            return              ;
                                ;
Turn_Left:    bcf    PORTB,1          ;
            bcf    PORTB,2          ;
            bcf    PORTB,6          ;
            bcf    PORTB,7          ;
            call   Relay_Delay      ; 76543210
            bsf    PORTB,1          ; 00  0110
            bsf    PORTB,2          ;
            return              ;
                                ;
Turn_Right:   bcf    PORTB,0          ;
            bcf    PORTB,3          ;
            bcf    PORTB,6          ;
            bcf    PORTB,7          ;
            call   Relay_Delay      ; 76543210
            bsf    PORTB,0          ; 00  1001
            bsf    PORTB,3          ;
            return              ;
                                ;
Move_UP:      bcf    PORTB,0          ;
            bcf    PORTB,1          ;
            bcf    PORTB,2          ;
            bcf    PORTB,3          ;
            bcf    PORTB,6          ;
            bcf    PORTB,7          ;
            bcf    PORTB,4          ;
            call   Relay_Delay      ; 76543210
            bsf    PORTB,5          ;   10
            return              ;
                                ;
Move_Down:    bcf    PORTB,0          ;
            bcf    PORTB,1          ;
            bcf    PORTB,2          ;
            bcf    PORTB,3          ;
            bcf    PORTB,6          ;
            bcf    PORTB,7          ;
            bcf    PORTB,5          ;
            call   Relay_Delay      ; 76543210
            bsf    PORTB,4          ;   01
            return              ;
;==================================================
====================
Relay_Delay:  movlw  D'250'           ;
```

```
        movwf  I                ;
RDly_Loop:    decf   I,F                ;
        movf   I,W                ;
        btfss  STATUS,Z           ;
        goto   RDly_Loop          ;
        return                  ;
;==========================================================
====================
Short_Delay:  movlw  D'250'             ;
        movwf  I                ;
SDly_Loop:    decf   I,F                ;
        movf   I,W                ;
        btfss  STATUS,Z           ;
        goto   SDly_Loop          ;
        call   Do_LED1            ;
        call   Do_LED2            ;
        call   Read_SW            ;
        call   Read_ADC           ;
        return                  ;
;==========================================================
====================
Delay:        movlw  D'100'             ;
        movwf  J                ;
Dly_Loop1:    call   Short_Delay        ;
        decf   J,F              ;
        movf   J,W                ;
        btfss  STATUS,Z           ;
        goto   Dly_Loop1          ;
        return                  ;
;==========================================================
===================
;                  CONFIGURE SERIAL PORT
;==========================================================
===================
Init_UART:                        ;uart specific initialization
                              ;txsta=Transmit STAtus and control reg.
        bsf    STATUS,RP0         ;Select Bank 1
        bcf    STATUS,RP1         ;
                              ;
        bcf    TXSTA,CSRC         ; <7> (0) don't care in asynch mode
        bcf    TXSTA,TX9          ; <6>  0  select 8 bit mode
        bsf    TXSTA,TXEN         ; <5>  1  enable transmit function
                              ;       *MUST* be 1 for transmit to work!!!
        bcf    TXSTA,SYNC         ; <4>  0 asynchronous mode.
```

```
                        ;       *MUST* be 0 !!!
                        ;       If NOT 0 the async mode is NOT selected!
                        ; <3>  (0) not implemented
;=================================================
===================
        bsf     TXSTA,BRGH        ; <2>  1 ENABLE high baud rate generator !!!
                        ;       0 DISABLE High Baud Rate Generator
;=================================================
===================
                        ; <1>  (0) trmt is read only.
        bcf     TXSTA,TX9D        ; <0>  (0)  tx9d data cleared to 0.
;baudrate     =       d'9600'           ;desired baudrate.
spbrg_value   =       d'103'            ; for BRGH = 1 (see TABLE 10-3 of
30292c.pdf)
; @16Mhz Crystal                        ;
        movlw  spbrg_value       ;set baud rate generator value
        movwf  SPBRG             ;
;************************************************************
***********
        bcf     STATUS,RP0        ;allow access to page 0 stuff again. (normal)
                        ;more uart specific initializat4ion
                        ;rcsta=ReCeive STAtus and control register
        bsf     RCSTA,SPEN        ; 7 spen 1=rx/tx set for serial uart mode
                        ;   !!! very important to set spen=1
        bcf     RCSTA,RX9         ; 6 rc8/9 0=8 bit mode
        bcf     RCSTA,SREN        ; 5 sren 0=don't care in uart mode
        bsf     RCSTA,CREN        ; 4 cren 1=enable constant reception
                        ;!!! (and low clears errors)
                        ; 3 not used / 0 / don't care
        bcf     RCSTA,FERR        ; 2 ferr input framing error bit. 1=error
                        ; 1 oerr input overrun error bit. 1=error
                        ;It is only cleared when you pulse cren low.
        bcf     RCSTA,RX9D        ; 0 rx9d input (9th data bit). ignore.
                        ;
        movf   RCREG,W           ;clear uart receiver
        movf   RCREG,W           ; including fifo
        movf   RCREG,W           ; which is three deep.
                        ;
        movlw  0                 ;any character will do.
        movwf  TXREG             ;send out dummy character
                        ; to get transmit flag valid!
        return                   ;
;************************************************************
**********
```

```
;               RS-232 SERIAL IN / SERIAL OUT ROUTINES
;*****************************************************************
**********
;exit with received serial data in W and in variable rx_data
ser_in:       clrf   is_data          ;Reset Flag
          btfsc  RCSTA,OERR        ;
          goto   overerror         ;if overflow error...
          btfsc  RCSTA,FERR        ;
          goto   frameerror        ;if framing error...
                             ;
          clrw                 ;
uart_ready:   btfss  PIR1,RCIF        ;
          goto   ser_inX           ;
          movf   RCREG,W           ;recover uart data
          movwf  rx_data           ;save for later
          bsf    is_data,0         ;
ser_inX:      return               ;
                             ;
overerror:    bcf    RCSTA,CREN        ;pulse cren off...
          movf   RCREG,W           ;flush fifo
          movf   RCREG,W           ; all three elements.
          movf   RCREG,W           ;
          bsf    RCSTA,CREN        ;turn cren back on.
                             ;this pulsing of cren
                             ;will clear the oerr flag.
          goto   ser_inX           ;try again...
                             ;
frameerror:   movf   RCREG,W           ;reading rcreg clears ferr flag.
          goto   ser_inX           ;try again...
;*****************************************************************
**********
          end                  ;
;*****************************************************************
***********
```

![MICROCHIP]

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

Devices Included in this Data Sheet:

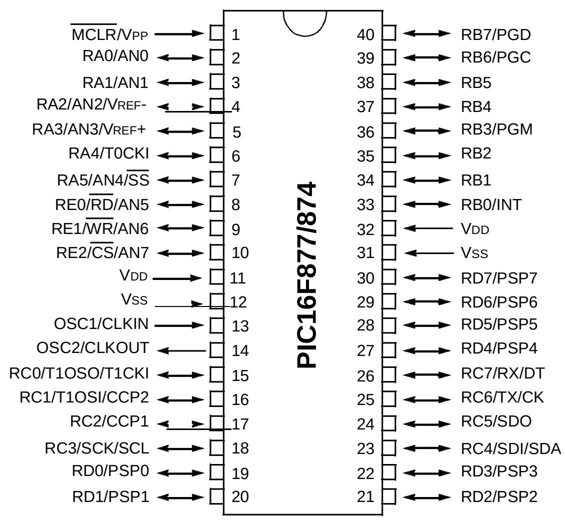
- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and
  Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 μA typical @ 3V, 32 kHz
  - < 1 μA typical standby current

Pin Diagram

PDIP

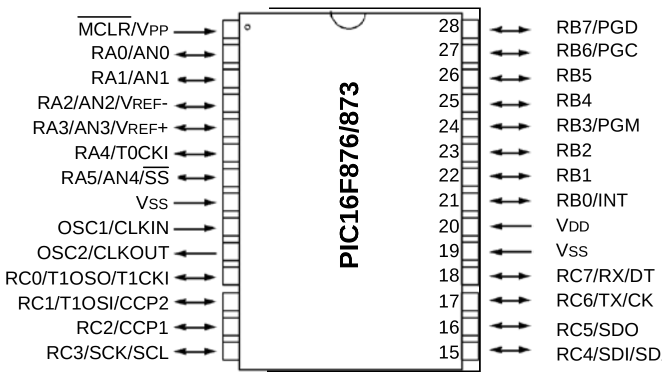


Peripheral Features:

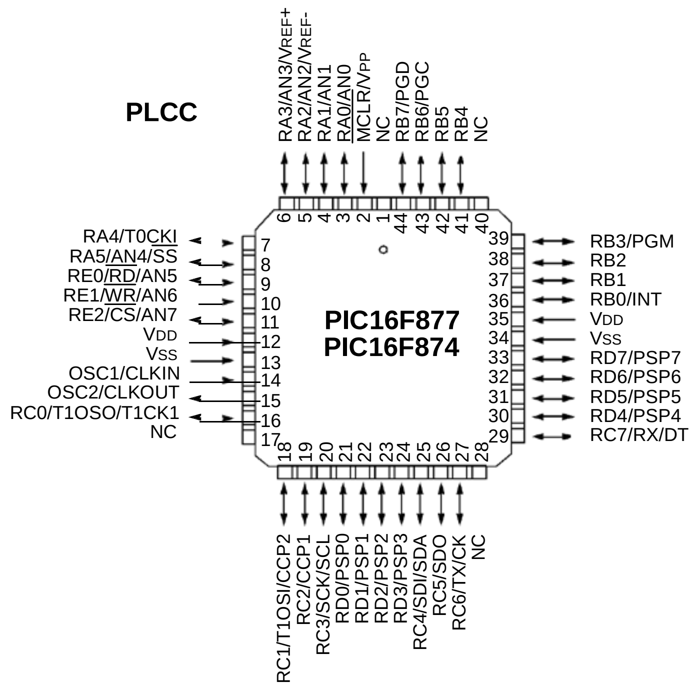
- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Pin Diagrams

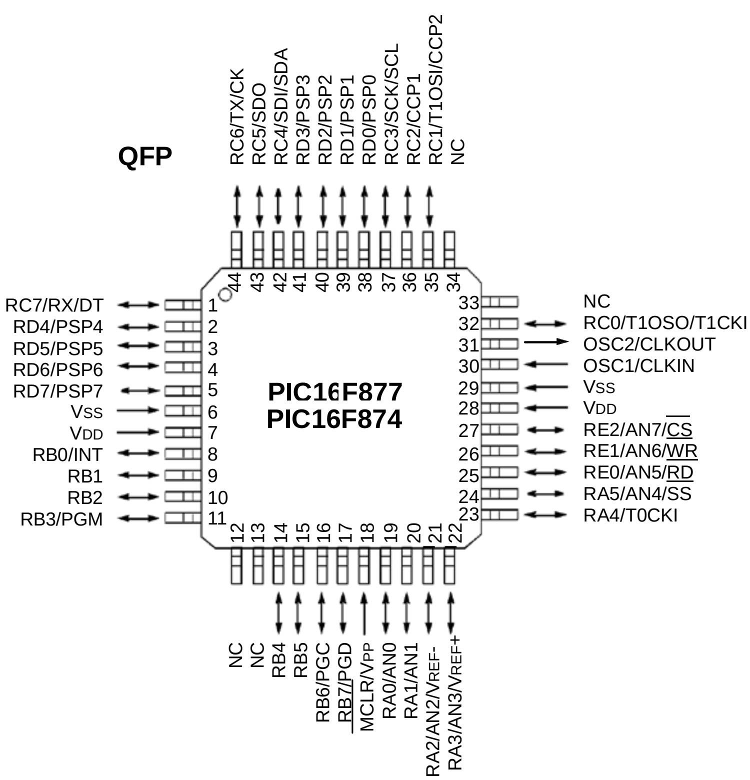
PDIP, SOIC



PLCC



QFP



Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	**PIC16F873**	**PIC16F874**	**PIC16F876**	**PIC16F877**
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/V_{PP}	1	2	18	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/V_{REF}-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/V_{REF}+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL TTL	
RB2	35	38	10	I/O	TTL TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	37	41	14	I/O	TTL/ST(2)	Interrupt-on-change pin.
RB5	38	42	15	I/O		Interrupt-on-change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O		Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION (CONTINUED)

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/ output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
V_{SS}	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
V_{DD}	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

3.0 I/O PORTS

Some pins for these I/O ports are multiplexed with an alternate function for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

Additional information on I/O ports may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023).

3.1 PORTA and the TRISA Register

PORTA is a 6-bit wide, bi-directional port. The corresponding data direction register is TRISA. Setting a TRISA bit (= 1) will make the corresponding PORTA pin an input (i.e., put the corresponding output driver in a Hi-Impedance mode). Clearing a TRISA bit (= 0) will make the corresponding PORTA pin an output (i.e., put the contents of the output latch on the selected pin).

Reading the PORTA register reads the status of the pins, whereas writing to it will write to the port latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, the value is modified and then written to the port data latch.

Pin RA4 is multiplexed with the Timer0 module clock input to become the RA4/T0CKI pin. The RA4/T0CKI pin is a Schmitt Trigger input and an open drain output. All other PORTA pins have TTL input levels and full CMOS output drivers.

Other PORTA pins are multiplexed with analog inputs and analog VREF input. The operation of each pin is selected by clearing/setting the control bits in the ADCON1 register (A/D Control Register1).

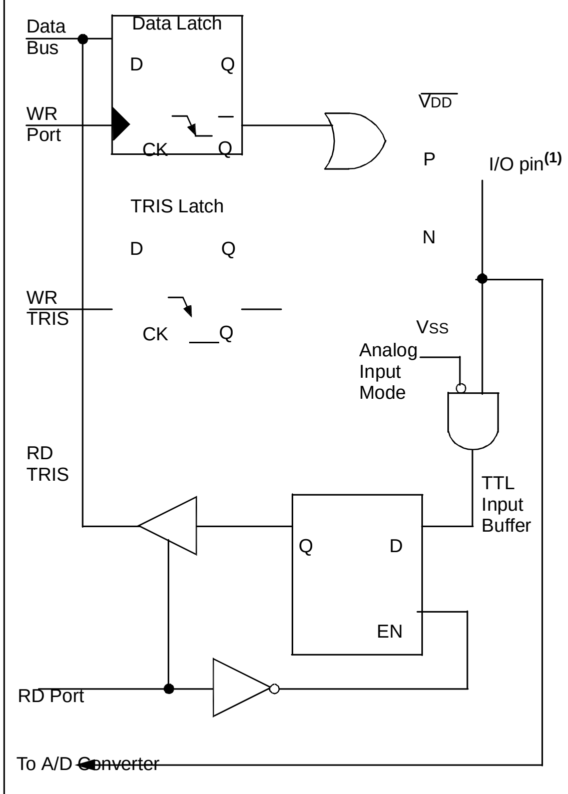
Note:	On a Power-on Reset, these pins are configured as analog inputs and read as '0'.

The TRISA register controls the direction of the RA pins, even when they are being used as analog inputs. The user must ensure the bits in the TRISA register are maintained set when using them as analog inputs.

EXAMPLE 3-1: INITIALIZING PORTA

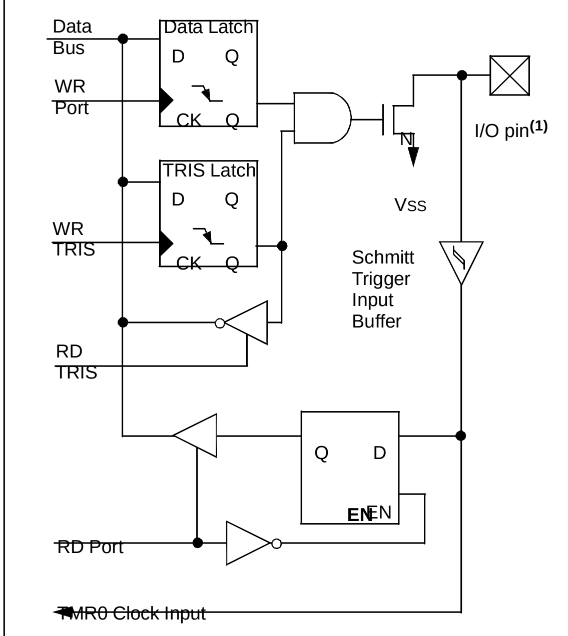
```
BCF     STATUS, RP0   ;
BCF     STATUS, RP1   ; Bank0
CLRF    PORTA         ; Initialize PORTA by
                      ; clearing output
                      ; data latches
BSF     STATUS, RP0   ; Select Bank 1
MOVLW   0x06          ; Configure all pins
MOVWF   ADCON1        ; as digital inputs
MOVLW   0xCF          ; Value used to
                      ; initialize data
                      ; direction
MOVWF   TRISA         ; Set RA<3:0> as inputs
                      ; RA<5:4> as outputs
                      ; TRISA<7:6>are always
                      ; read as '0'.
```

FIGURE 3-1: BLOCK DIAGRAM OF RA3:RA0 AND RA5 PINS



Note 1: I/O pins have protection diodes to VDD and VSS.

FIGURE 3-2: BLOCK DIAGRAM OF RA4/T0CKI PIN



Note 1: I/O pin has protection diodes to VSS only.

TABLE 3-1: PORTA FUNCTIONS

Name	Bit#	Buffer	Function
RA0/AN0	bit0	TTL	Input/output or analog input.
RA1/AN1	bit1	TTL	Input/output or analog input.
RA2/AN2	bit2	TTL	Input/output or analog input.
RA3/AN3/VREF	bit3	TTL	Input/output or analog input or VREF.
RA4/T0CKI	bit4	ST	Input/output or external clock input for Timer0. Output is open drain type.
RA5/SS/AN4	bit5	TTL	Input/output or slave select input for synchronous serial port or analog input.

Legend: TTL = TTL input, ST = Schmitt Trigger input

TABLE 3-2: SUMMARY OF REGISTERS ASSOCIATED WITH PORTA

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other RESETS
05h	PORTA	—	—	RA5	RA4	RA3	RA2	RA1	RA0	--0x 0000	--0u 0000
85h	TRISA	—	—	PORTA Data Direction Register						--11 1111	--11 1111
9Fh	ADCON1	ADFM	—	—	—	PCFG3	PCFG2	PCFG1	PCFG0	--0- 0000	--0- 0000

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'.
Shaded cells are not used by PORTA.

Note: When using the SSP module in SPI Slave mode and $\overline{SS}$ enabled, the A/D converter must be set to one of the following modes, where PCFG3:PCFG0 = `0100`,`0101`, `011x`, `1101`, `1110`, `1111`.

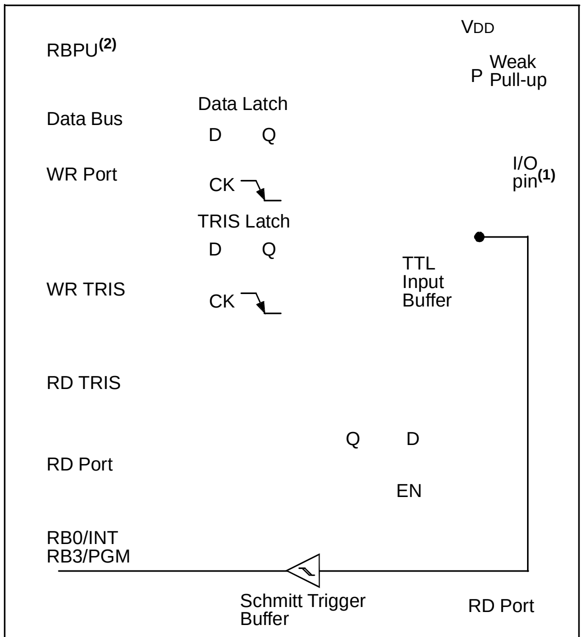
3.2 PORTB and the TRISB Register

PORTB is an 8-bit wide, bi-directional port. The corresponding data direction register is TRISB. Setting a TRISB bit (= 1) will make the corresponding PORTB pin an input (i.e., put the corresponding output driver in a Hi-Impedance mode). Clearing a TRISB bit (= 0) will make the corresponding PORTB pin an output (i.e., put the contents of the output latch on the selected pin).

Three pins of PORTB are multiplexed with the Low Voltage Programming function: RB3/PGM, RB6/PGC and RB7/PGD. The alternate functions of these pins are described in the Special Features Section.

Each of the PORTB pins has a weak internal pull-up. A single control bit can turn on all the pull-ups. This is performed by clearing bit RBPU (OPTION_REG<7>). The weak pull-up is automatically turned off when the port pin is configured as an output. The pull-ups are disabled on a Power-on Reset.

FIGURE 3-3: BLOCK DIAGRAM OF RB3:RB0 PINS



Note 1: I/O pins have diode protection to VDD and VSS.

2: To enable weak pull-ups, set the appropriate TRIS bit(s) and clear the RBPU bit (OPTION_REG<7>).

Four of the PORTB pins, RB7:RB4, have an interrupt-on-change feature. Only pins configured as inputs can cause this interrupt to occur (i.e., any RB7:RB4 pin configured as an output is excluded from the interrupt-on-change comparison). The input pins (of RB7:RB4) are compared with the old value latched on the last read of PORTB. The "mismatch" outputs of RB7:RB4 are OR'ed together to generate the RB Port Change Interrupt with flag bit RBIF (INTCON<0>).

This interrupt can wake the device from SLEEP. The user, in the Interrupt Service Routine, can clear the interrupt in the following manner:

a) Any read or write of PORTB. This will end the mismatch condition.
b) Clear flag bit RBIF.

A mismatch condition will continue to set flag bit RBIF. Reading PORTB will end the mismatch condition and allow flag bit RBIF to be cleared.

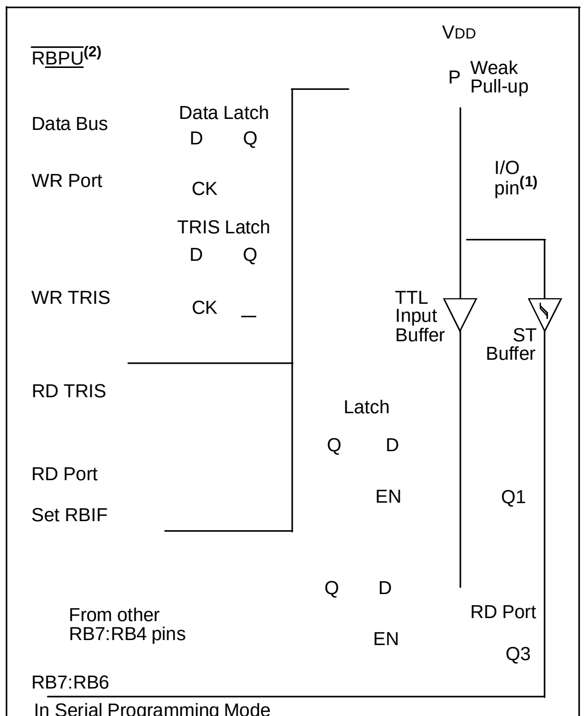
The interrupt-on-change feature is recommended for wake-up on key depression operation and operations where PORTB is only used for the interrupt-on-change feature. Polling of PORTB is not recommended while using the interrupt-on-change feature.

This interrupt-on-mismatch feature, together with software configureable pull-ups on these four pins, allow easy interface to a keypad and make it possible for wake-up on key depression. Refer to the Embedded Control Handbook, *"Implementing Wake-up on Key Strokes"* (AN552).

RB0/INT is an external interrupt input pin and is configured using the INTEDG bit (OPTION_REG<6>).

RB0/INT is discussed in detail in Section 12.10.1.

FIGURE 3-4: BLOCK DIAGRAM OF RB7:RB4 PINS



Note 1: I/O pins have diode protection to VDD and VSS.

2: To enable weak pull-ups, set the appropriate TRIS bit(s) and clear the RBPU bit (OPTION_REG<7>).

TABLE 3-3: PORTB FUNCTIONS

Name	Bit#	Buffer	Function
RB0/INT	bit0	TTL/ST(1)	Input/output pin or external interrupt input. Internal software programmable weak pull-up.
RB1	bit1	TTL	Input/output pin. Internal software programmable weak pull-up.
RB2	bit2	TTL	Input/output pin. Internal software programmable weak pull-up.
RB3/PGM(3)	bit3	TTL	Input/output pin or programming pin in LVP mode. Internal software programmable weak pull-up.
RB4	bit4	TTL	Input/output pin (with interrupt-on-change). Internal software programmable weak pull-up.
RB5	bit5	TTL	Input/output pin (with interrupt-on-change). Internal software programmable weak pull-up.
RB6/PGC	bit6	TTL/ST(2)	Input/output pin (with interrupt-on-change) or In-Circuit Debugger pin. Internal software programmable weak pull-up. Serial programming clock.
RB7/PGD	bit7	TTL/ST(2)	Input/output pin (with interrupt-on-change) or In-Circuit Debugger pin. Internal software programmable weak pull-up. Serial programming data.

Legend: TTL = TTL input, ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.

2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.

3: Low Voltage ICSP Programming (LVP) is enabled by default, which disables the RB3 I/O function. LVP must be disabled to enable RB3 as an I/O pin and allow maximum compatibility to the other 28-pin and 40-pin mid-range devices.

TABLE 3-4: SUMMARY OF REGISTERS ASSOCIATED WITH PORTB

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other RESETS
06h, 106h	PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0	xxxx xxxx	uuuu uuuu
86h, 186h	TRISB	PORTB Data Direction Register								1111 1111	1111 1111
81h, 181h	OPTION_REG	RBPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111

Legend: x = unknown, u = unchanged. Shaded cells are not used by PORTB.

3.3 PORTC and the TRISC Register

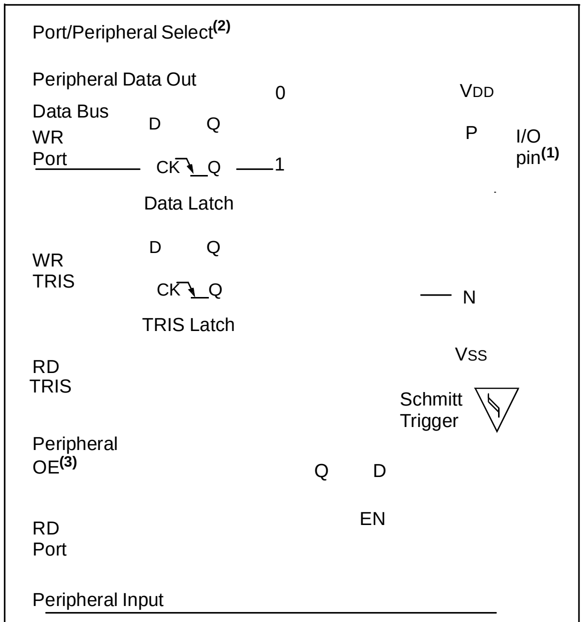
PORTC is an 8-bit wide, bi-directional port. The corresponding data direction register is TRISC. Setting a TRISC bit (= 1) will make the corresponding PORTC pin an input (i.e., put the corresponding output driver in a Hi-Impedance mode). Clearing a TRISC bit (= 0) will make the corresponding PORTC pin an output (i.e., put the contents of the output latch on the selected pin).

PORTC is multiplexed with several peripheral functions (Table 3-5). PORTC pins have Schmitt Trigger input buffers.

When the I^2C module is enabled, the PORTC<4:3> pins can be configured with normal I^2C levels, or with SMBus levels by using the CKE bit (SSPSTAT<6>).

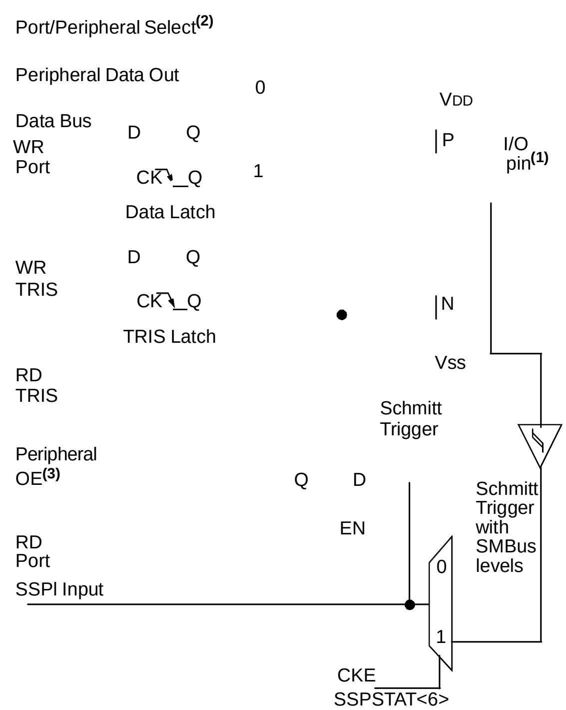
When enabling peripheral functions, care should be taken in defining TRIS bits for each PORTC pin. Some peripherals override the TRIS bit to make a pin an output, while other peripherals override the TRIS bit to make a pin an input. Since the TRIS bit override is in effect while the peripheral is enabled, read-modify-write instructions (`BSF, BCF, XORWF`) with TRISC as destination, should be avoided. The user should refer to the corresponding peripheral section for the correct TRIS bit settings.

FIGURE 3-5: PORTC BLOCK DIAGRAM (PERIPHERAL OUTPUT OVERRIDE) RC<2:0>, RC<7:5>



Note 1: I/O pins have diode protection to VDD and VSS.
2: Port/Peripheral select signal selects between port data and peripheral output.
3: Peripheral OE (output enable) is only activated if peripheral select is active.

FIGURE 3-6: PORTC BLOCK DIAGRAM (PERIPHERAL OUTPUT OVERRIDE) RC<4:3>



Note 1: I/O pins have diode protection to VDD and VSS.
2: Port/Peripheral select signal selects between port data and peripheral output.
3: Peripheral OE (output enable) is only activated if peripheral select is active.

TABLE 3-5: PORTC FUNCTIONS

Name	Bit#	Buffer Type	Function
RC0/T1OSO/T1CKI	bit0	ST	Input/output port pin or Timer1 oscillator output/Timer1 clock input.
RC1/T1OSI/CCP2	bit1	ST	Input/output port pin or Timer1 oscillator input or Capture2 input/ Compare2 output/PWM2 output.
RC2/CCP1	bit2	ST	Input/output port pin or Capture1 input/Compare1 output/ PWM1 output.
RC3/SCK/SCL	bit3	ST	RC3 can also be the synchronous serial clock for both SPI and I^2C modes.
RC4/SDI/SDA	bit4	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	bit5	ST	Input/output port pin or Synchronous Serial Port data output.
RC6/TX/CK	bit6	ST	Input/output port pin or USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	bit7	ST	Input/output port pin or USART Asynchronous Receive or Synchronous Data.

Legend: ST = Schmitt Trigger input

TABLE 3-6: SUMMARY OF REGISTERS ASSOCIATED WITH PORTC

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other RESETS
07h	PORTC	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0	xxxx xxxx	uuuu uuuu
87h	TRISC	PORTC Data Direction Register								1111 1111	1111 1111

Legend: x = unknown, u = unchanged

Parallax Say It Module (#30080)

The Parallax Say It Modules provides voice recognition functions for built-in Speaker Independent (SI) pre-programmed commands and up to 32 user-defined Speaker Dependent (SD) keywords (triggers, commands, or passwords).

When you speak into this module, it will match the spoken word to a set of keywords that it has been programmed to recognize. Once the module has determined if there is a match, it will take a defined action, either listening for the next keyword in another “wordset” or executing the commands associated with the word that was said. You can create up to 32 user-definable keywords.

The Say It GUI software for the BASIC Stamp 2 provides an easy interface for training the module and producing template code. Or, the simple and robust serial protocol provided can be used to access the Say It module functions from other Parallax microcontrollers. The 10-pin SIP header makes the module breadboard friendly, and is designed to fit in one row of the AppMod header found on the Board of Education and Boe-Bot Robot.

Features

- 23 Pre-programmed commands
- Up to 32 user-definable commands
- SIP for breadboard friendly projects (0.1” spacing)
- GUI provides training and template code for BASIC Stamp 2 modules
- On-board LED and microphone
- Voice controlled Boe-Bot examples

Key Specifications

- Power requirements: 3.3 to 5.5 VDC
- Communication: Adjustable Asynchonous Serial (9600 (default), 19200, 38700, 57600, 115200)
- Operating temperature: 32 to 158 °F (0 to 70 °C)
- Dimensions: 1.02 x 2.47 x .38 in (26 x 62.93 x 9.70 mm)

Application Ideas

- Voice-controlled entry systems
- Automated house applications
- Voice-activated robotics

Precaution

- Do not solely rely on the Say It module to recognize a command for a safety stop if your project requires one; take all appropriate precautions when implementing this module to maintain a safe project.

Using the Say It GUI Software

With the Say It GUI software for your PC and your BASIC Stamp 2 development board, you can test the Say It module and train it to recognize your custom commands. During training, the BASIC Stamp 2 handles the Say It module-to-PC communication through the provided PBASIC "bridge" program. Once your you have defined and tested your commands, the GUI software will generate a new PBASIC template program ready for you to add the actions to take when your voice commands are received.

Follow the steps below to connect to the Say It module via the GUI software. This example assumes you are using a Board of Education with BASIC Stamp 2, and you have previously installed the BASIC Stamp Editor and tested the programming connection.

1. With the power to your board turned off (switch position 0) Plug the Say It module into the AppMod header of the Board of Education (as seen in Figure 12); be careful to insert the module in the left row of the header and in the correct orientation (Vss at top, Vdd at bottom, RX to P0, TX to P2 and LED to P4).

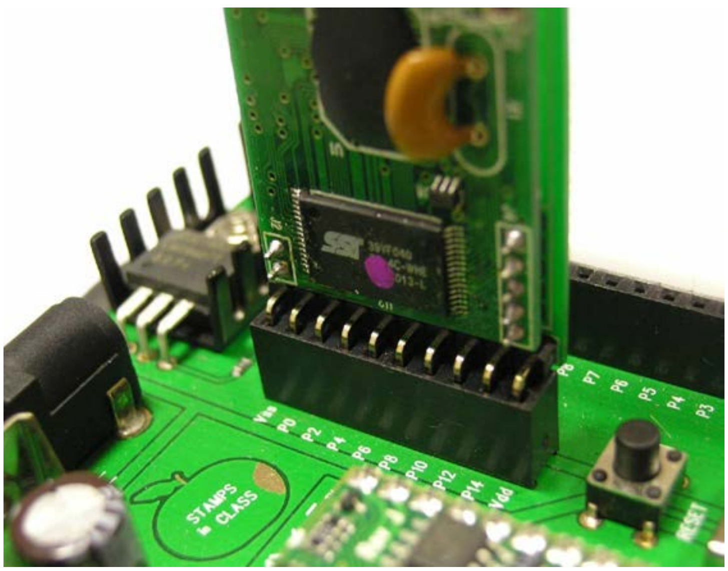


Figure 1

2. Download and install the Say It GUI software from the 30080 product page at www.parallax.com. Use the default installation path. For Windows Vista users, install as administrator.

3. Start the Say It GUI software, and then connect the Board of Education to your PC and turn the power switch on (position 1).

4. Select the serial port that the Board of Education/Say It module is connected from the toolbar (Figure 1) or File from the menu, then Connect. See Figure 2.

BASIC Stamp Editor Debug Terminal must be closed before selecting "Connect" in Say It GUI

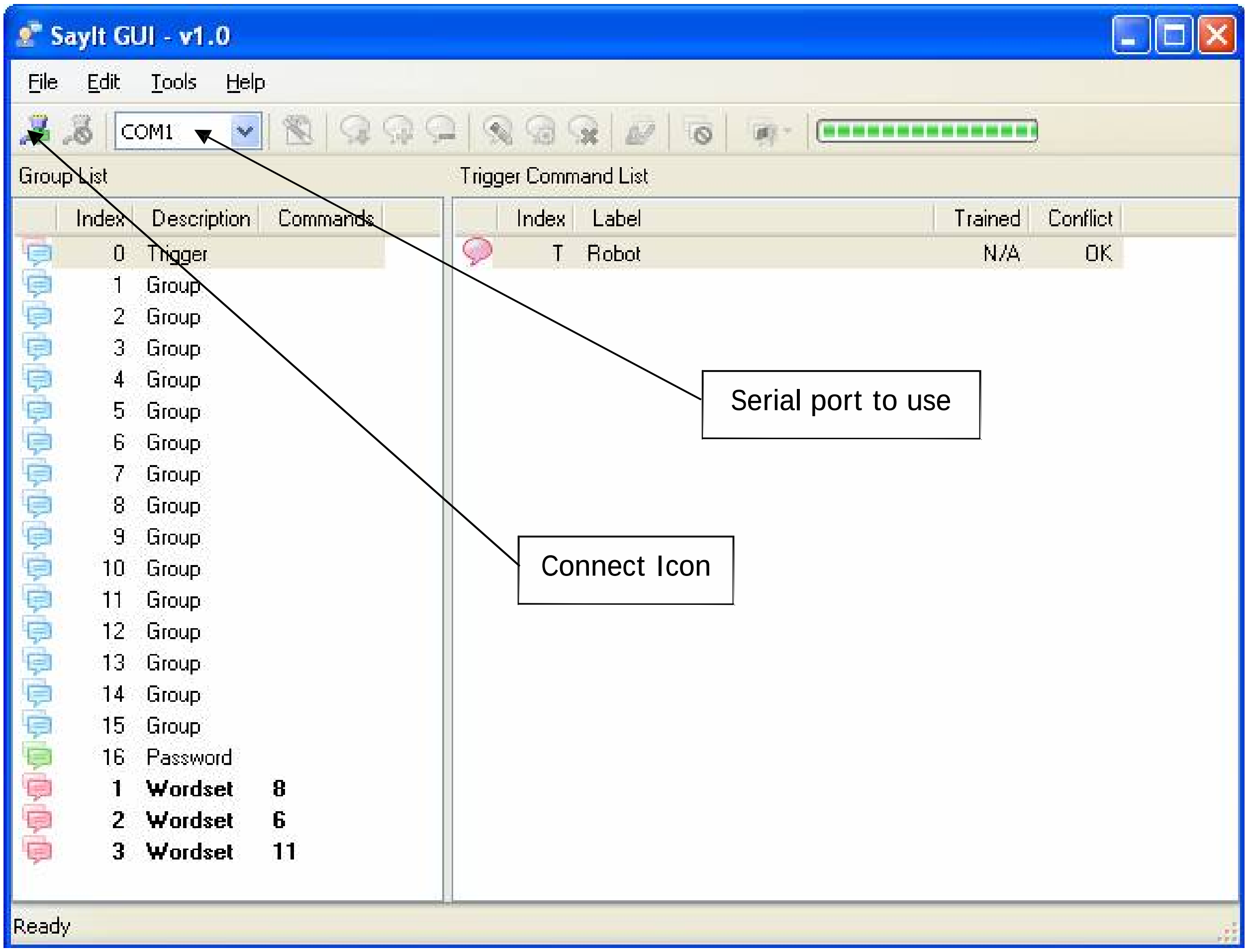


Figure 2

5. Once connected, the Say It software prompts you to download the PBASIC "bridge" program to the controller board, and switches to the programming mode (Figure 3). Choose Yes when prompted.

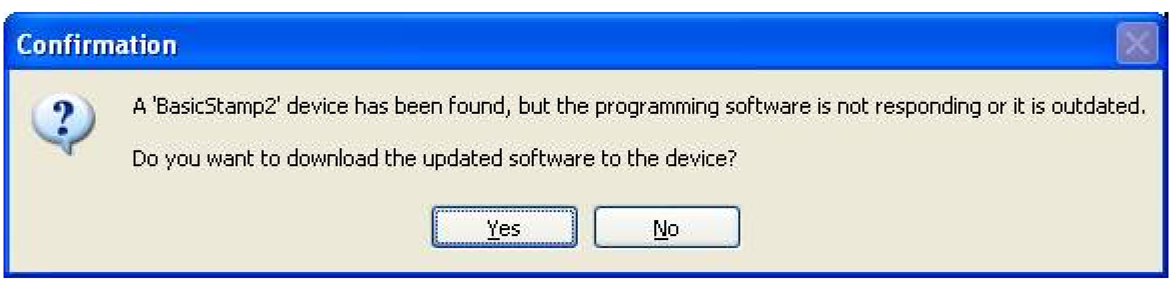


Figure 3

A PBASIC "bridge" program will automatically be downloaded to the BASIC Stamp 2. This bridge program allows the user to work with the set of SI commands the Say It module provides, as well as defining new commands.

6. Verify that the bridge download has been completed by the green status bar in the top right of the GUI; it should remain full.

Once you have successfully connected to the module you can insert, add, remove, rename, train, erase, test, reset all the commands, set the language used, or disconnect from the GUI. First, let's cover testing the pre-existing commands.

Testing Commands

Let's begin by testing the words that are already programmed in the Say It module. These are grouped under Trigger and three Wordsets (Figure 4).

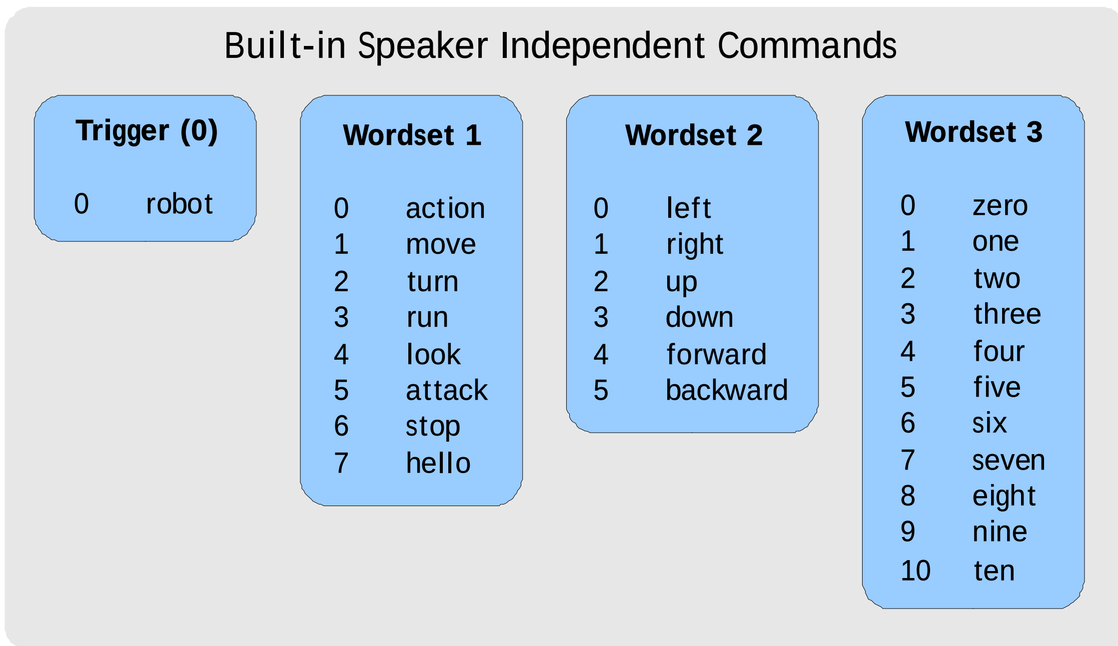


Figure 4

1. Select a Trigger or Wordset to test by highlighting the option in the left window pane (Figure 5) and then click "Test Group" from the tool bar. This example, I chose "Trigger" to test.

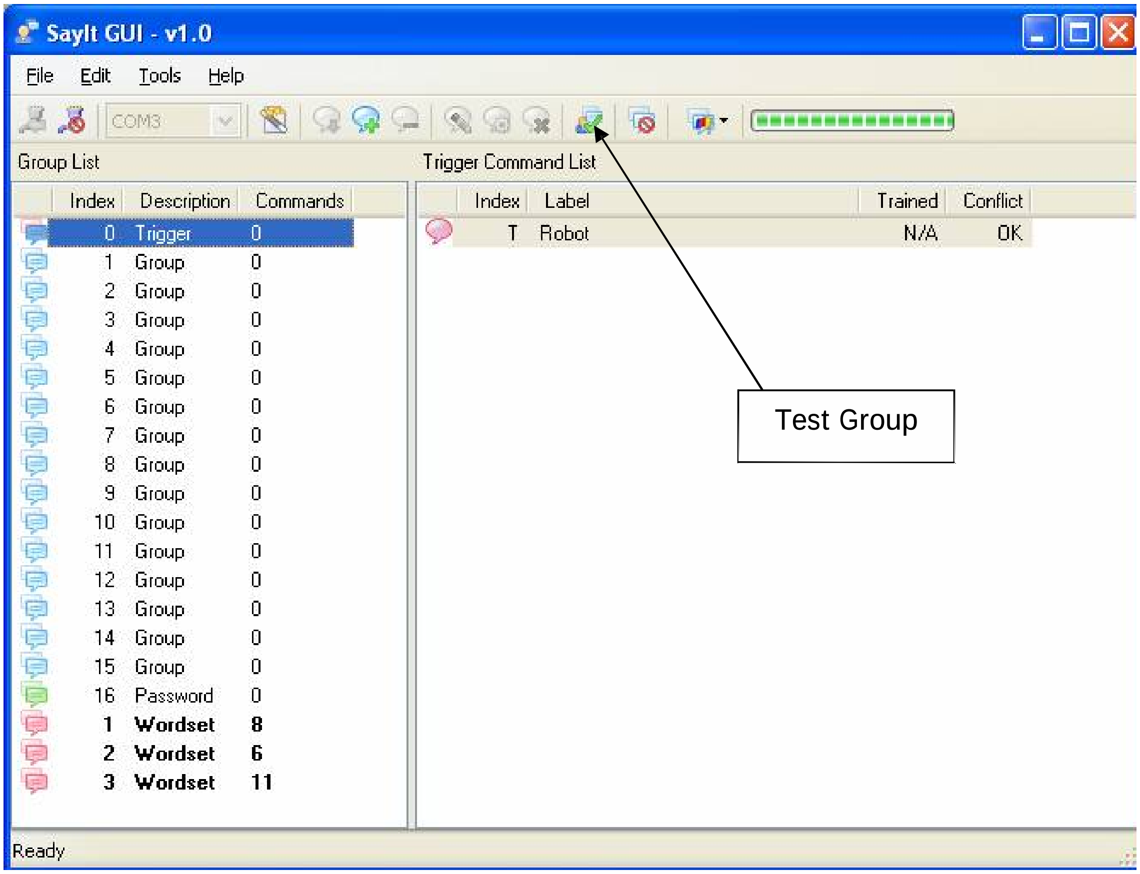


Figure 5

2. When the red LED indicator light on the module and the software window prompt you to speak, speak clearly and directly at the microphone on the module. If the module understands, you will see the command highlighted in green.

You can continue this with all the words that need to be tested. If the module does not understand the word or there is nothing said, an information window will pop up indicating an error of a timeout. Later you will want to use the same process to test any new commands that you train it to recognize.

Adding or Deleting Commands

When you want to create your own command, you can do so by using the Say It GUI. There are 4 types of commands in the GUI:

- Trigger – Trigger words are used to start the voice recognition process; all spoken command phrases will begin with a trigger word. “Robot” is the SI trigger word, and you may train one additional trigger word.
- Group – Groups of user-definable SD commands. You may add up to 32 commands total (31 if you also define a trigger word).
- Password – A special group for “vocal passwords,” up to 5 may be defined.
- Wordset – Built-in groups of Speaker Independent (SI) commands (Figure 3)

The user can define groups of SD commands or passwords and generate a PBASIC code template to handle them. The recognition function of Say It modules works on a single group at a time, so that users need to group together all the commands that they want to be able to use at the same time.

When Say It GUI connects to the module, it reads back all the user-defined commands and groups, which are stored into the Say It module's non-volatile memory for later review and editing.

When training SI commands, simulate the environmental background noise in which you want to use this module for the best results for recognition.

Adding a SD command can be completed by doing the following while the Say It "bridge" program is running.

1. Select a group that you would like to add the word(s) to (Figure 6).

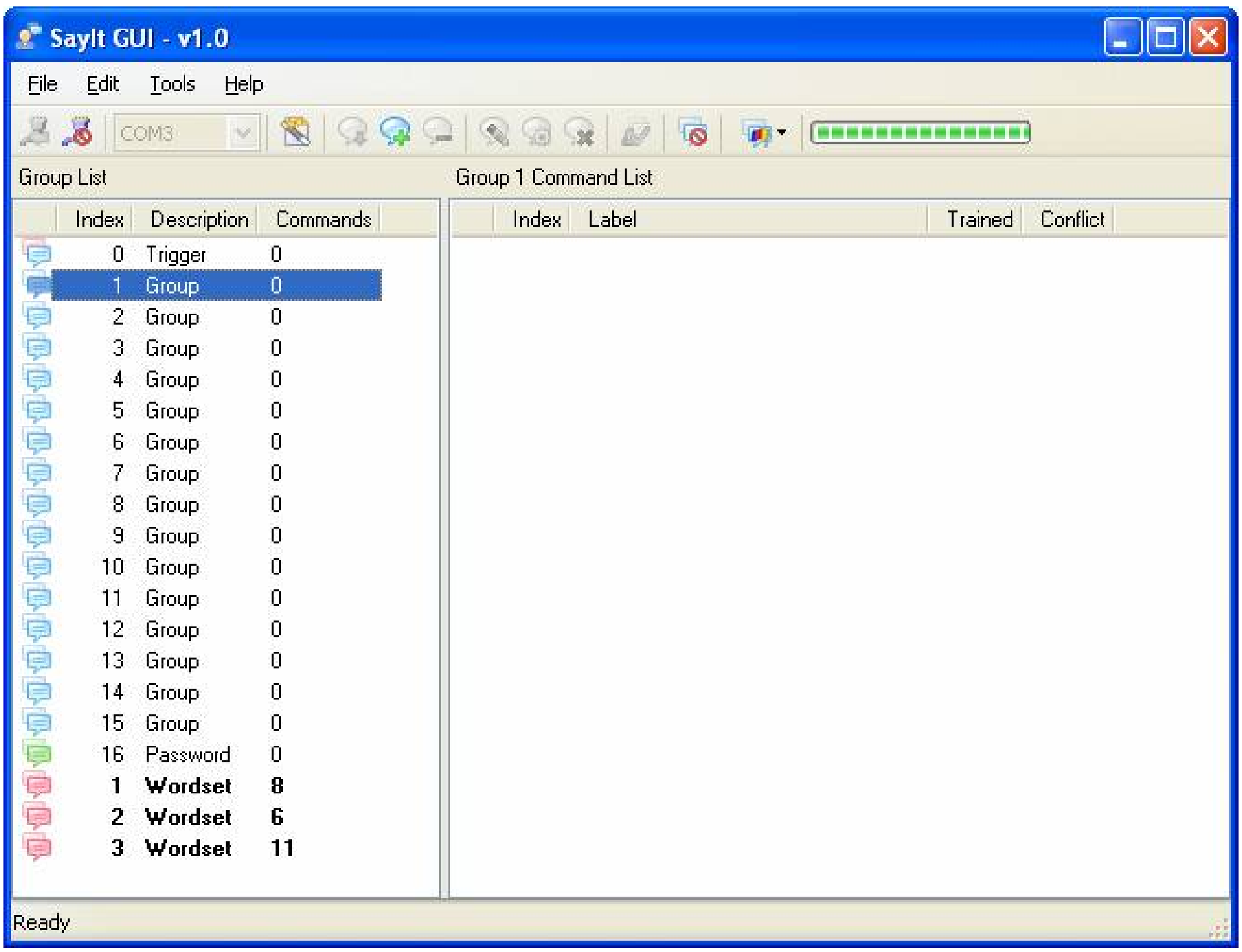


Figure 6

2. Click “Add Command” from the tool bar or menu (Figure 7), and provide a label. In this example, the label “CREATE_LABEL_HERE” has been created; however it is suggested that you use a label that you can later review and know what the word is.

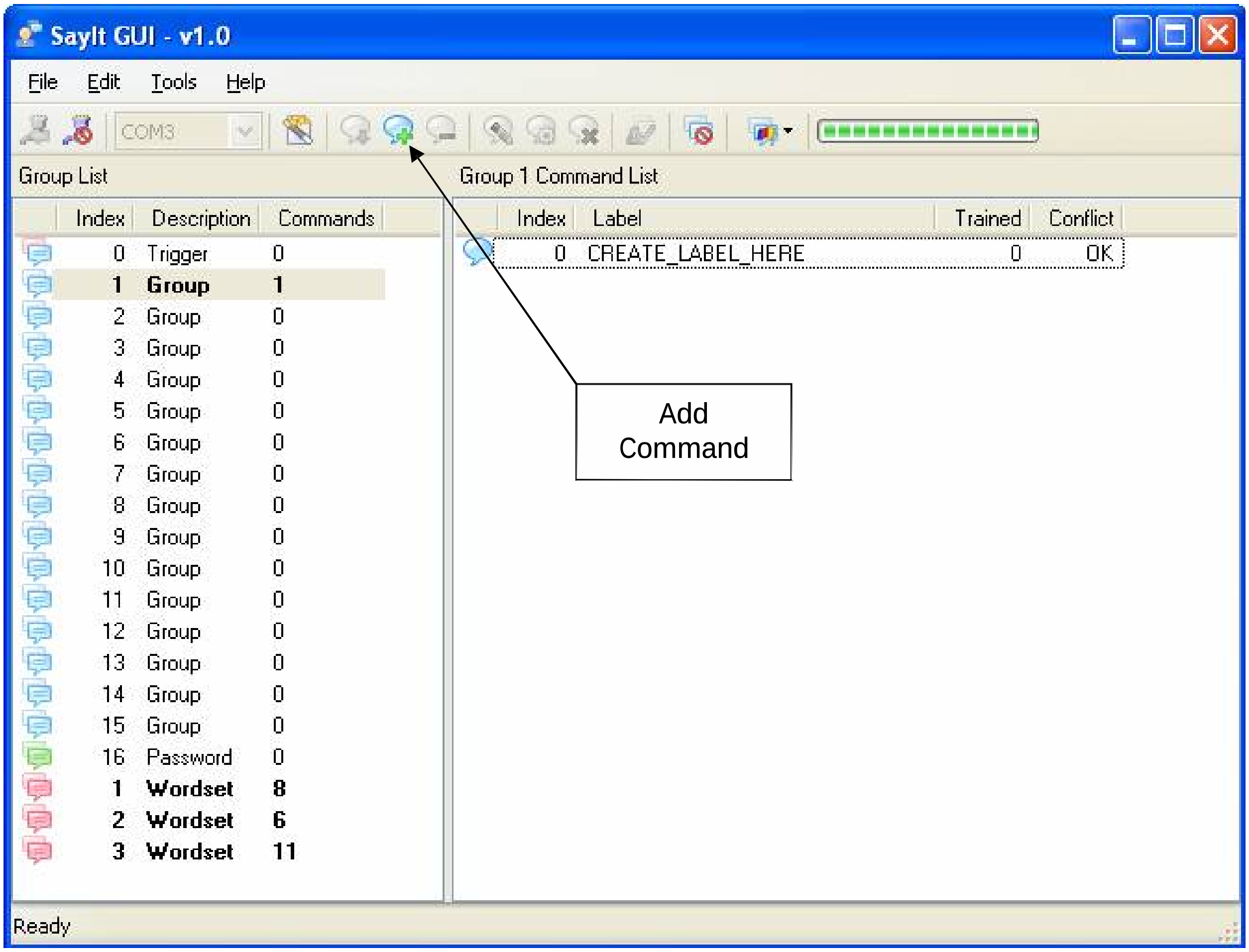


Figure 7

3. Select the label that in the right window pane, and click “Train” from the tool bar or menu (Figure 8).

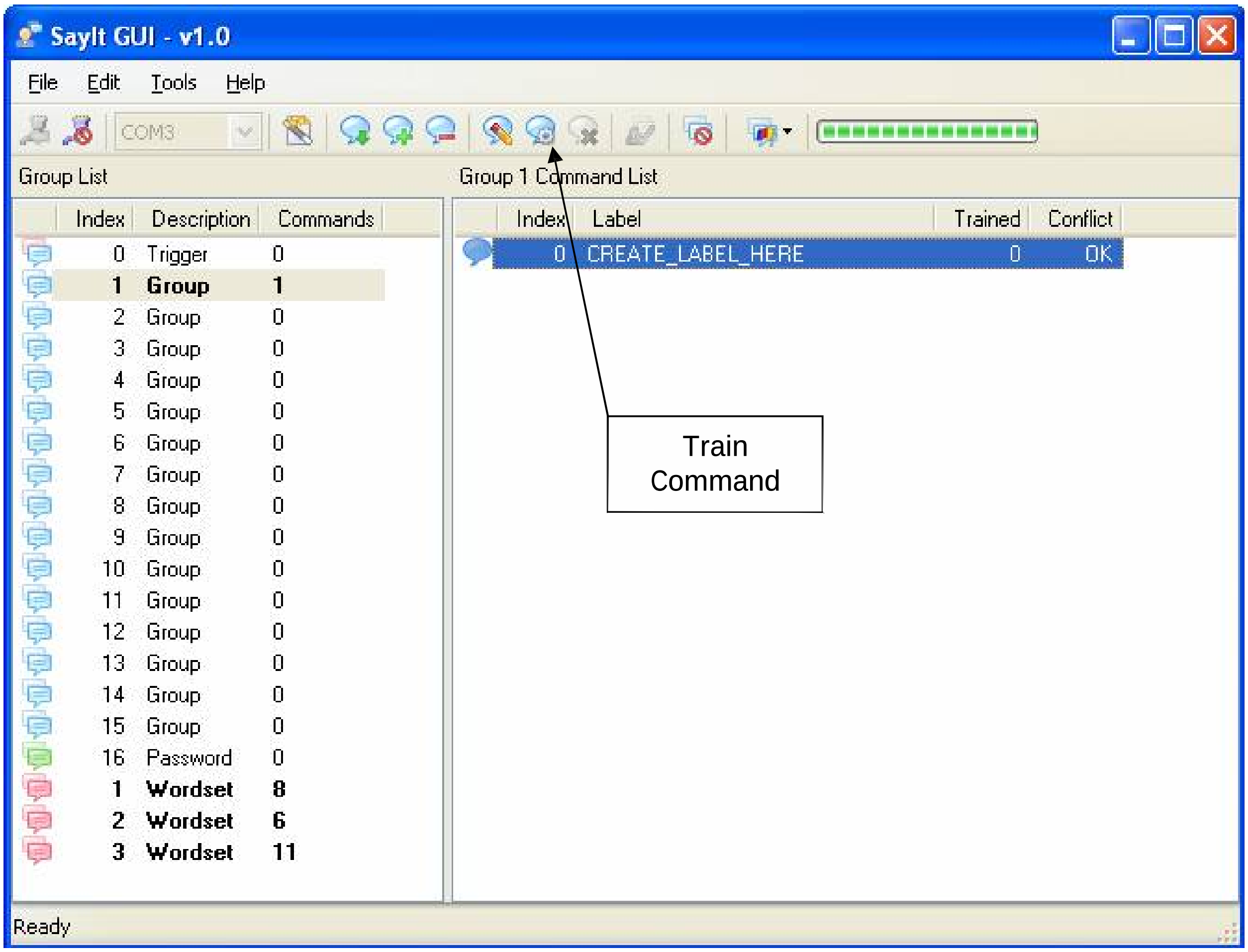


Figure 8

4. Once you have selected Train Command; you will be prompted to say the phrase twice (figure 8) to complete the training of a specific word; keep the words simplistic for optimal recognition. If you are unhappy with the training, select erase training, and start the training process over from step 3 until satisfied.

Figure 9

5. Once you have successfully created a phrase, you can test to confirm that it will recognize it, it is suggested that you test each group after you are finished to ensure successful training. Once finished you will see a number next to the group you trained; indicating how many words belong to that group (Figure 9).

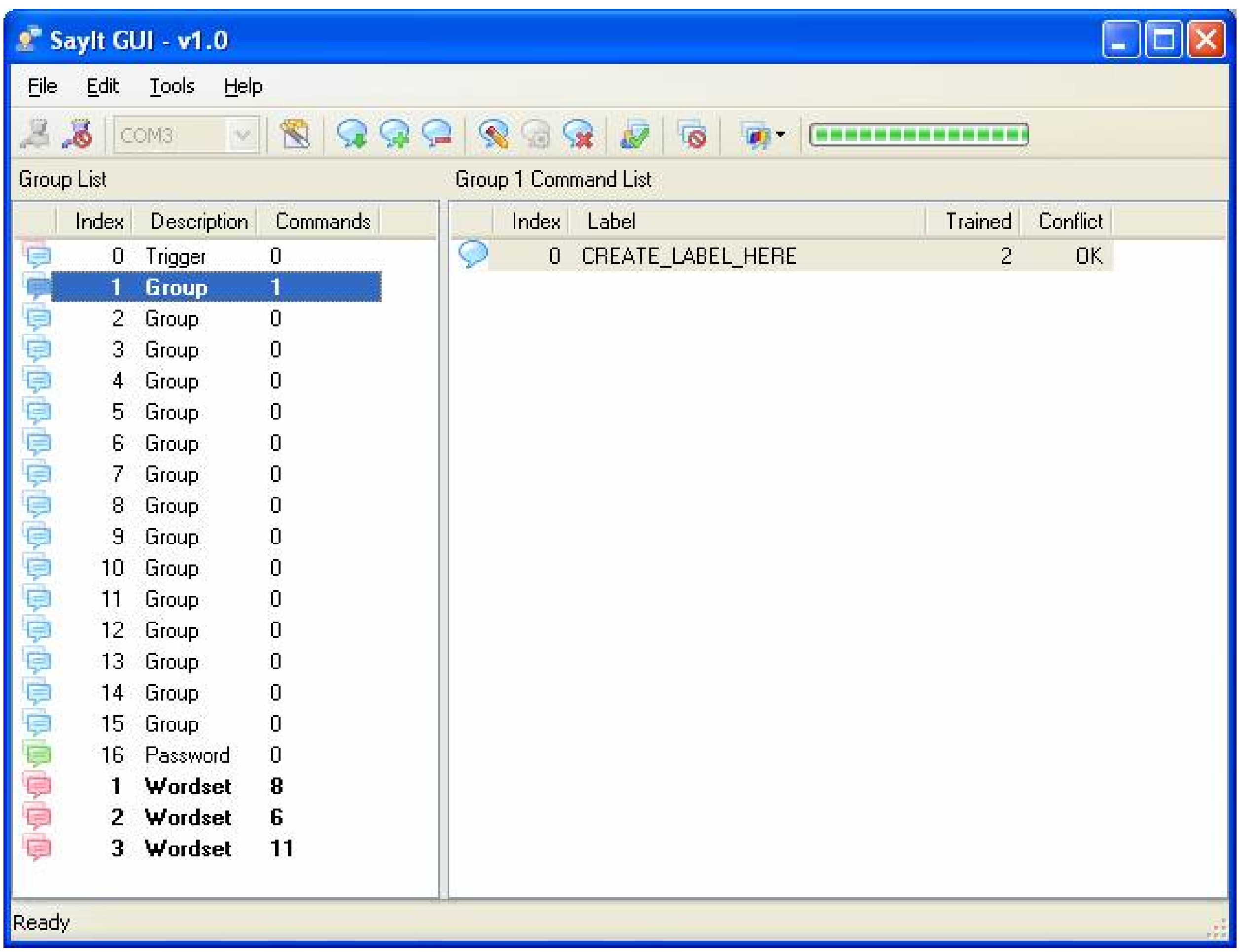


Figure 10

If you want to remove a command, you can use the “remove command” from the tool bar or menu and it will remove the selected command; once this is done it can not be undone so be sure you want to remove a command prior to clicking this action.

Each of the Group, Password, and Trigger words are created and edited in the same manner that these steps cover. Note: The Passwords (group 16) are much more sensitive to background environment noises and distance from the microphone; but sure to train the password in conditions similar to where it will be used.

Generating Code

Once you have created and trained all your desired commands, you can generate the PBASIC code to then edit and assign actions to each of the words created. You can do that be completing the following:

1. Select the “Generate Code…” icon on the toolbar or from the menu (Figure 11)

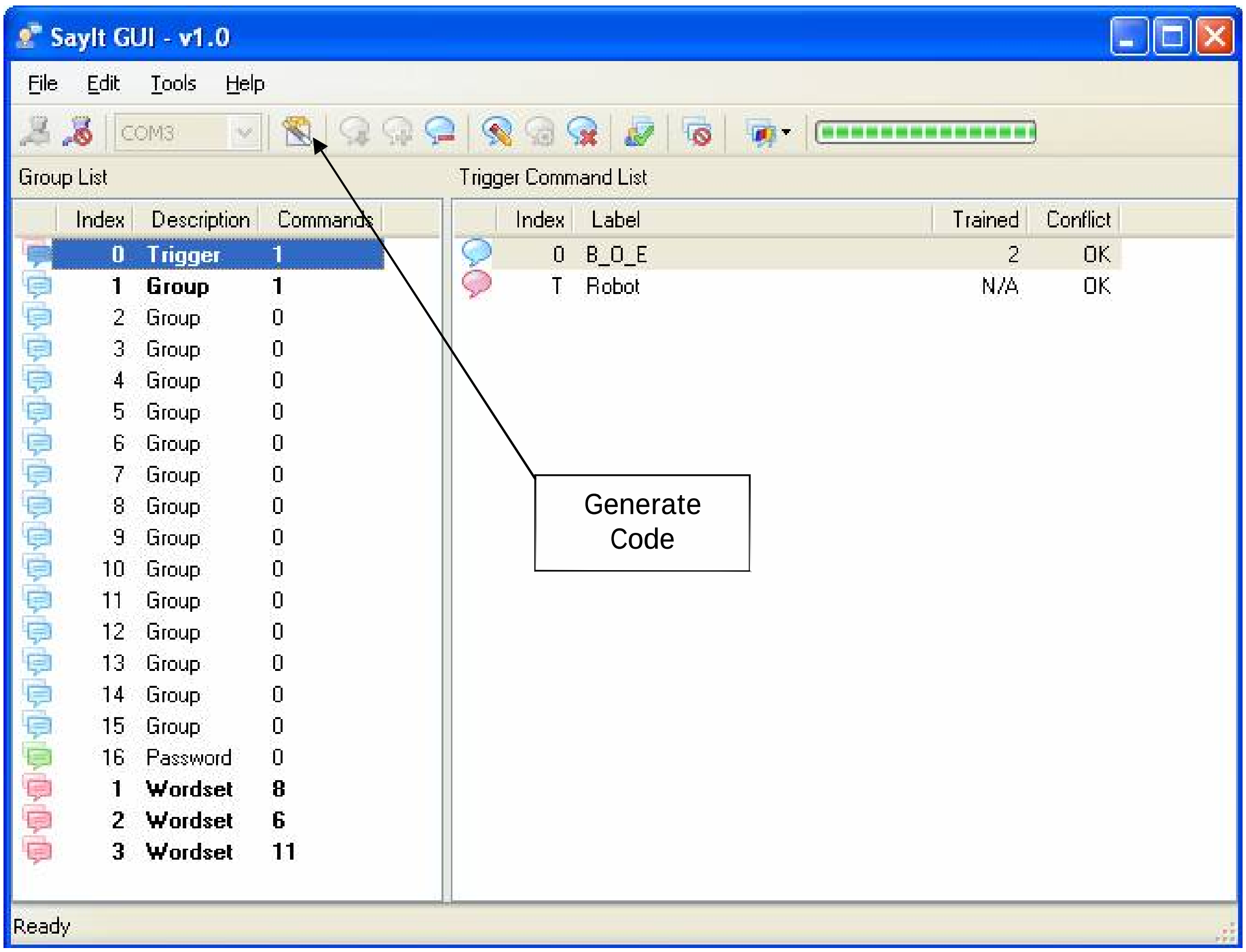


Figure 11

2. You will be prompted to save the file to then edit within the BASIC Stamp Editor (Figure 12).

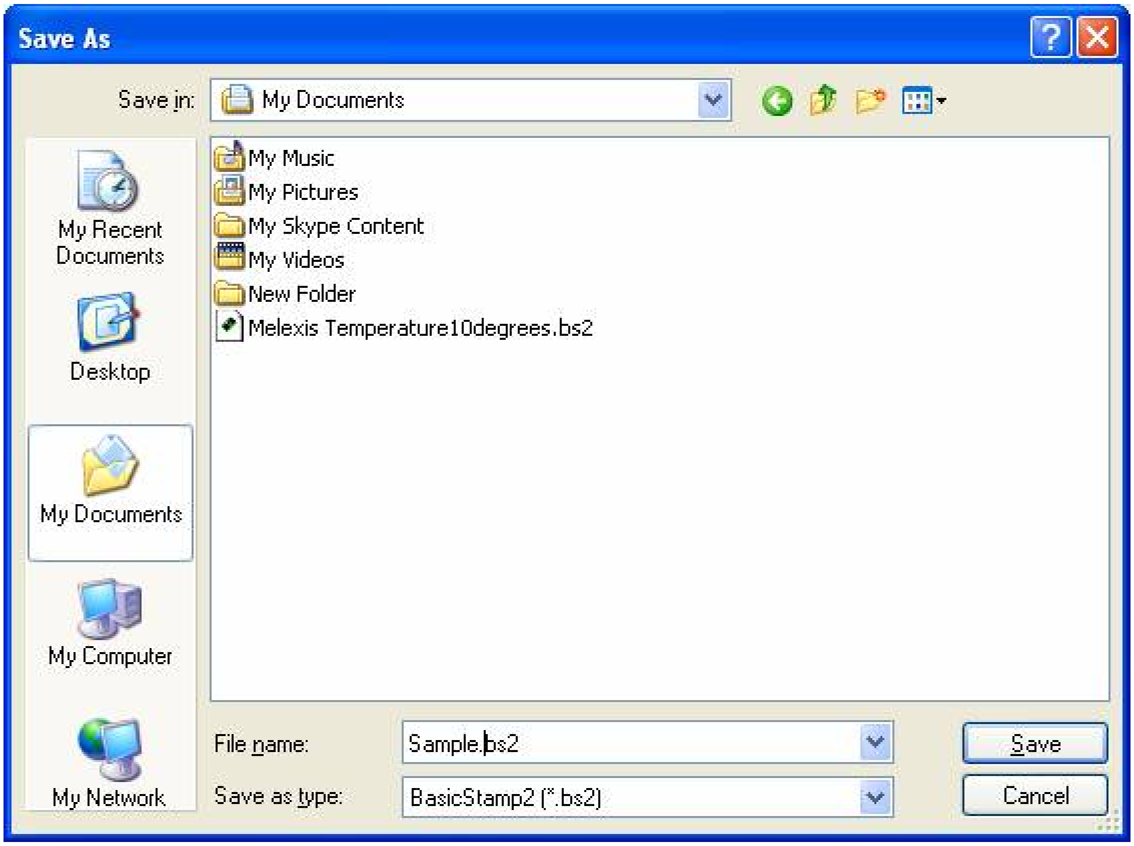


Figure 12

3. Click "Disconnect" in the GUI and open the file with the BASIC Stamp Editor.

4. Once the program is opened in the BASIC Stamp Editor, there will be portions of the code that will indicate where you will place the commands that will be used with the trained words. You will see a PAUSE 1 with "'-- write your code here" comments.

5. Save your program, and then download to the BASIC Stamp 2 module and enjoy playing with your new voice recognition module.

Sample Application for the Boe-Bot® Robot

Here is the sample applications that uses the Say It module to control a Boe-Bot robot with a BASIC Stamp 2 on a Board of Education platform. The sample code for this application is available for download on the Say It Module product page at www.parallax.com.

1. Plug the Say It module into the AppMod header of the Board of Education (as seen in Figure 1 on page 2); be careful to insert the module in the left row of the header and in the correct orientation (Vss at top, Vdd at bottom, RX to P0, TX to P2 and LED to P4).

2. Open the sample code labeled "SayIt_Demo.BS2" in the BASIC Stamp Editor.

3. Install any batteries as needed, plug in the battery pack, and move the Board of Education power switch to position 1

4. Download the program to the BASIC Stamp 2 module by clicking Run from the menu, and click Run from the dropdown (ctrl + r)

5. Move the power switch to position 0, and unplug the communication cable; then move the power switch to position 2.

6. Using the command list above (Figure 3); Say the trigger word (robot), and select then select a word from Wordset 1, 2 and then 3 if needed. You can verify the word has been correctly recognized by the red LED indicator on the Say It module.

When you say “robot”, the red LED will turn on for a short moment; once the LED is on, you can say the next word. Once the Say It module has received the last Wordset command, it will execute the proper routine associated with that command. Here are some samples that could be used and the descriptions of the actions.

Try saying the following examples:

Robot -> Move -> Forward	(This will move the robot forward)
Robot -> Hello	(Module will say hello on the debug screen, if one is open)
Robot -> Action -> Three	(Module will display 3 on debug screen, if one is open)
Robot -> Turn -> Right	(This will turn the robot right)
Robot -> Run -> Backwards	(This will move the robot backwards)
Robot -> Stop	(stops all movement)
(-> = small pause)	

After disconnecting from the Say It GUI, you can still verify that the Say It Module is detecting the right word by using the Debug Terminal. By leaving the Board of Education connected to the computer, each recognized verbal command will be printed to the Debug Terminal.

Note that not all commands will use a word from all 3 Wordsets to be a valid command. For example, “Hello” uses a Trigger word (Robot) and Hello from Wordset 1, which will end the command to then execute; that debugs “Hello” on the BASIC Stamp Debug Terminal.

Troubleshooting

From time to time there may be some snags that can cause what would seem like malfunctions in the module. If you experience any of the symptoms listed below, here are some quick fixes to try.

Q1. Keep getting a time-out error
A1. Make sure the power has not been cycled since the last time the GUI was connected.

Q2. Can’t connect to my Say It Module
A2.1 Be sure to close all terminal windows including the debug screen before connecting the GUI software.
A2.2 Check power and make sure it has ample voltage and current to turn on modules

Q3. Will not power up
A3. Check to make sure that all the connections are correct; if using an AppMod header be sure the orientation is correct.

Q4. I am running Windows Vista, and the Say It GUI will not install properly.
A4. Right Click on installer exe, and select “run as administrator”

Device Information

Specifications

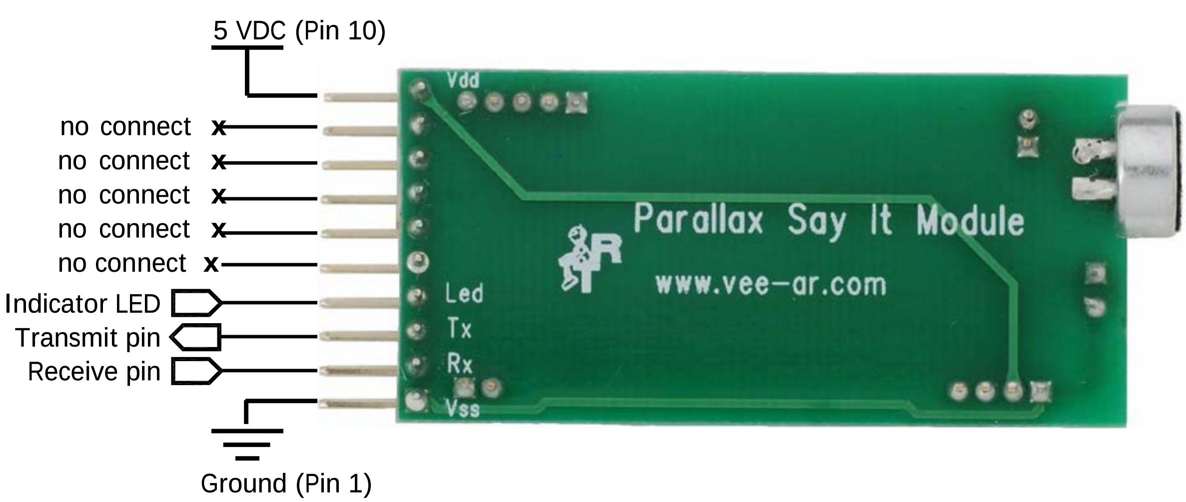
Symbol	Quantity	Minimum	Typical	Maximum	Units
Vdd	Supply Voltage	3.3	5.0	5.5	V

Pin Definitions

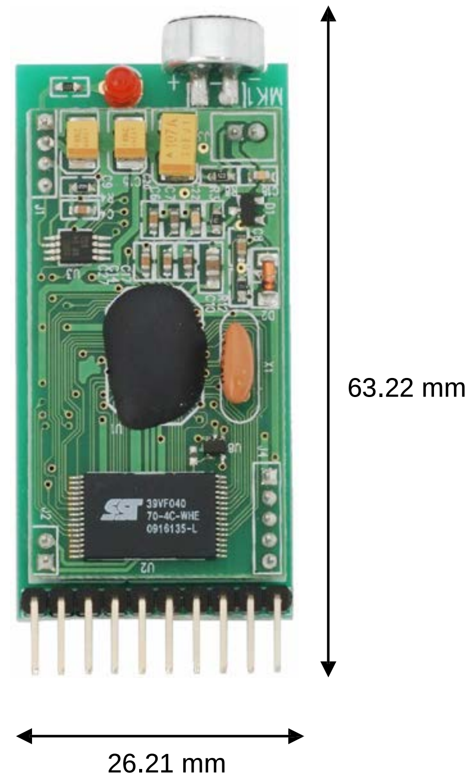
Pin	Label	Function
1	Vss	Ground
2	Rx	Receive I/O Pin (TTL & CMOS compatible)
3	Tx	Transmit I/O Pin (TTL & CMOS compatible)
4	Led	Red LED indicator
5	-	No Connection
6	-	No Connection
7	-	No Connection
8	-	No Connection
9	-	No Connection
10	Vdd	5 V regulated DC

Connection Diagrams

This is the back view of the module, the connection pins are indicated on the silkscreen.



Module Dimensions



Communication Protocol

Communication with the Say It module uses a standard UART interface compatible with 3.3V to 5V TTL logical levels. The initial configuration at power-on is 9600 baud, 8 bit data, No parity, 1 bit stop. The baud rate can be changed later to operate in the range 9600 - 115200 baud.

The communication protocol only uses printable ASCII characters, which can be divided in two main groups:

- Command and status characters, respectively on the TX and RX lines, chosen among lower-case letters
- Command arguments or status details, again on the TX and RX lines, spanning the range of capital letters

Each command sent on the TX line, with zero or more additional argument bytes, receives an answer on the RX line in the form of a status byte followed by zero or more arguments.

There is a minimum delay before each byte sent out from the Say It module to the RX line, that is initially set to 20 ms and can be selected later in the ranges 0 - 9 ms, 10 - 90 ms, 100 ms - 1 s.

The communication is host-driven and each byte of the reply to a command has to be acknowledged by the host to receive additional status data, using the space character. The reply is aborted if any other character is received and so there is no need to read all the bytes of a reply.

Invalid combinations of commands or arguments are signaled by a specific status byte, that the host should be prepared to receive if the communication fails. Also a reasonable timeout should be used to recover from unexpected failures.

The module automatically goes to lowest power sleep mode after power on. To initiate communication, send any character to wake-up the module.

Command Details

CMD_BREAK	
"b"	Abort recognition in progress if any or do nothing
Expected replies: STS_SUCCESS, STS_INTERR	
CMD_SLEEP	
"s"	Go to the specified power-down mode
[1]	Sleep mode (0-8)
Expected replies: STS_SUCCESS	
CMD_KNOB	
"k"	Set Speaker Independent (pre-programmed commands) knob to specific level
[1]	Knob level (0-4)
Expected replies: STS_SUCCESS	
CMD_LEVEL	
"v"	Sets Speaker Dependent (custom programmed commands) to specific level
[1]	Threshold (1-5)
Expected replies: STS_SUCCESS	
CMD_LANGUAGE	
"l"	Set Speaker Independent (pre-programmed commands) language
[1]	Language (0 = English, 1 = Italian, 2 = Japanese, 3 = German
Expected replies: STS_SUCCESS	
CMD_TIMEOUT	
"o"	Set Speaker Independent (pre-programmed commands) language
[1]	Timeout (-1 = default, 0 = infinite, 1-30 = seconds
Expected replies: STS_SUCCESS	
CMD_RECOG_SI	
"i"	Activate Speaker Independent (pre-programmed commands) recognition from specified wordset
[1]	Wordset Index (0-3)
Expected replies: STS_SUCCESS, STS_TIMEOUT, STS_ERROR	
CMD_TRAIN_SD	
"t"	Train specified Speaker Dependent (custom programmed commands) or Password command
[1]	Group index (0 = trigger, 1-15 generic, 16 = password
[2]	Command position (0-31)
Expected replies: STS_SUCCESS, STS_RESULT, STS_SIMILAR, STS_TIMEOUT, STS_ERROR	
CMD_GROUP_SD	
"g"	Insert new Speaker Dependent (custom programmed commands) or Password command
[1]	Group index (0 = trigger, 1-15 generic, 16 = password
[2]	Command position (0-31)
Expected replies: STS_SUCCESS, STS_OUT_OF_MEM	

CMD_UNGROUP_SD	
“u”	Remove Speaker Dependent (custom programmed commands) or Password command
[1]	Group index (0 = trigger, 1-15 generic, 16 = password
[2]	Command position (0-31)
Expected replies: STS_SUCCESS	
CMD_RECOG_SD	
“d”	Activate Speaker Dependent (custom command) or Password recognition
[1]	Group index (0 = trigger, 1-15 = generic, 16 = password
Expected replies: STS_SUCCESS, STS_RESULT, STS_SIMILAR, STS_TIMEOUT, STS_ERROR	
CMD_ERASE_SD	
“e”	Remove Speaker Dependent (custom command) or Password recognition
[1]	Command position (0-31)
Expected replies: STS_SUCCESS	
CMD_NAME_SD	
“n”	Give a label for a Speaker Dependent (custom programmed commands) or Password command
[1]	Group index (0 = trigger, 1-15 = generic, 16 = password
[2]	Command position (0-31)
[3]	Length of label (0-31)
[4-n]	Text for label (ASCII characters from “A” to “`”
Expected replies: STS_SUCCESS	
CMD_COUNT_SD	
“c”	Request count of Speaker Dependent (custom programmed commands) or Password commands in a specified group
[1]	Group index (0 = trigger, 1-15 = generic, 16 = password)
Expected replies: STS_COUNT	
CMD_DUMP_SD	
“p”	Read Speaker Dependent (custom programmed commands) or Password command label (label and training)
[1]	Group index (0 = trigger, 1-15 = generic, 16 = password)
[2]	Command position (0-31)
Expected replies: STS_DATA	
CMD_MASK_SD	
“m”	Request a bit-mask of non-empty groups
Expected replies: STS_MASK	
CMD_RESETALL	
“r”	Reset all commands and groups
“R”	Confirmation character
Expected replies: STS_SUCCESS	
CMD_ID	
“x”	Request firmware ID

Expected replies: STS_ID

CMD_DELAY	
“y”	Set Transmit delay
[1]	Time (0-10 = 0 – 10ms, 11-19 = 20-100ms, 28-28 = 200 to 1000ms)
Expected replies: STS_SUCCESS	
CMD_BAUDRATE	
“a”	Set communication baud-rate
[1]	Speed mode (1 = 115200, 2 = 57600, 3 = 38400, 6 = 19200, 12 = 9600
Expected replies: STS_SUCCESS	

Status Details

STS_MASK	
“k”	Mask of non-empty groups
[1-8]	4-bit value that form a 32-bit mask, LSB first
In replay to: CMD_MASK_SD	
STS_COUNT	
“c”	Count of commands
[1]	Integer (0-31)
In replay to: CMD_COUNT_SD	
STS_AWAKEN	
“w”	Wake-up (back from power-down mode)
In replay to: Any character after power on or sleep mode	
STS_DATA	
“d”	Provide command data
[1]	Training information (0-7 = training count, +8 = SD/Password conflicts, +16 = SI conflict
[2]	Conflicting command position (0-31)
[3]	Length of label (0-31)
[4-n]	Text for label (ASCII characters from “A” to “`”
In replay to: CMD_DUMP_SD	
STS_ERROR	
“e”	Signal recognition error
[1-2]	Two 4-bit values that form 8-bit error code (80h = NOTA, otherwise see FluentChip error codes)
In replay to: CMD_RECOG_SI, CMD_RECOG_SD, CMD_TRAIN_SD	
STS_INVALID	
“v”	Invalid command or argument
In replay to: Any invalid command or argument	
STS_TIMEOUT	
“t”	Timeout expired
In replay to: CMD_RECOG_SI, CMD_RECOG_SD, CMD_TRAIN_SD	
STS_INTERR	

“i”	Interrupted recognition
In replay to: CMD_BREAK while in training or recognition	

STS_SUCCESS	
“o”	OK or no error status
In replay to: CMD_BREAK, CMD_DELAY, CMD_BAUDRATE, CMD_TIMEOUT, CMD_KNOB, CMD_LEVEL, CMD_LANGUAGE, CMD_SLEEP, CMD_GROUP_SD, CMD_UNGROUP_SD, CMD_ERASE, CMD_NAME_SD, CMD_RESETALL	
STS_RESULT	
“r”	Recognized Speaker Dependent (custom commands), Password or training similar to Speaker Dependent (custom commands) and Password commands
[1]	Command position (0-31)
In replay to: CMD_RECOG_SD, CMD_TRAIN_SD	
STS_SIMILAR	
“s”	Recognized Speaker Independent (pre-programmed commands) work or training a similar Speaker Independent (pre-programmed commands) command
[1]	Wordset indext (0-31)
In replay to: CMD_RECOG_SD, CMD_TRAIN_SD,CMD_RECOG_SI	
STS_OUT_OF_MEM	
“m”	Memory Full Error
In replay to: CMD_GROUP_SD	
STS_ID	
“x”	Provide firmware ID
[1]	Version ID (0)
In replay to: CMD_ID	

Argument Mapping

ARG_MIN	
“@”	Minimum argument value (-1)
ARG_MAX	
“ ‘ “	Maximum argument value (-1)
ARG_ZERO	
“A”	Zero argument value