CHAPTER III

Hardware Design

3. Hardware Design

The human hand is considered to be the best gripping mechanism. Thus, our design makes use of the human hand's design and employs the same type of mechanism used by the human hand. The design can be divided into two parts:

• Mechanical design and

• Design of the prosthetic hand control electronics.

3.1 The mechanical design

The main considerations taken during the design process was to design a hand that resembles the human hand; the size should be similar, light and not too bulky, and the overall cost should be low in designing the mechanic part of the hand.

A human finger is composed of 3 main joints that have 3 degrees of freedom. We preferred relative motion between the joints for easy control and simplicity in the prosthetic hand's fingers. Open and closed positions of the index finger can be seen in Figures 3.1. The axis of rotation of all joints is coincident in a single axis in the open position.

3.1.1 Finger Design

One single finger was the starting point for the entire design process. The human hand was studied visually while grasping and handling many different objects. Being that the hand consists of four similar fingers and one thumb, it was logical to conclude that the finger design could potentially be replicated four times. This meant that if the size and space requirements to actuate one individual finger proved too large, then another method would be needed.

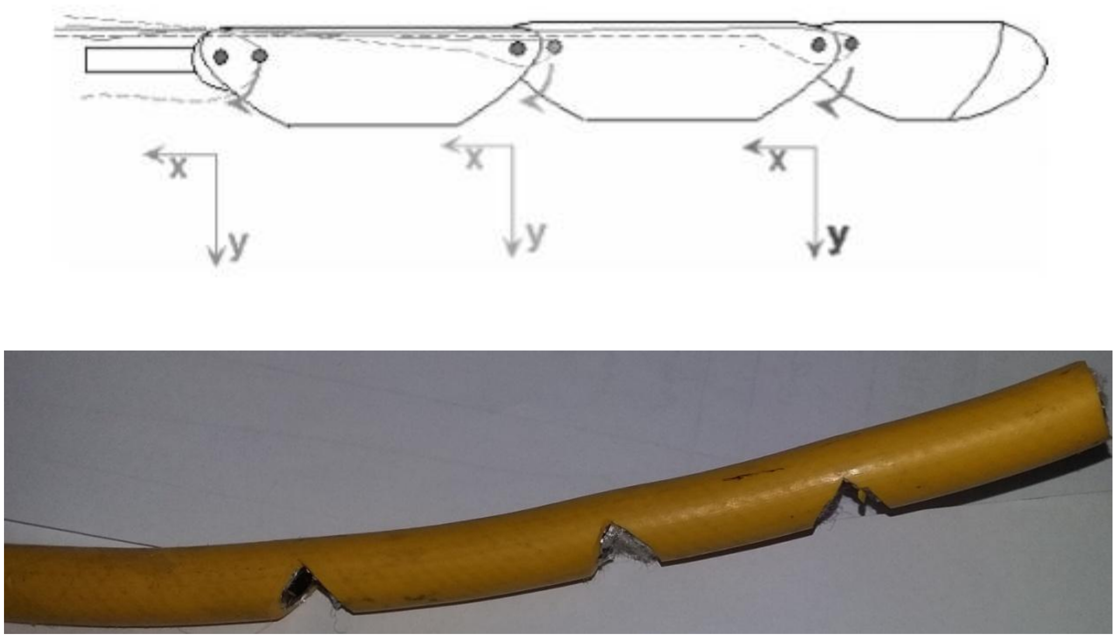

Figure 3.1: index finger joints

The finger design process began with determining what motion was required for each finger. The human hand was simply viewed gripping various household objects such as a cup and marker commonly found in a person's daily routine. The location of the various joints were measured and translated to drawings. The human finger is an amazing piece of engineering consisting of three individual pivot joints which can almost be individually actuated through muscular tendons. The four main fingers can also be spread apart sideways and rolled slightly culminating in an impressively large amount of total degrees of freedom. Fortunately, to perform the majority of common gripping tasks, only a small amount of motion should actually be required. The human finger achieves a conformal adaptive grip by bending the knuckles as an object is grasped.

3.1.2 Finger Actuating

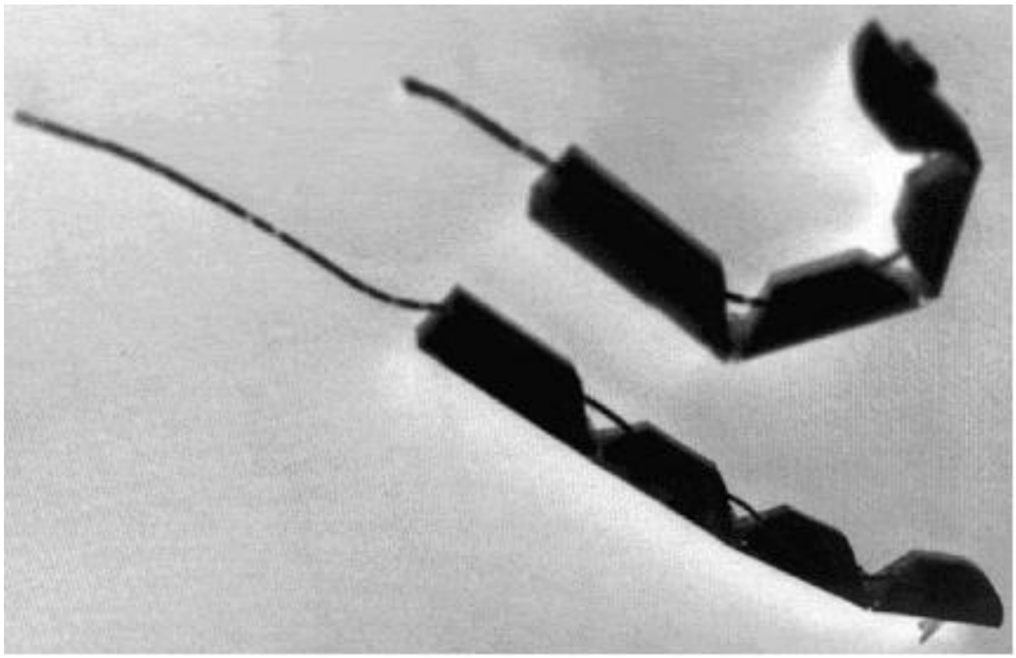

Figure 3.2: actuating fingers

Each finger made of PVC pipe figure (Figure 3.1) with three joints in each of four fingers and thumb.

Each finger is actuated by a cable running along its palm surface and attaching to the distal phalanx. This configuration is similar to that of the flexor tendons in the human hand.

Every single cable of the single finger is attached to the dc motor. When the motor actuated and rotate causing tension in the cable witch cause finger to flex and vice versa when the motor rotate in the reverse direction.

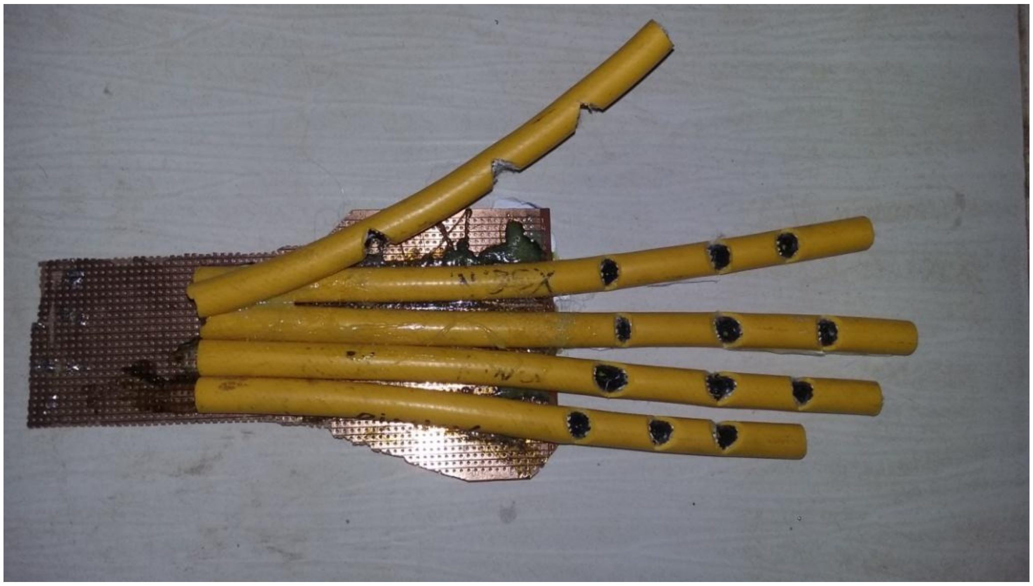

Figure 3.3: five fingers of the hand

3.2 Control System Design

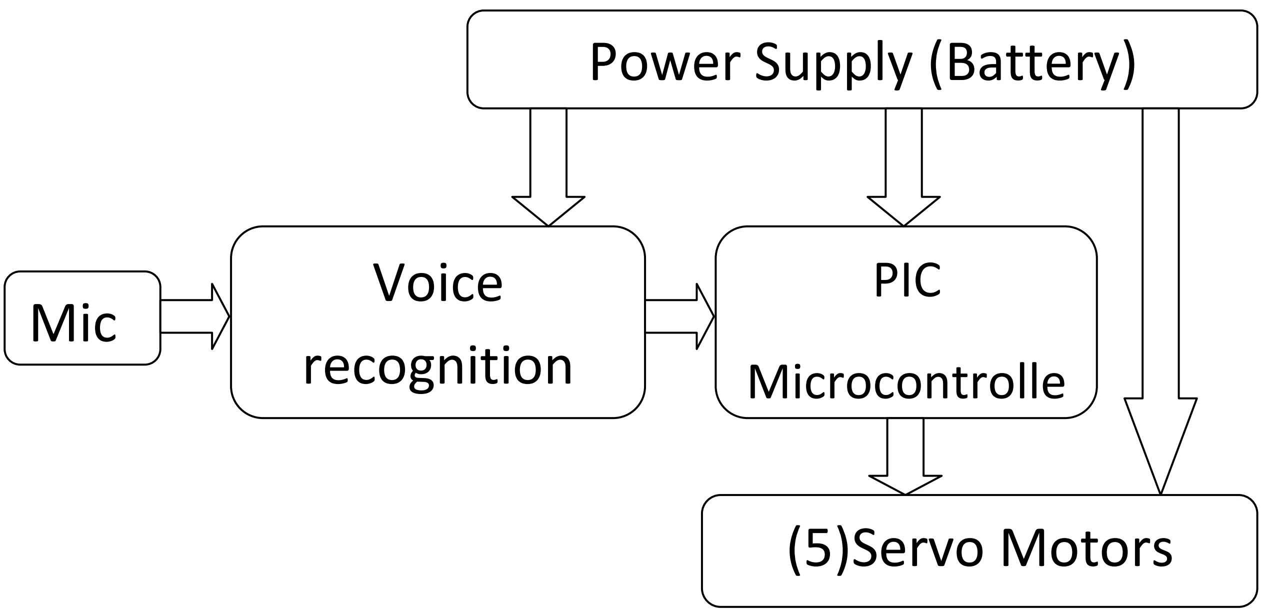

Figure 3.4: Prosthetic arm control system block diagram

The prosthetic arm control system is divided into five different blocks:

1. Voice recognition module
2. Main control system block
3. Motor drive circuit
4. DC Servo Motors
5. Power supply block

The hardware development processes or task of the system have to undergo several steps and stages and it shown in Figure 3.2.2

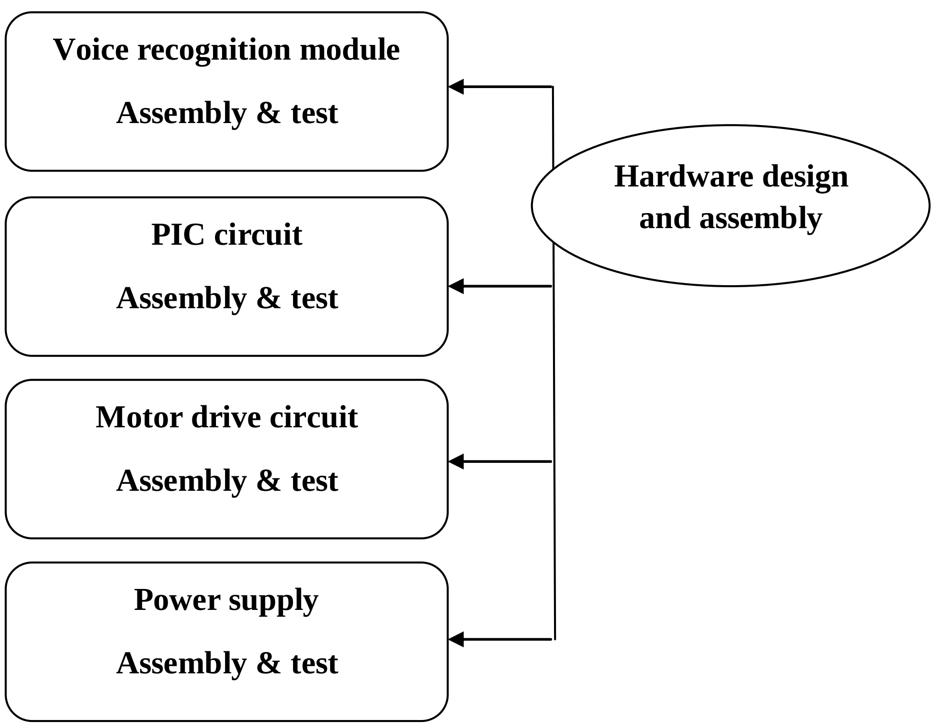

Figure 3.5: Hardware and task of the system

3.2.1 Main Control System Block

As for the hardware development stages, the first step is to assemble the main control system block. This is where the PIC microcontroller circuit is built, assembled and tested. PIC microcontrollers are popular processors developed by Microchip Technology with built-in RAM, memory, internal bus, and peripherals that can be used for many applications. PIC originally stood for "Programmable Intelligent Computer" but is now generally regarded as a "Peripheral Interface Controller".

PIC microcontrollers can be programmed in Assembly, C or a combination of the two. Other high level programming languages can be used but embedded systems software is primarily written in C. PIC microcontrollers are broken up into two major categories: 8-bit microcontrollers and 16-bit Microcontrollers.

Each PIC has unique features and subtle differences. The correct choice for your project depends on many factors:

1) Does the project require analog input or output?

2) Does the project require digital input or output?

3) How many I/O pins are required?

4) Does the project require precise timing?

5) How much memory does the project require?

6) Is serial I/O required?

PICs also come in several types of packages:

1) Plastic Dual Inline Package (PDIP)

2) Small-Outline Transistor (SOT)

3) Dual Flat No-lead (DFN)

4) Mini Small Outline Package (MSOP)

5) Thin Quad Flat Pack (TQFP)

6) Plastic Leaded Chip Carrier (PLCC)

7) Ceramic QUAD pack (CERQUAD)

The PIC used in this system architecture is PIC16F877A. The PIC16F877A CMOS FLASH-based 8bit microcontroller is upward compatible with the PIC16C5x, PIC12Cxxx and PIC16C7x devices. It features 200 ns instruction execution, 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, a synchronous serial port that can be configured as either 3-wire SPI or 2-wire I2C bus, a USART, and a Parallel Slave Port.

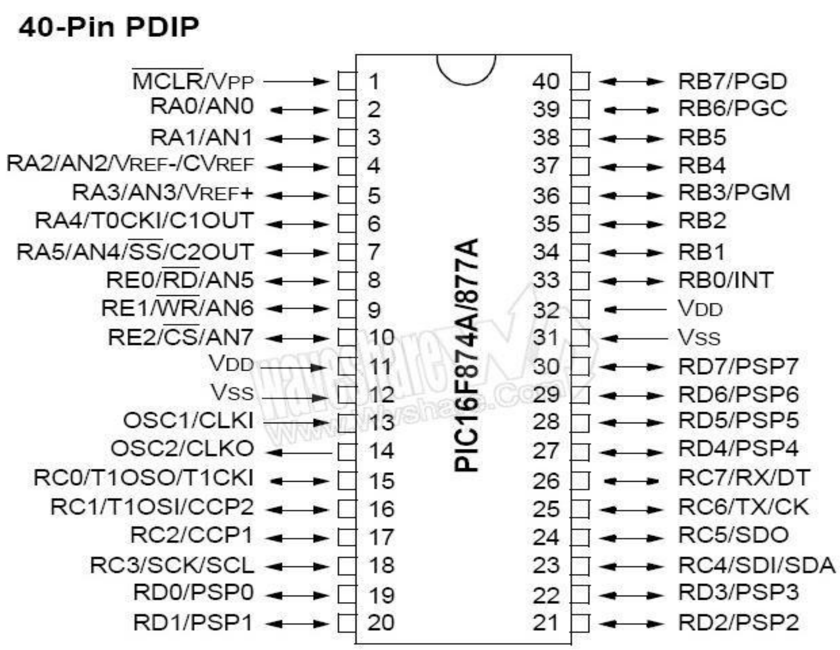

Figure 3.6: PIC16F877A pins layout

Microchip PIC16F877A Microcontroller Features

- High-Performance RISC
- operating speed: 20 MHz, 200 ns instruction cycle
- Operating voltage: 4.0-5.5V
- Industrial temperature range (-40° to +85°C)
- 15 Interrupt Sources
- 35 single-word instructions
- All single-cycle instructions except for program branches (two-cycle)
- Flash Memory: 14.3 Kbytes (8192 words)

And other features (see data sheet, appendix A)

The PIC circuit functional is checked and tested by using a simple program which receives input signals and turns the LEDs on and off. This checks the connection of the system input-output port. The system main program development initially starts once the PIC circuit has been assembled and tested. It can be started in stages until the whole control system is integrated. Meanwhile, the software simulation can be done to check its functionality by using the Professional Proteus Software environment.

3.3 Voice Recognition Module

Having complete testing the PIC, a voice recognition module or kit is tested and evaluated for its functionality. It consists of a main circuit board, and dedicated software tool for easy configuration.

General definition of a voice recognition or speech recognition is that, a

process of converting a speech or voice signal into a sequence of words, by means of an algorithm implemented as a computer program. It is the ability of a machine or program to recognize spoken words, by comparing the spoken commands with a sound sample. In this technology analog signal (voice) is 1. Converted into a digital signal by using an analog to digital converter. This digital signal is then compared to the digital database of the system which has been stored with digital speech patterns.

The voice recognition used in this thesis is The SpeakUp it's a speaker dependent speech recognition click board with standalone capabilities. You can set it up to recognize over 200 voice commands and have the onboard STM32F415RG MCU carry them out. It works by matching sounds with pre-recorded commands. Sound is received through an onboard microphone and then processed by a VS1053 IC with a built in stereo-audio codec. The SpeakUp comes with a dedicated software tool for easy configuration. The board is lined with 12 user programmable GPIOs for standalone functionality. It also carries a standard mikroBUS™ host socket.

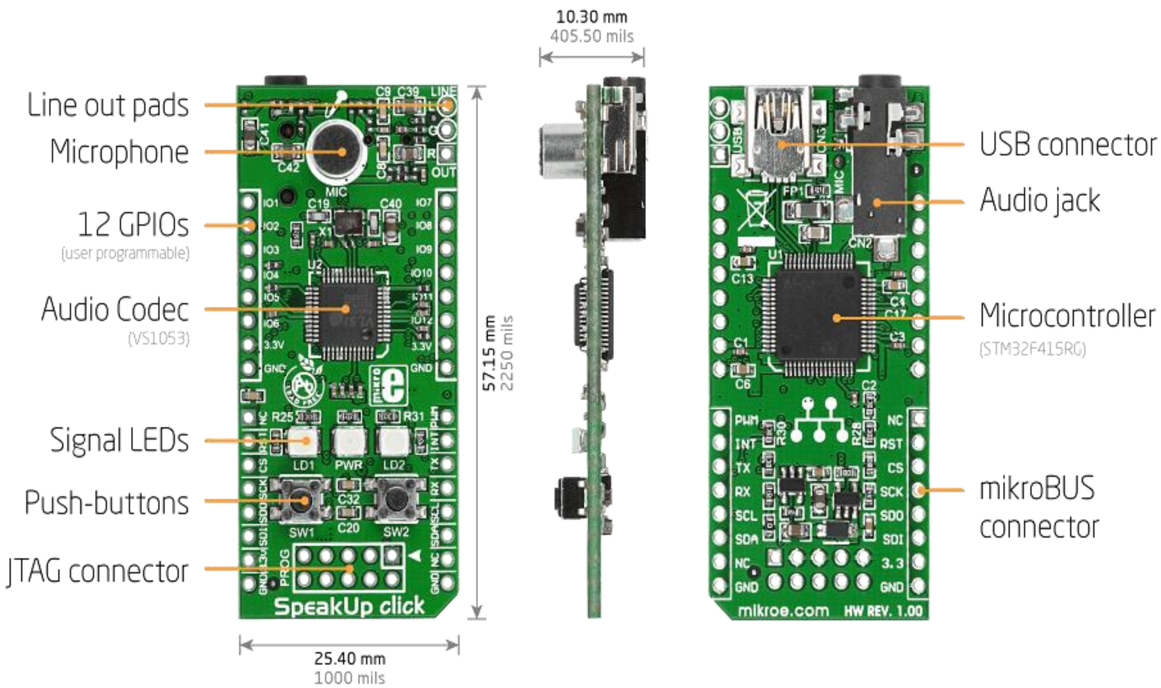

Figure 3.7: SpeakUp voice recognition module

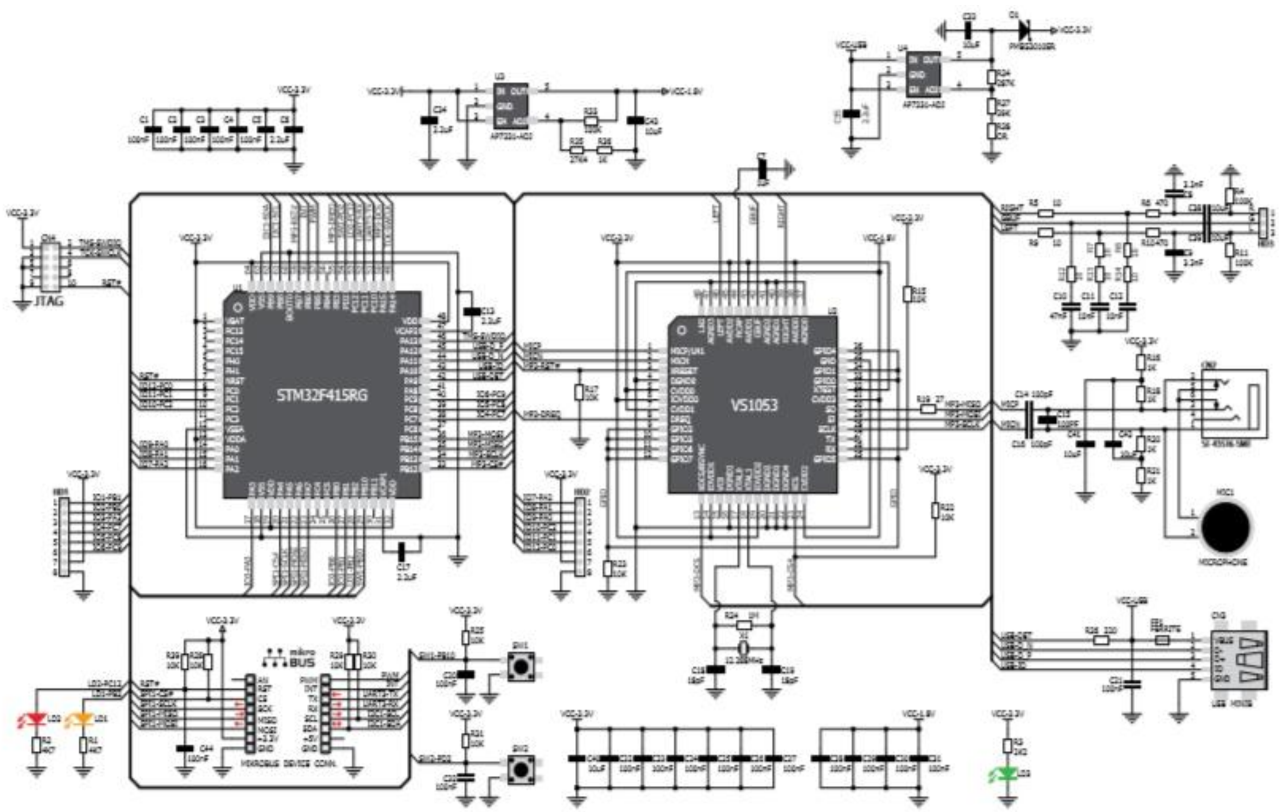

Figure 3.8: SpeakUp circuit board

3.4 Servo motors [23]

A servo motor is a dc, ac, or brushless dc motor combined with a position sensing device (e.g. a digital decoder). In this section, our discussion will be focused on the three-wire DC servo motors that are often used for controlling surfaces on model airplanes. A three-wire DC servo motor incorporates a DC motor, a gear train, limit stops beyond which the shaft cannot turn, a potentiometer for position feedback, and an integrated circuit for position control. Of the three wires protruding from the motor casig, one is for power, one is for ground, and one is a control input where a pulse-width signals to what position the motor should servo. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. As the coded signal changes, the angular position of the shaft changes.

Servos are extremely useful in robotics. The motors are small and are extremely powerful for their size. A standard servo such as the Futaba S-148 has 42 oz/inches of torque, which is pretty strong for its size. It also draws power proportional to the mechanical load. A lightly loaded servo, therefore, doesn't consume much energy. The guts of a servo motor are shown in the picture below. You can see the control circuitry, the motor, a set of gears, and the case. You can also see the 3 wires that connect to the outside world. One is for power (+5volts), ground, and the white wire is the control wire.

Figure : 3.9: DC Servo motor

3.4.1 Servo Operation

The servo motor has some control circuits and a potentiometer (a variable resistor, aka pot) that is connected to the output shaft. The potentiometer allows the control circuitry to monitor the current angle of the servo motor. If the shaft is at the correct angle, then the motor shuts off. If the circuit finds that the angle is not correct, it will turn the motor the correct direction until the angle is correct. The output shaft of the servo is capable of travelling somewhere around 180 degrees. Usually, it's somewhere in the 210 degree range, but it varies by manufacturer. A normal servo is used to control an angular motion of between 0 and 180 degrees. A normal servo is mechanically not capable of turning any farther due to a mechanical stop built on to the main output gear. The amount of power applied to the motor is proportional to the distance it needs to travel. So, if the shaft needs to turn a large distance, the motor will run at full speed. If it needs to turn only a small amount, the motor will run at a slower speed. This is called proportional control. How do you communicate the angle at which the servo should turn? The control wire is used to communicate the angle. The angle is determined by the duration of a pulse that is applied to the control wire. This is called Pulse Coded Modulation. The servo expects to see a pulse every 20 milliseconds (.02 seconds). The length of the pulse will determine how far the motor turns. A 1.5 millisecond pulse, for example, will make the motor turn to the 90 degree position (often called the neutral position). If the pulse is shorter than 1.5 ms, then the motor will turn the shaft to closer to 0 degrees. If the pulse is longer than 1.5ms, the shaft turns closer to 180 degrees.

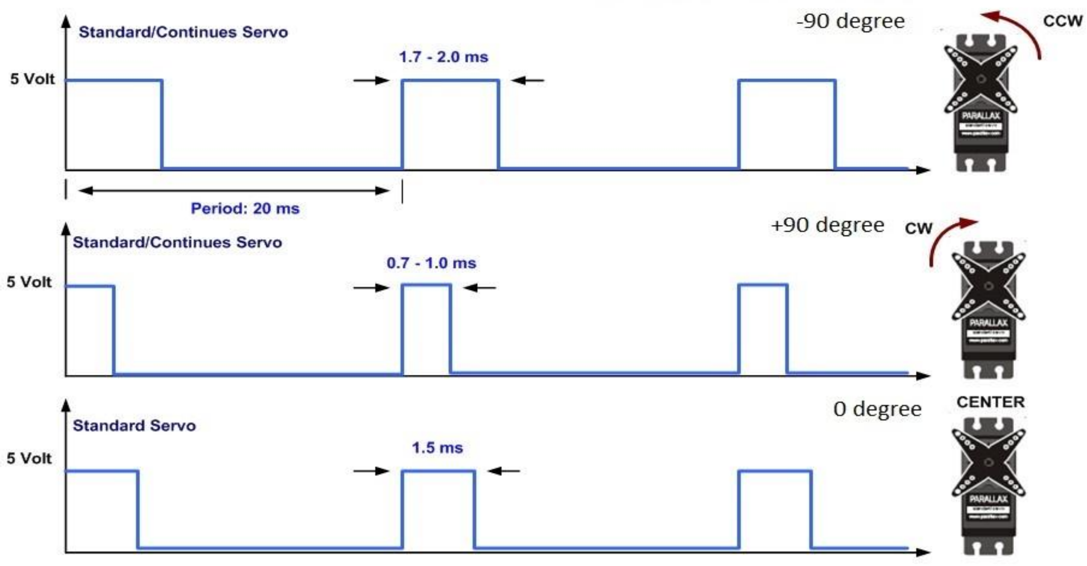

Figure : 3.10 Servo Motor PWM Timing Diagram

As you can see in the picture, the duration of the pulse dictates the angle of the output shaft. Note that the times here are illustrative and the actual timings depend on the motor manufacturer. The principle, however, is the same.

3.4.2 Servo Motor Interfacing

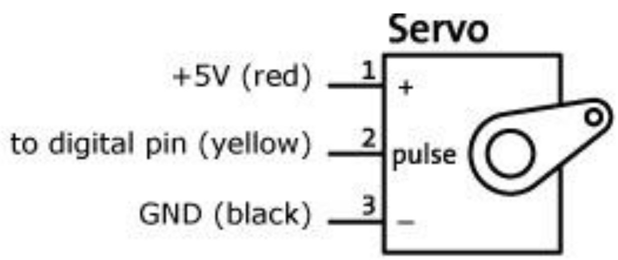

Figure : 3.11: Servo Motor Wiring Diagram

After complete testing the PIC microcontroller and voice recognition module, prosthetic arm/motors are assembled and tested. This circuit is tested by interfacing it to the PIC microcontroller circuit and a simple program is used to check the operability of the interface.

3.5 Power Supply Module

The power supply block consists of a +3.3V, +5V and +12V DC. The 12V is used for the prosthetic arm motors and the +3.3V DC is used for the voice recognition module and the +5V is used for the PIC Microcontroller module.

The circuit uses a +5V source which is provided by a voltage regulator IC LM7805 (Appendix B). This is important because this module will not working properly if the supply voltage drops below 5V and the recognition process disrupted and produces errors.

The circuit also uses a +3.3V source which is provided by a voltage regulator IC LM317 (Appendix C) adjustable 3-terminal positive voltage regulators is capable of supplying in excess of 1.5A over a 1.2V to 37V output range. They are exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. The input voltage for this regulators comes from 12V battery.

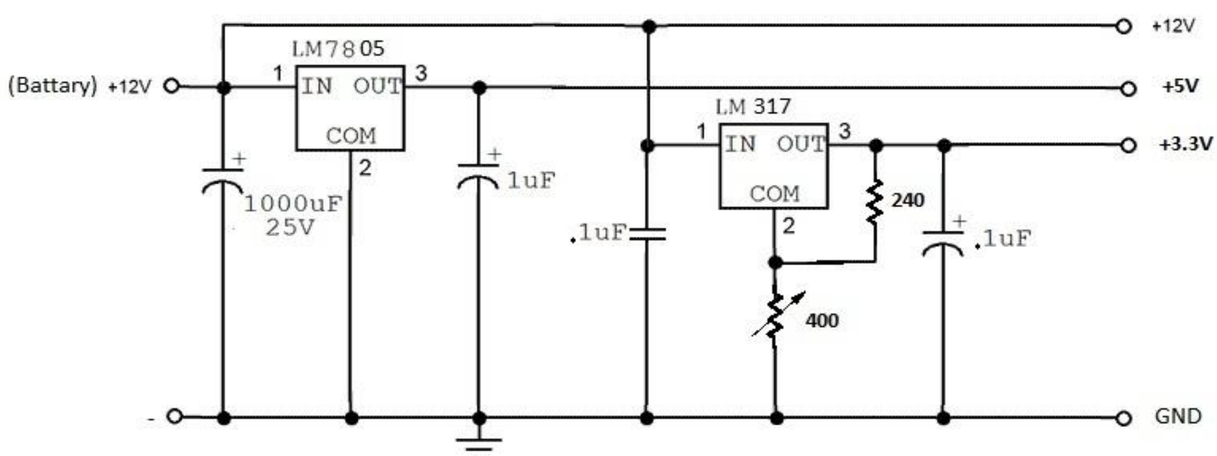

Figure: 3.12: Power Supply Circuit Diagram

Finally, after all the modules have been tested, they are integrated and connected together to work and become a complete system. This is the part where the software plays important role in running operating the system.

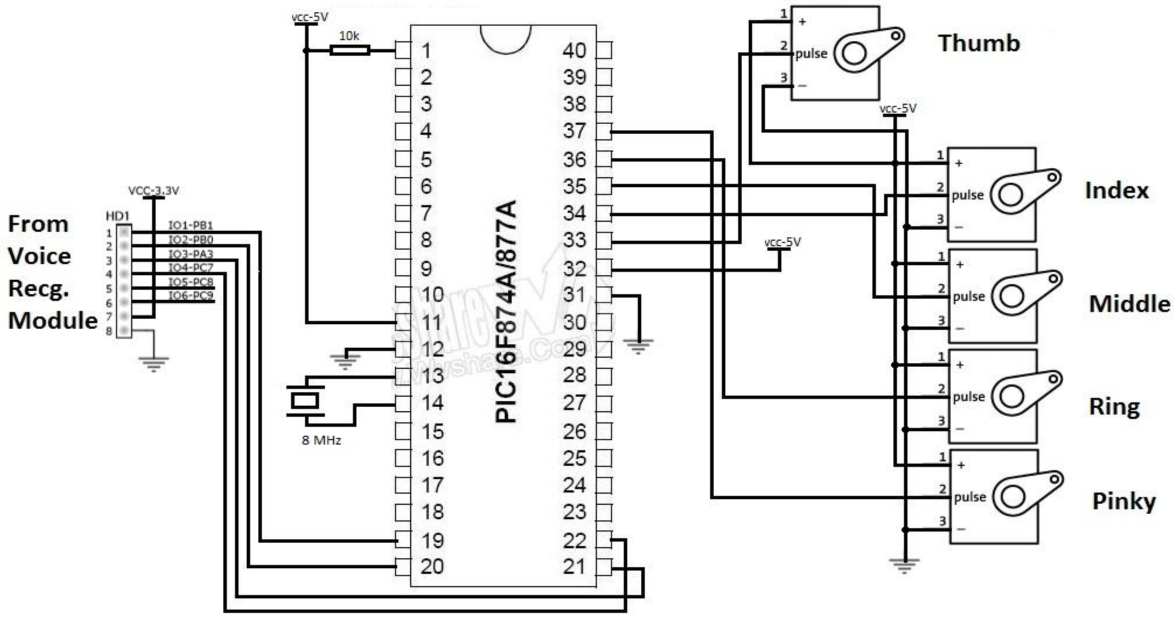

Figure: 3.13: system circuit diagram