DRAWBOT

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This thesis is submitted as partial fulfillment of the requirements for an award of the Bachelor of the Electrical Engineering (Electronics)

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JUDUL: **DRAWBOT**

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ABSTRACT

This final project is entitled drawbot. It is the robot that will draw with regular marking pens on piece of paper. The project focuses on drawing a geometric shape. The objective of this project is to design the drawbot using PIC microcontroller. To make the movements for drawing, 3 servo motor is used as a joints. In this particular project, PIC microcontroller is programmed into the instructions to control the servo motor. The drawbot will be able to draw the geometric shape when the switch is initiated and then back to initial condition. This project is using the MELabs software to create the program of drawbot. This software emulator of the microcontroller will always suffer limited simulation from the combination device interaction with the circuit. This project is meant to be in industries such as drawing pattern of kain batik and logo

ABSTRAK

Projek akhir ini dinamakan drawbot. Ia adalah robot yang akan melukis di atas sehelai kertas dengan menggunakan pen dakwat tebal. Projek ini lebih menumpu kepada melukis bentuk geometri. Projek ini bertujuan untuk mereka drawbot dengan menggunakan pengawalmikro PIC. 3 servo motor akan digunakan sebagai aplikasi sambungan untuk membuat pergerakan ketika melukis. Di dalam projek ini, pengawalmikro PIC akan diaturcarakan kepada arahan untuk mengawal servo motor. Robot ini berkebolehan untuk melukis bentuk geometri apabila suis dihidupkan kemudian balik ke keadaan asal. Projek ini juga menggunakan perisian MELabs untuk mencipta aturcara robot ini. Perisian yang diseragamkan dengan pengawalmikro ini akan sentiasa mencapai simulasi yang tiada terhad daripada percantuman antara alat yang digunakan dengan litar. Projek ini juga direka dalam industri contohnya melukis corak kain batik dan logo.

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LIST OF SYMBOLS

V – Volt

cm – centimeter

N – Newton

M – Mega

T – Torque

Kg – kilogram

LIST OF ABREVIATIONS

PIC - Peripheral Interface Controller

FKEE – Fakulti Kejuruteraan Elektrik dan Elektronik

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CHAPTER 1

INTRODUCTION

1.1 Why build robot

Robots are indispensable in many factoring industries. The reason is that the cost per hour to operate a robot is a fraction of the cost per hour to operate a robot is a fraction of the cost human labor needed to perform the same function. More than this, once programmed, robots repeatedly perform function with a high accuracy that surpasses that of the most experienced human operator. Human operators are, however, for more versatile. Humans can switch job tasks easily. Robots are built and programmed to be job specific. You wouldn't be able to program a welding robot to start counting parts in a bin.

Today's most advanced industrial robot will soon become 'dinosaurs'. Robots are in the infancy stage of their evolution. As robots evolve, they will become more versatile, emulating the human capacity and ability to switch job tasks easily.

While the personal computer has made an indelible mark on society, the personal robot hasn't made an appearance. Obviously there's more to a personal robot than a personal computer robots require a combination of elements to be effective: sophistification of intelligence, movement, mobility, navigation and purpose.

1.2 Robot

A robot is an electro-mechanical device that can perform autonomous or preprogrammed tasks. Robots may be controlled directly by a human, such as remotely-controlled bomb-disposal robots, robotic arms, or shuttles, or may act according to their own decision making ability, provided by artificial intelligence. However, the majority of robots fall in-between these extremes, being controlled by pre-programmed computers. Such robots may include feedback loops such that they can interact with their environment, but do not display actual intelligence.

For many people when heard about robot they think it is a machine that imitates a human such as the androids in Stars Wars, Terminator and Star Trek: The Next Generation, however much of these robot still only inhabit Science Fiction. This is how most people think of robots, but the robots really exist today are quite different from science fiction. Most are simply huge metal arms controlled by a controller. The type of robot that most frequently do the work are like too dangerous, boring, onerous, or just plain nasty. The robot can be found in auto, medical, manufacturing and space industries. In fact, there are about over million types of robot working for daily life today. The robots come in many shape and sizes and have their own abilities. Basically, a robot is simply use controller with some sort of mechanical body design to do the task or particular job. Usually it is able to move and has one or more electronics senses. Robotics is the science of studying and creating robots. It is a very broad and interesting science, because like humans, robots have many fascinating aspects. Robotics has been a real science only since the 1970's [1].

1.3 Overview of the drawbot

For this project, drawbot that were developed have a postion in industries applications. Nowadays, many of Textiles industries employ the human or people ti design or draw the pattern of 'kain batik using the ability or skills of each worker. By the way, this drawing job is not our concern occupations. But they must give a 100 percent concentration in their job to make a perfect design. However, human is not perfect to perform 100 percent. They also have a different mood in every time. Let see if they are in bad mood or poor condition, what happen in their job? Maybe they did the design as simple as they like and do not execute perfectly. This can influence the quality of design and make a lot of production wasted.

That's why we need an innovation of technology to convey an advantage of our industries. So this type of drawbot is suitable for our innovation to replace the human source to design and draw the pattern of 'kain batik'.

There are a lot of benefits if we submit an application to these innovations such as we can reduce the human salary and change the manufacture into our productions. Beside that, we can increase the productivity of the product and have a best production for the future development.

1.4 Objective of the project

PSM is a subject that require student to make their own project based on what they learn. So, there are several objective in this project that is;

- Design the drawbot using PIC microcontroller
- Able to program the movement of 3 servo motor

1.5 Scope of the project

In this project, there are several scopes that must achieve. Refer to the block diagram below, this project are using PIC microcontroller as a brain to interface output an input hardware. Remote as the input and servo motor movement as an output. The main scope for this project is drawbot is able to sketch the geometric shape.

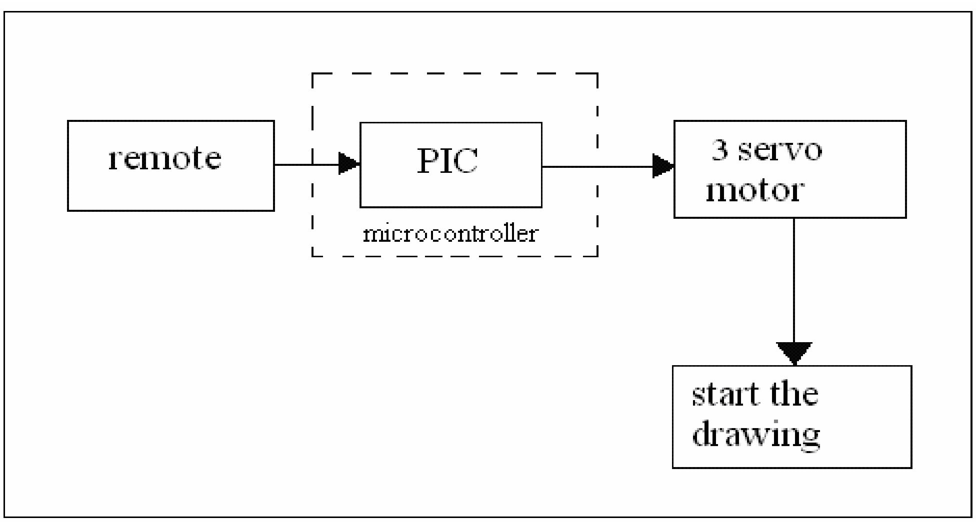

Figure 1.1: Drawbot Block Diagram

1.6 Organization of the thesis

Chapter 1 described about the basic overview or background of drawbot includes their benefits for the futures.

Chapter 2 explains about the literature review for the project as a reference during the project design, development and the implementation. The literature review covered like previous thesis, journal, books, experiments and any material which is give a good idea for the project development process.

Chapter 3 explains about methodologies or the step for the progress of the project. This chapter covered about the project design, component used, flow chart for the project progress and flow chart for the software development and this chapter also confirm which part or module need to be done first

Chapter 4 showing the results obtained from all the testing process and the result will be analyzed in this chapter. The result will be analyze to confirm the project realization and to make sure the result follow or fulfill the requirement in the task given

Chapter 5 discusses the conclusion for the navigation of the drawbot project, this chapter will conclude all the result and will confirm whether the project is successfully developed or not. The costing and recommendations and the better idea for the future development also included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will describe about the knowledge of drawbot or the literature review which is as a reference before develop this project, literature is one of the important part need to be consider before develop new project because it can be a good reference which is give a lot of information, theories, design and idea about the project develops. Literature review can be an article, journal, statement, research and the previous thesis done by others. Below show a few literature review referred before develop this project.

2.2 Drawbot 1.0

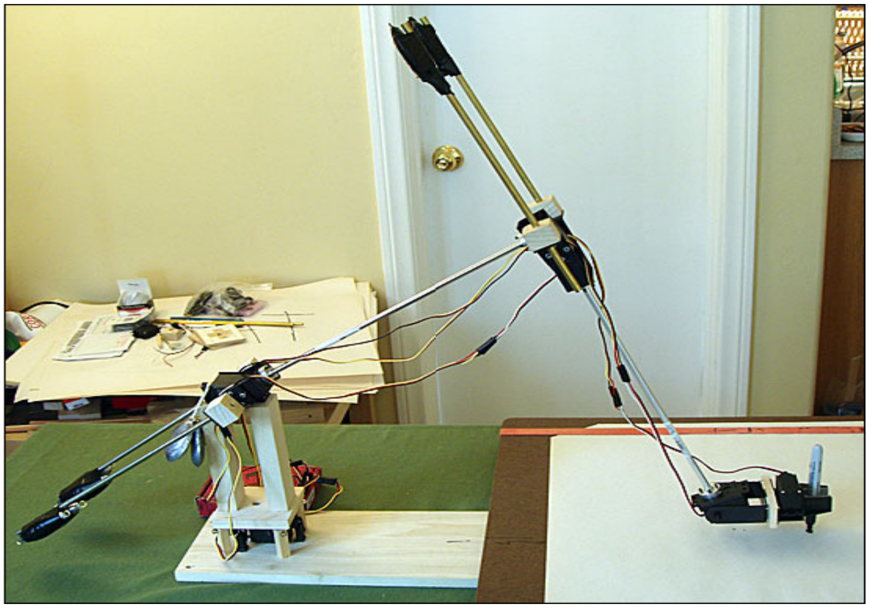

Figure 2.1: Drawbot 1.0

This reference build the drawing robot as same as this project. This robot is quite simply, a drawing robot. More specifically, it is a 30” robotic arm with shoulder, elbow and wrist joints. It is mounted on an easel like horizontal platform and it is capable of picking up and drawing with regular marking pens on pieces of paper up to 15”x 20” [2].

2.2.1 Interface

Drawbot is accessed with easy to use software that runs on any Windows PC with a USB port. By moving the mouse around the screen, the user controls the corresponding position of the pen over the easel. Tapping the space bar raises and lowers the pen onto the paper surface.

An exciting feature of the software is that the user can choose to record his or her session for playback at a later time. In this way, a nearly-exact copy of the original drawing is produced. Drawbot is highly skilled at retracing its earlier steps.

The potential for Drawbot to produce perfect geometrical shape, text and fonts of various styles, and even pointillist images, is nearly infinite. But no matter what input is used the process of creating artwork is as engaging as the final product itself. Drawbot is not a painter, but a performer [2].

2.2.2 Electronic and Mechanical Design

This robot is using PIC18F4550 microcontroller as a main control system with full speed USB 2.0 connectivity. It also uses standard motors to recreate the rotational motion of the human arm [2].

The DrawBot "bones" (upper-arm, forearm, and counterweights) are made out of lightweight 1/4" steel, brass, and aluminum tubing available at any hardware store. Much of the connecting hardware is available in prefabricated brackets made especially to mount servos and connect them with shafts or other servos [2]. A total of five "joints" are used in the DrawBot: two at the shoulder for up-down and left-right movement; one at the elbow to control the bending of the arm; and two at the wrist to control the rotation, and the gripping action, of the fingers. This freedom of movement allows DrawBot to pick up any sort of marking pen (as long as the cap is already off) and press it to the paper surface.

2.3 Servomotor

Servo motors are geared dc motors with positional control feedback and are used for position control. The shaft of the motor can be positioned or rotated through 180 degrees. They are commonly used in the hobby R/C market for controlling model cars, airplanes, boats, and helicopters [3].

Figure 2.2: Servo motor

Because of their widespread use in the hobby market, servo motors are available in a number of stock sizes. While larger industrial servos are also available, they are priced out of range for most hobby applications. This article is restricted to the hobby servo motors that are inexpensive and readily available.

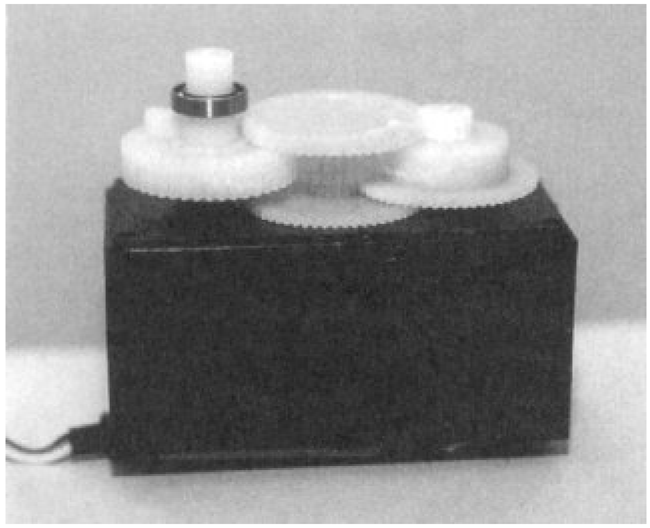

Figure 2.3: Gear box of servo motor

There are three leads to a servo. Two are for power, + 4 to 6 volts and ground. The third lead feeds a position control signal to the motor, and the control signal is a variable-width pulse. A neutral, midrange positional pulse is a 1.5-ms (millisecond) pulse, which is sent 50 times (20 ms) a second to the motor [3].

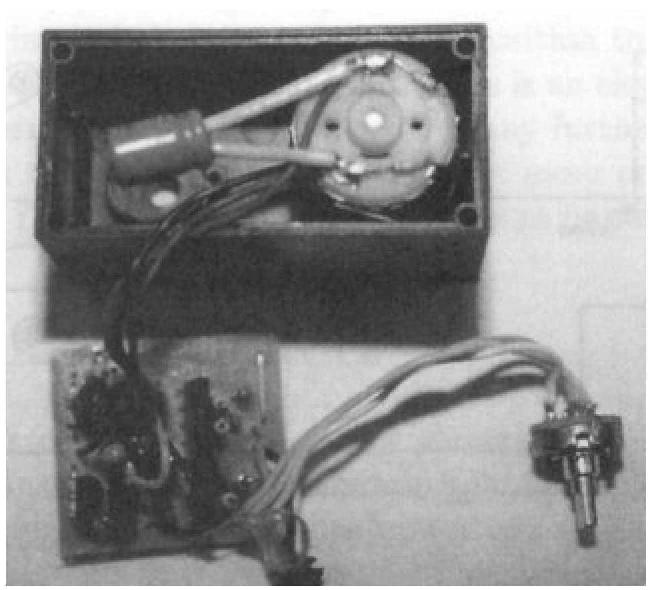

Figure 2.4: Motor controller of servo motor

The output shaft of a servo motor does not rotate freely, but rather is commanded to move to a particular angular position. The electronic sensing and control circuitry the servo feedback control loop drives the motor to move the shaft to the commanded position. If the position is outside the range of movement of the shaft, or if the resisting torque on the shaft is too great, the motor will continue trying to attain the commanded position.

Servo motors are used in model radio control airplanes and helicopters to control the position of wing flaps and other flight control mechanisms.

This pulse signal will cause the shaft to locate itself at the midway position +/-90 degrees. The shaft rotation on a servo motor is limited to approximately 180 degrees (+/-90 degrees from center position). A 1-ms pulse will rotate the shaft all the way to the left, while a 2-ms pulse will turn the shaft all the way to the right. By varying the pulse width between 1 and 2 ms, the servo motor shaft can be rotated to any degree position within its range.

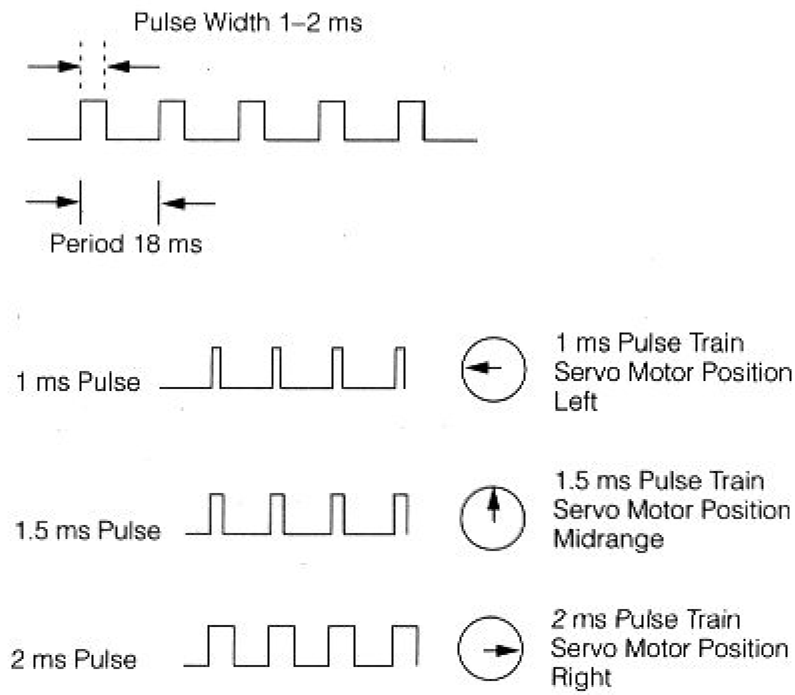

Figure 2.5: The servo motors pulse signal

2.3.1 How to use servo motors to walk!

In general, legged locomotion systems are quite complicated. There are however, a few simple variations. An insect like leg can be constructed using only two model hobby servos, as shown in Figure 2.6.

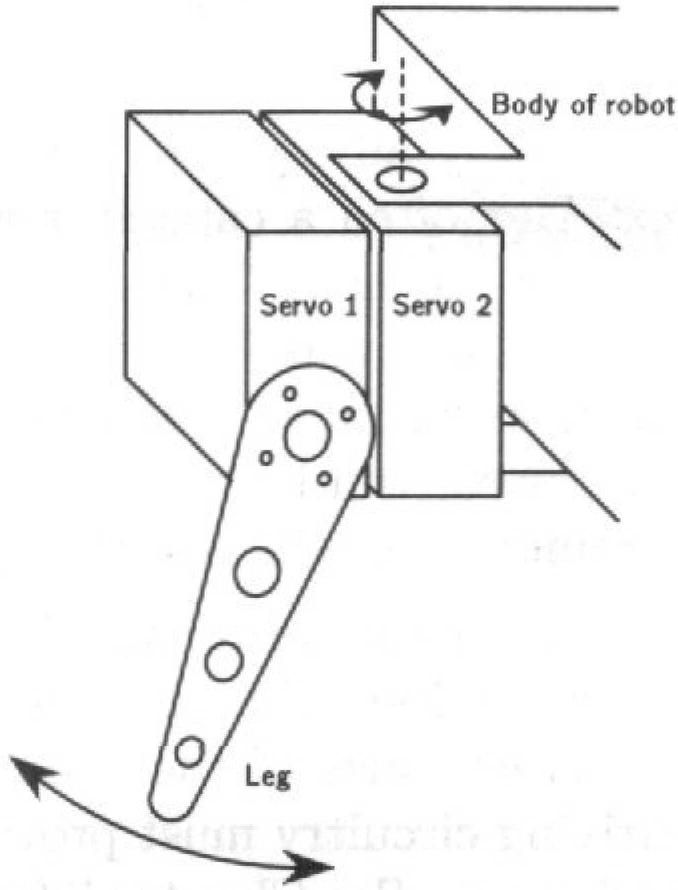

Figure 2.6: A simple two-degree-of-freedom leg

To take a step, servo 1 first swings the leg outward, away from the body. This is designed to raise the leg over any obstruction. Next, servo 2 rotates the servo pair so as to move the leg forward. Servo 1 then rotates the leg downward until it makes contact with the ground. Finally, servo 2 rotates back, pushing the robot forward. A coordinated motion of six such legs allows the robot to move forward or backward or to turn [4].

2.4 PIC Microcontroller

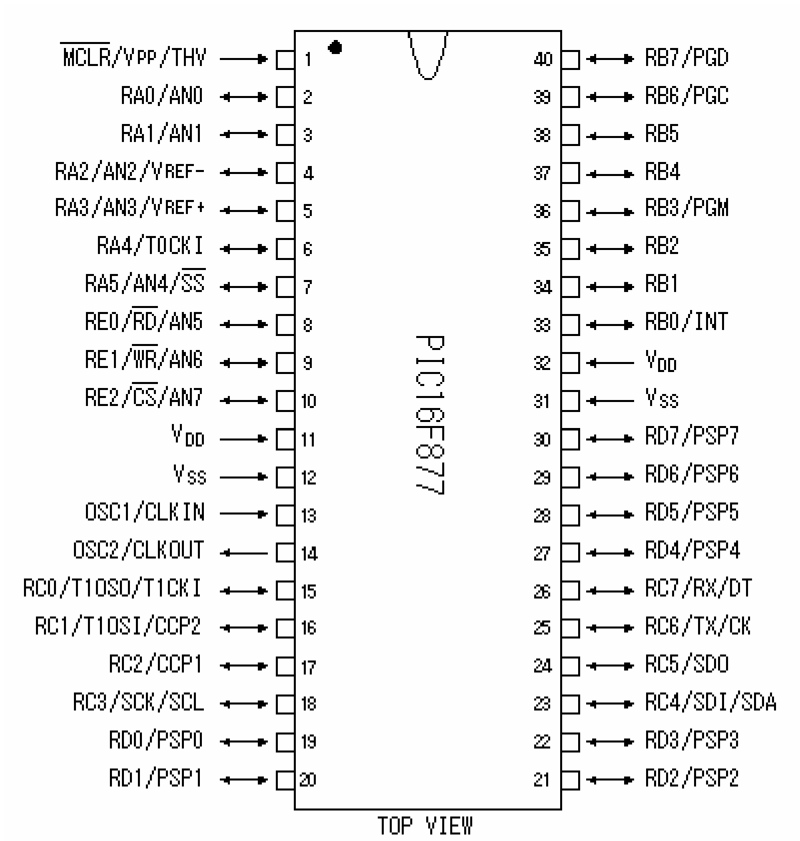

Figure 2.7: Specification of PIC16F877

The PIC16F877 Controller board is low-cost controller, ideal for standard embedded applications and incorporating into machinery, control systems and robots and also the one of the mainly popular microcontrollers on the market. The PIC16F877 Microcontroller includes 8kb of internal flash Program Memory, mutually with a large RAM area and an internal EEPROM. An 8-channel 10-bit A/D converter is also included contained by the microcontroller, assembly it ideal for real-time systems and monitoring applications [5].

All port connectors are bring out to standard headers for painless connect or disconnect and In-Circuit program download is also provided, enabling the board to be easily updated with new code and customized as necessary, without the must to remove the microcontroller.

The new PIC16F877 Controller is the best solution for use as a standard controller in many applications, the grand features include little solid size combined with easy program updates and modifications make it ideal for use in machinery and control systems, such as alarms, card readers, real-time monitoring applications and much more. This board is ideal as the brains of robot or at the center of home-monitoring system [5].

2.5 PIC programmer.

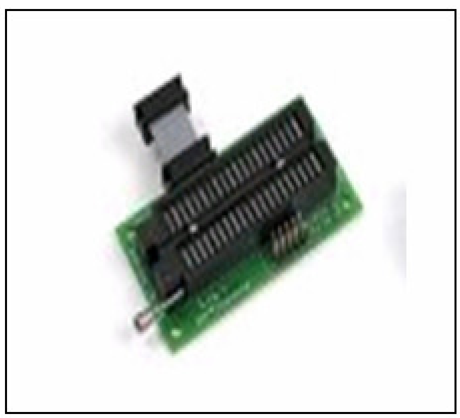

Figure 2.8: Burner for PIC programmer

Figure 2.9: Melabs Programmer toolbar

Programmer uses a serial port to interface to the computer. This makes it compatible with computers that don't have parallel ports. This programmer are the same with the FKEE lab used for program the PIC 16F877. It also allows the use of a USB-to-Serial adapter for those computers that only have USB ports. The programmer board is specifically designed for In-Circuit Serial Programming (ICSP). An adapter is available to allow the programming of DIP-packaged PICs from 8 to 40 pins. The programmer is also compatible with the complete line of Programmer Adapters. This allows user to program almost any ICSP-capable PIC in almost any package. The programmer board measures only 1.8" x 2.3". Power is supplied by a 15VDC, 500mA AC Adapter. A dual color LED indicates programmer status. The connection to the computer is via a standard 9-pin serial cable [6].

Some features of this programmer is it have a Fast serial operation at 115,200 bps, can be used with USB-to-Serial adapters, have dual-colour indicator shows ready/busy states, in-Circuit Serial Programming (ICSP) connector for interface to project board, full featured software included with support for all ICSP-capable PIC microcontrollers, compatible with Microchip HEX format files and with all Programming Adapters. The programmer includes software for Windows 98/Me/NT/2000/XP [6].This software will make sure the user to control the programmer and set the configuration bits on the PIC. The software may be run as a standalone application or launched from most program editor/IDE packages like MicroCode Studio (same as installed in the computer at the FKEE lab).

The Serial Programmer software is compatible with the standard Microchip HEX format files and any assembler or compiler for PIC microcontrollers can be used to create the program, including MPASM, CCS C, PicBasic, or PicBasic Pro .The software allows user to set configuration bits on the PIC with an easy-to-use list of options and each configuration option is selectable in a drop-down list. Configuration data may be read from a hex file or from a PIC. The consolidated view-memory window function to view each section of memory in the PIC with a click and a right-click gives the choice of viewing ASCII, Decimal, or Hexadecimal. A formidable list of options allows customizing the way of interact with the software and all operation can be control for example what areas of the device are erased, programmed, and verified. Save mouse clicks with options like "Disable completion messages" and "Erase before programming" [6]. The programmer's firmware can be upgraded electronically with the click of the mouse.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The project of developing drawbot hardware is having to done within one semester which is about three months. In this three month the project has need to successfully build and operate as the requirement. The first task of developing the prototype of drawbot is to find the equipments and the components. Then build the project of drawbot hardware and integrate all components to its design places.

The step of methodology flow chart is shown in Figure 3.1. This step is a guided to finish or produce the product. The discussion about methodology will be informed in the next subtitle.

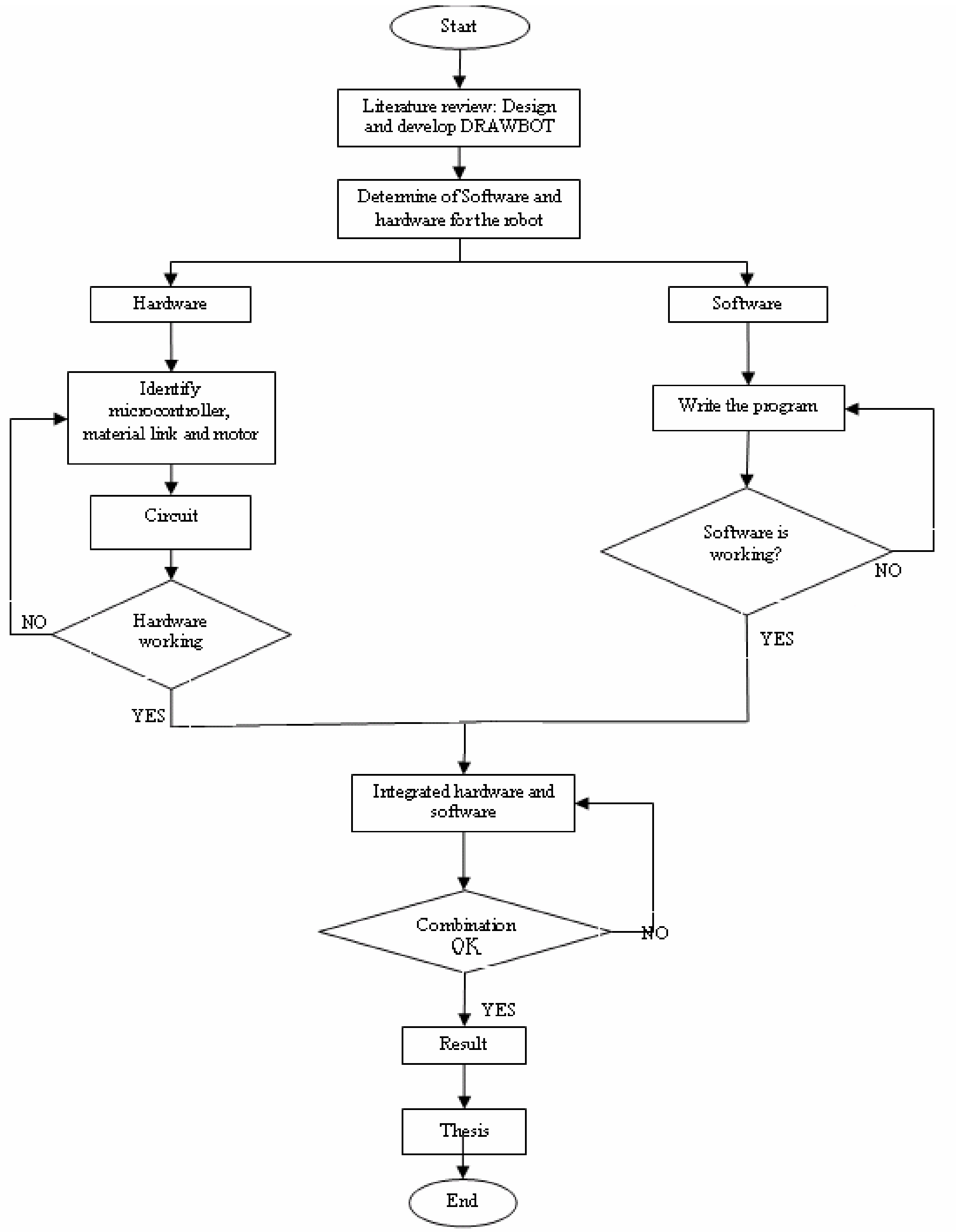

Figure 3.1: Flow chart of project methodology

3.2 Project methodolody

Find the data and decide the scope base on previous project of robot vacuum such as “Drawbot 1.0”

3.2.1 Finding Data

Searching and finding more information and data are most important part to design and develop this project to produce a better product of drawbot. We can get more knowledge and can compare and analyze the advantages and disadvantages to decide project scope and also a better design of drawbot. There have other types of robot vacuum in a market such as “Drawbot 1.0”, and “Drawing robot Artpartner” develop by Panasonic and many more.

3.2.2 List the specification of the robot.

From the surveying and discussion about drawbot that already in market, we can decide and list the suitable specifications or requirements for the project base on the objective and scope. It’s also importance because the components make the project to be operating well. For example there are many types of motor such as dc motor, stepper motor, ac motor and servo motor. For this project, servo motor have been choosing because its have many advantages and suitable in controlling the movement of robot. In choosing the component, we must select the more advantages and benefits that give to the project

3.2.3 Develop and test hardware modules

The better way to develop or build the hardware and test of drawbot is prefer done module by module or part by part. It is more safety and easy to troubleshoot when having a problems. By develop and test in module also the working of project can be more efficiency and finish by time. It's also shown that the work done doesn't have any problems before integrate with software.

3.2.4 Integrate hardware and software

The last methodology is test field. This is integrating the hardware of the robot with its software. So the project of develop drawbot will finish and can be use in FKEE laboratory.

3.3 Design

The draft design of drawbot is shown in figure 3.2. This is the first design to develop the drawbot.

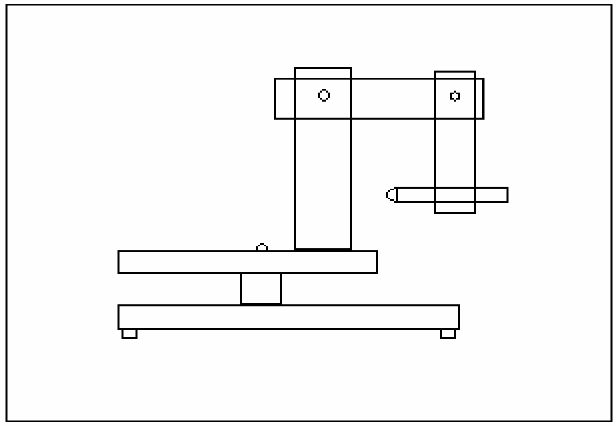

Figure 3.2: First design of drawbot

The design of real drawbot that have to build is almost like the draft design and also its structure. But this design is look not stable for the base to hold the other joint at above. So, to make the stabilities, this drawbot put some item as a holder. Figure 3.3 above show the design of drawbot after reconstruction.

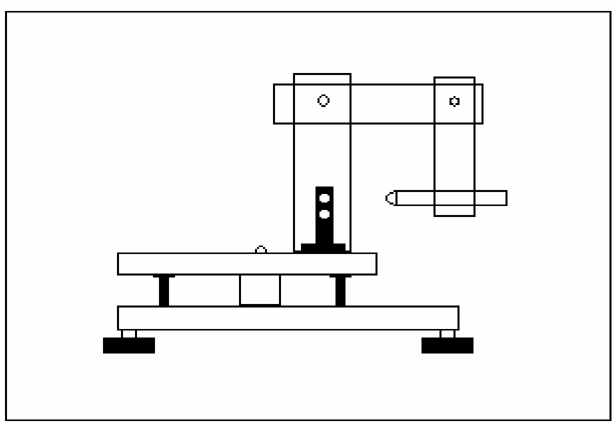

Figure 3.3: Design after reconstruction.

3.3.1 Components

This is a list of components that needed in this project

Table 3.1: List of components

Items	Quantities
Servo motor	3
Switch	1
Nails and screws	-
Bolts and Nuts	-
Reset button	1
IC (PIC16F877)	1
IC Regulator (7805)	1
Capacitors 100µF	4
Capacitor 25µF	1
Resistor 10kΩ	2
Crystal 20Mhz	1
Marker Pen	1
Arcylic (body)	-

The component has its own functions in operating the drawbot. For example, the servo motor is function to move the arm or joint in degree of freedom and it is able to move the arm up, down left and right depends on how that been programmed. All the components are decide and choose base on more advantages and benefit that give to develop the project. Its play some of the importance aspect that to reduce cost and most suitable for the design.

3.3.1.1 Crystal

This is a component that must include in the circuit. There are 2 type of crystal available in the market such as crystal 20 MHz and crystal 4 MHz. The pulse torque that generate from servo motor is depends on the value of crystal. For HI-TEC422 servo motor, its need a high pulse, so the available crystal for this servo motor is crystal 20 MHz. Appendix F shows the type of crystal that chooses for this project.

3.3.2 Software for programming

Figure 3.4 below shows the example of the Microcode Software front page which is used to develop the program for the drawbot navigation. Several step need to be done to finish develop the program. Firstly write the command or coding at the Microcode Studio and save, after finish save it check whether the program created is success or not by click at the ICD Compile button (F9), it will show whether the program have success or have an error and also show the size of the program at the bottom(left side) [7].

After that click the ICD Compile and Program button (F10) and it will check the program again, if the program is success (no error) the toolbar for the melabs Programmer will appear but if the program have an error it will highlight at the sentence that have an error with red colour and the melabs Programmer will not appear. At the melabs Programmer toolbar, first click at the view option and choose at the configuration, set the configuration with the right characteristic, after that click at the program button and it will burn (download the program) the PIC 16F877 with the program created. Its only takes about a second to finish burn the PIC and after that the PIC can be used to test the program.

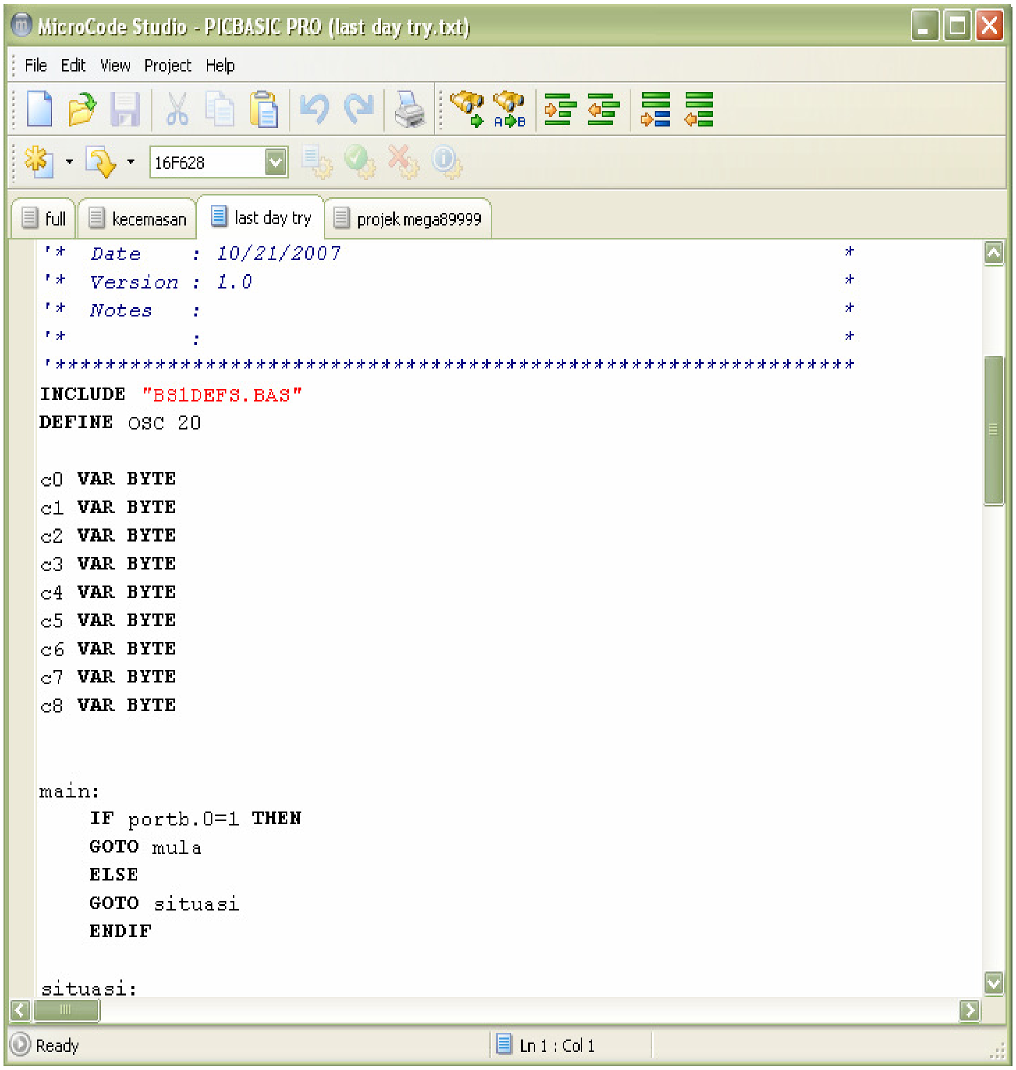

Figure 3.4: Example of the Microcode Studio front page

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This chapter discusses all result obtained and limitation of this project. All discussions concentrate on the result and performance of drawbot.

4.2 Hardware development

The process of hardware development for this project is has finish build and it is done by developing module by module. There are 2 modules or main part of drawbot such as body part of drawbot and circuit.

4.2.1 Develop body part of drawbot.

The starting process to develop the body of drawbot is choosing the suitable material. So this project had been choosing acrylic as a material to build the base and joint for this drawbot. The results have shown in figures below from side view, front view, back view and overall view.

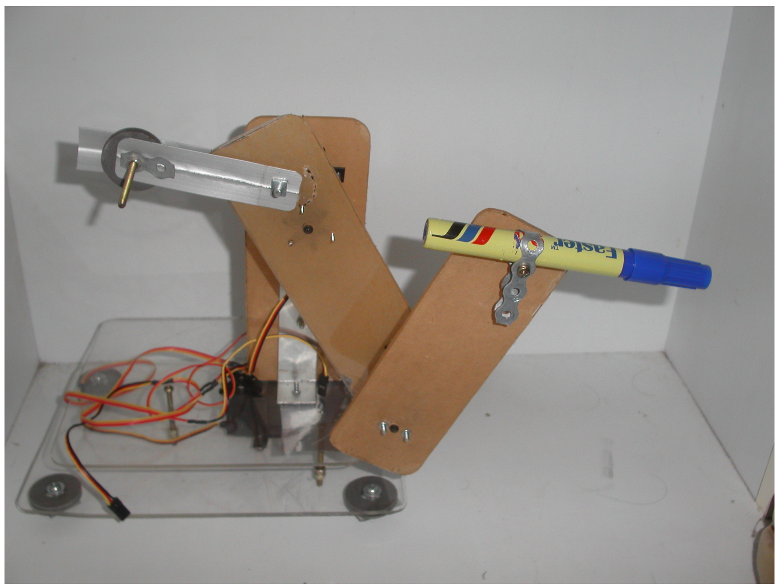

Figure 4.1: Side view

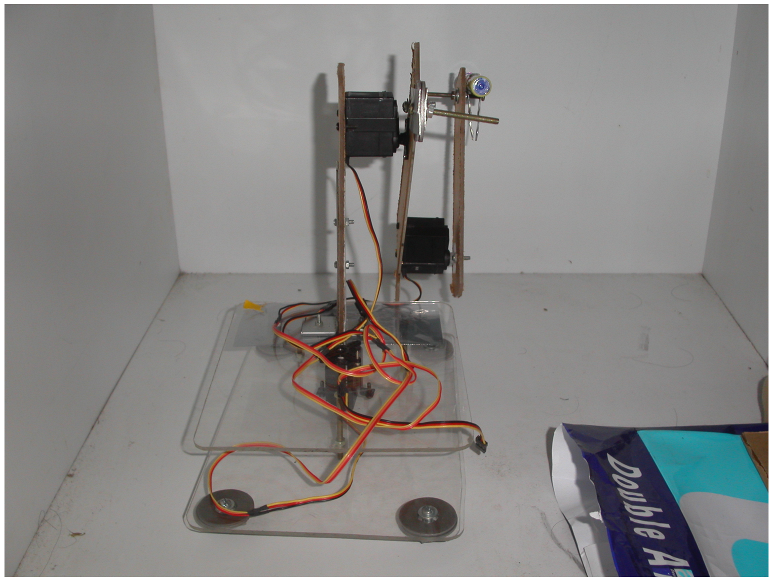

Figure 4.2: Front view

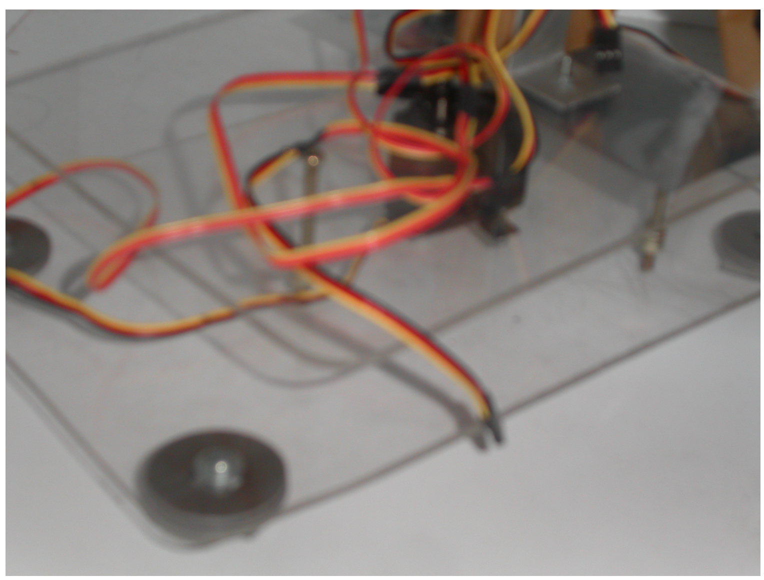

Figure 4.3: Back view

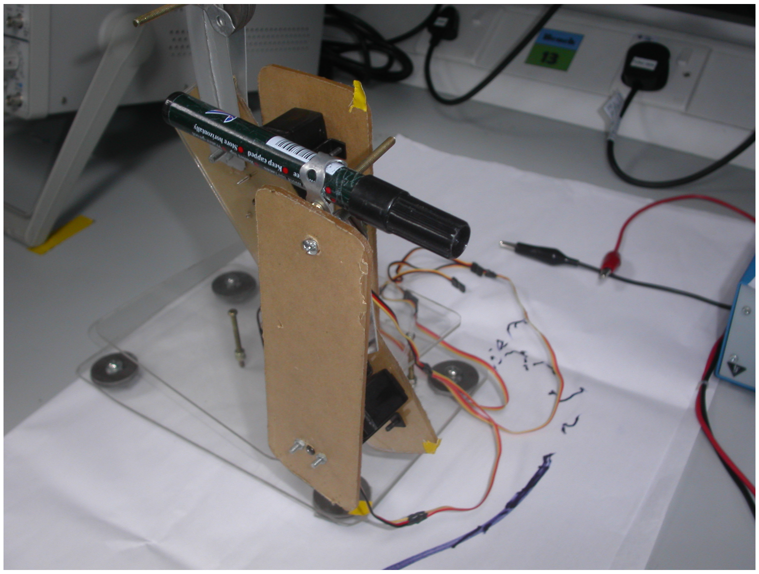

Figure 4.4: Overall view

From the figures, there are a lot of thing that must be achieved to make the drawbot easy to move right and left also move up and down.

4.2.1.1 Servo motor (analysis)

This project is use an acrylic as a body to connect with servo motor. To make the servo motor can easily rotate and functioning, mass of an acrylic must be determined in details. The weight of body depends on how much weight or torque that servo motor can hold. So this is an analysis of torque that must be achieved.

Torque servo motor

Torque = 3.3 kg.cm (spec from servo motor)

= 0.33 N/m

For design arm

$\Sigma\ \tau = \Sigma\tau$ (actuator) – $\Sigma\tau$ (weight of the arm)

= 0.33N/m – (m connector 1 × g × d connector gravity part 1) –

(m connector 2 × g × d connector gravity part 2) – (m load × g × d)

= 0.33N/m – (0.075 × 9.182 × 0.0016/2) – (0.097 × 9.812 × 0.0075/2) – (m load ×

9.812 × 0.020)

0 = 0.33N/m – (0.00058872) – (0.003569115) – (m load × 0.19624)

M load = 1.66043 Kg

The capable lifting for the first joint is 1.66043 Kg. However, this calculation is based on ideal condition. The minimum weight for this project is determined by 40% by the m load.

So,

Net m load = 40 × 1.66043 Kg / 100

= 0.664172 Kg

The m load that calculated above is fixed value for servo motor to pick up the mass. If the mass is heavier than m load, the servo motor cannot pick up the mass or the other word is not capable to do work.

4.2.1.2 Circuit development

Circuit is the second part in developing the hardware. All components that been listed in figure table are connected into this circuit not including servo motor.

This circuit is dividing by 4 sub-circuits such as power supply circuit, reset button circuit, switch and PIC microcontroller. Figures below have shown the circuit in an each position and also circuit diagram.

4.2.1.2.1 Reset button

Reset button is function to make the drawbot turning back into the initial position and start the movement again. Just press the button in the circuit and its will work.

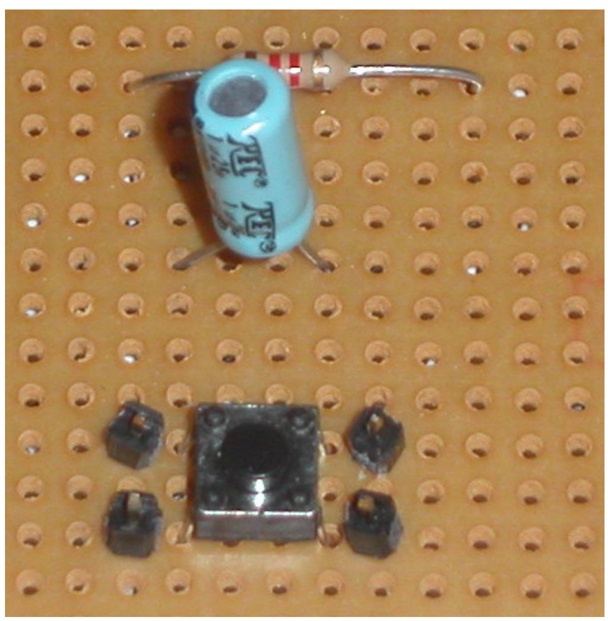

Figure 4.5: Reset button

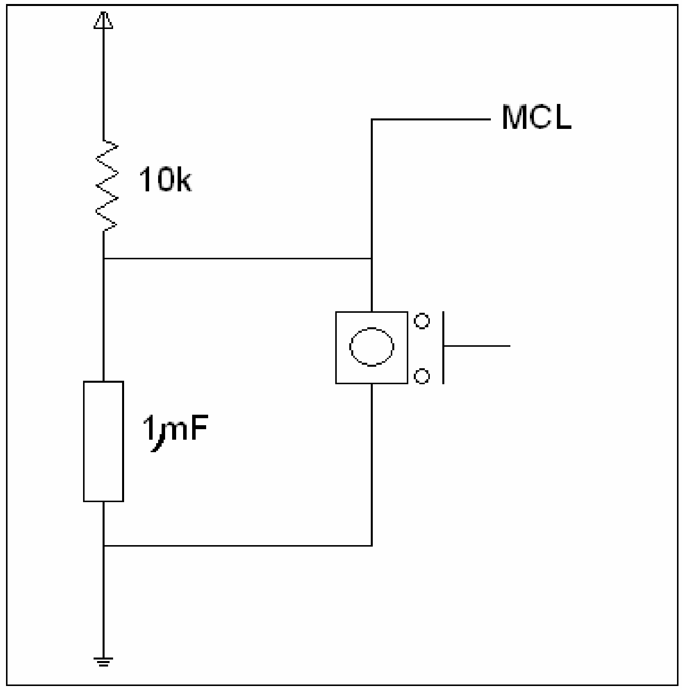

Figure 4.6: Circuit diagram for reset button

4.2.1.2.2 Power supply

To make the circuit functionally, there must have a power to supply energy into circuit. So, power supply circuit must be applied into this circuit. Actually these circuits demand a 5 voltage to energize the circuit. If it gives more 5 voltages, this circuit will blow and all components will break. This circuit will accept the higher voltage (input) and then produce 5 voltages as an output. The figure 4.7 below show how the power supply connected and its circuit diagram.

Figure 4.7: Power supply circuit.

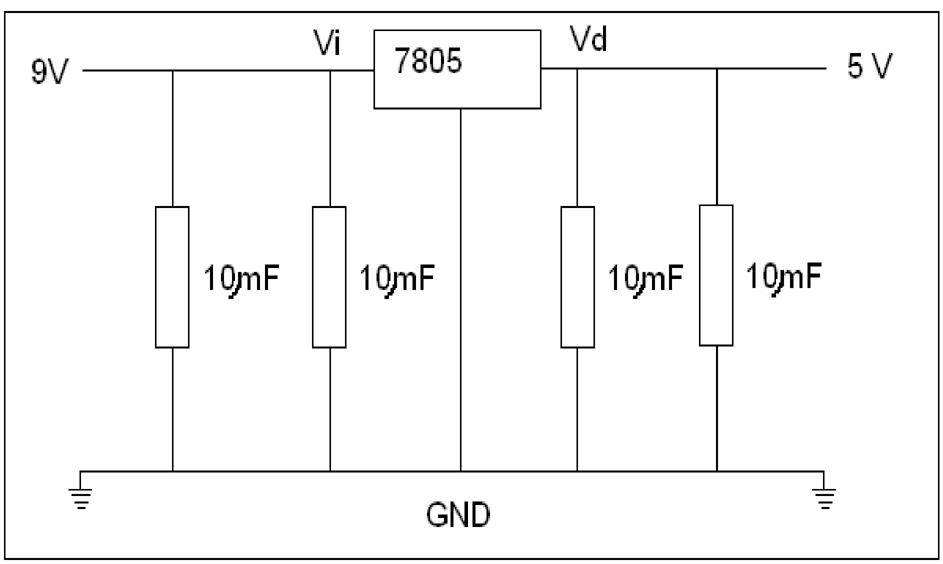

Figure 4.8: Circuit diagram for power supply circuit

4.2.1.2.3 Switch

Switch is function as give the output and input to controller. These projects apply the on/off switch to determine whichever the drawbot start drawing or not drawing. If switch is turn on, the drawbot will start the drawing continuously. Otherwise, if switch is turn off, the drawbot will back to the initial position and stop drawing.

Figure 4.9: Switch circuit

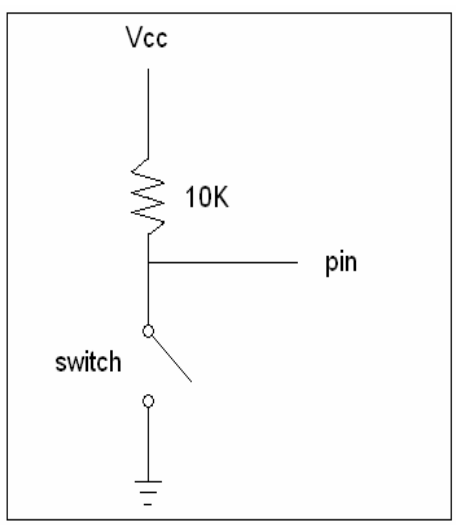

Figure 4.10: Circuit diagram for switch

4.2.1.2.4 PIC microcontroller circuit

PIC microcontroller is the main circuit or called brain of this project. All sub-circuit must be connected to these circuit because there have output and input. This circuit is use 4 output to fetch the pulse to make the servo motor move. Figure 4.11 at below shown how the circuits are instigated and figure 4.12 had shown the real circuit for this project.

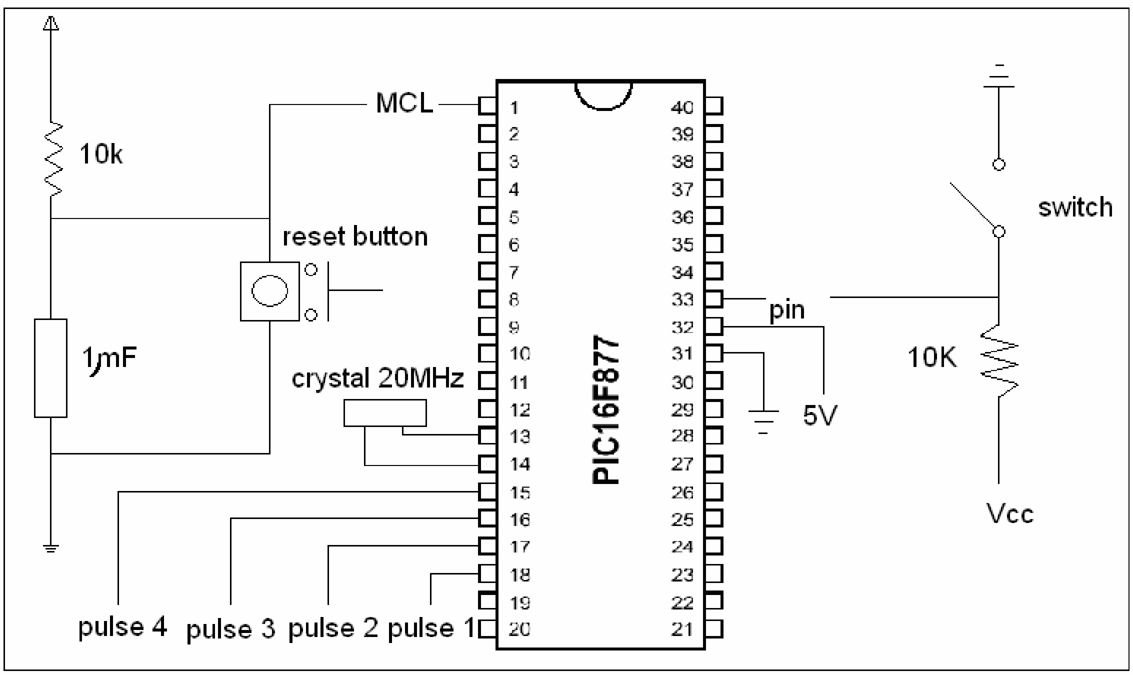

Figure 4.11: Circuit diagram of PIC microcontroller

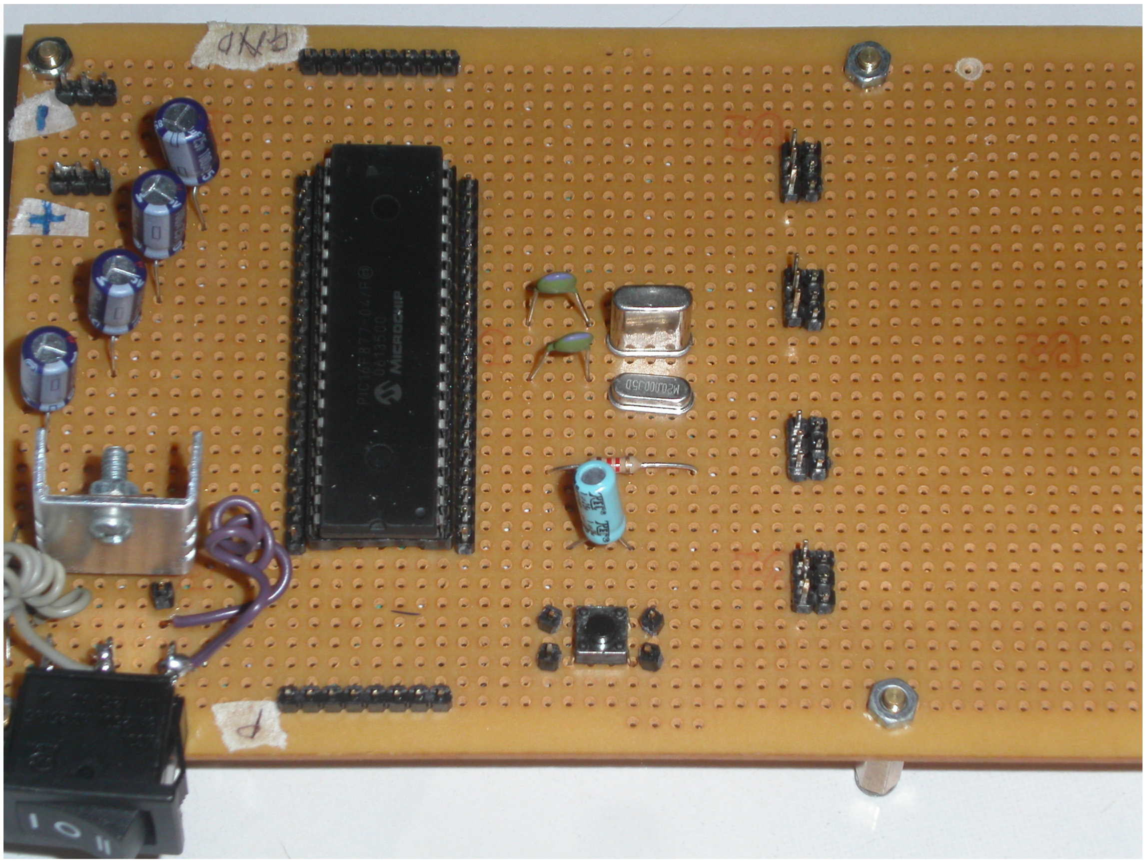

Figure 4.12: Overall circuit for this project

4.3 Software development

For the software development, the PIC16F877 need to be burn with the program first and after that integrated with the PIC controller board and the output from the controller board must be connected to the servo motor. To check whether the program is running properly it's depend on the movement of the servo motor. Figure 4.13 below shows how the project works.

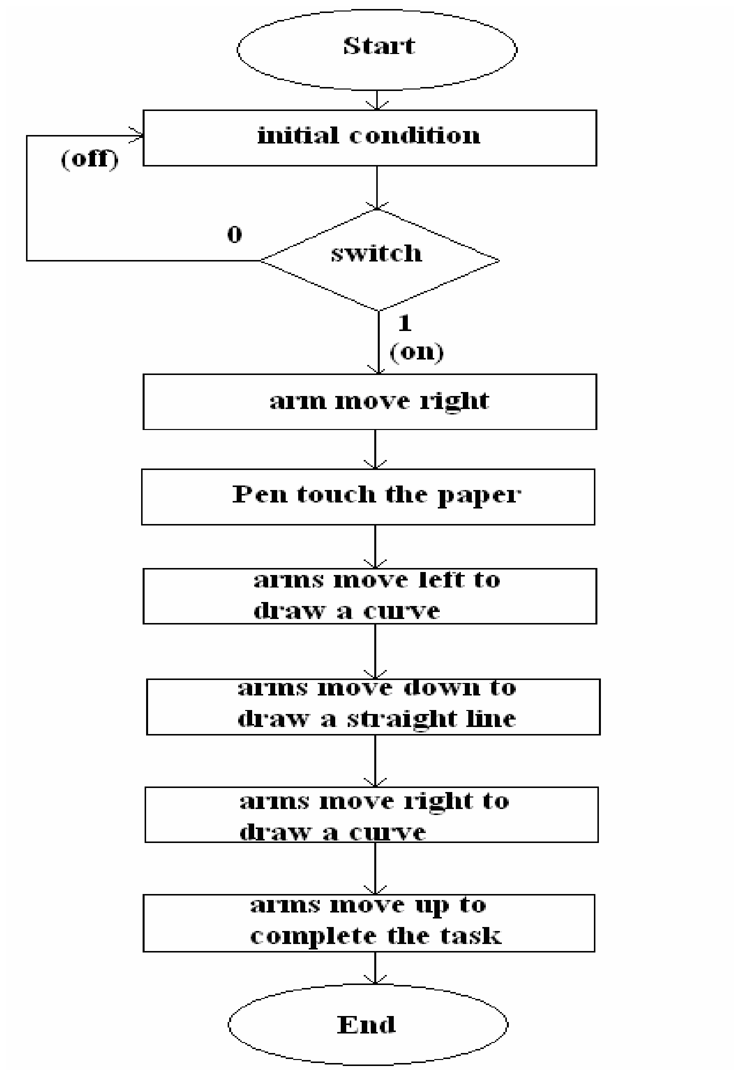

Figure 4.13: Flow chart for overall process

4.3.1 Main program for the drawbot navigation.

The program that developed how the drawbot drawing is shows in Appendix H.

4.3.1.1 Program analysis.

This program is consists of 2 condition how the drawbot works which is one part for initial condition and another part is for drawing. The initial condition is means the drawbot is not working and stay in 1st condition. If the port B is instigate low (= 0), it's mean at initial condition and otherwise, if the port B is instigate high (=1).the drawbot will start working or start the drawing. About the pulse, every pulse that been seeing in program is show the degree of freedom. Table 4.1 at the below shown the value of pulse for each degree.

Table 4.1: Specification of pulses and degrees

Degree (°)	Pulse
90°	325
60°	500
30°	625
0°	750
-30°	875
-60°	1000
-90°	1125

4.4 Final result

The final result for this project is estimated the objective and scope of the project. This drawbot is able to draw the geometric shape follow the step or tread that had been located. The figure 4.14 below had shown the steps of drawbot to sketch until drawing is completed. There are 4 steps to sketch this type of geometric shape.

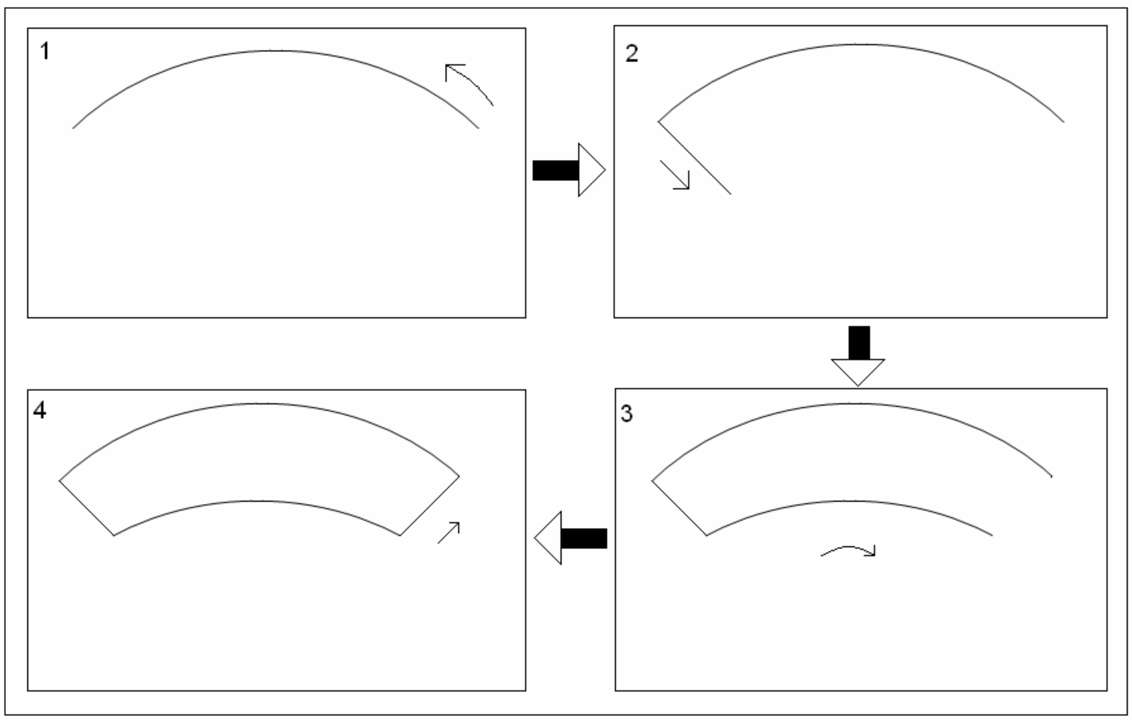

Figure 4.14: Steps of drawing

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 Conclusion

As a conclusion, in the end of this project, the hardware of drawbot that have been develops able to draw a geometric shape. The phototype of drawbot is performing well and better than had been expected. New sketch can be added to the project task. By complete this project, the drawbot brings a new of industry technology that can reduce the human power and also increase the productivity of industry productions.

In developing this project also new and innovation solutions are needed to tackle the design challenges that are encounter. Each problem must deal with research, discussion and trial and error method in a timely manner. Overall of the project, process of learning beside objective of this project provided an opportunity to research beyond the academic requirements and made mind thinking more creatively and effective suitable for the design of the project.

5.2 Suggestions

The project development the prototype of drawbot hardware need to add or made the improvement of certain part to be more effective and a quality product that can advertise in market to compete with other product of drawbot. The prototype of drawbot need to add the latest technology nowadays for makes the product up to date.

There are some suggestions for future development belongs to this project.

- For this time, this project able to sketch a geometric shape. So for future development, drawbot will able to sketch such as fonts, human face, and so on. Besides, this drawbot also able to colour the pictures and make a pattern by using the colours.

- To make a drawing for human face, this project will integrate with computer by capture the picture first. So this project must add the DB9 as a connecter to computer from circuit using IC MAX233 or MAX232.

- Add 1 servo motor on this project to make the drawing smoother and beautiful. So the total is 4 servo motor that used

5.3 Costing and commercialization.

This project has achieved the objective and expected result. The costing to produce this drawbot is around RM350.00. This is a raw cost because of using the material list below.

Table.5.1: Project Costing

	Material	Cost
Hardware	Acrylic	RM 50.00
Circuit	Based on circuit design	RM100.00
Robot actuator	Servo motor (3 unit)	RM150.00
	Total	RM300.00

From the table 5.1 above shows the material chosen to build drawbot is and the material selected is the proper material to build this project with low cost and high quality. This drawbot can be commercialized to other university and the industry to implement the technology or system design.

REFERENCES

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[4] Motor fundamentals, how does a servo work?

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Citing internet sources: http://www.microchip.com

[6] Microchip, book of artbot

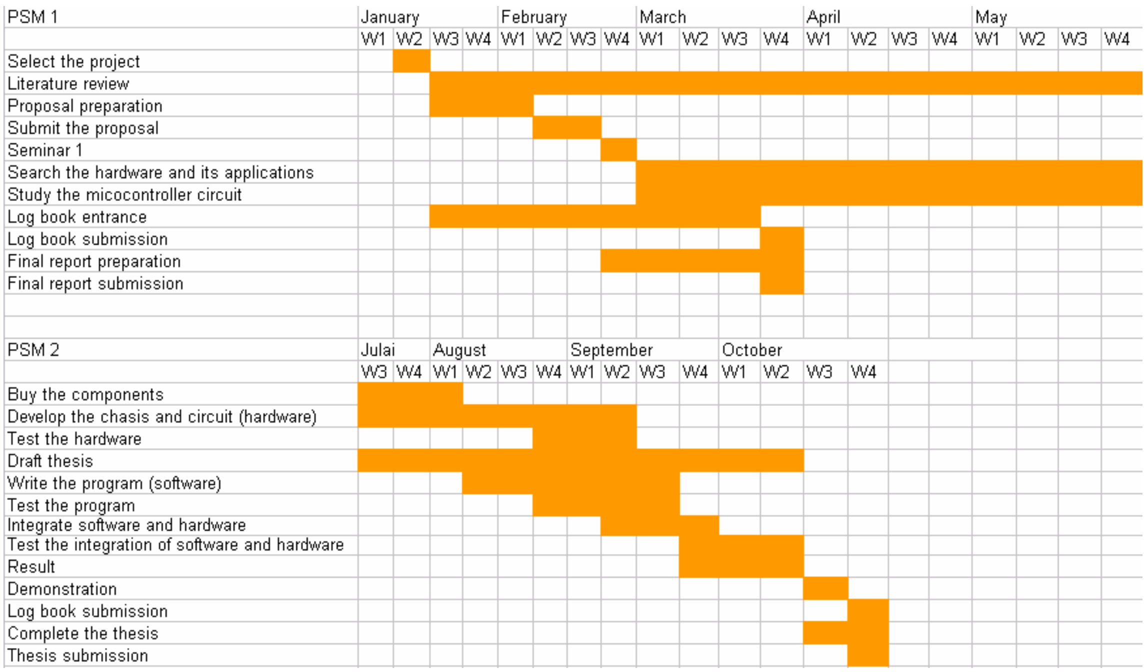
Citing internet sources: http://www.lxxl.pt/artsbot/index.html

[7] Assembly language, history

Citing internet sources: http://en.wikipedia.org/wiki/Assembly_Language

APPENDIX A

Gant Chart



APPENDIX B

MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

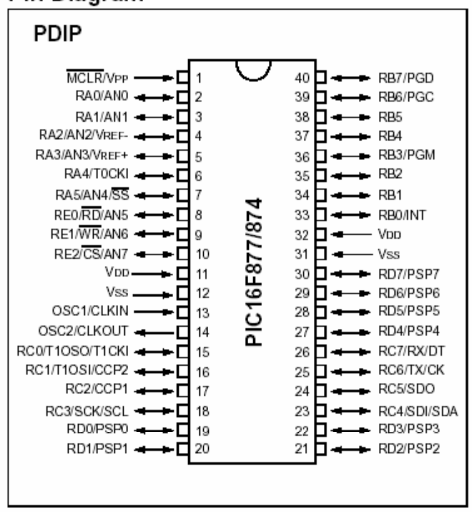
Devices Included in this Data Sheet:

- 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

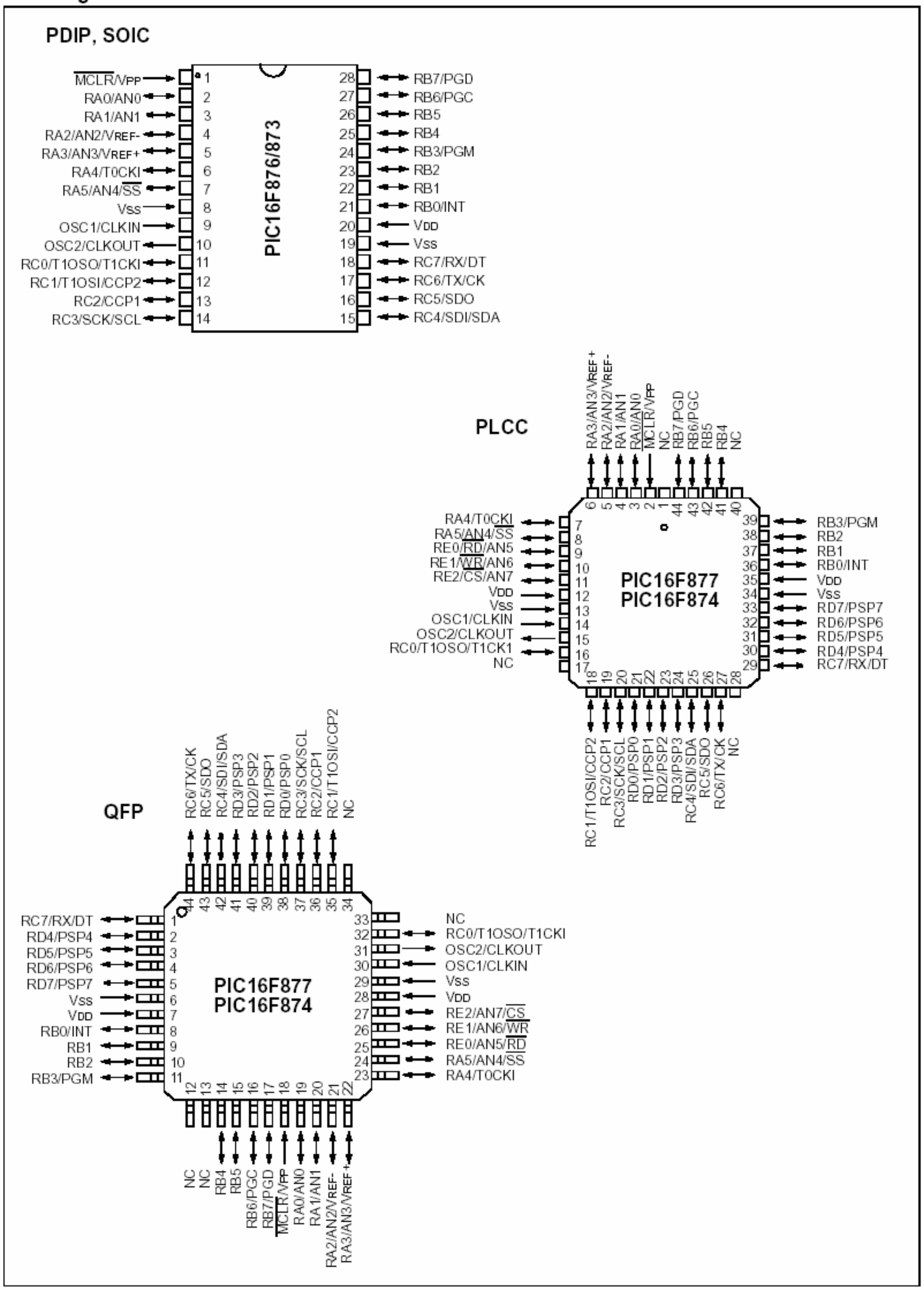


Peripheral Features:

- 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)

APPENDIX C

Pin Diagrams



APPENDIX D

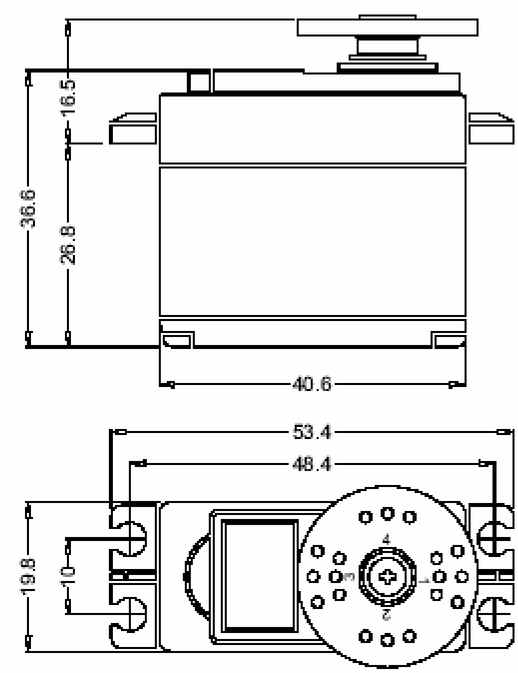
Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit 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

APPENDIX E

ANNOUNCED SPECIFICATION OF HS-422 STANDARD DELUXE SERVO

1.TECHNICAL VALUES

CONTROL SYSTEM	: +PULSE WIDTH CONTROL 1500usec NEUTRAL	
OPERATING VOLTAGE RANGE	: 4.8V TO 6.0V	
OPERATING TEMPERATURE RANGE	: -20 T0 +60°C	
TEST VOLTAGE	: AT 4.8V	AT 6.0V
OPERATING SPEED	: 0.21sec/60° AT NO LOAD	0.16sec/60° AT NO LOAD
STALL TORQUE	: 3.3kg.cm(45.82oz.in)	4.1kg.cm(56.93oz.in)
OPERATING ANGLE	: 45°/ONE SIDE PULSE TRAVELING 400usec	
DIRECTION	: CLOCK WISE/PULSE TRAVELING 1500 TO 1900usec	
CURRENT DRAIN	: 8mA/IDLE AND 150mA/NO LOAD RUNNING	
DEAD BAND WIDTH	: 8usec	
CONNECTOR WIRE LENGTH	: 300mm(11.81in)	
DIMENSIONS	: 40.6x19.8x36.6mm(1.59x0.77x1.44in)	
WEIGHT	: 45.5g(1.6oz)	



2.FEATURES
- 3-POLE FERRITE MOTOR
- LONG LIFE POTENTIOMETER
- DUAL OILITE BUSHING
- INDIRECT POTENTIOMETER DRIVE

3.APPLICATIONS
- AIRCRAFT 20-60 SIZE
- 30 SIZE HELICOPTERS
- STEERING AND THROTTLE SERVO FOR CARS
- TRUCK AND BOATS

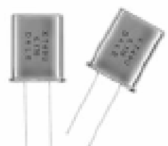
APPENDIX F

VISHAY

XT49U

Vishay Dale

Resistance Welded Holder Type Crystal Unit



The XT49U series is an industry standard AT cut crystal housed in a HC-49U package. It is our standard resistance weld type quartz crystal.

FEATURES

- Low cost
- Industry standard
- Excellent aging
- Wide frequency range
- 'AT' cut crystal

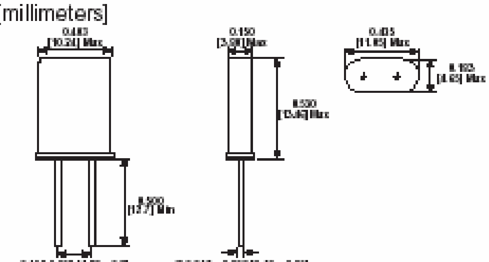
STANDARD ELECTRICAL SPECIFICATIONS

PARAMETER	SYMBOL	CONDITION	UNIT	MIN	TYPICAL	MAX
Frequency Range	F_O		MHz	1.8432		125
Frequency Tolerance	$\Delta F/F_O$	at 25°C	ppm	± 10	± 30	± 50
Temperature Stability	TC	ref to 25°C	ppm	± 10	± 30	± 50
Operating Temperature Range	T_{OPR}		°C	- 20		+ 70
Storing Temperature Range	T_{STG}		°C	- 40		+ 85
Shunt Capacitance	C_O		pF			7
Load Capacitance	CL	Customer Specified	pF	10		Series
Insulator Resistance	IR	$100V_{DC}$	MΩ	500		
Drive Level	DL		µW		100	500
Aging	Fa	at 25°C, per year	ppm	- 5.0		+ 5.0

EQUIVALENT SERIES RESISTANCE (ESR) AND MODE OF VIBRATION (MODE)

FREQUENCY RANGE (MHZ)	MAX ESR (Ω)	MODE	FREQUENCY RANGE (MHZ)	MAX ESR (Ω)	MODE
1.8432 to 1.999	650	Fundamental	6.000 to 7.999	50	Fundamental
2.000 to 2.999	500	Fundamental	8.000 to 12.999	35	Fundamental
3.000 to 3.499	250	Fundamental	13.000 to 32.000	25	Fundamental
3.500 to 3.999	150	Fundamental	24.000 to 29.999	60	3rd Overtone
4.000 to 4.999	100	Fundamental	30.000 to 79.999	40	3rd Overtone
5.000 to 5.999	80	Fundamental	80.000 to 125.000	90	5th Overtone

DIMENSIONS in inches [millimeters]



ORDERING INFORMATION

XT49U	R	- 20	SP	4M
MODEL	OTR	LOAD	OPTIONS	FREQUENCY/MHz
	Blank = Standard R = - 40°C to + 85°C	Blank = Series - 16 = 16pF - 20 = 20pF - 30 = 30pF - 32 = 32pF	Blank = Standard SL = Sleeve SP = Spacer	

APPENDIX G

idp PRODUCT DATA SHEET		Material Type: Acrylic Product Number: 64641
Processing Data	**English Values**	**Metric Values**
Injection pressure	10,000-20,000 psi	69-138 MPa
Melt Temperature	400-475°F	204-246 °C
Mold Temperature	75-150 °F	24-66 °C
Material Drying	4 hrs @ 200 °F	4 hrs @ 93 °C
Dew Point	5 °F	- 15 °C
Moisture Content	< 0.01%	<0.01%
Physical		
Specific Gravity	1.16	1.16
Mold Shrinkage, 1/8" (3.2mm)	0.005-0.006 in/in	0.5-0.6 %
Mechanical		
Impact Strength, Notched 1/8" (3.2 mm)	1.2 ft lbs/in	64 J/m
Impact Strength, Unnotched 1/8" (3.2 mm)	15.0 ft lbs/in	801 J/m
Tensile Strength	5,000 psi	34 MPa
Tensile Elongation %	10 +	10 +
Tensile Modulus	0.21×10^6 psi	1447 MPa
Flexural Strength	7,500 psi	52 MPa
Flexural Modulus	0.25×10^6 psi	1723 MPa
Electrical		
Volume Resistivity	10^{10}	10^{10}
Surface Resistivity	10^{10}	10^{10}
Static Decay, MIL B-81705C	< 2 seconds	< 2 seconds

APPENDIX H

```
'****************************************************************
'*  Name    : UNTITLED.BAS                                      *
'*  Author  : [select VIEW...EDITOR OPTIONS]                    *
'*  Notice  : Copyright (c) 2007 [select VIEW...EDITOR OPTIONS] *
'*          : All Rights Reserved                               *
'*  Date    : 10/21/2007                                        *
'*  Version : 1.0                                               *
'*  Notes   :                                                   *
'*          :                                                   *
'****************************************************************
include "BS1DEFS.BAS"
define OSC 20

c0 var byte
c1 var byte
c2 var byte
c3 var byte
c4 var byte
c5 var byte
c6 var byte
c7 var byte
c8 var byte


main:
   if portB.0=0 then
   goto mula
   else
   goto condition
   endif
   goto main
```

```
condition:
        gosub initial
        pause 10
        goto condition
        end

mula:

    gosub initial
    pause 10
    gosub arahan1
    pause 10
    gosub arahan2
    pause 10
    gosub arahan3
    pause 10
    gosub arahan4
    pause 10
    gosub arahan5
    pause 10
    gosub arahan6
    pause 10
    end

        initial:
                for c0=1 to 100
                pulsout 8,625
                pulsout 9,1125
                pulsout 10,500
                pause 20
                next
                return

        arahan1:
```

```
    for c1=1 to 100
    pulsout 8,875
    pulsout 10,500
    pause 20
    next
    return

arahan2:
    for c2=1 to 100
    pulsout 10,625
    pause 20
    next
    return

arahan3:
    for c3=1 to 100
    pulsout 8,500
    pause 20
    next
    return

arahan4:
    for c4=1 to 100
    pulsout 9,875
    pulsout 10,1125
    pause 20
    next
    return

arahan5:
    for c5=1 to 100
    pulsout 8,875
            pulsout 10,1125
    pause 20
```

```
	next
	return

arahan6:
	for c6=1 to 100
	pulsout 10,625
	pause 20
	next
	return
```