DESIGN OF MINI CNC MACHINE

NUR SURAINI BINTI HASHIM

BACHELOR OF MANUFACTURING ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **DESIGN OF MINI CNC MACHINE**

SESI PENGAJIAN: **2011/2012**

Saya **NUR SURAINI BINTI HASHIM (890404-03-5566)**

mengaku membenarkan tesis (Sarjana Muda/~~Sarjana~~ /~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐	**SULIT**	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD**	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	**TIDAK TERHAD**	

Disahkan oleh:

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat Tetap:

LOT 1453 KAMPUNG TELOK BARU,
GUCHIL BAYAM,
15200 KOTA BHARU,
KELANTAN

PROF. IR. DR. AHMAD FAIZAL MOHD. ZAIN

PEng., FASc, FIEM, Senior MIEEE

Tarikh:

Tarikh:

CATATAN:
* Potong yang tidak berkenaan.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai atau TERHAD.
♦ Tesis dimaksudkan sebagai tesis bagi Ijazah doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

DESIGN OF MINI CNC MACHINE

NUR SURAINI BINTI HASHIM

Thesis submitted fulfillment of the requirements

for the award of the degree of

Bachelor of Engineering in Manufacturing

Faculty of Manufacturing Engineering

UNIVERSITI MALAYSIA PAHANG

JUNE 2012

EXAMINER APPROVAL DOCUMENT

We certify that the thesis entitled “DESIGN OF MINI CNC MACHINE” is written by NUR SURAINI BINTI HASHIM. We have examined the final copy of this thesis and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Engineering in Manufacturing. We herewith recommend that it be accepted in fulfillment of the requirement for the degree of Engineering specializing in Manufacturing.

Name of External Examiner: **Signature:**

Institution:

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Engineering Manufacturing or Bachelor of Manufacturing Engineering.

Signature

Name of Supervisor: PROFESSOR IR DR. AHMAD FAIZAL B MOHD ZAIN

Position:

Date:

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature

Name: NUR SURAINI BINTI HASHIM

ID Number: FA08011

Date:

Dedicate to my beloved parents

HASHIM BIN MAHMOOD

NORLINA BT MOHAMMAD

and

My fellow friends

ACKNOWLEDGEMENT

Firstly I want to thanks to Allah for the time that HE gives to me to finish this project and also the strength for me to face challenges during this project.

Secondly, I wish to express my sincere appreciation to my major supervisor, Professor Ir Dr Ahmad Faizal b Mohd Zain, who provided me with his germinal ideas, invaluable guidance, continuous encouragement and the research opportunity that was both challenging and rewarding. He always impressed me with his outstanding profession conduct and his strong conviction in engineering field especially in aerospace field.

I would like to acknowledge all my friends who inspired me to finish this project during these years. They always support me and helped me in many ways and made my stay at UMP pleasant and unforgettable.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. They constantly encourage me to carry on my studies. I am cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Special thanks to them. I would like to acknowledge their comments and suggestions, which crucial for the successful completion of this study.

ABSTRACT

This thesis presents the design of Mini CNC Machine. This machine has 2axes, namely the Xand Y axis. Mini CNC machine is a small CNC machine that can operate like a normal CNC machine with a limited area of the machining. The objectives of this project are to develop the mini CNC Machine and to develop the software to control the machine. This thesis describes the development of the machine and the criteria needed to build the machine. The Mini CNC Machine is initially sketched by referring to the criteria that was decided. The criteria are the travel path length, type of linear motion, type of linear drive, motor and controller, and type of material that used. This machine's travel on the X axis is 15cm and Y axis is 15cm. The linear motion was used is a round linear rail and the linear drive used was a sliding element, lead nuts and lead screws. The motor used is a stepper motor with specification 2.1V and 3.0A. The frame material used is aluminium. This material is used because it is light in weight, easy to handle and machine and it is rust proof. The design was sketched using SolidWork software. For the next step is developing the wiring for motor and develop the program to control the stepper motor. The ULN 2803 is used to convert the signal from parallel port to specific winding energizing sequences to step the motor. The Visual Basic software is used to program the motor movement.

ABSTRAK

Tesis ini membentangkan reka bentuk Mini CNC Machine. Mesin ini mempunyai 2 paksi, iaitu paksi X dan Y. Mini CNC Machine adalah mesin CNC kecil yang boleh beroperasi seperti mesin CNC biasa dengan kawasan pemesinan yang terhad. Objektif projek ini adalah untuk membangunkan Mini CNC Machine dan untuk membangunkan perisian untuk mengawal mesin. Tesis ini menerangkan pembangunan mesin dan kriteria yang diperlukan untuk membina mesin. Mini CNC Machine mulanya dilakarkan dengan merujuk kepada kriteria yang telah diputuskan. Kriteria yang diputuskan adalah panjang laluan perjalanan, jenis gerakan linear, jenis pemacu linear, motor dan pengawal, dan jenis bahan yang digunakan. Perjalanan mesin ini pada paksi X 15cm dan paksi Y adalah 15cm. Pergerakan lelurus yang telah digunakan adalah rel linear yang bulat dan pemacu linear yang digunakan adalah elemen gelongsor, lead nuts dan lead skru. Motor yang digunakan ialah stepper motor dengan spesifikasi 2.1V dan 3.0A. Bahan bingkai yang digunakan ialah aluminium. Bahan ini digunakan kerana ia ringan berat badan, mudah untuk mengendalikan mesin dan ia adalah tahan karat. Reka bentuk yang dilakarkan menggunakan perisian SolidWork. Untuk langkah seterusnya membangunkan pendawaian untuk motor dan membangunkan program untuk mengawal stepper motor. ULN 2803 digunakan untuk menukar isyarat daripada parallel port kepada penggulungan urutan tenaga khusus untuk menggerakkan motor. Perisian Visual Basic digunakan untuk program pergerakan motor.

TABLE OF CONTENT

CHAPTER 2 THEORETICAL REVIEW OF PROJECT

CHAPTER 3 FLOW WORK AND METHOD OF THE PROJECT

CHAPTER 4 RESULT AND DISCUSSION

CHAPTER 5 CONCLUSION

LIST OF TABLES

LIST OF THE FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF PROJECT

Mini CNC machine is the machine that is similar to the usual CNC machine. Mini CNC machine is the small CNC machine that can operate like usual CNC machine but the area of the machining is limited. CNC machine is all about using the computer as a means to control machines that carves useful objects from solid block to material. For example, a CNC machine might begin with a solid block of aluminium, and then carved away just the right material to leave with a door handle.

There are many types of CNC machine. The common CNC machines are two-axis and three-axis CNC machine. The two- axis machine can move on vertical and horizontal only which are X and Y axis. Three-axis machine can do movement starting with three primary axis which are X, Y and Z axis. The Z axis is being parallel with the spindle (Micheal W. Mattson, 2010).

The CNC machine operation starts with the collecting the data from the programming that extract from the computer-aided design (CAD) and computer-aided manufacturing

(CAM). The programs produce the computer file and then will extract the command to operate the machine. The program will be transfer via post-processor and then be loaded into the CNC machine to start the machining. This is the flow of the CNC machine operation:

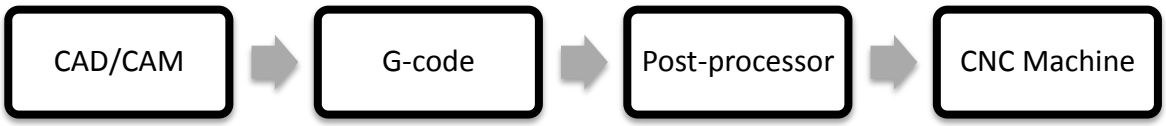


Figure 1.1: Flow of the CNC machine operation

The CNC machine is a system. To complete the system of CNC machine, there are 4 components which are mechanical design, drives module, system software and Automatically Programme Tool (APT) postprocessor.

For the mechanical design system, this part is the part of hardware of machine which is the part body. For the drive system, the command signal was received from microprocessor. Microprocessor is consisting of motors, amplifier units and a power supply. For the software system, it is generate the program to the CNC machine to start the movement of tools and workpiece. For the APT postprocessor, it was developed to produce the G-code and M-code that can be used by the CNC machine.

Figure 1.2: Flow of Mini CNC Machine

Besides that, CNC machine also include of wiring in order to connect the power to the machine. To complete the whole CNC machine, all the elements must be in the good condition and must put at the right place.

1.2 PROBLEM STATEMENT

Nowadays, the world are becoming highly technology with a lot of things become smaller and thinner. Even now the things especially in engineering and technology have the things in nano and micro size. Same goes to CNC Machine; this machine is now has variety of size in the market. All type of machine have own purpose, eventhough the size is big or small. The usual CNC machine can machine the big workpiece depends on the machine specification. The mini CNC machine only can machine the small workpiece depend on the machine specification. This project is about to overcome the problem of machining the small part. Even the usual CNC machine can machine the small workpiece, it will increase the time on setup the workpiece to the machine to get the accurate result. The mini CNC machine will give the small area of setup the workpiece and it will be easier to get the accurate place or result for the workpiece.

1.3 OBJECTIVES

The objectives of this study are:

- To develop the mini CNC machine
- To develop the software to generate the machine

1.4 SCOPE OF WORK

The scopes of this project are:

- Developing mini CNC machine with 3 axis
- Developing CNC programming
- Do wiring for the connection between machine and computer

1.5 PROJECT EXPECTATION

By the end of this project, student is expected to:

- Develop the Mini CNC Machine
- Learn to develop the program
- Learn how to connect the wiring of the circuit

CHAPTER 2

THEORETICAL REVIEW OF THE PROJECT

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of past research efforts related to Mini CNC machine and the important component in developing this machine. From the related journal and article, the idea in CNC machine is developed before go further for the next chapter in completing this project.

2.2 MINI CNC MACHINE

Mini CNC Machine is the small CNC Machine that can operate same likes other CNC machine. This machine is designed for the specific dimension. The CNC machines can be divided into two groups, which are turning machines and milling machine. A turning machine is generally made up of a device that spins a workpiece at high speed and the tool is moved back and forth and in and out until the desired shape is achieved. A milling

machine is a machine that has spindle which is same as the router, with a special tool that spins and cuts in various directions and moves in three different directions along the X, Y, and Z axis. (Patrick Hood-Daniel, 2009)

A CNC machine with several unique features, such as simplicity and reliability, was developed for studying computerized numerical control and its associated software. The machine is especially useful for educational and research purposes, and it is easy to integrate with other manufacturing systems. It can also be used to introduce the CNC aspect of CAM systems without involving too many complexities that are present in commercial systems.

The three-axis machine is capable of continuous path movement. Its design is carried out with the following considerations in mind:

- Intended as an instruction or research kit, it should be small in size and lightweight.
- The worktable must have sufficient movement.
- The spindle head must be restrained to a single degree of freedom.
- A reduction must be given to the Z-drive for higher torque.

2.2.1 Specification of The Machine

From research and journal of A CNC Machining System for Education, The machine is designed to perform end milling for soft material such as soft aluminium alloy or plastics. The machine occupies approximately a 450 × 300 × 150 mm^3 volume and can machine a cube contained in a 60 mm^3 volume. The maximum cutter diameter is 8 mm. The machine consists of 42 parts, which are simple in design and easy to assemble.

The movements are limited to 60-mm in the X and Y directions and 70-mm in the Z direction. The spindle speed that can be use is between 100 rpm to 4000 rpm. The maximum feed rate of the machine is 100mm/min. The maximum dept of cut is 0.3mm. The maximum torque along X and Z axis is 6Kg-cm. In this journal, he said that, the

complete system can be divided into four modules which are mechanical design, drives module, system software and the APT postprocessor. (A. A. Tseng, 1985)

CNC system consists of three basic components which are Part program, Machine Control Unit (MCU) and Machine tool (lathe, drill press, milling machine). The part program is a detailed set of commands to be followed by the machine tool. Each command specifies a position in the Cartesian coordinate system (x,y,z) or motion (workpiece travel or cutting tool travel), machining parameters and on/off function. The machine control unit (MCU) is a microcomputer that stores the program and executes the commands into actions by the machine tool. The MCU consists of two main units: the data processing unit (DPU) and the control loops unit (CLU). The machine tool could be one of the following: lathe, milling machine, laser, plasma and coordinate measuring machine. (B. S. Pabla, 1994)

From the other source from the website, the mini CNC Machine is that is build in this project uses Dremel rotary tool. The movements for this machine are limited to 150-mm in the X direction, 200-mm in Y directions and 50-mm in the Z direction. The feed rate of this machine is 6mm/s. The accuracy is about 0.25mm. (Contraptor)

2.2.2 The Fundamental Of The Mini CNC Machine

In these four modules, he elaborates the part one by one which is module by module. First module is about the mechanical design. Mechanical design of the machine involves conceptual of overall configuration of the machine, drafting and design analysis made to satisfy geometrical and force constrain. In this module, the machine specification is identified and the power for machining aluminium is calculated.

The second module is the drive module. This module show that the controller of the machine which is microprocessor that is receive the command signals. Drive module is consisting of motors, amplification units, and a power supply. The control signals are the first generated by the microprocessor to determine the direction of rotation of the motor.

The third module is system software. The system software can be defined as an instruction set required executing the functions of the system through a set physical component. The software system is designed to generate automatic stops for the tool and workpiece movements. This is done because the unit operates in the open loop mode.

Lastly, the fourth module is the Automatically Programmed Tool (APT) postprocessor. APT is a language that is used to control a variety of operations in machining and that is generating from the CAD/CAM software system. The APT postprocessor was developed to produce G-codes and M-codes that can be used by CNC machine constructed from the APT files produced by commercial CAD software.

From the book CNC Machines by B. S. Pabla, M. Adithan, they state that there are some features in CNC machine tools (B. S. Pabla, 1994). The features are:-

- The part programme can be input to the controller unit through key-board or the paper tape can be read by the tape reader in control unit
- The part programme once entered in to the computer memory can be used again and again
- The part programme can be edited and optimised at the machine tool itself
- The input information can be reduced to a great extent with the use of special sub-programmes developed for repetitive machining sequence
- The CNC machines have the facility for proving the part programme without actually running it on the machine tool
- CNC control unit allows compensation for any changers in the dimension of cutting tool
- With the CNC control system, it is possible to obtain information on machine utilisation which is useful to management

The combined characteristics of the machine tool and the control determine the precision of positioning. Three critical measures of precision are resolution, accuracy and repeatability. Control resolution (BLU) is the distance separating two adjacent points in the axis movement (the smallest change in the position) . The electromechanical components of

the positioning system that affect the resolution are the leadscrew pitch, the gear ratio, and the step angle in the stepping motor (open loop) or the angle between the slots in the encoder (closed-loop).

Accuracy of a CNC system depends on the resolution, the computer control algorithms, and the machine inaccuracies. The inaccuracy due to the resolution is considered to be (1/2) BLU on the average. The control algorithm inaccuracy is due to the rounding off the errors in the computer which is insignificant. Repeatability is a statistical term associated with accuracy. It refers to the capability of a positioning system to return to a programmed point, and is measured in terms of the errors associated with the programmed point. The deviation from the control point (error) usually follows a normal distribution in which case the repeatability may be given as +/- 3a where a is the standard deviation. The repeatability is always better than the accuracy. The mechanical inaccuracy can be considered as the repeatability.

2.2.3 Motor

The signals from the amplifiers are given to the stepper motors to produce movements in the X-, Y-, and Z-directions. An AC/DC motor is used to drive the spindle. The amplifier units form the intermediate stage between the controller and the drives. Control signals are first generated by the microprocessor to determine the direction of rotation of the motor. The number of pulses per second determines the actual speed of rotation. The current of the signal issued by the microprocessor must be sufficiently amplified before it is fed to the stepping motors which actuate the axis of motion. The drive module must be capable of supplying the output without distorting the switching sequence required to run the stepping motor. The stepper motor shaft is coupled to a screw rod that is connected to the work slide through a nut. The rotation of the stepper motor shaft results in linear motion of the slide.

The pulse rate determines the cutting velocity. The stepping motors used for this system are the four-phase type. The common terminals of the stepper motor are fed with a 7.5V

supply for the 'X' and 'Z' motors and with a 6 V supply for the 'Y' motor. The variable resistance may be used to get the correct drop across the corresponding terminals. The microprocessor chip acts as a buffer while double inverting the logic levels supplied to it from the microprocessor. The main drive corresponds to the motor that drives the spindle. The requirement for the main drive is that it must be capable of providing varying speeds of rotation corresponding to the different cutting velocities needed for machining various materials. An auto transformer capable of supplying variable voltage is connected to the AC/DC drive motor. Altering the voltage gives a new speed. The autotransformer is calibrated in terms of spindle speed.

The open-loop control means that there is no feedback and uses stepping motors for driving the leadscrew. A stepping motor is a device whose output shaft rotates through a fixed angle in response to an input pulse. The accuracy of the system depends on the motor's ability to step through the exact number. The frequency of the stepping motor depends on the load torque. The higher the load torque, lower would be the frequency. Excessive load torque may occur in motors due to the cutting forces in machine tools. Hence this system is more suitable for cases where the tool force does not exist. The stepping motor is driven by a series of electrical pulses generated by the MCU. Each pulse causes the motor to rotate a fraction of one revolution.

Closed -loop NC systems are appropriate when there is a force resisting the movement of the tool/workpiece. The encoder consists of a light source, a photo detector, and a disk containing a series of slots. The encoder is connected to the leadscrew. As the screw turns, the slots cause the light to be seen by the photo detector as a series of flash which are converted into an equivalent series of electrical pulses which are then used to characterize the position and the speed. The equations remain essentially the same as open-loop except that the angle between the slots in the disk is the step angle. Both the input to the control loop and the feedback signals are a sequence of pulses, each pulse representing a BLU unit. The two sequences are correlated by a comparator and gives a signal, by means of a digital-to-analog converter, (a signal representing the position error), to operate the drive motor (DC servomotor).

2.2.4 Software system

The software involves the building of an interpreter for the part program. The part program executed by the microprocessor consists of a series of instructions. Each instruction comprising a string of binary digits is decoded by the microprocessor and is then executed. The microprocessor requires these instructions to be written in Op-codes. An Op-code is an instruction that is composed of hexadecimal characters. The interpreter translates the G-codes into equivalent Op-codes.

The software for the system is designed to generate automatic stops for the tool and workpiece movements. This is done because the unit operates in the open loop mode. The backlash in the screw rod is estimated and the software is corrected for this error. The system software is developed by adopting the modular programming format. A module may be termed as a subroutine that forms a part of the main program. Every module comprises a set of general purpose instructions that can be accessed when required during the course of execution of the program. All the G-codes require stepping motors to be switched on and off. One module is set apart for switching on the stepper motors. This module is accessed by all the 'G' functions which mean that this module does not belong to any particular G-code.

Initially, the system software is loaded in random access memory (RAM) of the microprocessor for testing purposes. After the credibility of the program has been established, the addresses of the Op-codes are located in the ROM (read only memory) area designated by the makers of the microprocessor kit. The programs are then loaded into an erasable programmable read only memory (EPROM) to form a permanent part of the system, until a hardware erasure is affected. This is in contrast to the operation of a RAM, which loses its contents once the system is switched off.

The EPROM instructions are not accessible to the user. By removing the EPROM from the system software for milling, and inserting another EPROM into the microprocessor, which perhaps has lathe system software, the controller that is used to control a CNC

milling machine can then be used to control a CNC lathe. Once the software has been developed and tested, the manufacture of the system proves easy because the general purpose microprocessor loaded with this software in ROM becomes specific to the machine tool.

The machine operates in two modes - the manual mode and the automatic mode. The manual mode allows the motion in the machine to be controlled by manually pressing the appropriate keys. The automatic mode allows the execution of the instructions in the part program.

First, the machining parameters are determined. Second, the optimal sequence of operations is evaluated. Third, the tool path is calculated. Fourth, a program is written. Each line of the program, referred to as a block, contains the required data for transfer from one point to the next.

A typical line for a program is given below.

N100 G91 X -5.0 Y7 .0 F100 S200 T01 M03 (EOB)

The significance of each term is explained below.

Sequence Number, N. Consisting of typically three digits, its purpose is to identify the specific machining operation through the block number particularly when testing a part program. Preparatory Function, G. It prepares the MCU circuits to perform a specific operation. The G-codes. G91 implies incremental mode of operation. Dimension Words consist of Distance dimension words, X, Y, Z, Circular dimension words, I, J, K for distances to the arc center and angular dimensions, A, B. C

2.2.5 Advantages and disadvantages of CNC Machine

In this book also state about advantages and disadvantages of CNC machines. The advantages of CNC machines are reduced lead time, elimination of operator errors, operator activity, lower labour cost, smaller batches, longer tool life, elimination of special jigs and fixtures, flexibility in changes of component design, reduced inspection, less scrap and accurate costing and scheduling. The specific advantages of the CNC system are: 1) the simplicity--the operating principles of the machine and control system can be very easily understood, 2) since very few transmission elements are used, the reliability of the system is high, and 3) not many instruction systems of this type are currently available in the marketplace. (A. A. Tseng, 1985)

The disadvantages of CNC machines are higher investment cost, higher maintenance cost, costlier CNC personnel and planned support facility.

CHAPTER 3

FLOW WORK AND METHOD OF THE PROJECT

3.1 INTRODUCTION

Flow work and method of the project is generally a guideline for solving a problem. In this chapter, the methods of conducting the project are briefly discussed which involved specific components such as tasks, techniques and tools. The framework of flow work must clearly clarify in order to make sure the project will run smoothly and the objectives of project are able to achieve successfully.

3.2 GUIDELINE METHODOLOGY

The start of the flow work is to understand the fundamental of the Mini CNC machine. After doing some research and study about the Mini CNC machine, the next step that is needed to do is design the machine according to the understanding of the mini CNC machine concept. The designing of the machine including with the wiring connection and the software that is use to generate the program. Develop the machine base of the design that has been drawn.

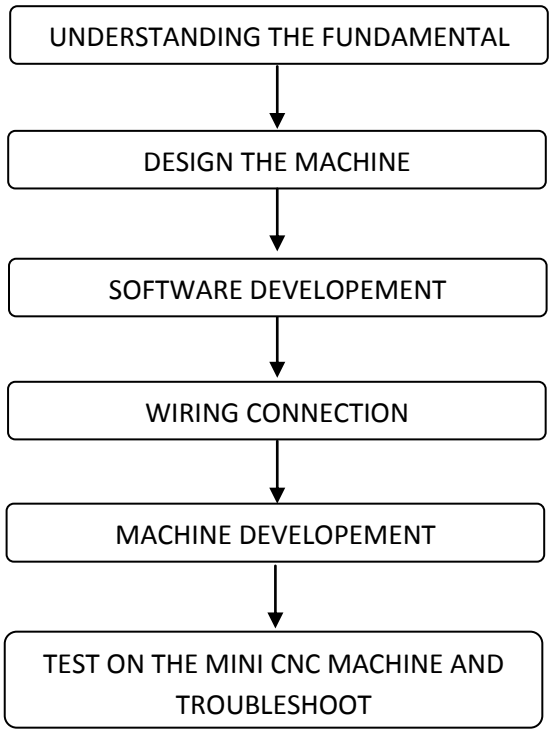


Figure 3.1: Flowchart of the methodology

3.2.1 Understanding the fundamental

In this stage, the understanding of the machine's concept is needed. The basic of the project is very important. To understand the concept of the project, the research on the past journals, books, articles, and the experiment of the area of machine development.

In chapter 2, the theoretical reviews of the project, are described about the fundamental of the Mini CNC Machine. The resource is collect from the books which are CNC Machines by B. S. Pabla, M. Adithan, Programming of CNC Machines: Student Workbook by Ken Evans, CNC Programming: Principles and Applications by Micheal W. Mattson, Mike Mattson and Build Your Own CNC Machine by Patrick Hood-Daniel, James Floyd Kelly.

The other resources are from journal and articles which are about the Mini CNC Machine. For example, A CNC Machining System for Education by A.A.Tseng, S.P.Kolluri and P.Radhakrishnan, Computer Numerical Control by Dr. Aseel A.Al-Hamdany, and Evaluation of Performance Criteria of CNC Machine Tool Drive System by Venkatram Ramachandran. All the resources are combined together then summarize it into chapter 2.

3.2.2 Design the machine

In this stage, the machine will be design to the desire design. The initial design will be drafting or sketching then when the design is approve. Then step to the next stage of design which is draw the design using the software SolidWork. Finally, come out with the complete drawing.

Before start the sketching, there are some criteria that must be decided. Firstly, decide the length of travel. The length of travel is the length of X, Y, and Z axis move from one point to the other point. The X axis move left - right, Y axis move front - back, Z axis move up – down. The travel length that have been decided is X axis 15cm, Y axis 15cm and Z axis 5cm.

The next step is deciding the type of linear motion system. There are many options to choose from for linear motion. Commonly used methods for CNC routers include, drawer slides, skate bearings, v-groove bearings, round linear rail and profile linear rail. For this project, the choosing of linear rail and linear bearing because this system uses precision ground and hardened steel shafts and linear bearings that use small steel balls that roll on the shaft and re-circulate through channels within the bearing. This offers smooth low friction movement and has good resistance to forces placed on the bearing in any direction. (Instructables)

Screw drive systems work by attaching a nut to the movable part of each axis, a threaded rod is then fed through the nut and locked into position at both ends. The screw is turned by the drive motors and the nut moves along the screw. Lead screws have trapezoidal threads that are either cut or rolled into a steel rod. Lead screw threads are used on common C-clamps. Their thread shape makes the screw stronger than the threads on standard bolts. When these threads are precision cut they are perfectly suited to drive a CNC router. Probably the most common and cheapest lead thread size is 1/2"-10. That means 1/2” in diameter and 10 threads per inch. Ten threads per inch mean that if the screw in spun around 10 times the attached nut will move 1 inch along the screw. For any screw size multiple individual threads can be cut on the screw, this is referred to as the number of starts the screw has. A single start screw has one thread a 2-start has two threads and a 5-start has five threads. First multiple start screws are more efficient at turning the rotational force on the screw into linear force on the nut. This means it takes less torque for the drive motors to move each axis. Second, multiple start screws increase the lead of the screw, which is how far a nut would move if the screw was rotated once. To determine the lead for a screw divide the number of starts by the number of threads per inch. For example, a 1/2”-10, 5 starts, lead screw would have a 5/10 or 1/2” lead. This means for every rotation of the screw the nut moves 1/2”. This is important because the electric drive motor can produce the most torque at low speeds, and with a higher lead the nut will move farther per revolution of the screw and that means the motor can spin at a lower speed to move the axis of the machine..

The next step is deciding the motor and controller. For CNC routers two basic options exist, stepper motors or servo motors. Stepper motors are used in the wide majority of DIY CNC routers. CNC router source has some excellent information comparing these two types of motors. The key difference in these motors is servo motors provide position feedback to ensure proper positioning while stepper motors do not. Servo motors are more expensive and require more expensive controllers then comparable stepper motors for the sizes that are commonly used on CNC routers. Also stepper motors are highly supported in the DIY router community. The motors that are chosen for each axis are stepper motor with specification 2.1V and 3.0A.

After choosing the motor, the designing of the machine is nearly to be sketches. Before that, choosing the right material to build this machine is very important. The material that is choosing to build this machine is Aluminium. It is because the Aluminium light in weight, cheaper than steel and easy to move everywhere.

After deciding everything, the step of sketching is starting. After finish the sketching, get the approval, then by using the software SolidWork, the sketches is convert to the drawing. The SolidWork software is 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows and is being developed by Dassault Systèmes SolidWorks Corp., a subsidiary of Dassault Systèmes, S. A. (Vélizy, France). SolidWorks is currently used by over 1.3 million engineers and designers at more than 130,000 companies worldwide.

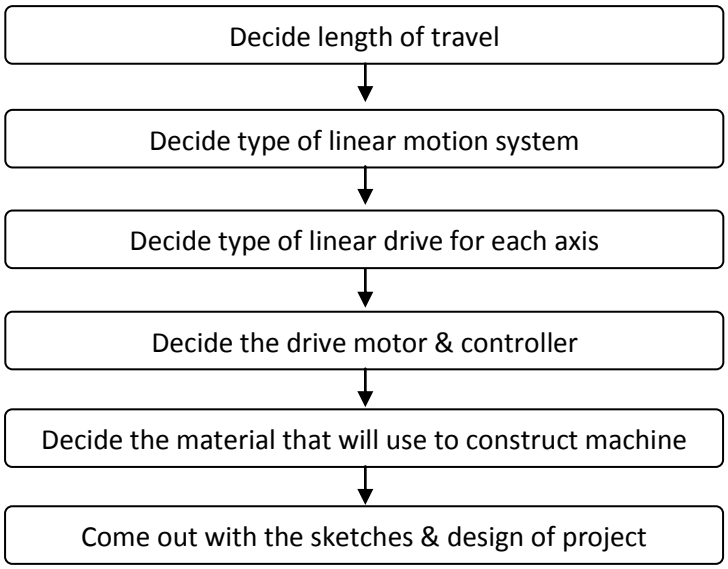


Figure 3.2: Flowchart of the machine design

3.2.3 Software development

The software is developing to generate the CAD/CAM file into the machine. The file is transfer to the machine via microprocessor to process the file and send the command to the machine to do the job. The software to generate the motor is Visual Basic. Visual Basic is the event-driven, meaning code remains idle until called upon to respond to some event (button pressing, menu selection). Visual Basic is governed by an event processor. Nothing happens until an event is detected. Once an event is detected, the code corresponding to that event (event procedure) is executed. Program control is then returned to the event processor.

Visual Basic is an application development tool which has event-driven programming concepts, terminology, and available tools and it also the fundamentals of designing, implementing, and distributing a wide variety of Visual Basic applications. With controls like these users can create many applications which use certain parts of windows. First create the control on the screen, and then write the code which would be executed once the

control button is pressed. With this sort of operation in mind, simple programs would take very little code.

Before starting the programming, flow chart should be design in which standard graphical symbols are used to represent the logical flow of data through a function. In graphical symbols, each symbol represent a function for the next step show in table 3.1 below, and from this symbol can develop flow chart that show work flow how the system function from the beginning to the end. (Evans, 2003)

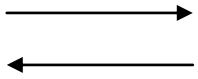
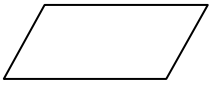
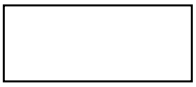
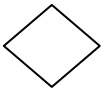
Symbol	Name	Meaning
	Flow line	Direct of process
	Terminal (START/END)	Start/end of a program
	Input/output	Read data/ print result
	Process	Statements that performs computations or data manipulations
	Decision/selection	Compare the rules
	Connector	Connecting points in an algorithm

Table 3.1: Flow Chart symbol

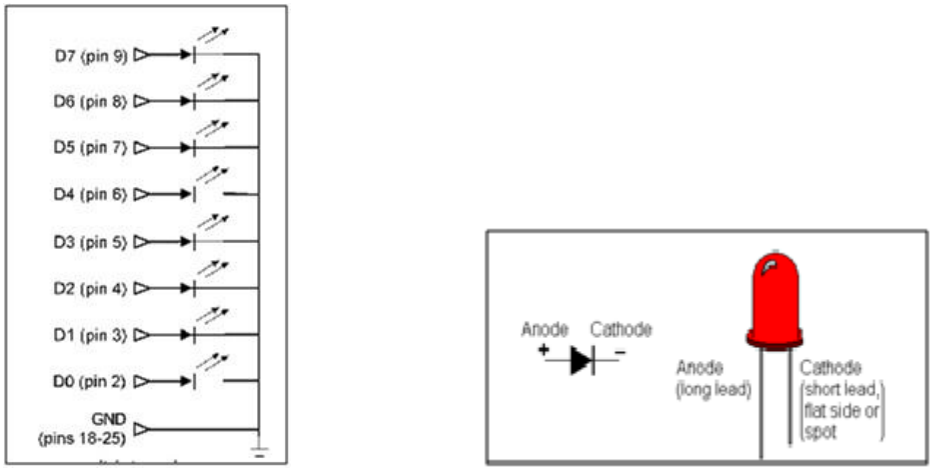
There are many advantages to explicitly typing variables. Primarily, ensure all computations are properly done, mistyped variable names are easily spotted, and Visual Basic will take care of ensuring consistency in upper and lower case letters used in variable names. Because of these advantages, and because it is good programming practice, we will explicitly type all variables.

3.2.4 Wiring connection and motor movement

The circuit will be connected to the machine and the computer. The function of circuit is to connect the electronic device at machine to the computer. Before starting to set up stepper motor, basic prototype of the circuit will be develop. This prototype is developing to understand how to control the motion of stepper by using Visual Basic as programming language. This prototype function to control LED so it can blink and off followed by the program, it's same when to turn stepper motor on and off.

A set of eight LEDs, one connected to each data bit from the parallel port, when a data pin is set to "0" it will find 0 V on it. When it set to "1", it will find 5 V on it. This is enough to turn LEDs, but not enough to turn the stepper motor because the motor need the heavier devices. All eight LEDs connect to status port (pin no 2- no 9) and get one ground pin (any pin from 19 -25) to connect to the cathode terminal (negative terminal) from all LEDs. From figure 3.3 (a) show schematic for using parallel port.

Since LEDs have polarity, it should pay attention to correctly locate its anode (positive) and cathode (negative) terminals, figure 3.3 (b). As for building circuits, proto board will be use. This is because proto board allows assembling LEDs without needing to solder. After connection LEDs to proto board, printing cable is use to connect proto board to parallel port.



(a) (b)

Figure 3.3: (a) Schematic for using parallel port, (b) Terminals from LEDs

Most common and ready to use devices are named parallel port. For special application, there are dozens of parallel-port devices for use in data collection, testing and control system. The parallel port is the interface of choice for many one of a kind and small scale project that require communication between the computer and external device. Usually port are founded on the rear of computer and are of following type that was male ports (pins coming out of port) and female port (holes for pins), parallel port generally have a 25 pin female connector with which a printer is usually attached.

Every pin has own function. Pin1 is for data acknowledgement when the signal is low. Pin 2 to 9 is for data transfer pins. Pin 10 is for acknowledge that the data has finished processing and when the signal is high indicates ready for more. Pin 11 is when the signal goes high indicate that the printer has accepted the data and is processing it. Once this signal goes low and Pin 10 goes high will accept additional data. Pin 12 is for printer paper jam when signal is high or no signal if printer jams. Pin 13 is when high signal printer is indicating that it is on-line and ready to print. Pin 14 is when low signal PC has indicated that the printer inset a line feed after each line. Pin 15 is for printer sends data to the computer telling it that an error has occurred. Pin 16 is when low signal PC has requested

that the printer initiate an internal reset. Pin 17 is when low signal the PC has selected the printer and should in return prepare for data being sent. Pin 18 to 25 is ground.

In data port it includes pin 2 to pin 9 with pin names data-0 to data-9, it is usually for data output according to old “standard parallel port” standard. Status port include pin 10 to pin 15, is an input only port, data can’t be output on this port but it can be read. Lastly is control port, it is a read/write port include pin 14, 16, 14 and 1.

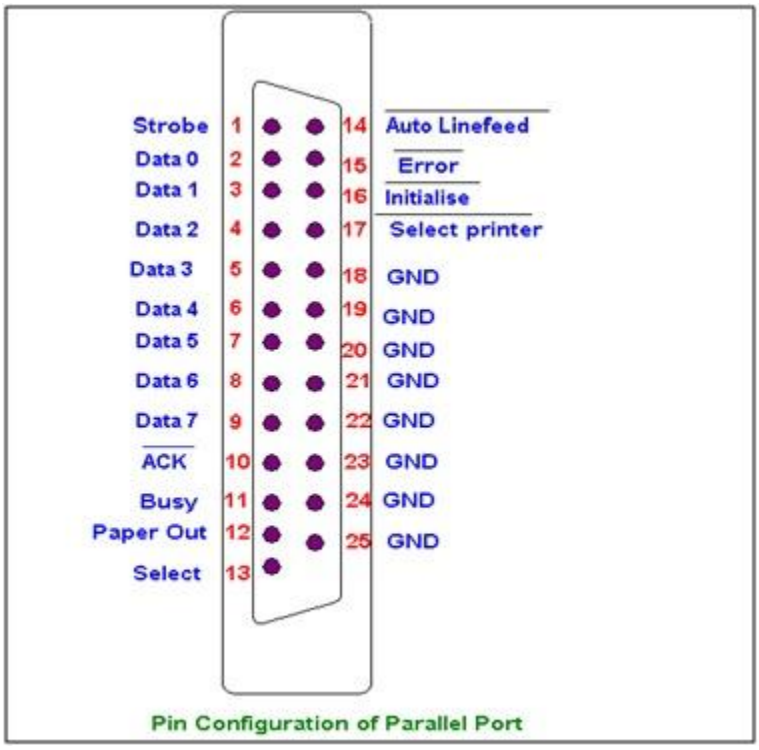


Figure 3.4: Pin Configuration of Parallel port

An interface is a tool and concept that refers to a point of interaction between components, and is applicable at the level of both hardware and software. This allows a component, whether a piece of hardware such as a graphics card or a piece of software such as an Internet browser, to function independently while using interfaces to communicate with other components via an input/output system and an associated protocol.

Hardware interfaces exist in computing systems between many of the components such as the various buses, storage devices or other I/O devices. A hardware interface is described by the mechanical, electrical and logical signals at the interface and the protocol for sequencing them (sometimes called signaling). A standard interface, such as SCSI, decouples the design and introduction of computing hardware, such as I/O devices, from the design and introduction of other components of a computing system, thereby allowing users and manufacturer's great flexibility in the implementation of computing systems. Hardware interfaces can be parallel where performance is important or serial where distance is important.

The development of circuit and wiring to make sure this machine can be functionally. For the first motor is the base circuit to build the circuit for the second motor, it just a same circuit but it control with different pin at the parallel port. For first motor it control by using pin number 2 to pin number 5, and second motor using pin number 6 to pin number 9. In the program, it has justified each pin to control each motor base on the value at each pin

In this project a 6-wire 4-phase unipolar motor will use, this motor have two "common" wires there was north and south common wire. To determine this two common wire by measure the resistance between the wire using multimeter. Firstly pick any wire randomly, this wire will become the first wire of pair one. Then pick another wire at random and measure resistance, if got a resistance, that's a pair. In this stepper motor the value of resistance between pair is 1.8Ω. Finally to determine the common wire or power supply wire, pick pair that gives the higher resistance that is the common wire.

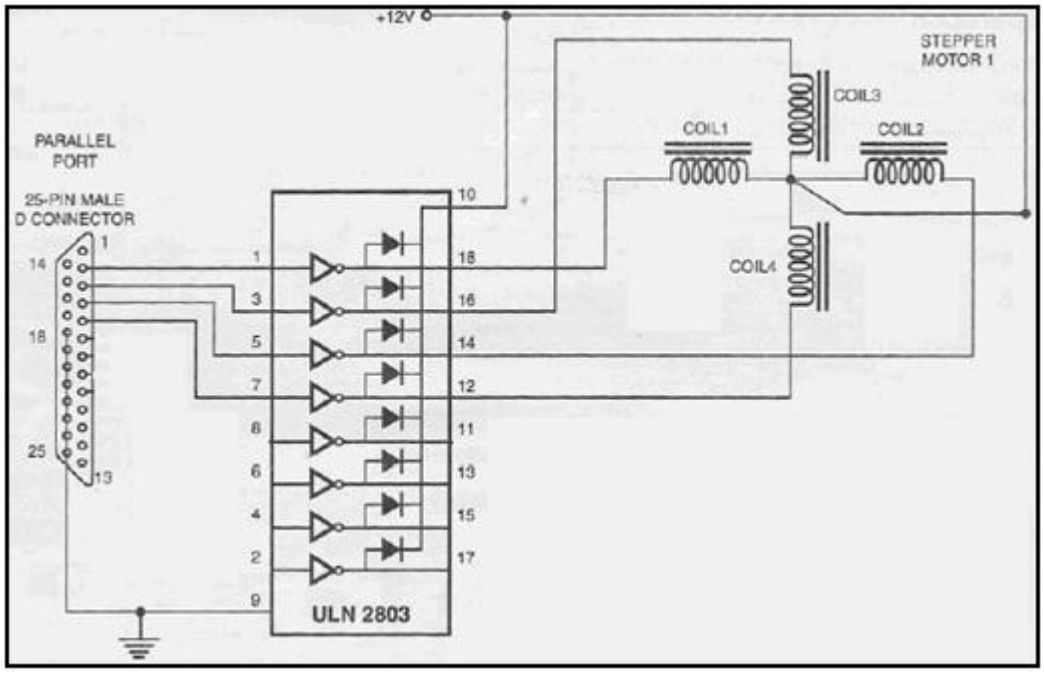


Figure 3.5: Circuit to control First motor

First motor is control by using pin no 2 until pin no 5, this pin will give the current pulse to stepper motor obey to the programming. The pulse given to motor base on the type that need by the stepper motor, usually there have full step and half step to move the stepper motor. In this project the programmer will use half step. This is because half step is more accurate during operation compare with full step.

The IC that was ULN 2803 converts the signal from the parallel port to a specific winding energizing sequence to step the motor. The output signal from ULN 2803 is sent each winding. ULN 2803 generates pulse signal as and when it receives the control data from the computer/program. The pulses in (from high to low state) activate the circuit and send signals to two sets of winding on the stepper motor. The first set of signal changes the 1^{st} winding polarity and the 2^{nd} set of signal changes the 2^{nd} winding polarity, causing the motor to rotate one step.

The second circuit is same with the first method, but it connected to pin number 6 to pin number 9 to control the motor. Figure 3.6 show the combination circuit to control motor

1 and motor 2. Figure 3.8 show the development circuit by using Eagle software version 6.1.0. PCB machine are use to machine this circuit.

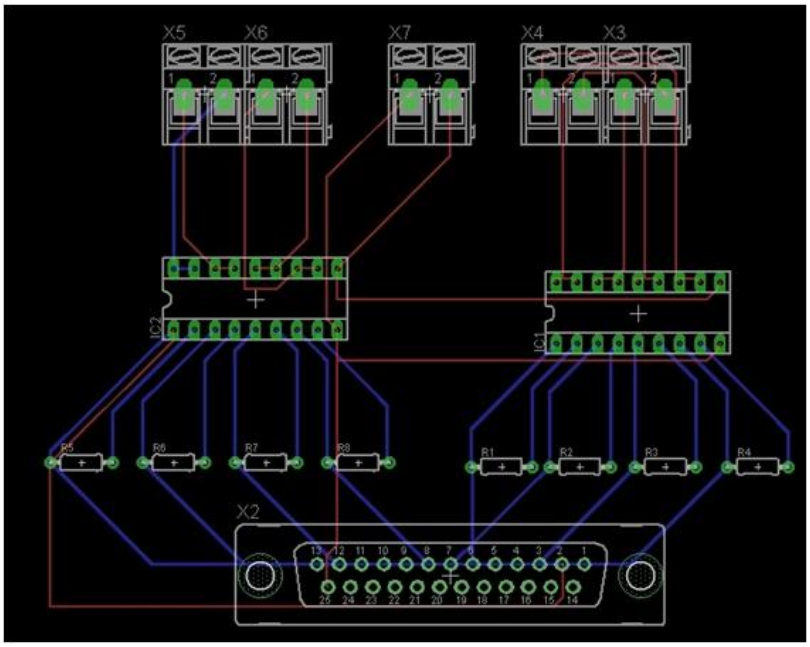


Figure 3.6: Schematic Drawing of Circuit to control 2 axis motor

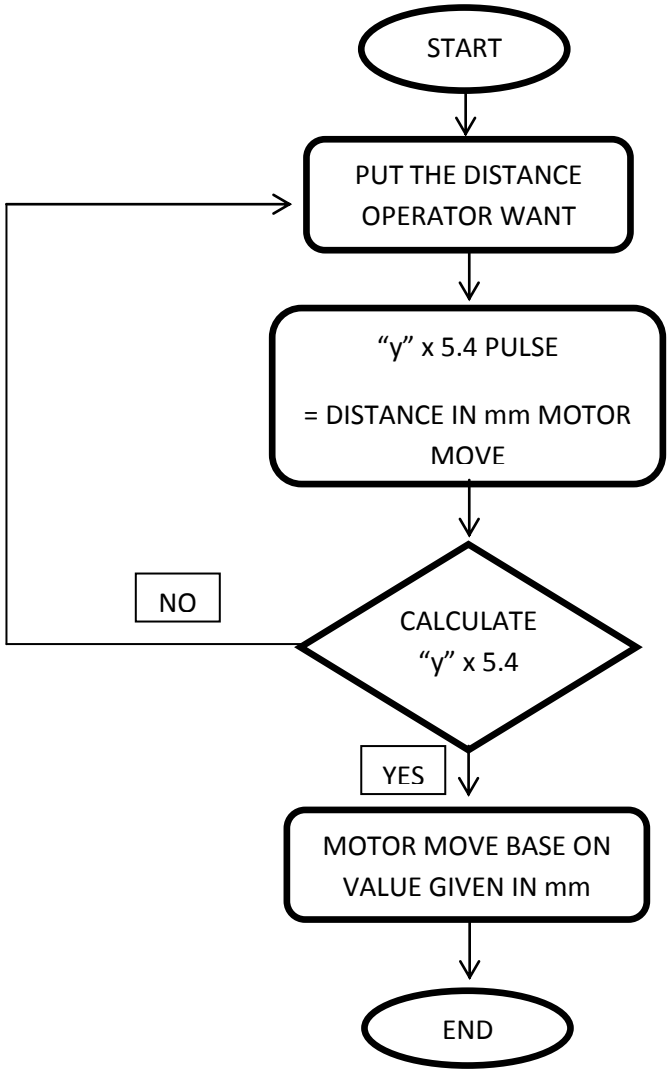


Figure 3.7: Flow chart to control 1 axis

Firstly operator will put the value in mm into the two text box. First box is for positive movement and the second box is for negative movement, then the program would times the value with 5.4 this is because during calibration process the output data show that 5.4 pulse will turn the motor 1mm. Third stage, program will calculate the value if the value can calculate the motor will move base on the value in the text box.

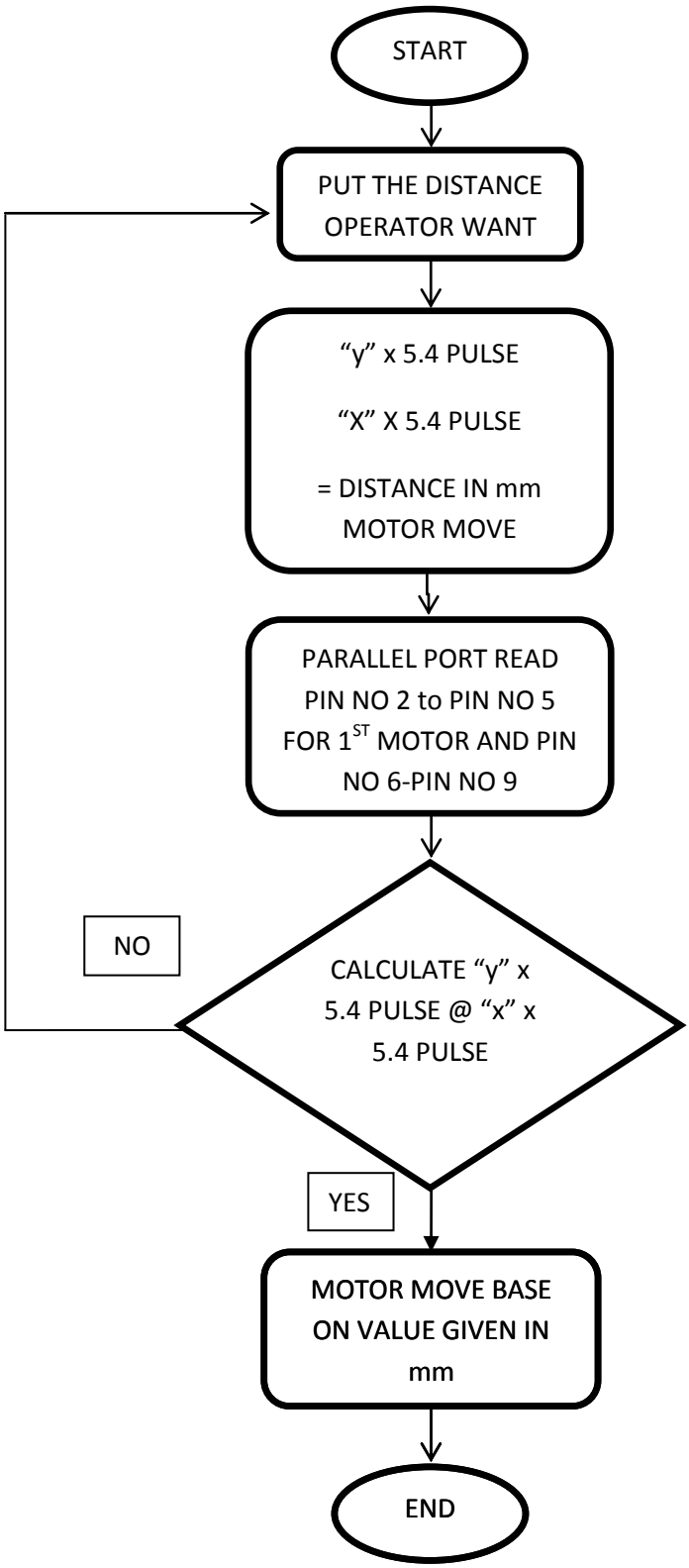


Figure 3.8: Flow chart to control both of motor

In controlling both of motor it still use the same concept with controlling first motor, the different is operator must put the value in 4 text box that was 2 text box for X axis and 2 more for Y axis.

3.2.5 Machine development

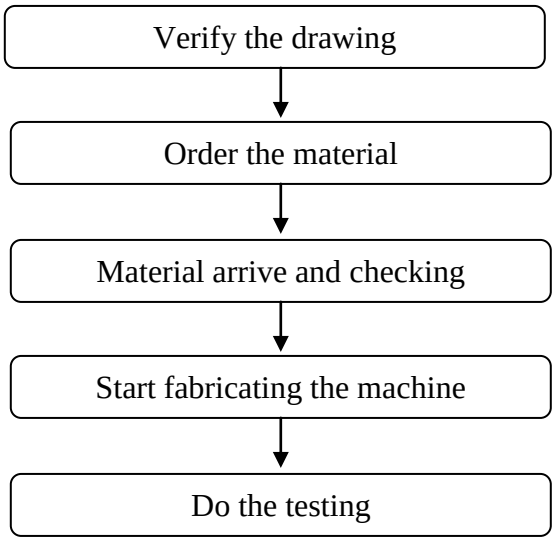


Figure 3.9: Flow chart of machine development

After get approval of the drawing, the drawing will be verified and do the specifications to make a list of material that will be used. The material and the equipment will be order before the machine will be setup or installed. The machine will be develop using the Aluminium material and will tide up with the screw, nut and bolt. The processes that occur during this fabrication of the machine are cutting material, marking, drilling, assembly the material and tide up screw.

When the machine is completely setup, the machine will be troubleshooting. If the result is negative, the machine must be check again. Repair the error that occurs. If the result is positive, make final touch to the machine. Then continue with the reports and result is discussed.

CHAPTER 4

RESULT AND ANALYSIS

4.1 INTRODUCTION

The purpose of this chapter is to verify that every experiment on the methodology or the flow of work is come out with the result and analysis of the result. The result of this project will include the design of the machine, the wiring of the motor, the Visual Basic program that program the motor and the machine's model.

4.2 THE DESIGN OF THE MACHINE

The initial design of the machine is by hand sketches. The technical drawing of the design is sketches to build the idea from the criteria that have been decide. The sketches show the base frame of the machine, the X axis and Y axis design. The estimation of travel axis is X axis is 15cm and Y axis is 15cm. The estimation of machine dimension is 35cm x 50cm x 50cm.

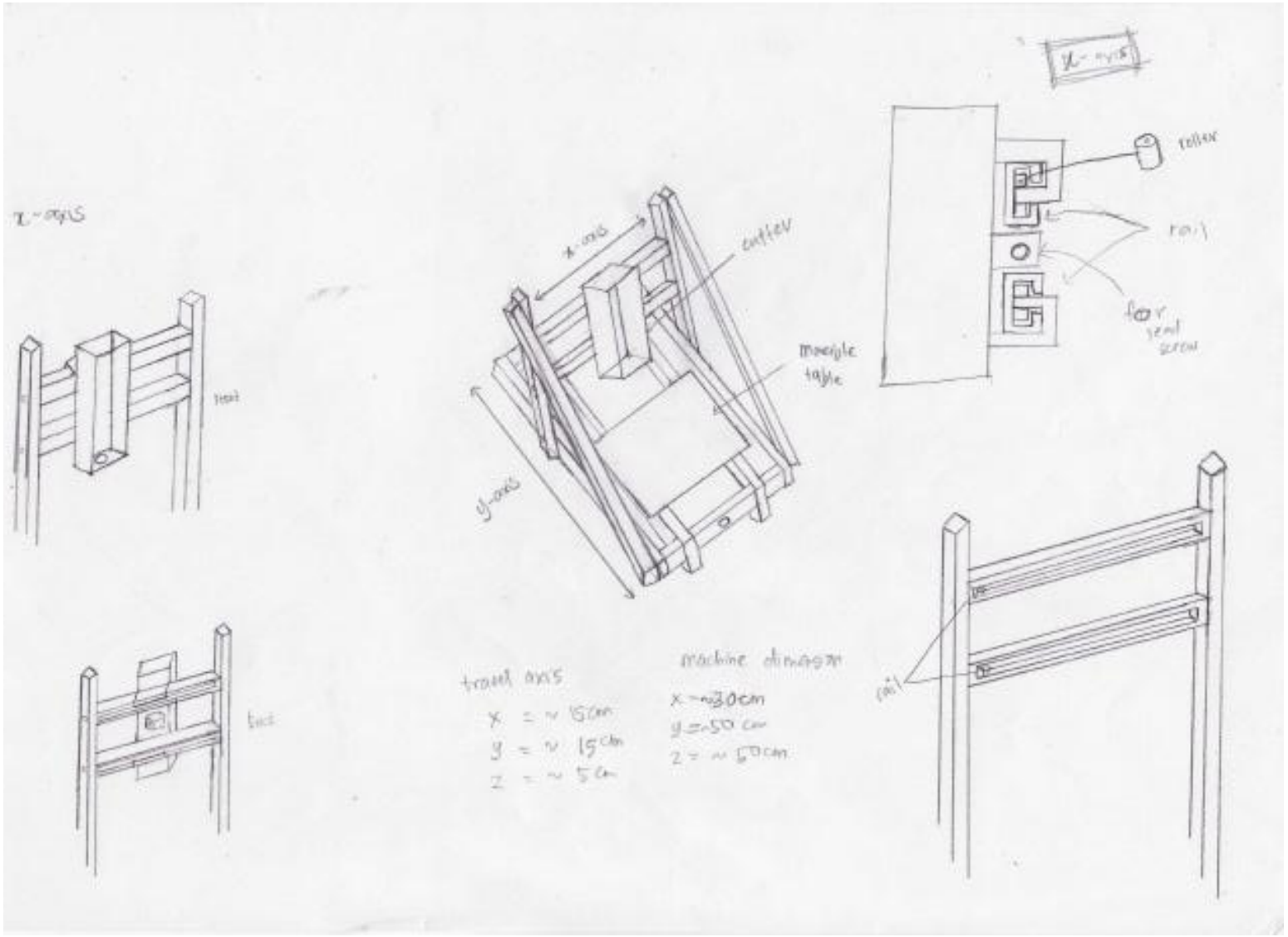


Figure 4.1: Sketches of basic frame and X axis

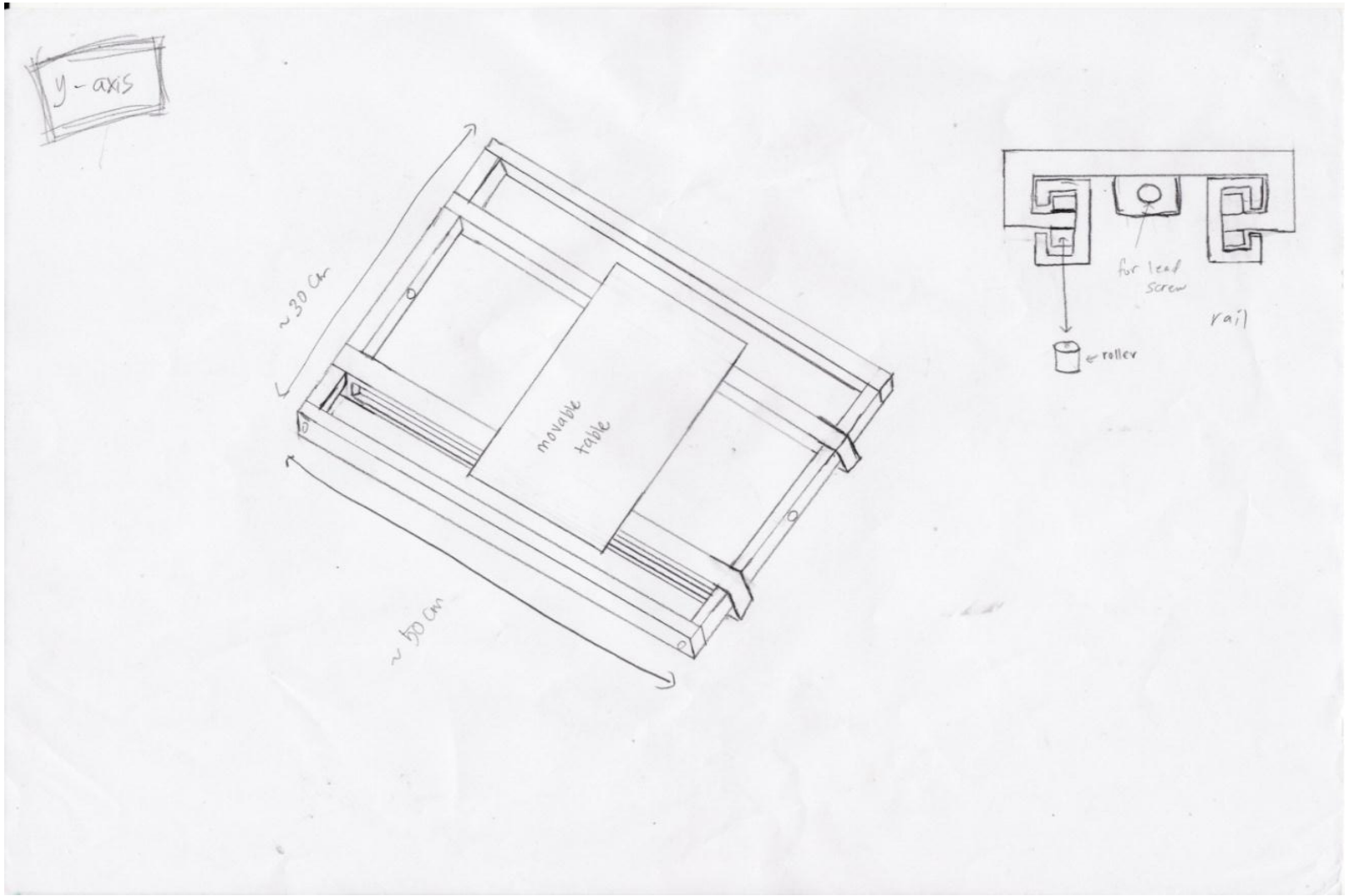


Figure 4.2: Sketches of Y axis

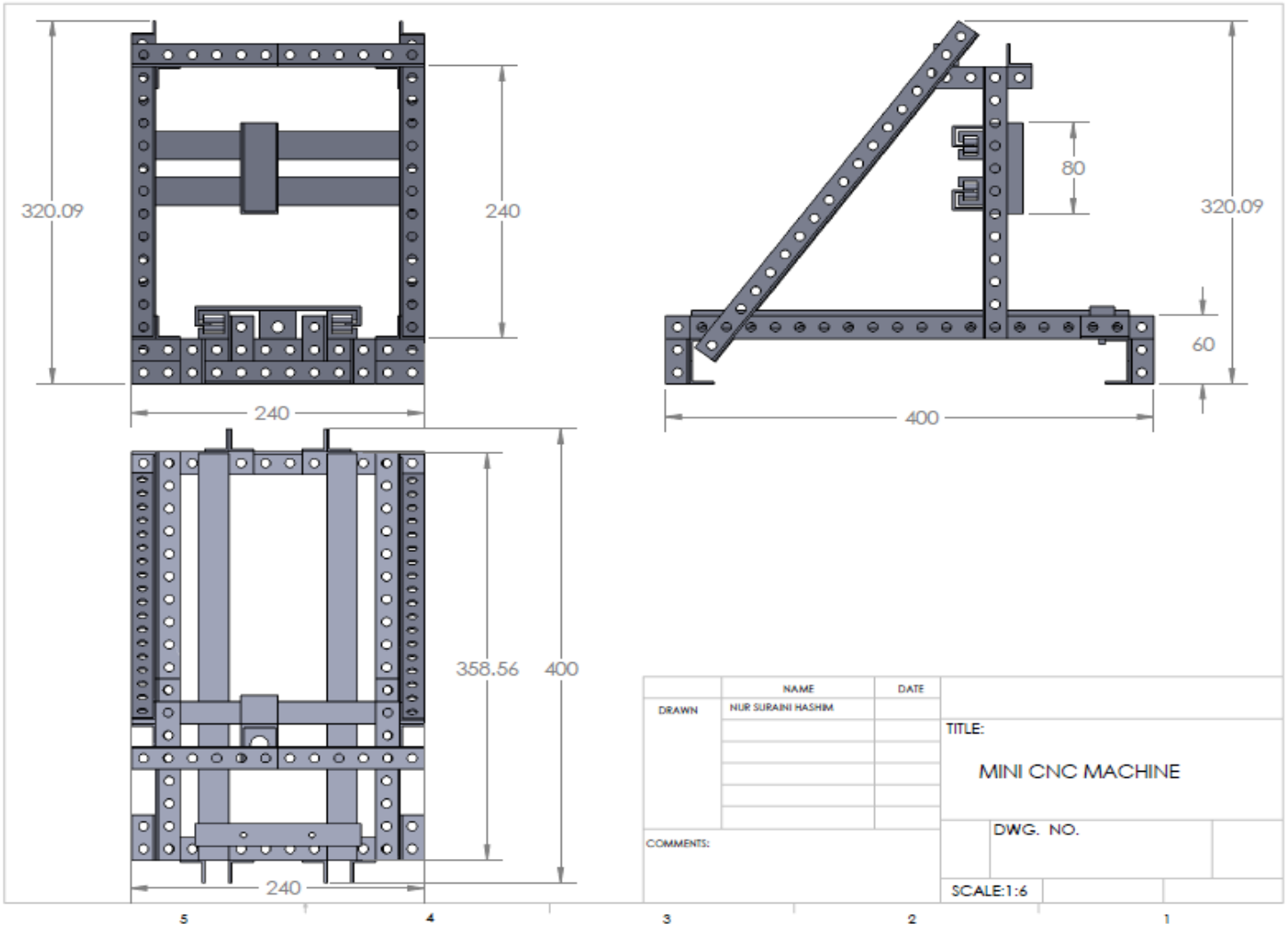


Figure 4.3: Drawing of the machine

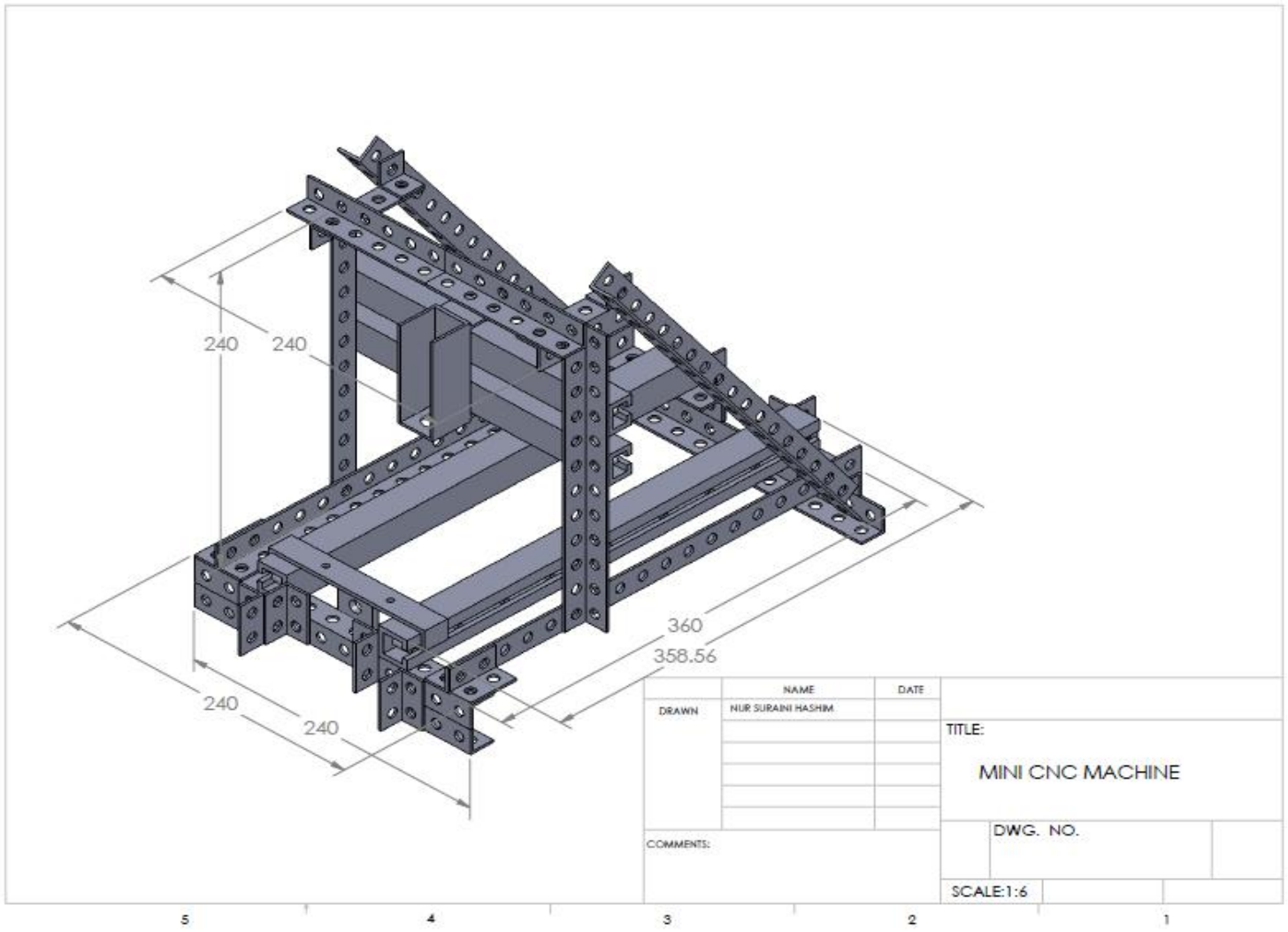


Figure 4.4: Drawing of the machine with dimension

4.3 WIRING CONNECTION AND MOTOR MOVEMENT

The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided. Figure 4.5 shows a typical cross-sectional view of the rotor and stator of a stepper motor. From this diagram the stator (stationary winding) has four poles, and the rotor has six poles (three complete magnets). The rotor will require 12 pulses of electricity to move the 12 steps to make one complete revolution. Another way to say this is that the rotor will move precisely 30° for each pulse of electricity that the motor receives. The number of degrees the rotor will turn when a pulse of electricity is delivered to the motor can be calculated by dividing the number of degrees in one revolution of the shaft (360°) by the number of poles (north and south) in the rotor. In this stepper motor 360° is divided by 12 to get 30°.

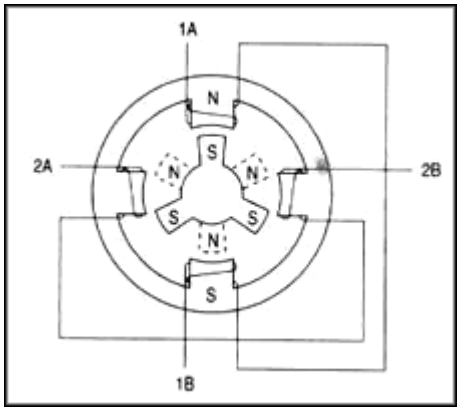


Figure 4.5: The position of the six-pole rotor and four-pole stator of a typical stepper

Motor

Each of motor has their pin at parallel port to control the motion of the motor, for X axis motor pin that use is no2, no3, no4 and no5 and for Y axis pin no6, no7, no8, and no9. From this pin the pulse given from parallel port to ULN2803 converts the signal from the parallel port to a specific winding energizing sequence to step the motor.

Table 4.1: Pin use to control two axis stepper motor

PIN USE TO CONTROL TWO AXIS STEPPER MOTOR			
Motor X		Motor Y	
Pin Value	Binary value	Pin Value	Binary Value
128	10000000	8	1000
144	10010000	9	1001
16	10000	1	1
48	110000	3	1100
32	100000	2	10
96	1100000	6	110
64	1000000	4	100
192	11000000	12	1100

Table 4.2 show the value of each pin at parallel port from pin number 2 to pin number 9. From this pin, each data can transfer to ULN 2803 and control the motion of stepper motor. This value for motor X and motor Y is for clockwise movement, for anticlockwise it takes value from bottom to upper at the program.

In full round of stepper motor there have 360° or 360°/revolution, so to fill 360°/rotation there need 400 steps. Stepper motor takes one step per pulse, so, to complete 400 steps/revolution, it needs 400 pulses current.

$$\text{pitch} \times \ \text{num. of tooth} \ = \ 1\text{revolution distance motor move (x)}$$

The relationship of the stepping motor's rotation and input pulses is expressed as follows.

$$\theta \ = \ \theta s \ \times A$$

Where θ = rotation angle of the motor output shaft in degree

θs = step angle

A = pulse number

The speed of the rotation is then proportional to the speed of the pulses. The relationship of the pulse speed (Hz) and motor speed (revolution/min) is expressed as follows:

$$N \ = \ \frac{\theta s}{360} \times f \ \times 60$$

Where N = speed of the motor is output shaft in r/min

f = pulse speed in Hz.

Table 4.2: Analysis result from actual calibration

STEPS	DISTANCE MOTOR MOVE (mm)	STEPS/mm	OUTPUT (V)
40	7	5.71429	0.731
60	11	5.45455	0.732
80	15	5.33333	0.747
100	19	5.26316	0.813
120	22	5.45455	0.913
140	27	5.18519	0.949

Table 4.3 show the result from the analysis that has been made, this analysis is determining the distance motor move when *j* value or steps are given. This result will be use in the program to turn the motor to distance that required. The value of steps/mm times with the distance ask so the motor will move certain mm, equation below show how this value are use.

$$Distance\ required\ \times 5.4005\ = Distance\ motor\ move$$

Value 5.4005 is average values that get from the data, this value are use in the calculation to move the motor. Two of motor that use are using the same equation because this two motor have a same specification.

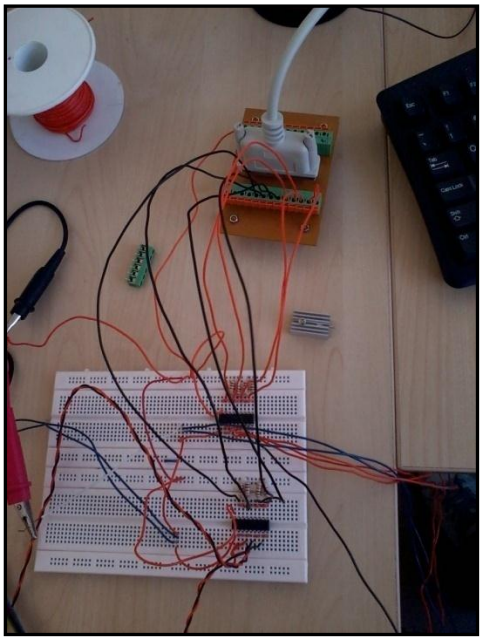


Figure 4.6: ULN connect to two stepper motor

Calibrating a machine is the first step process after the machine has been develop, operator want to get their tool to move exactly to the place that he want, in this process there have 2 methods usually use. First method is use dial indicator and mach 3 (axis calibration under setting tab) to calibrate a short distance and the second method use step/mm or step/revolution base on pitch and teeth at the stepper motor.

In this calibration process, I use second method that base on step/mm or step/revolution. In the program the *j* value are adjust to move the machine table, by using a pen it will sketch linear line when machine move.

Figure 4.7: Calibration process

4.4 THE DEVELOPMENT OF THE MACHINE

The machine is planning to develop as the design. The travel length of the X axis is 15cm and Y axis is 15cm. The machine will have the linear rail and the linear bearing as the linear motion system. The lead screw is used as the drive motion system. During this project is progressing, there are some problems occur. The project is not completely finished. The frame of the machine is built but the linear rail and bearing of the X axis and Y axis is not complete.

Figure 4.8: The frame of the machine

Figure 4.9: The frame of the machine

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter will conclude all the work that has been done during this project. Starting with the chapter one until chapter four, the conclusion will be include with all the progress and the working area of the project.

5.2 THE CONCLUSION

The Mini CNC Machine theoretically consist of 4 components which are mechanical design, system software and Automatically Program Tool (APT) postprocessor. Compare to the basic CNC machine, this machine is more suitable for the mini part to be machine and to reduce the lead time. This machine also can reduce the cost of development and maintenance of the machine.

This thesis is discussed about the MINI CNC Machine and the development of it. To develop the CNC machine, there are some important parts that must be considered which are the sketches and design of the machine, the program that have been using to control the stepper motor and the circuit to connect the software to the motor. In this project, the machine had been designed using the SolidWork software. To develop the program that control the stepper motor, the Visual Basic programming had been use and to convert the signal from Visual Basic programming to turn the motor. The ULN 2803 had been used.

5.3 THE RECOMMENDATION

The recommendation of this project for the future research is as the project is not complete yet; in the future, the next studies of this case will complete it with flying colours. I recommend them to continue and do the experiment of this project to validate the data and to make sure the machine can completely function.

REFERENCES

A. A. Tseng, S. K. (1985). A CNC Machining System for Education. *Journal of Manufacturing System* , 207-214.

B. S. Pabla, M. A. (1994). *CNC MACHINES.* New Delhi: New Age International (P) Limited.

Contraptor. (n.d.). Retrieved October 2011, from Contraptor: http://www.contraptor.org/mini-cnc

Evans, K. (2003). *Programming of CNC Machines: Student Workbook.* New York: Industrial Press Inc.

Instructables. (n.d.). Retrieved January 2012, from DIY CNC Router: http://www.instructables.com/id/DIY-CNC-Router/step2/CNC-Router-Design/

Micheal W. Mattson, M. M. (2010). *CNC Programming: Principles and Application.* Canada: Delmar Cengage Learning.

Patrick Hood-Daniel, J. F. (2009). *Build your Own CNC Machine.* United States of America: Paul Manning.

S.P. Kolluri, A. T. (1989). Computer in Industry. *Simulation of CNC Controller Features in Graphic-Based Programming* , 135-146.

Vermeeren, P. (n.d.). *isnare articles.com*. Retrieved December 2011, from The Mini CNC Machine: http://www.isnare.com/?aid=26786&ca=Business

APPENDIX A

Figure A: The hardware of machine (front view)

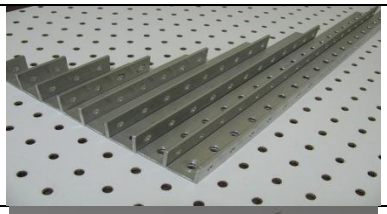
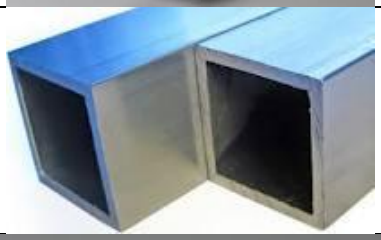
Figure B: The hardware of machine (isometric view)

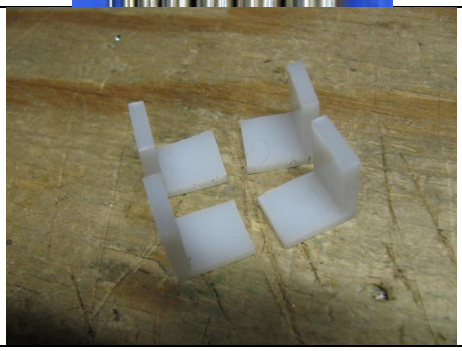
APPENDIX A

Figure C: Wiring Connection to turn the Stepper Motor

APPENDIX B

LIST OF THE COMPONENT

COMPONENTS	LENGTH	EXAMPLE
Aluminium angle (hole) size: 2.5cmX2.5cm	890cm	
Aluminium angle (no hole) Size: 2.5cmX2.5cm	200cm	
Aluminium square tube Size: 4cmx4cm	70cm	
Aluminium rectangle tube Size: 5cmx4cm	50cm	
Aluminium channel Size: 2.5cmx1.25cm	175cm	

Drill rod Diameter: 0.6cm	350cm	
UHMWPE channel Size: 3.1cm x 1.9cm	80cm	

APPENDIX C

LIST OF THE PARTS

PARTS	QUANTITY (piece)	EXAMPLE
XL240 belt Length: 61cm Teeth: 120 Pitch: 0.5cm Width: 1cm	1	
XL280 belt Length: 71cm Teeth: 140 Pitch: 0.5cm Width: 0.6cm	1	
pulley-XL10T	4	
Bearing Size: 0.6cm x 1.3cm x 0.5cm Inner dia.: 0.6cm Outer dia.: 1.3cm	8	
bearing Size: 0.5cm x 1.3cm x 0.5cm Inner dia. : 0.5cm Outer dia. : 1.3cm	16	

Thrust ball bearing	2	
motor-coupling-set	3	
Threaded rod Diameter = 0.6cm Length = 54cm	4	
Hex Nut Diameter = 0.6cm	20	
Coupling Nut (notched) Diameter: 0.6cm	4	
Spring-washer Diameter = 0.6cm	10	
Square-nut Diameter = 0.6cm	50	

screw M5 (button socket cap) Length = 1cm Length = 1.25cm Length = 1.9cm Length = 2.5cm	50 100 20 20	
screw M5 (Phillips) Length = 1.6cm	20	
screw M5 (flat) Length = 2.2cm	50	
Hex nut M5	250	
screw M3.5 (button socket cap) L = 0.6 cm L = 1cm	70 10	
screw M3.5 (nylon) Length = 0.6cm	50