



**NATIONAL TECHNICAL UNIVERSITY COLLEGE OF  
MALAYSIA**

## **X-Y Table Plotter to Simulate Handwriting**

Thesis submitted in accordance with the requirements of the  
National Technical University College of Malaysia for the Degree of  
Bachelor of Engineering (Honours) Manufacturing (Process)

By

**Shakiwan bin Shabri**

Faculty of Manufacturing Engineering

October 2005

© Universiti Teknikal Malaysia Melaka



## KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

### BORANG PENGESAHAN STATUS TESIS\*

JUDUL: X-Y TABLE PLOTTER USED TO SIMULATE HANDWRITTING

SESI PENGAJIAN : 2004/2005

Saya SHAKIWAN BIN SHABRI

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Kolej Universiti Teknikal Kebangsaan Malaysia (KUTKM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Kolej Universiti Teknikal Kebangsaan Malaysia.
2. Perpustakaan Kolej Universiti Teknikal Kebangsaan Malaysia 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 yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

(TANDATANGAN PENULIS)

Disahkan oleh:

(TANDATANGAN PENYELIA)

Alamat Tetap:  
4243, LORONG SERAMPANG 9  
TAMAN RIA JAYA  
08000 SUNGAI PETANI, KEDAH

Cop Rasmi **SHARIMAN BIN ABDULLAH**  
 Pensyarah  
 Fakulti Kejuruteraan Pembuatan  
 Kolej Universiti Teknikal Kebangsaan Malaysia  
 Karung Berkunci 1200  
 Ayer Keroh, 75450 Melaka

Tarikh: 19/12/05


Tarikh: 22/12/05

\* 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).

\*\* Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

## DECLARATION

I hereby, declare this thesis entitled “X-Y Table Plotter Used to Simulate Handwriting” is  
the results of my own research  
except as cited in the reference.

Signature :   
Author's Name : Shakiwan b. Shabri  
Date : 19/12/05

## **APPROVAL**

This thesis submitted to the senate of KUTKM and has been accepted as fulfillment of the requirement for the degree of Bachelor of Engineering (Honours) Manufacturing (Process). The members of the supervisory committee are as follows:

**SHARIMAN BIN ABDULLAH**

**Main supervisor**

**Faculty of Manufacturing Engineering**

## **ABSTRACT**

Plotter is a common concept used in many manufacturing appliance such as the printer. There a various types of plotter and the one of them is pen plotter. Pen plotter is basically used to plot or draw by line while printer print a dot. The X-Y Table Plotter is a designed mechanical device which a pen is applied to the plotter in order to produce handwriting onto a paper. Detail of the project development will be explained in next chapter of the report. It contain the study of literature review which focusing on the parts that going to be used in the project and the development of the fabricating the X-Y Table Plotter with it function capability.

## **ABSTRAK**

Pelukis adalah satu konsep yang banyak digunakan dalam aplikasi pembuatan contohnya seperti pencetak. Terdapat berbagai jenis pelukis dan salah satu daripadanya ialah pelukis pen. Pen pelukis pada asasnya digunakan untuk melakar atau melukis melalui garisan manakala pencetak pula mencetak titik-titik. Meja Pelukis X-Y adalah rekaan alatan mekanikal di mana pen digunakan pada pelukis untuk menghasilkan tandatangan pada kertas. Penerangan lanjut mengenai pelaksanaan projek ini akan diterangkan di dalam bahagian berikutnya dalam laporan. Ia mengandungi kajian ilmiah yang mengfokuskan mengenai bahagian-bahagian peralatan yang akan digunakan dan perkembangan dalam penghasilan Meja Pelukis X-Y dengan keupayaan untuk berfungsi.

## DEDICATION

I humbly dedicate this to,

My family,  
All of your supports and cares make me so comfortable and confident in my journey to  
success.

My lecturers,  
Who always guide me when I need them.

And

My friends,  
Thank you for everything you've done for me.

## **ACKNOWLEDGMENT**

I would like to take this opportunity to express my gratitude and it gives me a pleasure to acknowledge the assistance of the following in preparation of this report writing.

I would like to express my appreciation to En. Shahrman for his enthusiastic support and supervision of the report revision. With his help and guidance I'm able to gain more understanding about the project.

I'm also happy to present my gratefully acknowledge to Mohd Faizal, Ahmad Zuraimi, Mohd Salihudin, Mohd Zaem Alwi, Mohd Nizam Daud , Afda Rizan and to whom have helped directly or indirectly in writing this report for their contribution in guidance me to finished this report.



# TABLE OF CONTENT

	<b>PAGE</b>
<b>ABSTRACT</b>	<b>i</b>
<b>DEDICATION</b>	<b>iii</b>
<b>ACKNOWLEDGEMENT</b>	<b>iv</b>
<b>TABLE OF CONTENT</b>	<b>v</b>
<b>LIST OF TABLES</b>	<b>x</b>
<b>LIST OF FIGURES</b>	<b>xi</b>
<b>NOMENCLATURE</b>	<b>xiv</b>
<b>CHAPTER 1: INTRODUCTION</b>	
1.0 INTRODUCTION	1
1.1 PROBLEM STATEMENT	2
1.2 OBJECTIVE	2
1.3 PURPOSE OF THE PROJECT	2
1.4 SCOPE OF PROJECT	3
1.5 PROJECT OVERVIEW	3
1.6 PROJECT PLANNING	4
1.7 PROJECT FLOW CHART	6
<b>CHAPTER 2: LITERATURE REVIEW</b>	
2.0 INTRODUCTION	6
2.1 TYPE OF MOTOR	7
2.1.2 Stepper Motors	12
2.1.3 Types of stepper motors	13
2.1.3.1 Variable Reluctance	14
2.1.3.2 Permanent Magnet	14
2.1.3.3 Hybrid	15

2.1.4	Motor Windings	16
2.1.4.1	Unifilar	16
2.1.4.2	Bifilar	17
2.1.5	Step Modes	17
2.1.5.1	Full Step	18
2.1.5.2	Half Step	18
2.1.6	Design Considerations	19
2.1.6.1	Inductance	19
2.1.6.2	Series, Parallel Connection	19
2.1.6.3	Driver Voltage	20
2.1.6.4	Motor Stiffness	20
2.1.6.5	Motor Heat	20
2.2	DRIVER TECHNOLOGY OVERVIEW	20
2.2.1	Types of Step Motor Driver	21
2.2.1.1	Unipolar	21
2.2.1.2	R/L	22
2.2.1.3	Bipolar Chopper	22
2.2.2	Indexer Overview	23
2.2.2.1	Stand Alone Operation	25
2.2.2.2	Integrated Control	25
2.2.2.3	Multi-Axis Control	26
2.2.3	Stepper Motor Characteristics	28
2.2.3.1	Single Step Response and Resonances	28
2.2.3.2	Torque vs. Speed Characteristics	29
2.3	SCREW DRIVE	31
2.3.1	The Square thread.	31
2.3.2	The Buttress thread	32
2.3.3	The Acme thread	32

2.4	BALL SCREW	33
2.4.1	Benefits of Ball Screws	34
2.4.2	Handling & Installation Considerations	35
2.4.3	Radial loads and torque	35
2.4.4	Efficiency (Theoretical)	36
2.4.5	Driving Torque	37
2.5	LEAD SCREW	37
2.5.1	Lead screw advantages	38
2.5.2	Driving Torque	39
2.5.3	Handling & Installation Considerations	39
2.5.4	Radial loads and torque	39
2.5.5	Lubrication	40
2.6	SUMMARY	40

### **CHAPTER 3: DESIGN**

3.0	DESIGN OF X-Y PLOTTER	41
3.1	DESIGN CONCEPT	41
3.2	PROPOSED DESIGN	42
3.2.1	How Design Work	42
3.3	PARTS SELECTION	44
3.3.1	Frame Body	44
3.3.2	Motor	45
3.3.3	Type of Drive	46
3.3.4	Aluminum Balancing Shaft	46
3.3.5	Bearing	47
3.3.6	Part List and Estimation Cost	47

3.4	PROPOSED DESIGN	49
3.5	CONTROL SYSTEM	49
3.6	MOTION CONTROL REQUIREMENT	50
3.7	TORQUE CALCULATION	53
3.8	ACTUAL DESIGN	60
3.9	MATERIAL SELECTION	61
3.10	MECHANICAL PARTS AND MANUFACTURING PROCESS	64
3.11	CONTROLLER PARTS	66

#### **CHAPTER 4: MOTION CONTROL**

4.0	INTRODUCTION	67
4.1	ELEMENTS OF MOTION SYSTEM	68
4.2	PURPOSE OF THE MOTION CONTROLLER	70
4.3	APPLYING CONTROL SYSTEM INTO A DESIGN	70
4.3.1	Parallel Mode Information	73
4.3.2	Parallel port basics	73
4.3.3	Control of Stepping Motor	76
4.3.4	Parallel Port Stepper Motor Interface	77
4.3.5	Typical Parallel Port Interface	78

#### **CHAPTER 5: RESULT AND DISCUSSION**

5.1	EQUIPMENT	81
5.2	SOFTWARE SETUP	82
5.3	TEST OPERATION	85
5.4	TEST RESULT	86
5.5	MODIFICATION	91

**CHAPTER 6: CONCLUSION AND SUGGESTION** 92

**REFERENCES** 94

**APPENDIX**

**APPENDIX A STEPPER MOTOR**

**APPENDIX B STEPPER MOTOR DRIVER**

**APPENDIX C DRAWING**

## LIST OF TABLES

DESCRIPTION	PAGES
Table 1.0: Project Planning for PSM I	4
Table 2.0: Project Planning for PSM II	5
Table 3.0: Part List and Cost Estimation	50
Table 4.0: Material Densities	55
Table 5.0: Typical lead screw efficiencies	55
Table 6.0: Lead screw coefficient of friction	56
Table 7.0: Material for the design	67
Table 8.0: Parts and it manufacturing process	71
Table 9.0: Controller parts	72
Table 10: Register and Addresses	77
Table 11.0: Summary of result	85

## LIST OF FIGURE

<b>DESCRIPTION</b>	<b>PAGES</b>
Figure 1.1: Project Flow Chart	6
Figure 1.2: Implementation of PSM II	7
Figure 2.1: Existing Plotter Project	8
Figure2.2: Cross section of servo motor	10
Figure2.3: Brushless servo motor	11
Figure2.4: Ac motor	12
Figure2.5: Stepper Motor	13
Figure2.6: Variable reluctance motor	14
Figure2.7: Permanent Magnet Motor	15
Figure2.8: Hybrid Motor	16
Figure2.9: Unifilar Motor	16
Figure2.10: Bifilar Motor	17
Figure2.11: Resolution Vs. Step Frequency	18
Figure2.12: Series vs. Parallel Connection	19
Figure2.13: Switch set circuit	21
Figure2.14: Bipolar Chopper Driver Switch Circuit	23
Figure2.15: Indexer/Controller	24
Figure2.16: Stand Alone Operation	25
Figure2.17: Integrated Control	26
Figure2.18: Multi axis Control	27
Figure2.19: The single-step response characteristics of a stepper motor	29
Figure2.20: Torque versus speed characteristic	30
Figure2.21: Square Thread	31

Figure2.22: Buttress Thread	32
Figure2.23: Acme thread	32
Figure2.24: screw tooth profile	33
Figure: 2.25 Ball screw	34
Figure2.26: Ball Screw assembly	36
Figure2.27: Lead screw	37
Figure 3.1: Positioning Concept	44
Figure 3.2: Frame body	45
Figure 3.3: Frame Body with dimension	45
Figure3.4: Side view of frame body	46
Figure3.5: Stepper Motor	47
Figure3.6: Lead Screw	48
Figure3.7: Lead screw dimension	48
Figure3.8: Balancing Shaft	49
Figure3.9: Shaft dimension	49
Figure3.10: Bearing	50
Figure3.11: Stepper Motor Specification	51
Figure3.12: X-Y table Plotter	52
Figure 3.13: Top View	52
Figure 3.14: Side View	53
Figure3.15: Assembly Drawing	53
Figure3.16: Example of control system	54
Figure 3.17: Actual Product	64
Figure 3.18: 3D isometric drawing	64
Figure 3.19:2D isometric drawing	65
Figure3.20: Top view	65
Figure 3.21: Side view	66
Figure 3.22: Stepper motor	72
Figure 4.1: Basic Motion Control System	74
Figure 4.2: Element of Motion System	74



Figure 4.3: Parallel ports	78
Figure 4.4: First byte of data received	80
Figure 4.5: Second byte of data received	80
Figure 4.6: Three bytes of data received	81
Figure 4.7: Parallel Port Stepper Motor Interface	84
Figure 4.9: Printer Cable	85
Figure 4.10: Computer power Supply	85
Figure 4.11: Complete Assembly	86
Figure 5.1: Unit Measurement Selections	88
Figure 5.2: Port selection	89
Figure 5.3: Pin set up Option	89
Figure 5.4: System Timing	90
Figure 5.5: Control Panel	91
Figure 5.6: X-axis movement	93
Figure 5.7: Y-axis movement	93
Figure 5.8: The pen movement along X-axis	94
Figure 5.9: The Pen Movement along Y-axis	94
Figure 5.10: Plotting result	95

## LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

- $e$  = Efficiency  
 $Fl$  = Load force, lb  
 $Ff$  = Friction force, lb  
 $Fpf$  = Preload force, lb  
 $g$  = Gravitational constant, 386 in./sec<sup>2</sup>  
 $J$  = Inertia, lb-in.-sec<sup>2</sup>  
 $Jls$  = Leadscrew inertia, lb-in.-sec<sup>2</sup>  
 $Jl$  = Load inertia, lb-in.-sec<sup>2</sup>  
 $Jm$  = Motor inertia, lb-in.-sec<sup>2</sup>  
 $Jt$  = Total inertia, lb-in.-sec<sup>2</sup>  
 $Jp$  = Pulley inertia, lb-in.-sec<sup>2</sup>  
 $L$  = Length, in.  
 $m$  = Coefficient of friction  
 $N$  = Gear ratio  
 $Nl$  = Number of load gear teeth  
 $Nm$  = Number of motor gear teeth  
 $p$  = Density, lb/in.<sup>3</sup>  
 $P$  = Pitch, rev/in.  
 $R$  = Radius, in.  
 $Ri$  = Inner radius, in.  
 $Ro$  = Outer radius, in.  
 $Sl$  = Load speed, rpm  
 $Sm$  = Motor speed, rpm  
 $Tf$  = Friction torque, lb-in.  
 $Tl$  = Load torque, lb-in.  
 $Tm$  = Motor torque, lb-in.

$T_r$  = Torque reflected to motor, lb-in.

$V_l$  = Load velocity, ipm

$W$  = Weight, lb

$W_{lb}$  = Weight of load plus belt, lb

# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 INTRODUCTION**

A plotter can be defined as a computer output device that draws graphs or pictures, usually by moving a pen. The plotter was the first computer output device that could print graphics as well as accommodate full size engineering and architectural drawings.

There were many types of plotter available at the market nowadays and one of them is a pen plotter. Pen plotters use drawing pens that provide infinite resolution, because the lines are actually drawn. All other printing devices print dots.

X-Y plotter is a mechanical device designed which is function to transfer a signature from a computer into a piece of paper. Using the driven mechanism there will be a pen which can plot a signature onto a paper based to the signature drawn from the computer.

The application of the pen plotter basically used the common concept of positioning element mechanism. This is because it required accuracy movement and placement. The example of positioning element mechanism can be described such as the x-y table of CNC Machine.

## 1.2 PROBLEM STATEMENT

The positioning element mechanism such as numerically controlled XY table using the conventional lead screws or the recirculating ball screws which is quite popularly used for the related application such as a plotter. But this is not the economical option always as there are numerous light duty operations where the power capacity of the lead screw or ball screw unit becomes redundant.

## 1.3 OBJECTIVE

- to determine basic design for the project
- to identify suitable driven mechanism for the project
- to fabricate the mechanical design
- to establish a plotter with handwriting function

## 1.4 PURPOSE OF THE PROJECT

The main objective of the project is to design a mechanical device which is involving controlling the positioning mechanism.

To do analysis on the traveling mechanism related to the actuator accuracy at speeds rivaling the lead screw models. In this project the purpose is to develop an XY table using the motor drive and screw drive which can be used effectively in light duty operations such as a plotter.

The advantages of this design are summarized below:

- Comparatively low cost
- Low maintenance required

- Remarkable accuracy can be achieved
- High Reliability
- Low capacity motors can be used

## **1.5 SCOPE OF PROJECT**

The scope of this project is to design and develop the mechanical device for the plotter. At this stage basic design of the plotter will be determined and suitable driven mechanism is identified.

Another scope of the project is to develop a controller for the plotter for handwriting purpose. This controller will read a feedback signal and accomplish task for given application.

## **1.6 PROJECT OVERVIEW**

Basic design of the X-Y table plotter consist the shape, actuator and other parts related to fabricate the mechanical device.

X-Y table plotter is designed to plot an input from a computer onto a piece of paper. This design consist a system where the input from a computer is send to a controller. The controller then sends a signal to the driver and produces the output through the plotter.

# 1.7 PROJECT PLANNING

Table 1.0: Project Planning for PSM I

NAME : SHAKIWAN BIN SHABRI  
 MATRIC NO : B050120030  
 TITLE : x-y PLOTTER FOR HANDWRITTING  
 SUPERVISOR : EN. SHAHRMAN BIN ABDULLAH

NO	ACTIVITY	NOV				DEC				JAN				FEB			
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14		
1	Proposal Proposed Title, Objective, Scope																
2	Literature Review																
3	Data Collections																
4	Analysis Result																
5	Draft Report																
7	Presentations Prepared																

Remark  
 Planning  
 -Actual

Table 1.0 : Project Planning

Table 2.0: Project Planning for PSM II

**NAME :** SHAKIWAN BIN SHABRI  
**MATRIC NO :** B050120030  
**TITLE :** x-y PLOTTER  
**FOR HANDWRITING**  
**SUPERVISOR :** EN. SHAHRIDHAN BIN ABDULLAH

NO	DESCRIPTION	JULY	AUGUST	SEPT	OCT	NOV	DIS
1	Parts and Material Selection	█					
2	Product Fabrication	█	█	█			
3	Correction on Design and Fabrication		█	█	█		
4	Interfacing Product and Driver			█	█		
5	Software Testing					█	█
6	Report Writing			█	█	█	
7	Project Presentation						█