


“I declare that I have read this thesis and in my opinion, it is suitable in term of scope and quality for the purpose of awarding a Bachelor Degree in Electronic Engineering (Industrial Electronic)”

Signature : 
Supervisor : MRS. MARDIANA BINTI BIDIN
Date : 30/3/2005

THE DESIGN OF SMART MOTOR CONTROLLER


KHAIRUDDIN BIN OSMAN

**This Report Is Submitted In Partial Fulfillment Of Requirements For The
Bachelor Degree of Electronic Engineering (Industrial Electronic)**

**Faculty of Electronics And Computer Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia**

MARCH, 2005

“Hereby, I declare that this report is a result of my own research idea except for works that have been cited clearly in the references.”

Signature : 
Name : KHAIRUDDIN BIN OSMAN
Date : 30/03/2005

Special dedicated to my dearest parent, sisters and brothers

ACKNOWLEDGEMENT

I would like thanks all of the people who helped to make this project a reality, especially my super visor Mrs Mardiana Binti Bidin who shares his time and attention to make sure my project is done with success. I would like to acknowledge the contributions of my colleagues at Kolej Universiti Teknikal Kebangsaan Malaysia (KUTKM), who contributed to this project. Without their support this project may have not came to fruition. Those who contributed to this project required special thanks here. The continued support through all phases of this project by the Faculty of Electronic and Computer Engineering and Prof. Abdul Hamid Hamidon, Dean, was invaluable for the completion of this work. I also would like to express my appreciation to my parent, who gave full executive support to the whole project. There are other thank; namely those with whom I did not have the pleasure of interacting personally, but whose contributions are extremely valuable, nevertheless.

ABSTRACT

Smart motor controller is build to produce a prototype for close-loop control system. The application of this project is as to resolve the problems facing by the industries and as replacement the pneumatic system operation for such a restricted place and for the short distance track conveyer. This project includes the knowledge of PIC program and the combination of controller circuit, such as the motor speed controller and the sensor. Types of motor used are the stepper motor and the detectors of sensor used are the ultrasonic sensor. Stepper motors are a digital motor that move accurately according to the degree of the rotation after it was set by the motor controller circuit. The project operations are more on the differential control and the movement efficiency with the sensor and the programming control. The motor can move forward and reverse. If they are an obstacle, it will stop after the sensors sense the obstacle more than 10 meter. They will stop at each set point the have been set the by programming in the microcontroller. From the output analysis result, variable resistor on the speed controller circuit proportional with time ($R \propto T$) and inverse with motor speed ($R \propto 1/\text{motor speed}$). Other than that, stepper motor will move imitate by degrees after receive pulse from motor driving circuit about 7.5° per step.

ABSTRAK

Pengawal Motor Pintar dicipta untuk menghasilkan satu prototaip sistem kawalan gelung tutup. Aplikasi projek ini adalah untuk menyelesaikan masalah-masalah industri bagi menggantikan operasi pneumatik untuk tempat-tempat yang terhad dan bergerak di atas landasan penggerak yang pendek. Projek ini menggunakan kawalam mikro PIC untuk mengawal pergerakan motor dan menggunakan alat pengesan bagi mengesan objek atau halangan apabila motor bergerak. Jenis motor yang digunakan adalah motor pelangkah dan alat pengesan yang digunakan pula adalah alat pengesan ultrasonik. Operasi kawalan pergerakan motor adalah untuk mengawal kelajuan motor, pergerakan motor bergerak samaada kehadapan dan kebelakang dan berhenti mengikut jarak yang ditetapkan. Pada masa yang sama, sensor ultrasonik akan beroperasi memberhentikan pergerakan motor dengan serta merta apabila terdapat objek atau halangan ketika motor bergerak pada jarak lebih daripada 10 meter. Pengawal Motor Pintar bukan sahaja dapat beroperasi seperti mana yang dirancang, malah dari hasil projek ini juga dapat mempelajari dan mengkaji secara menyeluruh mengenai operasi, kecekapan dan kaedah kawalan dengan menggunakan aturcara yang telah ditetapkan. Di dalam operasi Pengawal Motor Pintar, rintangan boleh laras pada litar kawalan kelajuan berkadar langsung dengan masa ($R \propto T$) dan berkadar songsang dengan kelajuan motor ($R \propto 1/\text{kelajuan motor}$). Selain itu, motor pelangkah akan bergerak mengikut darjah setelah menerima denyutan dari litar pembawa motor sebanyak 7.5° pada setiap langkah.

CONTENT

CHAPTER	TITLE	PAGE
	PROJECT TITLE	i
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	CONTENT	vii
	LIST OF TABLE	xi
	LIST OF FIGURE	xii
	ABBREVIATION	xiv
	LIST OF APPENDIX	xvi
I	INTRODUCTION	
	1.1 BACKGROUND	1
	1.2 OBJECTIVES	2
	1.3 PROJECT SCOPE	3
	1.4 PROJECT OVERVIEW	3
II	LITERATURE REVIEW	
	2.1 INTRODUCTION	6

2.2	WHAT IS A MICROCONTROLLER?	6
2.3	WHY USE A MICROCONTROLLER?	7
2.4	PIC MICROCONTROLLER	9
2.5	PIC16F84A MICROCONTROLLER	9
2.5.1	Memory	10
	2.1.5.1 Flash Program Memory	10
	2.1.5.2 EEPROM Data Memory	12
2.5.2	Peripheral	12
2.5.3	Power Supply	13
2.5.4	Clock-Oscillator	13
2.6	STEPPER MOTOR	14
2.6.1	Stepper Motor Advantages and Disadvantages	15
2.6.2	Stepper Motor Type	16
	2.6.2.1 Variable-reluctance (VR)	16
	2.6.2.2 Permanent Magnet (PM)	17
	2.6.2.3 Hybrid (HB)	18
2.6.3	Phases, Poles and Stepping Angles	19
2.6.4	Torque	21
2.7	ULTRASONIC SENSOR	23
2.7.1	Selection of Ultrasonic Sensor	24
2.7.2	Ultrasonic Motion Detector	25

111

HARDWARE AND SOFTWARE DEVELOPMENT

3.1	INTRODUCTION	26
3.2	CIRCUIT DESIGN AND CIRCUIT EXPLANATION	26
3.2.1	Power Supply Circuit	27
3.2.2	Stepper Motor Controller	28
	3.2.2.1 Motor Driving Circuit	29
	3.2.2.2 Speed Controller Circuit	30
	3.2.2.3 Start/Stop Circuit	32
	3.2.2.4 Oscillator	32
3.3	ULTRASONIC MOTION DETECTOR SENSOR	33

3.3.1	Transmitter Section	33
3.3.2	Receiver Section	34
3.4	CIRCUIT TESTING ON THE PROTOBOARD	35
3.5	SCHEMATIC DIAGRAM AND PCB LAYOUT	35
3.5.1	An Overview	35
3.5.2	Schematic Diagram	36
3.5.3	PCB Layout	37
3.5.4	An Introduction to the OrCAD - Capture CIS	38
3.5.5	An Introduction to the OrCAD - Layout Plus	37
3.6	PCB FABRICATION	42
3.7	SOLDERING PROCESS	43
3.8	AN INTRODUCTION TO THE MPLAB IDE	45
3.8.1	MPLAB IDE Project Overview	47
3.8.2	Editing Project Information	48
	3.8.2.1 Opening a Project	49
	3.8.2.2 Entering the Target Filename	49
	3.8.2.3 About the Include, Library and Linker Script Paths	49
	3.8.2.4 Setting the Development Mode	51
	3.8.2.5 Adding a Nod to the Project	51
	3.8.2.6 Setting Node's Properties	51
3.8.3	Running and Debugging on MPLAB IDE Project	52
	3.8.3.1 Running an MPLAB IDE Project	52
	3.8.3.2 Debugging an MPLAB IDE Project	53
3.9	PROGRAMMING STRATEGY	55

IV RESULT AND ANALYSIS

4.1	INTRODUCTION	60
4.2	MOTOR DRIVING CIRCUIT ANALYSIS	60
4.2.1	Result of Motor Driving Circuit Analysis	61
4.2.1	Conclusion of Motor Driving Circuit Analysis	63

4.3	ULTRASONIC MOTION DETECTOR CIRCUIT ANALYSIS	62
4.3.1	Result of Ultrasonic Motion Detector Circuit Analysis	64
4.3.2	Conclusion of Ultrasonic Motion Detector Circuit Analysis	65

V CONCLUSION AND SUGGESTION

6.1	CONCLUSION	66
6.2	SUGGESTION	67

	REFERENCE	68
--	------------------	----

	APPENDIX A - I	69
--	-----------------------	----

LIST OF TABLE

NUM	TOPIC	PAGE
2.1	Some 8-bit Microcontrollers and their features	8
3.1	Process description table on of layout's overall design process	41
4.1	Analysis result at the base of Darlington transistor	61

LIST OF FIGURE

NUM	TOPIC	PAGE
1.1	Process closed-loop	4
2.1	Pin diagram of PIC16F84A	10
2.2	Program memory map and stack	11
2.3	The timer0 feature PIC16F84A	13
2.4	The Stepper Motor	14
2.5	Cross-section of a variable-reluctance (VR) motor	17
2.6	Principle of a PM on tin-con stepper motor	18
2.7	Magnetic flux path through a two-pole stepper motor with a lag between the rotor and stator	19
2.8	Frictional torque is the force (F) required to move a load multiplied by the length of the lever arm (r)	
2.9	The 40 KHz Ultrasonic Sensor	23
2.10	Ultrasonic motion detector	25
3.1	Project work flow	27
3.2	Power supply circuit	28
3.3	Motor driving circuit	29
3.4	Speed controller circuit	30
3.5	Start/stop circuit	32
3.6	Oscillator	33
3.7	The window of OrCAD Layout/Layout plus	38
3.8	The window of OrCAD Capture CIS	39
3.9	The processing of PCB design using Capture CIS	40
3.10	Layout's Overall Design Process	41
3.111	Manufacturing process chart of a single-sided PCB	44

3.12	The window of MPLAB IDE	46
3.13	A problem-solving and programming strategy	56
3.14	Shows a structures algorithm flow chart that is easily to assembly language	59
4.1	Resistance versus time graph	61
4.2	'Base' of Darlington transistor waveform	62
4.3	No moving object	63
4.4	Moving object	63

ABBREVIATION

A/D	-	Analog to digital
ASM	-	Assembler
BCPL	-	Basic Combined Programming Language
CAD	-	Computer-Aided Design
CADD	-	Computer-Aided Design Directories
CIS	-	Component Information System
DC	-	Direct Current
EMF	-	Electro Motor Force
GPR	-	General Purpose Registers
HB	-	Hybrid
HEX	-	Hexadecimal
I/O	-	Input / Output
IC	-	Integrated Circuit
IDE	-	Integrated Development Environment
KUTKM	-	Kolej Universiti Teknikal Kebangsaan Malaysia
LED	-	Light Emitting Diode
LSI	-	Large Scale Integration
MCU	-	Microcontroller
MPU	-	Microprocessor
MB	-	Mega Bytes
PC	-	Personal Computer
PCB	-	Printed Circuit Board
PIC	-	Peripheral Interface Controller
PM	-	Permanent Magnet
RAM	-	Random Access Memory
RX	-	Receiver

SCI	-	Scalable Coherent Interface
SEC	-	Second
SFR	-	Special Function Register
SR	-	Set Reset
SRAM	-	Static Random Access Memory
TMR	-	Timer
TTL	-	Transistor-Transistor Logic
TX	-	Transmitter
UV	-	Ultraviolet
V	-	Voltage
VR	-	Variable-Reluctance
WIN	-	Window

LIST OF APPENDIX

NUM	TOPIC	PAGE
A	Advantages of PIC Microcontroller	69
B	Further information about PIC16F84A	71
C	Register File MAP	73
D	Schematic Diagram	74
E	PCB Layout	76
F	Explanation for every stage of the processing of PCB design using Capture CIS	78
G	Generic MPLAB IDE project – files and Associated Tools	80
H	Programming code	81
I	Model of Smart Motor Controller	86

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Smart motor controllers will allow easy programmability for individual application [1].

It a soon be possible to construct a low-cost motor control with enough memory to store several built-in motor functions and its control strategies. The end user would simply hook up in a small personal computer to the motor drive's communication port and pick up the appropriate motor control parameters required for a specific application. This would be accomplished with an easy-to-use program with graphics in which would not involved programming languages. Essentially, the user would just click on the appropriate graphic boxes and enter a specific value to program the motor drive. The motor drive would then retain these user-defined variables in a nonvolatile memory and execute its latest program.

In the last decade, progress in microelectronics and very large scale integration (VLSI) technology has fostered the widespread use of computing and electronics devices for commercial use. This has resulted in the development of a

highly integrated microprocessor and microcontroller. Microcontroller is widely used in robotics, motors and electronics devices. They are used in industrial world to control the many types of equipment, ranging from consumer to specialized devices. Also, there is a growing need for off-line support of a computer's main processor.

The user then could customize the controller of each applications, whether it is a temperature-controlled variable-speed fan, or a multiple-speed motor used in a factory tool. Stepper motor is one of the most popular motor uses in the manufacturing area. Thus, stepper motor which provides accurate position control has the requirement needed in this project.

1.2 OBJECTIVES

The objective of this project is specified below:

- a. To design, test and build a prototype module of a microcontroller device that can measure and indicate motor movement using stepper motor and ultrasonic sensor.
- b. At the end of the project, we shall manage to demonstrate on how the Smart Motor Controller operates.
- c. To study how on the stepper motor movement, operation forward and backward by using the speed controller.
- d. To study the variety step of sensor and their operation procedure.
- e. To study the PIC microcontroller and how to program it with the PIC programmer.

1.3 PROJECT SCOPE

Smart Motor Controller refer to three elements such as PIC microcontroller, motor and sensor.

a. PIC microcontroller

PIC microcontroller is a main element for this project because PIC can be controlled others elements. The types of PIC microcontroller used are 16F84A.

b. Motor

Types of motor used are the stepper motor. Stepper motors are a digital motor that move accurately according to the degree of the rotation after it was set by the motor controller circuit.

c. Sensor

Types of sensor used are the ultrasonic sensor. Circuit sensor is added circuit to give a close loop response for order reactions. For example, function motor can be stops after the sensors sense the obstacle.

1.4 PROJECT OVERVIEW

Smart Motor Controller using PIC16F84A is devices that were capable to measure the motor movement efficiency with the sensor and the programming control. In order to get a high accuracy measurement, several condition must be fulfilled which will discuss later.

Basically, this project consist of hardware and software programming. The hardware are such as the PIC microcontroller, stepper motor, ultrasonic transducer and others. The programming language used to programmed the PIC chip was assembly a language.

This project needs on overall understanding regarding of the microcontroller, motor and the sensor. Theoretically, there are many type of stepper motors. Unipolar type, Bipolar type, Single-phase type, Multi-phase type, and the PM type. Single-phase stepper motor is often used for quartz watch. In the PM type stepper motor, a permanent magnet is used for rotor and coils are put on the stator. At the same time, this project also needs to find a suitable circuit to be use in design which is more to process closed-loop (feedback control) system. The generic architecture of a close-loop system Smart Motor Controller is shown in figure. Furthermore, we will discuss it later.

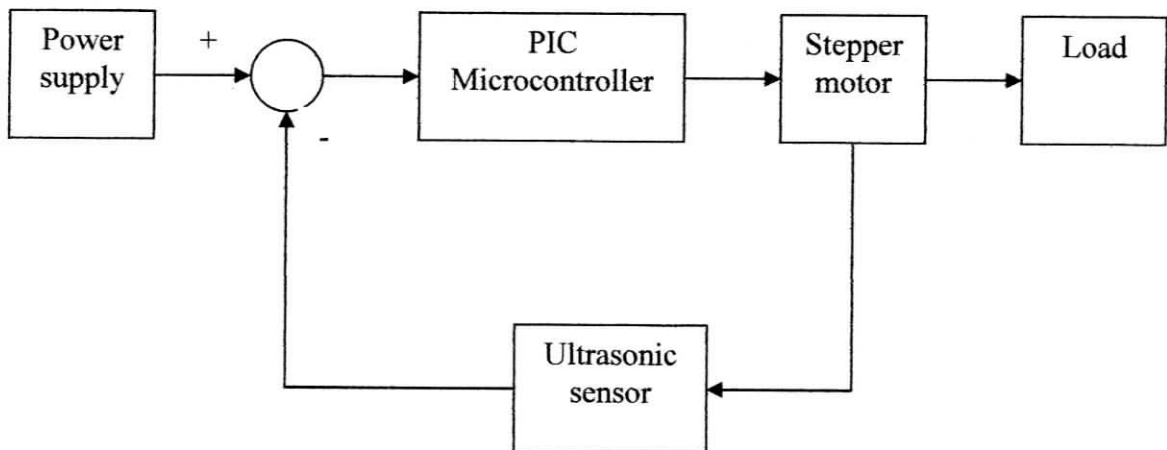


Figure 1.1: Process closed-loop

Structurally, types of motor used are the stepper motor and the detectors of sensor used are the ultrasonic sensor. Stepper motors are a digital motor that move accurately according to the degree of the rotation after it was set by the motor controller circuit. The degrees of the rotation control the speed of the motor.

Lastly, the result from this project is the PIC microcontroller will be able to control the motor movement and the sensor detection. In the motor controller section, the motor can move forward or reverse depending on the distances that have been program. Meanwhile, the motor speed can be controlled manually by the variable resistor. The sensor can be operated as a safety control in which when the sensor sense an obstacle in front, it when the motor is running.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Smart Motor Controller refers to three elements; PIC microcontroller, Motor and Sensor. PIC microcontroller is the main element in this project because the PIC can controlled the next elements. The types of PIC microcontroller used are 16F84A. Types of motor used are the stepper motor. Stepper motors are a digital motor that move accurately according to the degree of the rotation after it was set by the motor controller circuit. Types of sensor used are the ultrasonic sensor. Circuit sensor is circuit to give a close loop response for the in order reactions. For example, function motor can be stops after the sensors senses on obstacle.

2.2 WHAT IS A MICROCONTROLLER?

A computer revolution in the last 15 years has produced computer with a very high speeds and a computing power while keeping their sizes compact. This revolution has occurred as a result of a development of Large-scale Integration (LSI)

and Very Large-scale integration (VLSI) technologies, which contents thousands of transistor on a single chip. This has made possible to fabricate the heart of a microcomputer as a single chip called a microprocessor (MPU). This chip, with an additional auxiliary chips called peripherals, constitutes 'a microcomputer'. Such peripherals are I/O ports, memories, timers and others.

The new technology has also made it possible to integrate this microprocessor and its peripherals in a single chip called a microcontroller (MCU) That is the reason a microcontroller is called a *single-chip microcomputer*.

2.3 WHY USE A MICROCONTROLLER?

Microcontroller is inexpensive. It's ability to store and run unique programs make it extremely versatile. For example, we can program a microcontroller to make a decision (perform functions) based on the predetermined situations (I/O line logic) and selections. The microcontroller's ability to perform math and logic functions allows it to mimic sophisticated logic and electronic circuit.

Others program can make the microcontroller behave like a neural circuit or a fuzzy logic controller. Microcontroller is responsible for the "intelligence" in the most smart devices in market.

There are literally hundreds of microcontrollers on the market. Listed here are some of the popular 8-bit microcontroller and their features [2]. These devices are the lowest cost representative devices from respective manufactures.