DEVELOPMENT OF A PI SPEED CONTROLLER FOR DC MOTOR DRIVE USING RABBIT MICROPROCESSOR

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MAY 2008

"I hereby declared that I have read through this report and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)"

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This Report Is Submitted In Partial Fulfilment of Requirement for the Degree of Bachelor in Electrical Engineering (Power Electronic and Drive)

Fakulti Kejuruteraan Elektrik
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May 2008

“I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references.”

Signature : …………………………………………………………

Name : …………………………………………………………

Date : …………………………………………………………

To beloved father and mother

ACKNOWLEDGEMENT

First of all, I would like to express my gratitude to my supervisor, Professor Madya Dr Zulkifilie Bin Ibrahim for his guidance and precious information along the progress of this project in order to fulfil my research.

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Finally, I would like to thank my parents who have fully supported me along the way to finish this research project. Not forgotten to my friends and course mates who have assisted and given important advice to me in the effort to complete this research project.

ABSTRACT

The title of this project is 'Development of PI Speed Controller for DC Motor Drive Using Rabbit Microprocessor'. This project involves the tasks of designing, developing and system interfacing to realize a PI speed controller mainly for dc motor drive by using the Rabbit Microprocessor. This report traces the development process, from its design stages to construction, and finally the functional testing of the software implementation on the hardware prototype.

The overall PI speed controller developed is based on digital implementation with the application of an eight bit Rabbit Microprocessor. The designation of this project can greatly eliminates the present mechanical or electronic analogue based controller. In this project, it needs both hardware and software development in order to achieve the target of the project. The main hardware implementation in this project is Rabbit microprocessor. Rabbit microprocessor is chosen due to its several specifications and features which can be utilised with low voltage consumption

Hence the completion of this PI digital controller will be an effective and reliable control prototype in industrial world.

ABSTRAK

Projek ini bertajuk “Pembangunan pengawal kelajuan digital *PI* untuk aplikasi motor *DC* dengan menggunankan mikropemproses Rabbit.” Projek ini merangkumi kerja merekabentuk, membangun dan membina untuk menghasilkan satu pengawal kelajuan PI khusus untuk diaplikasikan ke atas motor *DC*. Laporan ini mencatatkan kesemua proses perlaksanaan dari rekabentuk sehingga ke pembinaan dan seterusnya pengujian fungsi ke atas prototaip yang telah dihasilkan.

Secara keseluruhanya, pengawal kelajuan *PI* adalah berasaskan digital implimentasi oleh mikropemproses Rabbit. Ini dapat mengantikkan penggunaan system pengawal lama yang berasaskan mekanikal atau elektronik analog. Perlaksanan projek ini memerlukan pembangunan kedua-dua *hardware* dan *software* bagi menghasilkan satu system pengawal *PI*. Mikropemproses Rabbit dipilih sebagai perkakasan yang utama disebabkan ciri-ciri unikya.

Dengan itu, hasil perlaksanaan projek ini akan menyediakan satu pengawal kelajuan digital *PI* yang efektif untuk diaplikasikan di dunia industri.

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LIST OF ABBREVIATIONS

PI	- Proportional-Integral
PID	- Proportional-Integral-Derivative
DC	- Direct Current
PWM	- Pulse Width Modulated
PC	- Personal Computer
CPU	- Centre Processing Unit
HID	- Human Interface Devices
I/O	- Input and Output
RAM	- Random Access Memory
GUI	- Graphical User Interface
ROM	- Read Only Memory
MCU	-Micro Controlling Unit
RCM	- Rabbit Core Module
PLC	- Programmable Logic Controller
MOSFET	- Metal Oxide Semiconductor Field Effect Transistor

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CHAPTER 1

INTRODUCTION

1.1 Background of Project

The use of PI (Proportional-Integral) controller technique has become common in industrial application despite continual advances in control theory. It is widely used as control loop feedback mechanism for various closed loop systems. The PI controller attempts to eliminate the error between the measured process variable and the desired value set point by computing and providing corrective action to adjust the input signal accordingly. Thus the system can gain stability and independent to external disturbances. In this project, the PI controller is used to control a DC motor which is part of actuation system.

The reasons of the popularity of PI controller in industries are due to the simplicity of its structure and can be used to control most of the control processes in industrial plant. The conventional PI controllers mainly constructed based on the mechanical or electronic analog devices. However both types of these controllers are no longer suitable in industrial world. The mechanical type PI controller (pneumatic controller) often requires costly maintenance because mechanical wear will leads to control degradation. While electronic analog based controller that constructed using analog components faces constraints of accurate control, environmental disturbances and difficulties in manual tuning.

Hence this project focuses on the development of a digital PI speed controller for a DC motor drive using 8 bit Rabbit Microprocessor. Digital controller implementation has the advantages as they are relatively cheap, highly reliable and reasonably flexible with respect to the implementation of the PI speed controller algorithm. The developed controller system will enable the control of motor speed via software implementation on the Rabbit microprocessor.

1.2 Objectives

The title of this project is 'Development of a PI Speed Controller for DC Motor Drive Using Rabbit Microprocessor'. The aim of this project is to develop an embedded PI speed controller system with Rabbit Core Module 3100 microprocessor as the main controller of the closed-loop system.

The main objectives are:

- To develop a digital Proportional-Integral (PI) speed controller system using Rabbit Microprocessor.
- To develop a closed-loop variable speed control for DC motor drive that consists of Rabbit microprocessor, DC motor, motor driver, and other supporting components.
- To develop an embedded speed control prototype that is suitable for industrial application.

1.3 Scopes

The project execution can be categorized into scopes of:

- Develop a closed-loop system for DC motor by implementing PI control method through Rabbit Microprocessor.
- Design and construct a DC motor power drive for variable speed application.
- Develop PI speed controller algorithm on Rabbit Microprocessor.
- Interface and implement DC motor drive with PI speed control algorithm and test the functionality of the prototype under various environments and tasks.

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Embedded Microcontroller

Embedded microcontroller is a devise that perform embedded control. The main differentiating feature of an embedded controller is that all system operation is not controlled by external PC. In fact the CPU running the system is actually built into the I/O system itself. While a typical, slaved data acquisition system is hosted by some type of general purpose Personal Computer complete with mouse, monitor and other human interface devices (HID), an Embedded Controller's processor is usually dedicated to controlling the I/O system and often does not provide any direct human interface.

Differences between an embedded controller and a standard PC are easily observed. However, the differences in software are equally noticeable. While most PCs operating systems for your desktop and laptop computer are large (in terms of RAM and hard drive space needed), operating systems developed for embedded systems are likely to be smaller and have been developed without all of the built-in GUIs as well as much of office equipment peripheral support.

Embedded controllers are often the heart of an industrial control system or a process control application. They may also be at the center of a portable data acquisition system or remote controller that allows an application to keep running even if its umbilical link to the outside world is cut. **[1]** In this project, Rabbit Microprocessor is used as main embedded controller for the variable speed drive of a DC motor.

2.2 DC Motor Speed Control

Speed control of dc motor could be achieved using mechanical or electrical techniques. In the past, speed controls of dc drives are mostly mechanical requiring large size hardware to implement. Advances in the area of power electronics have brought a total revolution in the speed control of dc drives.

DC drives are widely used in applications requiring adjustable speed; good speed regulation and frequent starting, braking and reversing. Some important applications are rolling mills, paper mills mine winders, hoists, machine tools, traction, printing presses, textile mills, excavators and cranes. Fractional horsepower dc drives are widely employed – as servo means for positioning and tracking.

Adjustable speed drives may be operated over a wide range by controlling armature or field excitation. Speed below rated is controlled by armature voltage control and above rated using field excitation variation, development of various solid states switching devices in the form of diodes, transistor and thyristor along with various analogue or digital chips used in firing or controlling circuits, have made dc drives more accessible for control in innumerable areas of applications.

The solid-state power electronic switching devices can be broadly grouped into:

- Those supplied from ac source. Thyristor bridge rectifiers (converters)
- Those employing dc supply namely choppers and inverter. **[3]**

The use of power electronics for the control of electric machines offers not only better performance caused by precise control and fast response, but also maintenance, and ease of implementation. In parallel with the advance in power electronic there have been great advances in microcontroller-based control systems due to the microcontroller flexibility and versatility. This is because all the control algorithms are implemented in the software. **[2]**

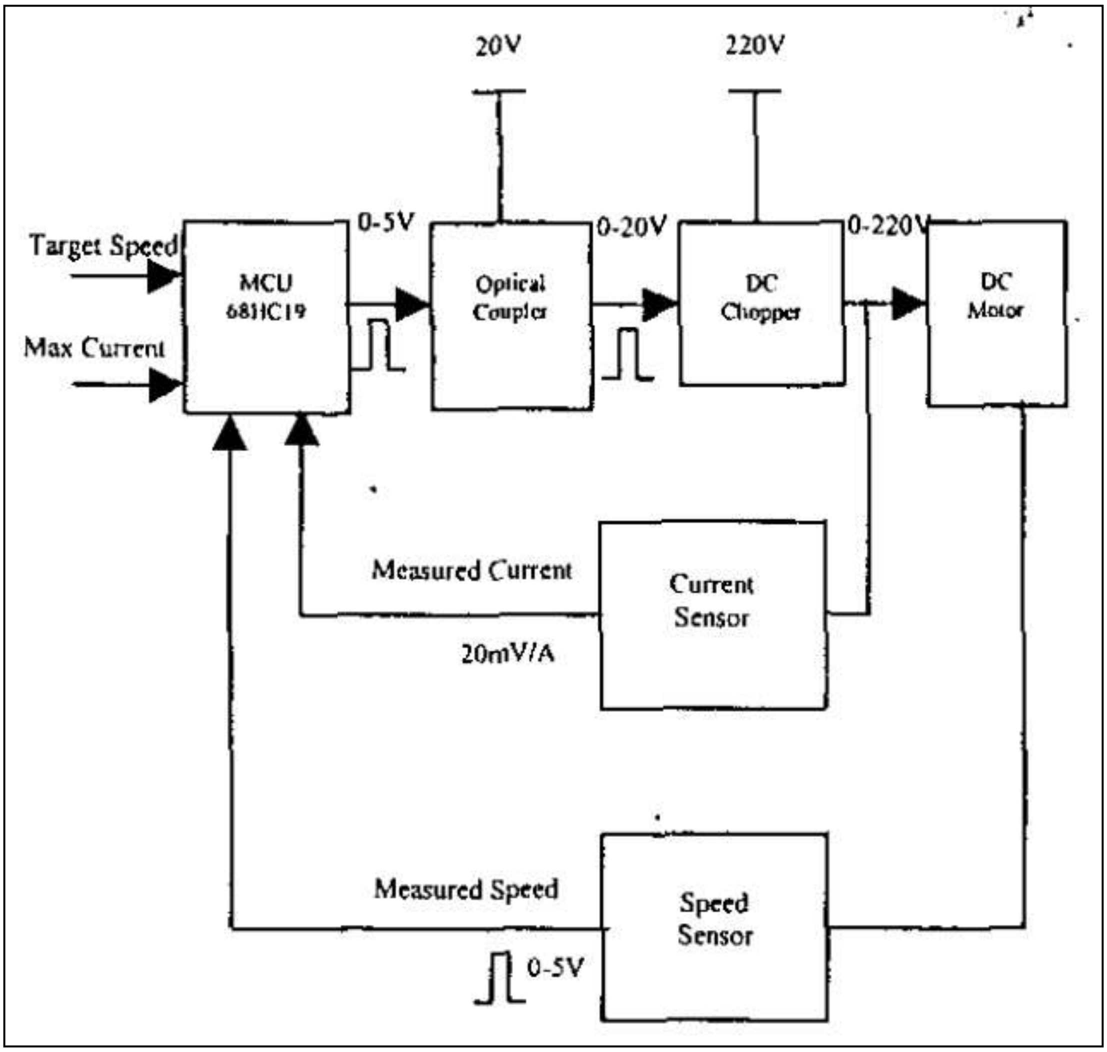

Figure 2.1: Block diagram of automatic speed control system

2.2.1 Digital Speed Controller for DC Motor

The speed control of DC motor is very crucial, especially in applications where precision and protection are of essence. **[4]** The use of stand-alone micro controller for the speed control of DC motor is past gaining ground. Nicolai and Castagect have shown in their paper how a microcontroller can be used for speed control. The operation of the system can be summarized as: the drive forms a rectified voltage. It consists of chopper driven by a PWM signal generated from a micro controller unit (MCU). The motor voltage control is achieved by measuring the rectified mains voltage with the analog to-digital converter present on the micro controller and adjusting the PWM signal duty cycle accordingly. **[4]**

Another system that uses a microprocessor is reported in the work of Khoel and Hadidi a brief description of the system is as follows: The microprocessor computes the actual speed of the motor by sensing the terminal voltage and the current, it then compares the actual speed of the motor with the reference speed and generates a suitable signal control signal which is fed into the triggering unit. This unit drives a H-bridge Power MOSFET amplifier, which in turn supplies a PWM voltage to the DC motor. **[5]**

2.3 Proportional-Integral (PI) Controller

A proportional-integral controller (PI controller) is a generic control loop feedback mechanism widely used in industrial control systems. Its popularity stems from the fact that the control engineer essentially only has to determine the best settings for the Proportional, Integral, and Derivative action terms needed to achieve a desired closed-loop performance. **[6]**

2.3.1 Propotional-Integral Control

The proportional term makes a change to the output that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant Kp, called the proportional gain.

$$P_{\mathrm{out}} = K_p \, e(t)$$

Where

* Pout: Proportional output
* Kp: Proportional Gain, a tuning parameter
* e: Error = SP − PV
* t: Time or instantaneous time

Higher Kp value increases the response time and reduces steady-state error of a system. The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. Summing the instantaneous error over time (integrating the error) gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain and added to the controller output. The magnitude of the contribution of the integral term to the overall control action is determined by the integral gain, Ki. The integral term is given by **[7]**: