MICROPROCESSOR BASED 3-PHASE SIX-STEP VSI FED AC MOTOR DRIVE BASED ON RABBIT MICROPROCESSOR

HEW WAI ONN

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)"

Signature

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Supervisor"s Name

: ………………………………………………………

Date

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MOTOR DRIVE BASED ON
RABBIT MICROPROCESSOR

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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
Universiti Teknikal Malaysia Melaka

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

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To beloved father and mother

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ABSTRACT

The project is titled as "Microprocessor based 3-phase Six-step VSI fed AC motor drive based on Rabbit Microprocessor". The purpose of this project is to design and develop a variable speed AC motor drive based on 3-phase Six-step Voltage Source Inverter (VSI) and Rabbit Microprocessor. The drive consists of Voltage Source Inverter, Rabbit controller board, sensor interfacing board, Brushless DC motor with encoder and Hall sensors. The software development is based on Dynamic C programming language and developed speed control algorithms is compiled and uploads into flash memory of the Rabbit controller.

The Rabbit controller developed is based on Rabbit Microprocessor and its core module model RCM 3100. The interfacing between RCM 3100 and Voltage Source Inverter (VSI) that drives the Brushless DC motor by Six-step control switching signals. The Six-step control switching signals are generated by using Rabbit controller based on 3-phase Voltage Source Inverter and Hall sensors of Brushless DC motor. To control the variable speed Brushless DC motor in term of Dynamic C programming language.

The target of the project is to achieve a laboratory scale functioning prototype in order to demonstrate variable speed control of Brushless DC motor driven by 8-bit Rabbit Microprocessor and 3-phase VSI.

ABSTRAK

Projek ini bertajuk "Penggunaan Tiga-Fasa Enam-Langkah Voltage Source Inverter (VSI) untuk aplikasi kawalan arus ulang-alik motor dengan menggunakan mikropemproses rabbit." Matlamat projek ini adalah merekacipta and membangunkan dengan boleh berubah kawalan kelajuan Brushless DC motor dengan menggunakan VSI dan mikropemproses rabbit. Perkakasan yang diperlukan dalam projek ini ialah VSI, pengawal rabbit, sensor interfacing board, Brushless DC Motor dengan encoder dan Hall sensors. Perisian yang digunakan ialah bahasa pengaturcaraan Dynamic-C yang dikhaskan untuk mikropemproses Rabbit dan ingatan flash akan disimpan dalam pengawal rabbit.

Dalam projek ini, satu pengawal rabbit yang dibangunkan adalah berteraskan mikropemproses Rabbit dan modul terasnya RCM 3100. Pengabungan antara RCM 3100 dan VSI akan menggerakkan Brushless DC motor dengan enam-langkah control switching isyarat. Enam-langkah control switching isyarat ini dijadikan berdasarkan Enam-langkah VSI dan Hall sensors daripada Brushless DC motor. Dengan kebolehubahan kelajuan Brushless DC motor ditentukan oleh bahasa pengaturcaraan Dynamic-C.

Matlamat projek ini adalah untuk merekacipta dan membangunkan satu prototaip yang berfungsi dalam skala makmal. Prototaip ini diharapkan dapat mendemonstrasikan kebolehubahan kelajuan Brushless DC motor dengan 8-bit mikropemproses Rabbit dan tiga-fasa VSI.

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LIST OF ABBREVIATIONS

DSP	- Digital Signal Processor
PLC	- Programmable Logic Controller
PC	- Personal Computer
RCM	- Rabbit Core Module
BLDC	- Brushless Direct Current
DC	- Direct Current
CPU	- Central Processing Unit
IC	- Integrated Circuit
VSI	- Voltage Source Inverter
RS	- Radio Standard
IIC	- Inter-Integrated Circuit
SPI	- Serial Peripheral Interface Bus
CAN	- Controller Area Network
CISC	- Complex Instruction Set Computer
DRAM	- Dynamic random access memory
PAC	- Parallel Architecture Core
VLIW	- Very Long Instruction Word
ORC	- Open Research Compiler
NMOS	- N-Type Metal Oxide Semiconductor
μP	- Microprocessor
CSI	- Current Source Inverter
I/O	- Input/ Output
RAM	- Random Access Memory
ROM	- Read Only Memory
PWM	- Pulse Width modulation
EISC	- Extendable Instruction Set Computer
ER	- Extension Register
EF	- Extension Register
ASIC	- Application-Specific Integrated Circuit
DTC	- Direct torque control
V/F	- Volts per Hertz
EMF	- Electromagnetic Field

SAC	- Symmetrical Angle Control
AAC	- Asymmetrical Angle Control
TRC	- Time Ratio Control
RMS	- Root Mean Square
MOSFET	- Metal Oxide Semiconductor Field-Effect Transistor
IGBT	- Insulated Gate Bipolar Transistor
GTO	- Gate Turn-Off
SCR	- Silicon Controlled Rectifier
MLVSI	- Multi Level Voltage Source Inverter
FBI	- Full Bridge Inverter
ZVS	- Zero-Voltage Switching
NTC	- Negative Temperature Coefficient
MOV	- Metal Oxide Varistor
AC	- Alternating Current
DAQ	- Data Acquisition
D	- Duty Cycle
CMOS	- Complementary Metal Oxide Semiconductor
TTL	- Transistor–Transistor Logic
PCB	- Printed Circuit Boards
PF	- Parallel Port F

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

In the advanced world of science and technology nowadays, microprocessor is a programmable digital electronic component that incorporates the functions of a central processing unit (CPU) on a single semiconducting integrated circuit (IC). Microprocessors typically serve as the CPU in a computer system, embedded system, or handheld device.

This project is titled as "Microprocessor based 3-Phase Six-step VSI fed AC motor drive based on Rabbit Microprocessor". In this project, the embedded controller developed is based on Rabbit microprocessor and its core module model RCM 3100. The control method implemented in this project is Six-step Voltage Source Inverter (VSI) to control variable Brushless Direct Current (BLDC) drive.

1.1 Objectives of the Project

- To generate Six-step square wave control switching signals by using Input/output ports of Rabbit controller based on the position of the Hall sensors
- 3-phase Voltage Source Inverter based on Six-step control switching signals and 120° conduction signal to produce 3-phase square wave output voltage to Brushless DC motor
- To design & develop a variable speed Brushless DC (BLDC) motor drive based on 3-phase Six-step Voltage Source Inverter (VSI) and 8-bit Rabbit Microprocessor

1.2 Scope of the Project

- To generates Six-step desired square wave control switching signals by using Dynamic C programming language based on Hall sensor signals of 3-phase Brushless DC motor and Rabbit Microprocessor
- To interface between Rabbit Core Module (RCM) 3100 and Voltage Source Inverter (VSI) that drives the Brushless DC motor by Six-step control switching signals
- To control variable speed Brushless DC motor in term of Dynamic C programming language

1.3 Problem Statement

Nowadays, AC motor controller drive based Digital Signal Processor (DSP), Programmable Logic Controller (PLC) and PC based control are widely used for conventional drive. In addition, the development of DSP is considering very high investment and large scale application. Then, need to develop cost effective, programmable and minimize number of components needed by using 8-bit Rabbit Microprocessor.

So for this project, a cost effective and high efficiency embedded controller is developed by using 8-bit Rabbit Microprocessor to control variable speed Brushless DC motor based on Six-step Voltage Source Inverter. Unlike a conventional brushed DC motor drive, the commutation of a Brushless DC motor is controlled electronically. The speed of Brushless DC motor is determined by the electronics and so better accuracy can be achieved than in standard Brushed DC motor

1.4 Project Planning Schedule (Gantt chart)

	2007						2008			
Project Activities	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Report PSM I & II	√	√	√	√	√	√	√	√	√	
Study the architecture design and technical specification hardware of RCM 310	√									
Study the architecture design and technical specification hardware of VSI	√									
Study the Dynamic C language		√								
To generate desired six-step square wave signal from RCM 3100		√	√							
Study the Brushless DC Motor Six-step commutation sequence			√							
Integration between RCM 3100 and VSI that shows commutation sequence of Brushless DC Motor			√							
Presentation PSM I			√							
Hardware and software design				√	√					
Hardware and software Integration						√	√			
Develop and control variable speed of Brushless DC motor drive								√		
Functional tests, debugging and retest									√	
Presentation PSM II										√

Table 1.1: Gantt chart of Project PSM 1 & PSM 2

CHAPTER 2

LITERATURE REVIEW

2.1 Embedded Controller and Embedded System

Microprocessors in embedded systems are typically optimized to perform a single task, often a control application. The design of these embedded systems requires a consideration of limiting factors such as small memory, slow processing speed, and limited electrical power that are rarely addressed in general-purpose computers. Microprocessor support for Embedded Systems applications must include interfacing the microprocessor with the user and other devices. In addition to direct pin-by-pin port I/O, protocols such as RS-232, SPI, IIC, and CAN are widely supported. Embedded Systems are often used for real world control so analog-to-digital and digital-to-analog conversions and their implications, such as the Nyquist criterion, need to be emphasized. Similarly, for many control applications, timing is critical so the ability to use event timers, watchdog timers, and related applications such as PWM are important. [1]

The embedded system performs some of the image processing tasks and sends the processed data to a personal computer (PC) - based system. The PC based system tracks persons and recognizes two-person interactions by using a gray scale side-view image sequence captured by a stationary camera. The optimum division of tasks between the embedded system and the PC, simulated the embedded system using dataflow models in Ptolemy, and prototyped the embedded systems in real-time hardware and software using a 16-bit CISC microprocessor. This embedded system processes one frame image in 89 ms, which is within three frame-cycle periods for a 30Hz video system. In addition, the real-time embedded system prototype uses 5.7K bytes of program memory, 854K bytes of internal data memory and 2M bytes external DRAM.[2]

The methods and experiences of developing software and toolkit flows for PAC (Parallel Architecture Core) VLIW DSP processors. Parallel Architecture Core (PAC) is a five-way VLIW DSP processor with distributed register cluster files and multi-bank register architectures (known as ping-pong architectures. Our toolkits include compilers, assemblers, debugger, and DSP micro-kernels. We first retarget Open Research Compiler (ORC) and toolkit chains for PAC VLIW DSP processor and address the issues to support distributed register files and ping-pong data paths for embedded VLIW DSP processors. We also deploy software pipelining techniques with the considerations of distributed register file architectures. The linker and assembler of our toolkits are able to support variable length encoding schemes for DSP instructions. In addition, the debuggers were designed to handle dual-core environments. The debugger is also integrated with Eclipse IDE. The footprint of micro-kernel is also around 10K to address the code-size issues for embedded devices. [3]

2.1.1 Microprocessor

A microprocessor is a programmable digital electronic component that incorporates the functions of a central processing unit (CPU) on a single semiconducting integrated circuit (IC).

The world's first microprocessor, the 4004, was co-developed by Busicom, a Japanese manufacturer of calculators, and Intel, a U.S. manufacturer of semiconductors. During the development of a general-purpose LSI for not only desktop calculators but also other business machines, originally based on a decimal computer with a stored program method, a basic architecture of 4004 was developed in August 1969. Microprocessors, which became the "technology to open up a new era," brought two outstanding impacts, "power of intelligence" and "power of computing". First, microprocessors opened up a new "era of programming" through replacing with software, the hardwired logic based on IC's of the former "era of logic". At the same time, microprocessors allowed young engineers access to "power of computing" for the creative development of personal computers and computer games, which in turn led to growth in the software industry, and paved the way to the development of high-performance microprocessors. In 20th century, microprocessors were used for increasing "power of intelligence". In 21st century, microprocessors will evolve into "tool to bring forth wisdom" for all mankind. [4]

Today, microprocessors for personal computers get widespread attention and have enabled Intel to become the world's largest semiconductor maker. In addition, embedded microprocessors are at the heart of a diverse range of devices that have become staples of consumers worldwide. Microprocessors have become specialized in many ways. The desktop computer market tends to discard old processors in just a few years, many processors survive for an amazingly long time in the embedded market. Personal computers have moved from 8-bit to 16-bit and now to 32-bit processors and many workstations and servers are already using 64-bit microprocessors. Microprocessors for personal computers get the most public attention because the performance and compatibility of PCs depend on the microprocessors at their cores. [5]

i. 8-bit Microprocessor

A single chip multiple channel digital to analog converter is presented which can operate in a stand-alone fashion, without any external control. The NMOS chip contains a combination of digital and analog functions. Eight output channels with 8 bit accuracy are provided and each channel has programmable end points. The values for the data and the end points are stored in an internal RAM. Sample-and-hold functions are completely on-chip. All storage of digital and analog data occurs on chip so that no external components are required. Sometimes the analog signals require different amplitude ranges but mostly 8 bit accuracy is sufficient. The converter is microprocessor compatible. This means that the converter can act as a memory mapped I/0 devices to the