INVERTED PENDULUM ROBOT

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This report is submitted in partial fulfilment of the requirements for the award of Bachelor of Electronic Engineering (Industrial Electronics) With Honours

Faculty of Electronic an Computer Engineering
Universiti Teknikal Malaysia Melaka

MAY 2008

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN

PROJEK SARJANA MUDA II

Tajuk Projek: Inverted Pendulum Robot

Sesi Pengajian: 2007/08

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For **my mother (Hamidah binti Rahmat)** and **my father (Mahmood bin Hasnan)** that provide the big support all the while

My sisters …**Marina, Mariana, Martina** and **Maria** that provide some advice throughout my study life.

My kind hearted supervisor **En. Ahmad Sadhiqin bin Mohd Isira** that guided me in the right direction and offering encouragement.

All my dearest friends that able to discuss together and share their resources for the thesis.

ACKNOWLEDGEMENT

First I would like to express my thanks to Allah S.W.T, the almighty who has helped me always to achieve so much in my life and career.

On this opportunity, I would like to take this opportunity to express my sincere thanks to all people whom was contributed and helping me in completing this project. I would like to express my deepest appreciation to my supervisor, En. Ahmad Sadhiqin bin Mohd Isira , for his help and support during the development of this project. He provides his valuable knowledge, ideas and advice to me for completing this project.

I am grateful to my family especially my dearest mom and dad, Puan Hamidah binti Rahmat and En. Mahmood bin Hasnan and my sibling for their help throughout the years, without which I would not have been able to come to Universiti Teknikal Malaysia Melaka to study.

Last but not least, I thank all my friends who were always around during some very difficult times.

ABSTRACT

Control systems major contribution is in the area of advance science and engineering today. Automatic control has become an important and integral part of modern manufacturing and industrial process. Inverted pendulum is a typical example of unstable system and has been used for educational purposes to understand the process design of an automatic control system in most universities in the world. Analysis, design, and control of the inverted pendulum are simple but it can be the basic knowledge that are useful to analyze the complex systems such as balancing robot, the movement and the smoothness operation of the robot. Therefore, in this project, it will focus on how to balance a two wheel robots that has a platform above. The platform height is defined from the centre of the wheel. This system is similar with the other inverted pendulum system but only the cart is the difference between this system.

ABSTRAK

Sistem kawalan banyak memberikan sumbangan penting dalam kemajuan sains dan kejuruteraan pada masa kini. Kawalan automatik kini amat penting dan merupakan sebahagian daripada proses pembuatan moden dan pemprosesan dalam industri. Pendulum songsang merupakan satu contoh sistem yang tidak stabil yang kebanyakan universiti seluruh dunia menggunakannya sebagai bahan pembelajaran tentang proses rekabentuk sistem kawalan automatik di dalam kuliah atau makmal-makmal. Analisis, rekabentuk dan kawalan bagi pendulum songsang bukan sahaja menarik malah amat berguna dalam menganalisis masalah yang berkaitan dengan sistem yang lebih rumit seperti keseimbangan robot, pergerakan dan kelancarannya. Maka, dalam kajian ini akan memfokuskan tentang bagaimana hendak mengawal kestabilan suatu robot yang mempunyai pelantar dengan ketinggian tertentu dengan hanya menggunakan dua buah roda sahaja. Sistem ini menyerupai sistem sebuah pendulum songsang. Cuma perbezaan yang jelas antara kedua-dua sistem ini adalah pada pembawanya *("cart")*.

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LIST OF ABBREVIATIONS

PIC	-	Programmable Interrupted Controller
DC	-	Direct Current
PCB	-	Printed Circuit Board
CG	-	Centre Gravity
PLC	-	Programmable Logic Controller
CCD	-	Charged Coupled Device
I/O	-	Input/ Output
CPU	-	Central Processing Unit
VB	-	Visual Basic
GUI	-	Graphical User Interface
ADO	-	Applications and a Complex Database Object Library
IDE	-	Interactive Development Environment
RAD	-	Rapid Application Development
COM	-	Component Object Model
DCOM	-	Distributed COM
OLE	-	Object Linking and Embedding
ADC	-	Analog to Digital Conversion
UV	-	Ultra Violet

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CHAPTER I

INTRODUCTION

1.1 Background

Robotics are becoming widely used in the automation, medical, manufacturing industries, also in many science fiction films and many others fields. Building and programming a robot is a combination of mechanics, electronics, programming and also problem solving skills. Nowadays, robots are constructed tended to be human-like.

This project must be completed within 6 months. The ultimate goal is to ensure the inverted pendulum robot capable to balance itself from collapse. Beside this, a program is also made to make it go forward and backward for the balanced movement.

The purpose of this project is to integrate current technology in electronics and control system into an inverted pendulum robot. The inverted pendulum robot will be equipped with two sensors, two motors and will be control directly from a PIC. For control, this project will implement C programming, which is very popular nowadays.

The micro controller chosen for this project is PIC16F876A micro controller from Microchip Company. Overall there are two sensors installed to sense the distance of the floor and ensure the inverted pendulum robot always moving and balancing itself. These sensors are manufactured by Sharp. The motor chosen are manufactured by Cytron and total of two servo motors was constructed to materialize the motion the mechanism.

1.2 Objective of the Project

The main objective is to complete the project within the required period. It must be built with the capability of self balancing, and will successfully move forward and backward in balanced condition and different speeds.

Initially, the aim of this project was to design and fabricate a robot capable of sustaining a vertical orientation by balancing action on only two wheels. The balancing robot is a highly unstable two wheeled robot. The largest mass, the battery pack, is positioned high above the axle, making the robot an inverted pendulum model with a low natural frequency. The robot will naturally tend to tip over, and, the further it tips, the stronger the force causing it to tip over.

The original plan was to use a gyroscope and an accelerometer to measure the rate of angular rotation and the relative source of gravity; however, these devices are too expensive for the project. Therefore a less expensive GP2D12 was used to measure the angle of the robot relative to the floor. In addition, a microcontroller was used to process the data from the sensors, and control the motors accordingly to allow the robot to balance.

Besides getting the tangible output, it will also trigger the interest of the students towards the beauty of the electronic, mechanical and software programming through hands-on experience.

1.3 Project Scope

This project integrates by 3 types of single modules, which are PIC16F876A micro controller (figure 1.1), Servo motor subsystem (figure 1.2), Sensor subsystem (figure 1.3) and electronic/mechanical parts. Beside that, only 1 type of language is used. There is C Programming for PIC16F876A micro controller. The power supply, which is 9 volt DC input to produce 5 volt output for micro controller use and 6 volt DC input direct to servo motor subsystem.

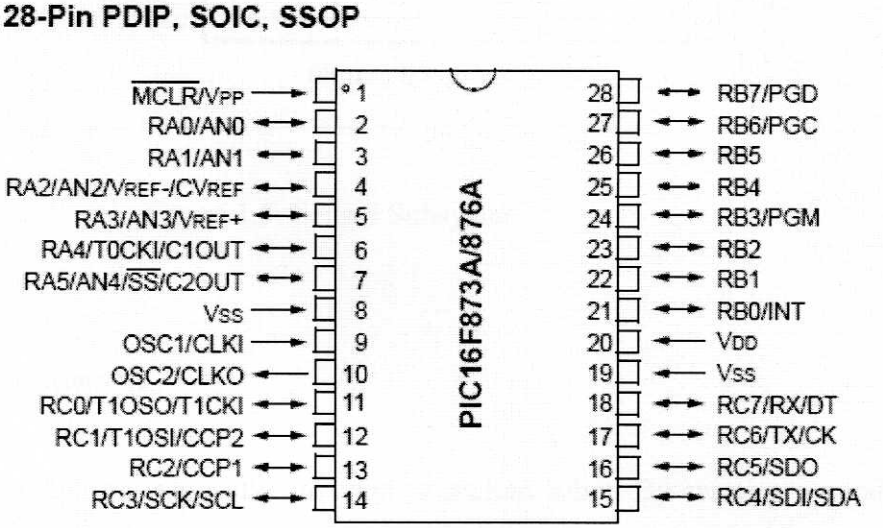
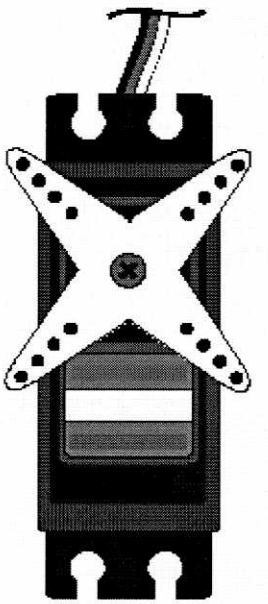


Figure 1.1: PIC16F876A Micro Controller



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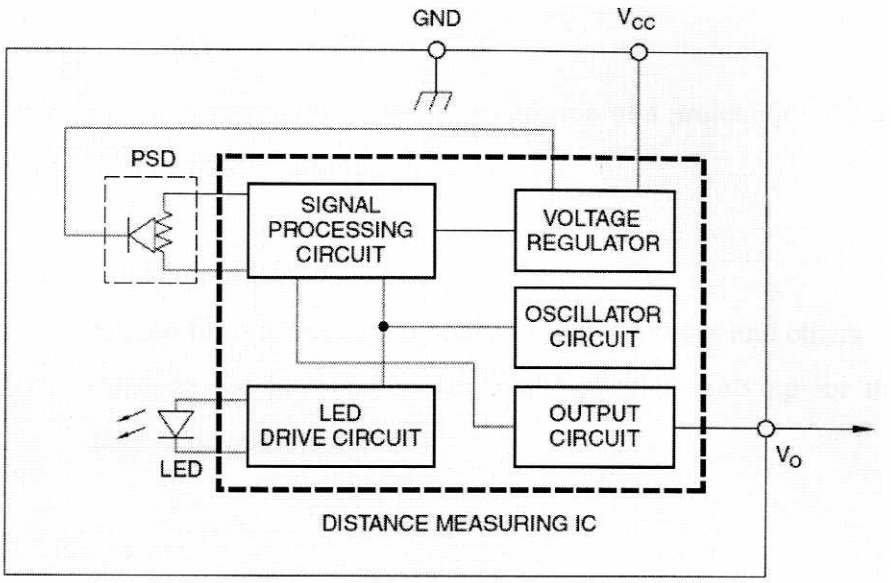

Figure 1.3: Sensor Subsystem

1.4 Problem Statement

Stability problem arises in the inverted pendulum robot. By creating a good control system, the stability problem in the pendulum can be solved. This project will focus on solving the stability problem using a closed loop system controlled by PIC

1.5 Scope of Work

The scope of work is very important for the execution of a project or a thesis. In this project, this section is divided into four sections.

1. Inverted Pendulum Robot Research
   (a) Search for information in books, internet sources and others.
   (b) Analyze the information and make problem solving for the project development.

2. PIC Programming
   (a) To create the programming syntax language using C language.
   (b) To test and improve the programming language.

3. Inverted Pendulum Robot Construction
   (a) To test the simulation circuit by using Multisim circuit simulator.
   (b) To design the PCB layout and construct the circuit.
   (c) To test the circuit by using multimeter and oscilloscope.
   (d) To construct the robot referring to the specification.

4. Overall Test
   (a) To make sure the inverted pendulum robot can operate as planned.
   (b) To make modification and development to the robot if any problems occurred.

CHAPTER II

LITERATURE REVIEW

In short, this chapter discusses the research findings of literature reviews from past researches. It discusses the inverted pendulum, the modeling of the inverted pendulum robot and others along with the important mechanisms that are used to build a control system for an inverted pendulum robot. This chapter will also include the research findings from reading, observing and information seeking to further the knowledge about the tools being used. This is to give a clear view on the project.

2.1 Inverted Pendulum

An inverted pendulum (also called a cart and pole) consists of a thin rod attached at its bottom to a moving cart. Whereas a normal pendulum is stable when hanging downwards, a vertical inverted pendulum is inherently unstable, and must be actively balanced in order to remain upright, typically by moving the cart horizontally as part of a feedback system.

The inverted pendulum is a classic problem in dynamics and control theory and widely used as benchmark for testing control algorithms. Variations on this problem include multiple links, allowing the motion of the cart to be commanded while maintaining the penum system on a see-

saw. The inverted pendulum is related to rocket or missile guidance, where thrust is actuated at the bottom of a tall vehicle. The largest implemented use is on huge lifting cranes on shipyards. When moving the shipping containers back and forth, the cranes move the box accordingly so that it never swings or sways. It always stays perfectly positioned under the operator even when moving or stopping quickly [5].

Another way that an inverted pendulum may be stabilized, without any feedback or control mechanism, is by oscillating the support rapidly up and down. If the oscillation is sufficiently strong (in terms of its acceleration and amplitude) then the inverted pendulum can recover from perturbations in a strikingly counterintuitive manner. If the driving point moves in simple harmonic motion, the pendulum's motion is described by the Mathieu equation [5].

In practice, the inverted pendulum is frequently made of an aluminum strip, mounted on a ball-bearing pivot; the oscillatory force is conveniently applied with a jigsaw.

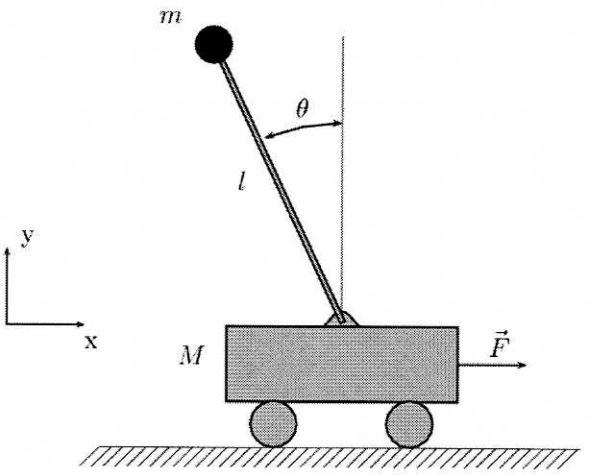

Figure 2.1: Example of Inverted Pendulum Cart