TWO WHEEL BALANCING ROBOT

SUHADAH BINTI MUSLIM

MAY 2009

" I hereby declare that I have read through this report entitle "Two Wheel Balancing Robot" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Mechatronic)"

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This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor in Electrical Engineering (Mechatronic)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APRIL 2009

I declare that this report entitle "Two Wheel Balancing Robot" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

To my beloved mother and father

AKCNOWLEGDEMENT

First and foremost, I would like to thank to my supervisor Pn. Ainain Nur Binti Hanafi who had taken a lot of efforts to meticulously go through my Final Year Project 1 and came up with helpful suggestion. Without helping from her, I surely came into deep problem in completing this report to fulfill the requirement in FYP 2. Besides that, I' am indebted to the numerous people who have contributed their time, effort, advice, help and constructive criticism throughout my project for FYP 2 on two wheel balancing robot. Finally, I would like to express my heartfelt gratitude to my family and friends for their support, constructive suggestion and also criticism.

ABSTRACT

This project is to design and develop a *"Two Wheel Balancing Robot"* using PIC microcontroller. This project combines the knowledge of software, electrical, and mechanical. The objective of this project is to investigate and analyses the characteristic of 3-axes accelerometer, to construct the balance control of a two wheel robot, and to design the two wheel robot base. "*Two Wheels Balancing Robot*" uses a PIC microcontroller as the control system to control all the activities. Input devices such as accelerometer will send a signal to PIC and then PIC will make a response accordingly. The responses normally are to move FORWARD or BACKWARD which are output signal to some of out devices such as DC motor. When the robot is balanced, the robot will stay in their position for a given time.

ABSTRAK

Projek ini telah dikhususkan bagi membina sebuah robot yang dinamakan sebagai *'Two Wheel Balancing Robot'* dengan menggunakan PIC mikropengawal serta meter pecut 3-paksi sebagai input. Projek ini merupakan kombinasi daripada beberapa cabang pengetahuan iaitu perisian, elektrik dan mekanikal. Objektif daripada projek ini adalah untuk mengkaji serta menganalisis ciri-ciri meter pecut 3-paksi, membina kawalan keseimbangan robot dua roda, serta mereka badan robot agar mencapai keseimbangan. *'Two Wheel Balancing Robot'* menngunakan PIC mikropengawal sebagai sistem kawalan untuk mengawal segala aktiviti robot. Peranti masukan seperti meter pecut akan menghantar signal kepada PIC dan kemudiannya PIC akan memberi tindakbalas kepada keluaran. Tindakbalas yang dikesan oleh PIC akan mngeluarkan isyarat keluaran kepada DC motor yang melibatkan pergerakan KEHADAPAN atau KEBELAKANG. Apabila robot telah mencapai tahap keseimbangan yang dikehendaki, robot akan statik untuk masa tertentu.

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A/D	-	Analog to Digital
PIC	-	Peripheral Interface Controller
DC	-	Direct current
RC	-	Radio Control
PID	-	Proportional Integration Derivation
ADC	-	Analog to Digital Converter
PWM	-	Pulse Width Modulation
CCP1	-	Capture/Compare/PWM 1
CCP2	-	Capture/Compare/PWM 2

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CHAPTER I

INTRODUCTION

1.1 Project Background

The two wheel balancing robot is developed for BEKU 4973, a project design for final year electrical engineering students; supervised by Pn. Ainain Nur Binti Hanafi. After discussing possibilities for final year projects, the idea for a balancing robot was agreed upon. The research on balancing robot has gained momentum over the last decade in a number of robotics laboratories around the world. This is due to the inherent unstable dynamics of the system. The capabilities of balancing have the potential to solve a number of challenges in industry and society. For example, a motorized wheelchair utilizing this technology would give the operator greater maneuverability and thus access to places most able-bodied people take for granted.

The advantages of a two wheeled balancing robot are the flexibility and maneuverability over unpaved terrain, small holes or obstacles comparing with other 3 point based supporting robot. Beside that, two wheeled balancing robot is a good platform for researchers to investigate the efficiency of various controllers in control system. The research on two wheeled balancing robot is based on inverted pendulum model. Therefore, a two wheeled balancing robot needs a good controller to control itself in upright position automatically. Nowadays, various types of controllers were implemented on two wheeled balancing robot for examples Linear Quadratic Regulator, Pole-Placement Controller, Fuzzy Logic controller, Proportional Integrated Derivative Controller. Such robot is characterized by the ability to balance on its two wheels. These capabilities have the potential to solve a 2 number of problems and challengers in society and industrial. For example, in USA they are utilizing this technology to invent a motorized wheelchair. This motorized wheelchair would help the disable people to move around all various types of terrain like slope and stair by just pressing a navigation button. Beside that, this technology

also implemented in a personal vehicle called 'SEGWAY', it helps humans to travel short distances in a small area, university, factories as opposed to using cars which is more polluting. Further more, this technology also implement in entertainment field. Hitachi Company was implementing this technology in designing a two wheeled humanoid robot called "E-MIEW".

Apart from the above, this thesis will delve into the suitability and performance of balancing the two wheel robot using only one input from the three axis accelerometer and a controller in balancing the system. The robot utilizes a PIC microcontroller on steering method for balancing control. An accelerometer is used to measure the tilt of the robot and gives the output to the motor to measure the wheel's rotation.

The initial part of the project had been structured in other to familiarize with the ADXL 3-axis accelerometer with the PIC16F877A Microcontroller. The PIC16F877A is an 8-bit processor with reduced instruction set computer (RISC) architecture, maintaining a high level of performance with a low level of power consumption. The Microcontroller is basically the heart of the project, being the engine that really drives the robot's wheels to maintain balance. This robot uses small DC motors to maintain balance. Once it was able to maintain upright status, it will static on its position for a given time to be a balancing robot.

The two wheel balancing robot is used three-axis accelerometer. These sensors send data to a PIC microcontroller. In addition to the A/D from microcontroller would take information from the accelerometer and the PIC would send it serially to the driver motor and drive the wheel. My robot would detect inclines and then move forward or backward to the floor as keep maintains balance. These behaviors, however, had to be modified over the course of the project due to unforeseen difficulties in sensor and software integration.

1.2 Project Objective

The objectives of this project are to design, develop, evaluate, and demonstrate a two wheel balancing robot, and investigate and analyses the characteristic of 3-axis accelerometer. The main objective of this project is to design and fabricate a two wheeled

balancing robot that has the ability to balance itself on a flat terrain. Therefore, a powerful control system algorithm is needed in this project because it is vital to guarantee the success in balancing the robot.

1.3 Project Scope

For this project, the scope is limited to certain selected fields, which are:

Design and construct the structure of the robot. The structure of the robot must be symmetrical and the center of the gravity of the robot must be higher.

Design the software to implement the programming on balancing the robot in the microcontroller for stabilizing the balancing robot.

Design an electronic circuit board for the robot to interface the sensor inputs and DC motors to the microcontroller.

The movement of the robot is controlled by PIC microcontroller such drive forward or backward to be balance.

1.4 Executive Summary

This project was broken down into several chapters, each of which is summarized below:

Chapter 2: Literature Review. This chapter contains a review of previous work in balancing robot.

Chapter 3: Project Overview. This chapter contains an overview of the conventional sensor used, type of motor and the related circuit used.

Chapter 4: Mechanical Design. The development of robot structure of two wheel balancing robot, the actuator and wheel used by the robot, and the position of the sensor will be cover on this chapter.

Chapter 5: Electronic Design. This chapter covers the basic circuit of the robot in balancing robot.

Chapter 6: Programmed. This chapter describes the outcome of the programming of the robot on how to balance it.

Chapter 7: Experiment and Result. All the experiment, test and run, forward and backward test and also the achievement of the robot will cover in this chapter.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Balancing robot is most commercialized now and it is famous among the robot inventor. Conducting literature review prior to undertaking research project is critical as this will provide much needed information on the technology available and methodologies used by other research counterparts around the world on the topic. This chapter provides the summary of literature reviews on key topics related to balancing a two-wheeled robot. Below are the several previous projects related to this project:

2.2 Balancing Robots

In the field of control engineering, inverted pendulum problem has gained many researchers and robotics enthusiast's interest around the world. In recent years, researchers have applied the idea of mobile inverted pendulum model to various problems like designing walking gaits for humanoid robot, robotic wheelchairs and personal transport system.

2.2.1 Joe Robot

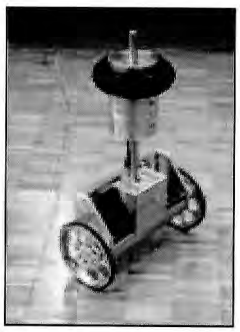

Figure 2.1 Joe Robot

Researchers at the Industrial Electronics Laboratory at the Swiss Federal Institute of Technology have built a Digital Signal Processor control two wheeled robot (JOE) based on the inverted pendulum with weights attached to the system to simulate a human driver. A linear state space controller utilizing sensory information from a gyroscope and motor encoders is used to stabilize this system. This robot is able to traverse on all terrain. The direction of robot can be controlled by using RC remote control.

2.2.2 Nbot

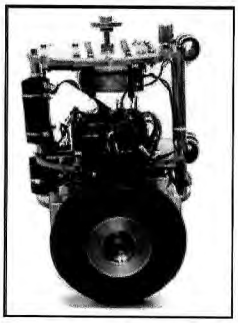

Figure 2.2 Nbot

Another good example is Nbot, a two-wheeled balancing robot similar to JOE built by David .P Anderson, this robot uses a commercially available inertial sensor and position information from motor encoder to balance the system. Nbot is able to traverse on all terrain and the direction of the robot is programmed.

2.2.3 Legway

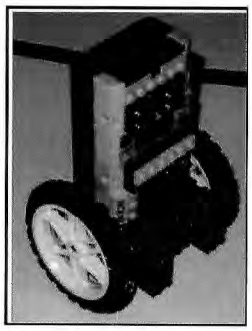

Figure 2.3 Legway

Steven Hassenplug has successfully constructed a balancing robot called Legway using the LEGO Mindstorms robotics kit. Two Electro-Optical Proximity Detector (EOPD) sensors are used to provide the tilt angle of the robot to the controller. Steven Hassenplug is using BrickOS, a C/C++ like programming language specifically for LEGO Mindstorms to control the robot.

2.2.4 Balibot

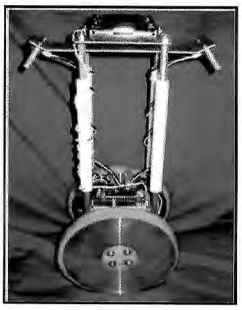

Figure 2.4 Balibot

Balibot is built by hobby researcher. The structure of Balibot is small and light. The actuator of this robot is two servo motor. It only operates on flat terrain. The direction of the robot is uncontrollable. To detect the tilt of the robot, two distance measurement sensors and Motorola MMA2260 low G Accelerometer was used. The controller of this robot is Proportional control system. PIC 16F 877A microcontroller was used on this robot.

2.2.5 Segway

Figure 2.5 Segway

The robot's design was modeled after the Segway Human Transporter. It utilizes a mass imbalance actuated by a servo to control the vehicle's forward and reverse operation. In order to control the robot move forward or backward, the operator can control the servo by using RC transmitter. Motorola HC11microcontroller was used. An accelerometer is used to measure platform angle and a rate gyro is used to measure the platform's angular rate. PID controller was used as the control system of the robot.

CHAPTER III

PROJECT OVERVIEW

3.1 Introduction

This project is to design and development of two wheeled balancing robot where it has the ability to stabilize on flat terrain. The movement of the robot can not control by operator and it's using Three Axis Accelerometer. The robot was able to maintain its balance after executing movements like drive forward and backwards.

First of all, the robot structure must be robust, symmetrical & the center of gravity of the robot must be high. In order to make the center of the gravity of the robot to become higher, the first idea come out was, a battery box is placing on top and center of the robot. Besides that, a simple mechanism is implemented in the robot in order to control the forward and backward movement.

One general purpose distance measuring sensors (ADXL330 Accelerometer) are used to detect the current position of the robot. The sensors will be place at the body of the robot. The position of accelerometer is toward the ground at an angle. The output of the sensor is an analog voltage that is further amplified and conditioned by circuitry on the controller board.

Microcontroller is used to be the brain of the robot. All the programming is stored in the microcontroller's program memory. PIC 16F 877A is used as the brain of the robot. The microcontroller received the analog reading from sensor and converted it into digital value by using Analog to Digital Converter (ADC) function in microcontroller. The microcontroller executed the control algorithm and outputs a pulse width modulated (PWM) signal to two DC motors.