# DEVELOPING AN AUTONOMOUS SELF-BALANCING (AUSB) BICYCLE MINIATURE MODEL

By

Yuvens Putra Barata
11111058

BACHELOR'S DEGREE
in

MECHANICAL ENGINEERING – MECHATRONICS CONCENTRATION
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

SWISS GERMAN UNIVERSITY
EduTown BSD City
Tangerang 15339
Indonesia

August 2015

Revision after the Thesis Defense on 5th August 2015

## STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Yuvens Putra Barata

Student Date

Approved by:

Kirina Boediardjo, ST, M.Sc.

Thesis Advisor Date

Dr. Rusman Rusyadi, B.Sc., M.Sc.

Thesis Co-Advisor

Date

Dr. Ir. Gembong Baskoro, M.Sc

Dean Date

SGU SWISS GERMAN UNIVERSITY

# ABSTRACT

DEVELOPING AN AUTONOMOUS SELF-BALANCING (AUSB) BICYCLE MINIATURE MODEL

By

Yuvens Putra Barata
Kirina Boediardjo, ST, M.Sc., Advisors
Dr. Rusman Rusyadi, B.Sc., M.Sc., Co-Advisors

SWISS GERMAN UNIVERSITY

The purpose of this thesis is to create a self-balancing bicycle. The basic principal of the self-balancing bicycle is the same as inertia wheel inverted pendulum. Whenever the bicycle tilts, the flywheel will rotate to generate reactionary force in order to balance itself in the vertical axis. This thesis uses an IMU as the main sensor to detect tilting angle, a permanent magnet DC Motor as the actuator, an Arduino as the microcontroller. For the controller, a PID control system is used to control the PWM of the DC motor. In order to control the PWM accurately, a tuning need to be done with the PID. The tuning itself is done by using manual tuning method, where the P, I, and D parameter is tuned separately while observing the behavior of the system when the parameter is changed.

*Keywords: Self-balancing, Inverted Pendulum, Inertia Wheel, PID controller, Inertia Measurement Unit.*

© Copyright 2015
By: Yuvens Putra Barata
All rights reserved

SWISS GERMAN UNIVERSITY

# DEDICATION

I dedicate this works for my family, my friends, my advisors and to all of my lecturers.

SGU®
SWISS GERMAN UNIVERSITY

## ACKNOWLEDGEMENTS

First of all, I would like to thank God for letting me finishing my thesis. I also would like to give my deepest gratitude for my family which are always believing in me and supporting me when I am down morally during the thesis project.

I would like to give my thanks to my advisors, Ms. Kirina Boediardjo and my co-advisors, Mr. Rusman Rusyadi. Without your guidance, I believe I wouldn't be able to finish my thesis on time.

Also, special thanks for all of my friends. Thank you for your motivation, thank you for your support, and thank you for helping me by sharing your knowledge and giving your opinion regarding my project. Also, thanks for always keeping the class lively.

So, once again, I thank all of you for everything from the bottom of my heart. This thesis won't be comes to realization without all of your help and support.

SGU ®
SWISS GERMAN UNIVERSITY

# TABLE OF CONTENTS

Page

STATEMENT BY THE AUTHOR ..... 2
ABSTRACT ..... 3
DEDICATION ..... 5
ACKNOWLEDGEMENTS ..... 6
TABLE OF CONTENTS ..... 7
LIST OF FIGURES ..... 10
LIST OF TABLES ..... 12
LIST OF EQUATION ..... 13
CHAPTER 1 - INTRODUCTION ..... 14
1.1 Thesis Background ..... 14
1.2 Thesis Purpose ..... 15
1.3 Thesis Scope ..... 15
1.4 Thesis Limitation ..... 16
CHAPTER 2 - LITERATURE REVIEW ..... 17
2.1 Self-Balancing Bicycle ..... 17
2.2 Permanent Magnet DC Motors ..... 18
2.3 Motor Driver (H-Bridge) ..... 19
2.4 Microcontroller ..... 20
2.5 Pulse Width Modulation (PWM) ..... 20
2.6 Sensors ..... 21
2.6.1 Rotary Encoder ..... 22
2.6.2 Accelerometer ..... 24
2.6.3 Gyroscope ..... 24
2.7 PID Controller ..... 26
CHAPTER 3 - METHODOLOGY ..... 27
3.1 Mechanical Design ..... 27
3.1.1 First Prototype ..... 36
3.1.2 Second Prototype ..... 39

SWISS GERMAN UNIVERSITY

3.1.3 Third Prototype ..... 40
3.2 Electrical Design ..... 42
3.2.1 IMU GY-85 Series ..... 43
3.2.2 EMS (Embedded Module Series) 2A Dual H-Bridge ..... 44
3.2.3 GB37Y3530-251R Permanent Magnet DC Motor ..... 45
3.2.4 Arduino Uno ..... 46
3.2.5 Wiring Connection Tables ..... 47
3.3 Software Design ..... 49
3.3.1 IMU Reading ..... 50
3.3.2 PID (Proportional-Integral-Derivative) Controller ..... 51
3.3.3 Angle Control PID ..... 52
3.3.4 Motor Angular Velocity Control PID ..... 54
3.3.5 Cascaded PID ..... 55
3.3.6 Safety Code ..... 55
3.3.7 Code Flowchart ..... 56
CHAPTER 4 - RESULTS AND DISCUSSIONS ..... 60
4.1 IMU Testing Result ..... 60
4.2 Angular Acceleration Test ..... 63
4.2.1 First prototype ..... 63
4.2.2 Second prototype ..... 65
4.3 Motor Testing Result ..... 66
4.4 Maximum Correction Angle Testing ..... 66
4.4.1 Second Prototype ..... 66
4.4.2 Third Prototype ..... 68
4.5 PID Result ..... 71
4.5.1 Second Prototype ..... 72
4.5.2 Third Prototype ..... 72
CHAPTER 5 - CONCLUSIONS AND RECCOMENDATIONS ..... 77
5.1 Conclusion ..... 77
5.2 Recommendation ..... 78
GLOSSARY ..... 79
References ..... 80
APPENDICES ..... 81

SWISS GERMAN UNIVERSITY

CURRICULUM VITAE .....100

SGU®
SWISS GERMAN UNIVERSITY