BI-WHEEL SELF BALANCING ROBOT

P Jayaganesh[1], C Sankaranaraayanan[2], P Sankara Narayanan[3], R Vishnu Prabu[4]
1(Mechanical Department, Meenakshi Sudararajan Engineering College, Chennai
Email: jayaganesh.msec@gmail.com)
2(Mechanical Department, Meenakshi Sudararajan Engineering College, Chennai
Email:hari24sekar@gmail.com)
3(Mechanical Department, Meenakshi Sudararajan Engineering College, Chennai
Email:narayanan.sankar007@gmail.com)
4(Mechanical Department, Meenakshi Sudararajan Engineering College, Chennai
Email: vp0053@gmail.com)

Abstract:

The concept of two wheel self-balancing robot is based on Inverted pendulum theory. This type of robot has earned interest and fame among researchers and engineers worldwide as it uses sensors and micro controller to stabilise a falling object. These robots provide exceptional durability and capability due to their small size and low power requirements. These types of implementation find applications in several purposes such as surveillance & transportation. This project is based on developing a self balanced bi- wheeled robot. In particular, the focus is on the electro-mechanical systems & control algorithms required to enable the robot to identify and act in real time.

Keywords—Torque,Self-balance,PID,Stepper motor,Sensors,Accelerometer,Gyroscope

I. INTRODUCTION

THE MAIN OBJECTIVE OF THE PROJECT IS TO DESIGN AND FABRICATE A SELF BALANCING ROBOT USING GYROSCOPE AND ACCELEROMETER SENSOR. THIS WILL HELP IN AUTOMATION OF THE BALANCING OF ROBOT TRAVELLING IN AN INCLINED PLANE OR UNEVEN SURFACE.

The use of this project have a lot of advantages

1. The robot occupies small space and less in weight
2. The fabrication of this type of self balancing robot is simple
3. This robot can travel in small spaces ,inclined plane and even in uneven terrain
4. As this bot contains electronic components it can be controlled remotely.
5. The manuvering of this robot is easy and it can turn a full rotation of 360 degree from a fixed point

This project will help in better understanding the concept of gyroscope which is the main concept based on which self balancing can be done. The advantage of using a stepper motor in this project instead of using a DC motor is to eliminate the delay of operation time, also the stepper does not change its performance in case of low power while the DC motor performance reduces in this case.

There are also many ways in which the self-balancing can be achieved other than using the MPU-6050 gyroscope sensor. Some of the other methods are using of flywheel in which the flywheel acts as a counter couple to control the moment, so that the robot is balanced. The another method is the use of gimbal or in other words control moment gyro in which the moment acts based on the angle of inclination to control it. There is also the use of axles for self-balancing the bot, which is also used in the futuristic concept of the self-balancing bike. However all this types are all based on a common working principle i.e. Gyroscopes, which is the main concept used to determine the falling of the robot and the balancing mechanism are only varied. These different types of balancing mechanism are used based on the design of the model and use of components. The Gyroscope sensor is the simplest way and an easy way of balancing the robot.

COMPONENTS USED

A. Frame

The whole frame of the body is constructed using fabricated acrylic sheet for the base and is supported using steel rods which are locked using nuts and washer. The frame arrangement and dimensions are shown in Fig2.1. The whole components along with its frame weighs 4 kg. For movement, wheels of diameter 100mm is used along with a variable shaft diameter in which it can lock smaller diameter using a screw bolt.

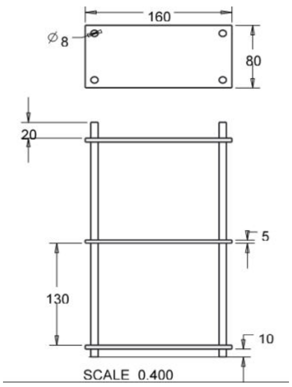


Fig 2.1

B. NEMA-17 Stepper Motor

1. Holding Torque :4.2 kgcm

Fig 2.2 NEMA-17 Stepper Motor

C. Arduino

Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control both physically and digitally.

Arduino board designs use a variety of microprocessors and micro controllers. The boards are equipped with sets of digital and analog input/output pins that may be interfaced to various other expansion boards or breadboards and other type of circuits. The pin configuration of the Arduino Nano is shown in Fig 2.3 the boards feature serial communications interfaces, including USB on some models, which are also used for loading programs from personal computers. The micro-controllers are typically programmed using a terminology of features from the programming languages C and

C++. In addition to using traditional compiler tools, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

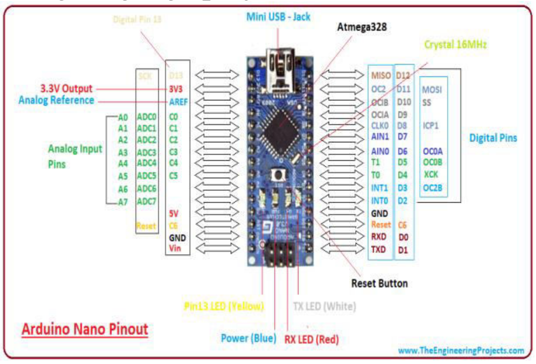


Fig 2.3 Arduino Nano Pin Configuration

D.Motor driver

This product is a carrier board or breakout board for Allegro's A4988

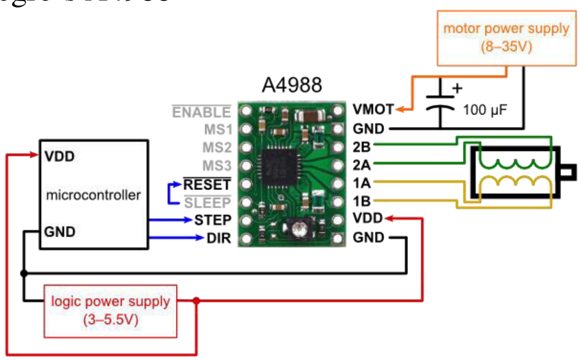


Fig 2.4 A4988 Motor Driver Pin Configuration

E.MPU6050

The MPU 6050 is an IC device used to calculate both axial displacement and angular tilt.

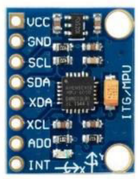


Fig 2.5 MPU-6050 Sensor

F.Power Source

A battery is an electrochemical cell (or enclosed and protected material) which can be charged electrically to provide a static potential for power or released electrical charge when needed. The power source used here will be sealed lead acid batteries which are 12volt, inexpensive and it can be rechargeable.

Fig 2.6 Lead -Acid Battery 12V

III. UNITS

- Torque - Nm (or) kgf-cm
- Dimensions – mm (or) cm
- Speed – rpm
- Force – N
- Weight – kg
- Angle – degree

IV. CALCULATION

Torque Calculation Of Motor and PID Control Working

Components	Mass
Frame	1kg
Motors	.48kg
Batteries	2kg
Wheels	.3kg
Electronics	.22kg
Total Load	4kg

- Radius of the Wheel=5cm=0.05m
- Weight of the robot= 4kg

Net Torque =Weight of Robot *Radius of sprocket wheel

=4*5

=20 kgfcm

Torque required moving the robot in flat surface is1.44 kgfcm and coefficient of friction is considered to be 0.5 for moving in ground.

Reaction Force(F)=Friction*Weight of robot

=0.5*4

=2N

Reaction Force(F)=2N

V. WORKING

G. Working Of PID Control

Changing the set point for the PID controller individually for two motors can control the translational motion of the robot. The motor power increases by the proportional term as the system leans further over and decreases the motor power as the system approaches the upright position .

Let *Kp* be the proportional factor

Kd be the differential factor

Ki be the integral factor

A gain factor, *Kp*, determines how much power to apply to the motor for any given lean.

Proportional Term =*Kp**Error

The differential term of the PID algorithm acts as a damper which reduces the oscillation simultaneously. The other gain factor, *Kd*, determines how much power is applied to the motor.

Differential Term =*Kd**(Error-Last Error)

The proportional and differential terms neither of the algorithm will remove all of the slant because both the terms go to zero as the orientation of the system settles near vertical. The integral term sums the collected error tries to drive the lean towards zero till it achieves the zero point.

Integral Team=*Ki**Sum of Error

Motor Speed= Proportional Term of Motor +Differential Term of Motor +Integral Term of Motor

H.PID Turning

For tuning the PID control of motor speed, the value of *Kp, Ki* and *Kd* assumed by trial and error method. Although this method is not efficient enough, it can control the speed well. The robot starts to oscillate about the axis position by setting *Kp* and *Kd* term as zero initially and then adjusting *Kp*. *Kp* set large enough for the robot to move. With *Kp* set, the robot accelerates faster when off balance by increasing *Ki*. The robot is able to self-balance for a few seconds if *Kp* and *Ki*are properly varied and tuned. Finally, the robot would move about its balanced position more gentle by increasing the value of *Kd*.

	RISE TIME	OVERSHOOTS	SETTLING TIME	STEADY STATE ERROR
Kp	DECREASE	INCREASE	SMALL CHANGE	DECREASE
Ki	DECREASE	INCREASE	INCREASE	ELIMINATE
Kd	INCREASE	DECREASE	DECREASE	NO CHANGE

Table5.1

I. Maximum Angle of Tilt

To determine the maximum angle of tilt the point beyond which the system will not be able to come back to stable front position, Impulsive external forces were provided various times and plotted. As a result of these experiments, it balances many times, but sometimes not. The maximum angle in any of the plots would determine the desired threshold angle. The fig5.1 shows the graph for the maximum angle of tilt. The maximum angle is approximately 12 degrees.

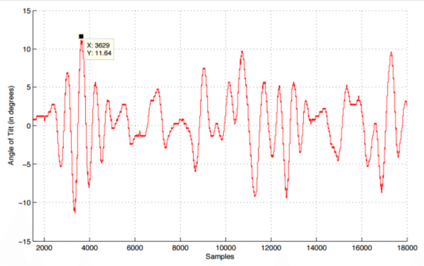


Fig 5.1 Graphical Representation of Maximum Angle of Tilt

J. Bot Working

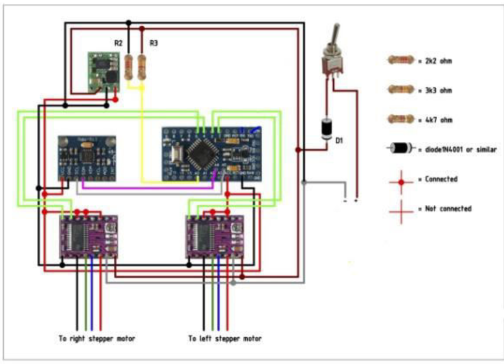
The self-balancing bot works with the principle of providing counter torque to the movement of the robot. This is achieved with the help of accelerometer gyro sensor MPU6050. MPU6050 clock signal is set to 400KHz and is take by SCL which is connected to the analog pin 5 in Arduino. The output of the sensor is given to the micro controller via SDA pin which is connected to A4. The sensor and the microcontroller interact with each other with the help of 'Wire' library. The outputs of the gyro sensor is taken as input to the Arduino (angular displacement).

The program involves PID control i.e. to convert the Arduino to a PID convertor using coding. Once that is achieved there are different constants set for proportional-K_p, integration-K_i and derivation-K_d. Only these constants can be manipulated after the codes are set.

Then the output of the Arduino is given in the digital pins 2,3,4,5 of Arduino. These out pins are connected in such a way that the step of motordriver1 is connected to pin 2 and direction of motordriver1 is connected to pin 3. Similarly, the step of motordriver2 is connected to pin 4 and direction of motordriver2 is connected to pin 5.

The motor driver is given a 3.3V-5V supply with the help of voltage rectifier for the driver to work, this is given in the pins VDD and the ground next to it. Then a 12V supply is given for the motors in the pins VMOT and the ground pin next to it. The Reset is set to sleep by joining both the pins using jumpers.

The output pins of stepper motor drivers 1 and 2- 1A, 1B, 2A, and 2B are connected to the respective output pins.



VI. RESULT

1. This project was successful in achieving its aim to balance a two-wheeled self balancing autonomous robot based on the inverted pendulum model. The control strategy called the proportional integral derivative controller is to control the trajectory of the robot which calculates the exact error value.
2. Modelling based on the inverted pendulum shows that the system is unstable without a controller. A simple PID-controller can be implemented, but only to control the angle deviation, w.

3. Since the demonstrator can receive angular data and position data, it is possible to get data for all the states that are required for a state space controller.

4. The results of the validation process demonstrates that the model is not reliable. That conclusion was made because of the big difference in settling time of the impulses between the physical demonstrator and the corresponding simulation.

5. All required hardware for a robot controlled via LQR is mounted on the demonstrator, so if the errors in the model are handled, the demonstrator is fully prepared for implementation. Though, if the demonstrator is supposed to handle impulses bigger than 8°, faster motors are recommended.

ACKNOWLEDGEMENT

We are grateful to our mentors Mr.P.Jayaganesh and Dr.K.Balasubramaniam for helping us through the course of this experiment.

REFERENCES

1. Liu Kun, Bai Ming, Ni Yuhua, :"Two-wheel self-balanced car based on Kalman filtering and PID algorithm" Vol 1,2011.
2. N. M. Abdul Ghani, N. I. Mat Yatim, N. A. Azmi: "Comparative Assessment for Two Wheels Inverted Pendulum Mobile Robot Using Robust Control".
3. Nawawi, S. W., Ahmad, M. N. and Osman, J. H. S (2008) :"Real-Time Control of Two-Wheeled Inverted Pendulum Mobile Robot"
4. Mrs.Lekshmy.S, Aleesha George, Athira C.V, “Self Balancing Robot” International Journal of Computer Engineering in Research Trends, Volume 2, Issue 12, December-2015.
5. Stepper Motors : Fundamentals, Applications And Design ,By V. V. Athani.
6. Motors for Makers: A Guide to Steppers, Servos, and Other Electrical Machines, By Matthew Scarpino.
7. Properties and Stability of Acrylic Sheet Containing Silica and Poly (methyl Methacrylate)-g-deproteinized Natural Rubber , By Chaiwute Vudjung.
8. Stepper Motors : Fundamentals, Applications And Design, By V.V Athani.
9. A4988 Electronic Component Datasheet ,By Allegro Microsystems.
10. Exploring Arduino: Tools and Techniques for Engineering Wizardry, By Jeremy Blum.
11. Engineering Materials And Mettalurgy ,By R.K. Rajput
12. Basic Sensors in iOS: Programming the Accelerometer, Gyroscope, By Alasdair Allan
13. Lead-Acid Batteries: Science and Technology, By D. Pavlov