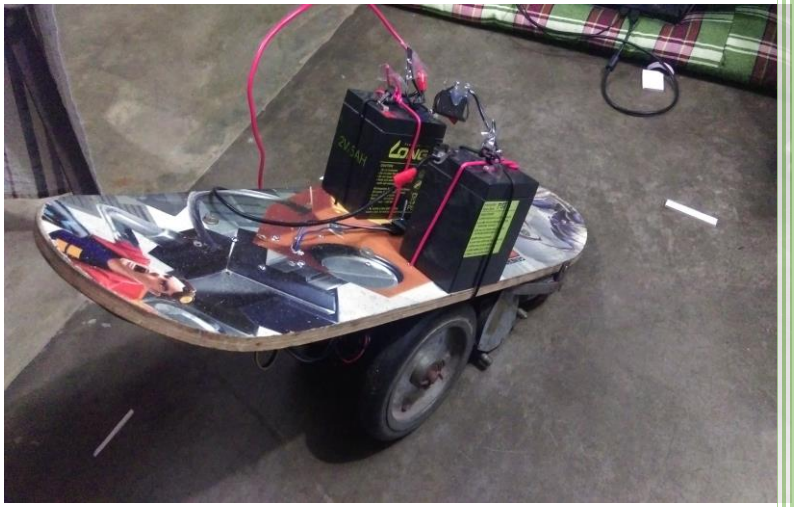
HERMES

Self-balancing Electric Skateboard



Project Group: 05

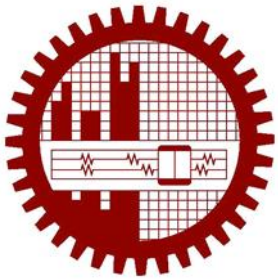
Dept.: EEE

Section : B-1

Level -4 Term -1

EEE 402

Control System I Laboratory



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Date of Submission :

08.06.2016

FORWARDING LETTER

8th June, 2016

Dr. Mohammad Ariful Haque, Professor

Md. Mukhlasur Rahman Tanvir, Lecturer

Dept. of EEE

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Dhaka

Dear Sir,

It is our pleasure to submit the report on "HERMES" (a self-balancing skateboard) under your excellent supervision. Our cities are packed with traffic jam. There are lots of reasons behind it. But if we can reduce the number of vehicles in road and can make the size of personal transportation system smaller, it can go a long way in solving the traffic issues present in our country. That's why our effort has been put on HERMES which is a battery-powered self-balancing skateboard. It can save your time in transportation as well as takes much less area within very limited cost.

Sir, we have tried our best to make this project come true. But there were lots of constraints such as the price of high speed motor. Please consider our limitations in a compassionate way.

Sincerely,

Shovon Dey, Mahdi Zaman, Md. Toufique Aziz, Mustafizur Rahman,

Syed Tanzim Mubarrat.

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ABSTRACT

Hermes is a rechargeable self-balancing electric skateboard. It can easily balance itself on its two wheels placed along its center, so that a user can easily mount Hermes for personal transport. A wired or wireless remote controller will be available for the user to control the speed and direction of Hermes, depending on the user's preference. Also, an emergency kill switch will be present to turn Hermes off for safety.

INTRODUCTION

The goal of this project was to build a system that is practical and pragmatic. A system for use in daily life as well as in industries. It is easy to build, doesn't cost much and mostly environment-friendly.

Hermes is such a vehicle which can make our everyday transportation a lot easier. It is a rechargeable self-balancing electric skateboard. It can easily balance itself on its two wheels placed along its center, so that a user can easily mount on it for personal transport. A wired or wireless remote controller will be available for the user to control the speed and direction of Hermes, depending on the user's preference. Also, an emergency switch will be present to turn it off for safety. Driving mechanism is very easy. When the rider leans forward, Hermes moves forward and when the rider leans back, Hermes moves back.

Hermes is 27inches in length & 8inches in width. It weighs around 8kg. It can balance anything on its two wheels. People weighing upto 100 kgs can easily ride it..

By incorporating some additional features, it may have a significant impact in the transportation system of Bangladesh. A lot of people in this crowded Dhaka city has to use bus for transportation, even though the population outnumbers the supply of buses. So, many people waste hours and hours on

the road. If we work a bit more on this prospect, an alternative solution may be found for the traffic system using Hermes.

EQUIPMENTS

Integral parts

- ✓ Skateboard
- ✓ Wheel(1 pair)
- ✓ 24V DC motor (1 pair)
- ✓ Motor Driver BTS7960 (1 pair)
- ✓ 12 V, 5 Ah Lead-Acid battery(1 pair)
- ✓ Arduino Mega 2560
- ✓ Gyroscope (MPU-6050)
- ✓ 11.1V 800 mAh Li-Po Battery

Miscellaneous

- ✓ Drill machine
- ✓ Soldering Iron
- ✓ Glue gun
- ✓ Super Glue
- ✓ MSeal
- ✓ 12V transformer(for charging Lead-Acid batteries)
- ✓ Switch
- ✓ Jumpers & Cables
- ✓ Wood
- ✓ Screws & Nuts
- ✓ Gears
- ✓ Chain etc.

Managing the equipment:

Required ICs and electronics (e.g, Arduino mega, gyroscope etc) were bought from electronic markets in Patuatuli. The two motors, wheels, chains were bought from salvage markets in Dholaikhal. Skateboard was bought from Gulistan. Only the motor drivers were ordered online.

Description and Placement of the Equipment:

Wheels: These are wheels bought from salvage markets. The two wheels are placed at the center of the skateboard. An axis of rod is fixed strongly under the board via an angle bracket. The wheels can rotate around this axis separately. The wheels are to be driven by the motors.

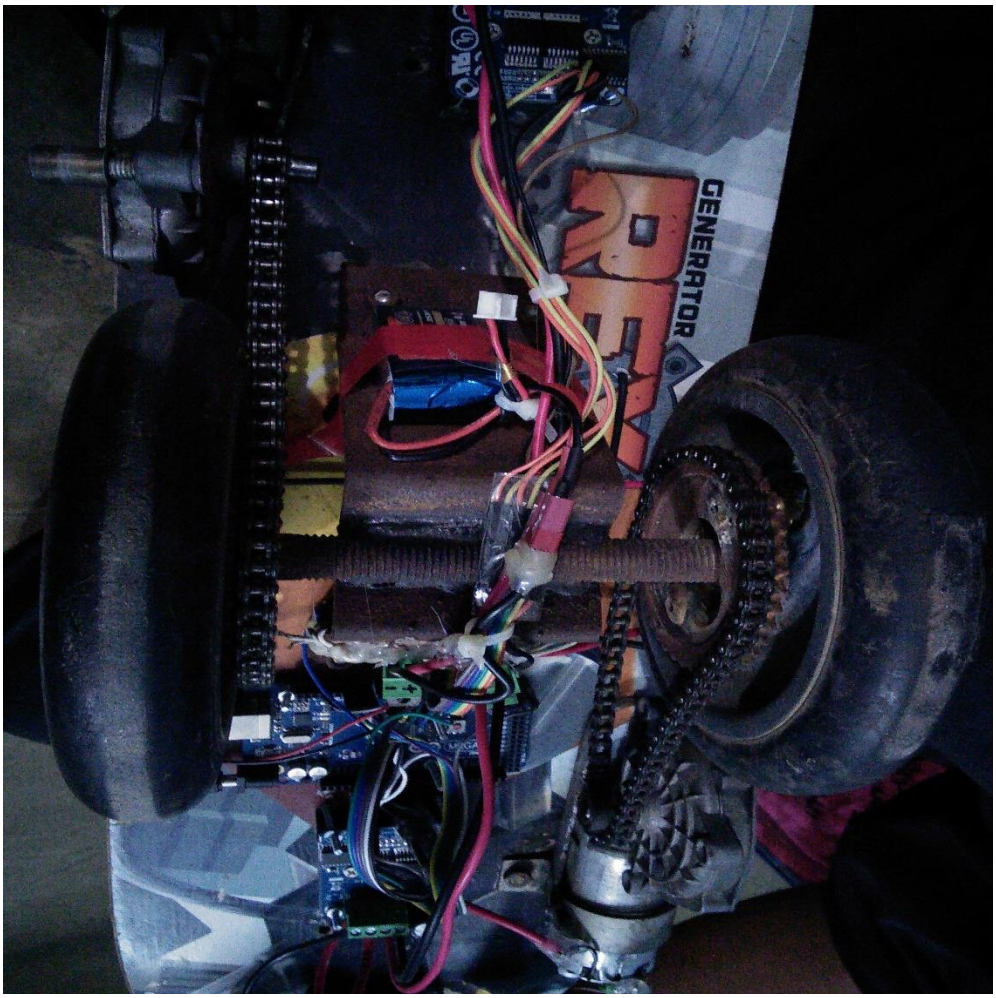


Fig. Wheels along with their axis

Motors: These are each 24V DC gear motors, also bought from salvage markets. The two motors are used to drive two wheels separately. Each motor is placed at the edge of the board facing the perimeter of the wheel. Each motor & wheel is connected using gears and chain. Chain should not be too tight nor too loose. It was tightened using trial and error method.

Fig. Motor connected to wheel via chain

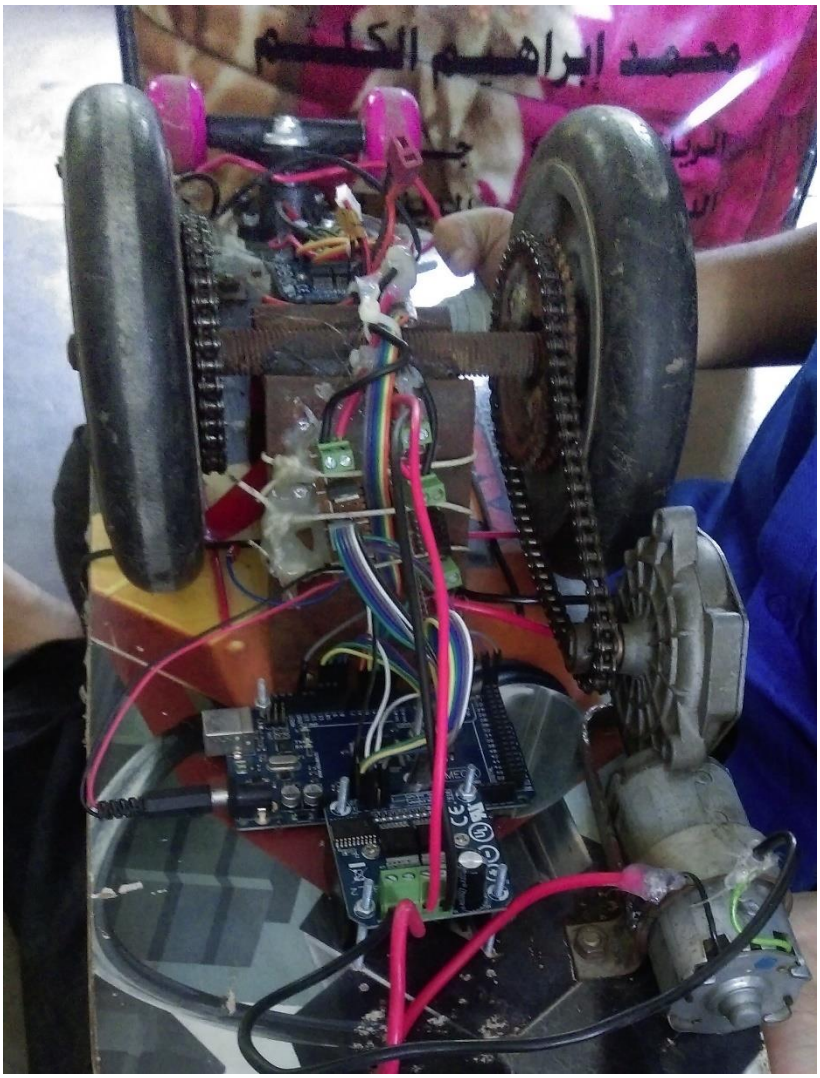


Fig: Each motor connected to each wheel

Arduino Mega 2560: The Arduino Mega 2560 works as the control center of the whole system. It is placed at one side of the angle bracket. It is fixed with the board using screws & nuts.

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Fig: Arduino Mega 2560 specifications

Motor Controller BTS-7960: The BTS 7960 is a fully integrated high current half bridge for motor drive applications. The Operating Voltage is 24V And it can handle continuous current of 43A Max. It has PWM capability of up to 25 kHz combined with active freewheeling. The motor controllers are placed at the side of each motor. Each motor is connected to one motor controller. Each motor controller is also powered by the lead acid batteries in series. Also, the pins of the motor controllers are connected to different pins on the Arduino Mega 2560.

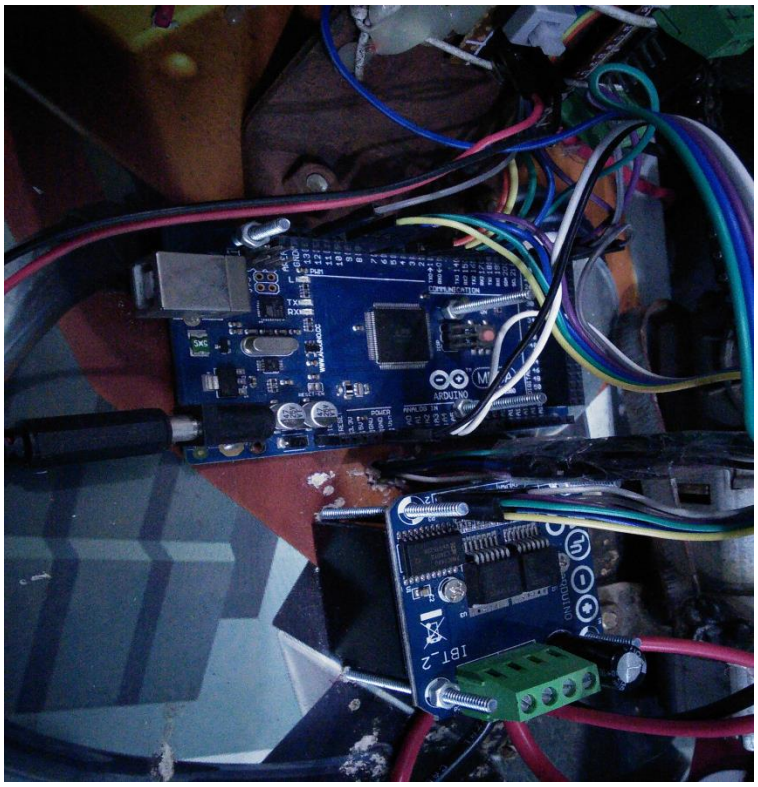


Fig. motor controllers along with Arduino

Lead-Acid Batteries: two 12 V batteries are connected in series to provide 24 V. they are placed at the middle of the top of board. Necessary connections are made using crocodile clips.

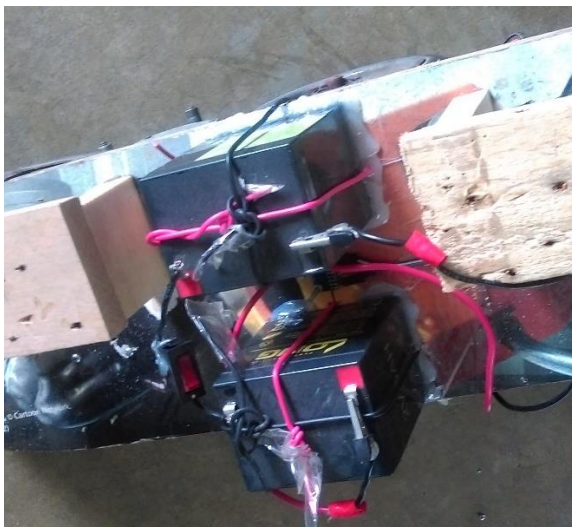


Fig. Top view of Hermes showing the two Lead-acid batteries connected in series

Gyroscope: The MPU-6050 sensor contains a MEMS accelerometer and a MEMS gyro in a single chip. it contains 16-bits analog to digital conversion hardware for each channel. Therefor it captures the x, y, and z channel at the same time. It is placed exactly at the middle of the top of the board. Its pins are connected to different pins on the Arduino Mega 2560. As the connections are to be made at the bottom of the board, we made a hole in the board using drill.

- Power supply: 3v-5V power
- gyroscope range: + 250 500 1000 2000 °/ s
- Acceleration range: ± 2 ± 4 ± 8 ± 16 g

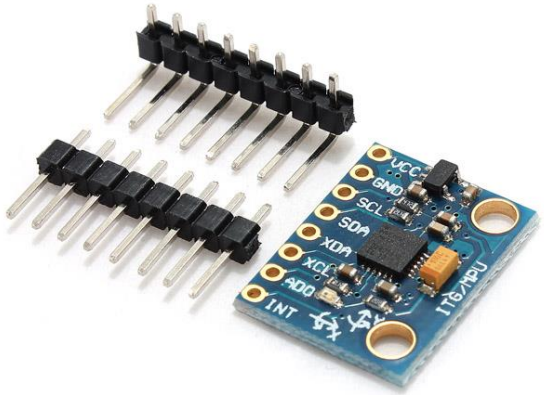


Fig. Gyroscope

LiPo battery: It is a 11.1V 800 mAh LiPo battery. It was fastened to the underside of the skateboard. It was used to power the Arduino through a 7809 voltage regulator.

Fig: 11.1V 800 mAh LiPo battery

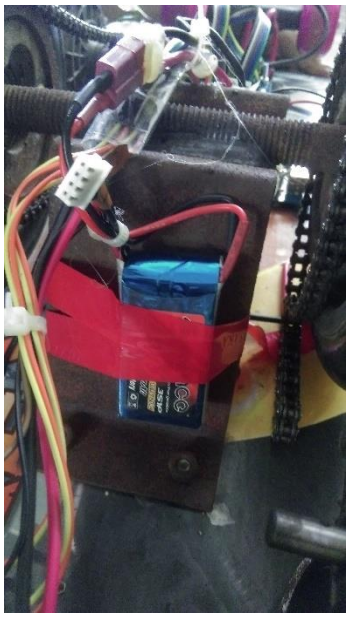


Fig: LiPo battery fastened to the skateboard

LiPo battery charger: A LiPo battery charger was purchased along with the battery to recharge it from time to time.

Fig: LiPo battery charger

Lead acid battery charger: Lead acid battery charger was not available in the market. So, we had to make one. For that, we neede a 12V 3A transformer, a

10A bridge rectifier and some 100uF 50V capacitors. We transformed the 220V DC to 12V DC using a transformer and a bridge rectifier was used to rectify that to about 18V DC. 3 capacitors were used in parallel to smoothen the rectified dc.

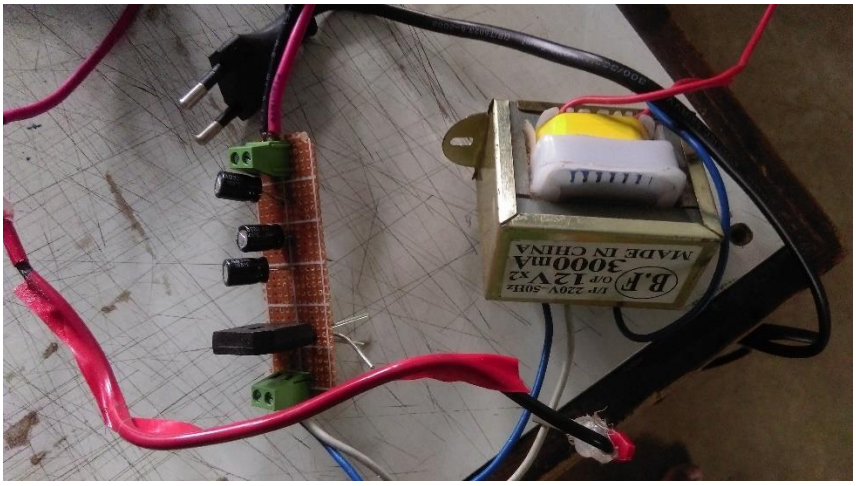
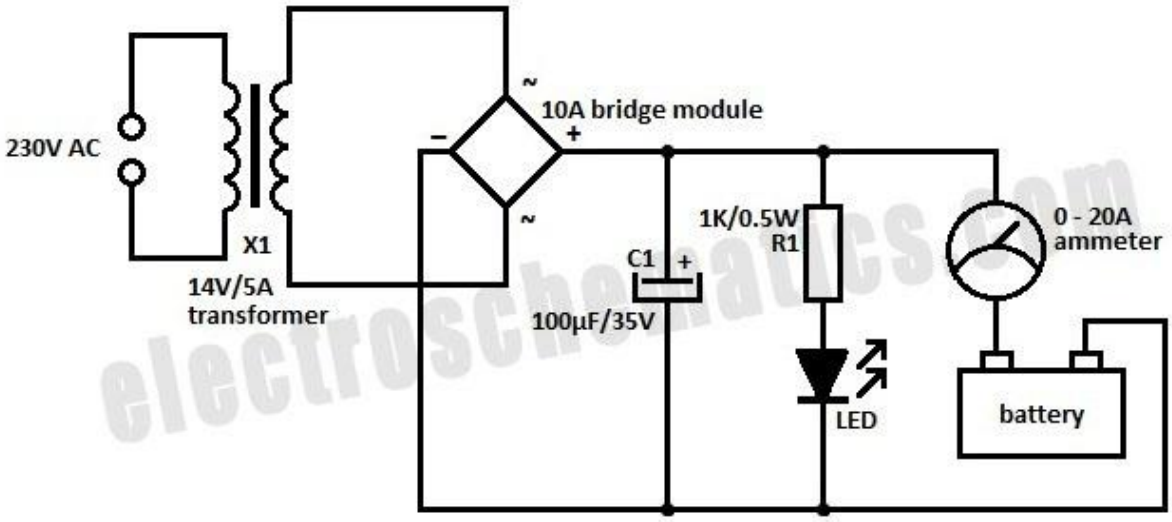


Fig: Lead acid battery charger

The following image was used as a reference.



Miscellaneous: There is also a platform on Hermes where the user can easily place their foot.

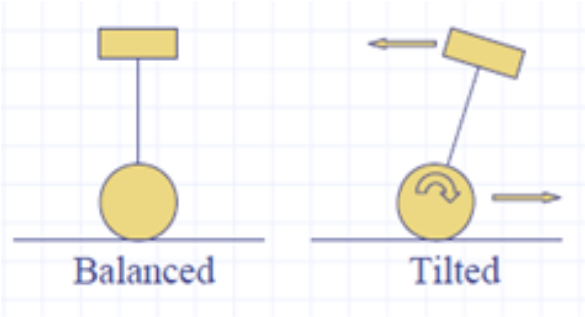
WORKING PRINCIPLE

Overview:

- ✓ 2 wheels are placed at the center of the skate board. They rotate via a fixed axis.
- ✓ 2 motors are placed at two sides of the board. Each motor is linked with a wheel with chain.
- ✓ A motor driver is used to drive a motor.
- ✓ A gyroscope is used to measure the inclination of the skateboard on both forward and backward directions.
- ✓ All these are interfaced to an Arduino mega which acts as the control unit of the full system.
- ✓ Data is read from the gyroscope, processed and sent by the Arduino to the motors turning the wheels.
- ✓ To drive the skateboard, the user simply has to lean forward to drive forward and lean backwards to drive backwards.
- ✓ Two 12V 5Ah lead-acid batteries are fixed at the top of the skate board. They supply the required power for the motors. Another 11.1V 800 mAh LiPo battery supplies power for the Arduino.
- ✓ 2 small sized wheels are placed at the edge of each side of skateboard for safety issue.
- ✓ If anyone places himself on the board, it will first balance itself and then the user can go forward or backward.
- ✓ With a controller, one can control direction. The user can steer left or right and trim the balancing factor forward or backward.

Theory:

Hermes will be prevented from falling by giving acceleration to the wheels according to its inclination from the vertical. If the bot gets tilts by an angle, the wheels will accelerate in that direction. Then, the center of mass of the bot will experience a pseudo force which will apply a torque opposite to the direction of tilt.



Connections:

Connection between MPU-6050 gyroscope and Ardunio Mega 2560 is made as follows:

Gyroscope pin	Arduino Mega pin
VCC	5V
GND	GND
SCL	Digital pin 21
SDA	Digital pin 20
INT	Digital pin 2

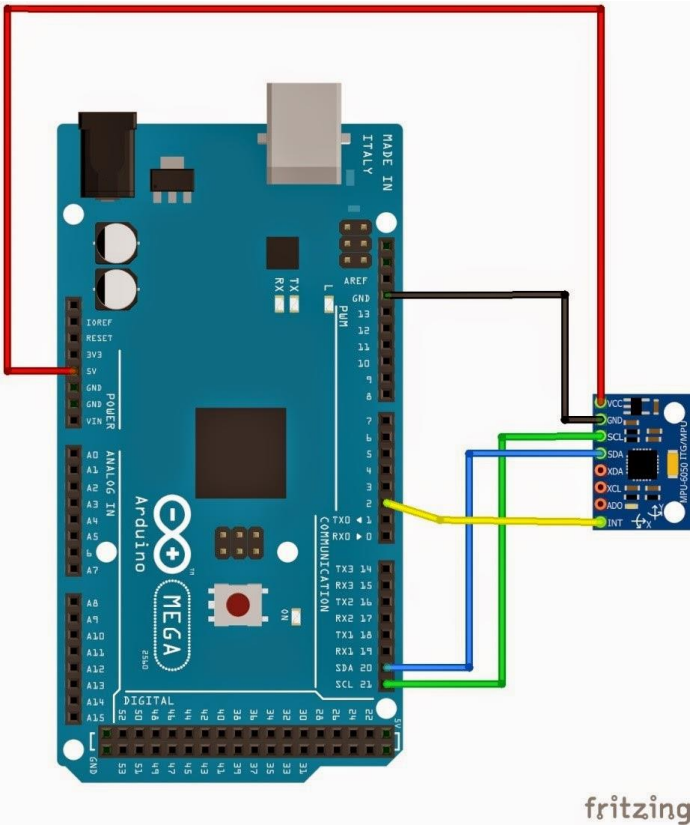


Fig: Connection between gyroscope and Arduino Mega

The connection between each motor and motor controller BTS-7960, which in turn connects to the Arduino Mega 2560 is a follows:

The image below was used as a reference for the connection. Of course, the Arduino Uno in the figure was replaced by our Arduino Mega. And the pin numbers were also different. But the most important thing we had to be aware of was to connect the RPWM and LPWM pins of the motor controllers to PWM pins on the Arduino Mega. Each motor controller was powered using the two 12V lead-acid batteries connected in series.

Motor controller 1 pins	Arduino Mega pins
VCC	5V
GND	GND
L_EN	Digital pin 8

R_EN	Digital pin 9
LPWM	Digital pin 10
RPWM	Digital pin 11

Motor controller 2 pins	**Arduino Mega pins**
VCC	5V
GND	GND
L_EN	Digital pin 3
R_EN	Digital pin 4
LPWM	Digital pin 5
RPWM	Digital pin 6

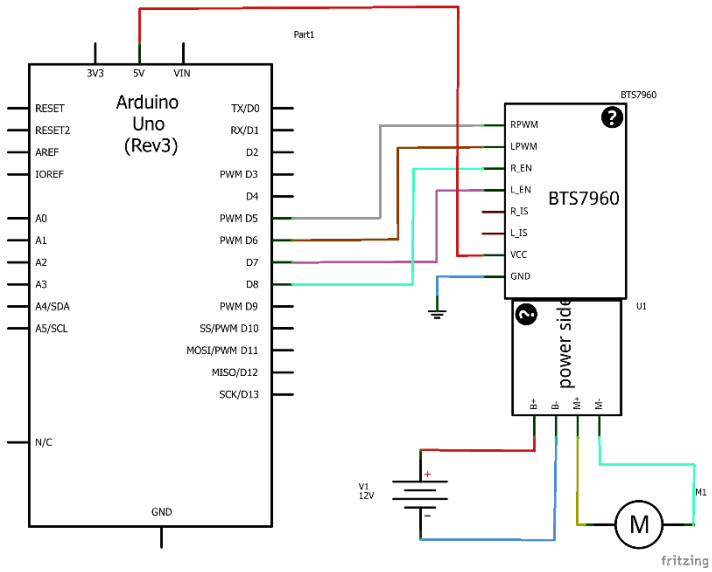


Fig: Reference image for connection between each motor with a motor controller BTS-7960, which connects to the Ardunio Mega

The Arduino Mega was separately powered using a 11.1V 800 mAh LiPo battery through a 7809 voltage regulator, so that it constantly supplies 9V to the Arduino Mega.

Working Procedure:

We could measure the yaw, pitch and roll of the skateboard from the gyroscope using a library in Arduino.

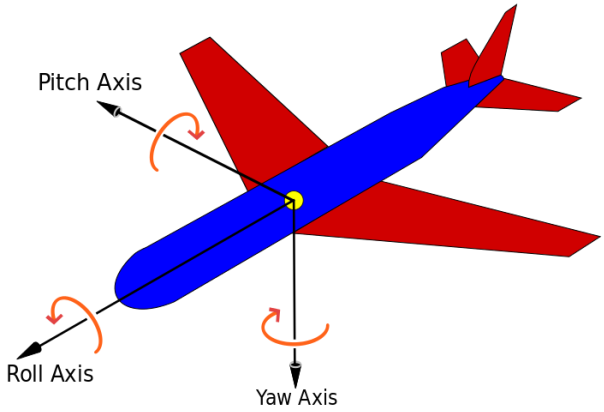


Fig: Example of yaw, pitch and roll for an aeroplane

But since we only needed to calculate the inclination angle of the board, we only had to use any one of the three. In our project we have used the pitch. The change in angle is measured via gyroscope and using PID algorithm we have measured the value of speed for the motor.

The speed of the motor has been sent to the PWM Pins of the Arduino mega. From Arduino mega , it was sent to motor controller from which motor was driven. We have used two separate motor controllers for two motors.

APPLICATIONS

- ✓ Cheap personal transportation system. It will be able to reach speeds up to 5-10 kmph and will be able to travel about 5 km in one full charge.
- ✓ As the Segway can be manually controlled by the user or automated, it can be used in transportation of hazardous and corrosive materials, even during turbulence.
- ✓ Extremely useful in self-stabilization of robots.
- ✓ Application in laboratory and production houses.
- ✓ Also useful for waiters and automated catering bots in restaurants and cafes.

LIMITATIONS

- ✓ The motors that we have used do not have enough speed. Finding the proper motors which have preferable torque-speed characteristics. We were also constrained by budget problems. For this reason, Hermes cannot balance heavier object. But by using better and more expensive motors, this problem can easily be solved.
- ✓ We needed to use 24 V power supply for driving the motors. For that, LiPo batteries would have been most preferable as they have very low weight to power ratio. But, they are also very expensive. So, we had to opt for using two 12 V Lead-acid batteries. Although they are cheap, they are very heavy, which reduced the performance of Hermes.

IMPROVEMENT OPTIONS

Since this prototype of Hermes is a budget version, there is a lot of room for improvement. For example, its balance can be greatly improved by using 250Watt 24V electric scooter motors, which are fast enough to balance heavy objects. Also, using pneumatic tyres instead of the old wheels and using LiPo batteries instead of the lead-acid batteries will greatly improve its performance. Furthermore, instead of using a skateboard, the whole chassis can be built from scratch in order to fully customize it. Also, the chain and gear system of motor-wheel drive can be replaced with only gear system, which is more costly and complex, but also more effective.

CONCLUSION

We believe the Self-Balancing Segway is a practical and useful project that has the potential to influence the lives of many. We hope it will prove to be a useful utility. And we also hope that it will inspire others to undertake innovative projects that are much, much better.

DISCUSSION

- ✓ The mechanical construction was one of the most challenging part of the project. The placement and connections of all the components had to be near perfect.
- ✓ The chain and gear system of motor-wheel drive caused us some problems. It was difficult to get the chain tension exactly right and it wasn't very effective. The chains tend to fall off after driving some time. A gear-only system for motor-wheel drive would have been much superior, but that was more costly and complex.
- ✓ The motors tend to get hot after driving for a few minutes.
- ✓ The PID tuning was also one of the most difficult part of the project. The Kp, Ki and Kd values were chosen after a lot of trial and error, so that we could get the best performance out of the system.

GLOSSARY

Yaw: It is one of the Tait-Bryan angle which indicates the heading of the vehicle.

Pitch: It is the angle of the pitch-cone of the element and its axis.

Roll: It is the angle at which the object rotates about its own axis.

Skateboard: It is a board with wheels. People stand on it and uses their forces to move forward

Li-Po: Lithium-Polymer