# WobbleBot

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# 1 Introduction

## 1.1 Objective

Problem: It is a challenge to build a robot that is capable of balancing atop a cylinder. Many people studying robotics or controls would be interested in experimenting and improving upon a robotic platform like this, and it does not currently exist.

Solution: We will build such a robot in an affordable way, using hardware and software that enables precise realization of the control algorithm chosen by the researcher. The robot will measure data, process it, and actuate its motor so that it will stay on top of the cylinder. Once this project is complete, it will be easier for others interested in the problem to test out their own designs.

## 1.2 Background

People have been designing these kinds of robots for years, using different kinds of sensors, algorithms, and actuators to make them better and better. A good example of such a robot is our very own Professor Dan Block's Segbot [1]. Today, fast processors and algorithms exist along with precision sensors and actuators, making these kind of robots possible.

This robot is an example of a dynamic, unstable system. In order to create and control such a dynamic system, many design choices must be made. First, the system itself must be designed and manufactured in a way that is predictable and controllable. An accurate system model must be developed so that a good controller can be designed. The controller is then installed into the system, used to precisely and predictably steer the unstable system towards stability, as fast as possible. This particular robot was chosen for the complexity of the robot's dynamics. It will take intelligent system design, accurate system modeling, and excellent controller design to create a robot that is capable of high performance at the task of balancing on top of a cylinder.

## 1.3 High-level Requirements:

- The robot must be able to recover from an initial tilt angle of 40 degrees from vertical
- The robot must cost less than $200 to build
- The robot will be able to move a distance of 3 feet along the ground in less than 3 seconds. The robot and cylinder must be stationary at both the beginning and end of the movement.

# 2 Design

## 2.1 Physical Design:

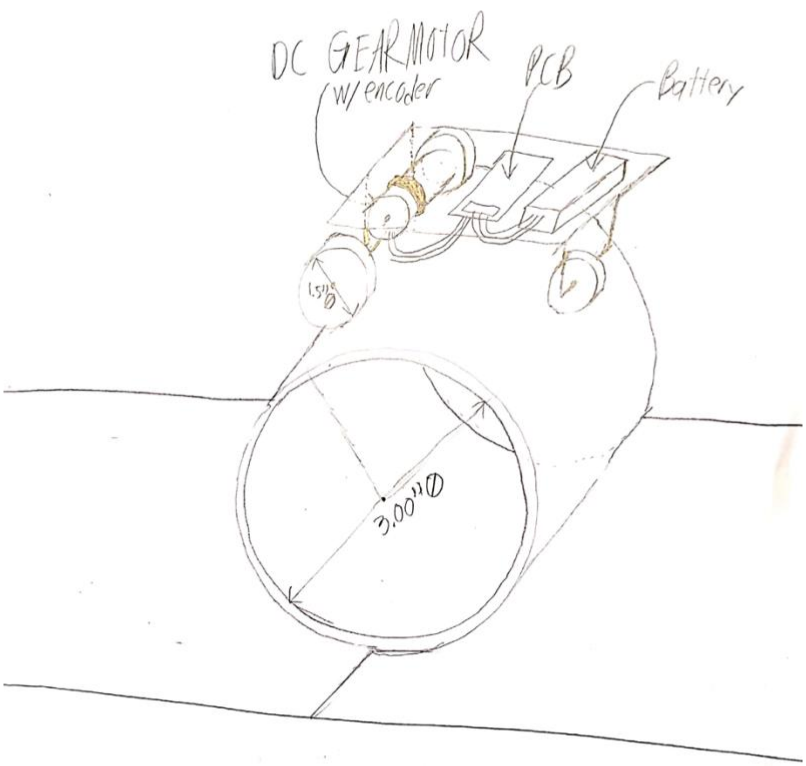


*Figure 1: Physical Design Sketch*

This sketch represents the physical design of the robot. It consists of three wheels attached to a platform holding the PCB and (possibly) a battery. One of the three wheels is driven by a DC gear motor. The robot rests atop a hollow cylinder.

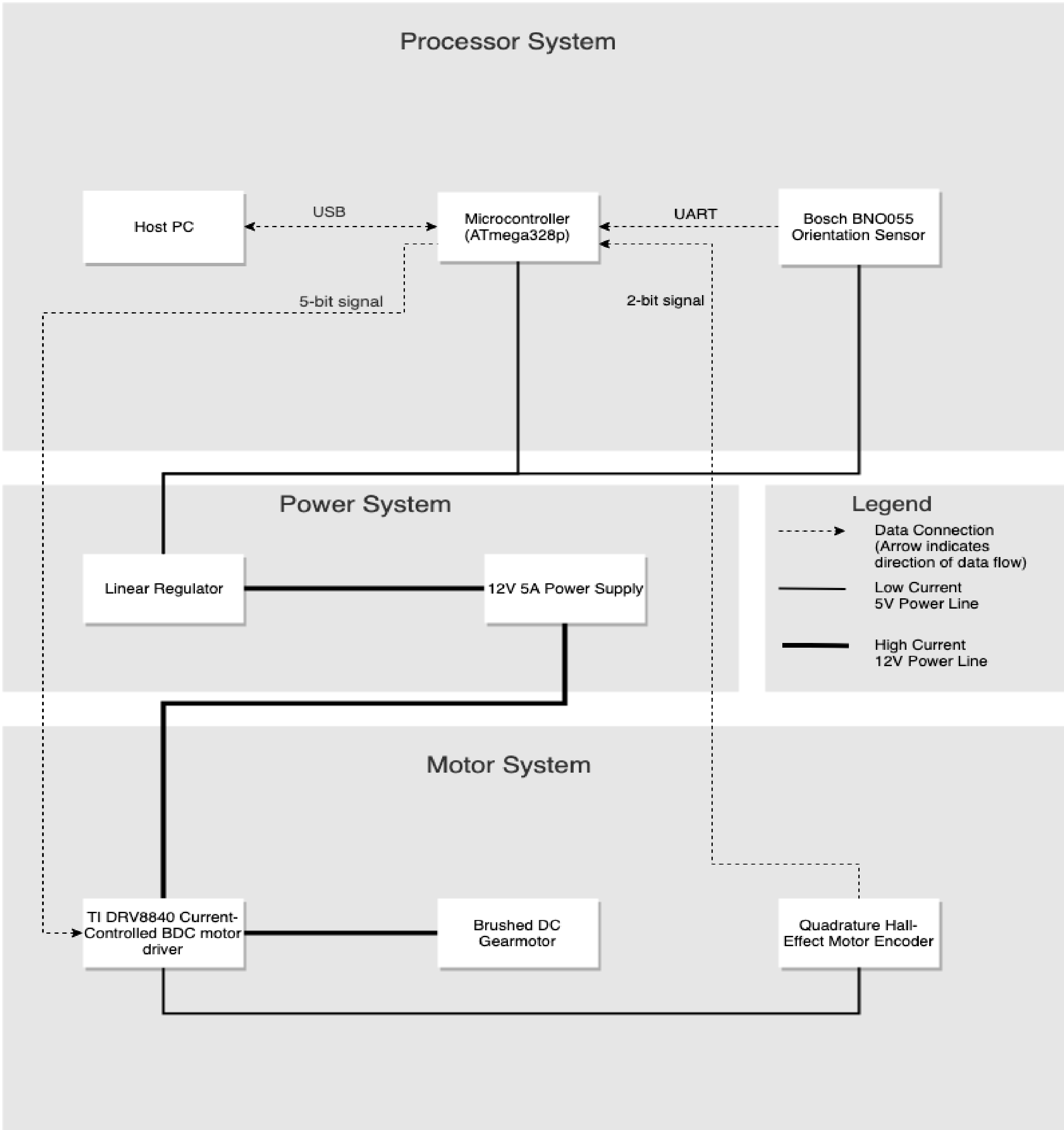


*Figure 2: Block Diagram*

The design illustrated will satisfy the high level requirements. The fast, high accuracy orientation sensor and motor encoder, paired with the fast processor and torque controlled motor system will be able to return the robot to stability from a 40 degree tilt angle, and it will be able to drive the robot quickly from one spot to another. All the components involved will have a sum cost of less than 200 USD.

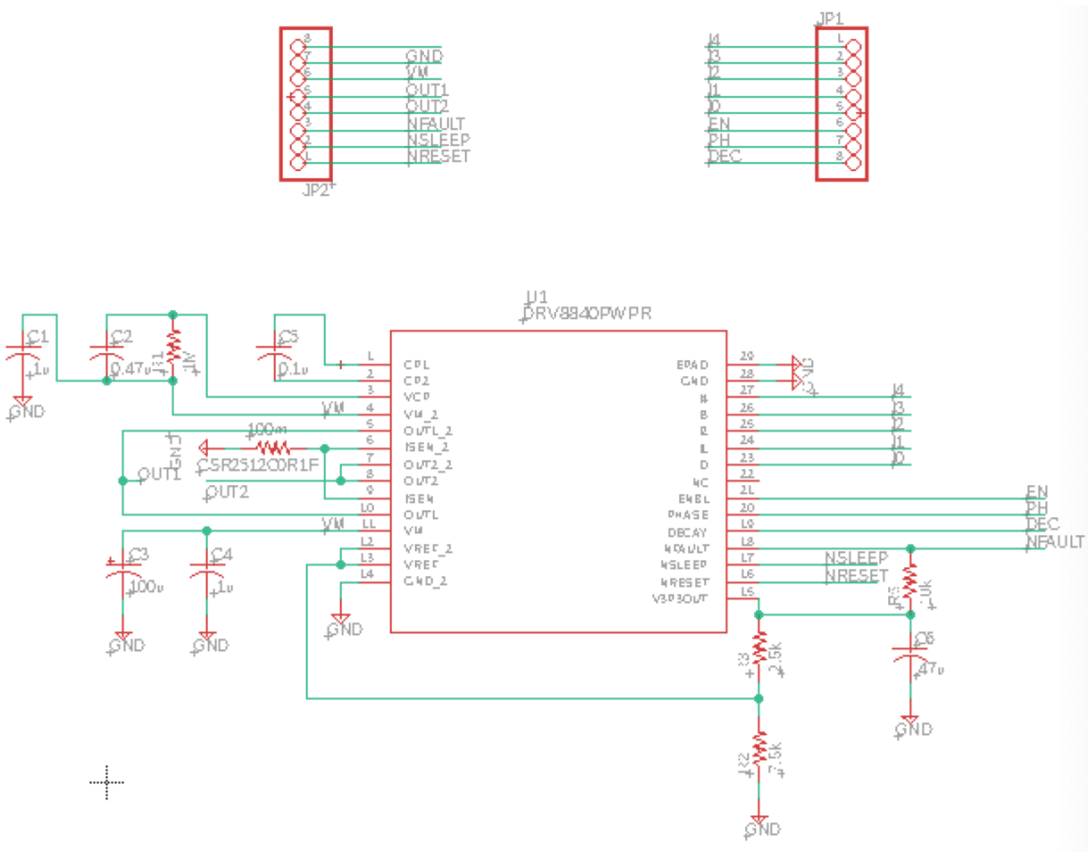


*Figure 3: Motor Driver Schematic*

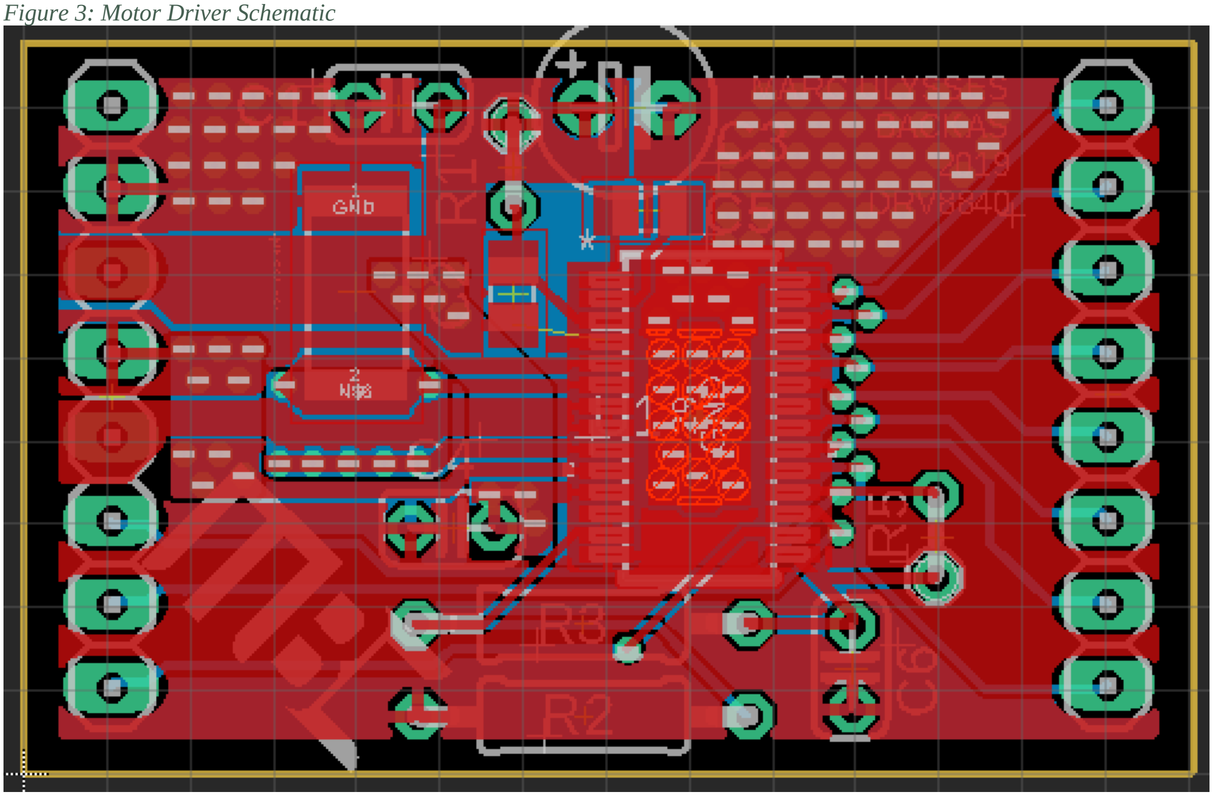


*Figure 4: Motor Driver Layout*

## 2.1 Power System

This system will deliver power to all other blocks in our design so that the robot remains functional. The system consists of a 12V 5A power supply and a 5V linear regulator.

### 2.1.1 Wall Power Supply

Supplies the power needed by all other blocks. Once it is connected to the PCB via a barrel connector, it is directly connected to the motor driver and the linear regulator through copper traces on the PCB.

*Requirement 1: Must provide 5A of current at 12V continuously without overheating.*
*Requirement 2: Output voltage must remain within 5% of 12V.*

### 2.1.2 Linear Regulator(LM1117-5.0/NOPB)

Sources the stable 5V signal needed to power the MCU and orientation sensor.

*Requirement 1: Must provide the maximum current required by the components it supplies at 5V continuously while staying cooler than 125 degrees Celsius.*
*Requirement 2: Voltage output must remain within 5% of 5V over all conditions.*

## 2.2 Motor System

This system will exert the necessary torque, calculated by the processor system, on the drive wheel to balance the robot.

### 2.2.1 Motor (ROBOT ZONE 638260)

Converts current output by motor driver into torque output to the drive wheel. The torque applied will drive the robot toward stability atop the cylinder.

*Requirement 1: Must rotate at a max speed of 153rpm*
*Requirement 2: Provide at least 1.86 in-lbs of torque when stalled.*
*Requirement 3: Must provide torque output proportional to the applied current*
*Requirement 4: Must not overheat during operation under load*

### 2.2.2 Motor Driver (TI-DRV8840)

Converts the digital control signal from the MCU into a precise current used to drive the motor.

*Requirement 1: Must output maximum of 5A of current at 12V continuously*
*Requirement 2: Must output current proportional to control signal (coefficient TBD) through motor load*

### 2.2.3 Motor Encoders (included with motor)

Reports the shaft position of the motor to MCU. Necessary to compute proper control signal.

*Requirement 1: Must report shaft position within 5% accuracy at all times*
*Requirement 2: Must report shaft position at least 100 times per second*

## 2.3 Processor System

### 2.3.1 Microcontroller (ATmega328P)

The microcontroller (or MCU) will run the control algorithm, processing data prom the sensors and generating a control signal for the motor driver.

*Requirement 1: Must process sensor data and output control signal at 100Hz*
*Requirement 2: Must communicate with orientation sensor over UART*

### 2.3.2 Orientation Sensor (Adafruit BNO055 absolute orientation sensor)

Measures the tilt angle of the robot in the world reference frame, reporting it to the MCU. The goal of the robot is to drive this angle to zero degrees from vertical

*Requirement 1: Must report tilt angle with less than 3% error at all times*
*Requirement 2: Must report tilt angle at least 100 times per second*

## 2.4 Risk Analysis

The block that poses the greatest risk to the success of the project is the orientation sensor. This sensor works by fusing data from three different sensors, with some error associated with each. The output of this sensor is an estimate of the actual quantity, and if it contains too much error, the MCU will not calculate the correct control signal required to balance the system, and the robot will fail to balance atop the cylinder altogether.

# 3 Safety and Ethics

Our robot contains hard, possibly fast moving parts which could cause injury to a person in the event of a collision. This event would go against IEEE #9 “to avoid injuring others.”[2] To avoid this, people will be kept clear of the robot’s trajectory while it is powered on, and a group member will be prepared to disconnect power rapidly if the robot begins to behave dangerously.

Our project has the potential of furthering others' knowledge in the area of control systems and robotics, but only if it is made available for use. This concerns IEEE code of ethics #5, “to improve the understanding by individuals and society of the capabilities...of conventional and emerging technologies, including intelligent systems.”[2] To abide by this, our hardware and software designs will be open source, freely available for duplication by anyone interested in the topic.

Our project team consists of three students who wish to gain valuable technical experience. Although there are many individual areas of work to be done, it is possible for one or more group members to take responsibility for the project’s completion away from the others, denying them of the experience they wish to gain. This would go against the IEEE code of ethics #10, which requires its members to “assist colleagues and co-workers in their professional development.”[2] To prevent this, our group will ensure the work to be done is shared equally, and allocated according to each member’s overall career development goals.

# References

[1]U. Control Systems Instructional Laboratory at University of Illinois, "UIUC Segbot - Home", *Coecsl.ece.illinois.edu*, 2019. [Online]. Available: http://coecsl.ece.illinois.edu/segbot/segbot.html. [Accessed: 20- Sep- 2019].

[2] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 9-19 Sep-2019]