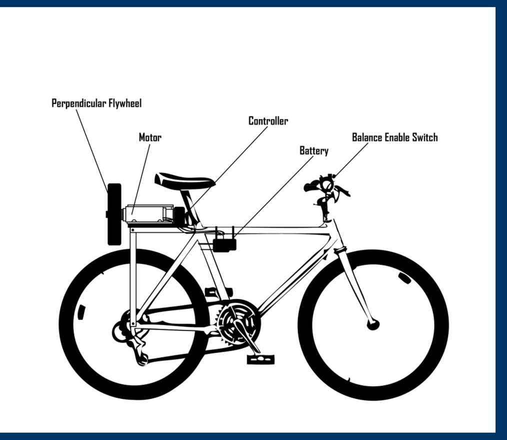
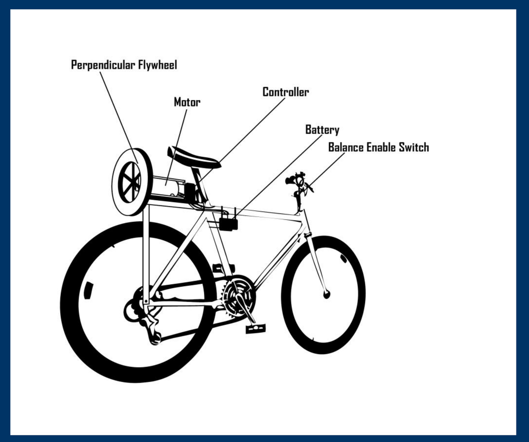


Assisted Balance Bicycle

Daniel Dunbar, Daniel Golden, Mason Nixon, Brett Smith, Bryan Wall

Auburn University
Electrical Engineering

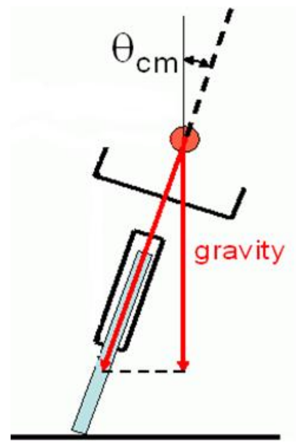


Concept

Riding a bike is an action that many people take for granted. However, the theory behind keeping a bike balanced is a nontrivial matter. The problem of balancing a bicycle is directly comparable to the classic nonlinear control systems problem of the inverted pendulum. There are many ways to go about balancing a bike. One way is to steer out of a fall. Another is to use a gyroscope to stabilize the bike. The method chosen for this design was to use a rotating mass attached to the bike that would generate a force in opposition to the fall of the bike that would assist a person in riding.

Bicycle Dynamics

A falling bicycle generates a torque, also called a moment. The force being applied to the bike by gravity can be modeled as a single force acting on the center of gravity for the bike. Once the center of gravity has been calculated, and the mass is known, the angle, velocity, and moment of the bike as it falls can be calculated for any given time.

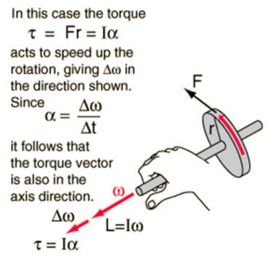


Bike Falling

$$T_b = M_b \times {R_b}^2 \times \alpha_b$$

Flywheel Dynamics

The primary principal that allows a falling object, such as a bicycle, to have its position and angular acceleration changed by an accelerating flywheel is something that is called "coupled forces". This essentially means that as long as the flywheel is fixed to the bicycle, the moment, also called torque, which is generated by the angularly accelerating flywheel, is transferred to the angular acceleration of the bicycle which is then used to rotate the bicycle back to the vertical position.



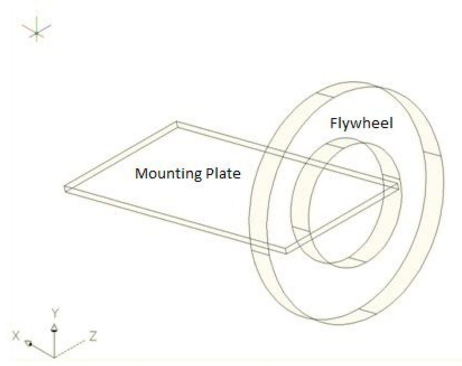
Flywheel

$$M_b \times {R_b}^2 \times \alpha_b = M_f \times {R_f}^2 \times \alpha_f$$

Structure

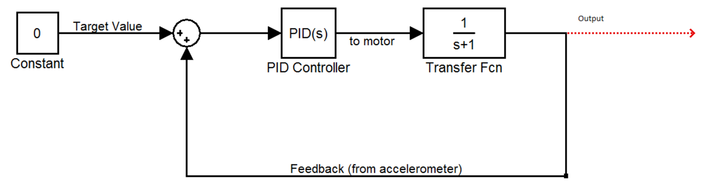
An aluminum mounting plate was used to attach the motor, the motor controller, DC/DC converter, and the microcontroller to the bicycle. The mounting plate is secured at three points: on mounting brackets just below the seat, and on each side of the rear wheel axel. The mounting design was chosen to decrease torque loss due to torsion. The battery for the system operation is mounted on a wooden shelf in the middle of the bar just above the pedals. This position was selected in an effort to lower the center of gravity.

Flywheel



Balancing Control System

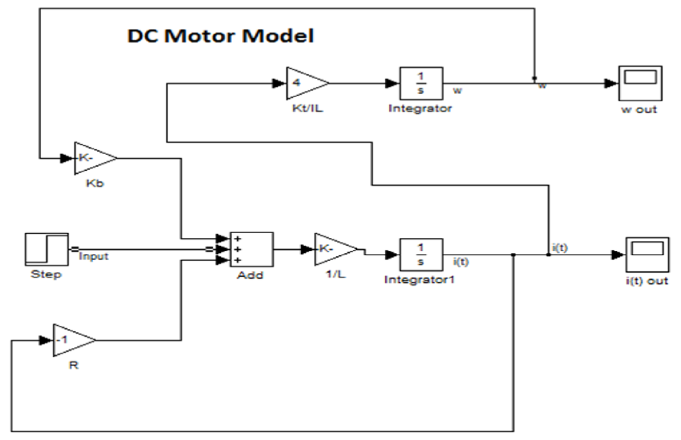
- Using a PID Controller



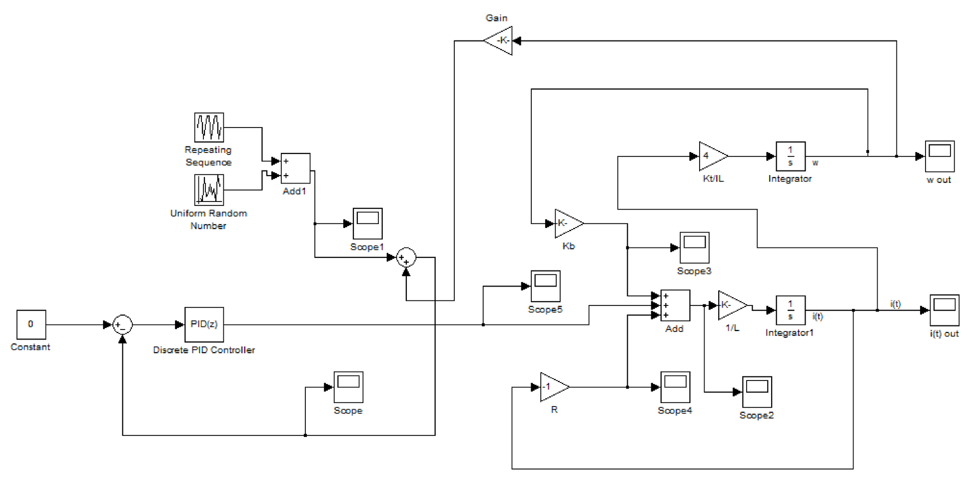
- Simulate Control System using SIMULINK
- Model the motor (plant) using differential equations:

$$\frac{d\omega(t)}{dt} = \frac{K_T}{I_L} i(t) \quad , \quad \frac{di(t)}{dt} = \frac{1}{L}[V_s - Ki(t) - K_b\omega(t)]$$

- K_T, I_L, R, L, and K_b are parameters of the motor



- Implemented in full SIMULINK model



- Implemented on Microcontroller using embedded C programming

Motor and Power System

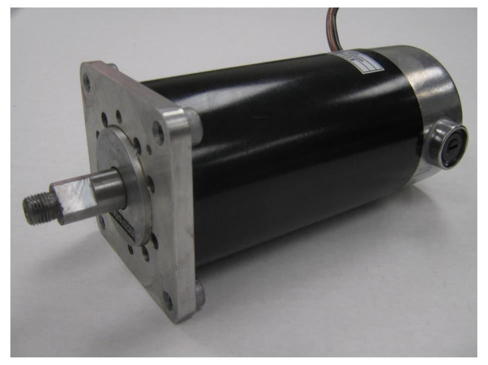


Figure 1

Figure 2

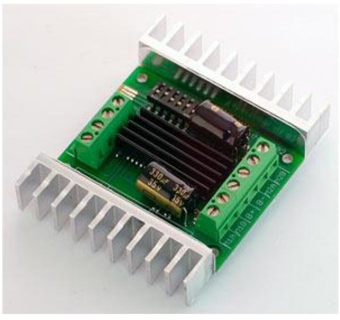


Figure 3

Figure 4

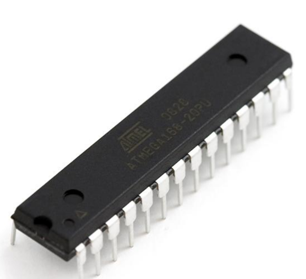
- 24V, 500W, 4300 RPM Motor (Figure 1)
- 18V Litheon™ Battery (Figure 2)
- Sabertooth 2x25 Motor Driver Rated at 24V, 25A (Figure 3)
- 18V Litheon™ 30-Minute Battery Charger (Figure 4)

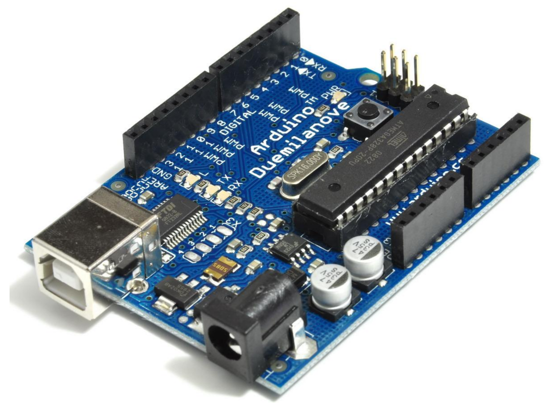
Embedded Software Architecture

For our embedded hardware system, we chose to use an ATmega168 processor via the Arduino Duemilanove. Inputs to the hardware include both analog and digital inputs from various switches and sensors. Our embedded software is then responsible for reading those inputs and determining how to adjust the microcontroller's outputs. The decision logic executes according to the software flowchart below.

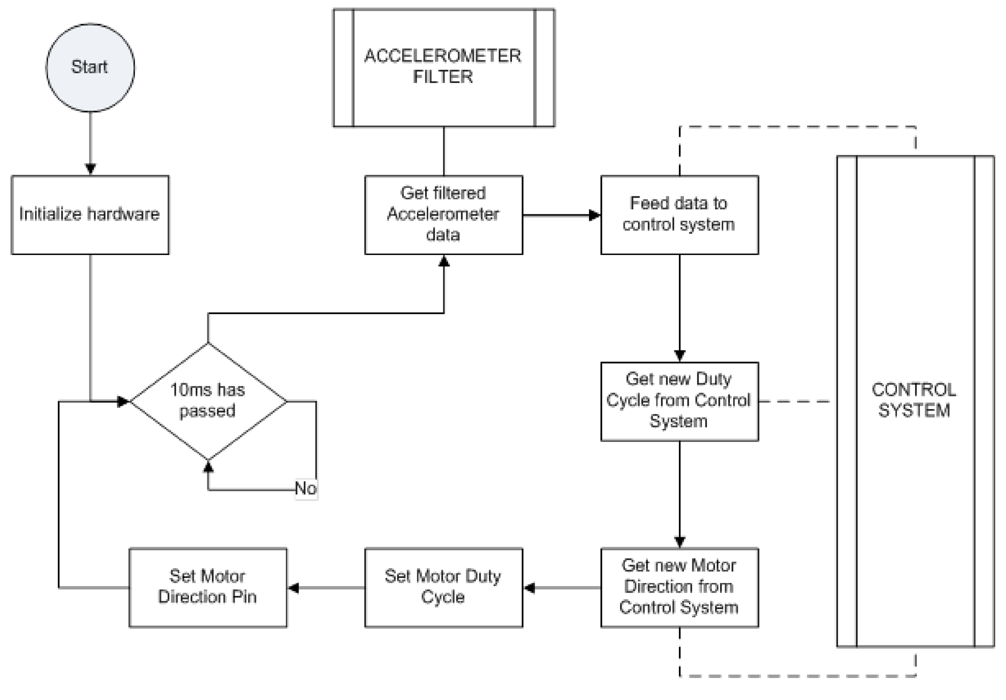
Microcontroller

Atmel AVR ATmega168 → Arduino Duemilanove Board

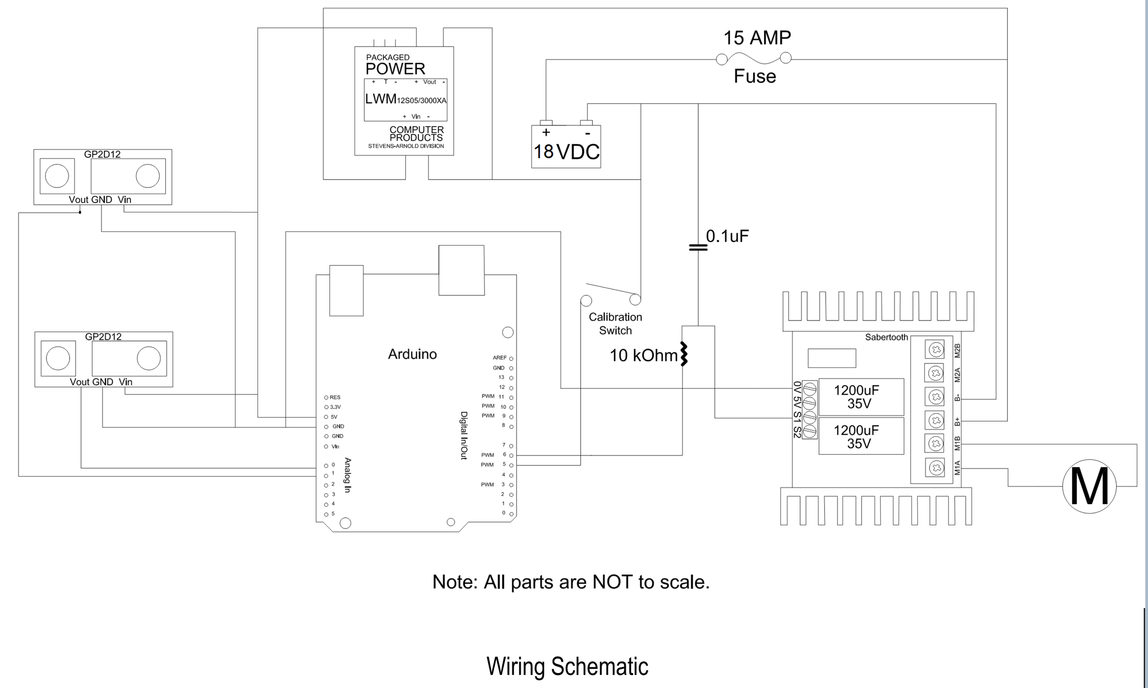




Software Flowchart



Electrical Schematic



Schematic created in AutoCAD 2009

Budget

Item	Price
Batteries/Charger	$153.49
Motor	$60.00*
Flywheel	$100.00*
Bike	$50.00*
Microcontroller	$29.99
Motor Controller	$124.99
Mounting Hardware	$100.00*
IR Sensors/Accelerometer	$60.89
Developmental Costs	$30.00*
Total	$709.36

* Cost Has Been Estimated

Conclusion

This design presented many interesting challenges. Knowledge was gained in the areas of control systems, mechanical dynamics, embedded programming, sensors, and motors to name a few. Admittedly, this project was a little to mechanics heavy for an electrical engineering design. A design like this would be best undertaken by a multidisciplinary team including electrical, mechanical, and industrial engineers. Electrical engineers could handle wiring, sensors, and programming. Mechanical engineers could take care of motors and bike dynamics. Industrial engineers could fabricate flywheels and mounting hardware. Valuable experience was acquired in the areas of teamwork and team management. Each member worked alone and with other members on various aspects of the project that were coordinated to come together and function harmoniously. This is where Redmine, a project management web application, became an indispensable tool. This design could be easily extended by a future senior design team. One major addition could be autonomy. A bike that balances, drives, and navigates itself would be quite an achievement.

Acknowledgements

Special thanks to Calvin Cutshaw, Linda Barresi, and David Golden. These individuals helped immensely in the fabrication and mounting process. Also, thanks to Mr. and Mrs. Stringfellow for providing the funds to make this project possible.