EEL4914 Senior Design

Final Design Report

Electric Super Bike

The Best Team in the World

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Abstract

Our project is an electric bicycle that automatically varies motor torque according to the amount of force the rider applies to the pedals. The amount of assistance provided can be adjusted continuously between 0 (the motor never turns on) and 100 percent (full power at "saturation" pedal force).

The motor is powered by three 13V lead-acid batteries, which can be recharged by the motor when braking or coasting. An LCD displays speed, distance traveled, motor power and assist setting, and the current operation mode.

Project Features

LCD screen: The main control box includes a 128x64 pixel graphic LCD that shows the current speed numerically and graphically, the distance traveled, the selected level of motor assist, the current duty cycle of the motor, and the operating mode (running or charging).

Wheel Rotation Sensor: A bipolar Hall effect sensor mounted near the front wheel is used to determine speed and distance.

Variable Motor Assistance: A knob mounted on the control box allows the rider to vary the level of motor assistance. At 0, the motor will never turn on. At 100% the motor runs at full power when the saturation force, approximately 500N, is applied to either pedal (see figure 1). At any setting, the duty cycle of the motor varies linearly with the force applied.

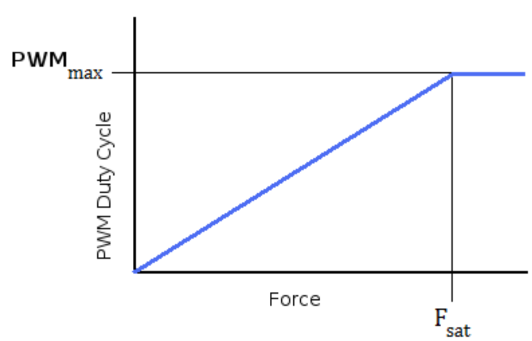


Figure 1: Force and PWM duty cycle: saturation point

Regenerative Braking: When the brake is applied, the system switches to charging mode. In this mode, the batteries are connected in parallel, the duty cycle is set to zero, and the current produced by the spinning motor is used to charge the battery.

Wireless LCD: short range Xbee modules, Compact two-line LCD. Will display current speed, distance traveled, and motor duty cycle. Driven by a PIC processor.

Concepts and Technology

Control Box and Sensors

Atmel ATMega32 microcontroller: The ATmega32 offered plenty of digital and analog I/O pins, moderate power use, high speed, and an excellent free IDE in AVR Studio.

Graphic LCD: While quite difficult for the beginner, (the model we used lacks a character generator and comes with an inaccurate datasheet) it has high resolution and a large screen area, so it can display a lot of information in an easy-to-read layout.

Hall Effect Sensor: A bipolar latched Hall effect sensor is mounted near the front wheel and detects the passage of two magnets fixed to the wheel. The bipolar sensor makes it easy to detect a complete wheel rotation. A unipolar sensor would be very inaccurate, as the magnet could be parked near the sensor and small movements would produce frequent “rotations”, leading to a useless speed calculation. The switching time of our sensor is adequate for speeds up to 73,863MPH, which we do not anticipate.

Force Sensors: FlexiForce sensors (see Figure 2) are mounted on the pedals to measure the amount of force applied. The sensor is a variable resistor and varies between ~10MΩ and ~1KΩ as force is applied.

Figure 2 – Flexiforce Sensor

The sensors are easy to use and the force applied can be measured via a simple voltage divider with a fixed resistor. The major drawback is that we are measuring force when the real quantity of interest is torque. The difference is apparent when one considers a rider standing on a pedal. No torque is applied to the pedal shaft, but a large force is measured.

Motor Control

When in running mode (default mode), the Atmel 32 weighs the duty cycle of a rectangular pulse-width-modulation (PWM) output, determined by the following inputs: assistance level potentiometer and the force sensor on the pedals. The assistance level potentiometer provides a ceiling for the duty cycle of signal, whereas the force sensors on the pedals determine the final duty cycle values below this ceiling.

The PWM signal is then fed into the current limiting circuit shown below, and the output of that is fed to the gate of 4 IRFP150 N-Channel MOSFETS, which drive the motor:

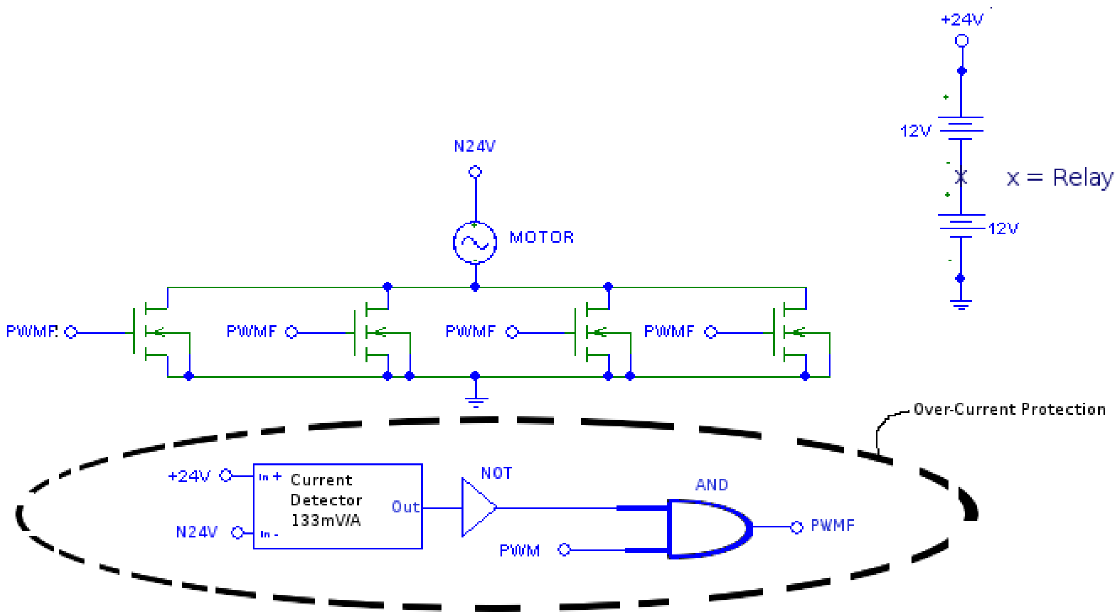


Figure 3: motor control circuit with over-current protection

Using this strategy, the duty cycle of the motor is varied properly with the pressure applied at the pedals, without the worry of flooding the motor with current when it is stalled. The sensitivity of this current protection can be biased using a voltage divider. However, it is still not recommended to stall the motor, as the MOSFETs could still overheat.

Recharging Capability

When a push button on the brake handle (attached to a microprocessor input pin) is pressed, the software runs in charge mode. The microprocessor then sends an active high signal to another IRFP150 N-Channel MOSFET. This MOSFET, whose drain is connected to the +12V terminal of one of the batteries, will drive relays which connect the batteries in parallel, to be recharged with the following circuit:

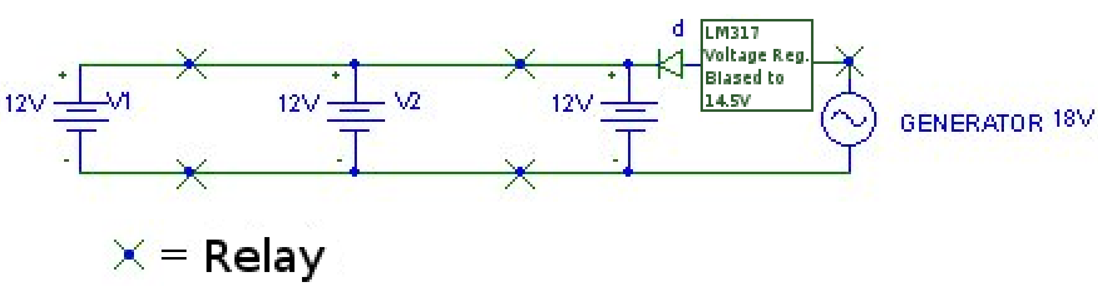


Figure 4: Battery rech

arge circuit

The peak voltage that the motor (now a generator) can reach is approximately 18V. This voltage is regulated with an LM317 to 14.5V. Values of voltage large enough to charge the batteries are only reached for a very short burst of time (about 1 second). A RCA port at the input of the LM317 was added to connect other charging devices to the circuit if needed (e.g. solar cell, DC power source, etc)

Wireless

The wireless LCD must update frequently and be reasonably accurate. The hall effect sensor will be simulated with a pushbutton switch that will be fed to an interrupt on the Atmega32. This should simulate the number of full rotations of the bike wheel in a given time interval. The force sensor on the pedal will be simulated with a potentiometer which will vary the voltage from 0 V to 2.5 V, serving as a model for the varying degree of force applied to the sensor. The plan is to integrate the wireless LCD with actual sensors on the bike if time permits.

The main challenge is to program the UART of the Atmega32 to send the data serially to the Xbee transmitter, and then to program the UART of the PIC to receive the data and display the necessary information on the LCD. The Xbees themselves must have a wireless link created between them through an interface board.

Project Architecture:

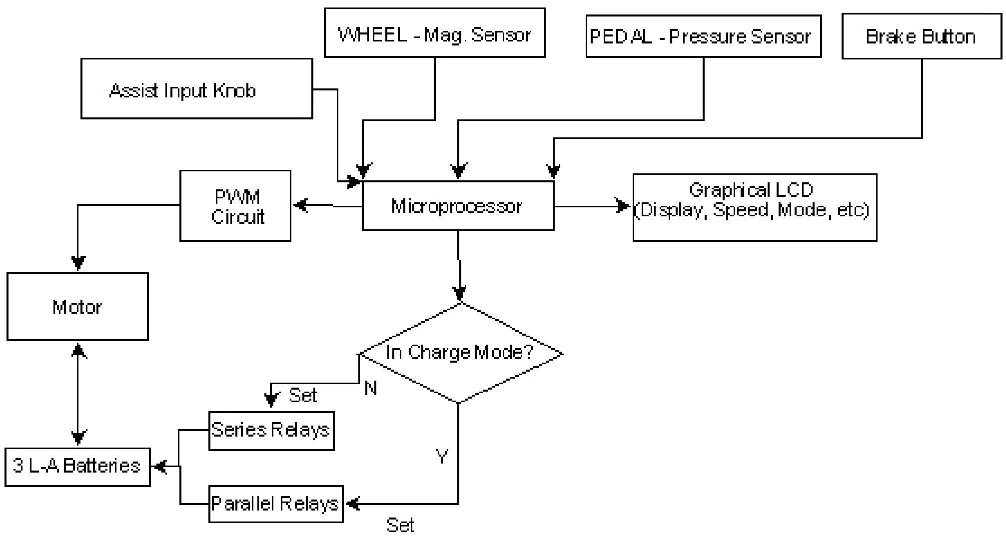


Figure 5: System block diagram

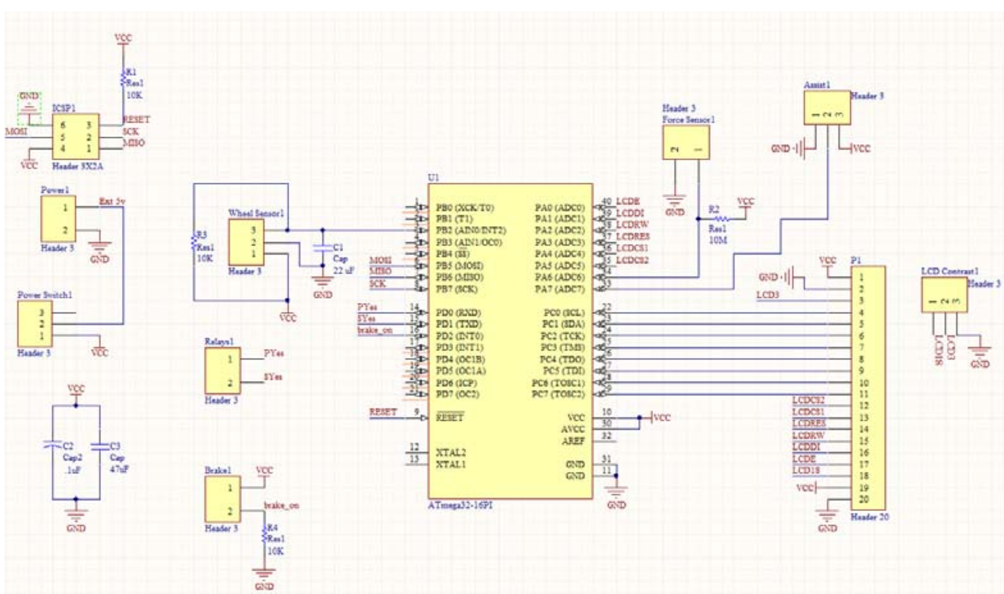


Figure 6: Control box schematic

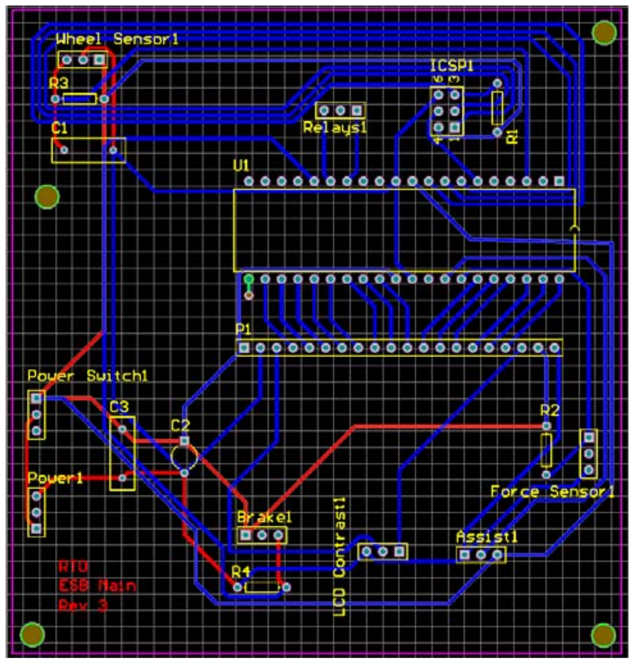
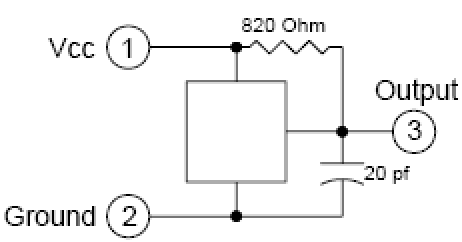
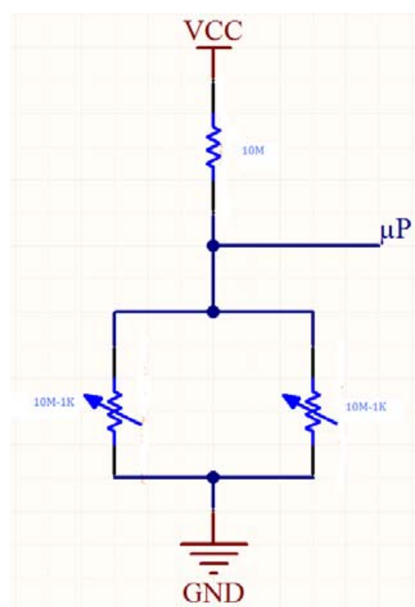


Figure 7: Control box PCB layout



Hall Effect Sensor



Pedal Force Sensors

Figure 8: Sensor circuits

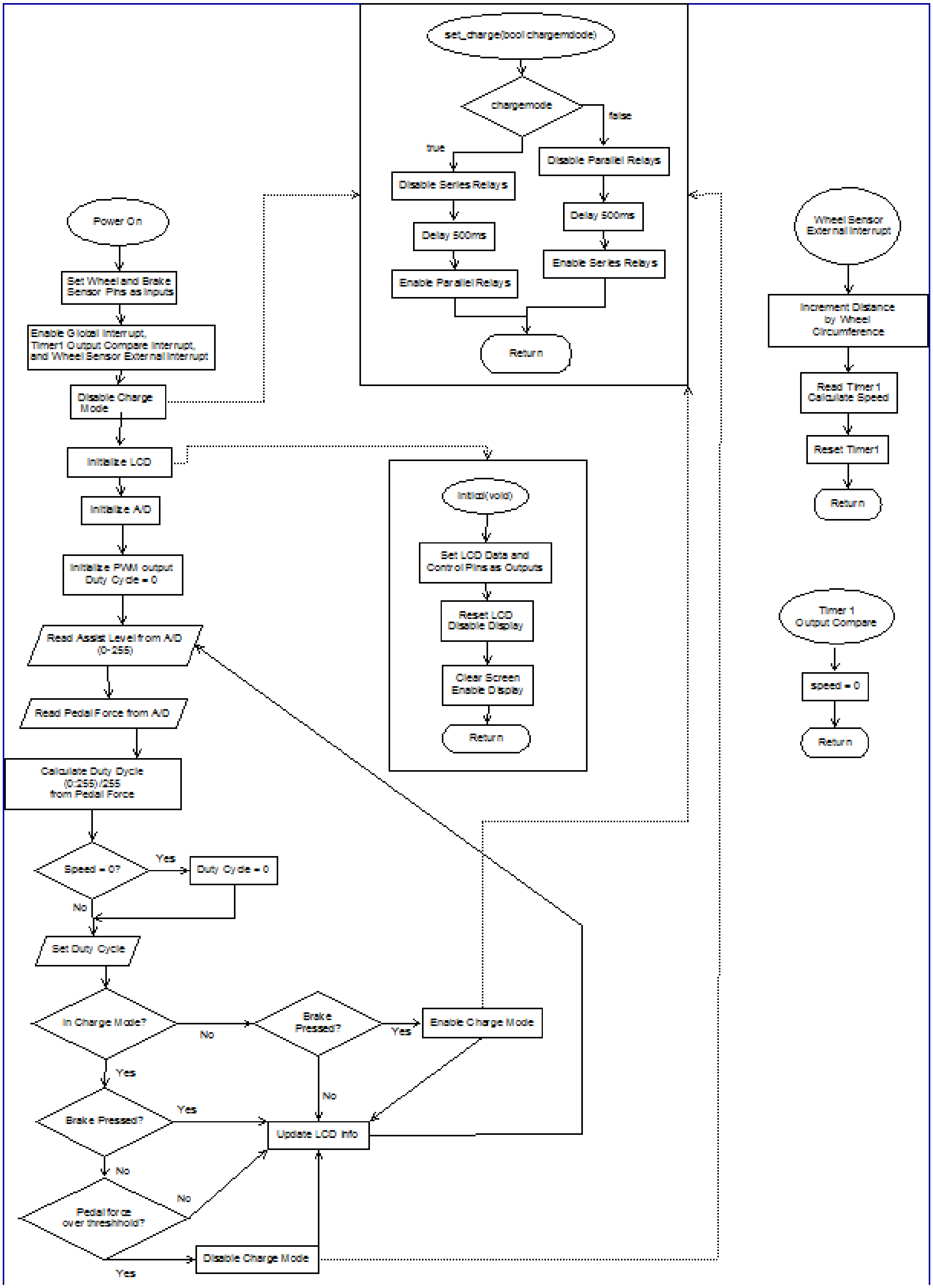

set_charge(bool chargemode)
chargemode
true
false
Disable Series Relays
Disable Parallel Relays
Delay 500ms
Delay 500ms
Enable Parallel Relays
Enable Series Relays
Return
Power On
Set Wheel and Brake Sensor Pins as Inputs
Enable Global Interrupt, Timer1 Output Compare Interrupt, and Wheel Sensor External Interrupt
Disable Charge Mode
Initialize LCD
Initialize A/D
Initialize PWM output Duty Cycle = 0
Read Assist Level from A/D (0-255)
Read Pedal Force from A/D
Calculate Duty Cycle (0:255)/255 from Pedal Force
Speed = 0?
Yes
Duty Cycle = 0
No
Set Duty Cycle
In Charge Mode?
No
Brake Pressed?
Yes
Enable Charge Mode
Yes
Brake Pressed?
Yes
No
Update LCD Info
No
Pedal force over threshhold?
No
Yes
Disable Charge Mode
Initlcd(void)
Set LCD Data and Control Pins as Outputs
Reset LCD Disable Display
Clear Screen Enable Display
Return
Wheel Sensor External Interrupt
Increment Distance by Wheel Circumference
Read Timer1 Calculate Speed
Reset Timer1
Return
Timer 1 Output Compare
speed = 0
Return

Figure 9: Software flowchart

Bill of Materials

600W Brushed DC Motor and 36V Battery Kit	$500
Atmel ATMega 32 microcontroller	$1.50
H9845 IRFP150 Power Mosfet (x8)	$24
365-1036-ND Hall effect Sensors	$3
SLD-12VDC-1C Automotive Relays (x4)	$12
SRD-S-105D Relays (x8)	$2.40
ACS715LLCTR-30A-T Current Sensor	$3.04
Misc. Cables and Connectors	$50
Graphic LCD	$30
Flixiforce Sensors (x2)	$30
TOTAL	**$655.94**

Gantt Chart

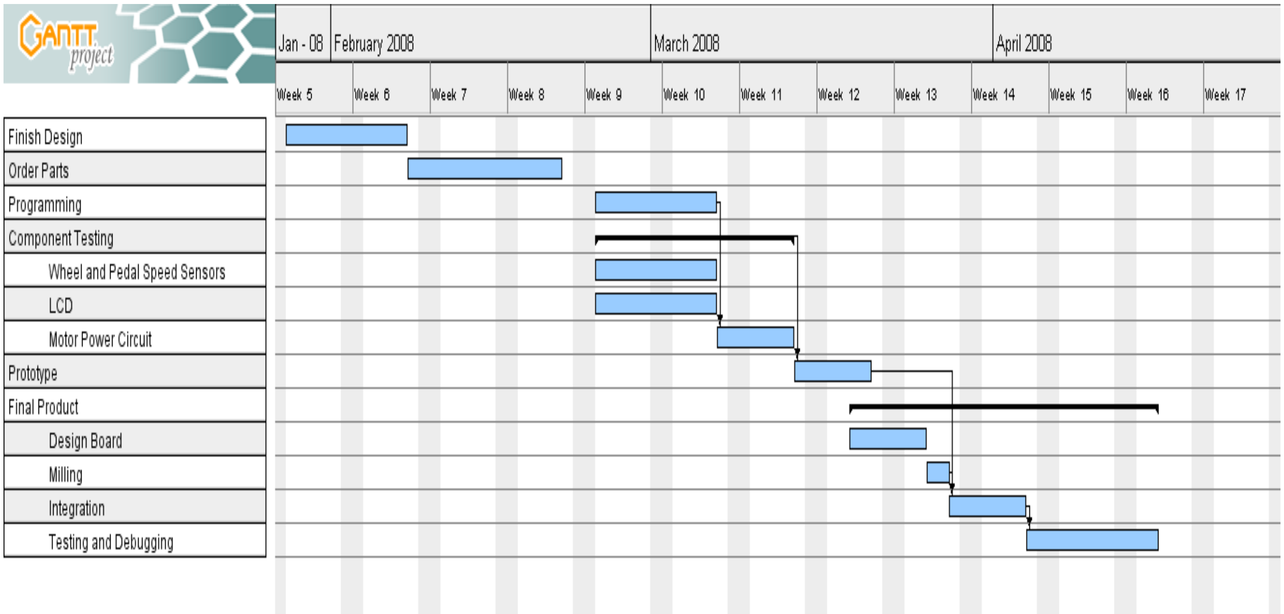


Figure 10: Gantt chart

Competition

The “Charger” bicycle (see Figure 11), manufactured by Electroportal, offers a very similar feature set. The main differences are that the Charger’s assist level is not continuously adjustable, and there is no display unit. While a speedometer may seem superfluous on a bicycle, these hybrid models are capable of sustained high speeds, and one could quite easily break the speed limit on, for example, a college campus. Additionally, the Charger retails for $1500, well above even the single-unit development cost of our project.

Figure 11: “Charger” competitor bicycle