Portland State
UNIVERSITY

Brushless DC Motor Electric Scooter

Version 0.01
October 23rd, 2016

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Table of Contents:

Needs Statement

With growing populations in urban centers, more and more commuters shy away from the typical combustion car as a primary form of transportation. With average speeds as low as 15-20 miles an hour, bicycles seem to be dominating short ranged transportation. With the recent improvements in lithium ion battery technologies, highly efficient electric bicycle hybrids are a popular, albeit expensive replacement for the traditional bicycle. While bicycles can be used for commutes of several miles, not all commutes are this far.

Many people, especially students at PSU live only a few miles from work or school, use a bicycle as their primary transportation, but find that leaving a bicycle outside leaves it prone to theft, or for secure parking, it requires a paid pass.

An electric scooter fills the niche of lightweight and inexpensive short range transportation, with parts costs ranging only in the realm of a few hundred dollars, compared at the $1000 electric bicycles you can find today.

Requirements

- Attach an electric motor to either an existing or manufactured kick board scooter for use as a personal electric vehicle.
- The vehicle must be capable of moving a full sized adult a constant speed of at least 6 miles per hour
- The motor controller should work efficiently enough so that you can travel more than 2 miles with 133 watt/hours of battery
- The vehicle should be able to transmit relevant driving information to the rider such as speed and battery voltage.
- The final vehicle including the motor, motor controller, scooter base and battery must be less than $300.

Project Proposal

Objectives

Using an electric drive motor, create a solution that will implement a standard scooter with an electric motor which will power this vehicle. The vehicle must function smoothly and safely. While giving the operator complete control over speed, acceleration and direction of motion.

- Develop a working electronic speed controller based on an AVR microcontroller
- Make use of PID control to create a smooth output drive for the electric scooter application
- Attach a sensored BLDC motor with a battery as well as a ESC and have a fully functioning electric scooter
- If time allows, attach a bluetooth HC-06 module and create a smartphone application to readout speed and battery data.

Scope

The end result should be a usable light transportation vehicle that functions at the flip of a switch, but could potentially have additional functionality with a smartphone as an output display.

Timeframe

	Task	Start and End Dates
Phase One	Learn and implement BLDC controller with Arduino	Oct 4th - Oct 17
Phase Two	Transfer Arduino code to atmega328p using atmel AVR - print new circuit board	Oct 17th - Nov 5th
Phase Three	Attach motor, ESC and battery to scooter, verify it will carry the load of a person	Nov 5th - Class end

Project Budget

Project budget is $300 for one finished product, which limits parts spending to about $250 for all the parts for the board as well as the scooter, so that we have some leftover money to purchase the PCB from OSHpark.

Concept Outline

Each concept is a segment of the overall design process that has been realized as a non-trivial design challenge that must be addressed. Each section outlined describes the physical or electrical requirements, how they can be completed and any issues that may arise in each case.

Functionality

- The scooter will be able to transport a user of various weights around by using its brushless dc motor. To control the motor the user will turn down the the throttle hand that is built into the scooter hand. Depending on the position of the hand the scooter will will various amounts of power. The more turned the handle, the more power to the motor which results in a higher speed.

Brushless Motor Control

-Create an ESC (Electronic Speed Controller) for our scooter. Create a PCB with MOSFET switches to power MOSFETS which will drive our 3 phase brushless motor. Use Atmega328p processor to integrate PWM (pulse width modulation) to control the motor drive speed and levels of throttle.

PWM Program

-Design software that will be able to create PWM signals to MOSFETs on the circuit to allow us to drive the brushless dc motor. Will need to create an algorithm to allow various speeds and acceleration requirements.

Motor Electric Power Calculations

- This is the physics of electric propulsion. Will the battery last long enough for the weight? Can the motor deliver enough power to propel a certain weight at a specific speed ? Is the electrical circuit safe ie can we regulate amperage and voltage to protect components and the user? We must take into account the specifications of the products we choose and see if they can feasibly meet the requirements.
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Atmega328p

- Learn the code instruction set for Atmega328p. Use some IDE for this processor which will run our code on the microprocessor.

Microprocessor Control Code

- Once the microprocessor and board design is finalized, basic low level control must be established via programming. Programming the microprocessor can be done in many ways, but one of the most common methods is using the JTAG interface to program while it is on-board. The Atmega328P microprocessor we have selected will require research into programming methods.

PID Control

- A proportional integral derivative controller must be developed to provide a feedback mechanism to the throttle. It's purpose will to smooth out the throttle response to prevent a "burnout" or excessive power delivered from standstill.

Bluetooth Connectivity

- If time allows, attach a bluetooth module to our microprocessor to transmit the inputs to the processor to a smartphone app. This is related to the following conceptual topic.

Smartphone Speed/ Battery Sensor App

- If time allows, develop a smartphone enabled application with GUI that allows for battery monitoring and other sensor details like temperature, and even speed (which is reported from hall effect sensors)

Scooter Bracket Mount

- To fully integrate the electric motor and scooter, we will use an existing adult sized scooter and modify it to fit our motor and electronics. This will require extensive modification of the rear wheel assembly. The most compact version, in order to make the most minimal visual adjustments of the scooter, will require a drive train consisting of a belt. Mounting this motor

Power protection

- To protect the circuit and pcb, the motor controller will feature a battery protection system, cutting off power once the 22.2V battery pack reaches a minimum voltage of 18V. The pcb will be thermally protected via passive cooling as well as an on board TMP36 module thermometer to ensure the board does not overheat, resulting in dangerous shorts. The scooter will also have a battery disconnect for saving on passive power

Implementation

Performance

-To test the performance we will use a speed tracking device that will tell us if we met the target speed or not.

-Use timer to measure duration of battery on scooter at constant speed

-Test various loads on the scooter

Parts List and Cost

Bill Of Materials					
Item Name	Quantity	Price	Price/ Board	Part # (DK)	Notes
Driver Mosfet	24 total - 6 per	$2	$12	IRFB4115PBF-ND	High power HEXFET
22.2V Lipo	1 per vehicle	$46.99	$46.99	Z50006S-30	http://www.hobbyking.com/hobbyking/store/__8590__ZIPPY_Flightmax_5000mAh_6S1P_30C.html
Gate driver mosfets	24 total - 6 per	$0.46	$2.76	ZVP3306A	Gate driving mosfet - BS250 equivalent
BLDC Motor	1 per vehicle	$46.99	$46.99	C5065-270KV	http://www.ebay.com/itm/172233379751?_trksid=p2060353.m2749.l2649&ssPageName=STRK%3AMEBIDX%3AIT
SMD 10k	48 total - 12 per	$0.10	$1.20		
Throttle Pot	1 per vehicle	$5.17	$5.17		
Chinese import scooter	1 vehicle	$59.99	$59.99		
L7805 Voltage Regulator -5V	6 total - 1 per	$0.25	$0.25	L7805	For powering Microcontroller
L7815 Voltage Regulator -15V	6 total - 1 per	$0.25	$0.25	L7815	For driving HEXFET Gates

Capacitors	A lot	$3	$3		
Processor	4 total - 1 per	$2	$2	Atmega328p	TQFP Package
Connectors	3 for motor 2 for batt	$	$		
Price of Circuit Board	4 total - 1 per	Unknown	Unknown		
		Total:	**$181**		

Working Timeline

Design Notes

- 10/17/16

To test out our knowledge of BLDC motor control theory, we're making a prototype PCB that should be able to spin the motor using NMOS 2n7000's to boost an Arduino's logic level to that of the IRFB4115's gate voltage. Note that in this current configuration, and because we didn't have any logic level PMOS devices, if the gate of the 2n7000 is left low or floating the power mosfets will fire causing short circuits to ground in the battery.

- 10/21/16

Starting design of the final board, questions for now:

- Does AREF have to be held to +5V?
- What's the deal with SCK? In some schematic examples it's help low through an led and opamp.
- IRFSXXXX are pretty good surface mount MOSFET's if the IRFB's take up too much space
- It appears that we will never be in a situation where we need to turn both mosfets on in a phase, so we might be able to half the number of pwm pins that we need depending on how the phase cycle goes, we will have to look into if this can be done safely.