Driver Assist

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***Abstract*—Driver Assist is an aftermarket attachment that allows the operator control over the steering wheel, braking, and throttle with one hand. Standard aftermarket attachments are expensive and require the use of both hands. Driver Assist will be cheap and easy to install, while only requiring the use of one hand. Driver Assist will give the operator the seamless control of the vehicle that other attachments cannot.**

I. Introduction

Being able to drive is one of the most important skills one can have. Not only does it give someone the sense of freedom, it opens up a window of opportunities in both personal and professional pursuits. While the act of driving is enjoyed by millions of Americans daily it can be a daunting tasks for those who have physical disabilities. There are currently 50 million Americans with registered physical limitations [1]. There are many solutions aimed at helping disabled drivers control their car, but all current products require the use of both hands (one hand to control the steering and the other to control the brake and gas). The most popular product on the market that allows a driver to control a car with just his/her hands uses a knob mounted on the steering wheel and a throttle that is similar to the one used on a boat to control the gas and the brake. Our solution is to create a single joystick that can control both the steering and the gas/brake. This would enable the driver to control the car with one hand. We believe this product will open up a window of opportunity for many citizens who were previously not able to drive and will be easier to use than the current solutions on the market. We believe this product will be simpler to use than other market alternatives for people who are physically impaired.

Our Joystick will have complete control over the car's steering and will be able to turn the wheel as fast as a driver with two hands. The system will also require a powerful motor strong enough to supply the torque needed to steer. It will also need to have control of the cars subsystems without interfering with today's latest safety features.

II. Design

A. Overview

The approach to solving this problem is to use a joystick to steer, brake and accelerate. The proof of concept will be demonstrated using a computer video game controller. The video game controller is an electronic steering wheel that provides haptic feedback with pedals to control the brake and throttle. The control of the brakes mimics a motorcycle's hand brake, which will manipulate a potentiometer to supply a reference voltage directly into the video game controller's input. Similarly, the throttle will also copy a motorcycle's throttle, which will rotate a potentiometer to supply a reference voltage to the video game controller's gas pedal. The control over the steering wheel will be implemented laterally moving the joystick, which will set a reference voltage from a potentiometer as an input on an Arduino microcontroller. The reference voltage from the microcontroller will then control the firing order of the phases of a Brushless Direct Current (BLDC) Motor, which will in turn control the direction of rotation for the BLDC Motor. The high work demands set forth by the motor will require substantial power. The car's battery voltage will be converted to a split power supply capable of providing up to 24 V. To supply enough power we will use both the car's battery and an external battery supply that will be integrated into our system. The external battery will be charged by the car's cigarette lighter port. This is effective because when the BLDC motor is not

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drawing maximum current, the system can instead charge the external battery. A motor driver that can deliver the necessary current at the motor's operating voltage will be made from discrete components to amplify the microcontroller's signals. This approach will succeed because the brake and throttle control mimics the video game controller's inputs. The steering wheel control should also succeed because BLCD motors are high power, efficient, and low failure rates. There were three possible design alternatives that were considered: the first alternative was to use linear actuators to depress the pedals, but was rejected because of the tradeoff between rate of depression and maximum applicable force by the actuators, which would sacrifice the users reaction time; the second alternative was in regards to rotation of the steering wheel, ferrous material would be attached to a jacket on the steering wheel jacket while high current would pass through conductive windings in close proximity in order to push and pull the wheel; the third choice was to use an Electronic Speed Controller (ECS) to drive the BLDC, but the need to boost and (Pulse Width Module) PWM the power supplied to the motor dictated a necessity to have the motor driver be created from discrete parts that can meet the demands. The current approach, to use electrical signals for brake and throttle control, was deemed to be the most appropriate path because modern cars no longer have mechanical linkage in regards to speed control, throttle and braking systems are done "by wire," where an onboard computer controls these signals. Steering "by wire" is a new technology that has only been applied to the newest of vehicles, and so a mechanical system was determined to be a reasonable approach to the problem.

A list of the requirements that were determined to be suitable for real world application can be found below in Table 1. The torque values were determined by the need to provide the same force at the edge of the wheel as a normal human can. Additionally, the response time and minimum revolutions per second were estimated through empirical means by measuring how fast each member of the group can react and rotate a steering wheel in a car, and were then improved to demonstrate that the system can make up for the time lost through machine calculations. Lastly, the battery life of the system should be long enough such that in the case of a power failure of the charging port of the car, the operator will have ample time to get the car to a safe location. Not on the table of requirements is a requirement that the system should not interfere with the functionality of the safety systems already in place such as the airbag.

Table 1. Design Requirements.

Requirements

SPECIFICATION	Value
Torque at Wheel	>6 Nm
Holding Torque	>3 Nm
Minimum RPS	>1.5
System Response Time	<50 ms
Battery Life	>30 min

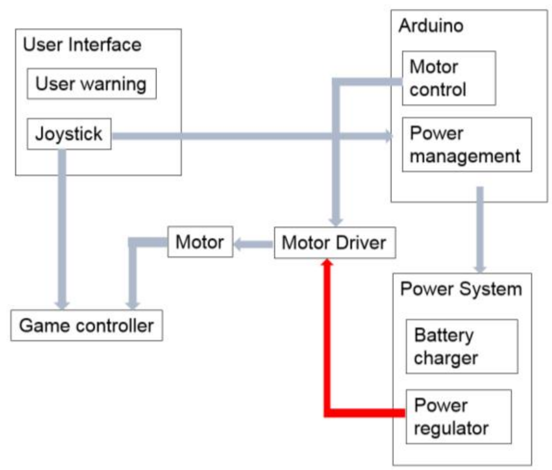

Figure 1. Block Diagram.

B. Joystick

The joystick will be a 3D printed vertical orientated cylindrical shape with a motorcycle throttle and hand brake attached perpendicularly to the side of the structure. The base will be attached to a fixed point on a potentiometer. The base structure will have one degree of freedom to rotate in a plane in order to adjust a voltage reference, which will then be sent to the microcontroller. The theory behind this method is that as the joystick tilts to a particular direction, the motor will rotate at a faster rate in the same direction. The joystick will be spring loaded to provide the operator feedback as well as place the joystick back to a home position in the center. The center position will indicate a holding position for the motor when the joystick is orientated vertically. A “home” position trigger will be employed so that the microcontroller will make the motor stay in whatever position it was last occupying. As the user changes the throttle position, the voltage reference will change accordingly. Likewise, as the handbrake is squeezed, the voltage reference for the brake input on the video game controller will also change as needed. The tools used to create this subsystem rely upon the knowledge learned in Circuits 1. The knowledge of how to physically create this device stemmed from outside knowledge not found in any of the coursed required in the EE or CSE track, since there is no course that specifically offers a Computer Aided Design (CAD) requirement.

When testing the brake and throttle first we had to find out how the game was receiving the input from the video game controller. After learning it was sending a voltage reference from the controller to the game we then had to find out what range of values were being sent. The values can be seen in Table 2. When building our own unit we used those specifications to make sure we were sending the right range of values for what we were looking for. A picture of the prototype device can be seen in Figure 2.

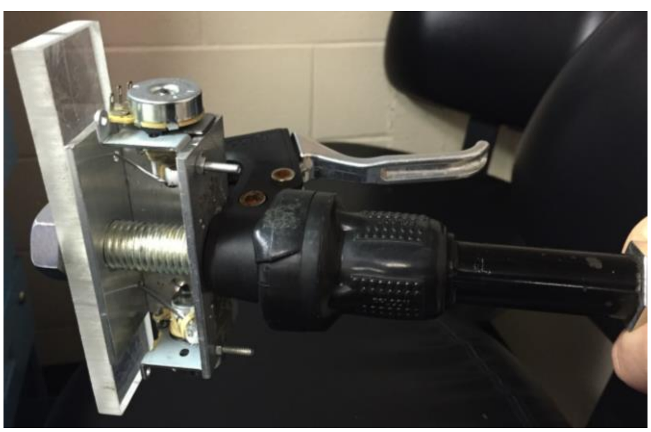

Figure 2. JoyStick Prototype

To test the steering component we will move the joystick a certain distance from the home position, and measure the voltage reference with a voltmeter.

C. Wheel Motor and Jacket

The need for the operator to adjust the steering wheel position at any moment influenced the choice of which motor to use. The decision to choose a BLDC motor over a stepper motor was a difficult choice. While the stepper motor provides a higher holding torque it has a substantially lower maximum RPM compared to the BLDC motor [2]. The stepper motor is also significantly larger than the BLDC motor, which would cause problems when trying to mount the motor in the car. A BLDC motor with an RPM rating of 4000 and a torque of 0.125Nm was chosen. Table 3 below includes the specifications of the motor and gear train used. The video game controller is capable of generating 3 Nm of torque on the wheel [3]. Consequently, it was estimated that 6 Nm of torque would be needed to counteract the feedback. To do this a gear train with the correct gear ratio was used to increase the motor's torque of 0.125Nm to 6 Nm. When doing this the max RPS was decreased to 1.5. This rate still allows our system to spin the wheel at a speed similar or faster than a human would be able to.

In order to ensure that the motor will never slip or wear on the steering wheel’s material a jacket was created. The jacket was drafted using AutoCAD, and is intended to attach to the steering wheel with an embedded bicycle chain. The motor’s gear train will be connected to the chain in the wheel jacket to allow the steering wheel to rotate. Figure 3 is of the side view of the wheel jacket, which depicts the groove for the chain. Figure 4 is the bottom view of the wheel jacket, which shows the area where the steering wheel will fit into the jacket. To create the steering wheel jacket a custom piece was 3D printed. The jacket has dimensions specific to the video game controller’s wheel of 10”. Since it is a jacket with the same shape as the steering wheel, it

TABLE 2
BRAKE AND THROTTLE VOLTAGE REFERENCE

Specification	Value
Brake	0.58V to 4.5V
Throttle	3.92V to 0V
2 Pots	10K

will not interfere with any of the safety features embedded in a normal steering wheel. The knowledge used to choose the gear train and motor values was acquired in Physics 1 and Physics 2. The knowledge of AutoCAD software was learned independently.

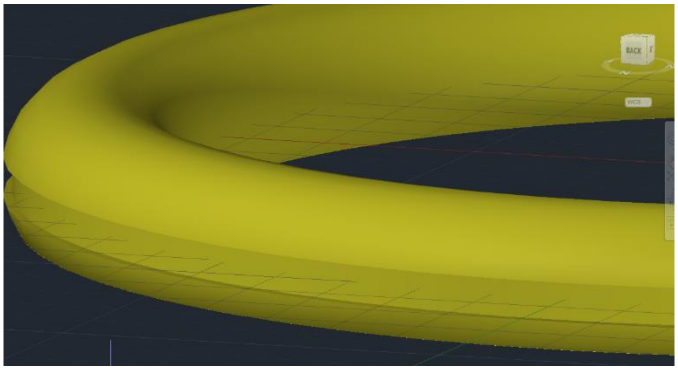

Figure 3. Side View of Wheel Jacket.

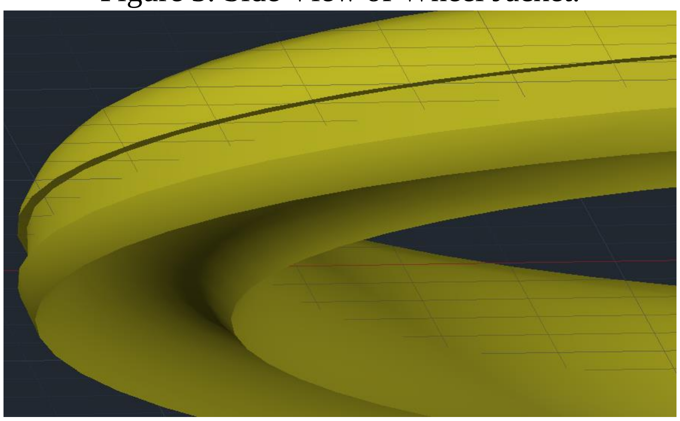

Figure 4. Bottom View of Wheel Jacket.

TABLE 3
BLDC MOTOR AND GEAR TRAIN VALUES

Specification	Value
Motor Torque Before Gearing	0.125 Nm
Gear Train Ratio	1 : 48
Torque After Gear Train	6 Nm
Max Rotational Speed Motor	>15 RPS

D. MicroController

The microcontroller subsystem takes in a reference voltage from the joystick in order to set the PWM signal to each phase of the motor driver. There are a total of six power MOSFET's that are used as switches to control the path of the current in the system. Three inverters labeled A, B, and C in Figure 5, are used to drive each phase of the BLDC. The PMOS's are labeled with the subscript 1 and the NMOS's are given the subscript 2, e.g., the PMOS and NMOS for inverter A is depicted as A_1 and A_2, respectively. The drains of each inverter are linked to the next corresponding inverter, i.e., the first phase of the motor is connected to the drain of inverter A, the second phase of the motor is connected to the drain of inverter B, and the third phase of the motor is connected to the drain of inverter C. For example, in order to have current pass through a motor's UV phase, A_1 and B_2 are turned on at the same time while the rest of the MOSFET's are turned off as shown in Figure 5. This is necessary because the motor is in a delta configuration and has 6 possible poles.

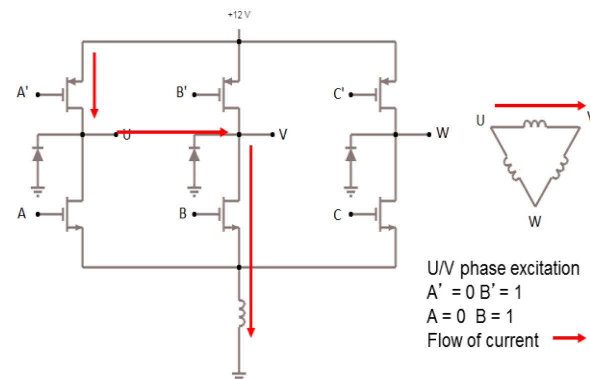

Figure 5. Motor Driver Current Path.

Motor speed is proportional to the rate at which current passes through each phase; the rate at which the motor spins in exponentially proportional to the joystick's position angle. When the holding position is triggered, the joystick is held in a constant position; a single phase of the motor will be active, which will stop motor from turning. The microcontroller would allow for slight deviations in possible voltage references in-between the rail values in order to allow for a holding position that could accommodate for physical wear as well as thermal drift. The courses needed to complete this part relied upon computer Systems, Physics II, and Electronics II. The subsystem was demonstrated by having a voltage value be given to the Arduino and then demonstrating the motor being driven.

E. Battery Recharger and Power Supply

Driver Assist will run off of both the car battery and an external battery pack. The external battery pack will be used when the car battery cannot provide enough current to drive the motor. The external battery pack will be plugged into the cigarette lighter port so it can be recharged by the car battery. It is very important to have a backup system in place if for some reason the power from the car fails, the system can still function.

A Hall Effect current sensor will be used to monitor the amount of current the Driver Assist module is drawing. This will be used determine whether the external battery helps drive the motor or is recharged by the car battery. Recharging will only occur when the current drawn from the car battery is low. A thermistor is embedded in the battery pack and used to monitor the temperature of the external battery pack as it is charged. Too high of temperatures decreases the life span of battery packs. To protect the battery from overheating, current flow will be reduced or stop based on the temperature reported from the thermistor [4].

To do this knowledge from power electronics, electronics I and II were used. Figure 6 is the schematic of the battery charger.

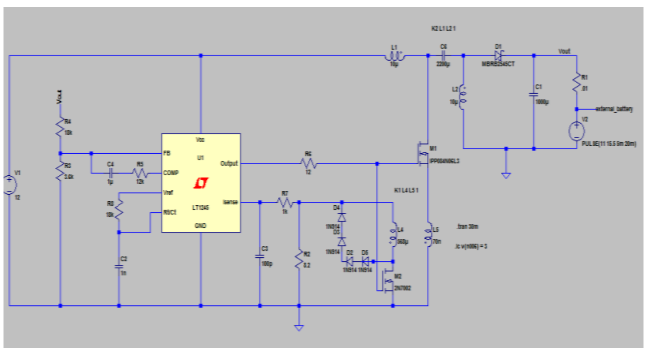

Figure 6. Schematic of Battery Charger.

A power supply is necessary to stabilize the voltage coming out of the main battery pack, and supply split voltage rails for both the Arduino and motor driver to operate. Figure 7 is the schematic of the power supply.

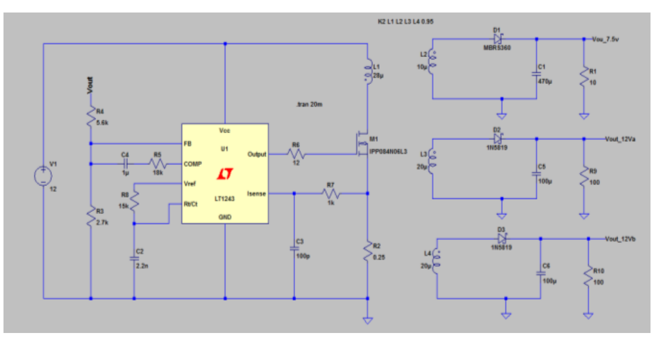

Figure 7. Schematic of Power Supply

The courses necessary to complete this subsystem were dependent upon Electronics II, Signal & System and the independent study that Professor Hollot gave Qingchuan over the summer.

III. Project Management

Table 4:

Team Member	Area of Focus
Sam Burke	Steering wheel cover, motor selection, gear train, steering wheel mount
Andrew Klinkowski	Design and implementation of motor driver circuit, coded the arduino
Steve Cook	Design and implementation of electric throttle and hand brake
Qingchaun Wu	Design and implementation of battery recharger, power circuits, and planning of motor driver and selection.

Table 4 shows the area of focus for each group member. Qingchaun Wu is an electrical engineering major focusing in power systems and circuit design. Because of his interests he is designing the battery recharger and power circuits.

Andrew Klinkowski is an Electrical Engineering student focused on antenna design, electromagnetic field theory, and computer programming. Andrew choose to design and implement the motor controller. This requires a vast knowledge of both circuit design and the implantation and programming of an Arduino.

Sam Burke is an Electrical Engineering student who is focusing on RF design but also has passion for motor control and user interface. Sam will be in charge of selecting the correct motor with the need output torque and speed. He will also design the wheel cover that will be used to attach to the motor.

Steve Cook is an Electrical Engineering student who is focused in the area of signal processing and has years of work with mechanical systems. Steve will be designing the joystick that will have control over both the gas/brake and the steering. Steve will be working closely with Andrew to make sure the signals sent from the joystick are compatible with the motor controller design.

Table 5:

MDR Deliverable	Accomplished Yes or No
Have motor selected with correct output torque and speed(have gearing ratio required computed)	YES
Have a wheel jacket prototype created and mounted on steering wheel base	YES
Have control over motors movements	YES
Have power circuit functioning to drive controller	YES
Have functioning brake and throttle prototype	YES
Have a functioning battery recharger	YES

Currently all of the promised MDR deliverables were completed and presented. The main goal with MDR was to make functioning prototypes for the wheel jacket, brake, and throttle to see if our ideas would work. Once we were able to prove that the concept would work our next plan is to 3D print all of the models we made in MDR. The 3D printing of these models have been included in our CDR goals. The 3D printed models will look cleaner and act more efficient than our prototypes. Aside from our 3D modeling we have several other areas that need improvement from MDR. We need to increase the sensitivity of control the motor driver has over the motor. This will be done by switching from an Arduino to a Raspberry Pi. Raspberry Pi microcontrollers have faster processers which will allow the motor to change phase faster, increasing the overall speed of the motor. We also need to increase the efficiency of our battery recharger.

The team has worked very well together throughout the semester. No one held back helping each other out, and there were many examples of great teamwork throughout the semester. Each member of the group came up with the design for their own subsystem but teamwork was used to actually put together each other's ideas. Our team had weekly meetings where we would meet for several hours to show our overall progress on our subsystem. This allowed for us to have knowledge over each other subsystems without micromanaging each other. We also meet with our advisor weekly to chart our team's progress and receive valuable feedback on our project.

IV. Conclusion

As team Driver Assist moves forward, we will continue to integrate our various subsystems into one compact system. With an integrated system we will be able to show fluid movement from the motor which is controlled by reference signals set from the joystick. Once fluid control over the motor is achieved full control over the steering wheel is easily attainable by attaching the motor to the steering wheel. Over the next couple of months drafting and prototyping of the joystick will occur to make a module that is easily controllable but robust and efficient at controlling the systems of a car.

References

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[2] *The Difference Between Brushless and Stepper Motors* [Online] Avalaiable: http://electronics.stackexchange.com/questions/79498/difference-between-brushless-motor-and-stepper-motor

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[4] Venkatanarayanan, S.; Saravanan, M., "Control of SEPIC converter using neural network tuned PI controller," in Power, Energy and Control (ICPEC), 2013 International Conference on , vol., no., pp.458-462, 6-8 Feb. 2013 DOI: 10.1109/ICPEC.2013.6527700

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