Bachelor of Engineering in Electronic Engineering

(Honours)

Semester 6

Project Report

Design of a DC Motor Controller and Power Stage instrumentation for a Electric Vehicle Application

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Declaration

I hereby certify that the material, which I now submit is entirely my own work and has not been taken from the work of others except to the extent that such work has been cited and acknowledged within the text of my own work.

Signature: ______________________________ Date: ___14/05/2020_________

Contents

Acknowledgements ... 3
Abstract ... 4
Chapter 1 – Introduction ... 4
1. 1 Project EV ... 5
1.2 Overview ... 6
1. 3 Main Objectives ... 6
1. 3 .1 Specific Objectives ... 6
Chapter 2 – Methodology ... 6
2.1.1 Design Methodology ... 6
2.1.2 Project Simulation ... 7
Project Planning ... 7
Chapter 3 – Literature review ... 8
3.1.0 DC Motor ... 8
3.1.1 Torque ... 8
3.1.2 Control of DC Motor ... 8
3.1.3 Pulse-Width Modulation ... 9
3.1.4 Power Stage ... 9
3.1.5 MOSFET ... 10
3.1.6 MOSFET Driver ... 11
3.1.7 Optocoupler ... 11
2.1.8 MSP430G2553 ... 12
Chapter 4 – Requirements/Bill of Materials ... 13
Chapter 5 – Schematic Design/Layout ... 15
Chapter 6 - Conclusion / Recommendation ... 17
Chapter 7 - Engineering implications ... 18
7.1. Environmental Issues Concerning Electronic Assembly ... 18
7.2 Production ... 18
7.3 Usage ... 19
7.5 Disposal ... 19
7.6 Conclusion ... 19
References ... 20
Appendices: Appendix 1: Electric Vehicle: Motor Speed Controller Initial Schematic ... 22
Appendix 2: Motor Speed Controller Final Schematic ... 22
Appendix 3: Power Stage Final Schematic ... 24
Appendix 4: PCB Design - Controller ... 25
Appendix 5: Source code ... 26

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Design of a DC Motor Controller and Power Stage instrumentation for a Electric Vehicle application

Preface

This report has been made during the second semester of third year as a standard integrated project yearly requirement of the Electronic Engineering (Hons) Bachelor of Engineering study at Technological University Dublin – Tallaght Campus, Dublin, Ireland.

Abstract

The concept of electric vehicle revolves around the use of electric energy to achieve propulsion. In its simplest form, the internal mechanics of an electric car draws power from the car battery which produces a magnetic force that propels the car forward. To control the vehicle is the govern the movement or speed of the motor. This project entails the development of a DC motor control system for an Electric Vehicle. To develop a speed control system to control the speed of a motor of an electric vehicle in response to the state at which throttle level is set by the driver. Our system will communicate with the MCU of the vehicle and the primary function of our circuit is to respond to the PWM signal received and translate the signal to the desired level allowing the driver of the vehicle to control the speed of a DC motor.

Keywords: **Electric Vehicle**, **DC Motor**, **MOSFET**, **Motor Controller**, **Speed Control**, **PWM**

Chapter 1 – Introduction

Internal combustion engines have been running on the streets for years now and power most cars around the world today. However, with the increase in demand for automobiles came the negative highlight of this commercial invention and its impact on the global-mean surface warming. One environmental study conducted on automobiles was published and shows that internal combustion-powered cars produced up to 70% of harmful emissions into the atmosphere [1] and another recent study of carbon dioxide emission show that 20% of the overall CO2 emissions origin from road traffic [2]. The result of these and many other environmental studies brought the attention of all available environmental protection organisations to start sounding an alarm about the pollution effect and became global. The environmental impact of the operation brought by internal combustion engines has shifted the attention of the mass population by supporting the research and use of on an alternative way to commute. And with the ever-advancing technology brought ground-breaking ideas have created an alternative form of transportation widely known as Electric Vehicle (EV).

Compared to an internal combustion engine which is reliant on combustion performance to produce an exothermic chemical reaction involving fuel and oxidants, the concept of electric vehicle revolves around electromagnetism.

The adaptation of Electric Vehicles (EV's) provides energy efficiency of up to 90% as to 25% efficiency on petrol engines [3]. Its concept is simply simple and innovative capable of operating with only one moving part and emits zero CO2 emission. A low noise system and almost silent in operation, this type of vehicle offers low maintenance, high reliability, low cost and provides environmentally sustainable driving experience throughout its operation. With the increasing growth of technology available, nowadays electric vehicles offer features and functionalities more than that of a generic combustion engine-powered car could possibly offer.

With many varieties of products available on the market today, in general term, an Electric Vehicle (EV) is a type of vehicle that primarily revolves around the use of electric energy to achieve propulsion. In its simplest form, the internal mechanics of an electric car draws power from the car battery which produces a magnetic force that propels the car forward. Primary components of an electric car are the electronic circuits, motor and the battery.

1. 1 Project EV

Project EV is a proposed activity to attempt and develop the necessary components for a functioning electric vehicle. Under electronics perspective, EV typically and importantly comprises of 4 sections:

1. **Battery Management System (BMS)** manages the effectiveness of the rechargeable batteries by maximising its safety, performance and longevity.
2. **Controller Area Network (CAN) Bus**, a standard in-vehicle network, is a high integrity serial bus system designed to allow microcontrollers and sub-systems to communicate effectively without a host computer.
3. **Master Control Unit (MCU)** an embedded system unit responsible for controlling one or more electrical system of the vehicle and responsible for taking input signals and deliver necessary output.
4. **Motor Controller (MC)** is a unit responsible for regulating the speed, torque, and protection against overload and electrical faults.

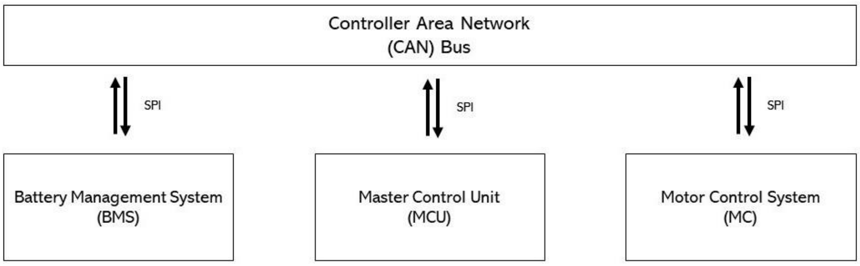

Figure 1: Block Diagram of Project EV - Circuit

The diagram shown in figure 1 is the overview of the electronic circuit of the entire EV Project. Each section of the diagram as shown are developed in parallel whilst adjacent to specific requirements. For example, for each module, such as the battery management system, Master Control Unit or Motor Speed Control System is expected to accommodate, integrate and communicate using the network protocol designed for communication and data transmission through the Controller Area Network. As each section is developed separately, the final activity following the successful testing and development of each part will be testing and coordinating to run individual parts as an overall system.

1.2 Overview

This project is based on speed control/regulation of DC motor for a Electric Vehicle. The design of the Motor Control Unit is comprised of two related interconnected electronic circuit, namely: Control Unit and Power Stage.

- ***The Control Unit*** hosts all low-medium voltage circuit components designed to integrate and interconnect with for network communication, signal regulation, sensor reading, signal conversion and other features to yield desired output.
- ***Power Stage*** is a special stage section of the MC unit which comprises of power components specifically designed to maximise motor performance and power delivery.

The approach to the design of the unit will initially start from generally understanding the behaviour, application and theory of relevant circuit components progressing to deriving the actual circuit. Critical design issues and derived solutions pertaining to overcoming difficulties to meet desired result will also be highlighted. The design will be kept as simple as possible, but not simpler - which will hopefully be evident throughout this report.

1. 3 Main Objectives

The main objective of this project is to design, develop and implement a control system hardware for speed control of DC Motor.

1. 3 .1 Specific Objectives

- Study the architecture, design features, specifications and requirements of relevant hardware components of the circuit related to the project.
- To propose, design, build and develop speed regulation of DC Motor capable of driving an electric vehicle.
    - Design power Stage
    - Design Control unit
- To test and evaluate the performance of the proposed design of DC Motor.

Chapter 2 – Methodology

2.1.1 Design Methodology

The design methodology is that of a specific approach. The design is based on the specific requirements as outlined in the objectives. Whilst project output is expected to work with other parts of the electric vehicle, this particular part of the project should work independently and thus testing and calibration is not dependent on any other working parts vehicle. The greater advantage of an application specific approach is designing a system to solve one task and not designing a generic system which can be ultimately impede the entire progress of the project. By taking this approach the design becomes more focused on solving the task at hand. The design should also allow for software and hardware modifications to any aspect of the system. This ensures that the system can be modified, changed and calibrated to meet the desired outcome during testing and maintains flexibility in the system configuration and implementation. The system ought to be designed as a passive system with minimal input from the user whilst incorporating fairly secured security measures to detect failures and errors during operation.

2.1.2 Project Simulation

The initial design and improvements of the system will mostly be initiated using a simulation software. This is to enact the circuit behaviour allowing prompt investigation and modification to meet expected output before the circuit is rolled out. Any significant findings will be added to findings section of this report accompanied with relevant information regarding the matter.

Project Planning

Details below shown in Table 1, expands the plan laid out for the duration of the semester. The design and implementation of the project will take the full semester to complete. A prototype product will be subject to testing which will be demonstrated at the end of the semester. For each week there are tasks that are set to complete with additional elements as the project progresses up to completion.

Table 1: Project Plan

Week	**Date**	**Description**
1	30/01/20	Complete schematic
2	06/02/20	- Define component footprints - Layout PCB
3	13/02/20	
4	20/02/20	Final PCB/Upload
5	27/02/20	- Order Components / BOM *(PCB Manufacture window)*
6	05/03/20	
7	12/03/20	Build/Test PCB
8	19/03/20	
9	26/03/20	- Final code Testing
10	02/04/20	
11	23/04/20	Report/Testing
12	30/04/20	Project Presentation

Chapter 3 – Literature review

This section discusses available information and relevant work done by others pertaining to this project.

3.1.0 DC Motor

The concept and operation of a DC Motor are relatively like any other DC Motor, its physical behaviour is based on electromagnetism. A DC motor generates torque directly from DC power source supplied to the motor by internal commutation, stationary magnets and by electrical magnets. It works on the Lorentz force principle to which any current carrying conductor placed within an external magnetic field experiences a torque or force known as Lorentz force law.

$$\vec{\boldsymbol{F}} = \overrightarrow{\boldsymbol{IL}} \times \vec{\boldsymbol{B}} \qquad (1)$$

Equation 1 shows the Lorentz force law which defines the force on a current carrying conductor situated in a magnetic field. Where the magnetic field exerts a force of $\vec{\boldsymbol{F}}$ on a current carrying conductor, $\vec{\boldsymbol{B}}$ is the magnetic flux density, $\vec{\boldsymbol{L}}$ is the length of the conductor exposed to the magnetic field and $\vec{\boldsymbol{I}}$ is the current flowing through the conductor.

The direction of the force is shown in Figure 2 is also adapted by Flemings 'left hand rule', a widely known mnemonic for visualizing the direction of magnetic force as given by Lorentz law. The magnitude of the force is $\vec{\boldsymbol{F}} = \overrightarrow{\boldsymbol{ILB}} * \boldsymbol{sin\theta}$ where θ is the angle <180 degrees between the magnetic force and the component of the conductor's length.

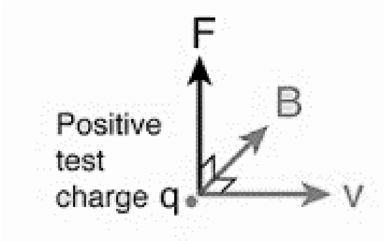

Figure 2: Magnetic Force Vector

This implies that if the current carrying conductor is in parallel to the magnetic flux, the resultant of the magnetic force is zero.

Thus, practical motors available on the market are always constructed in a way that the conductors are perpendicular to the lines of flux to maximise the force exertion.

3.1.1 Torque

A torque, rotational force developed by a motor is directly proportional to the force acting on the two conductors and the radius of the turn. Toque can be mathematically expressed using the equation $T = Fr$, where torque is expressed as (T), force is represented as (F) and radius of the motor is expressed as (r). The increase in number of conductors (z) in a motor, increases the torque developed by the motor.

$$T \propto Frz \qquad (2)$$

Since $T \propto Frz$, Substituting (F) in the equation 2 with equation 1, a new expression for the toque is developed, as seen in equation 3. Torque unit is Newton metre or joule/rad.

$$T \propto ILBrz \qquad (3)$$

3.1.2 Control of DC Motor

Since control of speed of the motor used in electric vehicle application forgo a demanding task and requires an instantaneous response for a change of drive speed to a value required, along with the bespoke control system capable to deliver the desired output, consideration of the motor, and control technique requires proper consideration.

By definition pertaining to our application, motor control is defined by means of controlling the speed of the motor. Speed control means intentional change of drive speed to a value required.

In general, DC motors are more adaptable speed drives than AC motors which are associated with a constant rotating field.

3.1.3 Pulse-Width Modulation

Pulse-Width Modulation (PWM) signal is a method for controlling analog circuits with a microprocessor and is abundantly used in modern motor controllers to vary the amount of power delivered to the motor from its source, see figure 2. And so, PWM will be used as a mean signal to control the speed of the DC motor.

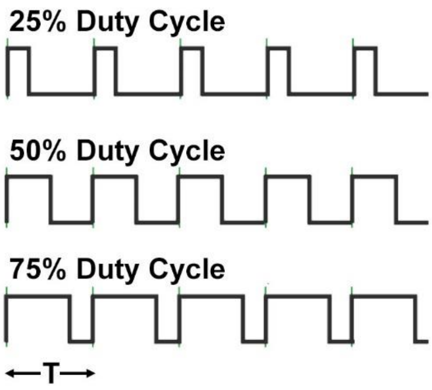

Figure 3: Pulse Width Modulation *[13]*

In theory, the modulation works by sending an analog signal to the circuit through a digital source such as a microcontroller. With PWM, the switching process of the connection between the source and the load very rapidly simulates a lower average voltage output which acts translated as a control signal. The modulation has two components, duty cycle and frequency. Duty cycle refers to the amount of time for the signal stays in a high state as a percentage of the total time PWM completes to one full cycle and the frequency refers to the speed at which PWM completes a cycle.

3.1.4 Power Stage

The power stage is the main core of the whole motor control unit. The designed motor controller contains a power stage circuit where input PWM signal translation occurs and addressing of the switching mechanics performing basic power conversion from an input signal to the desired output performance [4].

3.1.5 MOSFET

As we transition from a lower to much higher power usage and supply of the circuit en route to the target voltage supply and performing continuous switching operation, the previously used power transistor (TIP121) is not an ideal component to do the job. Based on the desired application, a MOSFET is best suited for the task.

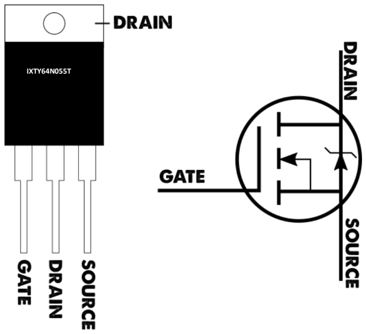

Figure 4: NPN Power MOSFET *[14]*

MOSFET stands for Metal Oxide Semiconductor Field Effect Transistor, a special type of semiconductor device widely used for switching and control applications. For switching power, MOSFET is a highly reputed component with high switching abilities and good efficiency at low voltages.

Unlike a bipolar transistor, which is current-driven, MOSFETs are voltage driven – a majority carrier device. As seen in figure 5, MOSFET has “gate”, “drain” and “source” terminals whereby inducing voltage to the gate, creates an electrical field enabling control of current flow between the channel of drain and source.

MOSFETs are available in two basic forms; Depletion type and Enhancement type. With key main difference being, Depletion type MOSFETs are “Normally Closed” switch while Enhancement type MOSFETs are “Normally Open” switch both requires toggle input to the Gate-Source (Vgs) voltage to switch the device off or on.

For evaluation, the same schematic used with TIP121 and was replaced with IXTY64N055T Power MOSFET, this type of device is an N-Channel Enhancement type a ‘normally open’ device. This device has a very low resistance at the gate and capable of operating up to 175°C a widely used device for automotive applications. Specified in the datasheet, a (Vgs) gate to source voltage threshold is between 2V – 4V and requires must be less than both the input voltage and the maximum gate to source voltage specified in the datasheet to turn the switch off and on.

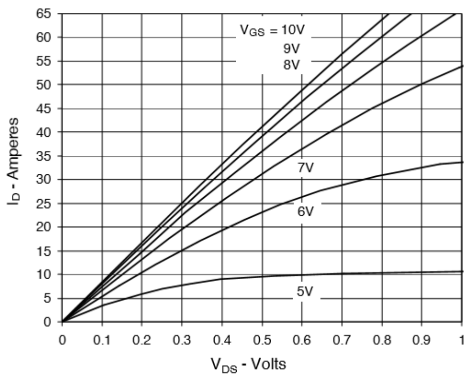

Figure 5: Output Characteristics @25°C

Taken directly from the MOSFET device datasheet, the curve is shown in Figure 6 is the output characteristics of the MOSFET when it is fully on. The MOSFET forward drop is measured as a function of current for different values of Gate-Source voltage. We refer to this curve to ensure that we have enough gate voltage is applied to toggle the device.

As seen in Figure 6, for each voltage applied at the gate, there is a range of drain to source voltage drop and strict linearity with the current is maintained. The detailed characteristics of the MOSFET are highly important information when using the device for any desired application to determine when at any given gate voltage, the current delivered has reached saturation.

Following use of the Power MOSFET to run a DC motor, we were able to obtain a sample data which we can use as a reference for future improvements of the circuit.

Table 2: Measured Values

Parameters	Results
Vcc	7V
Operation Current	1.2A (Max)
Vgs	0V – 9V

** Measured value at Vgs with a 10KΩ resistor, is out of range for the Vgs threshold for the device to function. When in range, the device takes ± 1sec to turn on. Thus, based on the value in the table, to properly control the motor circuit requires at a continuous operation.*

One of the reasons for the delay in switch on/off is the time it takes for the gate capacitance to charge and the charge storage of the MOSFET. Where gate capacitance requires current to charge and thee higher gate charge requirement, the higher the dissipation losses.

3.1.6 MOSFET Driver

To address issues regarding constraints in time constraints charging and discharging the MOSFET to turn the device to switch on/off, an additional IC be added to our circuit. This IC is known as a MOSFET driver which is a specialized circuit used to drive the gate of Power MOSFETs to gain effective and efficient switching to satisfy our demanding application. Its primary function is to translate any period square wave signals to a higher voltage and higher current to completely switching the gate of a MOSFET.

For smaller applications that use low voltage and current, an output pin of the MSP430 Microcontroller would be adequate to drive a small logic signal to the gate of a small logic signal MOSFET. However, for this application with a demanding load and with MOSFETs higher gate capacitance, the digital signal produced by the output pin of the microcontroller is inadequate to meet standard demand to power the gate enables a continuous switch on/off operation, in addition, due to the voltage and current level the circuit is aimed to operate, potential negative voltages could forcibly make way to the output pin of the microcontroller which may internal damage to the microcontroller.

The MOSFET driver available to use for motor control project is a dual high-speed Power MOSFET driver – TC448A, a capable driver which can operate between 4.5V up to 18V input and capable at handling up to 1.5Amperes, this MOSFET driver can easily charge and discharge up to 1000pF gate capacitance in 25ns. The MOSFET driver specification is enough to perform the required task during the prototype development.

3.1.7 Optocoupler

An Opto-Isolator (also known as Optocoupler) is a device used in isolating electric signals between two isolated circuits through optical transmission. A typical optoisolator depending on the light-responsive device and configuration mostly consists of a near-infrared light-emitting diode, a photodiode or a phototransistor, Its operation is based on the voltage induced to the power source from the transmitting circuit, to produce a near-light field beam which will travel across the channel to the sensor which will translate the optical energy to electrical energy.

When light is detected by the sensor, it will start to conduct electricity depending on the state and duration of the light. The whole process of signal transmission is conducted via optic allowing a separate and totally independent power source whilst maintaining a signal level from the input to output.

The purpose of the optoisolator for our application is mainly to protect and maintain the original signal level transmitted from the master control to be translated by the MOSFET driver to switch the power MOSFET on/off. Throughout the development of the motor control circuit, the required voltage will be greater than the output voltage of the output pin of the microcontroller typically 3.3V, thus, an isolation method to separate two signals is required.

2.1.8 MSP430G2553

We simulate the signal that is coming from the MCU to test the operation of the circuit. The microcontroller used as an MCU, MSP430G2553 IC, from the MSP430 family is of ultra-low-power microcontrollers. This type of microcontroller only requires voltage range from 1.8V to 3.6V to power on. This means that it is designed to be efficient in performing the task at a higher speed with low power consumption. Thus, it is the preferred microcontroller which will be used to send a signal to control the speed of the motor. There are other alternative microcontrollers in the market with similar specification as to our chosen microcontroller, however, although it provides more available pin sets it requires more power to run compared to MSP430G2553 and its performance is proven to be adequate to perform the task to deliver the desired signal for this application.

Chapter 4 – Requirements/Bill of Materials

Below is the table for the requirements needed to build the project.

SCHID	Component	Supplier	Quantity	Price
U3	MSP430	Farnell	1	**€1.95**
R1	RESISTOR, 47kΩ	Farnell	1	**€0.10**
C5	CAPACITOR, 1000pF	Farnell	1	**€0.17**
D2	DIODE, 1N4001G	Farnell	1	**€0.07**
J1, J2	HEADERS_TEST, HDR1X2	Farnell	2	€0.39
Q1	BJT_NPN, BC107BP	Farnell	1	€0.21
U1	Driver, TC4428	Farnell	1	**€1.27**
R3, R4	RESISTOR, 1000Ω	Farnell	2	**€0.39**
FIBRE_IN/OUT	PHOTOTRANSISTOR	DigiKey	1	€8.05
R6, R7	RESISTOR, 10kΩ	Farnell	2	**€0.10**
J3	HEADERS_TEST, HDR1X4	Farnell	1	**€0.39**
J6	HEADERS_TEST, HDR1X5	Farnell	1	**€0.43**
J7	TERMINAL_BLOCKS, 282834-8	Farnell	1	**€5.65**
J8	HEADERS_TEST, HDR1X2	NA	1	NA
X1, X2	SCHEMATIC_SYMBOLS, FUSE	Farnell	2	**€1.38**
R2, R5	RESISTOR, 1kΩ	Farnell	2	**€0.09**
RS_S1	SPST_2WAY_6mm, SPST-6mm	Farnell	1	**€0.29**
U2	12Vreguator, LM7812CT	Farnell	1	**€0.59**

R8	RESISTOR, 2kΩ	Farnell	1	**€0.09**
C3	CAP_ELECTROLIT, 470μF	Farnell	1	€1.00
Q2	DARLINGTON_NPN, TIP121G	Farnell	1	**€0.76**
ERROR, U8	LED_3mm, LED_red	Farnell	2	**€0.25**
FREE	LED_3mm, LED_Green	Farnell	1	**€0.18**
U6	VOLTAGE_REGULATOR, LM1117DT-3.3/NOPB	Farnell	1	**€1.26**
U4	VOLTAGE_REGULATOR, LM1117DT-5.0/NOPB	Farnell	1	**€1.26**
C1, C2, C4	CAPACITOR, 10μF	Farnell	3	**€0.33**
C7	CAPACITOR, 100μF	Farnell	1	**€0.19**
R9	RESISTOR, 1kΩ	Farnell	1	**€0.06**
U9	9pin282837, Connector Terminal – 9	Farnell	1	€3.39
U7	2X5header, 1787234	Farnell	1	**€0.43**
C6, C8	CAPACITOR, 22nF	Farnell	2	**€0.26**
TP1, TP2, TP3, TP4, TP5	HEADERS_TEST, TEST_PT_THT		5	
U10	87224_2, 87224-2		1	€0.01
			Total	**28.917**

**Note: The total cost listed is only the estimated price based from two the electronic supplier' website listing. Additional cost may incur for the future improvement of the circuit. The total cost of the development does not include the motor used as a load.*

Chapter 5 – Schematic Design/Layout

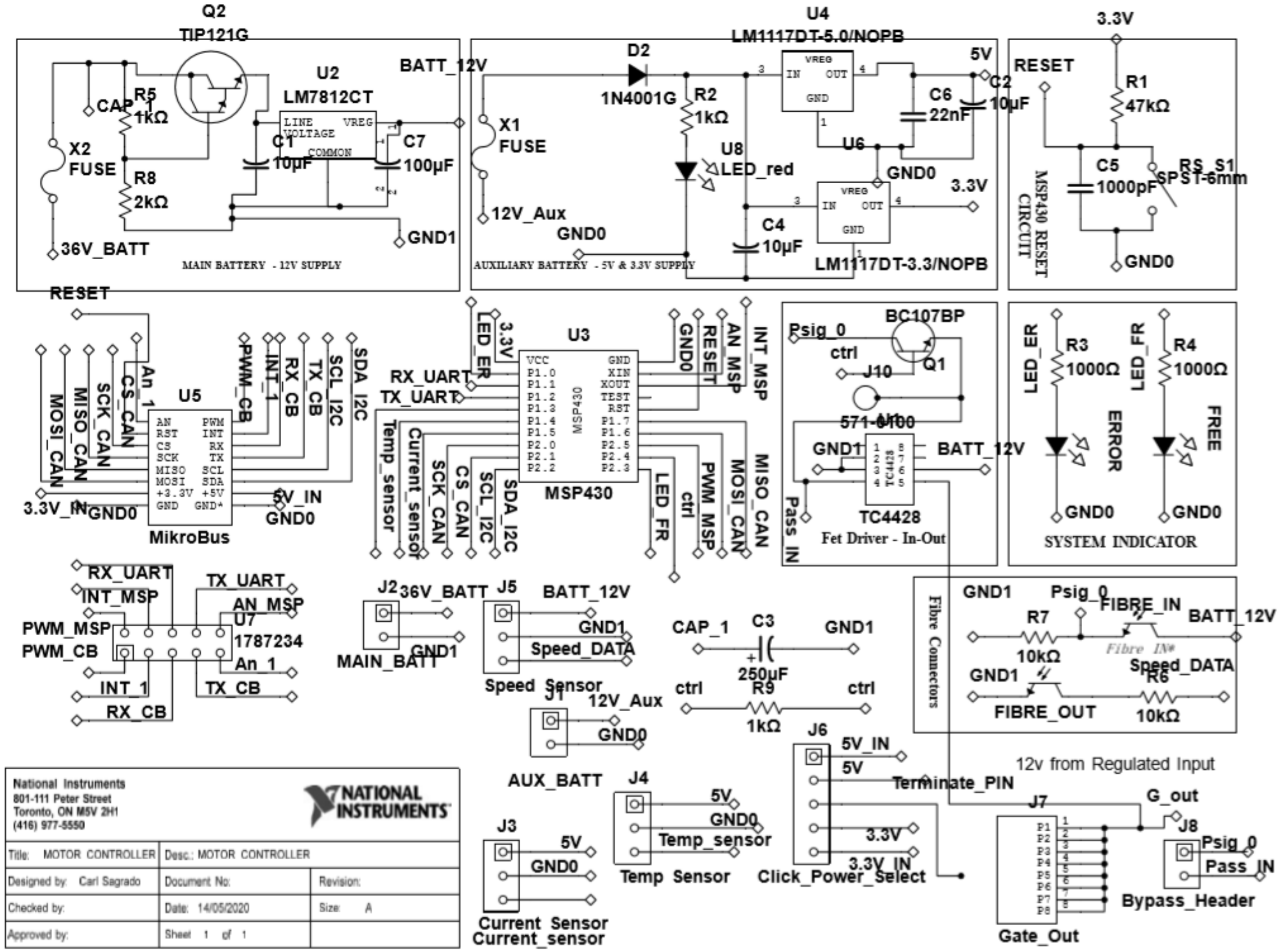

Figure 6: Full Schematic Diagram of the DC Motor Controller

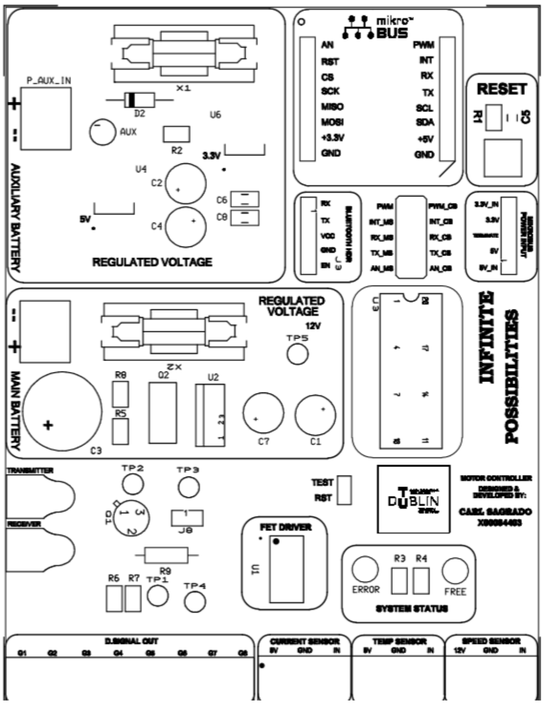

Figure 7: Physical Layout of the PCB

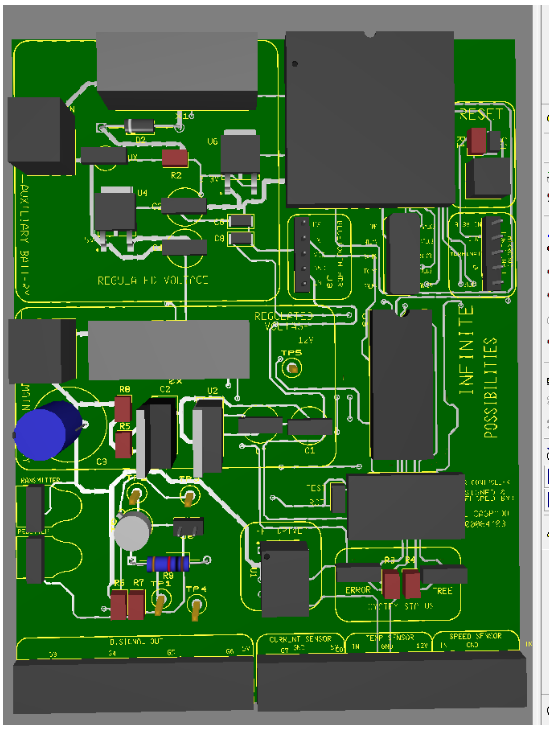

Figure 9: 3D Simulated Version of the PCB

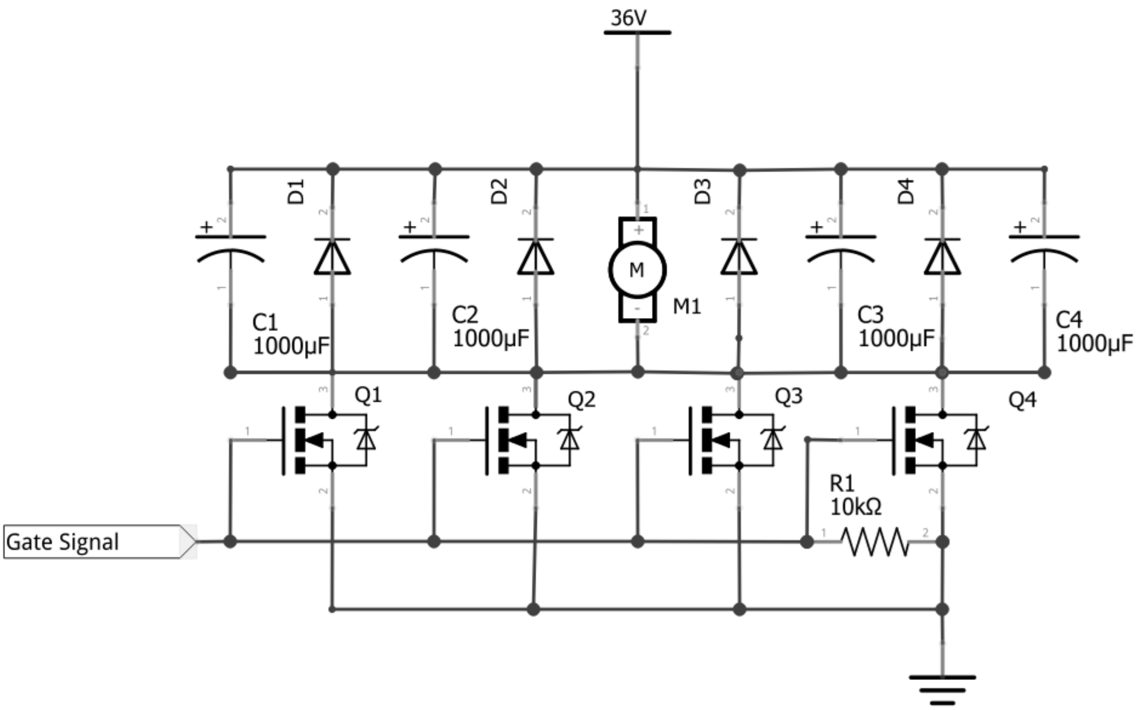

Figure 10: Power Stage Schematic

The motor control circuit as seen in figure 7 was designed with the reference to components discussed previously. The load used was significantly bigger than the initial motor which was used to test the functionality of the individual component added to the initial circuit. The motor was capable of drawing up to greater Ampere of current within the operating range of the power MOSFET. The result of the testing following power-up has provided several issues which are discussed and addressed as we continuously develop the circuit for testing.

The power stage section of this project was decided to be built in hardware to address thermal issues at the MOSFET prolonged operation. Along with the hardware components, bus bars, heatsinks, thermal paste, etc. will also be applied to eliminate possible occurrence of the issue which is highly hazardous to the component and to the entire certain as a whole.

Chapter 6 - Conclusion / Recommendation

Following simulation test during the design phase at each stage of the development and efforts troubleshooting the circuit as issues arises, the circuit is determined to be fully functional, with the help of simulation and physical testing of small to high powered motors we were able to confirm and verify the design to be able to control the speed of the motor. The circuit is capable at taking a PWM signal where we are able to control the speed of the motor between 10% and 90% of speed. The issues that arose during implementation and solution used may need further revision and investigation to fully optimize efficiency of the circuit. The pull-down resistor placed on the gate of the MOSFET and the resistor value used between the driver and the MOSFET may need re-evaluation and change as it may cause MOSFET switching efficiency and power dissipation which defeats the use of the driver. Textbooks and other online resources recommend the use of a much lower resistance component value and thus needs further consideration, otherwise the circuit is fully working.

The main objective of the project was met, and the system is built successfully. With reference to the PWM signal input the circuit provides a speed control of the motor. This project has provided me with great deal of experience and confidence in dealing with solid state components for demanding applications. As an electronic engineering student This project has brought in new sets of skills especially in fault finding, component datasheet sourcing, timekeeping and building projects from scratch. The project is very technical yet insightful experience which provides a great opportunity to understand the core mechanics behind the operation and building of an electric vehicle.

Although we were not able to completely build the physical circuit and physically conduct all the necessary tests due to unforeseen circumstances, the core objective of the project was met and thus, concludes this project.

Chapter 7 - Engineering implications

7.1. Environmental Issues Concerning Electronic Assembly

"The Electronics industry has far transformed the facet of society. In addition to providing the basis for the information revolution, electronics enable the society's vital support systems, including those that provide for such necessities as food, water, energy, transportation, health care, telecommunications, trade and finance." [4]

The emerging challenges of the Electronics Industry are its impact on the environment. And thus, the task to tackle this impact has become one of the challenges of the industry since the Electronics sector is by no means slowing down and stopping anytime.

7.2 Production

"The environmental impacts associated with a product include those that occur in the production processes to make it. These impacts occur not only at the final stage of assembling parts but also in the production of parts and their constituent materials." [5]

Consuming non-renewable resources including precious metals like gold are used to make electronic component e.g. Processor. The mining of such resources pollutes the water of surrounding the communities through cyanide contaminated waste ore and other abandoned mine waste including toxic metals and acid are often get released into lakes, streams, and the ocean, killing fish and contaminating drinking water. [6]

Another concern is the production of electronics such as microchips, printed circuit boards and computers is the use of many nasty chemicals during production. The industry has become globally competitive in the face of a rapidly changing technology which greatly increased the demand to produce more of the said products. The production requires a meticulous and tedious process which requires workers to be exposed with the chemicals and acids such as phosphoric acid, hydrofluoric acid, nitric acid, sulfuric ammonia, hydrogen peroxide, isopropyl alcohol, tetramethylammonium hydroxide, acetone, hexamethyldisilane, etc. which are harmful substances [7] and when processed, releases potential air emissions which include: toxic, reactive and hazardous gases that contributes to the rising global warming.

The products used to manufacture and produce technology often contain solvents called Volatile Organic Compounds, or VOC's which are Carbon-based compounds that vaporise easily at a certain temperature. VOC's affects the environment by contributing towards the formation of ground-level ozone, the main component of smog (an air pollutant) to which does not only have many detrimental effects in the environment, causes health problems to anyone when overexposed. [8]

Due to the alarming effect to global warming, regulations such as REACH (Registration, Evaluation, and Authorisation of Chemicals) were set out and established to have an immediate implementation globally and companies are required to meet the standards.

7.3 Usage

Power consumption and demand has risen due to technology. Though for some, technology has aided humanity to become efficient to their work and even for some allowed them to connect to individuals from far distances. As technology helped humanity get through our primitive beings and allow us to multi-task, the end game of this advancement is the toll to our environment. For example, we always need electric energy to keep our gadgets running, to keep our lights on, etc.

Electric energy is generated by the use of fossil or nuclear fuels on a large scale. New renewable technologies may have been available, however, that too creates and contributes to global warming. The exact type and intensity of environmental impacts may have varied depending on the specific technology used, location, and other factors, however, is still, in fact, contributes to global warming [9].

Another factor arising from the use of the electronic assembly is the heat generated by electronic devices. As the heat dissipates to the environment it creates carbon dioxide (CO2), a gas that stores heat which contributes to greenhouse warming [10].

To address the issue, a program called ENERGY STAR was developed, a product specification process that relies on rigorous market, engineering and pollution savings analysis to tackle the concurring greenhouse problem. The program test evaluates and validates products to control and reduce greenhouse emissions. The specifications laid out by ENERGY STAR aims to direct consumers to a more energy-efficient product [11] which would lessen the greenhouse gas contribution to greenhouse warming.

7.5 Disposal

Electronic assembly disposal has increasingly acute as more devices invented every day rendering previous devices obsolete. These electronic wastes are known as “Techno trash” where any broken or unwanted electrical or electronic device is currently the most rapidly growing type of waste. Most of these wastes contain non-biodegradable materials, heavy metals and toxic materials that end up in a landfill that contributes to the growing problem of land pollution, in addition to land pollution, over time, these toxic wastes end up contaminating the water that animals, humans, plants consume. [12]

7.6 Conclusion

While electronic devices have positively impacted society in a massive way. We must also take account of the negative impact it does to our environment. The government and the environmental organisation all over the world have participated acted towards preserving the environment as much as we can and therefore, everyone is incumbent to participate. There are number of ways we can help the environment, such as; avoid producing any electronic assembly that has too little impact or no significance to the society, monitor waste production, producing products that are energy sufficient, use devices when necessary and turn off when not needed, separate techno trash from ordinary household trash and dispose or donate unwanted electronic devices to be properly recycled.

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Appendices:

Appendix 1: Electric Vehicle: Motor Speed Controller Initial Schematic

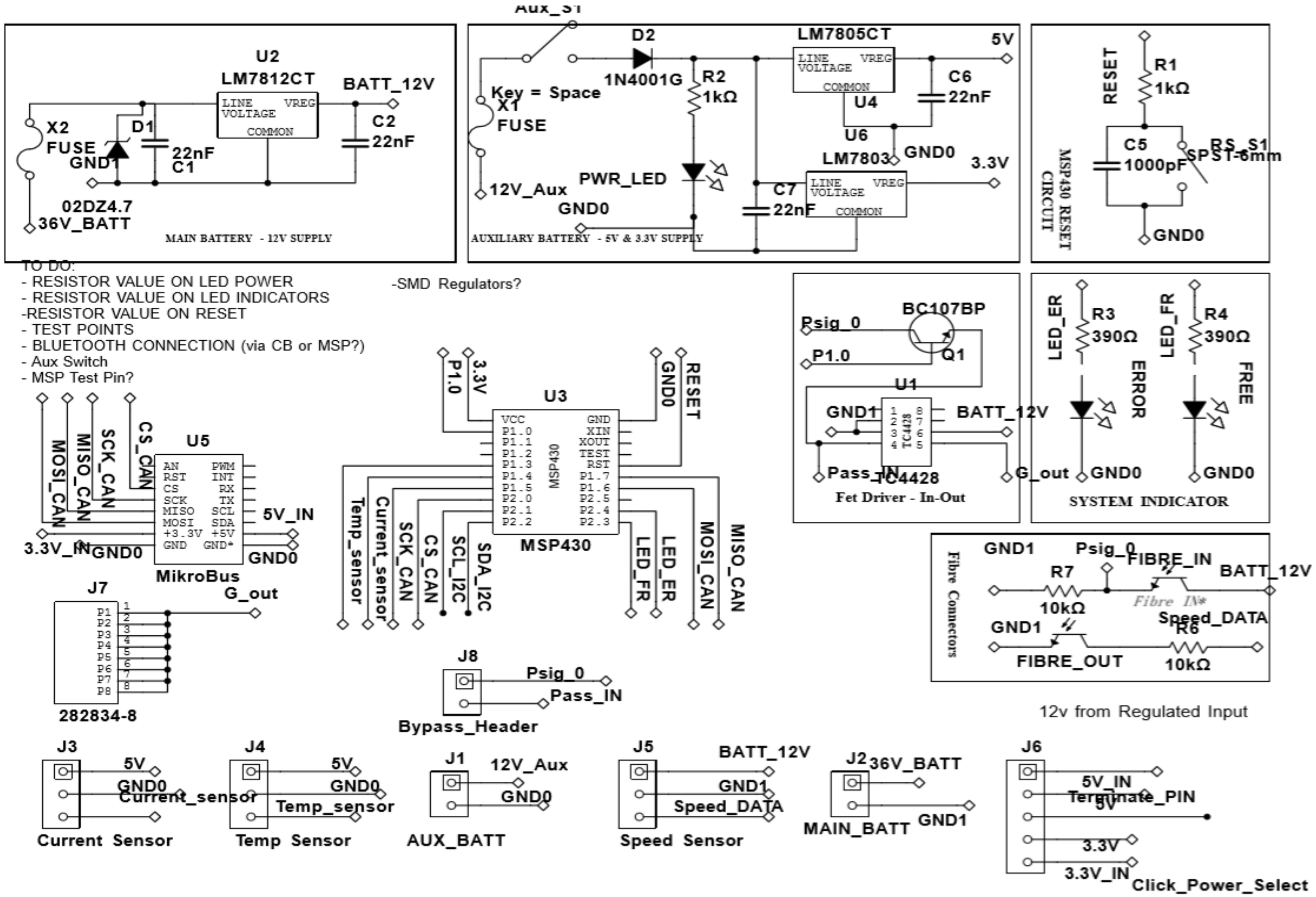


Figure 11: Initial Schematic

Appendix 2: Motor Speed Controller Final Schematic

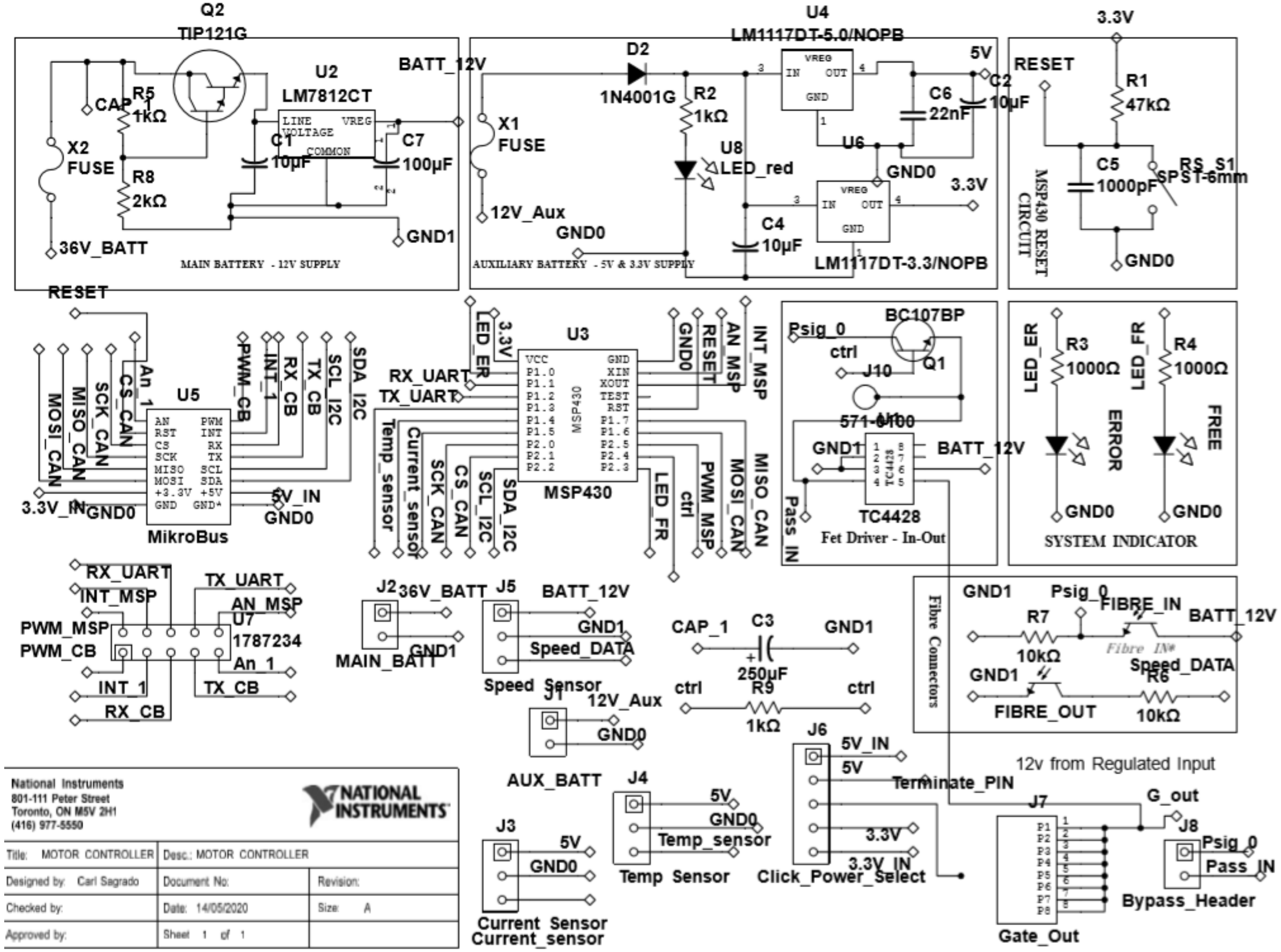


Figure 12: Final Schematic

Appendix 3: Power Stage Final Schematic

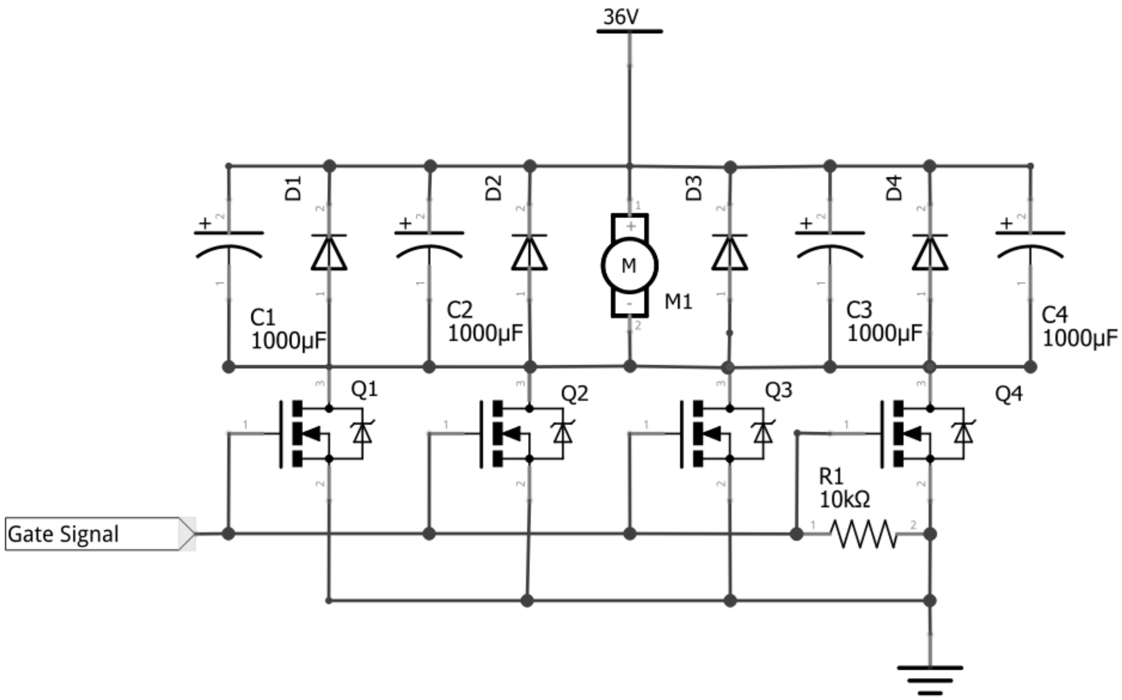
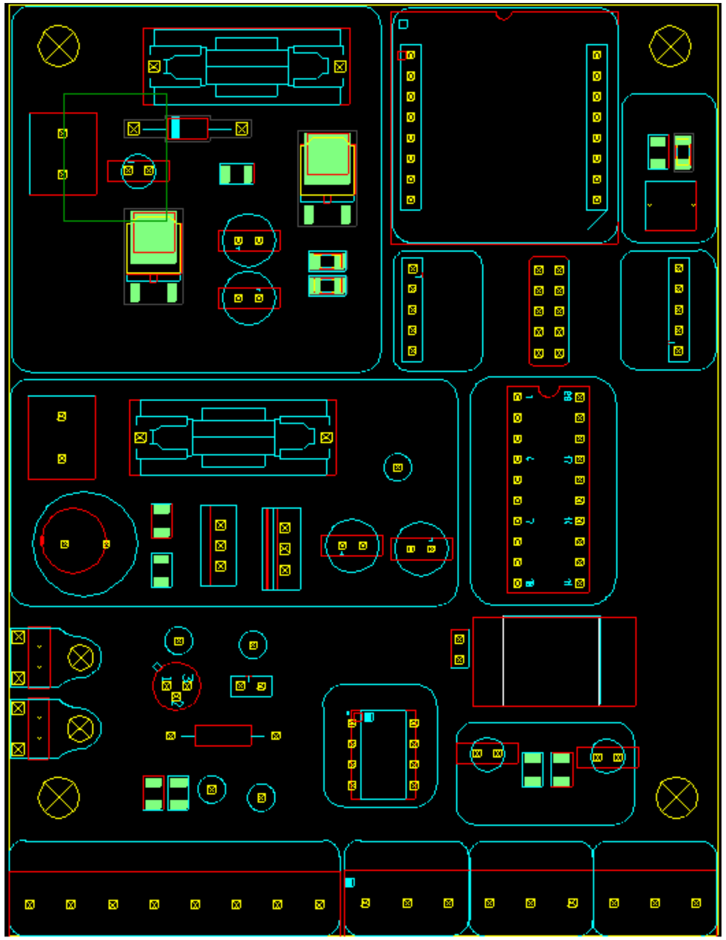


Figure 13: Power Stage Schematic

Appendix 4: PCB Design **- Controller**



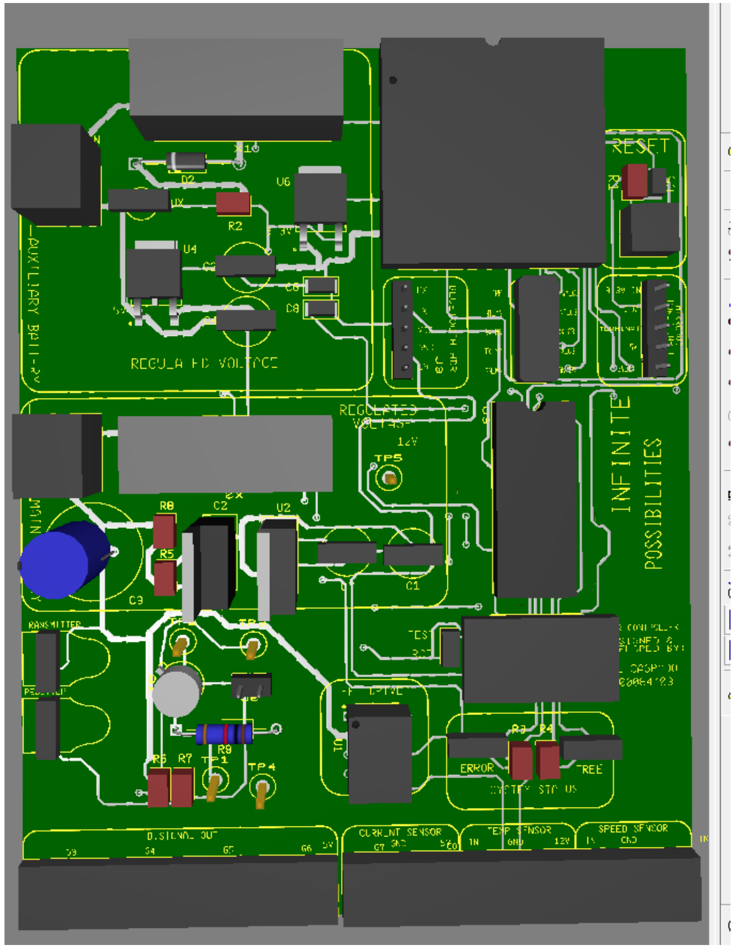


Figure 14:PCB Design Birds Eye View & 3D view

Appendix 5: Source code

PWM Code

```
/*
  Title: PWM Signal

  Name: Carl Sagrado
  Student no: X00084403

  Version 1.0

  Description:
              - Read the value of the throttle pot and convert into PWM
Signal

  Hardware Required:
  * MSP-MSP430G2553
  * 10-kilohm Potentiometer
  * hook-up wire
*/


long int outputValue;

void setup()
{
  // put your setup code here, to run once:
 // Serial.begin(9600);
  pinMode(P1_6,OUTPUT); //set pin to output
}

void loop()
{

   outputValue = analogRead(P1_0);
   int fadeValue = map(outputValue, 0, 1023, 0, 255);   // sets the value
(range from 0 to 255):
   analogWrite(P1_6, fadeValue);
  // put your main code here, to run repeatedly:
}
```