2018 SDSMT Clean Snowmobile Design Overview

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Abstract

The 2018 Clean Snowmobile Team at South Dakota School of Mines and Technology (SDSMT) is working on its first diesel utility snowmobile concept for competition in the Society of Automotive Engineers Clean Snowmobile Challenge. The team established performance goals for the 2018 competition year including maintaining a stock appearance, producing low emissions, and operating with minimal noise. By setting goals, the team has objectives to work towards and standards to uphold. By focusing on these goals, the team works to produce a snowmobile that is able to be operated in environmentally sensitive areas. Innovation is important to help the snowmobile industry progress. The team contributes innovative ideas by designing cleaner emission systems and diesel clutching compatibility. The stock appearance of the sled contributes to the team's professionalism and allows the team to create a product comparable to top snowmobile manufacturers. Within the past year, the team has made major steps to improve its outreach to the local community, fellow students, and its sponsors. More publicity and knowledge of the team fosters growth and improvement for team. In addition to growing the team, there is an emphasis on maintaining a professional and safe work environment. Professionalism and safety are habits the team strives to achieve that are able to follow the members throughout a professional career. The team collaborated, designed, and manufactured a diesel utility snowmobile to meet the team's goals. The result of of the design process is a snowmobile that is on the innovative front for snowmobiles used as research vehicles or could be offered to consumers for recreational applications.

Introduction

The Clean Snowmobile Team (CST) at South Dakota School of Mines and Technology is a multidisciplinary collegiate design team. The objective of the CST is to design a highly functional and innovative diesel utility snowmobile with minimal noise and emissions. The team is competing at the SAE Clean Snowmobile Challenge in the diesel utility class. The intent of the competition is to develop a snowmobile that produces low emissions for environmentally sensitive areas. The purpose of this document is to describe design innovations, key systems, performance, and cost of the snowmobile. The design outline in this document conveys why the CST is able to produce a highly competitive diesel utility snowmobile.

Innovations

In order to be on the leading edge of diesel snowmobile design, the team must be creative with its engineering approach. Innovations drive improvement and more efficient designs. The team made several innovations in its first ever diesel snowmobile build. One of the primary goals as a team is to maintain a stock appearance. This goal is met by using a professional approach when designing the various systems in the snowmobile. The team focused on several aspects such as: using space effectively, integrating stock parts, and using

a wiring harness. Externally, the snowmobile looks manufactured from the factory. Internally, the team has made numerous innovations. The team modified a stock clutching system to perform smoothly with the diesel engine. Another major innovation the team made was with the exhaust system. There are also innovative aspects to the electrical system and the fuel system.

Clutching

The clutching system for the sled is one of the most innovative areas of the snowmobile. The team is able to use the stock clutching system and modify it to be compatible with the RMP of a diesel engine. The designers tuned the factory clutch to diesel specifications by adjusting the clutch weights and the spring used in the primary clutch in order to work efficiently with the engine. To maximize the efficiency of the clutching system, the team uses 65 gram weights and a spring with a 55lb force at 2.5 inches and a 145lb force at 1.25 inches to synchronize the clutch to the engine.

Exhaust System

One of the primary goals of the SAE Clean Snowmobile Challenge is to design a snowmobile that is able to be operated in environmentally sensitive areas. In order to meet this objective, the NOx and soot emissions should be as low as possible. The team decided to use manufactured parts from diesel systems already in industry. This choice was made because creating an active regeneration exhaust system would be a tough challenge to overcome in the team's first year and on a limited budget. By combining stock DOC, DPF, and muffler parts, the team is able to design a clean and quiet exhaust system never utilized in unison before. This combination is able to be seen in Figure 1. This option not only reduced the expected cost of the exhaust system, but also allowed the team to be innovative with the design. The DOC and DPF system the CST uses is from a Turbocharged Direct Injection Volkswagen DOC and DPF. The muffler that is being used on the sled is a Walker Evans quiet flow muffler. The systems are combined to form an innovative solution for addressing the noise and emissions objectives for the snowmobile.

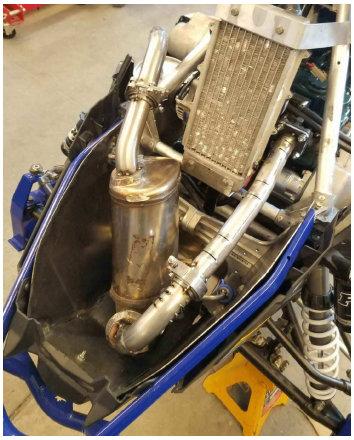

Figure 1: DOC and DPF with Piping

Electrical System

In order for the team to meet its goal of a stock appearance, an LCD display unit is incorporated into the electrical system in the same location as the original display unit. The team designed a custom tachometer to measure the engine RPM. The tachometer operates by using a hall effect sensor to detect a magnet connected on the crankshaft. An arduino uses the information from the sensor and it is programmed to calculate the RPM value of the engine. Another way the team was able to maintain a professional look by creating a wiring harness. The connections and lengths are custom, so use in combination with the diesel engine and additional sensors is a great fit.

Fueling System

The fuel system uses a fuel filter with water separator to ensure that the fuel is clean. The fuel filter and water separator quickly snaps in and out of its housing for easy routine maintenance. The design is routed while the the coolant system is routed. This minimizes the usage of space and guarantees that there is no interference between the two subsystems.

Team Organization and Time Management

The CST formed on campus in 1995 as the Alternative Fuel Vehicle Team. The team originated as a solar power vehicle team, then after 11 years in the solar vehicle competition, the organization moved on to the SAE Clean Snowmobile Challenge. After 11 years of competing as a zero emissions team, the team moved on to the Diesel Utility Class in 2018 because the Zero Emissions class was no longer offered.

Team Management

The CST has many leadership positions within the team. The President, Vice President, Treasurer, and Secretary work behind the scenes distributing workloads, overseeing projects, and taking care of financial business. The design work for the snowmobile is distributed among the Electrical Design Lead, Mechanical Design Lead, and the Manufacturing Lead.The team divides the responsibilities of the different areas of the sled into major subsystems. The Rules and Safety officer is active in each sub-system to make sure that the sled is rule compliant, professional, and safe. At the beginning of each weekly all team meeting, the Rules and Safety officer gives a safety presentation to help emphasize the importance of maintaining a safe work environment. The CST strives to promote safety in the lab to help team members develop safe and professional work habits. Another way the CST promotes a safe working environment is by having chemicals go through an approval process. The team keeps SDS information available for team members, so they can look up the hazards and know the necessary safety gear.

Timelines

To keep the CST on pace to finish the snowmobile in time for competition, the entire team meets weekly and there are sub-system meetings twice a week. These are opportunities to design, manufacture, order parts, and collaborate with other subsystems. The leadership positions also meet together weekly to give updates on ordering parts, system design, and other progress. The team officers also discuss financial business and event scheduling for the team. A gantt chart is used to track the progress the team makes during the season. The gantt chart shown in Appendix A is the chart the leaders set at the beginning of the year. Making sure progress is recorded and ensuring deadlines will be met are weekly tasks for the CST President, Vice President, and Manufacturing lead.

Outreach Activities

The CST is vastly expanding its involvement in both the school and the local events. By expanding the team's events, more people are able to become aware of the CST and other students may become interested in joining the team.

SDSMT CAMP program

Center of Excellence for Advanced Manufacturing and Production, also called CAMP, is a program that unites SDSMT's collegiate design teams under one organization. The CST helps CAMP participate in multiple events that outreach to college students and the local communities, such as, the Wharton 5K/10K Run, exhibition fairs, and Rapid City's Pumpkin Festival, Pumpkin Chuckin.

Paint the Town

During SDSMT's homecoming, the school and the downtown area join together to showcase student organizations. The team's painting is shown in Figure 2.

Figure 2: Paint the Town Involvement

STEM Night
STEM night is an event that promotes SDSMT and the STEM field to Rapid City's local high schools. CST had several members volunteer to help introduce science and engineering experiences to high school students.

Nostalgia Nights
Nostalgia Nights is a fundraiser for the library of SDSMT, at a local movie theater. Team members volunteered to hand out door prizes to the audience before a classic movie is played. The team is showcased before the event to the audience.

Updating Sponsors
In order to keep CST sponsors up to date, a seasonal newsletter is sent to them. This gives sponsors progress reports on the sled and thanks them for their support. Another method the team uses to maintain a good relationship with sponsors is through updates on the team's social media page. Using social media is a great way for the team to give shoutouts to the sponsors with a picture of their product on display to the team's followers.

Crowdfunding
The most recent endeavor for the CST's outreach is setting up a crowdfunding fundraiser. With college financial budgets becoming tighter, the team is searching for other possible ways to fund the snowmobile project. Setting up a crowdfunding fundraiser helps promote the team as a professional group of student engineers, helps promote the SAE competitions, and aids the team finance to build the diesel snowmobile.

Snowmobile Build Items

Chassis

The Chassis is a 2018 Titan Polaris Adventure. This model is a combination of utility and off trail mobility. This model can be seen in Figure 3. As competition rules state, teams are required to use a utility class chassis. Diesel engines are larger and heavier than gas engines, so having a larger chassis will allow for a diesel engine to fit. Plus, the Titan's wide frame is well suited for distributing the weight of the diesel engine. The articulated rear suspension and the Fox QS3 clicker shocks improve the overall mobility and handling by absorbing trail impacts and rough terrain. The track length on the Titan is 155 inches which is great for deep snow because there is more surface area on the snow.

Figure 3: 2018 Polaris Titan Chassis

Engine

Diesel engines are larger and heavier than gasoline engines for the same horsepower output. This makes fitting a diesel engine into a sled with enough power to move the sled at a minimum 35 MPH difficult. The team created an engine screening matrix with size, horsepower, weight, cost, and part availability as metrics to help the team narrow down an engine choice. After the screening matrix was completed, there were a handful of small diesel engines that the team would be confident using to compete with.

The engine that the team is using in the snowmobile is a Kubota D902. This small diesel engine is an excellent fit for this application. It is a 3 cylinder, 4 stroke, 898cc engine. It is the world's smallest, multi-cylinder, high-power density diesel engine. The stock engine can be seen in Figure 4. From Kubota's specifications, the engine outputs 20.4 horsepower at 3600 RPM. Kubota's E-TVCS technology reduces the emissions created which is a reason the team used this engine. The Kubota D902

meets tier 4 emission regulations. A key aspect to reducing the emissions, is by not having as many emissions to begin with. The engine also has a half-float valve cover and coated pistons to reduce noise levels and reduce transmitted vibration from valve area for better noise characteristics. The engine is an area the team knew would be a factor in being able to reduce the noise created by the snowmobile. In addition to reducing the emissions and noise, a super glow system is used for shortened pre-heat time and quicker engine starting in cold weather. All of these characteristics make the Kubota D902 a smart, reliable choice for a snowmobile application.

Figure 4: Kubota D902 Engine [1]

To maximize the area in the engine bay, the team used a three-dimensional structured light scanning technology to map the engine bay in 3D space. The team made measurements from the scan shown in Figure 5 to most efficiently place the engine and create engine mounts.

Figure 5: Engine Bay 3D scan

The motor mounts need to be structurally capable of supporting the weight of the engine and the torque applied to the system by the stub shaft. The designer created a mounting design that allows adjustments parallel to the stub shaft to adjust the primary clutch location. The designers perform a structural analysis of the motor mount using SolidWorks shown in Figure 6. Using a ¼ inch of 1040 steel for the motor mounts creates a strong fixture that adequately withstands the stresses.

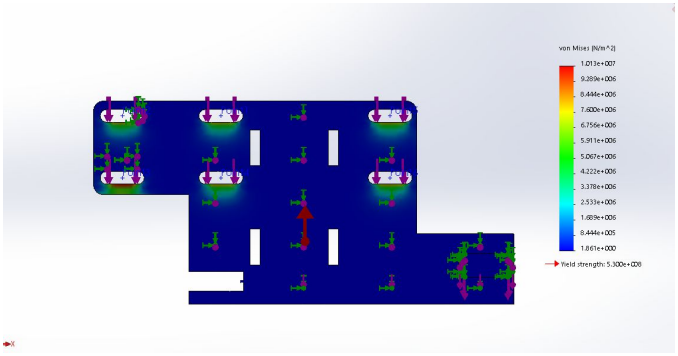

Figure 6: Stress Analysis on Motor Mounts

Track

The track used on the 2018 Polaris Titan is a camso track that is 20 x 155 x 1.5 Cobra. The track is 20 inches wide, 155 inches long, and the lugs are 1.5 inches high. The team installed Woody's traction studs 1450 grandmaster carbide studs. The track can be seen with the studs in Figure 7.

Figure 7: Track with Wood's Traction studs

Muffler

As stated in the innovations section, the team used a Walker Evans quiet flow muffler that can be seen in Figure 8. One of the main goals of the Clean Snowmobile Challenge is creating a quiet snowmobile. With noise being an issue, using a typical snowmobile muffler is not the best option**.** This muffler gives the team confidence in a quiet snowmobile. Also in order to keep a stock look, the muffler is in the same location as the original Titan.

Figure 8: Walker Evans quiet flow Muffler

Diesel Oxidation Catalyst

In order for the snowmobile to emit fewer emissions, the team chose to use part of an already existing exhaust system. The DOC and DPF system is from a Turbocharged Direct Injection Volkswagen car. The DOC and DPF can be seen in Figure 9.

Figure 9: DOC and DPF

Skis

The skis used on the sled are 8" wide Powder hounds manufactured by Slydog. These skis are wider snowmobile skis, which help to distribute weight and improve overall handling of the sled. The skis can be seen in Figure 10.

Figure 10: 8" Powder hound Slydog Skis

Fueling System

The fuel system incompasses all aspects of the diesel fuel flow. A 14 gallon stock fuel tank on the Titan is used for diesel fuel storage. The fuel tank is not modified in order to maintain stock appearance. The electric fuel pump in the Titian's tank is used as the fuel pump to push the diesel into the fuel filter, then to the engine. A Parker-Racor fuel water separator and 10 micron fuel filter is used to ensure clean fuel is supplied to the engine. There is also a return line back to the fuel tank. The fuel system has space parameters in which it must operate. Making sure the fuel line connections are easily

accessible is also considered in the design. Because of the limited space, the system is very compact. The fuel filter has a quick release mounting plate for quick maintenance when needed. Being able to work with the limited space, allows for other key systems to have more adjustability.

Cooling System

The cooling system contains all of the elements used to cool the engine. The Kubota D902 is liquid cooled. Underneath the track are heat exchangers that snow hits when the sled is under normal operation to cool the coolant from the engine. The stock radiator and fan are also used to reduce the coolant temperature. The coolant returns back to the engine to cool it off. This system needed to be adapted in order to fit the exhaust system in the snowmobile. The placement of the radiator can be seen in Figure 11.

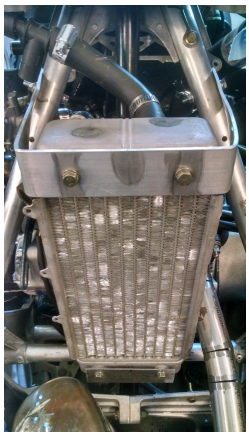

Figure 11: Location of Stock Radiator

Clutching System

In the innovations portion, the clutching system is mentioned. A sponsor graciously worked with the team to make a spline attached to the crankshaft for the primary clutch attach to. The clutch weights and spring are preliminarily chosen based off of calculations made by the designer. In order to maximize the system's efficiency, testing is going to be performed. A light spring is going to be used because it will allow for quicker engagement to utilize the power output of the engine sooner. And a 65 gram weights are used for in the primary clutch. The contour of the weight follows the contour of a diesel Polaris Ranger. The primary and secondary clutches are stock with modified components to work efficiently with the RPM of the diesel engine. The clutching system is key for the snowmobile to operate at a minimum of 35 MPH for the competition.

Exhaust System

The exhaust system encompasses all of the exhaust heat and gas exiting the engine. As stated in the innovations section, the DOC and DPF system the CST uses is from a Turbocharged Direct Injection Volkswagen DOC and DPF. A Walker Evans quiet flow muffler is used to reduce the noise from the engine. The systems are combined to form an innovative solution for addressing the noise and emissions objectives for the snowmobile. Figure 13 shows the layout for the exhaust pipes. The pipes have exhaust wrap on them to keep the tubes at a higher temperature. To prevent heat transfer from the emissions system to the chassis, the team built a steel shield to isolate the exhaust system and keep it at a higher temperature.

Figure 13: Exhaust piping

Electrical System

The main goal of the electrical design is to create a system that operates very similarly to a stock snowmobile. The team made a custom wiring harness to use in combination with the sensors and

an LCD display. The temperature and RPM are shown on the display unit to give the rider feedback from the sled. Electrical designers modified stock components to function with the diesel engine. The team integrated an LCD display with a custom design based off the Kubota engine manuel's electrical design. The diagram for the electrical system is shown in Appendix B.

Cost

The 2018 Polaris Titan Adventure retails for $14,999.00 new[2]. Factoring about 60% of that cost for a chassis without a powertrain, the chassis is valued at about $9000.00. Modifications to the sled, like adding a diesel engine, a clean exhaust system, an additional battery, aftermarket skis, and other components increase the value of the sled. Totaling the value of all the systems and added components, the manufacturer suggested retail price including design and labor, comes to a little over $16,500.00. This is on par with the original gasoline price. The team was able to use less expensive components for the exhaust system and really cut down on the cost of the machine. The goal of the CST is not to produce the least expensive snowmobile possible, but to produce a snowmobile that produces low emissions, minimal noise, and performs well.

Summary

The CST is working towards a low emission design and a quiet snowmobile. The goals of stock appearance, low emissions, and noise reduction help establish the objectives the team has as a professional organization. The CST displays professionalism by promoting safe work habits. In order to get more people involved, the team has a presence in the community, on campus, and reaches out to sponsors. The team designed this sled to be an efficient utility vehicle. Using modified stock components, especially in the exhaust system, creates a cleaner quieter snowmobile.

References

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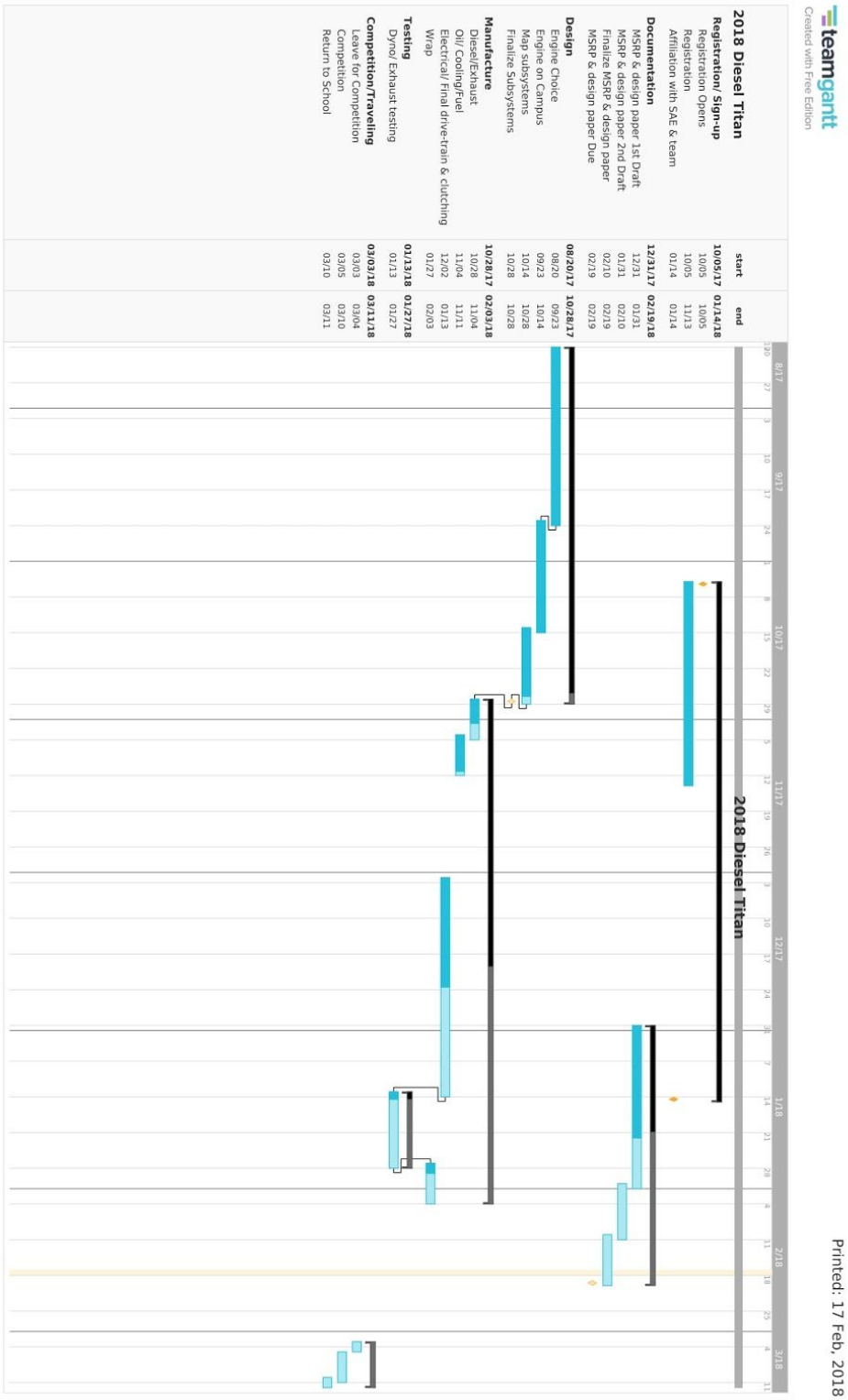
Definitions/Abbreviations

CAMP - Center of Excellence for Advanced Manufacturing and Production
CST - Clean Snowmobile Team
DOC - Diesel Oxidation Catalyst
DPF - Diesel Particulate Filter
MPH - Miles Per Hour
RPM - Revolutions Per Minute
SAE - Society of Automotive Engineers
SDS - Safety Data Sheets
SDSMT - South Dakota School of Mines and Technology

Appendix A



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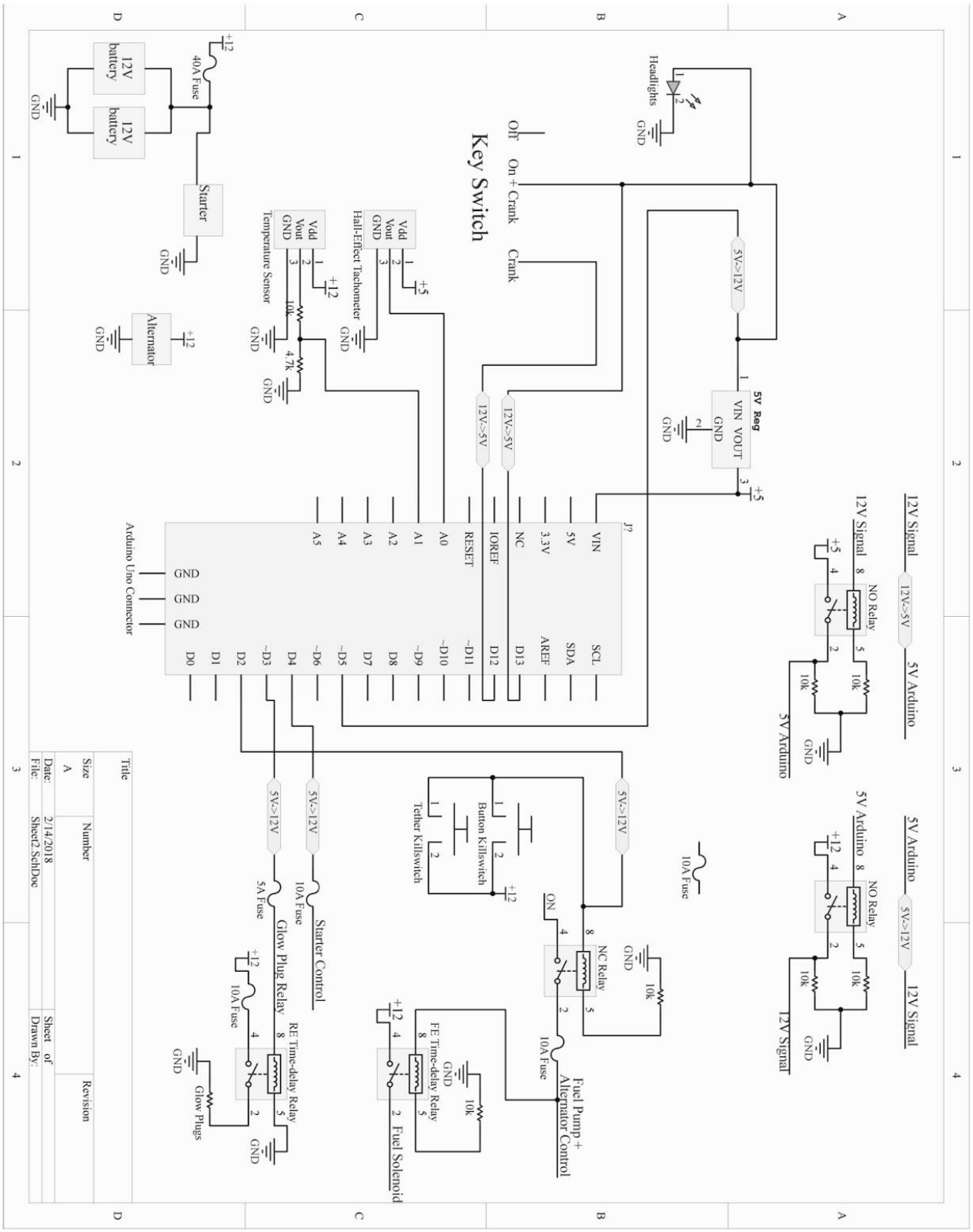
Appendix B


12V Signal
5V Arduino
12V Signal
5V Arduino
5V Arduino
12V Signal
Headlights
GND
Key Switch
Off
On + Crank
Crank
5V->12V
5V Reg
VIN VOUT
GND
12V->5V
12V->5V
J?
VIN
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3.3V
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RESET
SCL
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Glow Plug Relay
10A Fuse
Glow Plugs
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