Hybrid OTTPA Super Mini Modified Tractor Design

Phase 1 - Research and System Concept

Ivan J, Andy W, Jerry Z, Sanchit, Dhruv, Aauysh
Mr. Andrade
Engineering Design, Fall 2025

Project Overview

Through this project, our goal is to make a mini modified hybrid tractor, designing it to be compliant with the rules and regulations of the Ontario Truck & Tractor Pulling Association, and designing it to make it competitive. In this project we have divided it into 3 phases, to divide the work within the group, and to stay on track. The first phase is the conceptualization, planning, and research of the tractor, with no real calculations. Through this phase we want to have the entire tractor planned out, with the systems, and exactly what we want to make. This gives us a leg up from, making us prepared to handle any seen and unforeseen issues as we move onto phase 2. Phase 2 will be the calculation and CAD design of this project. Phase 3 being the reflection and documentation of the project.

Our main objective within this project is to use a hybrid-drivetrain system, where a diesel generator powers a battery pack. This battery pack will be connected to an electric motor, providing instant torque rather than the latter, where the diesel motor will be connected to the wheels instead, slowing it down. This allows us to be more competitive if we decide to follow through with this design in the actual competition. The motors should create a force around 1500 NM, which would allow the tractor to rest on its rear wheels, which is crucial for a tractor pull competition.

The rest of this document will detail phase one, with columns for necessities, nice-to-haves, detailed structure of the systems in the tractor (frame, drivetrain, electrical, and safety), research on what type of motor would work best/why it would work best, and some concept sketches. Through this phase, we can have a solid bedrock for the designing and CAD portions.

1 OTTPA Rules & Constraints

To make the competitions fair, safe, and equal for all participants, the OTTPA has created rules and regulations that all competitors must follow to be able to function. These rules heavily impact the design of the tractor, but also provide guidance on how we could innovate to get better designs and a more efficient machine.

There are several categories of constraints that need to be followed for this project, such as: Weight and Size Limits, tires, hitch and drawbar, drivetrain and transmission, electrical, safety, fenders and skid plates, engine, and exhaust.

Type of Constraint	**Requirements**	**Notes**
Weight and Size Limits	Maximum Weight: 2050 lbs; Maximum length forward of rear wheel centerline: 8 ft; Maximum Tread Width: 6 ft	Compliant with OTTPA standards
Tires	Must be: 18.4 x 16.1 allowed, no radicals	Standard pull tires
Hitch and Drawbar	Minimum 6" from rear axle; Maximum 13" from top of hitching device to ground	Fits pulling geometry
Drivetrain and Transmission	Reverse Lockout Required; Driveshaft shielding: full length, minimum 5/16" steel or 3/8" aluminum, SFI bellhousing	Meets safety requirements
Electrical	Kill switch, Battery Disconnect, Air Shut-Off	Included in design
Safety	Roll Cage, Seatbelts, Neck Brace, Fire Extinguisher, Helmet	Fully compliant
Fenders and Skid Plates	Fenders cover tires, Skid plate supports front weight	CAD layout includes these

Table 1: OTTPA Rules and Constraints

2 System Overview

Frame

Responsibilities for a frame is to withhold the parts of other systems and provide structural support. The other systems that the frame helps to hold are the electrical systems, drivetrain, safety, and is the most important part of the tractor.

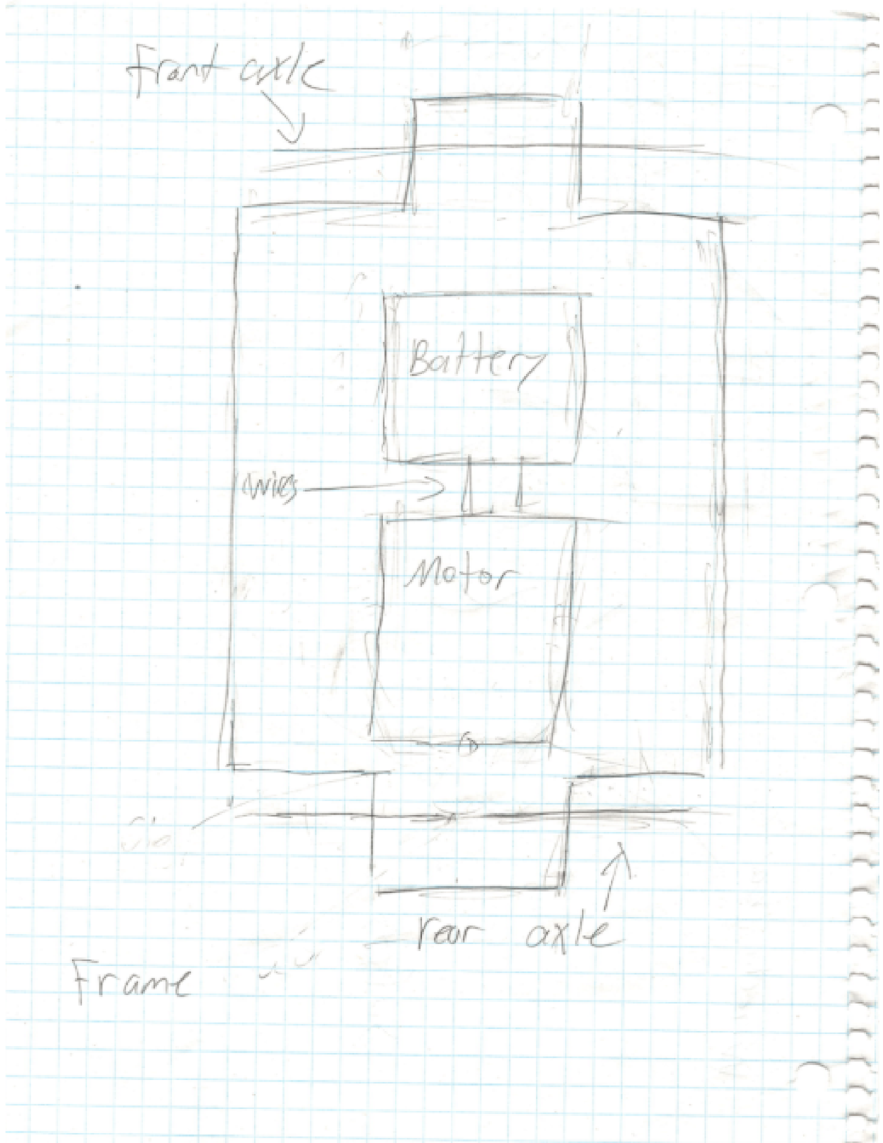

Figure 1: Frame structure

Drivetrain

Electric drive motor: An electric drive motor is a machine that converts electrical energy (from a battery or generator) into mechanical energy (rotational motion). In electric tractors, this motor replaces the traditional diesel engine.

The motor consists of:

- Stator – the stationary part that creates a magnetic field.
- Rotor – the rotating part inside the stator that turns when magnetic forces act on it.
- Power electronics – devices that control how much voltage and current go to the motor, managing speed and torque.

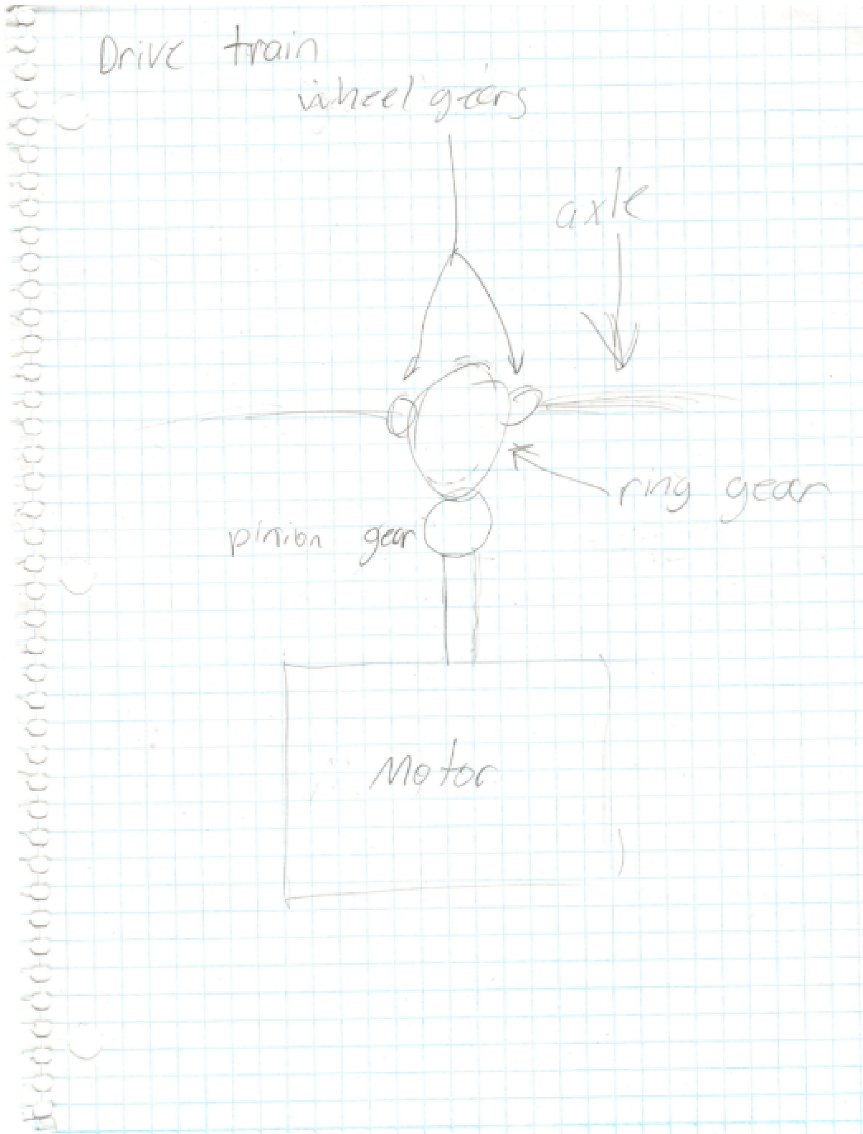

Figure 2: Drivetrain schematic

Electrical

- Diesel generator: Converts diesel fuel into electrical power (usually AC). Feeds the system or charges the battery.
- Rectifier / DC Converter: Converts generator AC to DC for charging or feeding inverter.
- Battery Pack: Stores the electricity to use in the electric motor to generate instant torque, accelerations, and basically fuels it.
- Sensors/Logic: Uses raspberry pi's to monitor speed, voltage, current, and balance. Which lets the driver have more control over the motor and the rest of the vehicle.

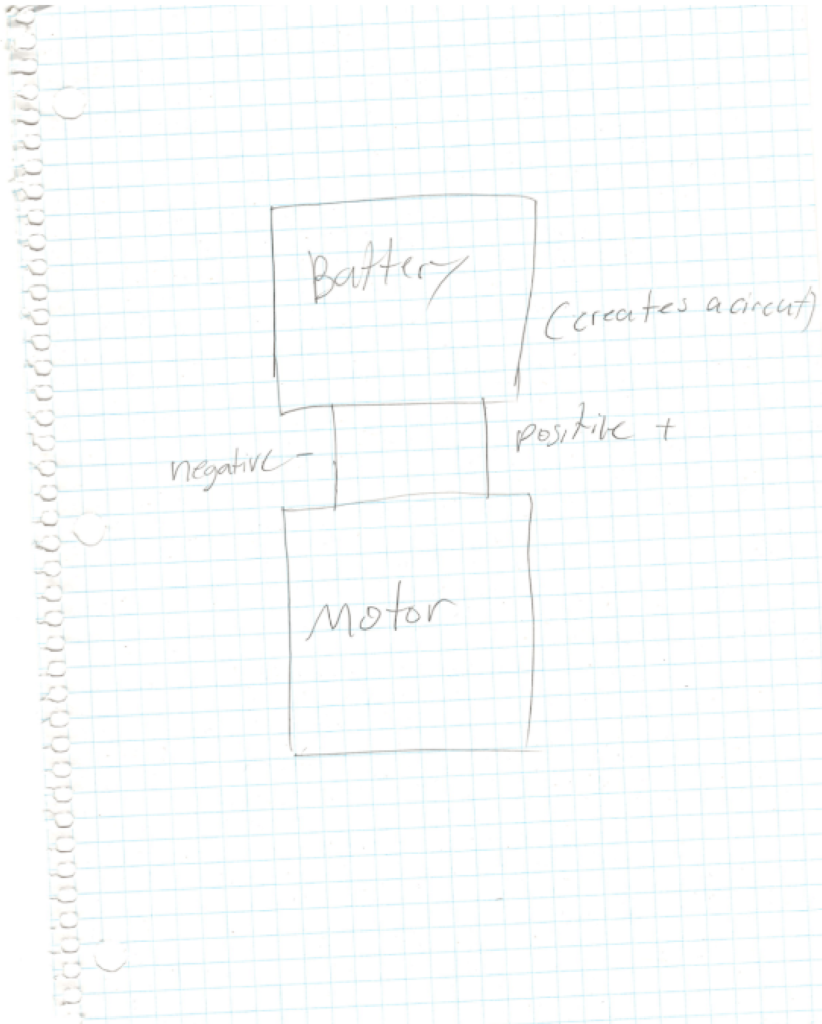

Figure 3: Electrical system

Safety

The safety system protects the driver and the rest of the people around them, the spectators from any mishaps that may occur during these competitions. The safety tools include:

- Roll Cage (SFI 47.3 Rated): to protect the driver from any rolling accidents, must be SFI 47.3 rated, which is a third-party rating system that protects the driver.
- SFI-approved safety harness - To keep the tractor driver buckled in and away from any harm that may happen to them.
- Fire-Extinguisher: for any fire related mishaps.
- Kill Switch/Shielding: During repairs or emergencies, moving parts of the drivetrain will be protected by shielding to stop any mishaps from happening to the drivetrain and to stop parts from being damaged, causing risk. There will also be a killswitch to stop the diesel reaching the generator and to remove power for the same reasons.

- Wheelie Bar: To protect the driver in case the wheelie goes too far and and it will stop the driver from falling backwards.

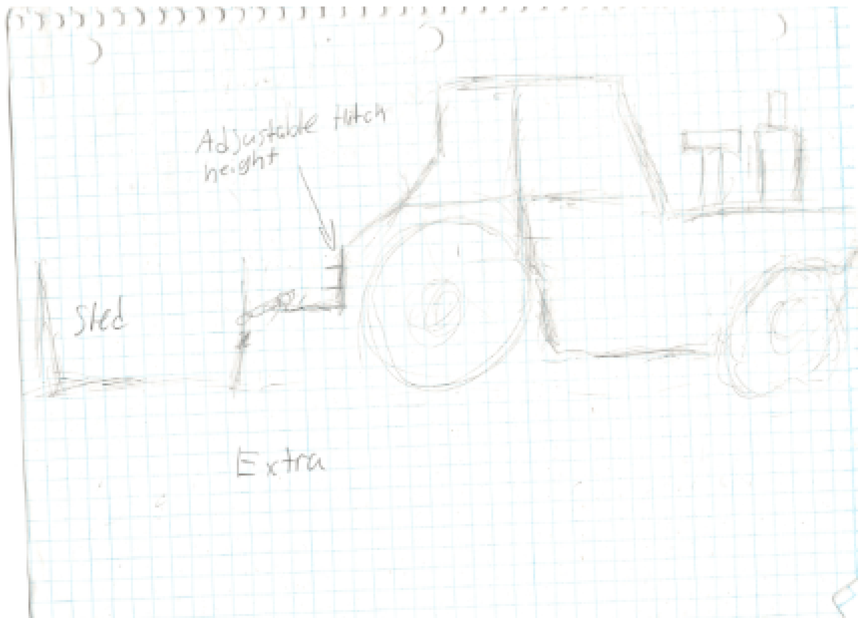

Figure 4: Extra Drawings .

2.1 Extra Drawings

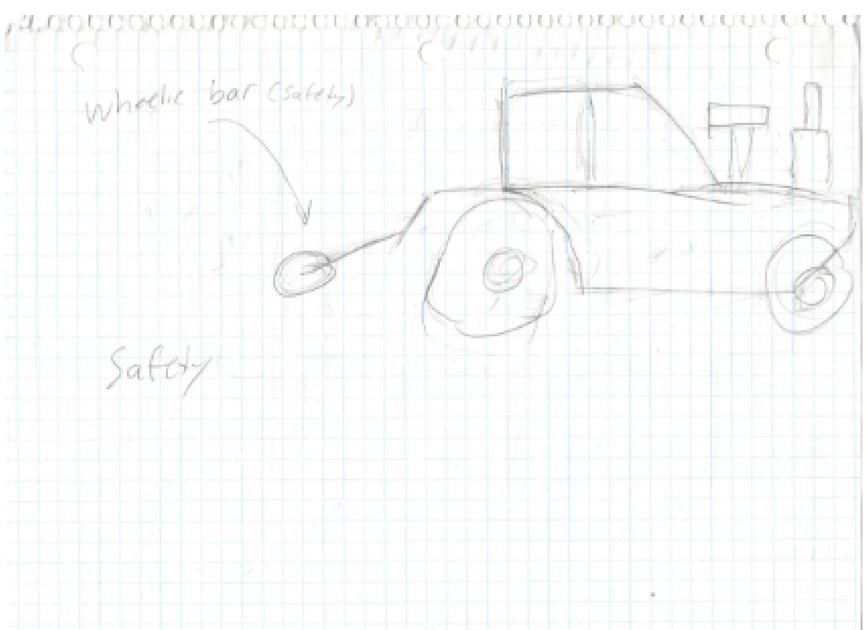

Figure 5: Safety system .

3 Torque and Power Analysis

Torque determines the pulling force available at the wheels. The basic equation is:

$$T = F \times r$$

Where T is torque, F is traction force, and r is wheel radius.

Assuming a traction force of 6000 N and wheel radius of 0.25 m:

$$T = 6000 \times 0.25 = 1500 \text{ Nm per wheel.}$$

This ensures sufficient pulling force to lift the front end. The diesel generator (about 20–25 kW) provides steady power while the battery handles transient peaks.

Additionally, power can be estimated using:

$$P = \frac{T \times \omega}{9550}$$

where P is power in kW, T is torque in Nm, and ω is rotational speed in RPM.

4 Needs vs Nice-to-Haves

Needs	**Nice-to-Haves**
"D" ring Hitch point (must be bright)	Adjustable hitch height, having an adjustable hitch height allows us to control how much torque is needed to do a wheelie. (Not sure if this is allowed)
Kill switch	Wheelie bar, we can use a wheelie bar to make wheelie's safer for our tractor when testing.
Air shut off (from driver's compartment and rear of vehicle.)	Using different tire materials and tire designs that interact differently with the terrain.
Fuel shut off	Adjustable track width
All safety-critical and important parts must be SFI compliant. (https://sfifoundation.com/)	—
Fire extinguisher	—
Driveshaft Shielding	—
Transmission Shields	—
Fenders	—
Roll cage	—
Seatbelts	—
Reverse Lights	—
Dead-Man throttle	—
RPM monitoring	—

Table 2: Needs vs Nice-to-Haves

5 Investigation for Hybrid Motors

My project uses a series-hybrid (diesel-electric) drivetrain, where the diesel engine powers a generator instead of driving the wheels directly. The generator produces electricity that charges a battery pack and powers electric motors connected to the rear wheels. This allows us to make instant torque, around 1500 Nm, ideal for pulling and controlled wheelies in competitions like the tractor pull organized by the OTTPA.

Electric motors provide full torque at 0 RPM, which is very good and instantaneous, removing the need for a transmission and simplifying the drivetrain, also reducing the weight that we need. The diesel engine can run steadily at its most efficient speed, recharging the battery instead of constantly changing RPMs which makes this more efficient as well.

The battery pack acts as a power buffer with three main functions:

- Peak shaving: supplies extra power during high-demand moments.

- Load leveling: keeps the generator running efficiently at constant speed.

A key challenge is generator sizing. Electric motors require high startup current (3–6× normal). Instead of using an oversized generator, I'll use the hybrid approach, where the battery handles short power surges while the generator maintains average load, which is ideal in competitions like this where we can consistently control the power given out, and it doesn't cause too much strain on the generator either.

In summary, this series-hybrid design combines diesel reliability with electric torque, creating a lighter, efficient, and high-performance pulling tractor. We are considering designs from the F150 Lightning, or the Edison motor's one that had been shown in class.

This type of generator is better suited for a project like this because of 3 main things:

- It's lighter, and less bulky than a typical generator.
- Has environmental risks and isn't clean to test and build around either.
- It's not against the rules like a fully electric engine.

And therefore it is the best suited for our uses.

6 Reflection

This project helped me understand how hybrid systems integrate electrical, mechanical, and control engineering principles. I learned to calculate torque and power, design within safety constraints, and document technical work professionally. However because of miscommunication with the teacher, and unclear/ambiguous instructions, our project took too long. This created a time delay for us, and with certain deadlines approaching our group could only accomplish so much in this allotted timeslot. Our CAD designs and our complex force calculations were due in the next phase, and next time a submission like this comes up, we will speak with the teacher to clarify the expectations given to us, and we will collaborate with other groups as well. As Ubuntu says, "I am, because we are", which shows us the significance of teamwork in fields such as engineering and product design, where knowledge is to be shared and used freely.