Electrically Powered Woodcut Car: Solo Steel Stallion

Sean Gentry

ME 2160: Introduction to Mechanical Engineering Design @ Vanderbilt University

Abstract

The goal of this project was to design and build an electric motor-powered car. I seek to compete in the fastest time, most pulling power, most school spirit, and most style. In this paper, you will see the process from start to finish on how I was able to create a sleek, modern design of a very unique muscle car. In the end, it was discovered work could be done on the structural integrity, pulling power, and torque. However, the finished product was rated by the community to be of the highest quality and grade of style.

1. Introduction

Mechanical design can be split into five sections: research, ideation, frustration, incubation, and eureka. Design requires deep knowledge of the world your project idea lies, and a lot of creativity to come up with a good idea and bring it to life. Diving into the task of developing an electrically motored car, you will see three of the five stages, skipping frustration and incubation to keep the paper short and sweet.

We use laser-cut parts alongside the specified parts of the Amazon kit [1] to develop a miniature car that is fast, has strong pull power, and is stylish. Using a series circuit we achieve high voltage and in turn high power. The result is a fast, strong, and stylish vehicle extremely inspired by a widebody modified Chevy Camaro.

2. Background Research

The project is limited to the parts of the Amazon kit [1], ⅛ in plywood for laser cutting and 3D printing cosmetics. The most trivial of the goals is the coolness factor and most school spirit, as those can be accomplished with decals and the design of the car's frame. These conflict with the goals of competing for the most pulling strength and speed. When it comes to strength and speed, there are conflicting trains of thought. A smaller gear ratio means a higher speed, but less torque, and a higher gear ratio means more torque, but less speed. This is supported by the gear ratio equation:

$$Gear\ Ratio \ = \ \frac{\omega_1}{\omega_2} = \frac{v_1}{v_2} = \frac{d_2}{d_1} = \frac{\tau_2}{\tau_1}\text{, where:}$$

- ω_1 and ω_2 = angular velocity in radian/sec for driver and driven gear
- v_1 and v_2 = respective gear speed in RPM.
- d_1 and d_2 = respective gear diameters
- τ_1 and τ_2 = torque input and output

The motors required for the car operate at 1.5 - 3V according to the specifications of the Amazon kit. However, the tolerance allows for operation at 6V as supported by the individual part specifications found online [2]. While the battery packs support only 2, AA, 1.5V batteries at a time, connecting the battery backs in series can allow us to achieve higher voltages across the motor by Kirchhoff's Voltage Law.

The aerodynamics, and weight of the car are the most important factors for speed apart from high power. A car that can move through the air with the least resistance will move faster and less weight means more acceleration by Newton's 2nd Law. Since the track is only a 10 ft straight away, a car with a low center of gravity, that is aerodynamically favorable and light, would be perfect to be the fastest [3]. However, competing in the coolness factor and school spirit will make this difficult.

3. Goal Statement

The goal of this project is to create a high-power, aerodynamic, high-efficiency, motor vehicle for maximum acceleration on a 10-foot track while incorporating a visually remarkable and clever aesthetic. The design will incorporate the required materials and blend speed and pull power with a sleek, modern design to ensure high-level performance and leave clients with an unforgettable visual experience.

The vehicle is limited to only using parts from the supplied hardware kit [link] for transmission components, laser-cut parts of ⅛ in plywood for framing and/or housing, and 3D-printed components for cosmetics. The transmission ratio will be at least 3:1 and the entire vehicle will fit in an 8”x8”x8” box.

4. Design Description

4.1 Gear Drive

The design of the vehicle starts with the Amazon kit, in the kit we have access to 4 motors, battery packs, 4 tires, axles of different lengths, and more miscellaneous items and accessories such as pulleys, gears, and stoppers. At the most basic level, the car should have some sort of belt or gear drive to transmit power from the motor to the axle. With the limit of having at least a 3:1 gear ratio, we would want to get as close to 3 as possible to be fast since the lower the ratio, the faster you go. The design features a 3.111:1 gear ratio, simply meshing a driving 18-tooth gear and 56-tooth gear on the axle. Choosing to have a simple, two-gear gear train reduces how much energy is lost to work from friction and energy from noise, transmitting power efficiently. This will be the core of the drivetrain of the car.

The next step should be answering the question of how to power this motor and move the car. I wanted to push the motor to the maximum potential, meaning the maximum power. To increase the power delivered to a resisting element, we must increase the voltage or current. By the equation:

$$p = \frac{v^2}{R}$$

This means doubling the voltage will quadruple the power delivered. We accomplish this with a series circuit of battery packs. Each battery pack holds two 1.5-V AA battery cells and setting these in series with a switch between them and connecting the other terminals to the motor accomplishes this. The following diagram shows the simplified circuit accomplished:

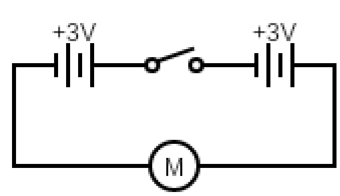


Figure 1. ***Diagram of final circuit*** [Made using https://www.circuit-diagram]

4.2 Subsection Chassis

Next is the chassis, which has gone through many iterations. The chassis has a few requirements. It must be wide enough to house two battery packs, must be aerodynamically favorable, and be able to have a frame attached to allow for styling. Here's an example sketch:

The first iteration was a test run that only focused on functionality and only featured enough space to house one battery pack. The design features cuts where wood was unnecessary in housing parts, to lower the weight and features a cow-catcher-like front to divide the air. The chassis also features an opening in the back to allow space for the 56-tooth gear. Finally, the bushing housings for the axle were cut along with the axle to house the front and back axles. Everything was assembled using hot glue as the adhesive, press-fit stoppers, and spare gears used to hold the axle from moving axially. I initially had the model resemble a 1:3 ratio rather than a 3:1 accidentally, which forced me to hand-cut out the full slot. This explains why the following model has such a gear ratio instead of the previously mentioned 3.111:1. Here are a few pictures of the SolidWorks and DXF files for the laser cut:

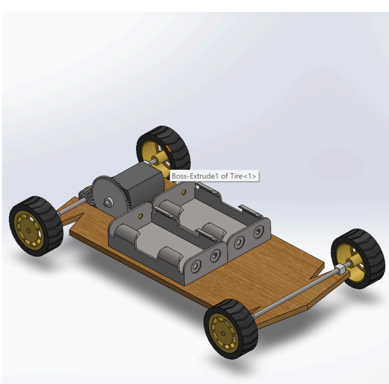


Figure 2. *Solidworks model of first iteration of car*

Figure 3b. *Solidworks model of first iteration of chassis, top-view*

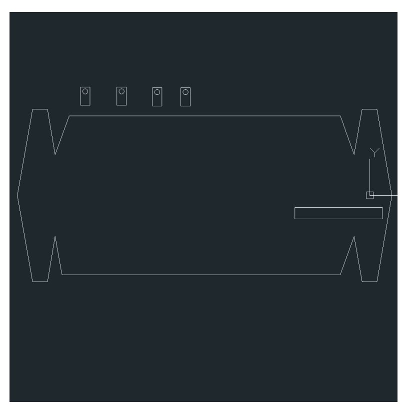


Figure 3b.*AutoCAD file of chassis cutout and axle holders*

And here's a few pictures of the first iteration, I made sure to have a 3:1 ratio as opposed to the 1:3 in the model:

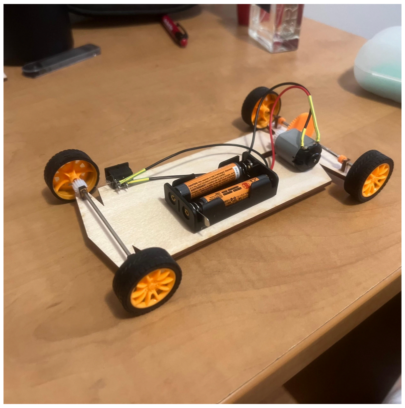


Figure 4a. *First iteration of car*

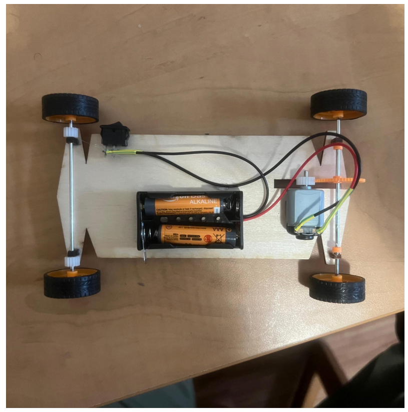


Figure 4b. *Top view of first iteration of car*

Figure 4c. *Underside view of first iteration of car*

The final iteration was based on these ideas: optimization of mass, an aerodynamic shape, and the same gear train. The final iteration features the theorized series circuit and notches to house the cosmetic frame. The chassis also has a drilled-out hole in the back to allow for towing for the competition of most pulling power. The chassis is also bigger, as we'd need more space to house the frame. Even though a bigger frame means more mass and therefore higher weight, this is a compromise we'll have to make to compete in the style categories. See the appendix for the final resulting chassis or follow along to not spoil yourself.

4.3 Frame

The frame is based on a Chevy Camaro and is meant to be attached and detached for the different competitions. The frame will only be attached when competing for the most school spirit, the highest "cool factor", and the most pull power. We accomplish this by using multiple layers of laser-cut parts. First, the base layer will be the base of the frame and the basic shape of a Camaro. The parts were cut with notches to mesh with the chassis and mesh with the other components of the frame. The frame was then held glued together with hot glue, in a similar fashion to fillet welding. This base was then tested to mesh with the chassis and came out to resemble a simplified version of the final goal. Here are some pictures of the first iteration or the base layer of the frame:

Figure 5a. *Base layer of frame and chassis assembled*

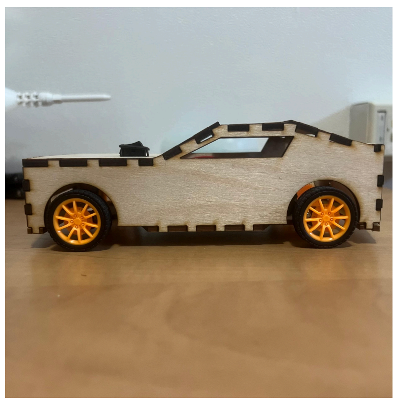


Figure 5a. *Side view of base layer of frame and chassis assembled*

Figure 6. *Inside of base frame view showing hot glue fillets*

On top of the base frame are other laser-cut parts that are hot-glued to define the frame. Featuring a wide body, the design resembles the stylish muscle car and has the speed to respect the original vehicle. There are two extensions to the left and right sides of the frame to add shape and curvature to the sides to really add to the widebody modded Camaro look I was going for. In the rear end, I added plates to protrude the back and shape out rear lights. Furthermore, I added small cylindrical cutouts to act as exhausts giving more realism to the car. I then added a spoiler and front hood covering to provide the front with some more curvature and make the car look better. To give you a sneak peek of the final results, here are some 3D renderings and drawings on SolidWorks:

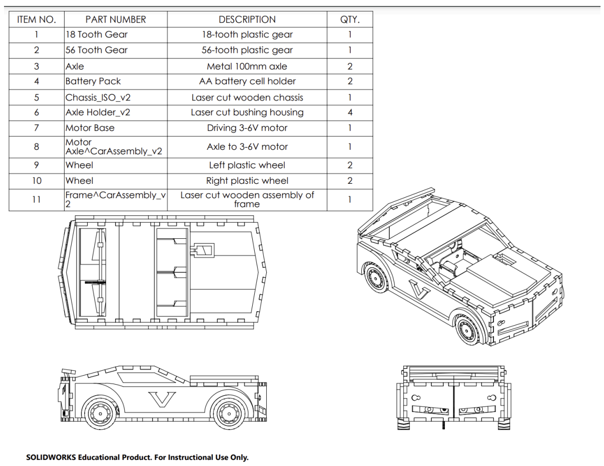


Figure 7a. *SolidWorks drawing of final car model (See appendix for full view)*

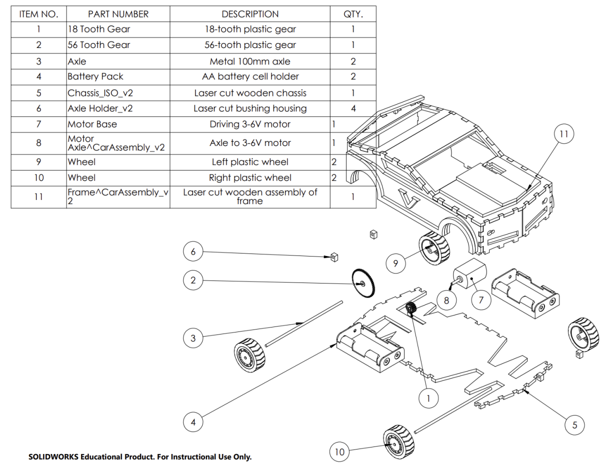


Figure 7b. *SolidWorks drawing of final car model exploded (See appendix for full view)*

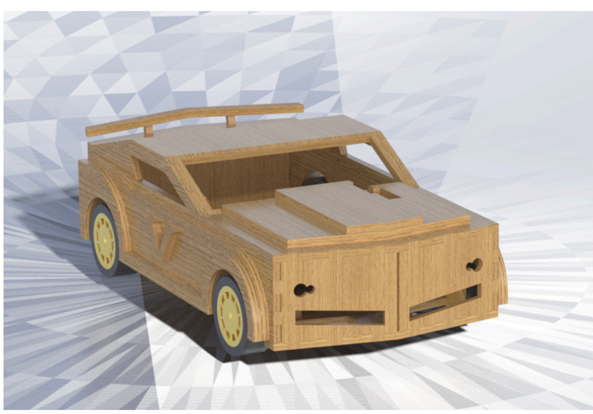


Figure 8a. *SolidWorks Visualize render of final car model (See appendix for more)*

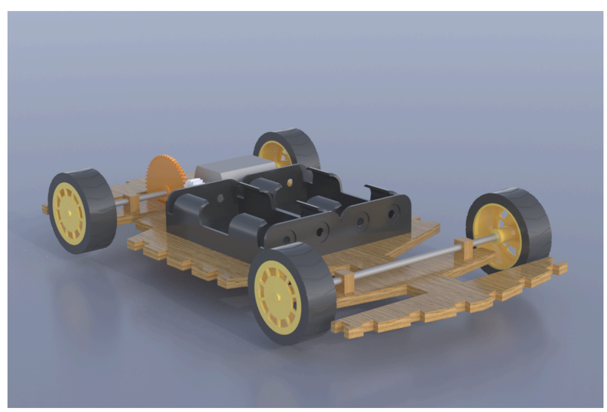


Figure 8b. *SolidWorks Visualize render of final car model chassis (See appendix for more)*

5. Final Remarks

5.1 Results

The result was a lean stylish machine with both speed and acceleration. For some numbers, the car didn't place for speed with a time very close to, but over, 2 seconds to go 10ft and landed 1st place for coolness factor. Here is the final project assembled:

Figure 9. Final product

The resulting circuit was a series circuit that delivered 6V to the motor, reaching the upper limit of the motor's safe zone to avoid long-term deformation and maintain user safety. Doubling the voltage of one battery pack, in turn, quadrupled the power delivered, meaning more torque and speed in the motor axle and wheel axle.

The final chassis came a long way from the first iteration, adding a lot of mass for the sake of style. The chassis has the space to hold the frame, which brings the piece together in terms of style. The frame resembles a widebody modified Chevy Camaro but is more rigid and has fewer curves. Here are some pictures of the final product separated:

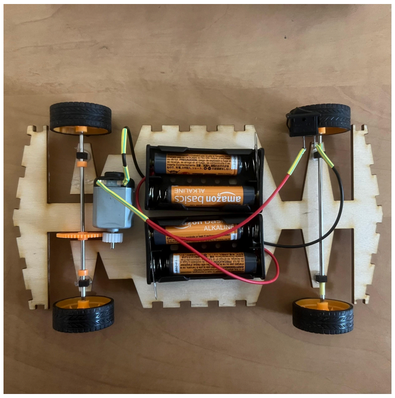


Figure 10. *Top view of chassis without frame*

Figure 11a. *Side view of frame without chassis*

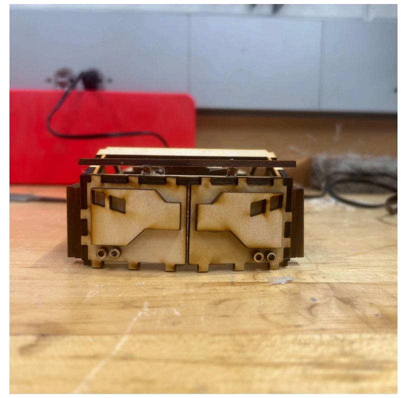


Figure 11b. *Side view of frame without chassis*

5.2. Conclusions

The car was successful in achieving the goals of speed, and style. The car was able to run the 10 ft track fairly quickly, and had an amazing-looking frame, but was not able to pull a fair amount of weight. There is definitely room for improvement.

From the 6V circuit, there is raised acceleration and torque. However, even though there was a raised acceleration, keeping the low end of the high gear ratio means that the torque will still be low, even if it's raised a bit by the power delivered. Even with the high acceleration, without torque, we cannot get the car from 0 to max speed as quickly as a higher gear ratio. With a higher gear ratio, the motor would be able to deliver more torque to the wheels. More field experimentation with gear ratios alongside the 6V circuit would allow me to find the optimal setup to complete the 10 ft track the fastest as well as to pull a weight load.

The chassis also broke in the race from the impact of a crash at the finish line. The axle holder had broken off, so the car could not compete in pulling power. Even so, the car was not able to move as fast with the frame attached. If I had a larger gear ratio, more torque would be delivered, so I should have paid attention to the sacrifices that came with low gear ratios.

The frame could be worked on as well, adding engraving to the frame could allow for curved surfaces and more possibilities to explore in creativity. Falling to the original idea, a Porsche 911 would be more feasible with that approach and with more experimentation and sandboxing. But with the way things came out, I know a muscle car like this was the right choice.

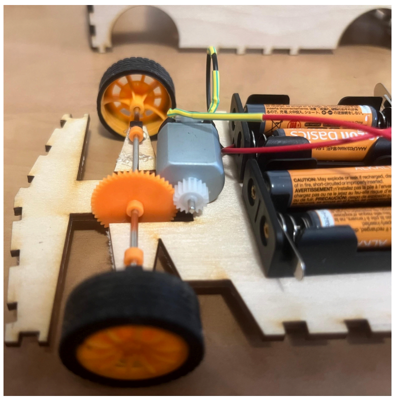
References

[1] EUDAX 6 set Rectangular Mini Electric 1.5-3V 24000RPM DC Motor with 84 Pcs Plastic Gears, Electronic wire, 2 x AA Battery Holder, Boat Rocker Switch, Shaft Propeller for DIY Science Projects https://www.amazon.com/gp/product/B077WWS63B/ref=ox_sc_act_image_2?smid=A27JQP2WM1GK86&psc=1. Accessed 4 Dec. 2024.

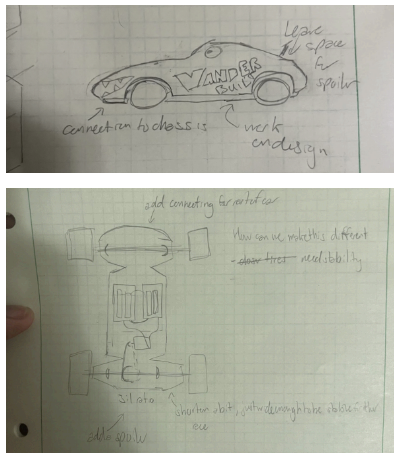
[2] 3V Miniature DC Motor https://quartzcomponents.com/products/miniature-dc-motor#:~:text=3V%20DC%20Motor%20Specifications%3A,Operating%20Voltage%3A%203V%20to%206V. Accessed 4 Dec. 2024

[3] Goff, Stanley. “What Makes a Car Fast?” Sciencing, Sciencing, 24 Mar. 2022, www.sciencing.com/car-fast-7564824/. Accessed 4 Dec. 2024

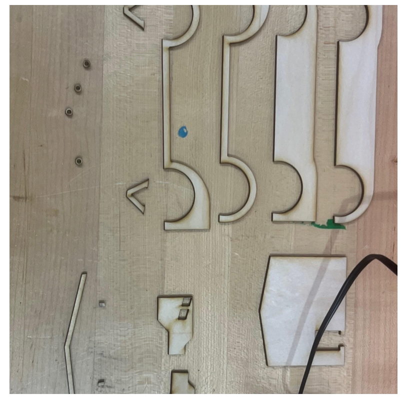
Appendices



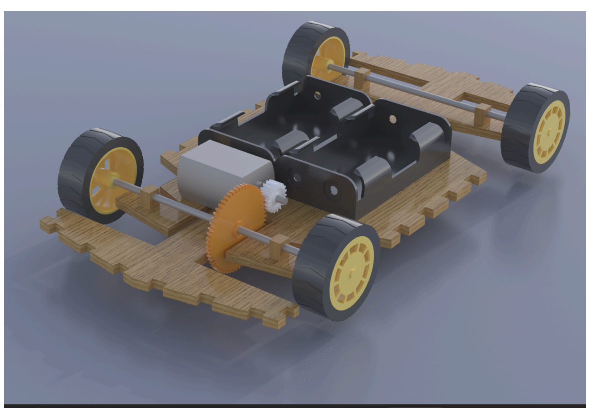
Picture of 56:18 gear ratio on motor to axle



Initial Sketches



Frame extending parts and spoiler pre-assembly

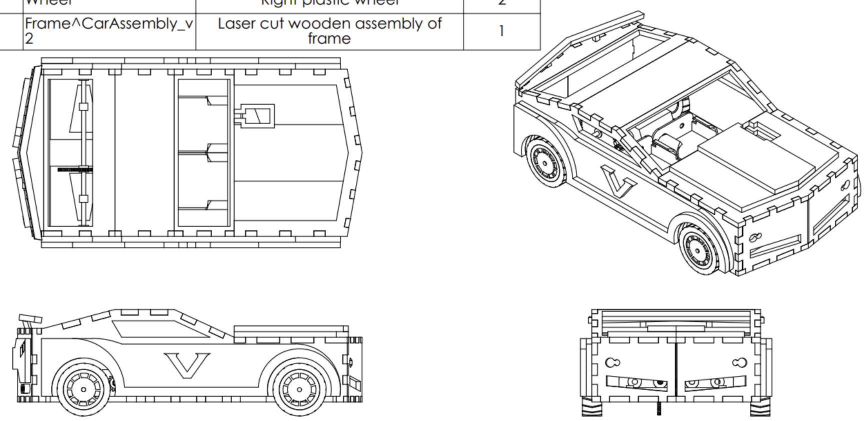


SolidWorks Visualize Render of chassis, view of gear and rear end

SolidWorks Visualize Render of final model, front view.

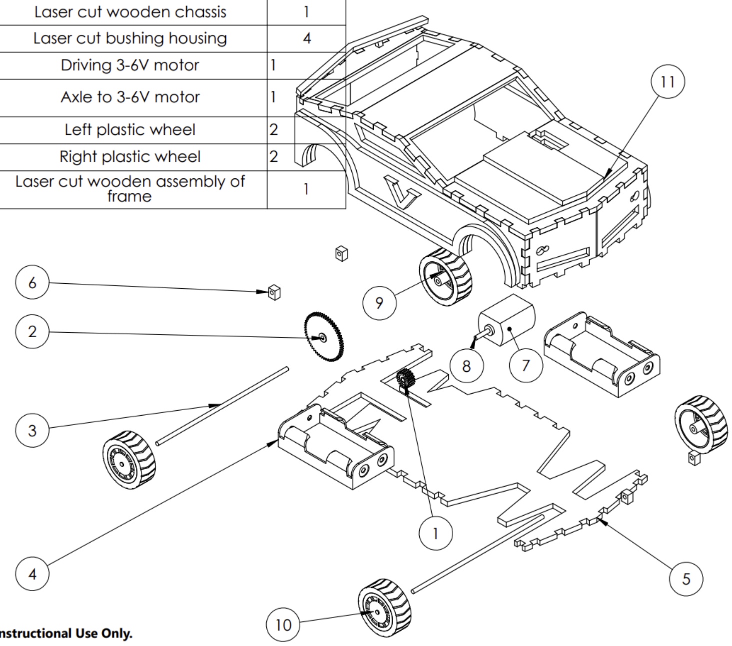
i. Part Drawings

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	18 Tooth Gear	18-tooth plastic gear	1
2	56 Tooth Gear	56-tooth plastic gear	1
3	Axle	Metal 100mm axle	2
4	Battery Pack	AA battery cell holder	2
5	Chassis_ISO_v2	Laser cut wooden chassis	1
6	Axle Holder_v2	Laser cut bushing housing	4
7	Motor Base	Driving 3-6V motor	1
8	Motor Axle^CarAssembly_v2	Axle to 3-6V motor	1
9	Wheel	Left plastic wheel	2
10	Wheel	Right plastic wheel	2
11	Frame^CarAssembly_v2	Laser cut wooden assembly of frame	1



SOLIDWORKS Educational Product. For Instructional Use Only.

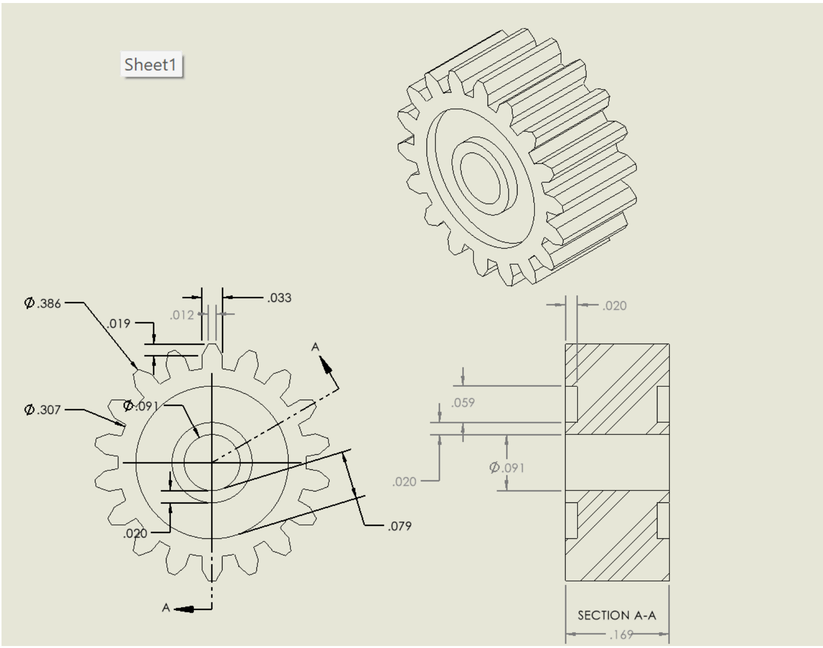
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	18 Tooth Gear	18-tooth plastic gear	1
2	56 Tooth Gear	56-tooth plastic gear	1
3	Axle	Metal 100mm axle	2
4	Battery Pack	AA battery cell holder	2
5	Chassis_ISO_v2	Laser cut wooden chassis	1
6	Axle Holder_v2	Laser cut bushing housing	4
7	Motor Base	Driving 3-6V motor	1
8	Motor Axle^CarAssembly_v2	Axle to 3-6V motor	1
9	Wheel	Left plastic wheel	2
10	Wheel	Right plastic wheel	2
11	Frame^CarAssembly_v2	Laser cut wooden assembly of frame	1



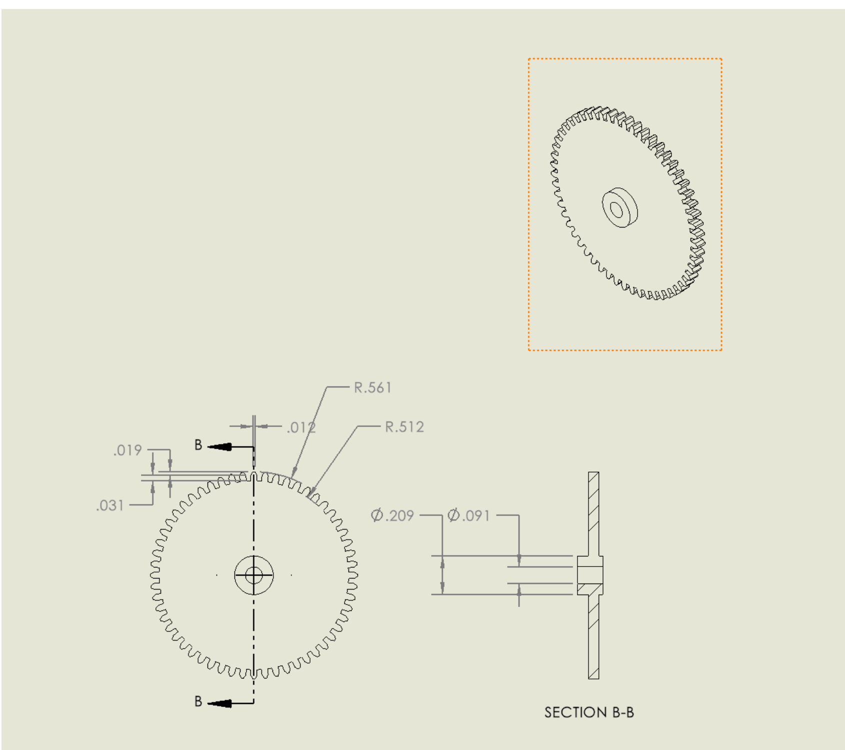
SOLIDWORKS Educational Product. For Instructional Use Only.

ii. Chassis Part Drawings

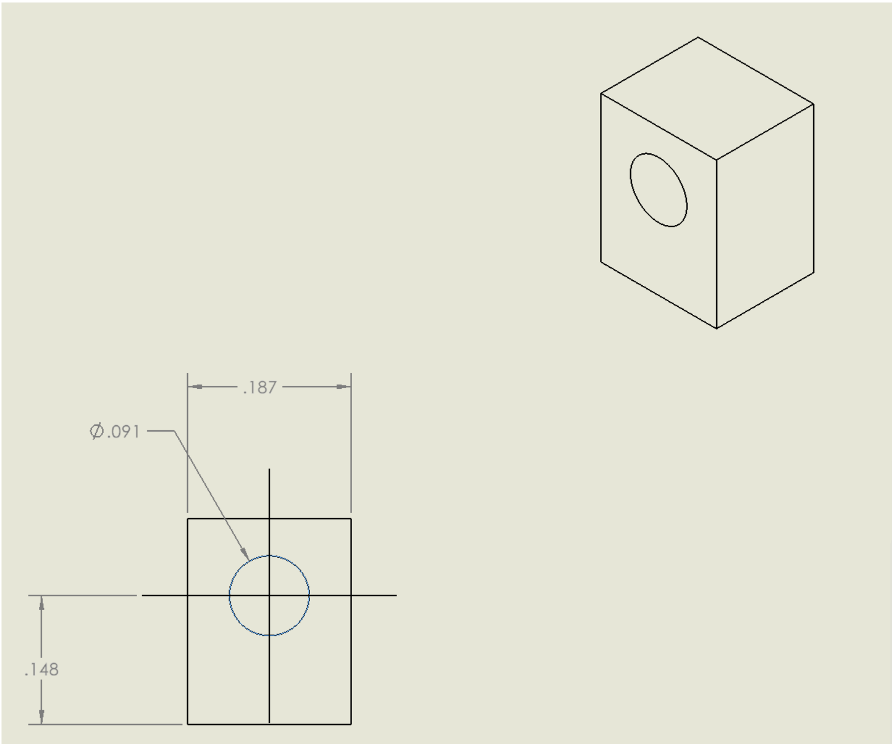
18 Tooth Gear



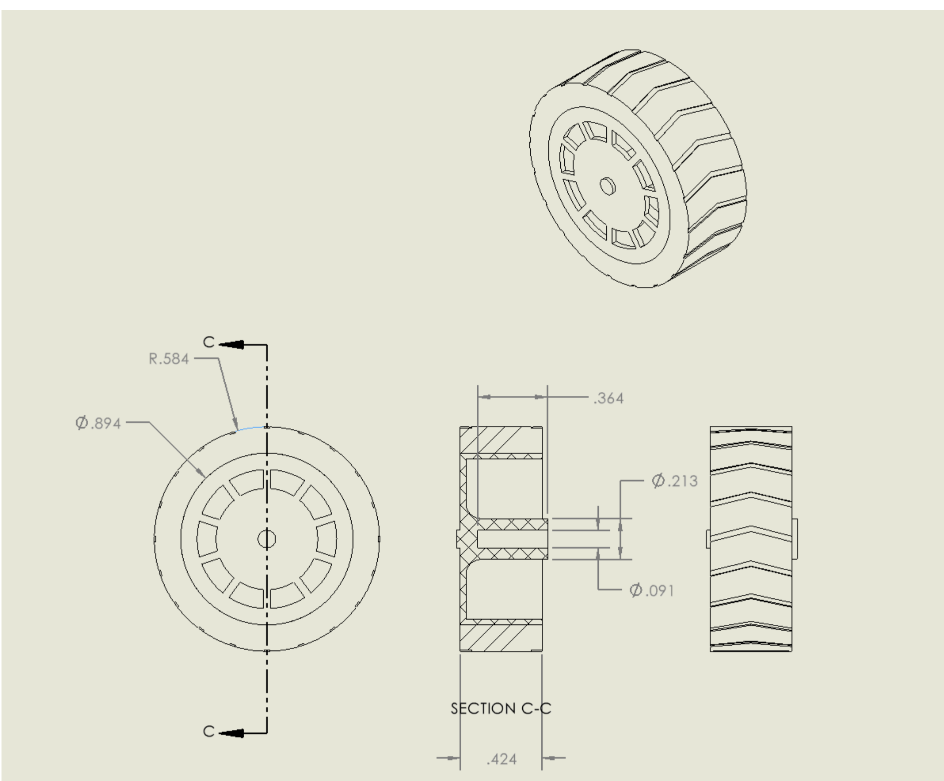
56 Tooth Gear



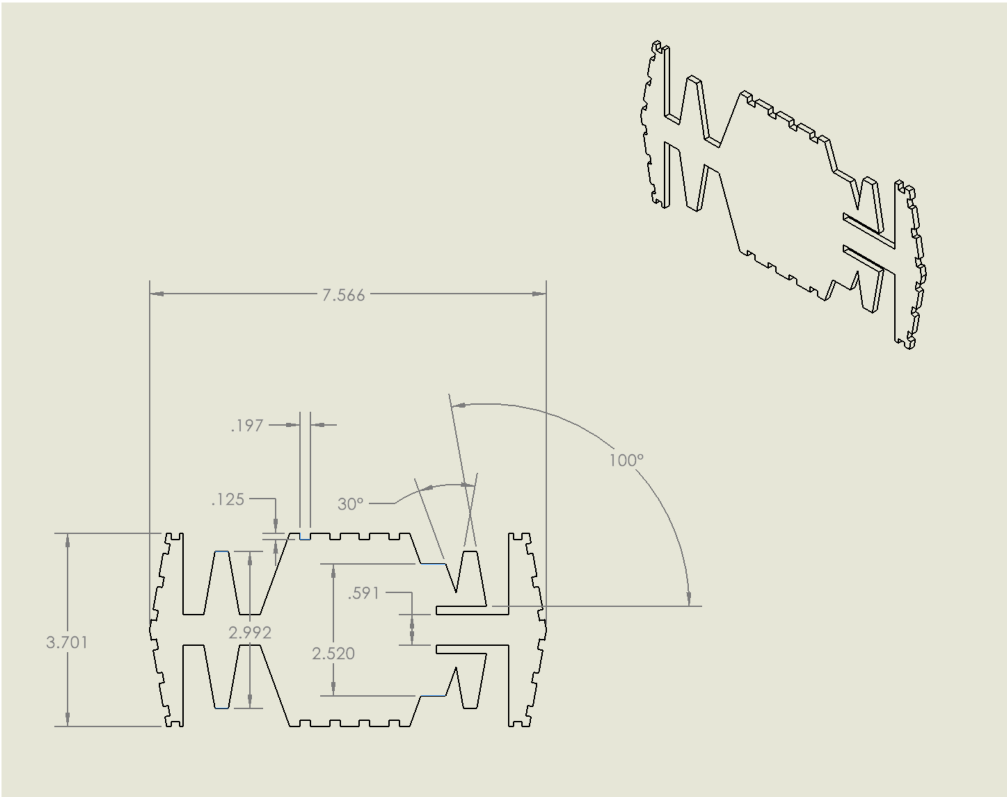
Axle Holder



Wheel

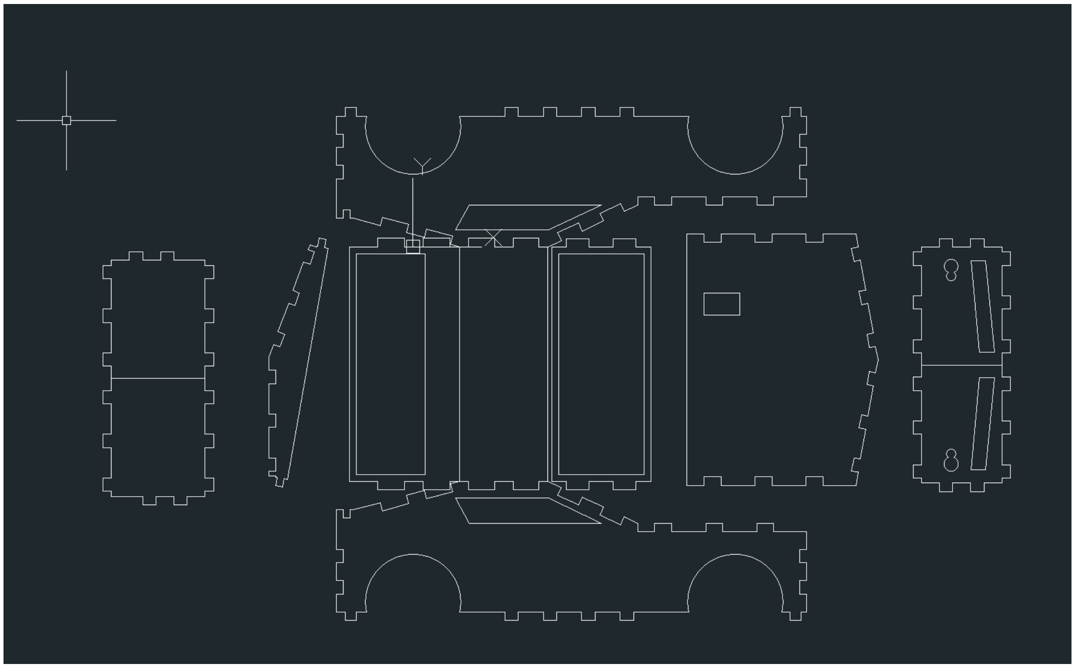


Chassis



iii. Frame Part AutoCAD DXFs

Base Frame



Frame Extensions