ENGINEER 1C03 - Engineering Design & Graphics
Engineering 1 Cornerstone Design Project

Instructor: Dr. McDonald

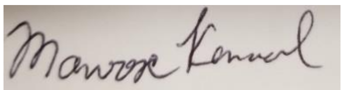
Team **100**
Lab Section**: L7**

Manrose Kanwal – kanwam1 – 400197884
Jordan Bierbrier – bierbrj – 400174140
Abd Elelah Arafah – arafaha – 400197623

Integrity Contract

As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario.

Submitted by [Manrose Kanwal, 400197884]



Signature

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Submitted by [Jordan Bierbrier, 400174140]

Signature

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Submitted by [Abd Elelah Arafah, 400197623]

Signature

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Introduction

First of all, it is important to mention that it is almost near to impossible to create a replication of a human body part. However, as time progresses the technology of the creation of prosthetic body parts are getting closer to the functionality and accuracy of operation to the real parts of a human. Engineers around the world are constantly working on developing and creating different types of artificial human body parts to be used in many different fields such as: using them in robotic machines or implanting them to a human that needs that specific human body part. Different fields of usage require different types of artificial body parts, the 3 most popular types of artificial parts are: 1. Myoelectric device (Requires attachment of sensors to muscles) 2. Body-powered device (Works with mechanical systems) 3. Aesthetic functional device (Focuses on physical looks of device). [1]

Design Problem

We are required to make a proof-of-concept, low-cost gripping prosthetic apparatus where the specific rotation speed for the thumb and forefinger must be 15 RPM and the input speed by the motor must be 180 RPM. When the thumb and the forefinger rotate, their tips must contact each other somewhere within the given 30mm by 30mm functional workspace. We are also required to construct a custom mounting bracket which fits inside the prosthetic frame and must have all our gears and fingers inside it. The bracket must be functional and appropriate to our design where it is considerate of all our gears and the dimensions of the prosthetic frame's dimensions.

Final Design

Our final design consists of 10 spur gears, 2 custom designed fingers, 10 threaded rods, 20 hex nuts, and 2 frame walls. Many of our gears are meshed together except for 2 gears which will be shown in our data table and our thumb and finger which are meshed to 2 gears as well. The gears that are axially connected to our thumb and finger rotate in opposite directions of each other so it can create the pinching motion. An example is if our motor was to rotate clockwise, our gear that is axially connected to our thumb is going to rotate clockwise whereas the gear-axially connected to the finger is going to rotate counter clockwise.

In this report, a detailed review of our design is discussed. This report consists of the diagrams of our gear train, pictures of both our printed prototype and gear train in inventor, the data produced by inventor's simulations, the challenges we faced and our team attendance with our schedule.

Gear Train Design Calculation

Group 100 × muliplier = ω

100 × 1.8 = 180 rpm

Module = 1 so $D = mz$

$D = (1)z$

$D = z$

Gear Ratio: $GR = \frac{\omega_i}{\omega_o} = \frac{180\,rpm}{15\,rpm} = 12$

Thumb

$$GR = \frac{z_2}{z_1} \times \frac{z_4}{z_3} \times \frac{z_6}{z_5} \times \frac{z_7}{z_6}$$

$$= \frac{36}{12} \times \frac{48}{12} \times \frac{20}{13} \times \frac{13}{20}$$

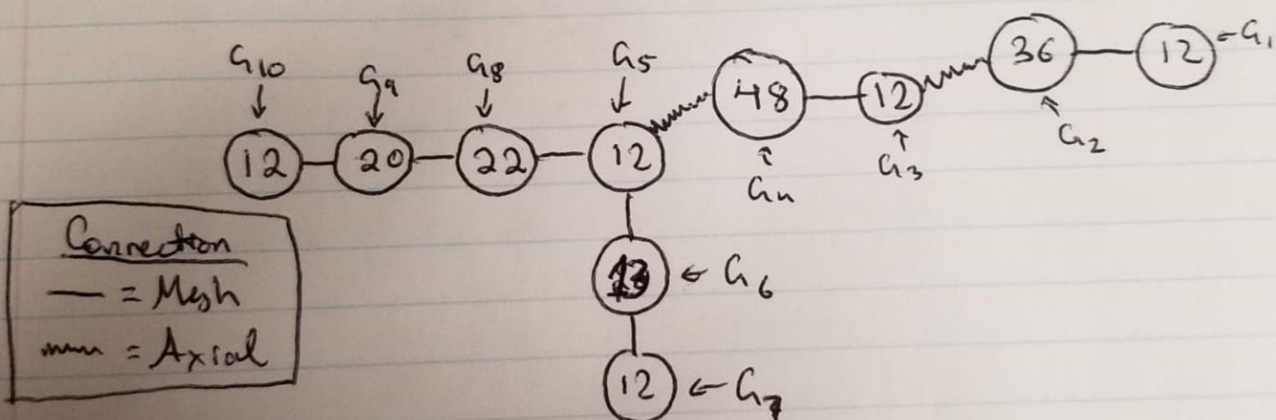
$$= 12$$

Finger

$$GR = \frac{z_2}{z_1} \times \frac{z_4}{z_3} \times \frac{z_8}{z_5} \times \frac{z_9}{z_8} \times \frac{z_{10}}{z_9}$$

$$= \frac{36}{12} \times \frac{48}{12} \times \frac{22}{12} \times \frac{20}{22} \times \frac{12}{20}$$

$$= 12$$



Gear Parameter Chart

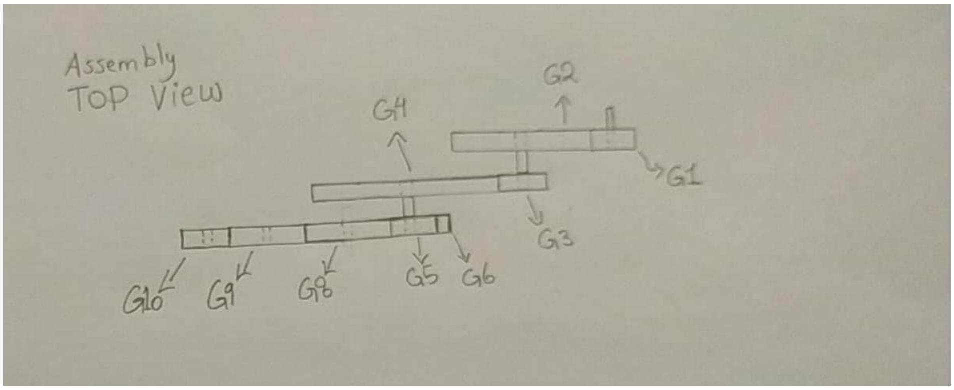
Gear Number	Type of Gear	Connection of Preceding Gear	Pitch Diameter (mm), D	Module (mm/tooth), m	Number of Teeth, z
1	Spur	N/A	12	1	12
2	Spur	Mesh to 1	36	1	36
3	Spur	Axial to 2	12	1	12
4	Spur	Mesh to 3	48	1	48
5	Spur	Axial to 4	12	1	12
6	Spur	Mesh to 5	13	1	13
7	Spur	Mesh to 6	12	1	12
8	Spur	Mesh to 5	22	1	22
9	Spur	Mesh to 8	20	1	20
10	Spur	Mesh to 9	12	1	12

Side Note

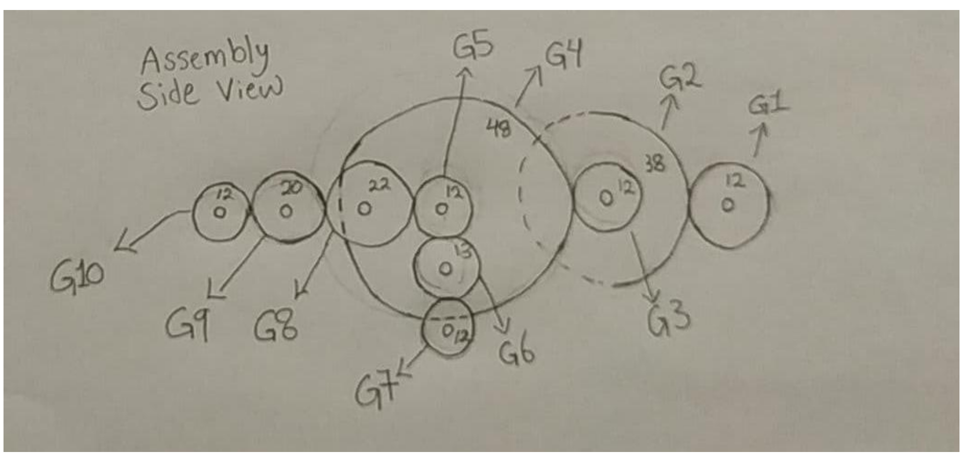
Our thumb is axially connected to gear 7 and our finger is axially connected to gear 10.

Simplified Gearing Mechanism Diagram

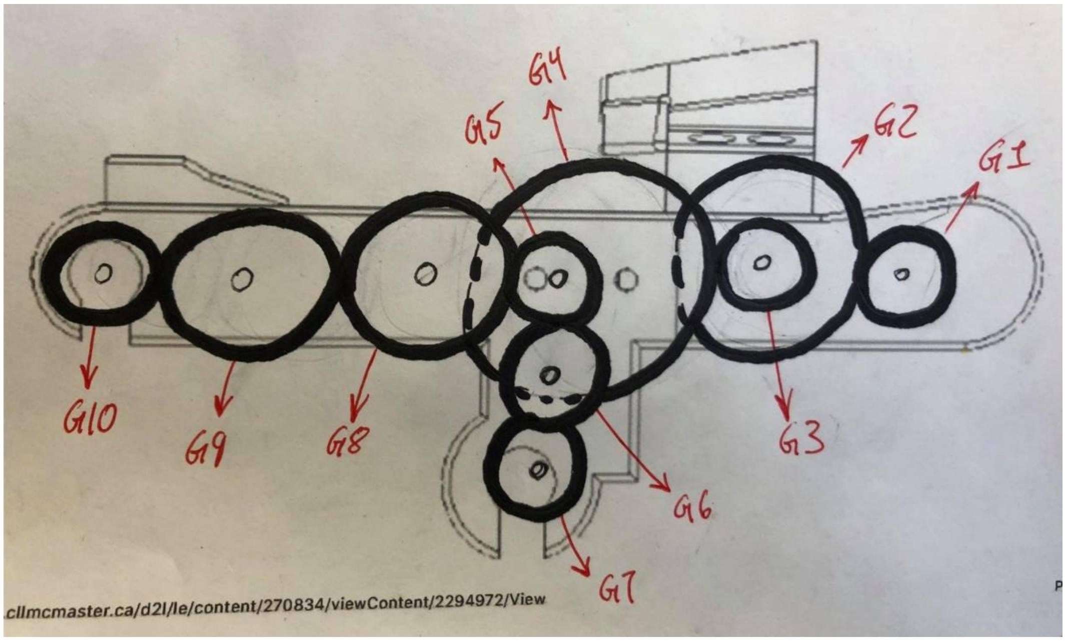
Assembly Top View:



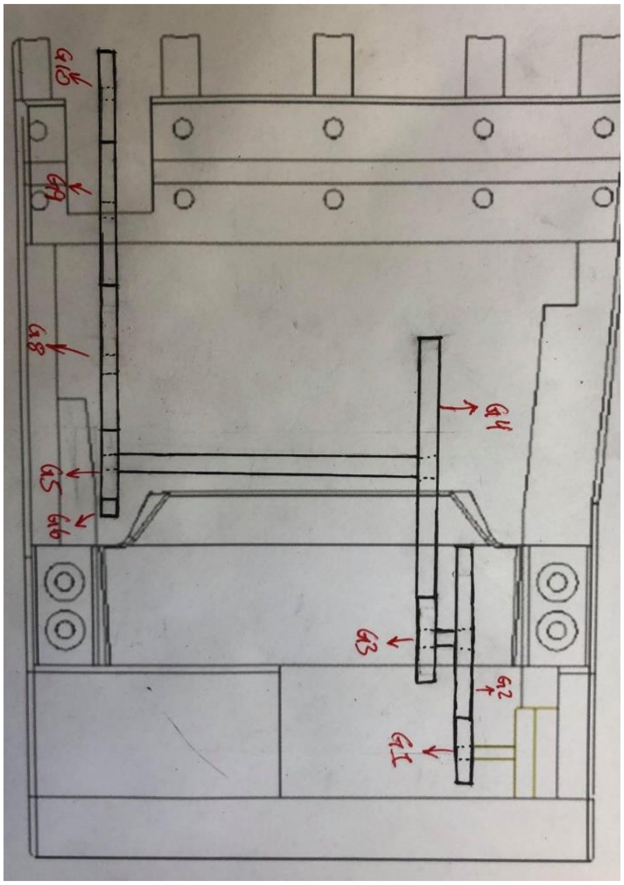
Assembly Side View:



Assembly Side View in the Front Frame:



Assembly Top View in the Prosthetic Frame:



Autodesk Inventor Models

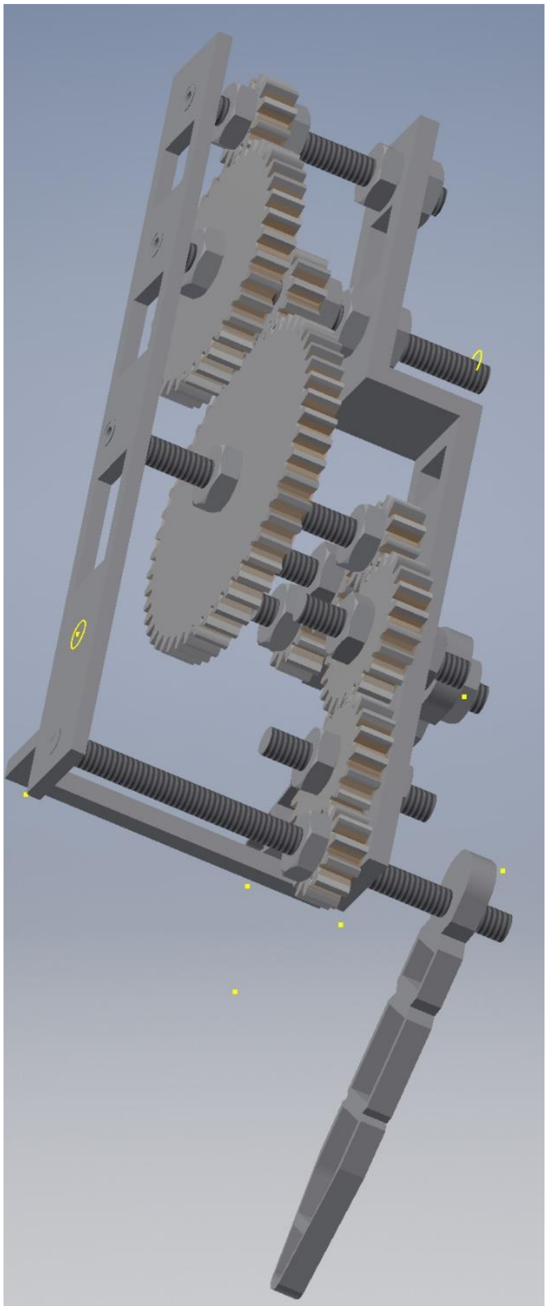


Figure 1: Gear Train view from top

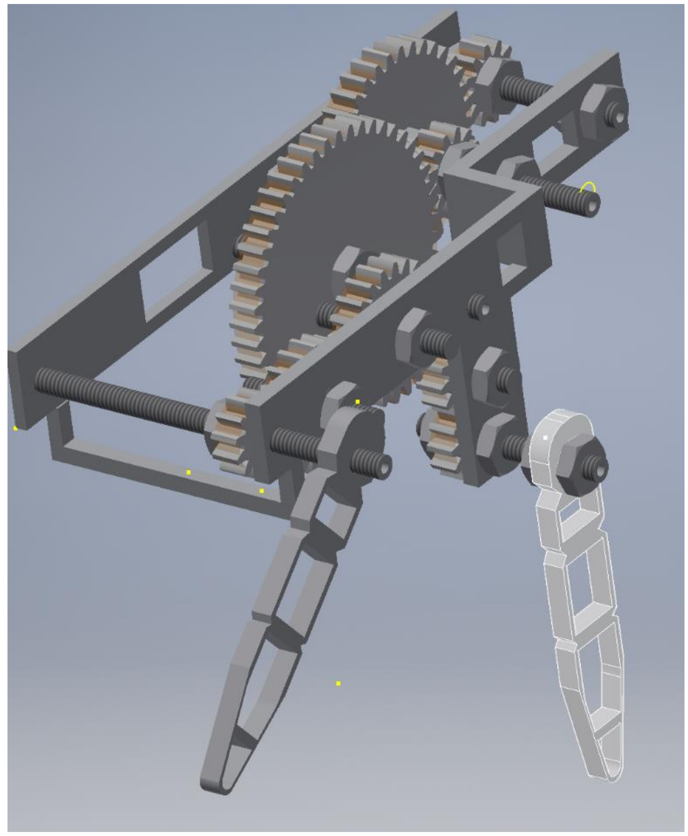


Figure 2: Gear Train view from top

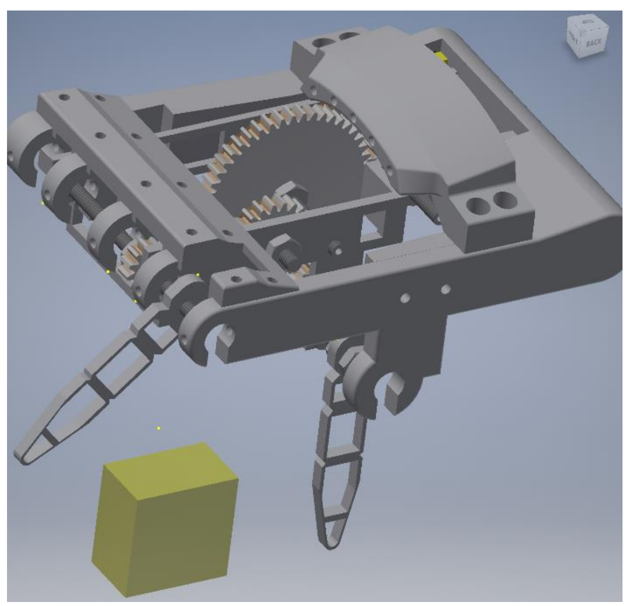


Figure 3: Gear Train inside Prosthetic Frame

Printed Prototype Pictures

Figure 4: Top view looking from the finger side

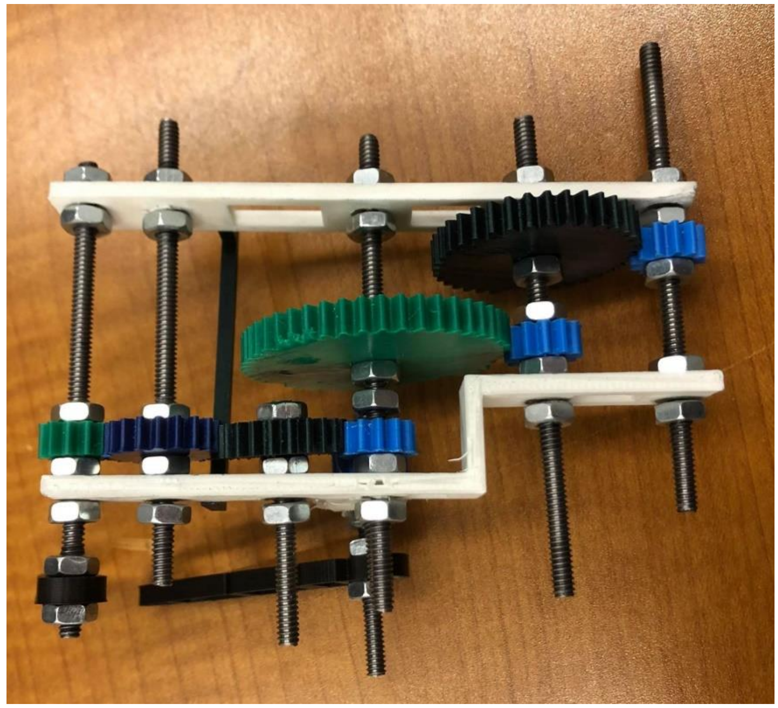


Figure 5: Top view looking from the front frame side

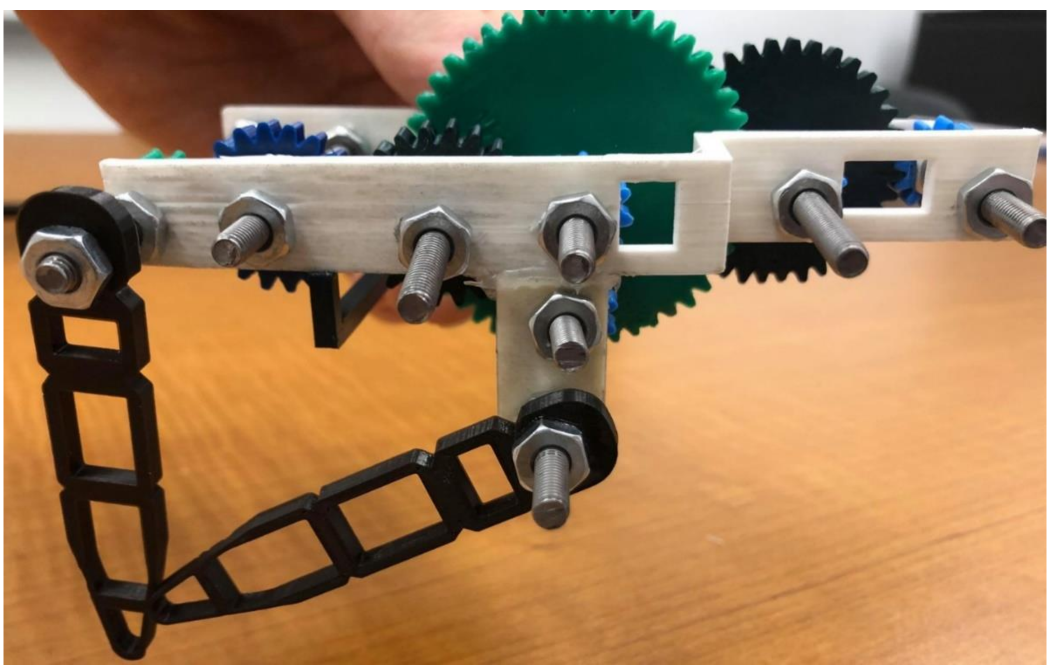
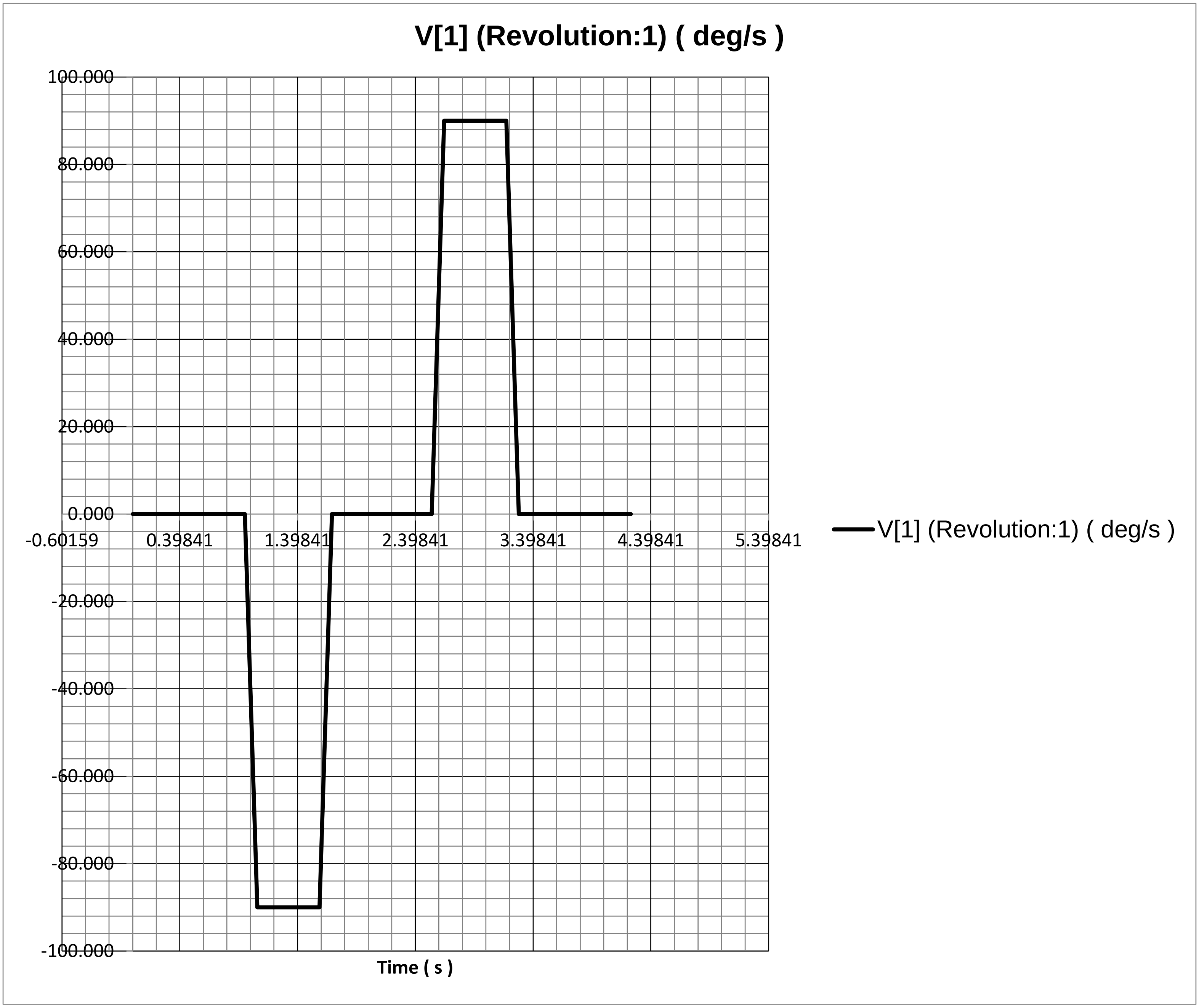


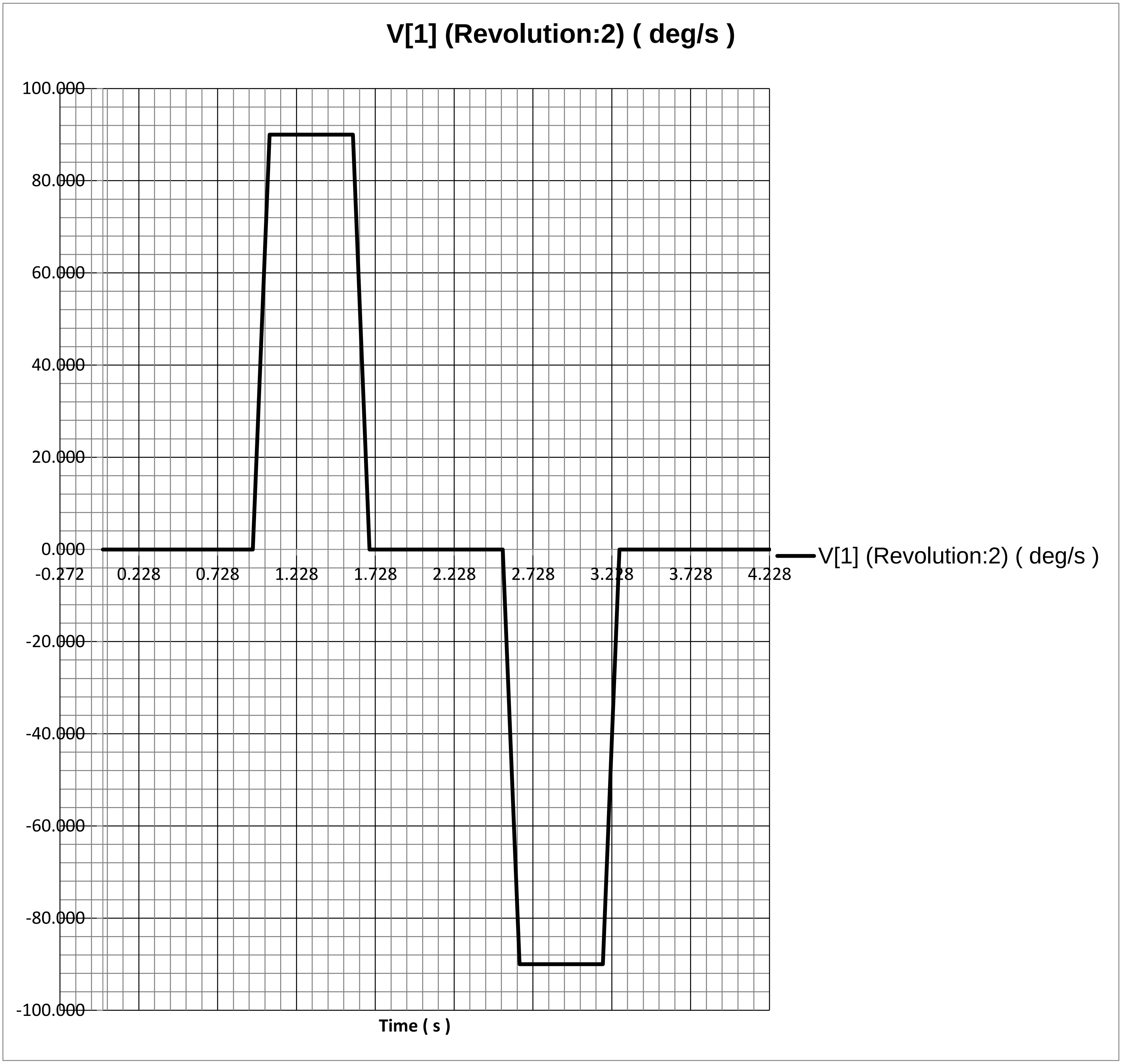
Figure 6: Side view of gear-train / custom bracket design

Output Graphs of Inventor's Dynamic Simulation

Graph of Finger



Graph of Thumb

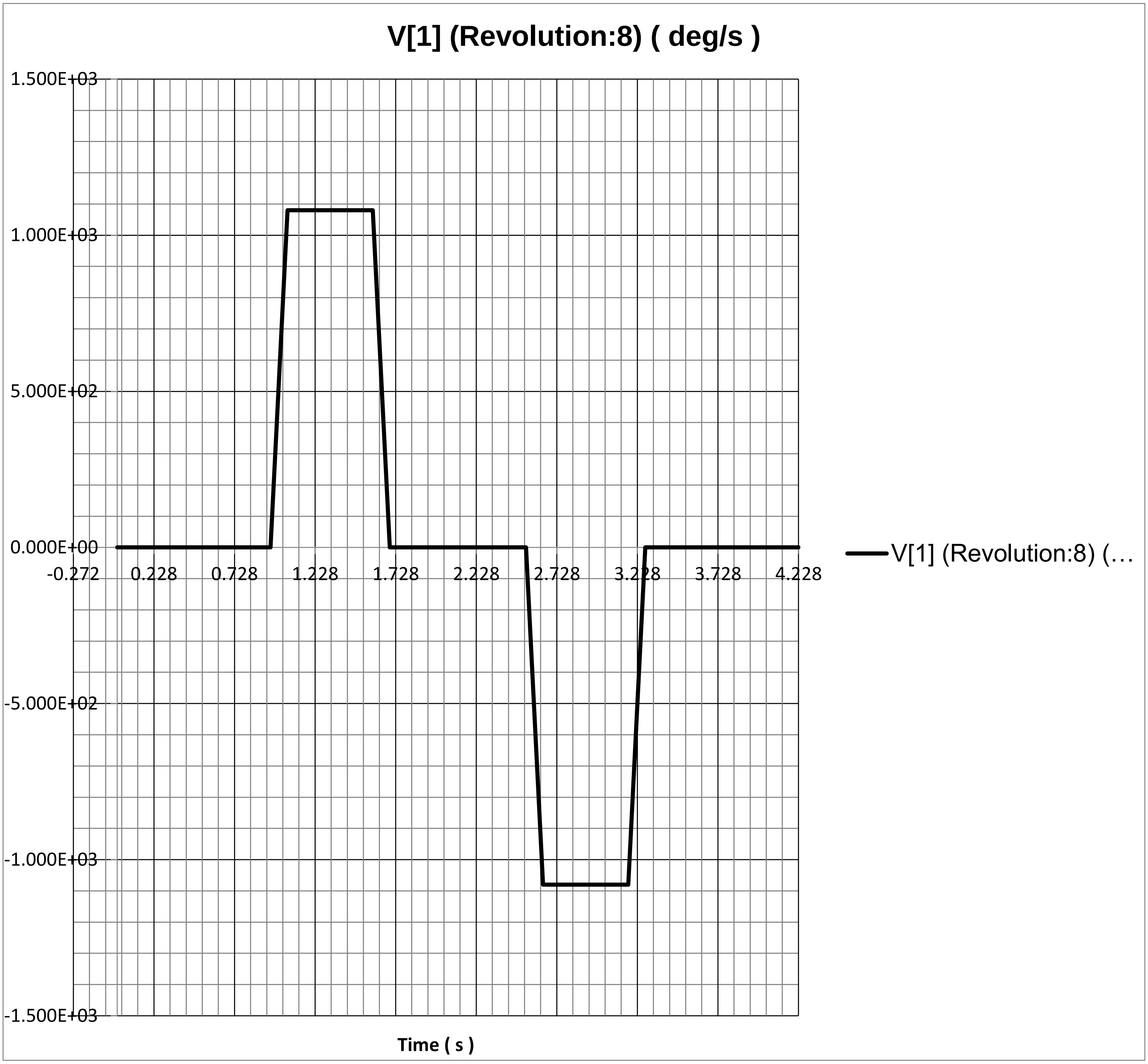


Data Points of Finger from Inventor

Export to FEA	Time (s)	V[1] (Revolution:1) (deg/s)	V[1] (Revolution:2) (deg/s)
	0.00000	0.00000	0.00000
	0.10570	0.00000	0.00000
	0.21140	0.00000	0.00000
	0.31710	0.00000	0.00000
	0.42280	0.00000	0.00000
	0.52850	0.00000	0.00000
	0.63420	0.00000	0.00000
	0.73990	0.00000	0.00000
	0.84560	0.00000	0.00000
	0.95130	0.00000	0.00000
	1.05700	-90.00030	90.00030
	1.16270	-90.00030	90.00030
	1.26840	-90.00030	90.00030
	1.37410	-90.00030	90.00030
	1.47980	-90.00030	90.00030
	1.58550	-90.00030	90.00030
	1.69120	-0.00025	0.00025
	1.79690	-0.00025	0.00025
	1.90260	-0.00025	0.00025
	2.00830	-0.00025	0.00025
	2.11400	-0.00025	0.00025
	2.21970	-0.00025	0.00025
	2.32540	-0.00025	0.00025
	2.43110	-0.00025	0.00025
	2.53680	-0.00025	0.00025
	2.64250	89.99970	-89.99970
	2.74820	89.99970	-89.99970
	2.85390	89.99970	-89.99970
	2.95960	89.99970	-89.99970
	3.06530	89.99970	-89.99970
	3.17100	89.99970	-89.99970
	3.27670	-0.00026	0.00026
	3.38240	-0.00026	0.00026
	3.48810	-0.00026	0.00026
	3.59380	-0.00026	0.00026
	3.69950	-0.00026	0.00026
	3.80520	-0.00026	0.00026
	3.91090	-0.00026	0.00026
	4.01660	-0.00026	0.00026

	4.12230	-0.00026	0.00026
	4.22800	-0.00026	0.00026

Graph of Input Motor



Data Points of Thumb from Inventor

Export to FEA	Time (s)	V[1] (Revolution:8) (deg/s)
	0.00000	0.00000
	0.10570	0.00000
	0.21140	0.00000
	0.31710	0.00000
	0.42280	0.00000
	0.52850	0.00000
	0.63420	0.00000
	0.73990	0.00000
	0.84560	0.00000
	0.95130	0.00000
	1.05700	1080.00000
	1.16270	1080.00000
	1.26840	1080.00000
	1.37410	1080.00000
	1.47980	1080.00000
	1.58550	1080.00000
	1.69120	0.00306
	1.79690	0.00306
	1.90260	0.00306
	2.00830	0.00306
	2.11400	0.00306
	2.21970	0.00306
	2.32540	0.00306
	2.43110	0.00306
	2.53680	0.00306
	2.64250	-1080.00000
	2.74820	-1080.00000
	2.85390	-1080.00000
	2.95960	-1080.00000
	3.06530	-1080.00000
	3.17100	-1080.00000
	3.27670	0.00306
	3.38240	0.00306
	3.48810	0.00306
	3.59380	0.00306
	3.69950	0.00306
	3.80520	0.00306

	3.91090	0.00306
	4.01660	0.00306
	4.12230	0.00306
	4.22800	0.00306

Prototype Design and Challenges

The final prototype design and our final design were very similar. The only difference was that positioning of the rods were slightly different due to printing errors. Other than this small difference, the final prototype design and final design were identical.

Many unique components/ solutions were incorporated within our prototype design to maximize effectiveness and efficiency. To begin, one important factor to consider was the printing time, which is proportional to the amount of material being used. To reduce our printing time and material used, we cut out material within the frame and fingers. This was done while ensuring our design had maximal structural integrity. In addition, we designed a frame with minimal amount of parts in order to save time assembling the prototype (this also made assembling the prototype very intuitive). Furthermore, we created a support bar that connects the two sides of the frame to increase the structural integrity of our design.

When making the design of our gear train, we encountered many issues going into it mainly because of our frame. Our main issue at first was making the back frame and front frame align inside the bracket so when the holes for the rods were made, the sum of the radii of 2 gears meshing were actually the distance between the 2 holes. An example of this issue was when the two frames were not perfectly aligned and we meshed the two corresponding gears onto the rod and then tried simulating it, we'd get an error. To fix this, we had to manually adjust our two frames by setting constraints with them inside the prosthetic bracket.

Another issue we faced was hitting the bridge of the prosthetic frame with our gear 4 (48-tooth gear). To remedy this, we had to manually adjust all the holes on the brackets so that the distance between the corresponding meshing gears worked well. We had to readjust the holes three times to get the perfect fit for all our gears. The only way to figure out if the gear fit under the bridge perfectly was by constraining the entire gear train into the prosthetic frame and running the simulation.

Team Responsibilities and Contributions

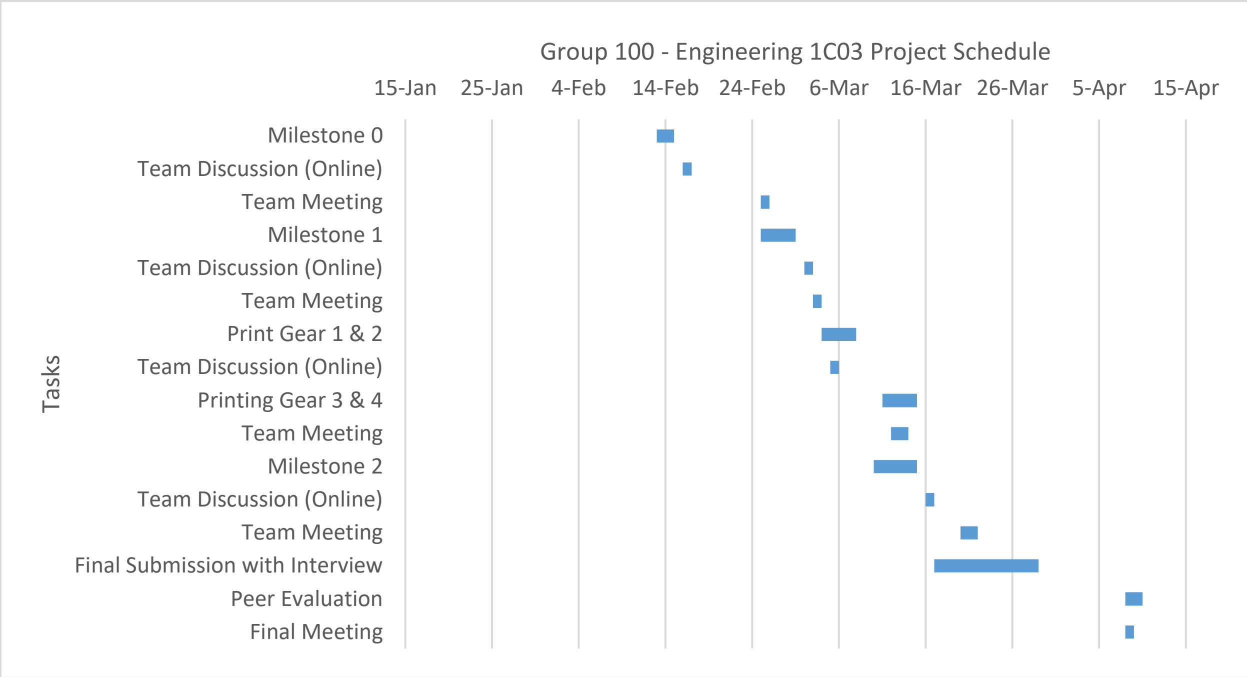
Names:	***Contributions:***
Abd Elelah	- Did Milestone 1 and rechecked milestone 0 - Made Slic3r files for most parts - Made the simulations in Inventor and produced the Output grapher - Set online reminders and sent emails to members who missed the meetings - Made the final Gear design/layout - Did the Working drawings
Jordan	- Did Milestone 1 and rechecked milestone 0 - Generated a couple of preliminary gear designs/layouts - Made the frames and did gear calculations - Assembled the prototype -Went to 5/6 of the scheduled printing days - Checked progress on every group meeting
Manrose	- Did Milestone 0, made the schedules, and checked over Milestone 1 for mistakes - Made Slic3r files for frames and finger and thumb - Designed the custom mounting frame and created the solid modelling on inventor - Made the gears and did the initial constraints inside the frames - Made the motion constraints to check if the thumb and finger moved as intended -Went to 5/6 of the scheduled printing days

	- Kept track of due dates

Team Meetings and Attendance

Date	Meeting Description	Attendance
Feb 15	Team Discussion	Everyone attended
Feb 18	Team Discussion (online)	Everyone attended
Feb. 25	Team Discussion	Everyone attended
Mar.7	Printing Session	Manrose didn't Attend
Mar.8	Printing Session	Everyone attended
Mar.11	Team Discussion	Everyone attended
Mar.12	Printing Session	Everyone attended
Mar. 16	Team Discussion (online)	Everyone attended
Mar. 22	Printing Session	Jordan didn't Attend
Mar.25	Team Discussion	Everyone attended
Mar. 28	Team Discussion (online)	Everyone attended
Mar. 30	Printing Session	Everyone attended
Mar. 30	Team Discussion (online)	Everyone attended
Mar. 31	Team Discussion	Everyone attended
April. 1	Team Discussion	Everyone attended
April. 2	Printing Session	Abd Elelah didn't attend
April. 2	Team Discussion and Assembly	Everyone attended
April. 3	Team Discussion and Assembly	Everyone attended
April. 4	Interview Day	Everyone attended

Team Gnatt Chart



References

[1] "Correlation coefficient based featue selection for actuating myoelectric prosthetic arm", 2017. [Online]. Available: https://ieeexplore.ieee.org/document/8064775 [Accessed: 04 – March – 2019]