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TITLE: Assessing the Role of the Socket Trim Line on Reactive Balance in People with Transfemoral Amputation

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14. ABSTRACT The biomechanical effectiveness of reactive stepping in response to lateral perturbations is likely to depend on the function of the residual limb hip. We argue that proximal socket trim lines, which compress more soft tissue and musculature around the hip, will interfere with hip muscle function to a greater extent than more distal trim lines, which will in turn negatively impact reactive stepping. To address this, we plan to compare mediolateral reactive stepping and measures of hip function between groups of people with above knee amputation who use sockets with high versus low trim lines to determine the effect of trim line on kinematic and behavioral aspects of mediolateral reactive stepping. We also plan to assess residual hip function both with and without a socket donned. To date we have finalized testing protocol related hip muscle testing, including assessments on N=2, and continue to develop a device to apply mediolateral perturbations.					
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1. INTRODUCTION

Over 50% of people with amputation fall annually, and that fall risk is generally higher in people with transfemoral amputation. Despite the high prevalence of falls, very little is known about fall risk factors specific to prosthetics users and even less is known for person with transfemoral amputation (TFA). In response to a loss of balance, a fall to the ground is inevitable unless a person can properly react to the balance loss. One of the most common ways of doing so involves taking a protective step. When protective steps are needed to recover a sideways directed loss of balance, the effectiveness of these steps is strongly dependent on strength and coordination of the hip abductor muscles. We argue that the ability of people with TFA to engage these muscles, and thus to prevent certain falls, can be impacted by the socket trim. Using sockets with high trim lines, i.e. ischial containment sockets, may compress the muscles on the side of the hip to a greater extent than sockets with lower trim lines, i.e. subischial, which may prevent these muscles from bulging and producing forces when they contract. Even if a person with TFA has the underlying muscular capacity to enact a protective step that would avoid a fall following a given level of destabilizing force, they may still fall if their socket prevents them from attaining that capacity (what we term “socket interference”). The objective of the proposed work is to provide preliminary evidence that socket trim can impact fall risk in lower functioning people with TFA. Namely, we seek to demonstrate that: i) in lower functioning people with TFA, reactive stepping responses after experiencing sideways directed destabilizing forces are biomechanically less effective when using an ischial containment socket; and that 2) ischial containment sockets cause greater socket interference, with regard to hip muscle function, than do subischial sockets.

2. KEYWORDS

Transfemoral, Trimline, Prosthetic Socket, Falls, Residual Limb, Hip Muscles

3. ACCOMPLISHMENTS

3.1. Major goals of the project

The major goals of the project and proposed timeline as stated on the SOW. Section 3.2 details the specific work accomplished under each goal

Aim 1: Determine the effect of socket trim line on kinematic and behavioral aspects of mediolateral reactive stepping in people with TFA. (month 1-15)

Major Task 1: Regulatory Review and Approval (month 1-6)

- 1a. Submit documents for local IRB review (100% completed)
- 1b. Submit IRB approval and documents for HRPO review (100% completed)

Major Task 2: Build Waist Pull Device (month 1) (ongoing)

Major Task 3: Pilot Testing to Finalize Protocol (month 1-3) (ongoing)

Major Task 4: Complete Data Collection, Analyses, and Interpretation for Aim 1 (month 6-15) (not yet initiated)

- 4a. Recruit, consent, and enroll 20 participants (N=2 enrolled)

- 4b. Collect reactive balance data in 20 participants (not yet initiated)
- 4c. Analyze and interpret data (not yet initiated)
- 4d. Author manuscripts on reactive stepping responses in people with transfemoral amputation (not yet initiated)

Aim 2: Evaluate the extent to which socket trim interferes with measures of prosthetic-side hip function that relate to mediolateral reactive stepping performance. (month 2-15)

Task 5: Write Program to Collect Force Data (month 2) (100% completed)

Task 6: Finalize Protocol and Pilot Test Hip Muscle Function Measures (month 1-2) (100% completed)

Task 7: Complete Data Collection, Analyses, and Interpretation for Aim 2 (on going)

- 7a. Collect hip muscle function data for 20 people with transfemoral amputation (10% completed)
- 7b. Analyze and interpret hip function data (not yet initiated)
- 7c. Author manuscripts on the relationship between hip muscle function measures and reactive balance (not yet initiated)

Below is the proposed timeline in grey. I indicates initiation of a task, C indicates completion of a task and orange indicates extension of task beyond proposed timeline.

	YEAR 1				YEAR 2			
All aims								
Regulatory Approvals and pilot testing	I	C						
Subject recruitment			I					
Aim 1								
Build waist pull device	I							
Pilot testing reactive balance task		I						
Data Collection								
Data analyses and interpretation								
Manuscript preparation and submission								
Aim 2								
Write program to collect hip force data	I/C							
Pilot testing hip muscle function protocol		I/C						
Data Collection			I					
Data analyses and interpretation								
Manuscript preparation and submission								

3.2. Activities accomplished under the major goals

Recruitment

As seen in the Enrollment table below, we had proposed to recruit 6 participants by the end of the first year. Due to delays in building the perturbation device for Aim 1 (described below) and in establishing protocols with the computerized dynamometer for Aim 2 (described below), recruitment was significantly delayed. Accordingly, we have recruited two participants to date

who completed activities under Aim 2 only. We plan to recontact these individuals once the perturbation system has been finalized and we are able to collect data for Aim 1. We will continue to recruit in this manner moving forward. We recognize that significant delays between collection of data from Aims 1 and 2 may present challenges when trying to relate the two. Therefore we will evaluate self-reported measures of activity and function at the start of each session and, should they show meaningful differences, will repeat Aim 2 data collection before collecting Aim 1 data.

Table 1. Enrollment Table. Red font is the proposed number and black font is actual enrollment.

	Year 1				Year 2				Total
Target Enrollment (per quarter)	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Site 1: RFU	0 (0)	0 (0)	0 (1)	1 (2)	2	2	3	0	10
Site 2: UM	0 (0)	0 (0)	1 (1)	0 (2)	2	2	3	0	10
Target Enrollment (cumulative)	0 (0)	0 (0)	1 (2)	2 (6)	10	14	20	20	20

Aim 1: Determine the effect of socket trim line on kinematic and behavioral aspects of mediolateral reactive stepping in people with TFA.

Major Task 1: Obtain Regulatory Approvals

We obtained all necessary IRB and OHRO approvals to begin testing under each aim.

Major Task 2: Build waist pull device

We originally proposed to assess reactive stepping in response to lateral perturbations by applying forces to the waist (waist pulls) via a weight and pulley system that was used previously in the literature (Figure 1). The system was to apply equal and opposite forces until the weights on one side were randomly released by turning off an electromagnet; this would lead to a force perturbation on the opposite side. Given that this design would require a considerable amount of manual labor and time to load the weights between each trial, we opted to explore automated system that could deliver mediolateral perturbations via force-controlled motors (Figures 2 and 3).

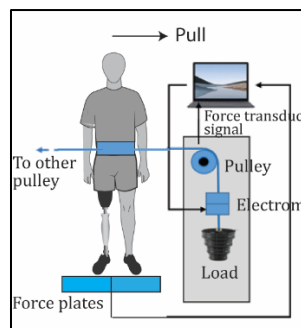


Figure 1. Original (proposed) version of the waist pull device

One of the primary decisions to be made for the new design was the choice of motors. In early December we ordered a motor with a built-in controller and with the capacity and speed

needed for the desired perturbations. We soon learned that there would be a several month delay in receiving the motor due to supply chain issues. In response, in January we ordered a stepper motor and driver, and a separate controller. Different wires were chosen to wind around the motor shaft (Figure 2); when the shaft rotates, the cables - which are attached to a waist harness equipped with embedded force sensors (Figure 2) - are pulled.

During the month of February, we worked to order the STF driver controller (STF06-R) and the associated power supply (Figure 2). As the controller did not come with product manuals, product manufacturers were contacted to understand the proper wiring information for the motor to the STF configuraton. It was also determined that a special connection was needed to connect the controller to the PC.

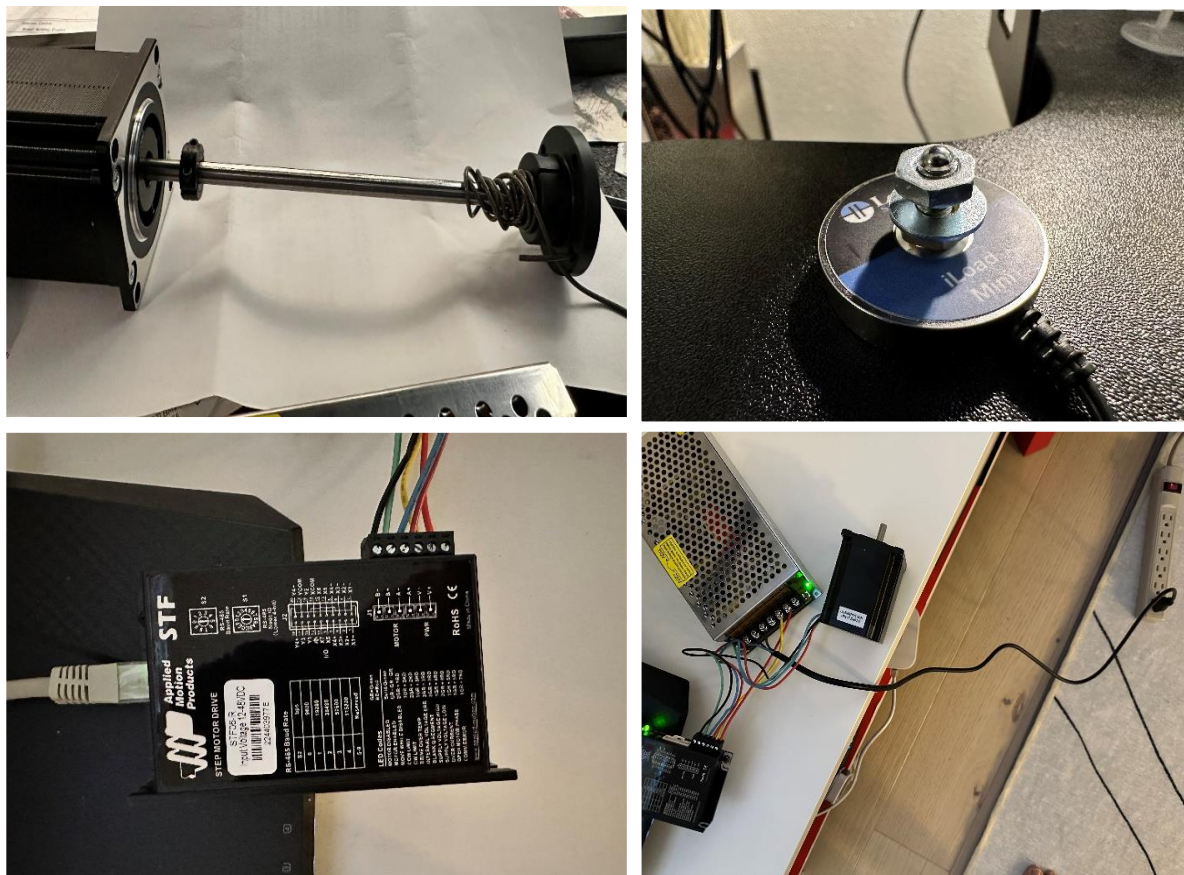


Fig 2. Initial set up and testing of components used in the waist pull device. (top left) Wire for the waist pull wound around the shaft of the motor; (top right) Miniature force sensor with nuts and washers used to measure force in the pulled wires. (bottom left) STF driver controller with wiring connected to motor; (bottom right) Power supply with wiring connected to STF configurator and motor

Once all components were received and functioning efforts turned to programming the motors to wind and unwind the wire using a feedback loop between the motor and force sensor. Specifically, we sought to design a system with motors controlled through a stepper driver and LabVIEW software that enabled the generation of varying force profiles (perturbation levels)

through adjustments in the speed of the motors (winding and puling of the cables) (Figure 3). Before programming the motors, preliminary experiments were conducted to establish target force values based on the behavior of healthy young subjects. Specifically, we manually applied perturbations by pulling and releasing the calibrated wires. Based on this testing we established values for the single stepping thresholds and multi stepping threshold as approximately 40 N and 200 N, respectively. Based on this empirical data, we sought to provide force levels at maximum of 250 N. Appendix 1, which is a series of slides decks created by the team at Michigan throughout the building phase inorder to document the processes and challenges encountered, provides additional details and result from this testing and all other testing described herein .

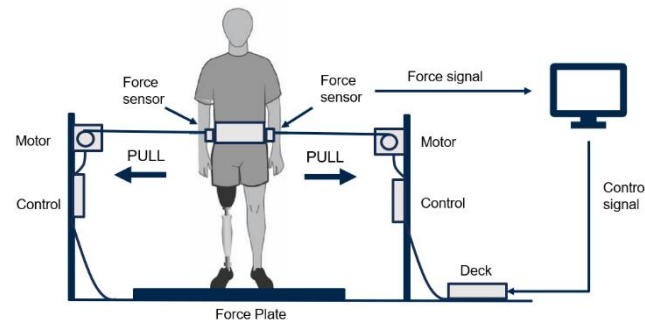


Figure 3. Initial design for an automated waist pull system using instrumented cables pulled by stepper motors controlled through the internal control program

During the testing phase, we encountered motor oscillation issues, wherein the motor exhibited continuous back-and-forth movements upon nearing the designated force level. This oscillation impeded the ability to have robust, reliable force control. To solve the oscillation problem, we inserted a spring into the wire line such that forces were generated based on manipulating the distance of the spring of the spring (Figure 4). This method successfully prevented the motor oscillations. We continued our work on designing and testing the control software for the motor and its integration with LabVIEW until we were able to create and validate a system that could provide a load up to 250 N and then release the load after a set period in equilibrium. Pursuant to this validation we began pilot testing with human subjects.

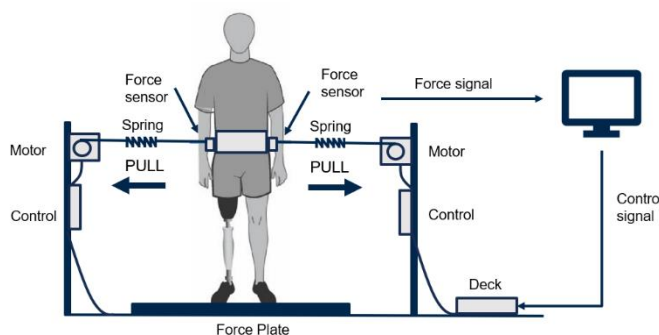


Figure 4. Updated design of the waist pull device that incorporates springs in parallel with cables shown schematically (left) and in a photo from the Michigan lab (right; note that the pull cables are difficult to see in the photograph)

Major Task 3: Pilot testing to finalize protocol

We attempted to elicit both a single step and multiple step response in a healthy young subject as they stood between the motors with cables attached via a waistbelt. The motors wound so that an equilibrium was reached, then one was triggered to rapidly unwind. Although the applied force exerted by the system exceeded 220 N, which we assumed would elicit multiple steps based on initial testing, we were unable to actually elicit multiple steps. Consequently, we are currently exploring alternative approaches to address this challenge. Upon reviewing our experimental setup, we determined that the duration of the force application, which affects the time available for participants to regain their balance, plays a crucial role in their reactions. With the open loop control and the fact that the motors can not truly sustain a load over a period of time, the perturbation impulse was minimum. This prevented a multiple step response. Given our current setup, modifying the duration of the applied force within appropriate limits is not feasible. Consequently, our next course of action involves experimenting with motors possessing higher force-generating capabilities (more similar to those we initially intended to purchase). This will enable us to provide a more substantial force that aligns with our intended objectives.

In parallel, we are looking into two alternative solutions: i) utilizing stepper motor controlled treadmills to deliver postural perturbation as prescribed acceleration profiles at the base of support. While this technique has been reported on and is not uncommon, this was not our initial choice as the treadmill at the University of Michigan was not designed for these type of perturbations; ii) returning to a simplified, purely mechanical design that does not require loading and dropping large weight stacks but rather relies on winches to wind wires. We are hopeful that one of these solutions will be successful and allow us to collect data under Aim 1 no later than October.

Major Task 4: Complete data collection, analyses, and interpretation for Aim 1

This task has not yet begun.

Aim 2: Evaluate the extent to which socket trim interferes with measures of prosthetic-side hip function that relate to mediolateral reactive stepping performance.

Major Task 5: Write program to collect force data

As the rate of torque development protocol requires real time feedback and collection of the raw force signal, and because our dynamometer at the time of proposal submission did not have means to do so, we assumed doing so would require writing a LabVIEW script. However, thorough funding from an external source were able to purchase software upgrades that provided many of these functionalities and which simultaneously allowed us to match the functionality of the system at Michigan. This upgrade was installed at Rosalind Franklin in late January 2023. After initial testing of the feedback and some of the hardware functionality, we were still interested in developing our own data collection and feedback in Lab VIEW. However, it was found that the dynamometer hardware could not be accessed, which was needed for several aspects of our testing, so we ultimately decided to utilize the existing visual feedback that offered by the dynamometer.

During initial testing of the existing collection and feedback system, we determined that the recommended set up of the participant on the testing chair did not provide enough clearance between the participants back and the arm of the dynamometer when performing the hip abduction

tasks. We worked with the dynamometer company (Cybex) to determine how altering participant position relative to the device would affect the data output and how to make the appropriate changes in the software to ensure accuracy of the data. We tested multiple iterations of participant positions and software configurations to ensure that the data we obtained was in the range of previously published values for these assessments.

Major Task 6: Finalize protocol and pilot test hip muscle function measures

In the last year, we developed a detailed testing protocol through pilot testing to ensure consistency across sites. The protocol includes pictures of each position for the participant, standard instructions for the participants, software implementation guidelines, and instructions for data export. A copy of the protocol is included in Appendix 2.

We tested this protocol on three individuals without amputation at the University of Michigan site and two at Rosalind Franklin University. We found that the full protocol took longer than expected, approximately 2 hours, and that participants began to fatigue by the end of testing. Accordingly, we decided to split our future collections into two days so that participants would complete the entire “socket off” condition on one day and the entire “socket on” condition on a second day. We also decided to add a Fatigue Questionnaire to assess participant fatigue throughout each session and ensure they are not fatigued.

The only aspect of the protocol which was somewhat nonstandard was the Rate of Torque Development protocol, in which participants generate quick contractions targeting 20, 40, 60 and 80% of their maximum voluntary strength. For this protocol participants saw these targets as a bar plot with a band of $\pm 10\%$ around the target. Data for a single individual is shown in Figure 5 below. Points on the plot represent individual contractions with the data plotted based on the actual torque achieved, rather than the target. The slope of a linear line fit to the data represents the Rate of Torque Development Scaling Factor (RTD-SF), the outcomes of interest. Here, we see that the data spans the range that the individual targeted and that the data is highly linear, which is expected for an individual with no impairment.

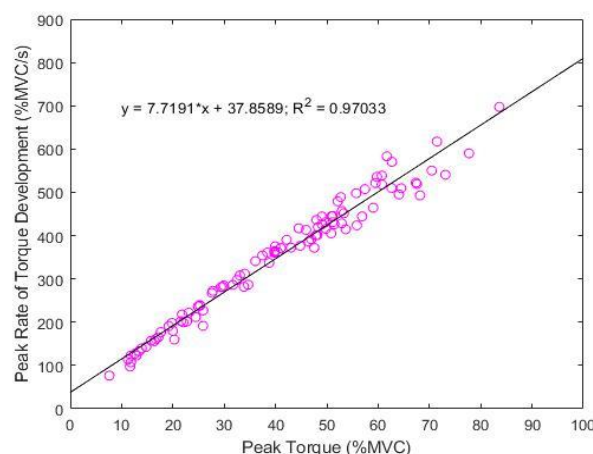


Figure 5. Hip abduction rate of torque development as a function of the peak torque for a single intact pilot participant.

Major Task 7: Complete data collection, analyses, and interpretation for Aim 1

We have recruited one participant with transfemoral amputation at each site to complete this aim. The participants successfully completed testing and surveys on two separate visits. On the first visit, the participants completed the AMPPRO to assess study eligibility and then completed the full muscle testing protocol with the socket off. On the second visit, they completed all testing with the socket on. The participants reported only mild fatigue during testing (rating of perceived exertion was 2-3 on a 10-point scale). RTD data for one of the participants for both conditions is shown in Figure 6 (the second is still being analyzed as it was run only recently).

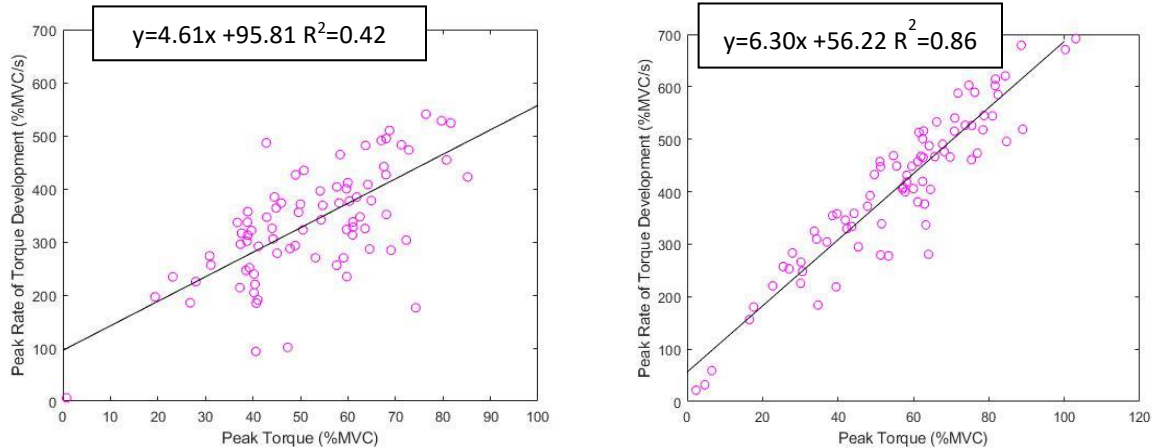


Figure 6.. Hip abduction rate of torque development versus peak torque during the socket off condition (Left) and during the socket on condition (Right) for one participant with transfemoral amputation.

During the first session (socket off; Figure 6 - left), the participant struggled to understand the visual feedback and timing of her contractions. She frequently either contracted before or during the start signal instead of directly afterward. While we provided frequent feedback, she stated that she had trouble staying mentally engaged during some of the testing blocks and wasn't understanding the targets completely. However, the data demonstrates that she reached torque value across the desired range. During the second visit, the participant had a better understanding of the task in terms of timing and target strength. She also stated that she "felt much more prepared." Based on this, we decided to increase the practice portion of the experiment. If the participant is still having difficulty with the task, we will provide a second practice testing block.

During initial testing with this prosthetic user, we also noted that the participant had vastly different MVCs during session 1 (socket off: 51.7 N.m) and session 2 (Socket on: 26.0 N.m). These sessions took place 4 days apart and the participant reported similar fatigue during each session. One thing we noted during collection with the socket on was that there was a gap at the lateral brim of the socket which made it challenging to contract against the dynamometer. While the prosthesis was strapped to the dynamometer testing arm, and locked at 15°, the gapping in the socket allowed for the participants residual limb and hip to settle more toward the midline of her body. With each contraction, she had to first move the limb to meet the edge of the socket and then further to push into the dynamometer testing arm pad. This is likely the biggest determinant of the discrepancy between the two MVC values. To mitigate this possible confounding factor, moving forward we will always perform the "socket on" condition first. In this manner, if the hip abduction angle must be manipulated to accommodate socket fit, then we will be able to apply the same

correction to testing with the socket off. Since all comparisons are within-subject, using a slightly different angle between participants should not affect the overall study findings. We will make sure that any modifications remain within the range of angles used in prior literature.

3.3 Opportunities for training and professional development provide by the project

Two graduate students at the University of Michigan and one post-doctoral fellow have worked on this project. They have been able to gain experience with study design, data collection, and new analysis techniques. Opportunities for training will increase as the project continues over the next year.

3.4 Dissemination of results to communities of interest

Nothing to report.

3.5 Plans for the next reporting period to accomplish goals

We plan to complete building of the perturbation device, will make all attempts to complete recruitment, data collection and analyses. We also plan to present any preliminary findings to relevant conferences including American Academy of Orthotists and Prosthetists and American Society of Biomechanics.

4. IMPACT

As the project is still in the early stages with data collection and analysis, it is still too early to ascertain the true impact of this work.

4.1 Impact on the development of the principal discipline(s) of the project

Nothing to report.

4.2 Impact on other disciplines

Nothing to report.

4.3 Impact on technology transfer

Nothing to report.

4.4 Impact on society beyond science and technology

Nothing to report.

5. CHANGES/PROBLEMS

5.1 Changes in approach and reasons for change

Nothing to report.

5.2 Problems or delays and actions to resolve them

The primary problem that the team faces related to unexpected delays in acquiring parts for building of the perturbation device and unexpected technical challenges associated with implement the design. Actions to resolve these problems are described above and include: i)

recruiting for Aim 2 while we wait for final device completion; and ii) considering multiple alternative designs in parallel. As noted, we are hopeful that we will be able to collect data on participants under Aim 1 within the next month.

5.3 Changes that had a significant impact on expenditures

Nothing to report.

5.4 Significant changes in use of human subjects

Nothing to report.

5.4 Significant changes in use of vertebrae animals

N/A

5.4 Significant changes in use of biohazards/ select agents

N/A

6. PRODUCTS

6.1 Publication, conference papers, and presentations

We had a single late breaking poster titled, “Perturbation System for Studying the Influence of Socket Trim Line on Hip Musculature Utilization in Individuals with Transfemoral Amputations” accepted for presentation at The 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2023) in October 2023 (see Appendix 3)

6.2 Other products

Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Rosalind Franklin University

Name:	<i>Noah Rosenblatt, Ph.D.</i>
Project Role:	<i>Principal Investigator</i>
ORCID ID:	
Nearest person month worked:	1.3
Contribution to Project:	<i>Dr. Rosenblatt has completed all the IRB documentation, been actively involved in protocol development and pilot testing, and overseeing design and fabrication of the waist pull device</i>

Name:	<i>Marco Avalos, MD, PhD</i>
Project Role:	<i>Post-doctoral fellow</i>
ORCID ID:	
Nearest person month worked:	6
Contribution to Project:	<i>Dr. Avalos has taken the lead at the RFU site related to developing the protocol for the dynamometer and in pilot testing the protocol; he will be in charge of data collection for this aim</i>

Name:	<i>Sai Yalla, PhD</i>
Project Role:	<i>Co-investigator</i>
ORCID ID:	0.48
Nearest person month worked:	
Contribution to Project:	<i>Dr. Yalla has taken the lead at the RFU site related to building of the perturbation device; he will be in charge of data collection for this aim</i>

University of Michigan

Name:	<i>Deanna Gates, Ph.D.</i>
Project Role:	<i>Principal Investigator</i>
ORCID ID:	0000-0002-6086-0913
Nearest person month worked:	1
Contribution to Project:	<i>Dr. Gates has overseen all aspects of the study at the Michigan site</i>

Name:	<i>Kristin Perrin, CPO</i>
Project Role:	<i>Graduate student</i>
ORCID ID:	4.8
Nearest person month worked:	
Contribution to Project:	<i>Ms. Perrin has taken the lead at the UM site related to developing the protocol for the dynamometer and in pilot testing the protocol; she will be in charge of data collection for this aim</i>

Name:	<i>Boer Chen</i>
Project Role:	<i>Graduate student</i>
ORCID ID:	
Nearest person month worked:	2
Contribution to Project:	<i>Ms. Chen has taken the lead at the UM site related to building of the perturbation device; she will be in charge of data collection for this aim</i>

8. SPECIAL REPORTING REQUIREMENTS

An Inclusion Enrollment Report is included below

Cumulative (Actual)

Racial Categories	Ethnic Categories									Total
	Not Hispanic or Latino			Hispanic or Latino			Unknown/Not Reported Ethnicity			
	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	
American Indian/ Alaska Native	0	0	0	0	0	0	0	0	0	0
Asian	0	0	0	0	0	0	0	0	0	0
Native Hawaiian or Other Pacific Islander	0	0	0	0	0	0	0	0	0	0
Black or African American	0	0	0	0	0	0	0	0	0	0
White	1	1	0	0	0	0	0	0	0	2
More than One Race	0	0	0	0	0	0	0	0	0	0
Unknown or Not Reported	0	0	0	0	0	0	0	0	0	0
Total	1	1	0	0	0	0	0	0	0	2

9. APPENDICES

Appendix 1 - Process Report: Building the waist pull device

Appendix 2 - Protocol document for hip function testing

Appendix 3 - Poster accepted for IROS 2023

APPENDIX 1

PROCESS REPORT: BUILDING THE WAIST PULL DEVICE

Requirements

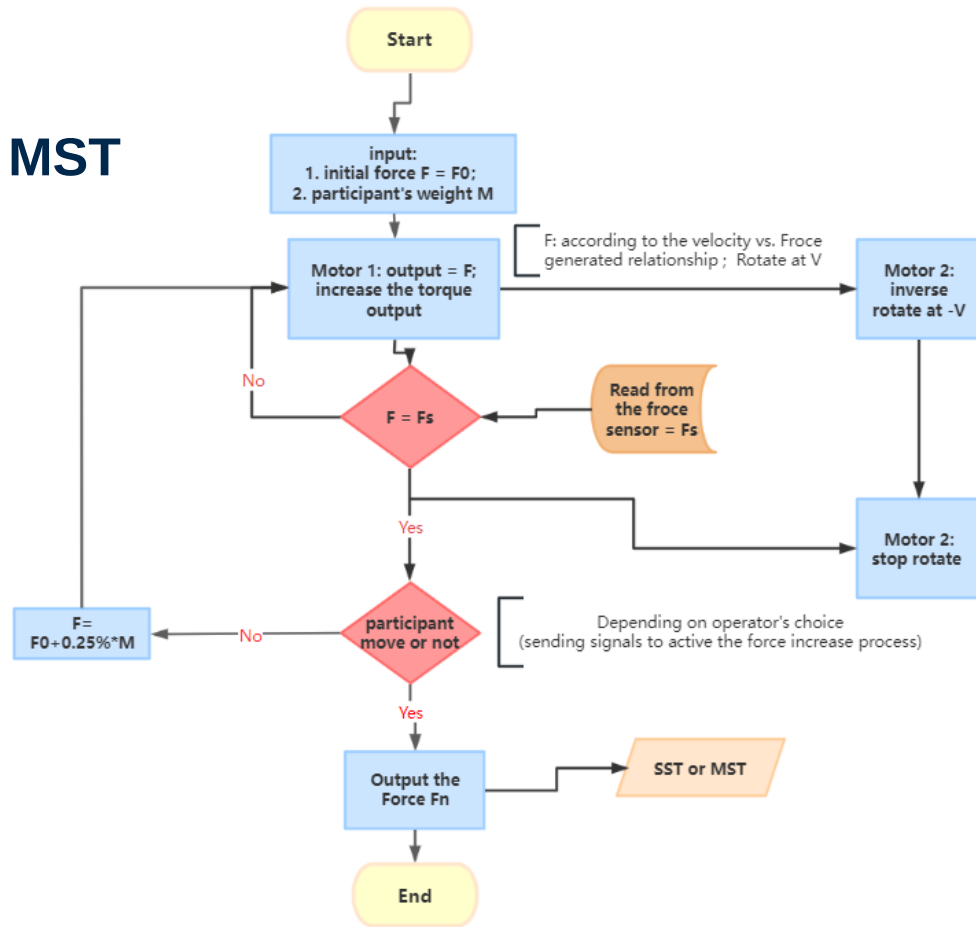
- Software:
 - LabVIEW (2021 SP1 32 bits & NAQmx 22.8 – 2022 SP4)
 - STF Configurator
 - LV 1000 LoadVUE Pro
- Hardware:
 - Stepper Motor
 - Control box (STF-R06)
 - Force Sensor (DQ-1000U)
 - Power unit (24V 5A 120W)
 - LabVIEW Deck 6210
 - RS-485
 - Wires (power and signal connections)

Details in parts needed file

Program Flowchart

Aim1: Deciding SST and MST

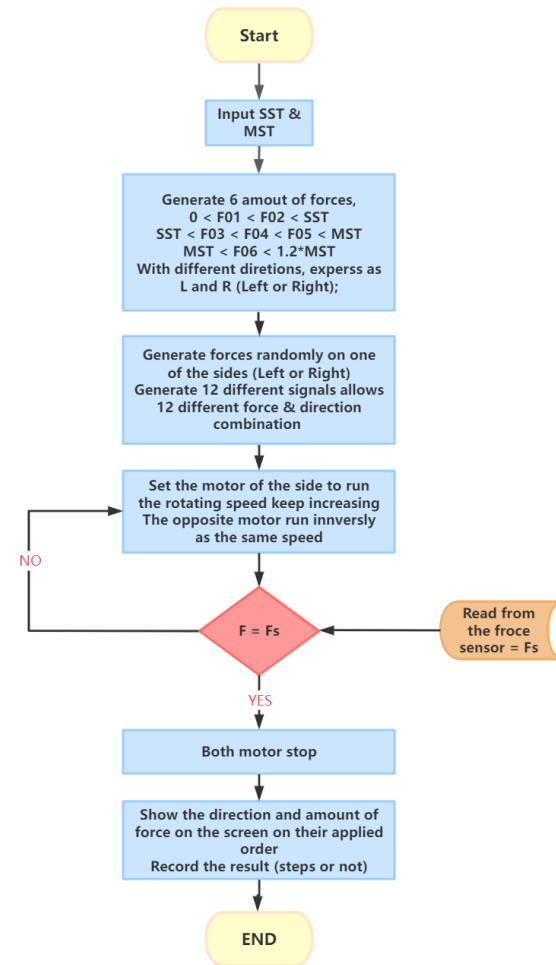
- INPUT:
 - LabVIEW
 - Force Sensor
- OUTPUT:
 - LabVIEW



Program Flowchart

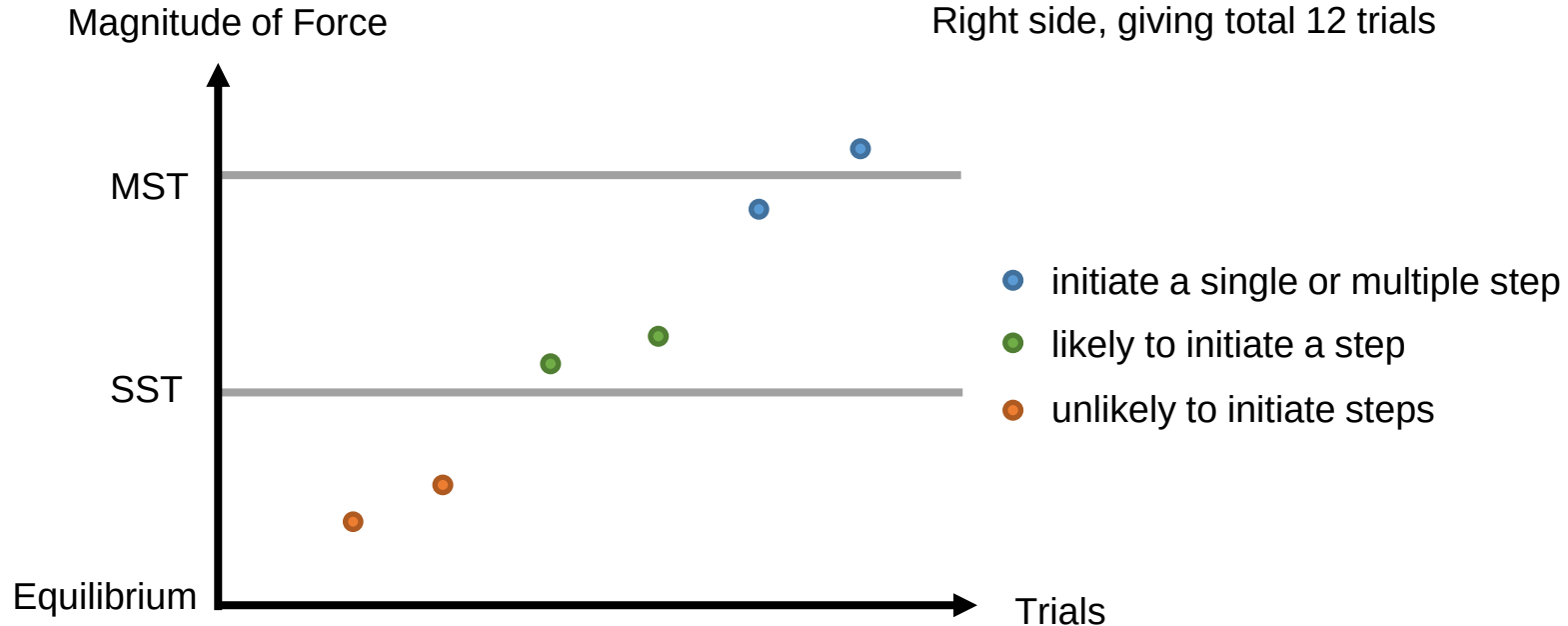
Aim2: Providing Random Force

- INPUT:
 - LabVIEW
 - Force Sensor
- OUTPUT:
 - LabVIEW

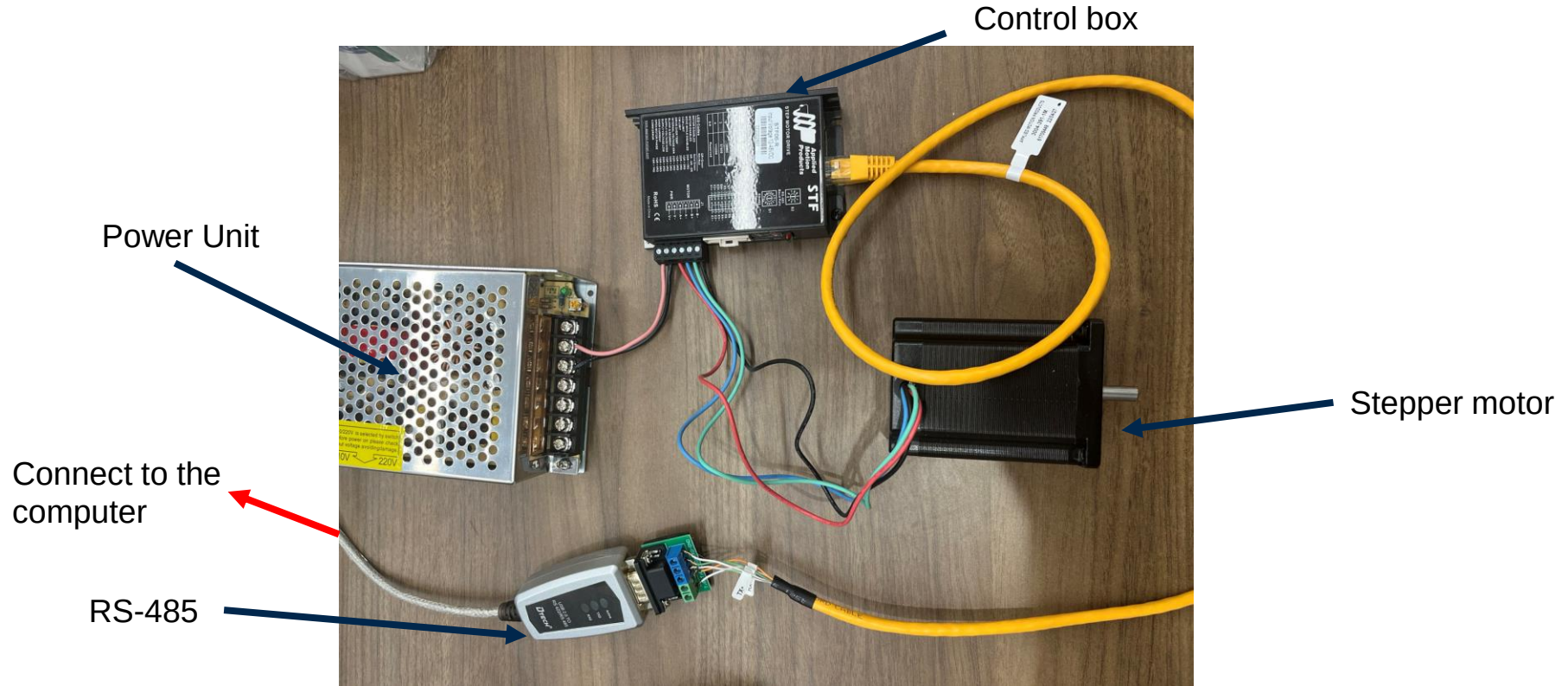


Random Force Generated

- The system is supposed to generate six different magnitudes of force to generate depending on the participant's MST and SST, from the Left or Right side, giving total 12 trials



Set up the Hardware Connection of the Motor

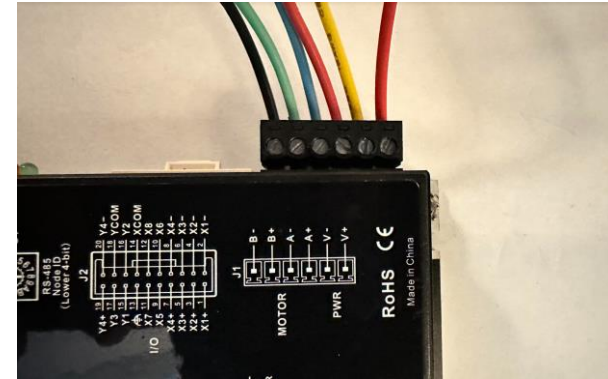


Set up the Hardware Connection of the Motor



From left to right:

- Half orange half white
- Orange
- Half green half white
- Green
- White



- Color as shown above

Set up the STF Configurator

Applied Motion Products

Drive: STF10-R ... Port: ... Enable Alarm Reset Upload All from Drive Download All to Drive STOP

Rev: ... Addr: 0 ... Force EN

Step 1: Configuration Step 2: Q Programmer Motion Simulation

1. Motor Config

X5718-077-20 ... Running Current: 1.18 Amps

☐ Reverse motor rotating direction Acc/Dec: 1000 rps/s

2. Control Mode

SCL/Q (Stream Command/Stand Alone)

3. Control Mode Settings

Node ID: High Low Select Low(Axis 0~15)

Transmit Delay: 2 ms

Data Format: ☐ Hexadecimal ☒ Decimal

☐ Auto Execute Q Program at Power Up

Electronic Gearing: 20000 Steps/Rev S-Curve acc/dec time: 10 ms ☒ Not used

4. I/O (X = Input, Y = Output)

Digital Input & Output

X	Y
X1: General Purpose	Y1: General Purpose
X2: General Purpose	Y2: General Purpose
X3: General Purpose	Y3: General Purpose
X4: General Purpose	Y4: General Purpose
X5: Drive enabled when closed	
X6: General Purpose	
X7: General Purpose	
X8: General Purpose	

Input Noise Filter(X1/X2): 1818.18 KHz@50% duty cycle

Standard Motor

☒ Customer Motor custom motor

Motor Spec

Motor Current: 2.00 A

Hold Torque: 467.320 oz in

Rotor Inertia: 2.0000 g cm2

Load Inertia

☐ Load Inertia 39.9630 g cm2

☒ Load Ratio 19.98 X rotor inertia

Open Winding Detect

☐ Waveform Smoothing Off

☐ Reverse motor rotating direction

☒ Open winding detect when motor is moving

Open winding detect velocity limit: 1.0 rps

Waveform Smoothing

Harmonic Gain: 0

Harmonic Phase: 0 Wizard

Drive Settings

Running Current: 2.00 A

Idle Current: 60 %(1.20A)

Idle Current Delay: 0.40 secs

Accel/Decel Current: 2.00 A

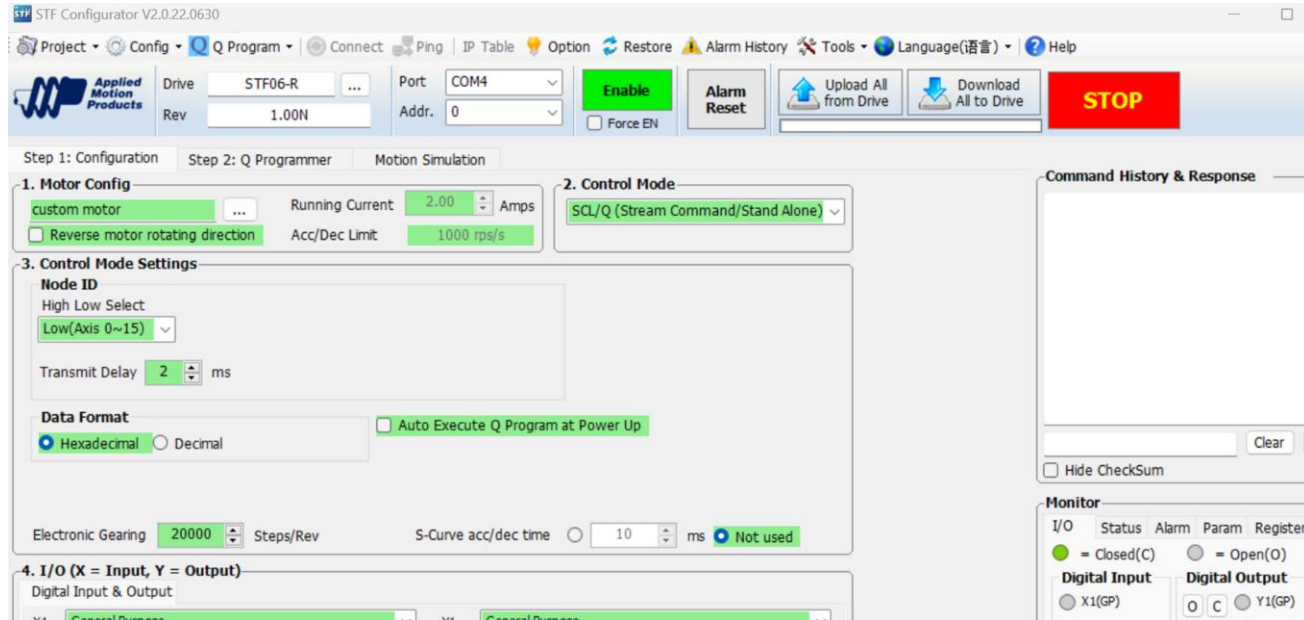
Accel/Decel Limit: 60000.000 rpm/s

OK Cancel

X8(GP)

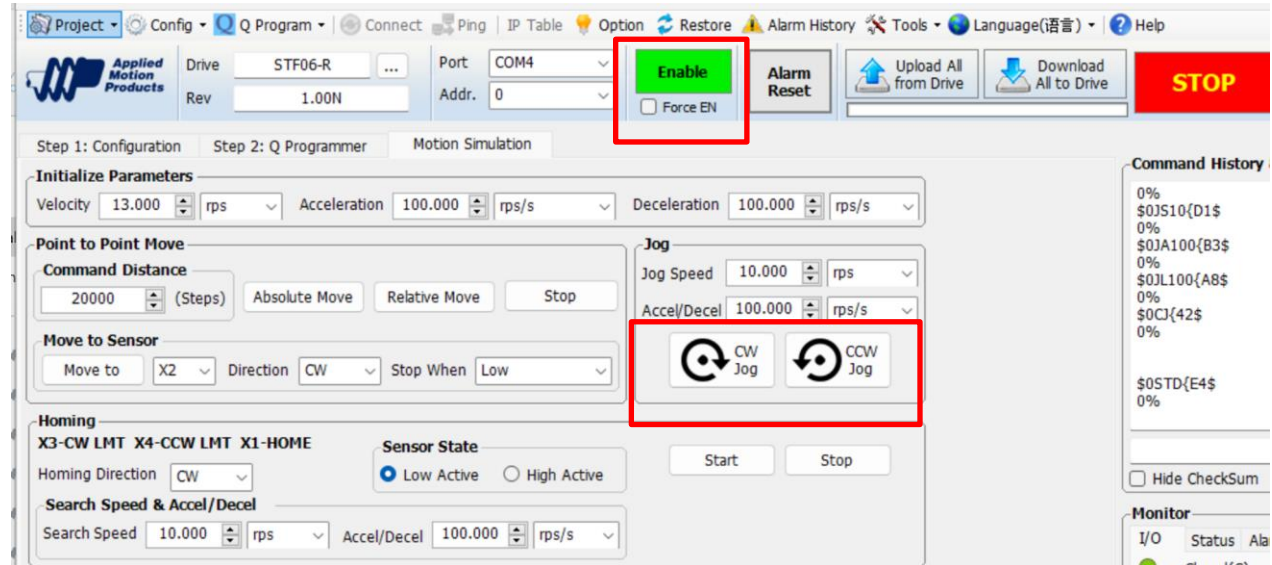
Set up the Connection of the Motor

- Choose the right Port number
- Click “Connect”
- Dialog will appear download all to drive
- When the boxes turn green as shown on the right, the connection is set

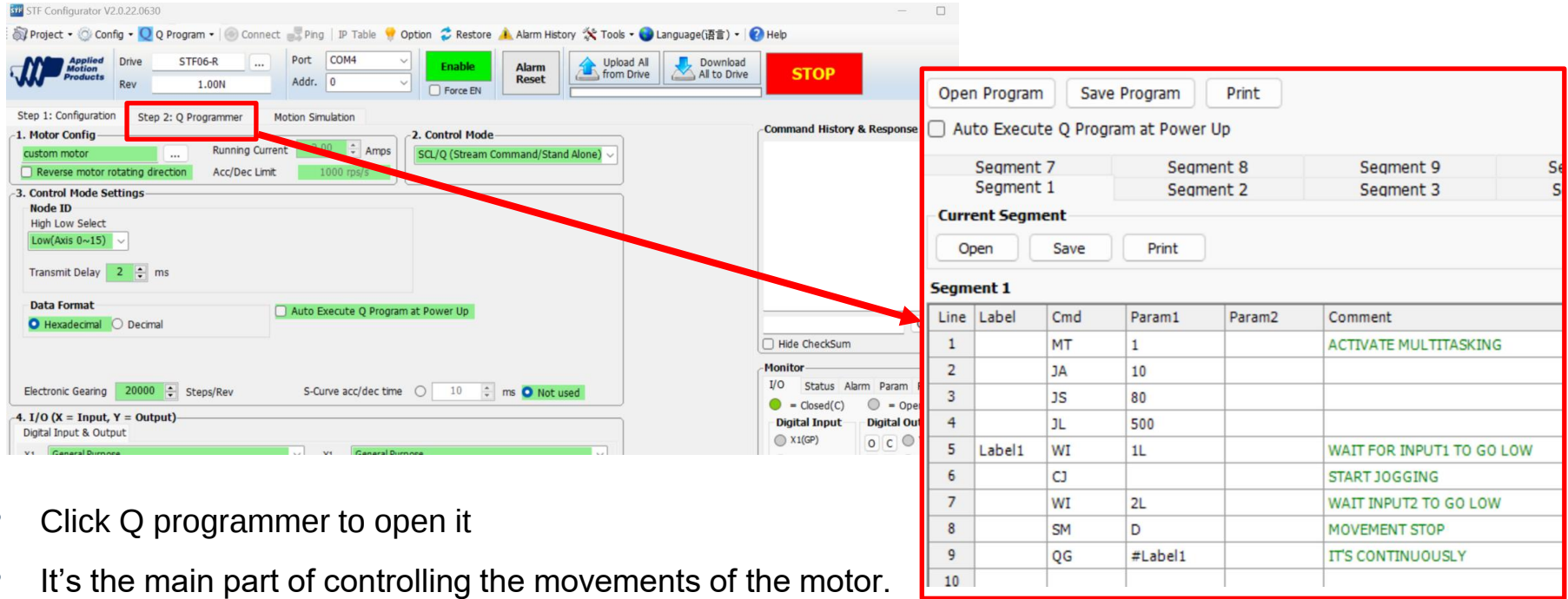


Test the software Connection to the Motor

- Click “Connect”
- Pop up window will appear, click download all to drive
- When the boxes turn green as shown in the right, the connection is set



Use Q programmer to control Motor's Movements



The screenshot shows the STF Configurator V2.0.22.0630 interface. The 'Q Program' tab is selected, and the 'Step 2: Q Programmer' sub-tab is highlighted with a red box. A red arrow points from this box to the 'Segment 1' table in the expanded view on the right.

Step 2: Q Programmer

Open Program Save Program Print

☐ Auto Execute Q Program at Power Up

Segment 7	Segment 8	Segment 9	Segment 10
Segment 1	Segment 2	Segment 3	Segment 4

Current Segment

Open Save Print

Segment 1

Line	Label	Cmd	Param1	Param2	Comment
1		MT	1		ACTIVATE MULTITASKING
2		JA	10		
3		JS	80		
4		JL	500		
5	Label1	WI	1L		WAIT FOR INPUT1 TO GO LOW
6		CJ			START JOGGING
7		WI	2L		WAIT INPUT2 TO GO LOW
8		SM	D		MOVEMENT STOP
9		QG	#Label1		IT'S CONTINUOUSLY
10					

- Click Q programmer to open it
- It's the main part of controlling the movements of the motor.
- Open the exist program or write a new one

Use Q programmer to control Motor's Movements

Applied Motion Products

Drive: STF10-R ... Port: ...

Rev: ... Addr: 0

Enable Alarm Reset

Upload All from Drive Download All to Drive

STOP

Step 1: Configuration Step 2: Q Programmer Motion Simulation

Open Program Save Program Print

Upload from Drive Download to Drive Execute Stop

Clear Q Program Set Password

Segment 7 Segment 8 Segment 9 Segment 10 Segment 11 Segment 12

Segment 1 Segment 2 Segment 3 Segment 4 Segment 5 Segment 6

Current Segment

Open Save Print

Upload Download Execute Clear

Segment 1

Line	Label	Cmd	Param1	Param2	Comment
1		MT	1		ACTIVATE MULTITASKING
2		JA	10		
3		JS	80		
4		JL	500		
5	Label1	WI	1L		WAIT FOR INPUT1 TO GO LOW
6		CJ			START JOGGING
7		WI	2L		WAIT INPUT2 TO GO LOW
8		SM	D		MOVEMENT STOP
9		QG	#Label1		IT'S CONTINUOUSLY
10					
11					
12					
13					
14					
15					
16					
17					
18					

Command History & Response

Hide CheckSum

Monitor

I/O Status Alarm Param Register

● = Closed(C) ○ = Open(O)

Digital Input Digital Output

X1(GP) Y1(GP)

X2(GP) Y2(GP)

X3(GP) Y3(GP)

X4(GP) Y4(GP)

X5(En)

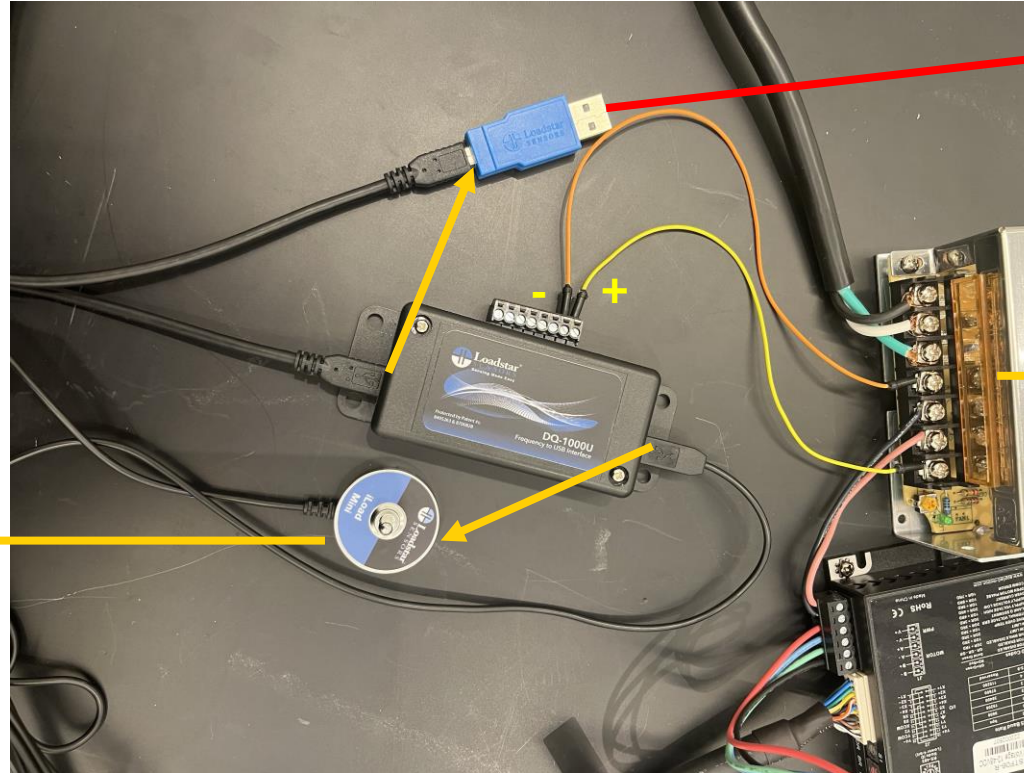
X6(GP)

X7(GP)

X8(GP)

- Click the empty box under Cmd to write command
- Click “download all to Drive” to load the program to the control box
- Click “execute” to run the program
- The step which one is running will be colored as yellow.

Set up the Connection of the Force Sensor



Connect to the computer

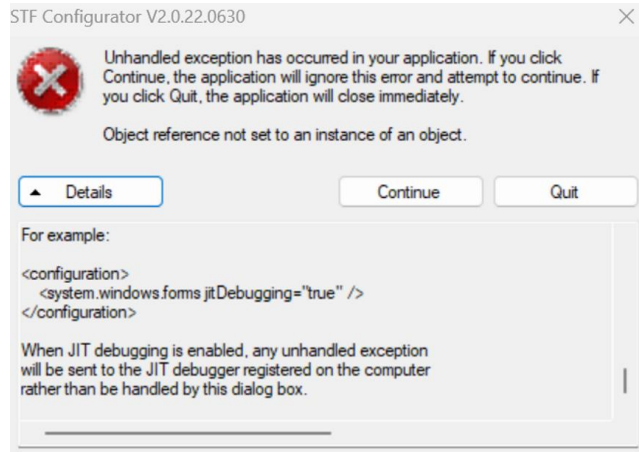
Power Unit

The Force Sensor needs to be powered.

Load Unit

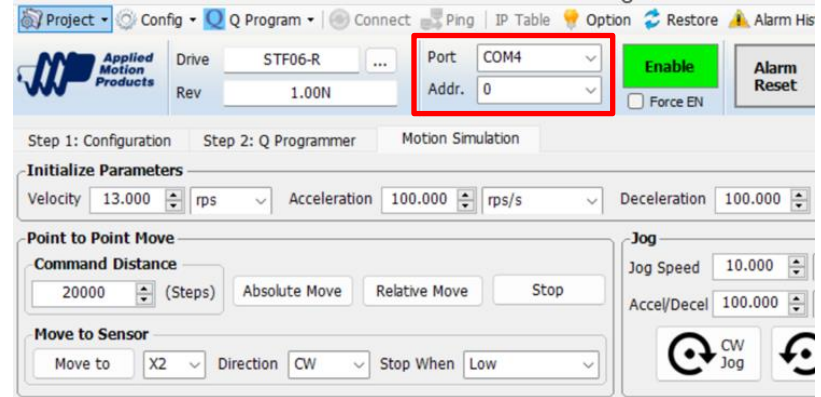
Attached to human body, linking to the pull string.

Problem 1: Cannot link



- Happened while connecting the control box with the STF configurator
- After clicking “Connect”

Solution 1:



- Must choose port number before clicking “Connect”
- Using Device Manager in the computer to check the exact number of the control box

Problem 2: Q programmer cannot tell “if”

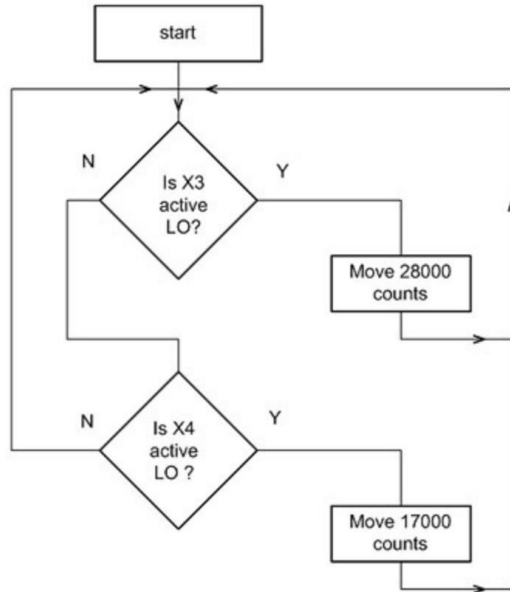
- Writing the Q programmer to execute correct control of the motor is the most important part of producing pull force.
- In our experiment, we requires the motor to move according to different conditions.
- The most common way is to set “if” conditions.
- However, the Q programmer reads the commends just follow the lines. We need to figure out a way to like it move.

Solution 2:

Segment 1					
Line	Label	Cmd	Param1	Param2	Comment
1		MT	1		ACTIVATE MULTITASKING
2		JA	10		
3		JS	80		
4		2L	500		
5	Label1	WI	1L		WAIT FOR INPUT1 TO GO LOW
6		CJ			START JOGGING
7		WI	2L		WAIT INPUT2 TO GO LOW
8		SM	D		MOVEMENT STOP
9		QG	#Label1		IT'S CONTINUOUSLY

- After reading every comment in the software, I figured out some ways to do it. This is the program we are testing recently.
- MT: enable the task to read and run more than 1 task in the same time, so that it can run “running the motor” and “testing the condition” at the same time.
- WI: “wait until” continue only when the condition is TRUE.
- QG: go back to the label we set and run again. This enables the loop.

Solution 2: Q programmer cannot tell “if”



input priority segment					
Line	Label	Cmd	Param1	Param2	Comment
1		AC	150		set the accel rate to 150 rev/sec/sec
2		DE	175		set the decel rate to 175 rev/sec/sec
3		VE	5		set the velocity to 5 rev/sec
4		FI	3	100	apply a 10 msec noise filter in X3
5		FI	4	100	apply a 10 msec noise filter to X4
6	LABEL3	TI	3L		test X3 for a LO condition ie: circuit is closed
7		QJ	T	#LABEL1	jump to LABEL 1 if TRUE, otherwise drop down to the next line
8		TI	4L		test X4 for LO condition ie: circuit is closed
9		QJ	T	#LABEL2	jump to LABEL 2 if TRUE, otherwise drop down to the next line
10		QG	#LABEL3		go to LABEL 3
11	LABEL1	DI	28000		set the distance for 28000 counts
12		FL			initiate the move
13		QG	#LABEL3		go to LABEL 3
14	LABEL2	DI	17000		set the distance for 17000 counts
15		FL			initiate the move
16		QG	#LABEL3		go to LABEL 3

- After searching online and reading through the whole forum related to Q programmer, I found some ways that could write “if loop” as well.
- However, this are not the same case as ours. I will figure it out later and update our program. (20230425)

Problem 3:SpeedMovement

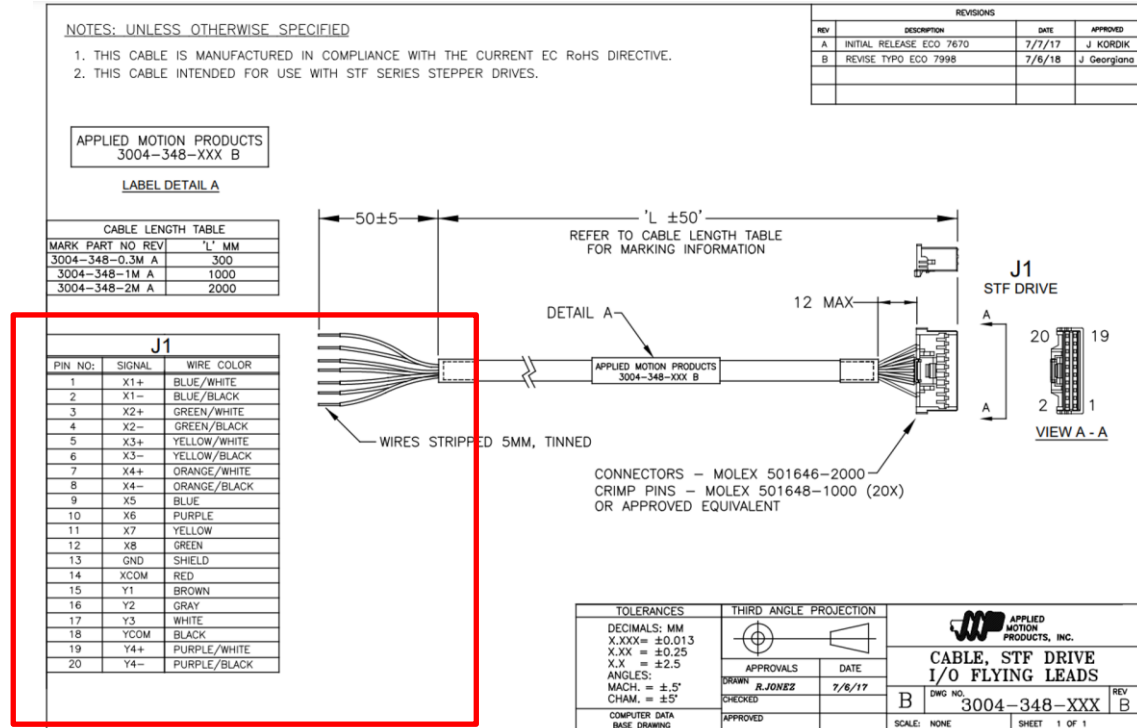
Solution 3:

Here are the problems solved and left to be solved for our Q program:

Q programmer follows the “distance and position set” to run the motor. This means we need to set the distance to run or the final position to reach, and only then can it control the motor to run as set speed and acceleration.	Use “Jog” comments to let it turn continuously. Jog allows the motor to keep rotating as the speed and acceleration we set. We can set a top speed to reach, and this can be used as the “safety speed”
Jog cannot be set as inverse rotating. But we need it!	Me may consider reading different signals to set different rotating speeds. In this case, the advanced “if loop” is considered to identify different signals. (SLOVED – 20230510)
The two motors should cooperate with each other; Considering the time needed to transform the force signal, the correct force need to be considered; Keep the force axial;	Waiting to be solved through further experiments.

Problem 4: Activate the motor without labVIEW

- While using the motor, we need to test the function of the Q programmer we write
- However, without LabVIEW deck and the ability to write one at the beginning (sorry)
- In this way, I figured out a way to test without LabVIEW, just using the power unit.

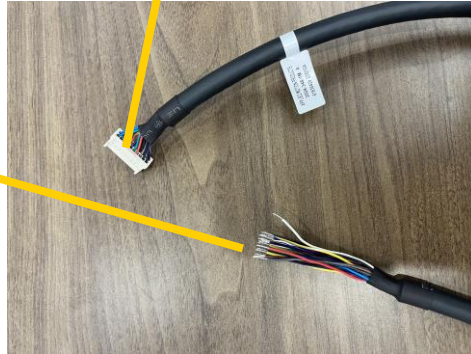


Solution 4: Activate the motor without labVIEW

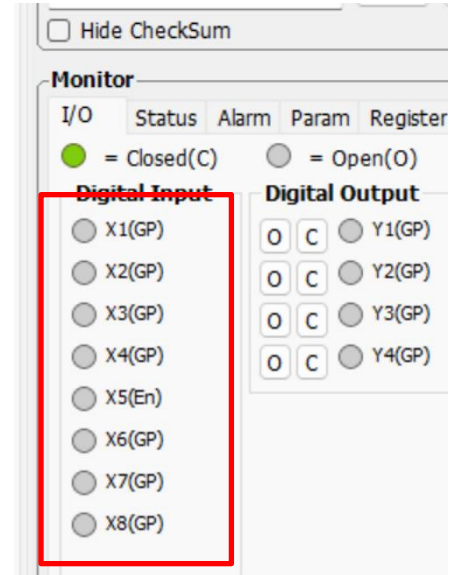
Power Unit



Connect to the control box



- Connect as shown on the left.
- Black to – and white to +.
- Use the color displaying different X1 X2 X3 based on our setting in Q programmer.



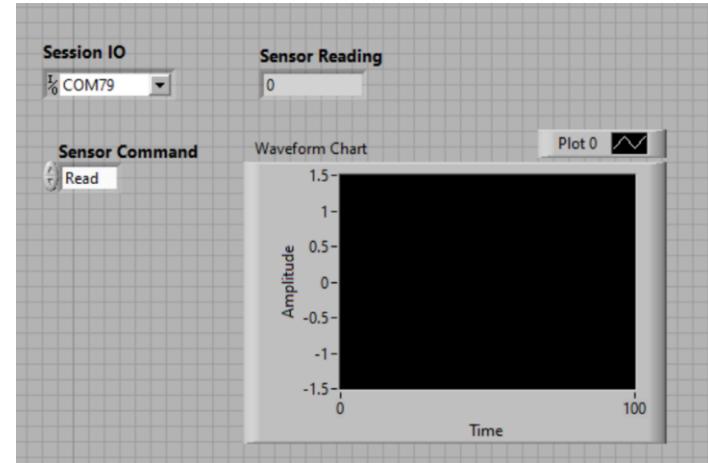
- When the Digital Input shown as Green, it means it has been connected. When it's green, it will read as "LOW". This enables our testing of Q programmer without LabVIEW.

Problem 5: Read from the Force Sensor

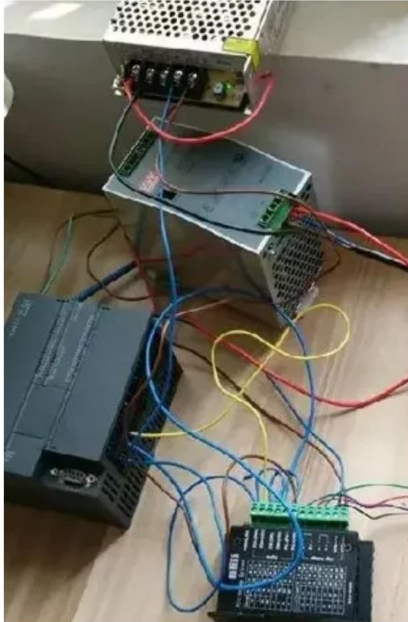
- The force sensor is from another company, and they are using their own software to read the force.

Solution 5:

- We used LabVIEW to read the values of the force sensor. We have written a specific VI file for this part.
- Using LabVIEW, it will read out the voltage signal passing through the port linked to the computer. We need to open the Device Manager on the computer and choose the correct Port number in the Session IO.
- Then, it will show the voltage value on the right, transformed to force value.
- The LabVIEW files is “iLoadDigitalUsb_working_with loop.vi”



Problem 6: Whether to use PLC



- Using PLC could be a way to control the motor simpler.
- But it means we need to purchase at least two more parts and learn new software and control language :(

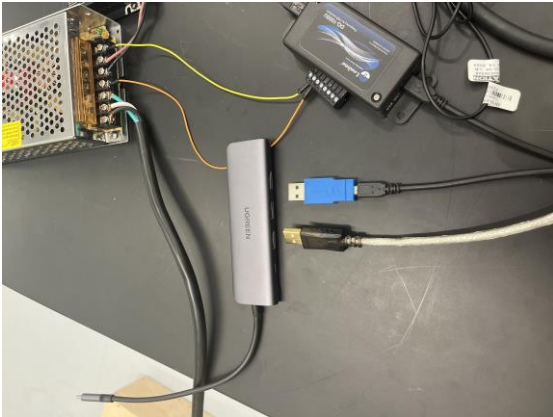
Solution 6:

- After searching on the Internet, I have found that Siemens S7-200 might be a good choice for us. It's simple and easy to control. (shown on the left)
- Still under Consideration
- Now we are using the deck as shown below (right).



Problem 7: Too many ports to connect

- Another problem for us is that, as we are using a lot of device to connect. In this case, we need to connect them to the computer, and figure out their port number at the same time.
- However, we have at least 5 device to connect to one computer.



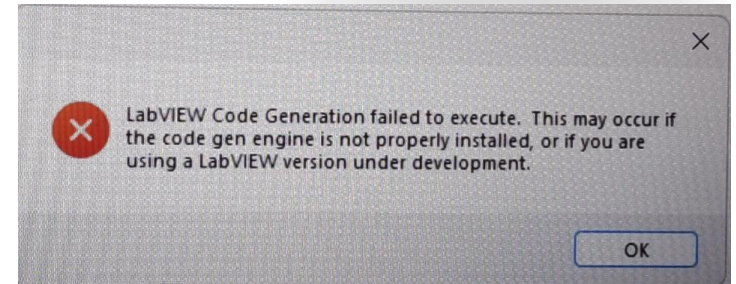
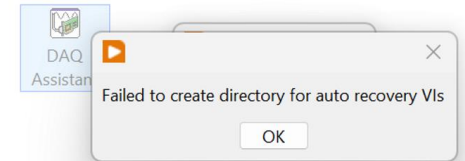
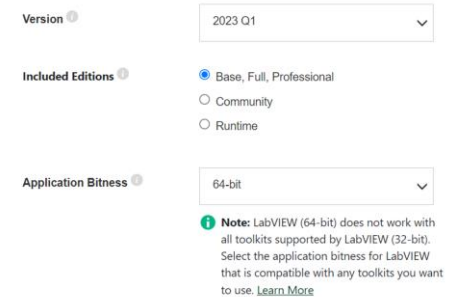
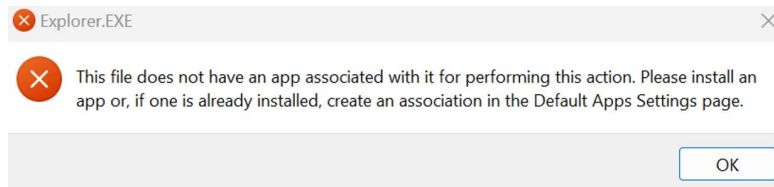
Solution 7:

- In this case, we need some extension port hub;
- But their functions need to be figured out clearly as well. Port numbers may change due to the hub. Some hubs may restrict the ability of signal communication.
- Some more control box or switch table is also under consideration to allow easier control.
- Purchasing a USB splitter cable.



Problem 8: LabVIEW related problems

- Problems related to LabVIEW are the most exhausting ones.
- Now we figured out the problems that may take place according to :
 - The version of LabVIEW.
 - The version of NAQmx.
 - Whether they can cooperate.
- Whether they can work correctly really influences the outcomes that we can get. We are still working on solving them.
- (SLOVED – in v2 version)



What we have reached – v1

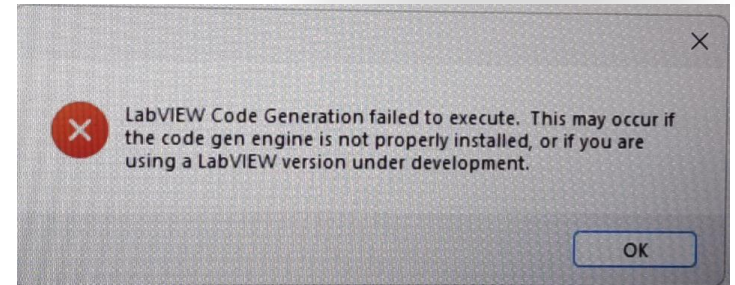
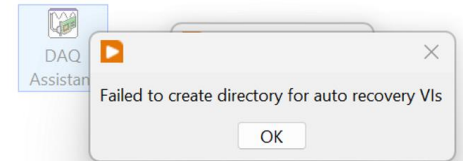
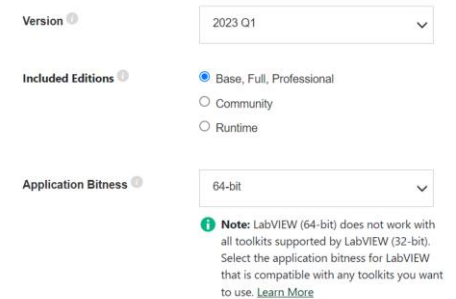
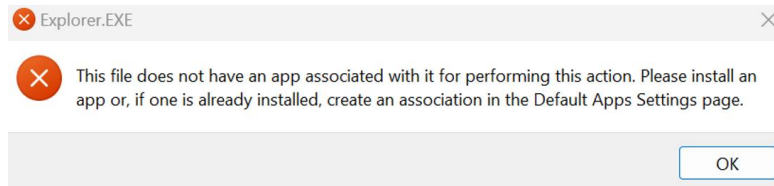
- Motor side
 - Able to generate different forces according to different signals
 - Build the overall control structure
- LabVIEW side
 - Able to read from the force sensor
 - Build the structure to send different signals

Key Problems Facing – v1

- Signal:
- Information input and output for different systems
- Unpredictable Software problems:
- Mainly on LabVIEW
- “Human-Centered” Design, Safety & Accuracy

Problem 8: LabVIEW related problems

- Problems related to LabVIEW are the most exhausting ones.
- Now we figured out the problems that may take place according to :
 - The version of LabVIEW.
 - The version of NAQmx.
 - Whether they can cooperate.
- Whether they can work correctly really influences the outcomes that we can get. We are still working on solving them.



Solution 8: LabVIEW related problems

Uninstall everything related to LabVIEW.

Download:

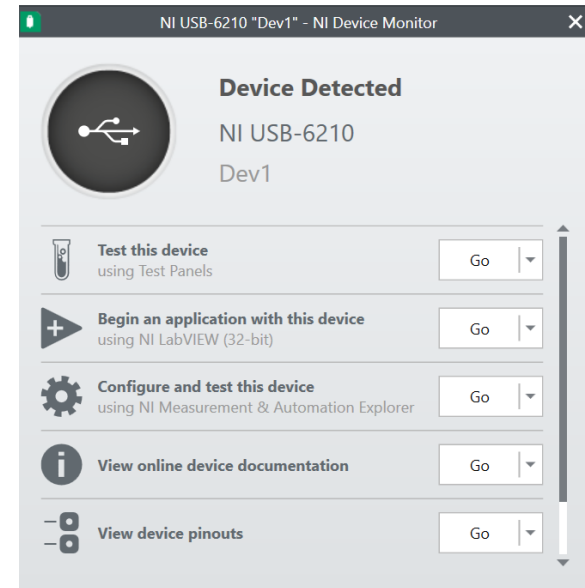
- LabVIEW 2021 SP1
- DAQmx 2022 Q4 – 22.8

And then they can cooperate.
(20230508)

The DAQ Assistant runs
successfully and shown as this:



If the Device successfully read out the
deck connected, the pop up window will
show like this:



Problem 9: Adjust the jog direction and speed

- It is said that there are ways to solve the problem using Q programmer in their application notes and handbook.
- However, they are just different!
- We cannot find the CS (change speed) command; and DI for the direction not work.
- What's more, they are using the Q programmer software, not STF Configurator. Although we can write Q programmer in STF configurator, and they are from the same company, so they should be able to work in the same way.
- But they just cannot work like that!
- I have sent an email asking about this, and not received feedback yet. (20230509)

Host Command Reference

CS - Change Speed

Compatibility: All drives
Affects: Jog speed while jogging
See also: CJ, JS, JA, JL commands

Sets or requests the jogging speed in rev/sec while jogging. When Jogging using the CJ command the Jog speed can be changed dynamically by using this command. The sign of CS can be positive or negative allowing the direction of jogging to be changed dynamically also. Ramping between speeds is controlled by the JA and JL commands. Setting CS does not change JS or DI.

Problem 9: Adjust the jog direction and speed

There may be solved using RX and RM command in Q programmer.

Problem can be solved using RX and RM! The command runs as described below:

- RX – load the number
- RM – sign the number to parameters

Received feedback from Applied Motion Applications Engineering. (2030510) So that we cannot use CS.

Hi Boer,

Thank you for contacting Applied Motion Products. The "CS" command is an immediate type command that cannot be used in the Q program. *Only buffered type command can be used in the Q program.

I would recommend using "RL" command to change the J parameter during the jogging as shown in the manual.

```
Sample Q program sequence
MT1      Turn Multi-tasking ON
FI58     Filter input X5 for 8 processor ticks (2 msec)
WIX5L    Wait for input X5 low
CJ       Commence jogging
RLJ450   Change speed to 2 rev/sec by directly loading the J register. Note, units are 0.25rpm.
WIX5H    Wait for input X5 high
SMD      Stop Move using the decel ramp set by JL
```

According to the manual, the "CJ" command starts the jog move using DI in the beginning. I would recommend using "DI" command before the CJ command and stopping the motion before changing the direction. Please see below for a sample q program.

```
TI2L
QJT3
DI500
CJ
WI4L
SMD
```

Solution 9: Adjust the jog direction and speed

Successfully make the motor runs as we want! (2030517)

Part 1: set the initial values

Use RL to pre-load the numbers.

Engineers from Applied Motion Company suggested me to put different tasks into different segments, but I haven't done so and haven't encountered problems yet. Can be a way for the future.

Line	Label	Cmd	Param1	Param2	Comment
1		MT	1		enable multiple motion tasks
2		JA	10		set the acceleration speed
3		JL	300		set the deceleration speed
4		JS	1		set the initial speed
5		RX	1	1	set the initial jogging speed (very slow)
6		RX	2	3000	
7		RX	3	-3000	make the motor run inversely
8		RX	4	5000000	
9		RX	6	-5000000	make the motor run iversely (double check)
10		RX	7	10000	
11	Label4	WI	1R		when port 1 is executed, the motor will start to rotate at a very slow speed
12		RM	1	J	the initial rotating speed
13		RM	7	D	
14		CJ			start to jog slowly

Solution 9: Adjust the jog direction and speed

Part 2: change the speed and rotation direction

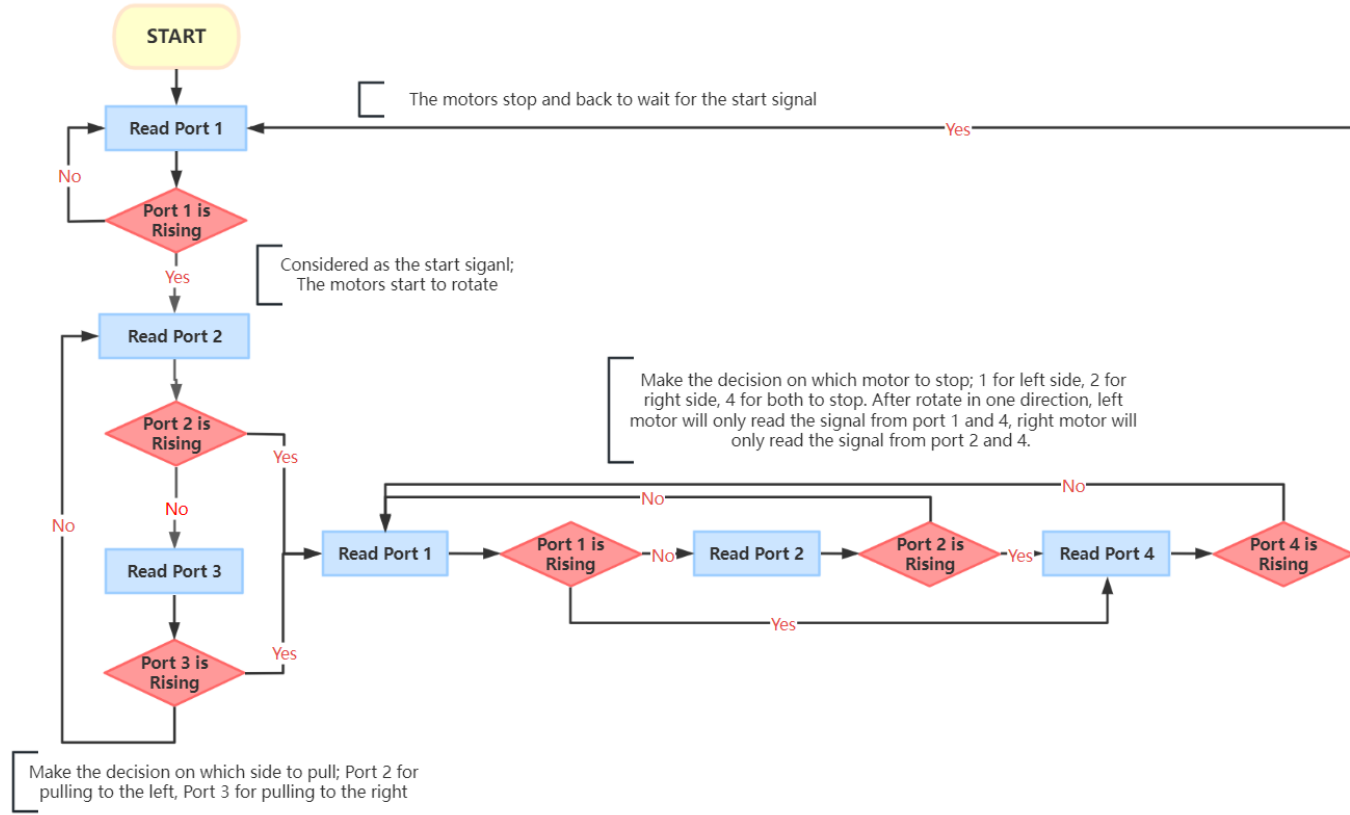
Here we applied the “if” decision in Q programmer. Then, we used RM to read the pre-loaded values.

Now we used R (Rising Edge) to decide for the condition.

Problem left: The DI cannot change the direction, and we need to rely on change the jogging speed to be positive or negative (for inverse rotation).

15	Label3	TI	2R		make the decision as "if"
16		QJ	T	#Label1	if port 2 is executed, the motor will speed up in the same direction
17		TI	3R		
18		QJ	T	#Label2	if port 3 is executed, the motor will speed up inversely
19		QG	#Label3		
20	Label1	RM	4	D	change jog DI
21		RM	2	J	change jog speed
22		WI	4R		when detected port 4 is executed, the motor will stop rotating
23		SM	D		stop rotating
24		QG	#Label4		goback to label 4 : whether to start the trail
25	Label2	RM	6	D	rotate inversely
26		RM	3	J	change rotate speed
27		WI	4R		
28		SM	D		
29		QG	#Label4		

Logic of our Q program with the Ports



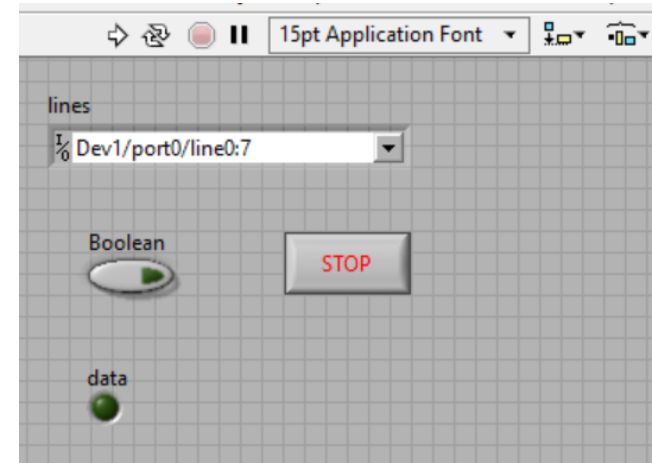
Problem 10: LabVIEW cannot trigger the control box

We are using a written file in LabVIEW to trigger signals. (Digital Write_Claire2.vi)
However, we cannot make the control box to read from the LabVIEW instructions.

Solution 10:

The problems take place from several aspects:

- Hardware problems:
The lines and ports have not been connected correctly.
- Software problems:
The Q programmer cannot read from the signal or cannot make the correct response as we want.
The device to generate the signals has not been chosen correctly.



The VI file to generate the Signal (Digital)

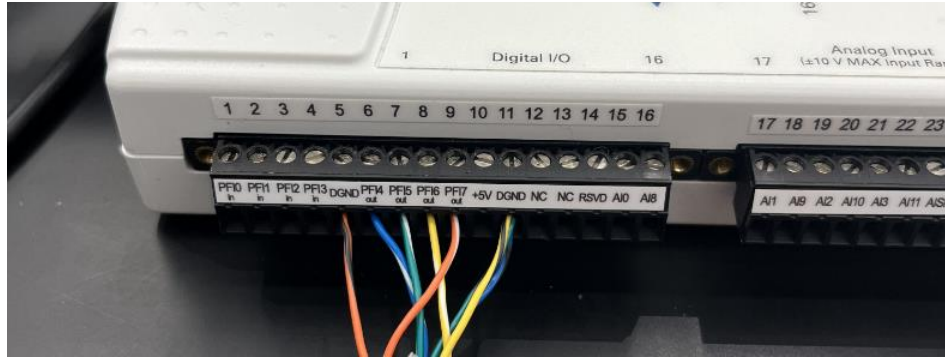
Solution 10: LabVIEW cannot trigger the control box

First, check whether the deck has been successfully connected from the hardware side.

From the manual for Deck USB-6210, we can identify the right port for input and output.

Here we are using the P1.0 to P1.3 for OUTPUT.

At first time we could not read out the signals because we connected to the INOUT ports. :(
The connection is shown as below.



USB-6210

USB-6210 Pinout

Figure A-1 shows the pinout of the USB-6210.

For a detailed description of each signal, refer to the *I/O Connector Signal Descriptions* section of Chapter 3, *Connector and LED Information*.

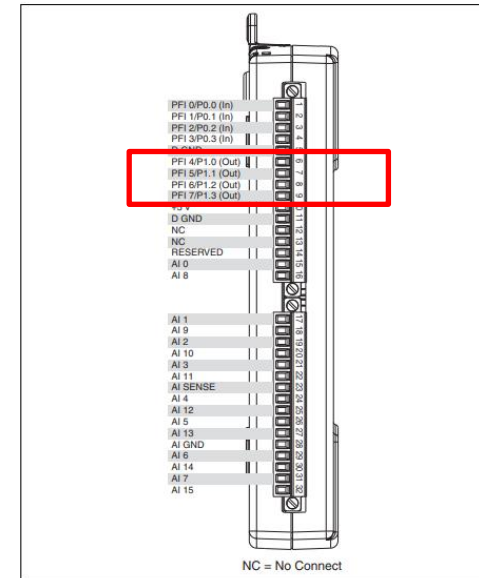


Figure A-1. USB-6210 Pinout

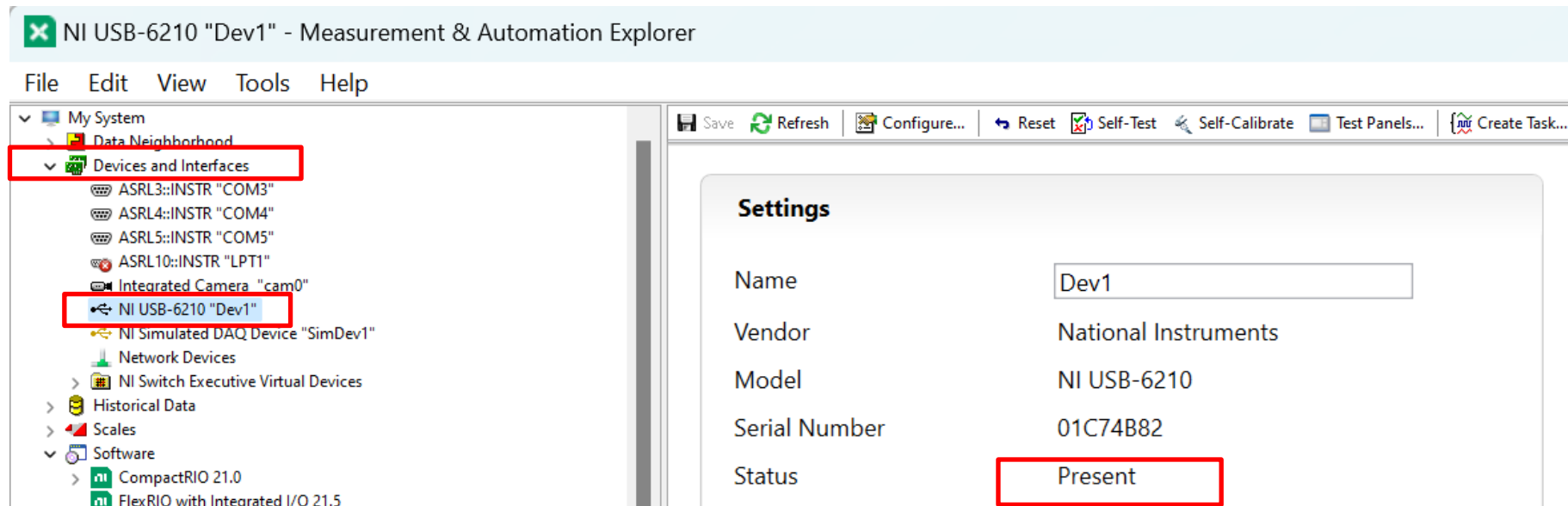
Solution 10: LabVIEW cannot trigger the control box

Then, check whether the deck has been successfully connected from the software side.

Using NI MAX (a software) to check whether it is connected correctly.

If it has been connected successfully, it should show as below:

Check the names. When we are using LabVIEW, the name will show as “Dev1”.

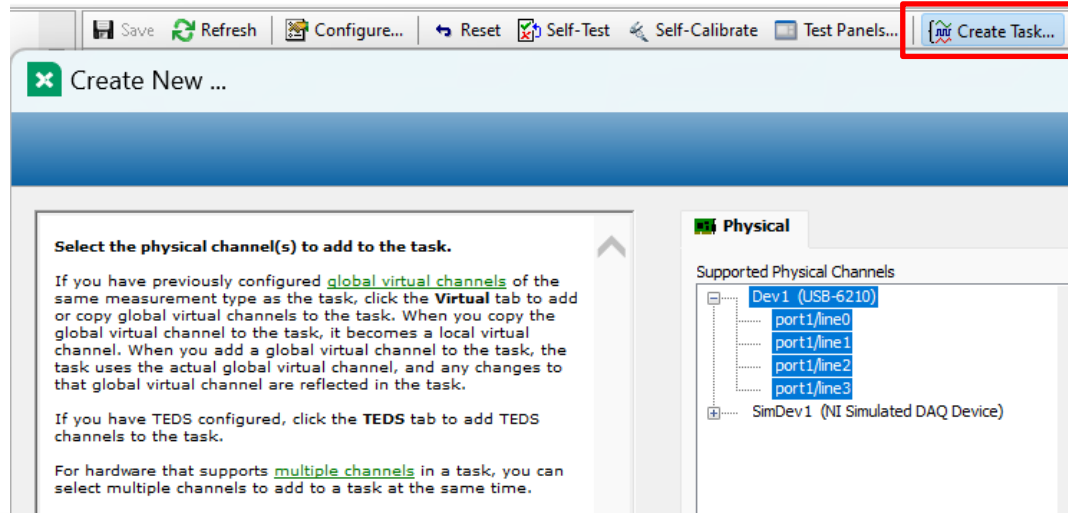


Solution 10: LabVIEW cannot trigger the control box

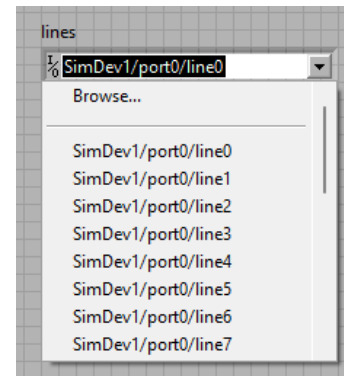
Using the Create Task, we can identify the exact ports.

Remember to check with the manual to find out what the ports exactly be.

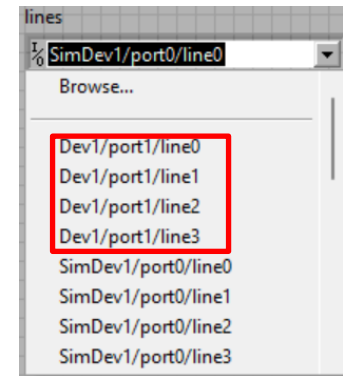
We can also identify whether it is successfully connected from the VI file. When we can see the ports names from the list in the file, it means now we can use these OUTPUT ports to generate the signals.



Not Success:



Success:

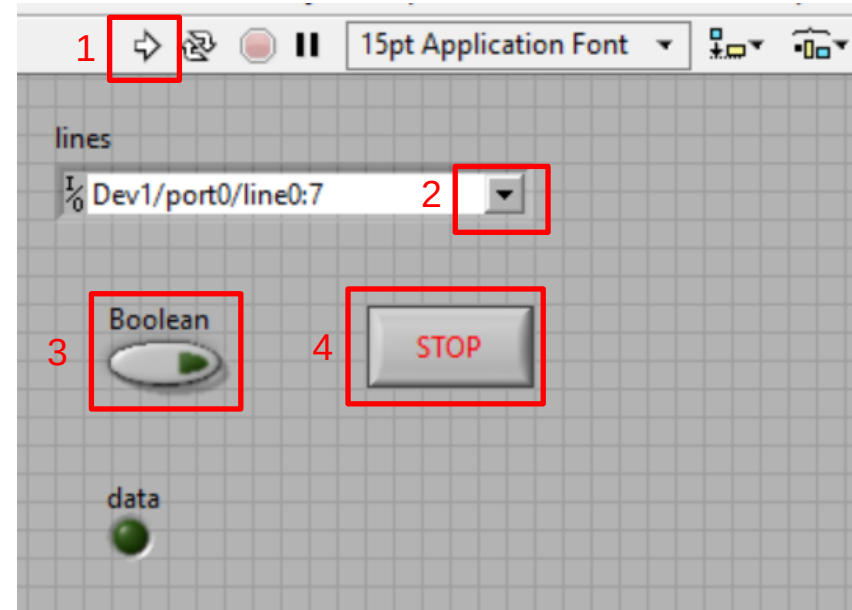


What we have reached –v2

- Overall, after solving all the problems listed above, we have finished the control set up for the motor side.
 - Now the motor has been able to generate according to different signals.
 - At first, the motors in the two directions will run at the same slow speed to create the equilibrium condition.
 - Then, the motors can rotate according to the signal received, creating force pulling to one side.
 - The motor can be stopped and run into the next trial smoothly.

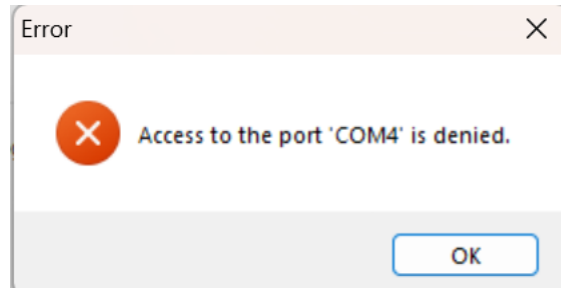
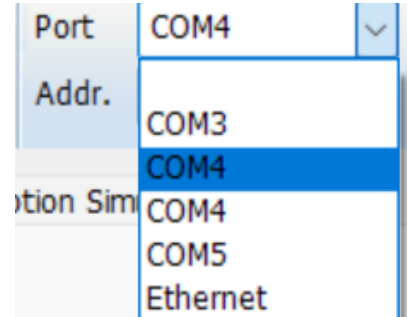
What we have reached –v2

- Now we can generate the signals using LabVIEW and STF configurator.
- 1. Click to start
- 2. Choose the right port from the drop-down list
- 3. Click Boolean to generate the signal
- (line numbered starting from 0 to 3, different to Q where 1 to 4)
- 4. Click STOP to stop the recent program
- Then goes back to the first step.



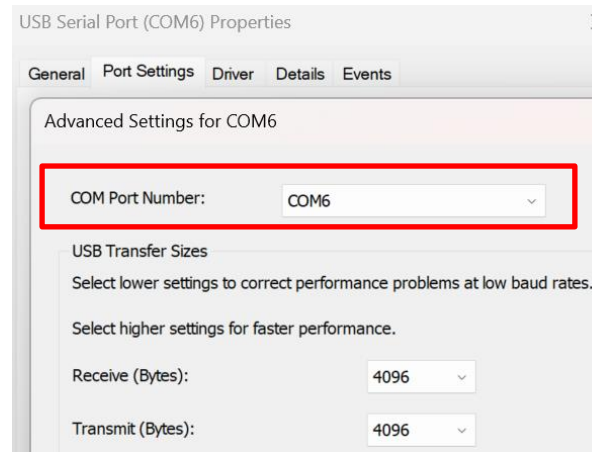
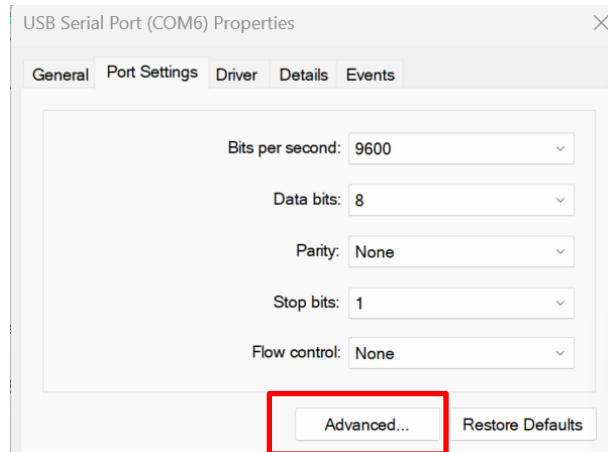
Problem 11: The same kind of items shared the same Port number!

- When we are connecting the same kind of items to the computer, in our case, the same RS-485 and the control box, it will be given the same port number in the computer.
- In this case, the connection will fail to send control signals because they cannot decide which is the exact port to control.
-
- Important: LabVIEW and LV-1000 could not read the force sensor if the port number is shared.



Solution 10: LabVIEW cannot trigger the control box

- To solve this problem, we can go to the Device Manager to change the port name of one of the control box. Choosing Advanced and change the name by choosing another port number.
- This will require you to restart the computer.
- And then we need to identify the number of the port correctly if we need to execute the right Q programmer file.
- Run check (using STF configurator – Motion Simulation) every time after connecting.

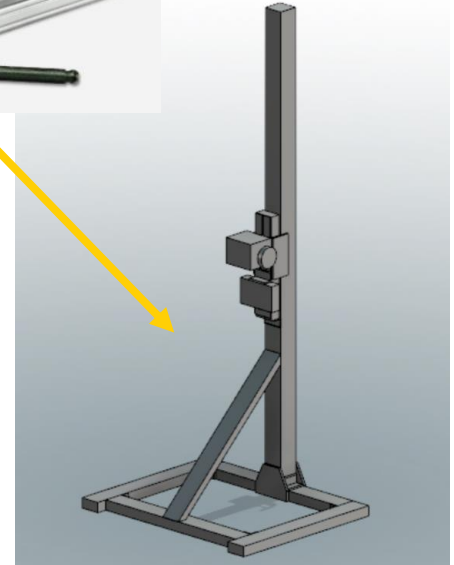


Key Problems Facing – v3

- Mechanical set up of the whole structure:
- It should be available of adjusting height according to the height of different participants.
- It should be able to connected to both sides tightly, stably and safely

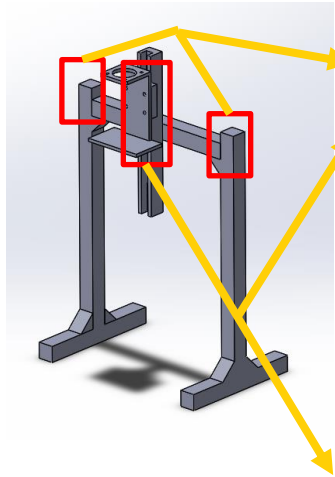
Problem 12: Adjustable Mechanical Structure

- According to the different waist height of participants, the structure should **be able to adjust height**.
- So, it should be able to adjust and stable at various height. The range of the height of people's waist should be taken into account in design.
- In the meantime, it must be capable to **carry on the weight** of the motor and overall setup.



The Recent Design:
Introducing in detail
later

Problem 12: Adjustable Mechanical Structure



Two Designs:
Moving the frame or
moving the motor.

For slots, it's easier for connecting
in the direction without any other
special design



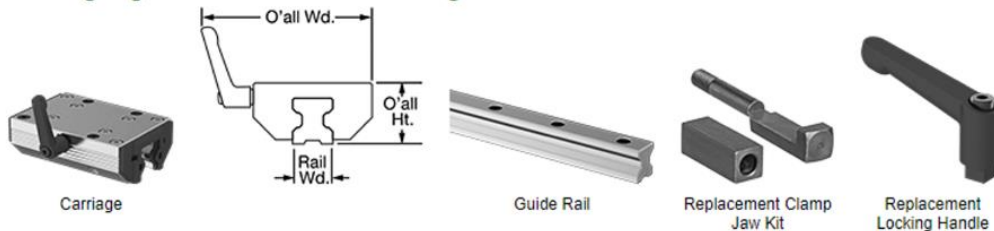
Pros

Many moveable parts with slot is
designed to be parallel;

Cons

Center of mass is too high: not stable;
if moving the frame, connecting bars
may not be parallel after moving; if
moving the motor, the carriage is not
easy to connect to the motor

Locking High-Load Track Roller Carriages and Guide Rails



A handle on the side of the carriage locks the carriage in place. Made with needle-roller bearings, these track roller carriages have higher load capacities than other track roller carriages. Carriages can be adjusted for a snug or loose fit on the rail. Rollers are permanently lubricated to save maintenance time and effort.

 For technical drawings and 3-D models, click on a part number.

Problem 12: Adjustable Mechanical Structure

The locking collar:

Locking Collars for Single and Quad Rails



Locking Collar

Locking collars mount to a quad rail with the included fasteners. Slide a single rail in to create a telescoping rail.

For Rail Ht.	Wd.	Lg.	Color	Material	Mounting Fasteners Included		Each
1 1/2", 3"	3"	3"	Blue	Anodized Aluminum	Yes	3136N517	\$95.65
40mm, 80mm	3"	3"	Gray	Anodized Aluminum	Yes	3136N523	95.65

Pros

Single structure is more stable;
flexible height

Cons

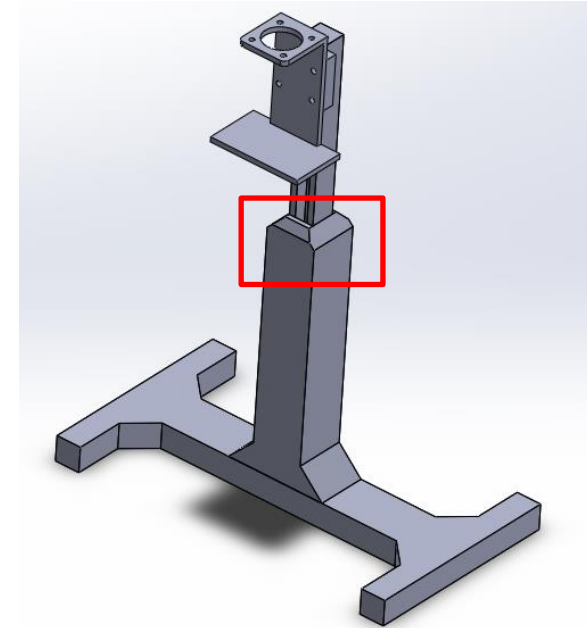
Potential hazard on be slippery
after multiple uses

The structure is a combination of quad T-slot and single T-slot.

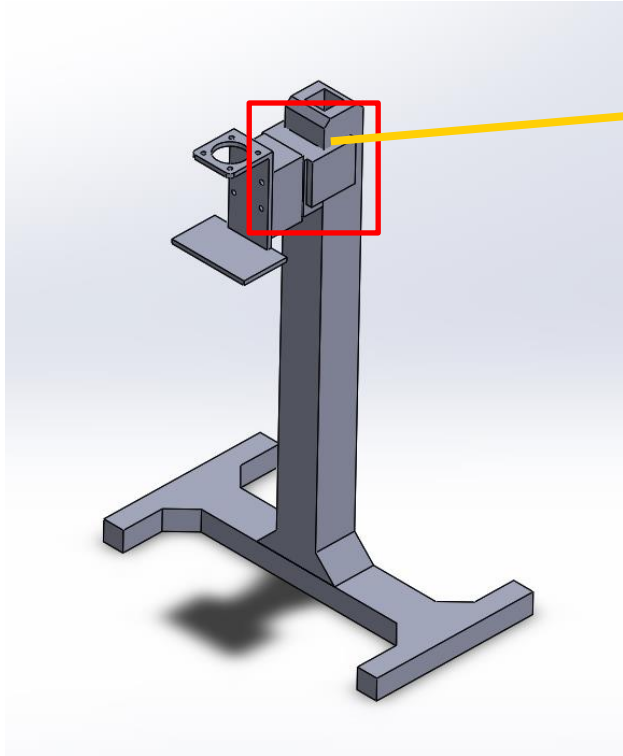
It's good.

But it only has size 3" x 3" ! Our T-slot is 2" x 2".

:(



Problem 12: Adjustable Mechanical Structure



Restricted by the items we can buy!!

The moving & locking part,
holding the motor

The rest are T-slots, mainly used the parts we have
already purchased, but need some more

Pros	Cons
Single structure is stable	Center of mass is too high: not stable
It could change very smoothly	The unibearing (the moving cart) from 8020 website is designed for horizontal movements.

Problem 12 Left: Adjustable Mechanical Structure

- Considering the direction of the force created by the pulley, weight should be added to the beam.
- We may need to purchase other parts (brackets, gussets or even 45 degree supports) to increase its stability before polit testing. At the same time, the number of some parts should be increased.
- The design of the harness should be taken into account. The connection may lead to potential problems.

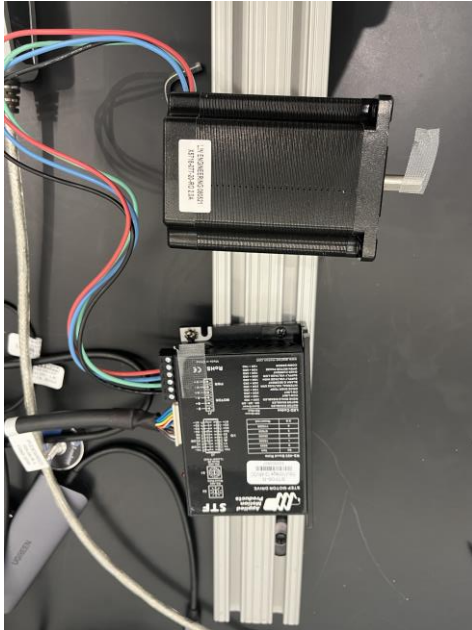


These lead to changes in the list of the parts to purchase.
See the list of “revised additional parts needed”

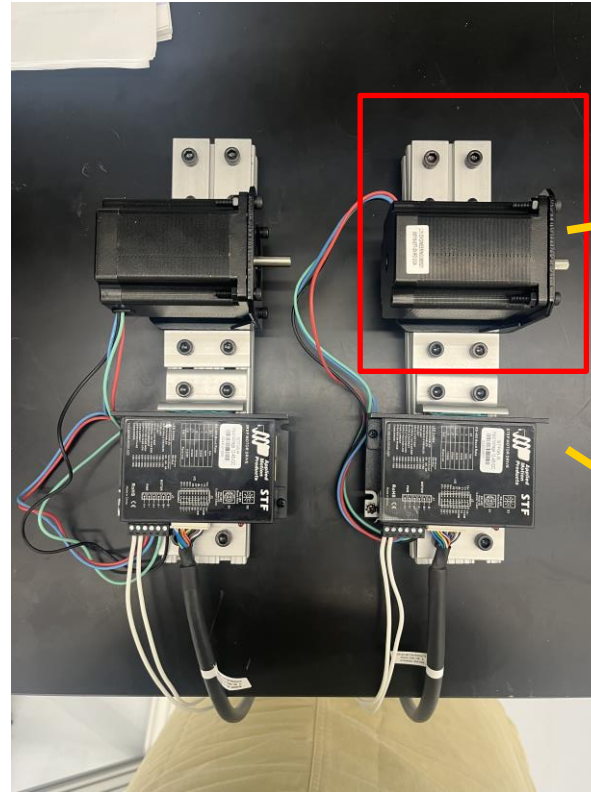


Recent Setup: connect the motors & control box

plan:



actual:



Problems may leave:
Use double-sided
adhesive to connect
the bracket and control
box

Recent Setup: the moving part



Part No. 6733

10 Series Long - Single Mount Unibearing™ Assembly

The long - single mount Unibearing™ assembly is commonly used for linear motion applications and is comprised of a long single mount Unibearing™ that is attached to a T-slot profile. There are pre-tapped holes in the profile ends as well as in the housing unit for connecting accessories. Shim kits are included.

[Add to Wish List](#)

Qty

Total Price.....\$86.89

Part No. 6850

10 Series "L" Handle Linear Bearing Brake Kit

The "L" handle linear bearing brake kit adds an adjustable stop to any brake-ready bearing by securing it into a semi-permanent position. It also adds a grip to aid with adjustments and provides secure lockdown capability for safety.

[Add to Wish List](#)

Qty

Total Price.....\$13.62

[Add to Cart](#)

The moving part, specially designed as “Unibearing” and the braker

Sliding the separate parts onto the slot and then fasten them;

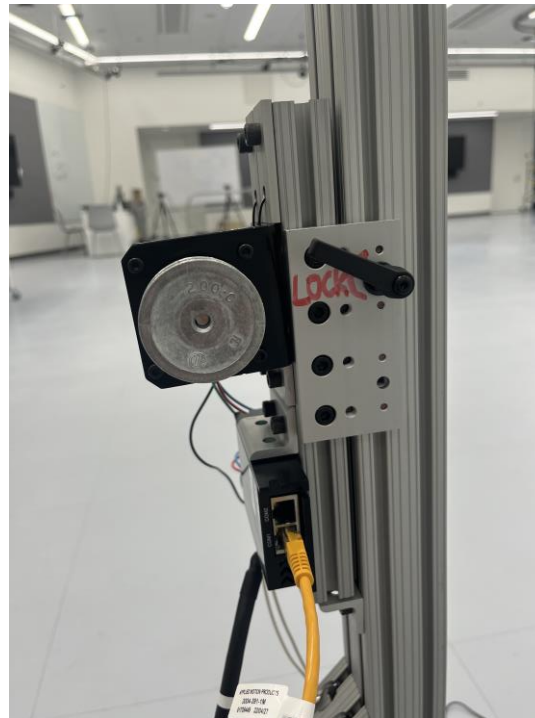
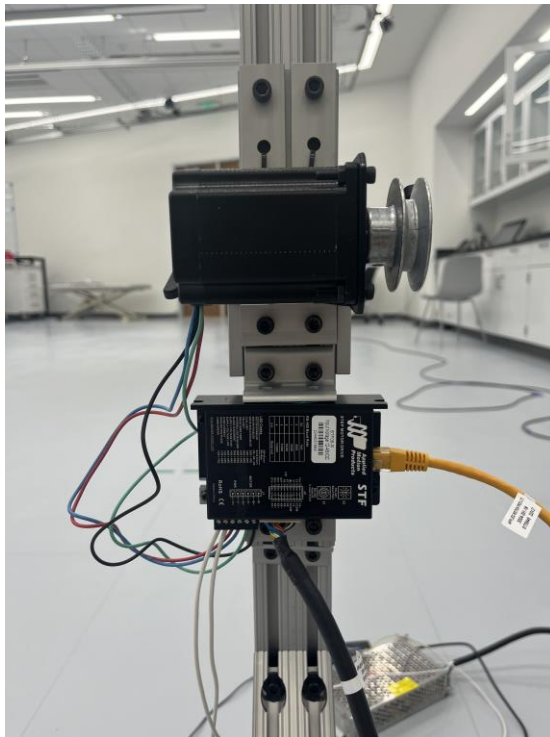
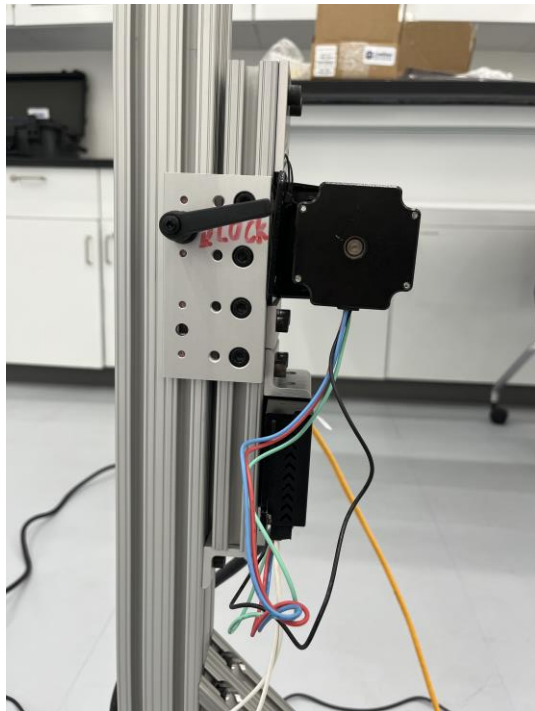
The stopper will be attached to the side holes.

The combination of them will be like the picture below:

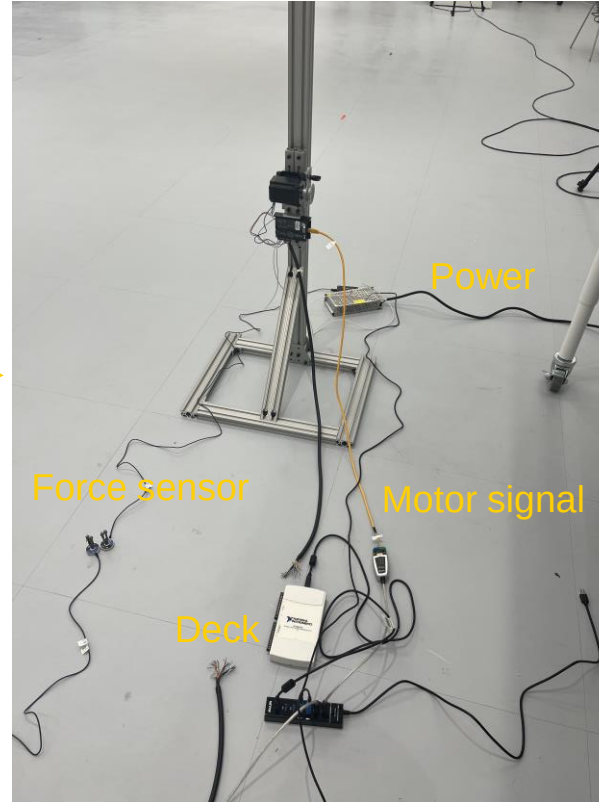


Recent Setup: Moveable motors & control box

The Recent Design



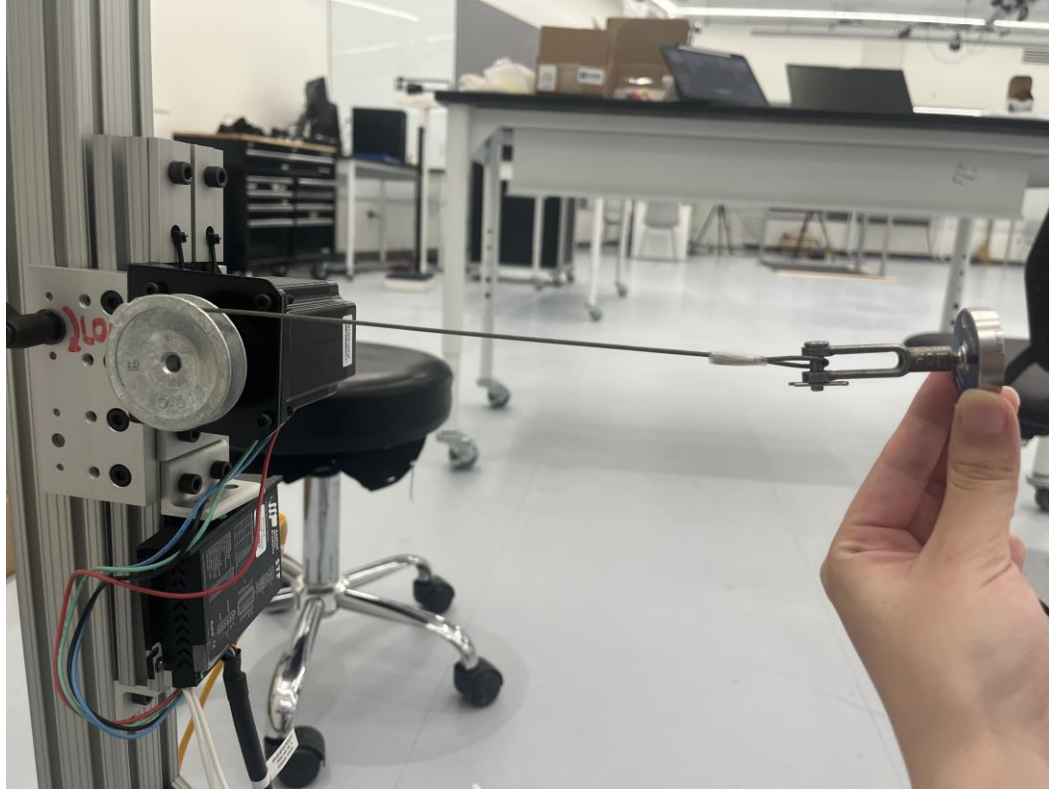
Recent Design: the Frame



Some small finds:
First attach the slide bracket to the slot, then slide them in;
After it reaches the position, fasten the screw.

This could be much easier to adjust the position in construction.

Recent Design: the connection between the force sensor & the motor



Problem 13: problems arising from actual construction

The screw and the bracket cannot work together!



As shown in the picture on the left, use two kinds of screw to work together; but one of them works really bad!

So, in this case, we may need to purchase another parts. (listed in the revised additional parts)

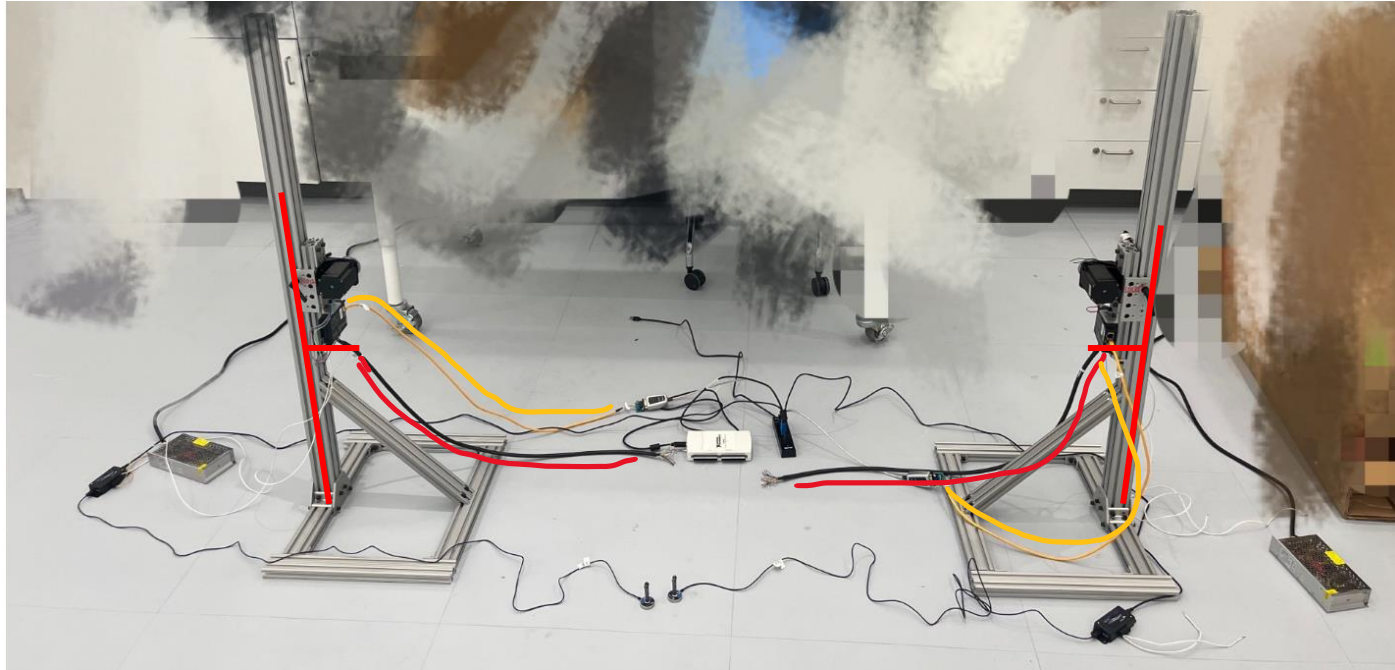
(later)

This problem leads to further and more serious problems! ! :(

Problem 14: problems arising from actual construction

The lines are not long enough! Especially for the RS-485 & I/O cable. The space people can stand is restricted.

We may need to purchase longer lines, or extend them.



Solution 14: problems arising from actual construction

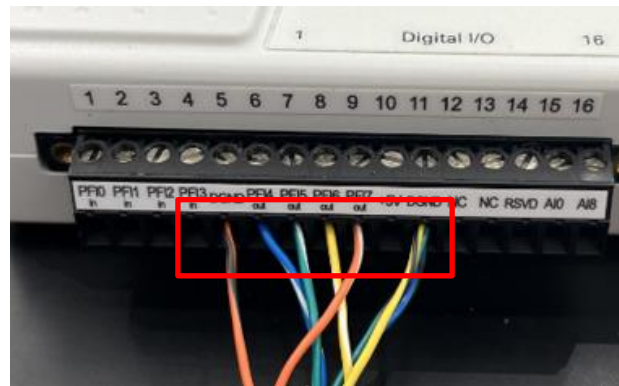
We may extend them in this way:

For the RS-485:



We use USB extension cable to extend it from the other end

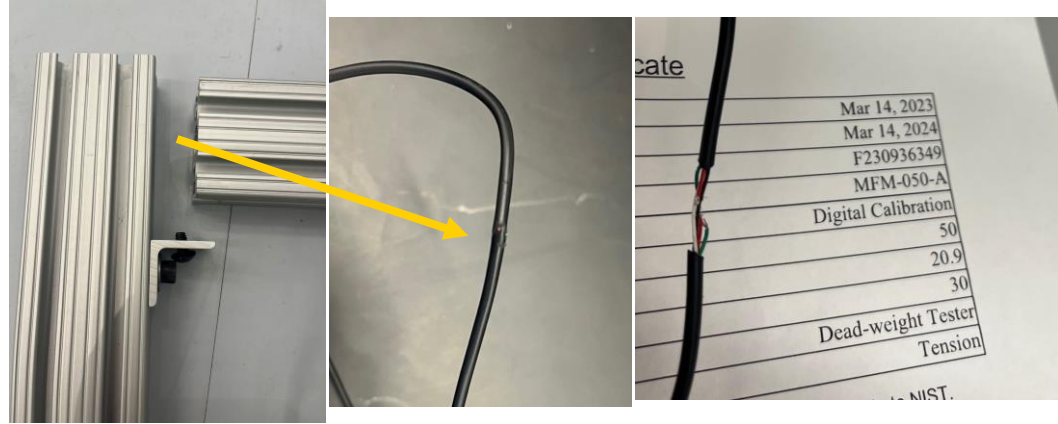
For the I/O cable:



Extend the lines from the connection linkage;
Need to soldering all of them! Not only the positive signal wires
but also the ones link to ground.
These lead to long wires around the participant. Ways to arrange
them better is under development.

Problem 15: Cutoff the line of the force sensor by accident!

This is an accident lead by the unfit screws!
The beams slid out can grab the lines of the
force sensor.
As a result, the green and red line inside is
totally cutoff!!



Solution 15:

I emailed the company to see whether I can replace them or repair it. However, they told me that it takes at least \$250 and two weeks to get it repaired by the company, and I can spend \$100 or \$200 to reduce the time needed. It's too expensive and time costing!! So that I decided to cut the line and solder them all by myself since the company said they could be connected by soldering.

And it works!!!



Design of the Waist Support



Waist support belt

The waist support may stretch while pull from the sides.

So, we decide to add another leather belt around, or to replace the stretch belt for the waist support to ensure a stable connection and an easier connection to the force sensor.

The support should work with safety harness designed for upper limb.

Fit waist up to 104cm/41"



Total Length:106cm/41.7"

Width:2.2cm/0.87"



Use screw and bearings to connect into the holes (the size are fit)

Leather belt



Design of the Waist Support



Design of the Waist Support

The Safety Harness we plan to use:



It should not impede the motion of the lower limb.



Design of the Waist Support: connection of the force sensor

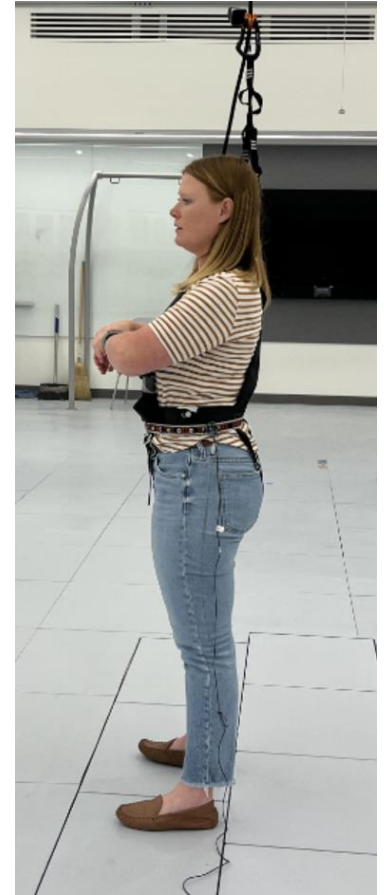


- Attached the force sensor to the belt; much more stable than I expected
- We can use the holes to connect them or using zip tape as shown in the picture.

Design of the Waist Support



Pull from the side from the leather belt



(Thank you so much!)

The Recent Setup



What we have reached –v4

- Overall, after solving all the problems listed above, we have finished the set up for the perturbation system.
 - Now the setup of the whole perturbation system is finished, and be able to test their ability.
 - When the LabVIEW program is finished, the system will go through the pilot testing.
- Now what left to do is finishing the pilot testing of the system.

Data Analysis Plan – based on our hypothesis

H1a:

People who use sockets with higher trim will have

- 1) lower **single step thresholds** following perturbations toward the prosthetic limb,
- 2) a greater percent of **unloaded side-step strategies** when pulled toward the intact side (i.e., stepping with prosthesis rather than loading it),
- 3) a higher **step count**.

H1b:

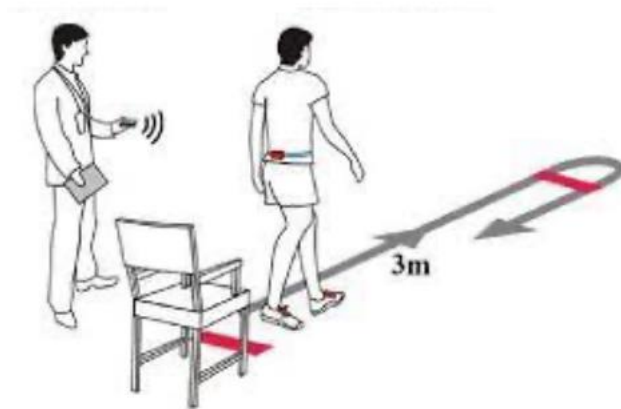
People who use sockets with higher trim will have

- 1) earlier **step onset**,
- 2) a more lateral **center of pressure** at step onset,S
- 3) longer total **recovery duration**

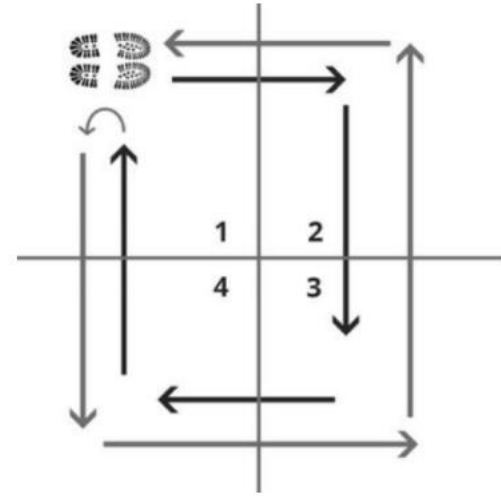
Beforehand Testing

1. Collect how many falls they have had in the last year, Residual limb length, cause of amputation, knee and foot type, waist height, age, sex, weight, prosthesis weight and veteran status, and finish the falls efficacy scale international (FES-I)

2. Timed Up and Go



3. Four Square Step Test



Beforehand Testing

- The beforehand testing is to test the reaction time needed for the participants.
- In another word, their risk factor for falls.
- The following thresholds were associated with future falls in unilateral transtibial amputees:
 - TUG greater than 19 seconds, FSST greater than 24 seconds;
- Some will use another test as weill, called “Turn 180 degree Test”:
 - turn time greater than 3.7 seconds, and more than 6 steps to complete the turn for the Turn 180° Test
- From “Risk Factors for Falls in People With a Lower Limb Amputation: A Systematic Review” & Dite W, Connor HJ, Curtis HC. Clinical identification of multiple fall risk early after unilateral transtibial amputation. Arch Phys Med Rehabil 2007;88:109-114.

Testing Experiment Design

The data we plan to gather especially for the testing:

- **Force created by the motor** (maximum force that could generate and its relationship with motor speed)
- Starting **MST & SST** (for later experiment)
- Will people step on the edges of the force plates very often?

Line	Label	Cmd	Param1	Param2	Comment
1		MT	1		enable multiple motion tasks
2		JA	10		set the acceleration speed
3		JL	300		set the deceleration speed
4		JS	1		set the initial speed
5		RX	1	1	set the initial jogging speed (very slow)
6		RX	2	3000	
7		RX	3	-3000	make the motor run inversely
8		RX	4	5000000	
9		RX	6	-5000000	make the motor run inversely (double check)
10		RX	7	10000	
11	Label4	WI	1R		when port 1 is executed, the motor will start to
12		RM	1	J	the initial rotating speed
13		RM	7	D	
14		CJ			start to jog slowly

Testing Experiment Design

The data we plan to gather the same as the experiment:

- The **number & types of steps** the participant takes
- Get the **MST & SST** for intact human body;
- Center of Mass
- **ground reaction force** data via force plates
- the **motion of markers on the ankles** using motion capture
- Test the **reaction time**

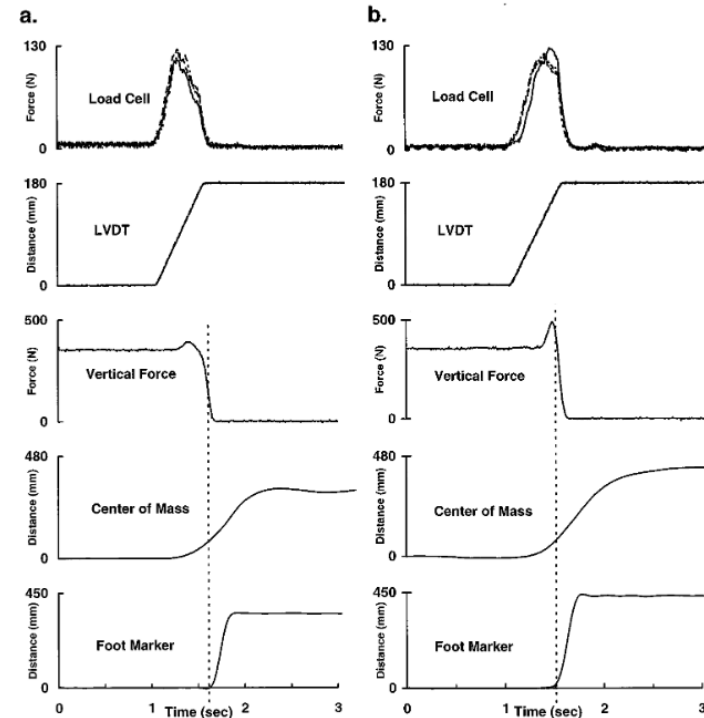


Fig. 3. Representative examples of stepping responses following a forward waist-pull in a young male (a), and an older female (b). The top two records respectively show the pulling force (load cell) and the pulling displacement (LVDT) for three repeated trials at the same perturbation levels. The vertical ground reaction force component beneath the initial stepping limb, the body center of mass displacement in the sagittal plane, and the displacement-time history of the foot (second toe) marker for the initial stepping leg are also shown. The vertical line is the onset of stepping as indicated by the foot marker.

A closed-loop stepper motor waist-pull system for inducing protective stepping in humans

Use of the Motion Capture & Force Plate in experiment

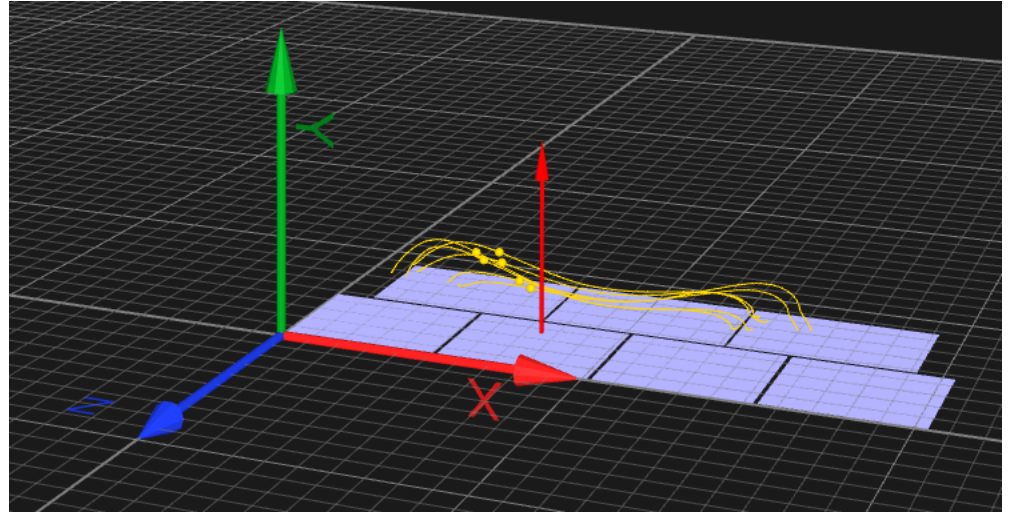
Using the **Qualisys Track Manager (QTM)**:

Information that we want to get using the force plate & motion capture system

1. Time (may considered as reaction time and time to regain balance).
2. Distance between the steps
3. Number of the steps to take

Using the **video recording**:

Record the number and types of the steps take



Data Analysis Plan

- Use their body weight (BW) and Bass of support (BoS)
- Normalize the force data and the distance they take to regain balan
- Use color to indicate different numbers of steps taken

		Force																	BW % SE %
		2.8 0.2	3.4 0.2	4.0 0.1	4.5 0.1	5.1 0.1	5.6 0.1	6.2 0.1	6.8 0.0	7.3 0.0	7.9 0.0	8.4 0.1	9.0 0.1	9.6 0.1	10.1 0.1	10.7 0.1	11.2 0.1		
Displacement	50.3 0.7	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.5	0.5	0.5	0.8	0.8	0.9	0.9	0.9		
	58.3 0.6	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.3	0.5	0.6	0.5	0.7	0.9	0.9	0.9	0.9		
	66.3 0.6	0.1	0.0	0.0	0.1	0.2	0.1	0.2	0.4	0.4	0.6	0.7	0.7	0.9	1	1	1		
	74.2 0.6	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.5	0.6	0.7	0.8	0.8	0.9	1	1	1		
	82.2 0.6	0.0	0.0	0.0	0.2	0.1	0.1	0.2	0.3	0.6	0.7	0.8	0.8	1	1	1	1		
	90.2 0.6	0.0	0.0	0.1	0.0	0.2	0.1	0.3	0.3	0.7	0.8	0.8	1	1	1	1	1		
	98.2 0.6	0.0	0.0	0.0	0.2	0.2	0.1	0.4	0.6	0.8	0.8	0.8	1	1	1	1	1		
	106.2 0.7	0.0	0.0	0.0	0.2	0.2	0.1	0.5	0.5	0.8	0.9	0.9	1	1	1	1	1		
	114.2 0.7	0.0	0.0	0.0	0.2	0.2	0.1	0.5	0.7	0.8	1	1	1	1	1	1	1		
	122.2 0.7	0.0	0.0	0.0	0.2	0.2	0.1	0.6	0.7	0.8	1	1	1	1	1	1	1		
	130.2 0.8	0.0	0.0	0.2	0.2	0.2	0.1	0.5	0.7	0.9	1	1	1	1	1	1	1		
	138.1 0.8	0.0	0.0	0.1	0.2	0.2	0.2	0.6	0.7	1	1	1	1	1	1	1	1		
	146.1 0.9	0.0	0.0	0.1	0.2	0.1	0.3	0.7	0.7	1	1	1	1	1	1	1	1		
	154.1 1.0	0.0	0.1	0.1	0.2	0.3	0.2	0.7	0.8	1	1	1	1	1	1	1	1		
BOS SE % %																			

Use of the Motion Capture: Data to Analysis

Questions left:

1. How to get the data/ which kind of Data we can get?
2. The shared force between separate force plate
3. How to get the center of mass/ exact position of the force?
4. Reflection of our setup (the belt, the beams, any metal parts, the shoes/cloths the participant may wear) – if we use markers
5. Can the force be generated correctly?

Motor ability test

- First test the equilibrium force.
- Then speed up the motor; get the slope of their change on force (using LV-1000)
- Change the speed settings in the STF configurator and get different slope.
- Pay attention to stop the motor at any time!
- Also measure its reaction time!

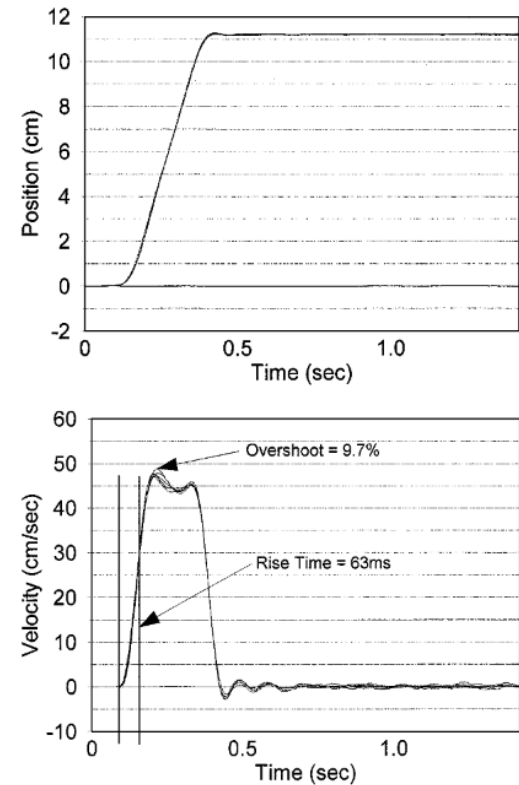


Fig. 2. Representative results of bench testing experiments showing position (top) and velocity (bottom) profiles for six loads ranging between 22 and 222 N. The loads were pulled 11.3 cm at a velocity of 45 cm s^{-1} and acceleration of 900 cm s^{-2} . The maximum overshoot and average rise time are indicated.

Next to do

- First test whether it's easy to reach equilibrium and the amount of force it is.
- Then speed up the motor; get the slope of their change on force (using LV-1000) ; get the time needed to reach that amount of force (also could be calculated using acceleration)
- Change the speed settings in the STF configurator and get different slope.
- Evaluate the ability of the motor to reach the amount of force we need.
- Also measure its reaction time!

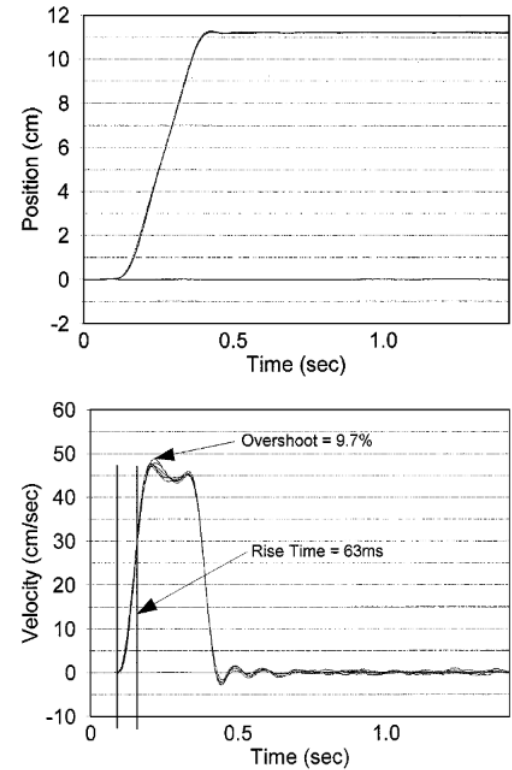


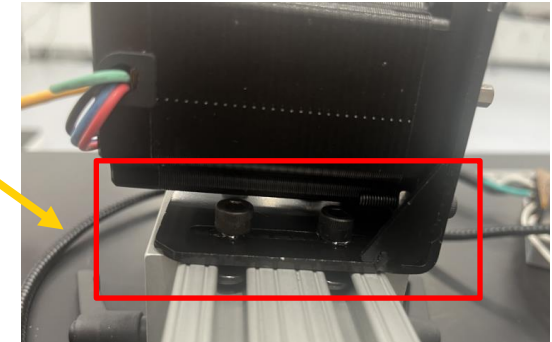
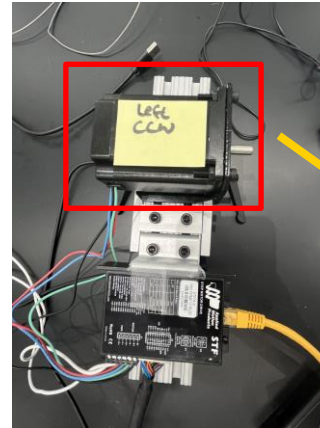
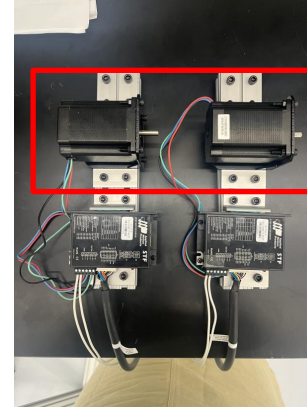
Fig. 2. Representative results of bench testing experiments showing position (top) and velocity (bottom) profiles for six loads ranging between 22 and 222 N. The loads were pulled 11.3 cm at a velocity of 45 cm s^{-1} and acceleration of 900 cm s^{-2} . The maximum overshoot and average rise time are indicated.

Problem 16: Stable connection between the motors and the beam

The zip tape is not stable!

When we are trying to run the motor and to reach equilibrium, the motor providing larger force to change the position of the bracket.

In this way, we need to figure out a new way to ensure a stable fix for it.



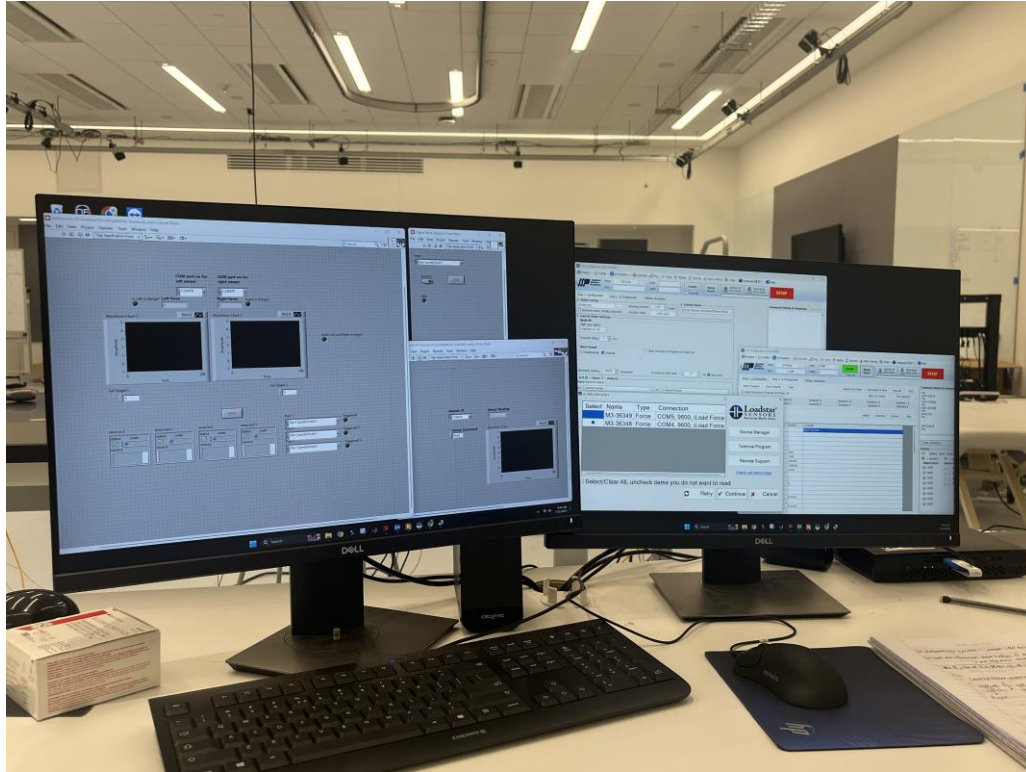
Solution 16:

We drill holes on the bracket, connect them directly to the beam using screws.

Motor ability test: the equilibrium state

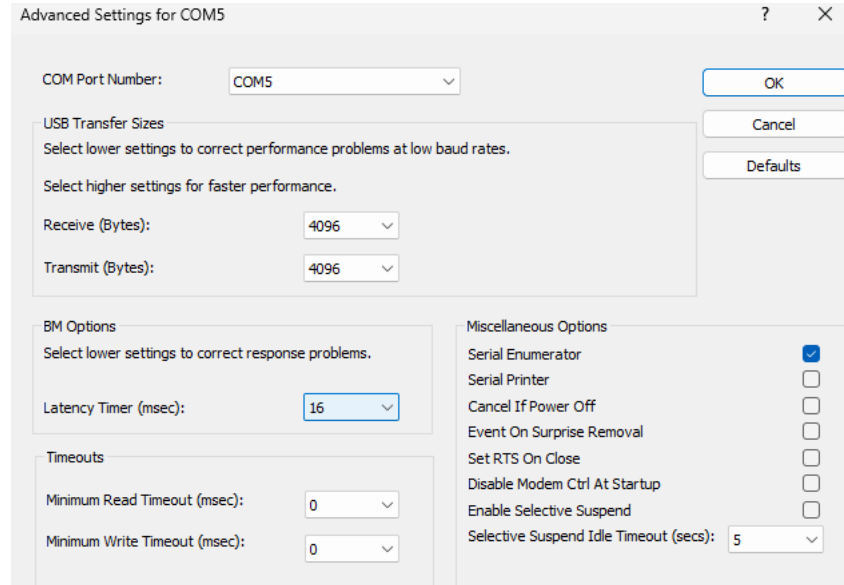
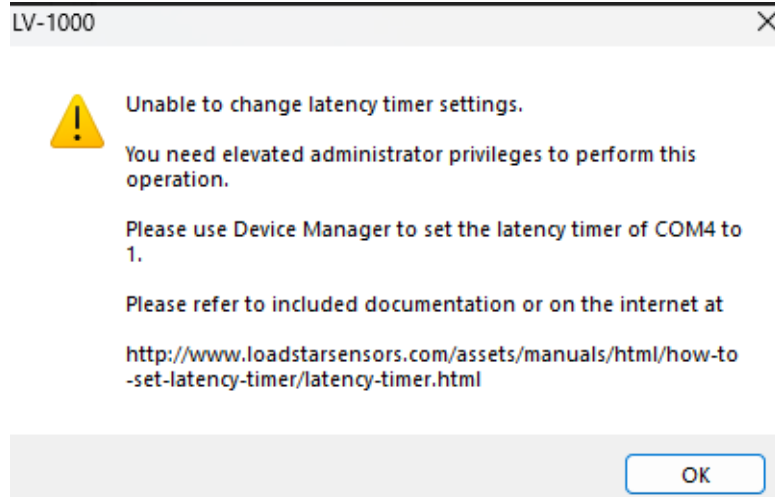
- First test the equilibrium force.
 - Then speed up the motor; get the slope of their change on force (using LV-1000)
 - Change the speed settings in the STF configurator and get different slope.
 - Pay attention to stop the motor at any time!
 - Also measure its reaction time!
-
- After testing, we could reach the equilibrium!

Problem arises too many windows to open



- Time sync; time lag;
- For the force sensor reader (only for test experiment)

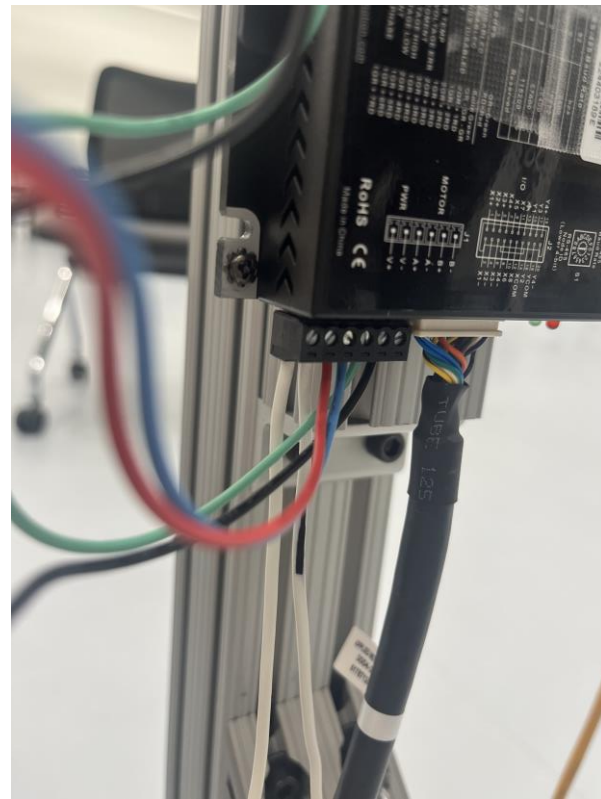
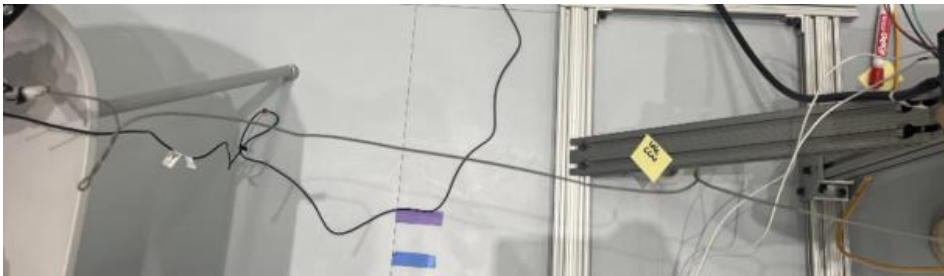
Set up requirement: latency timer reset



- We need to change the latency timer (msec) for the two force sensors to 1

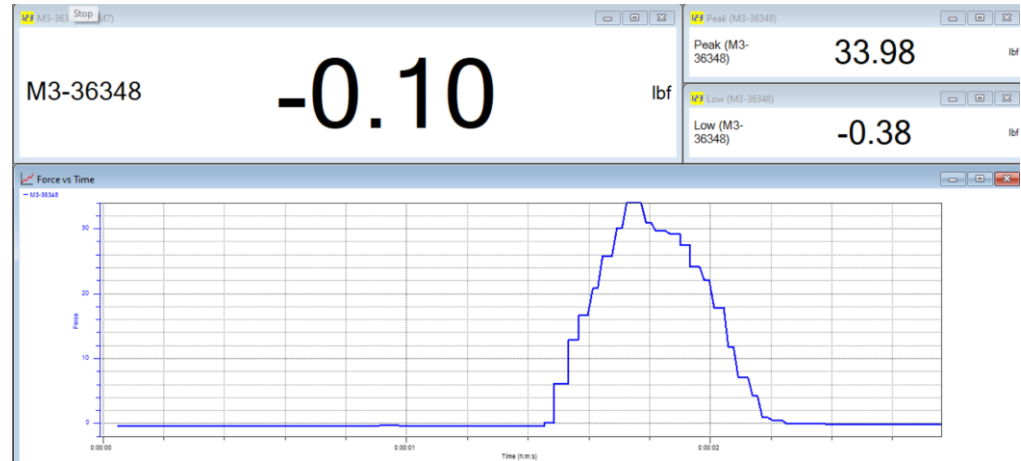
Problem: easy to lose connections

- Problems take place everyone!
- Conflicts of the port read;
- Lose force sensor signals;
- The wires are bad! – we replaced them with electrical wires
- The wires are easy to move to wrong position
- Lose control signal from the control box (the wires is short circuit)



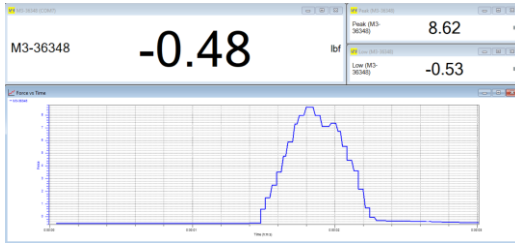
Motor ability test – First Stage – pull by hand

- We did the tests by pulling the participant to the side, testing by.
- We found that the threshold may not be able to show very clearly as a thin line. It could be a range.
- SST: about 8-13 lbf
- MST: about 30 – 33 lbf; but sometimes 24 lbf also drives the movement

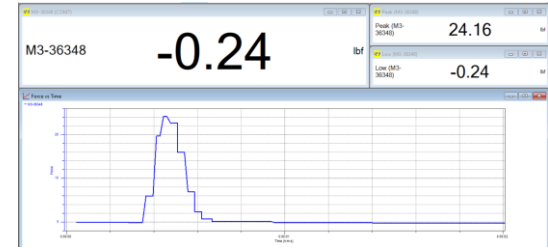
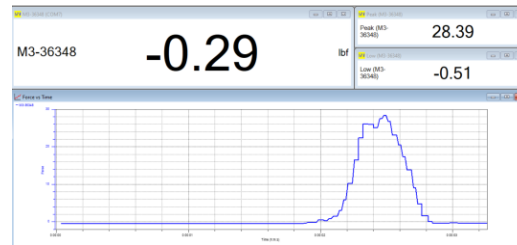


Motor ability test – First Stage – pull by hand

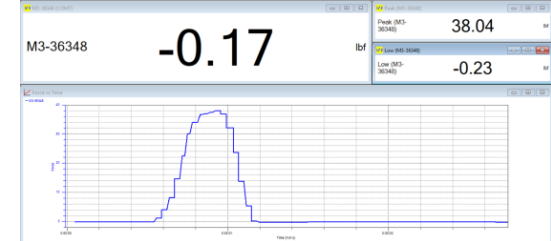
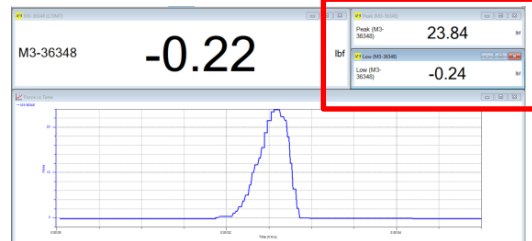
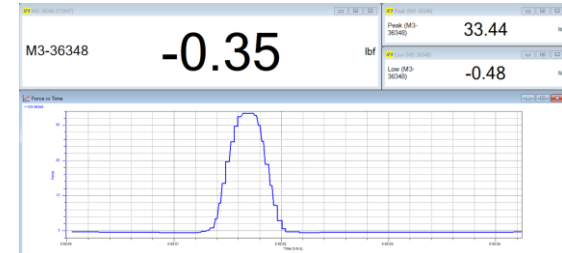
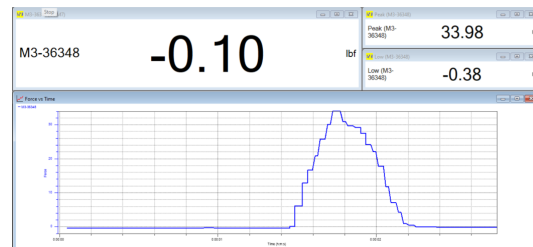
- One Step



- Larger Steps



- Two Steps

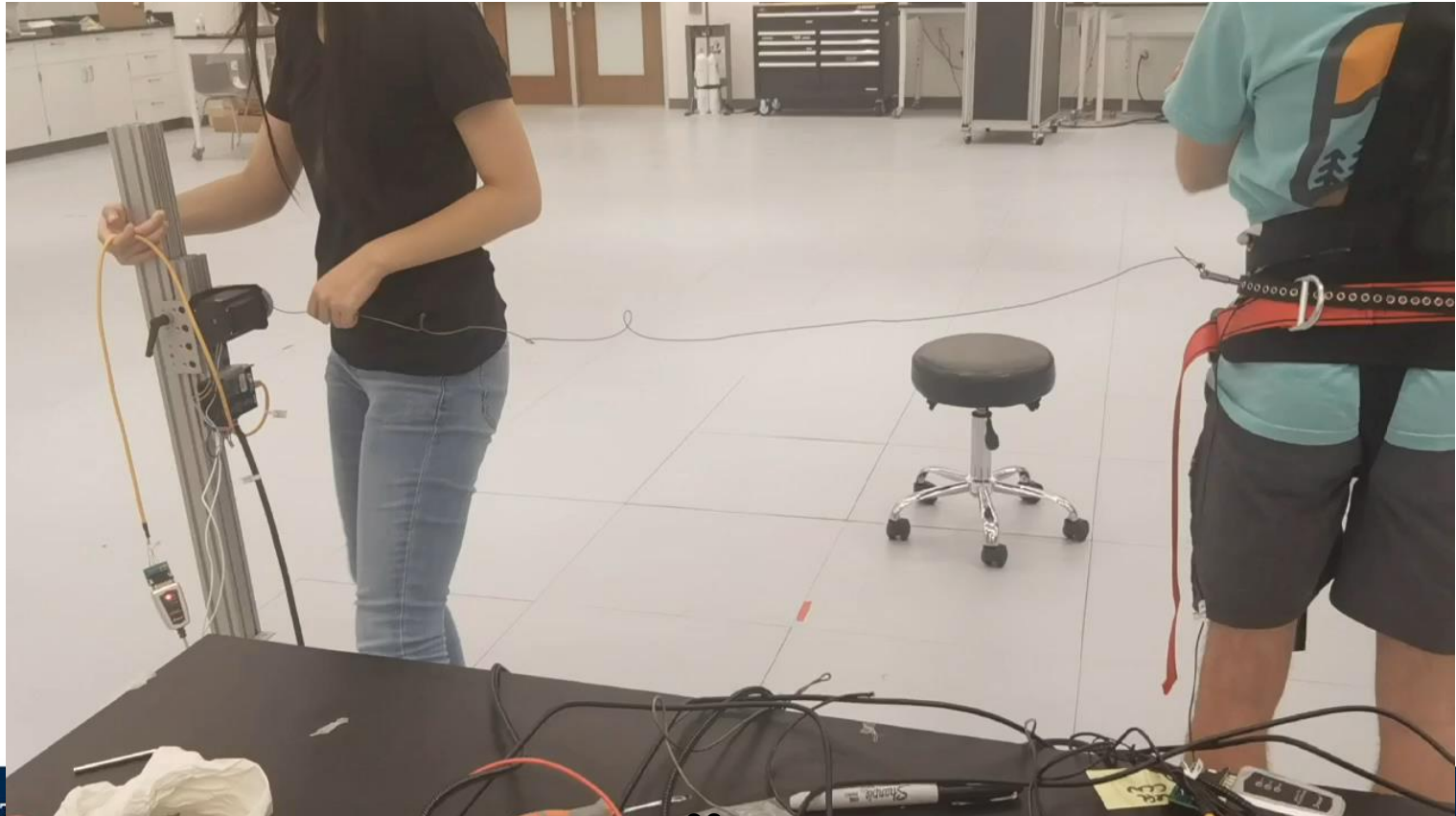


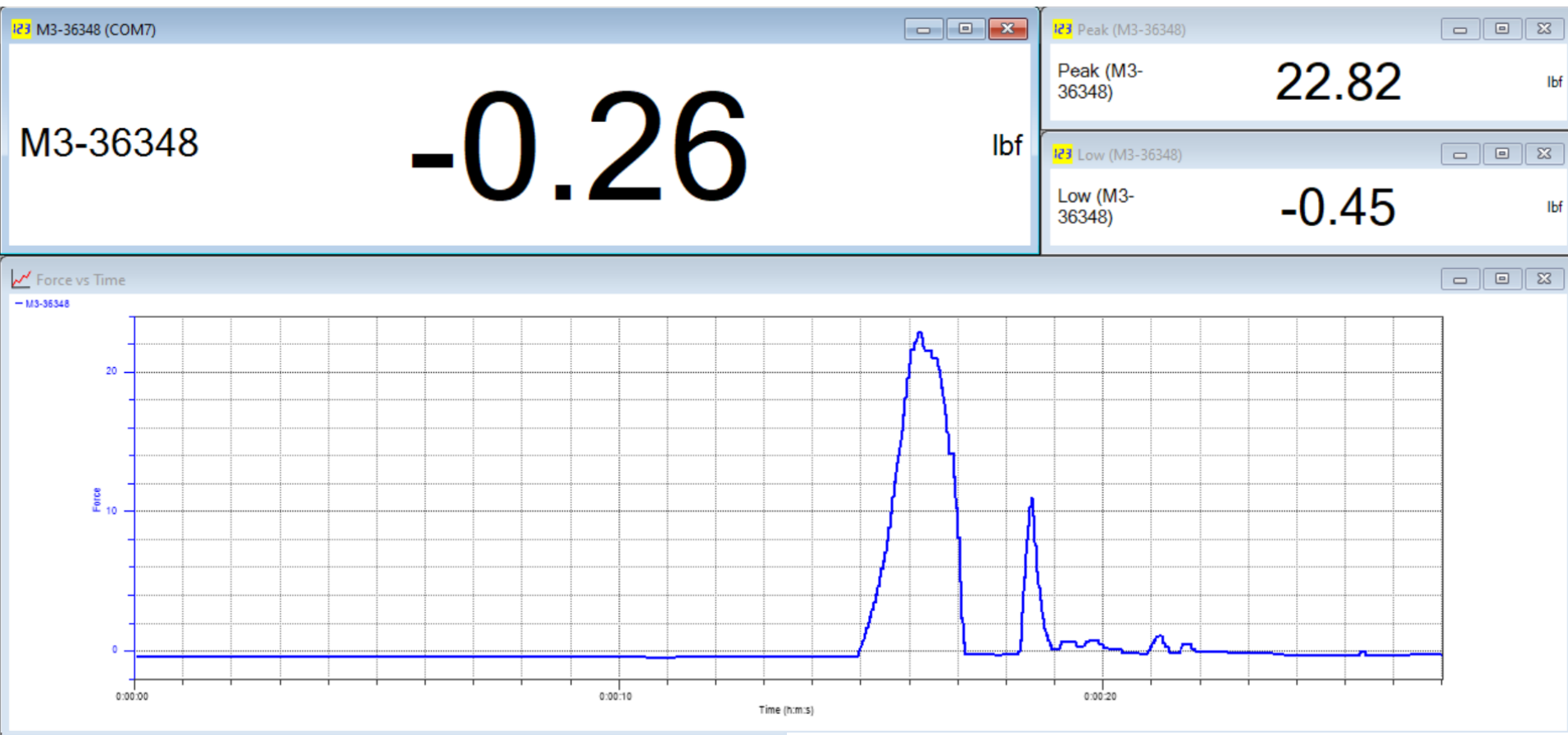
Motor ability test – Second Stage

- The setup: We only pull from one side for safety consideration.
- The electrical wires fail after several trails.

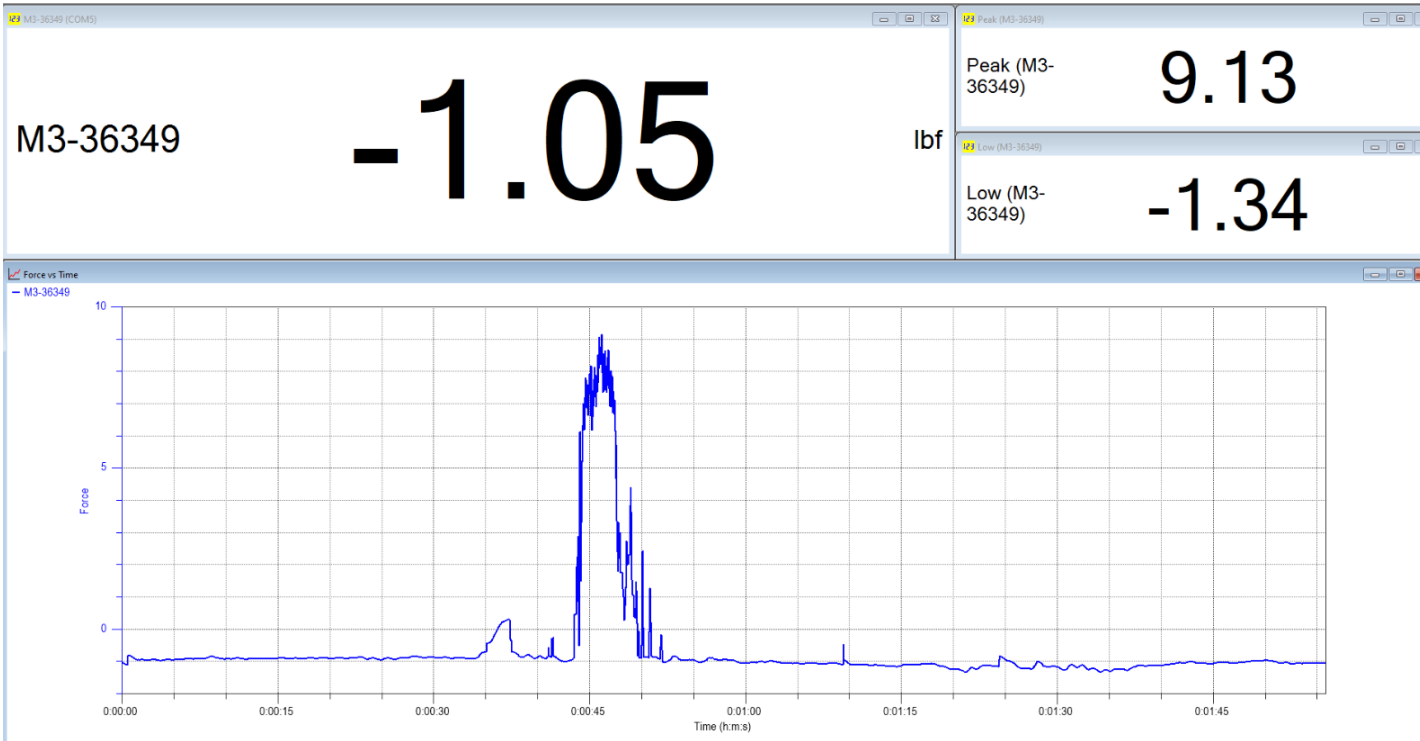


Motor ability test: max force producing



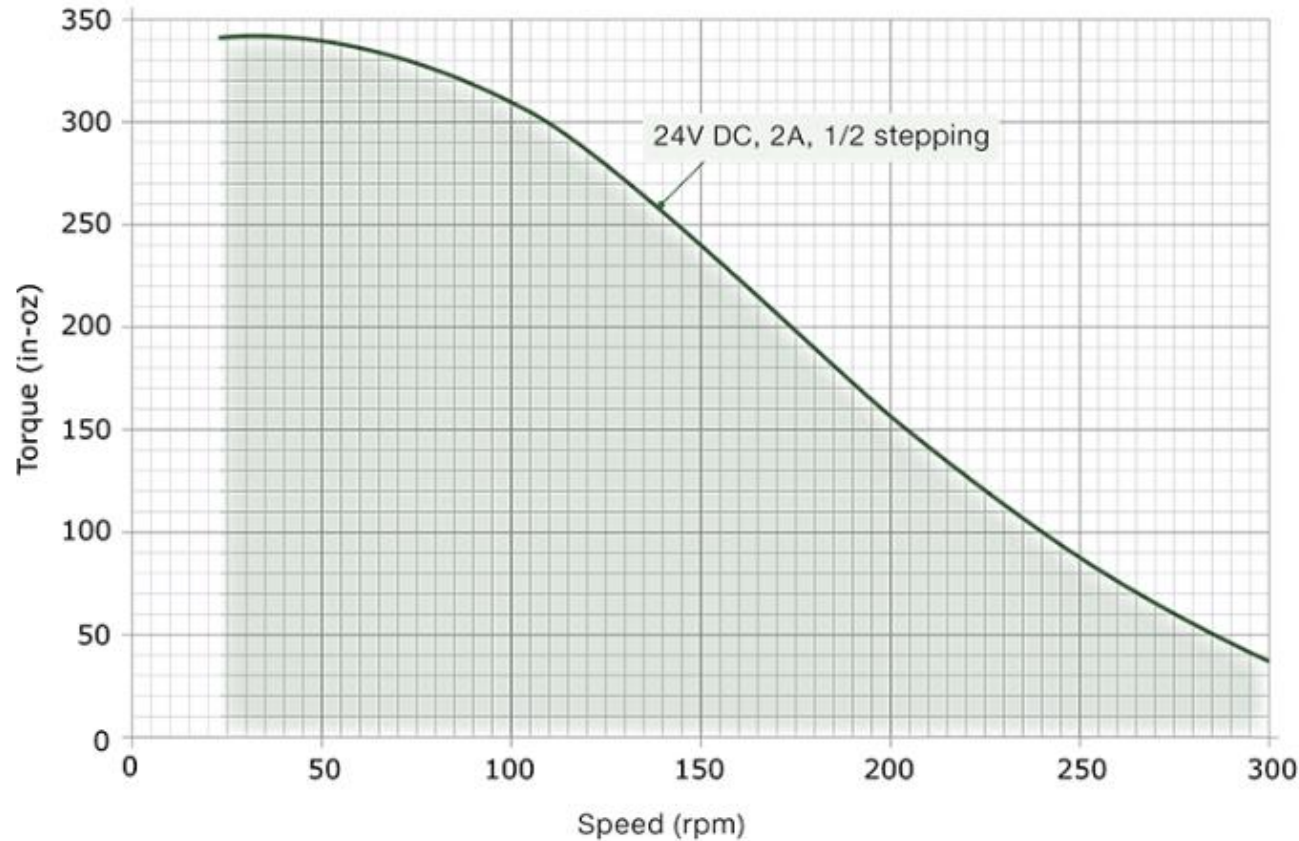


Motor ability test: max force producing



- Max force can reach:
- 9.13 lbf = 40.61 Newton

Torque-Speed Chart
for Stepper Motor (6627T923)



Maximum speed the motor can reach:

300 rpm = 5 rps

Motor ability test:

- The force could be provided, but it's ability to speed up is limited.
- The motor could speed up; but not quick enough. Hard to change the values; the unit is very confusing in the setting.
- Sometimes the motor fail. The logic behind it should be figured out.

	MT	1	
	JA	50	
	JL	30	
	JS	1	
	RX	1	500000
	RX	2	300000
	RX	3	-300000
	RX	4	50000000
	RX	6	-5000000
	RX	7	10000
Label4	WI	1R	
	RM	1	J
	RM	7	D
	CJ		

Motor ability test: Find the most proper value for the acceleration and speed for jogging!

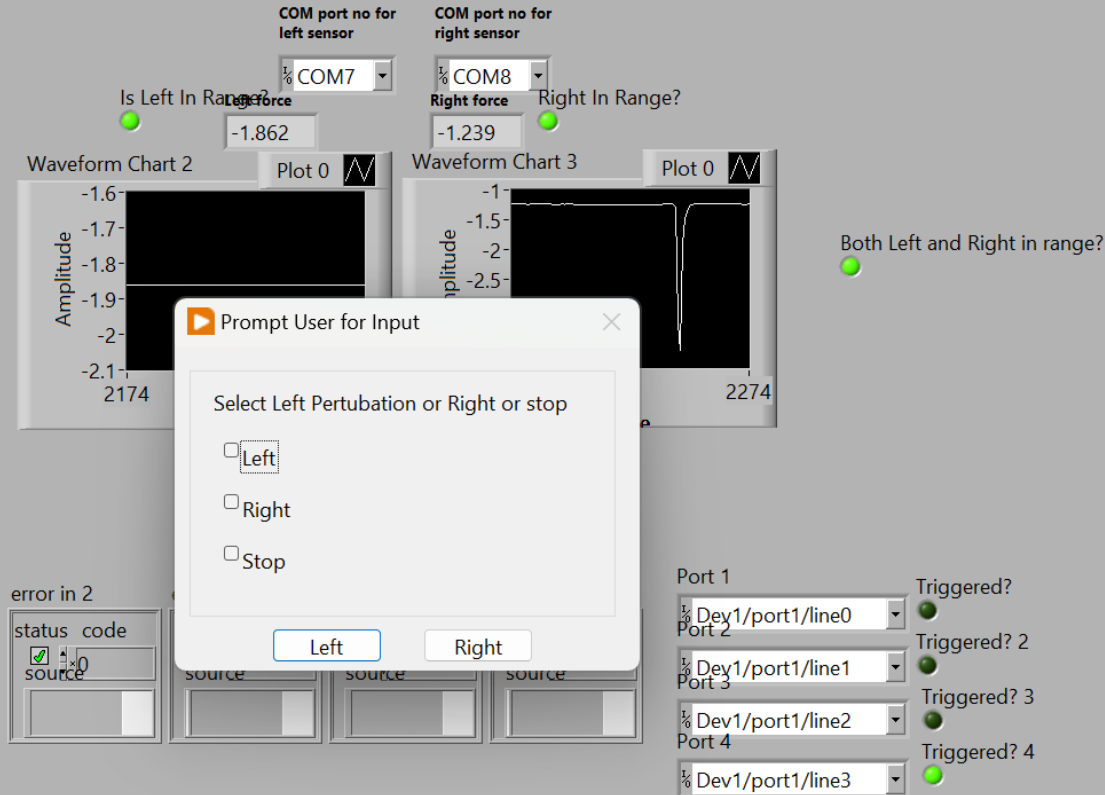
- The force could be provided, but it's ability to speed up is limited.
- The motor could speed up; but not quick enough. Hard to change the values; the unit is very confusing in the setting.
- Sometimes the motor fail. The logic behind it should be figured out.

	MT	1	
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	RX	2	300000
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	RX	4	50000000
	RX	6	-5000000
	RX	7	10000
Label4	WI	1R	
	RM	1	J
	RM	7	D
	CJ		

Motor ability test – Problems left

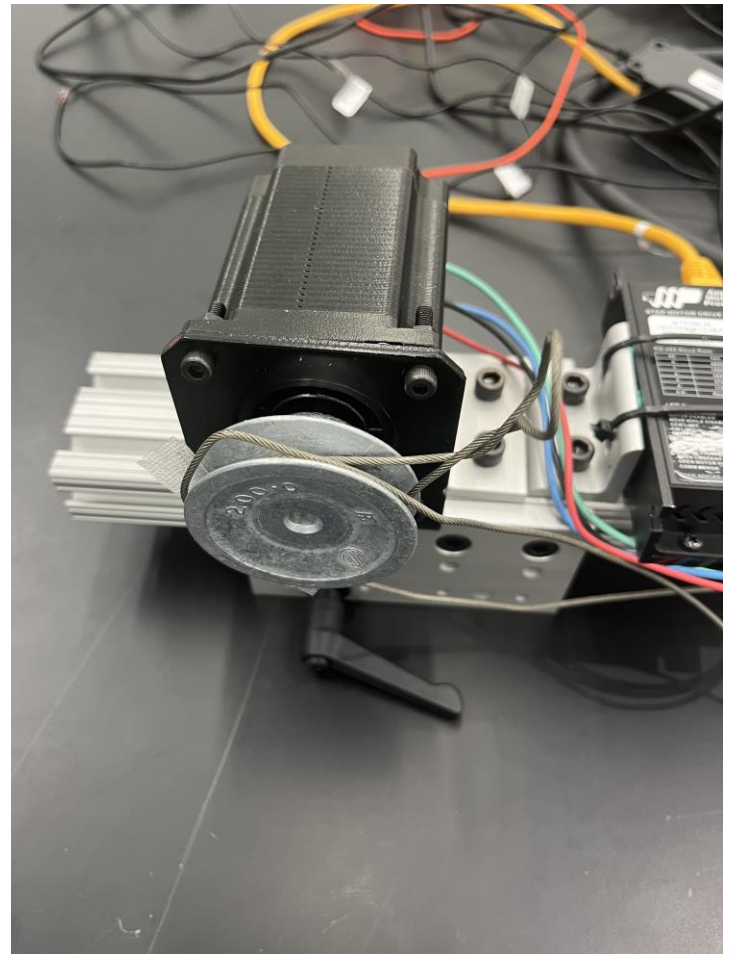
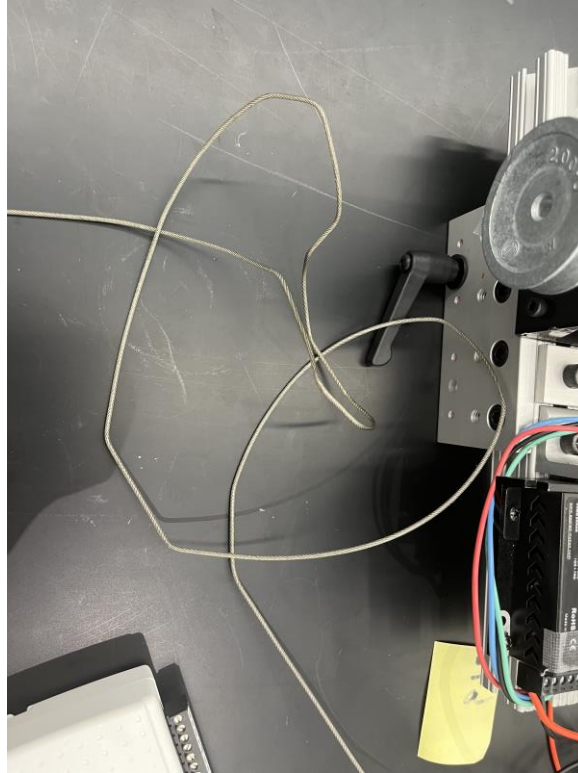
- The string always goes to the back of the roller; try to widen the edge of the roller.
- Sandbags are needed!
- The string could work. But still annoying.

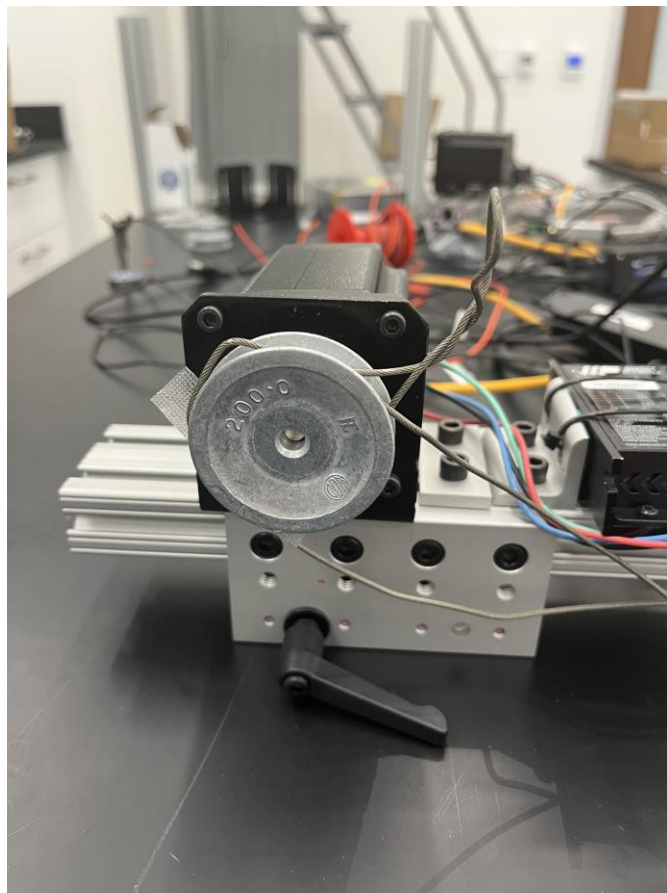
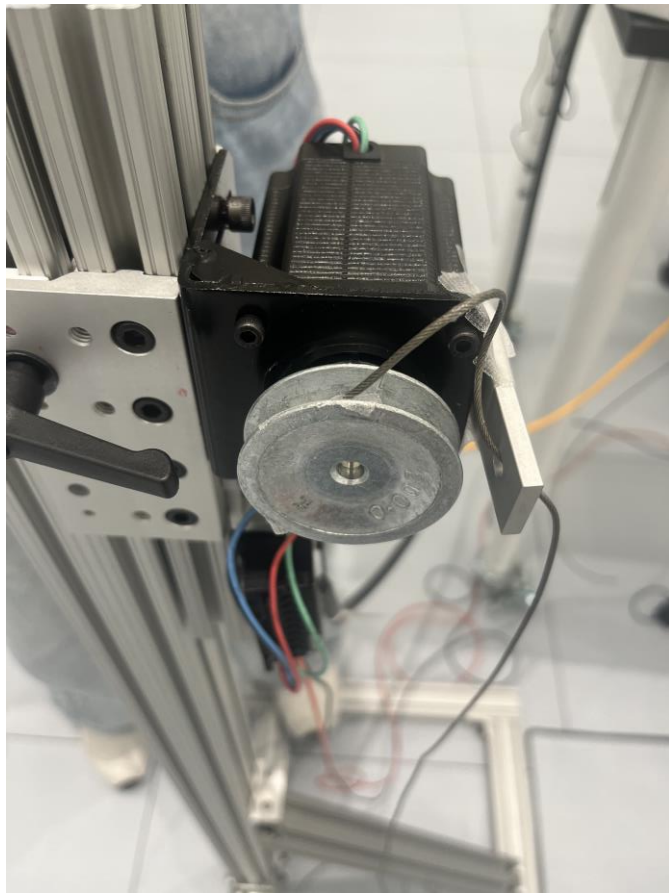




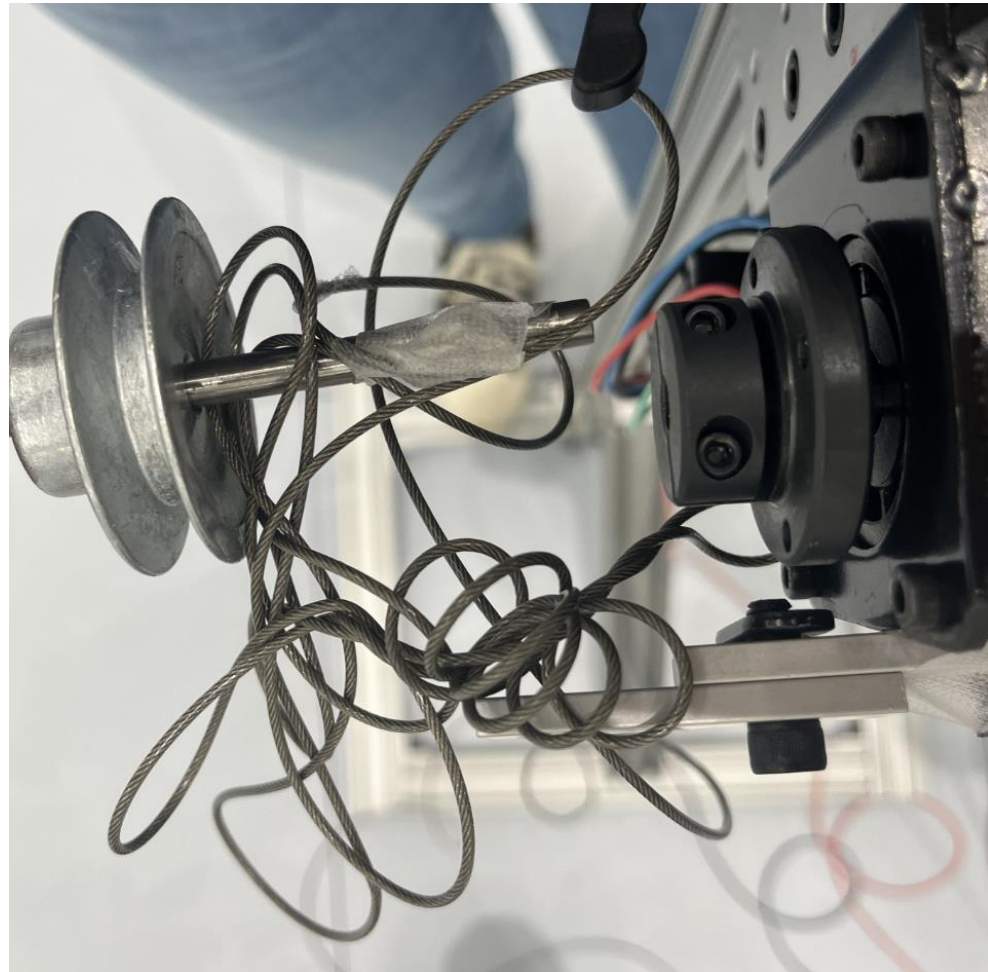
The wires not work well

- Replace them with new wires / ropes;
- Come up a design for the pulley, then build it through 3D printing.





If we use the rod:
It comes off easily, and the
wires get a mess



Why the problems of the settings take place:

The way to modify it's speed related to change the working current received by the motor & control box. However, the control box could only be modified trough STF configurator, which we could considered as a “closed” program.

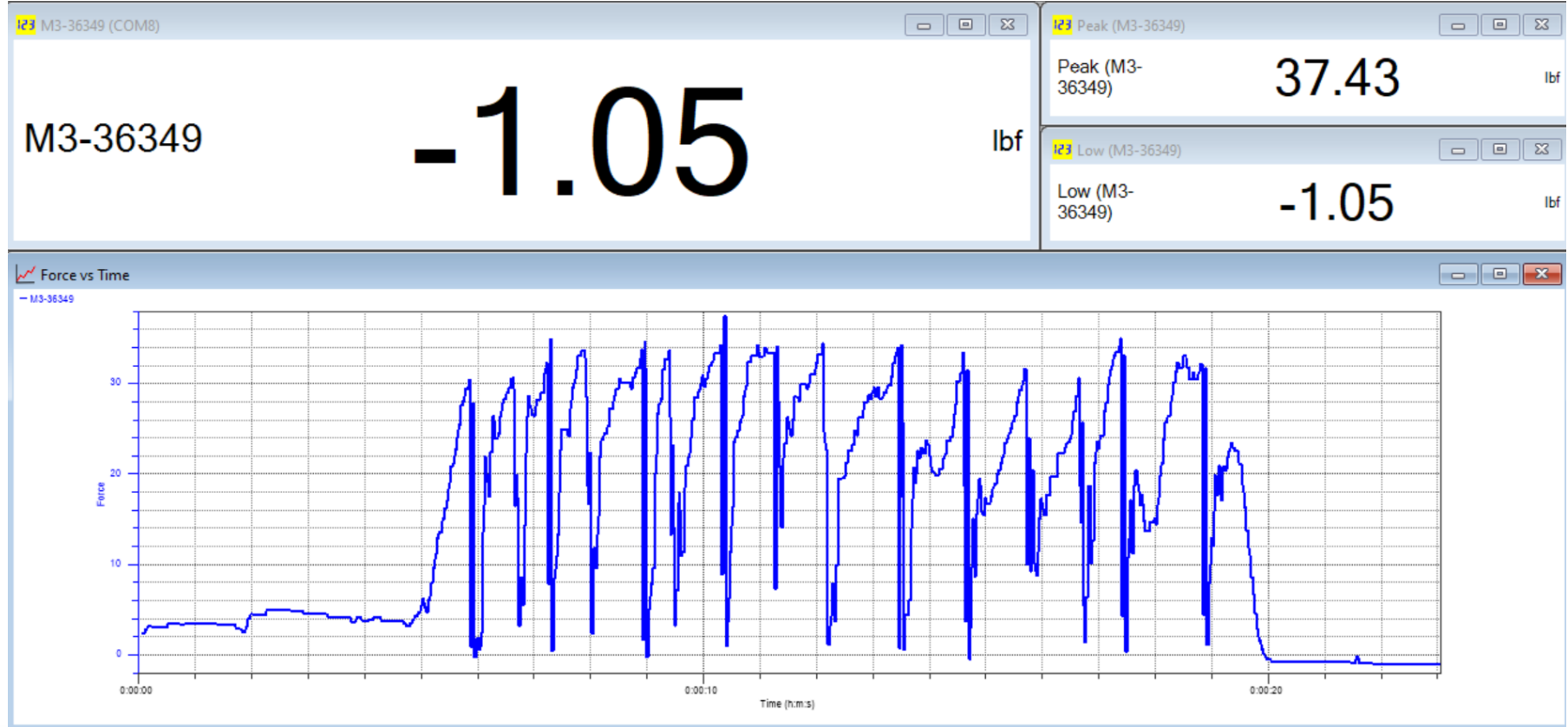
In this case, we cannot get the relationship easier but need to transfer to velocity and it's ability to create force, and cannot make it to run as a motor following an equation of the settings (relationship between the speed and force created).

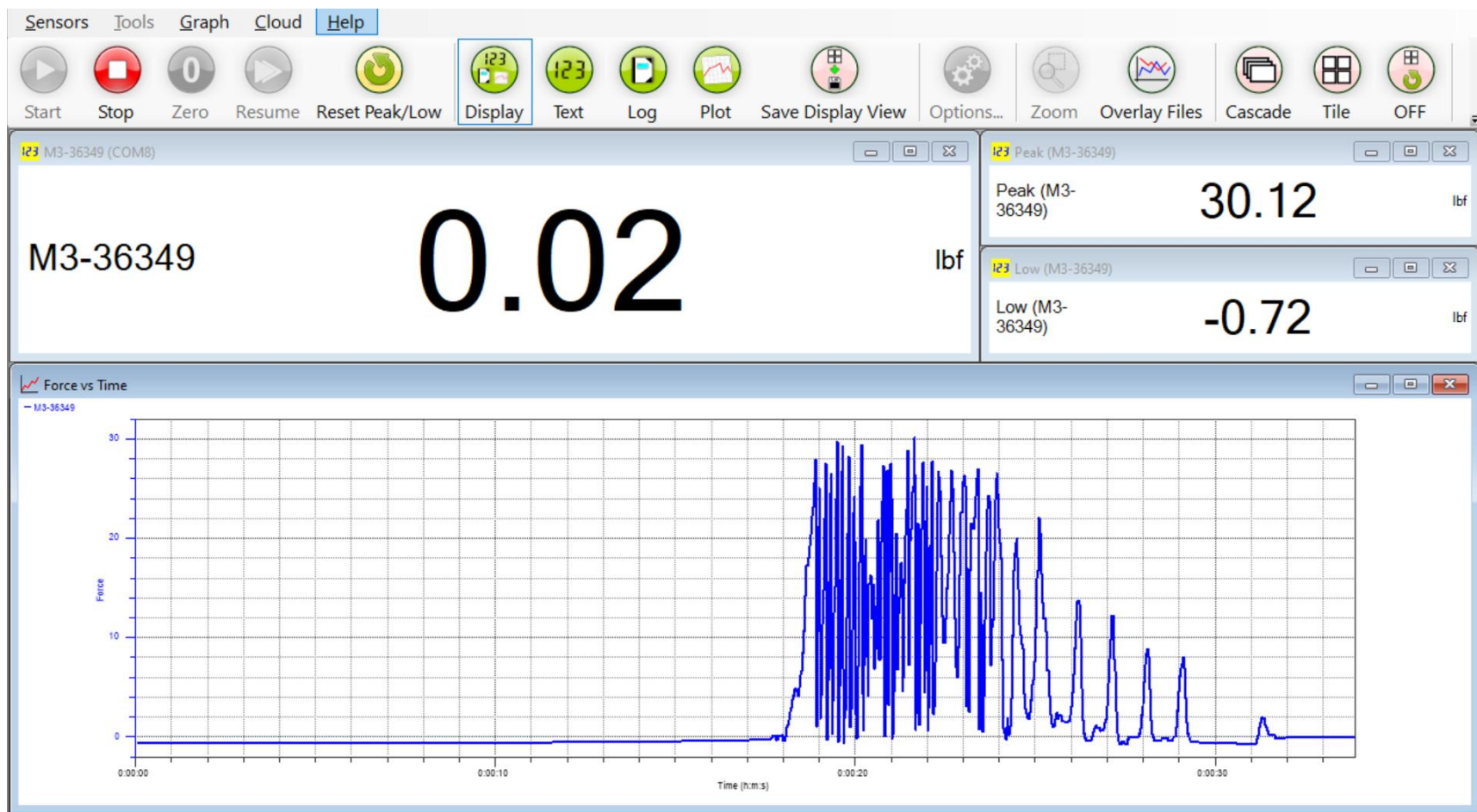
We tried to reach the equilibrium using the motor:

- The problem arises:
- The string could not be hold still, especially for larger force

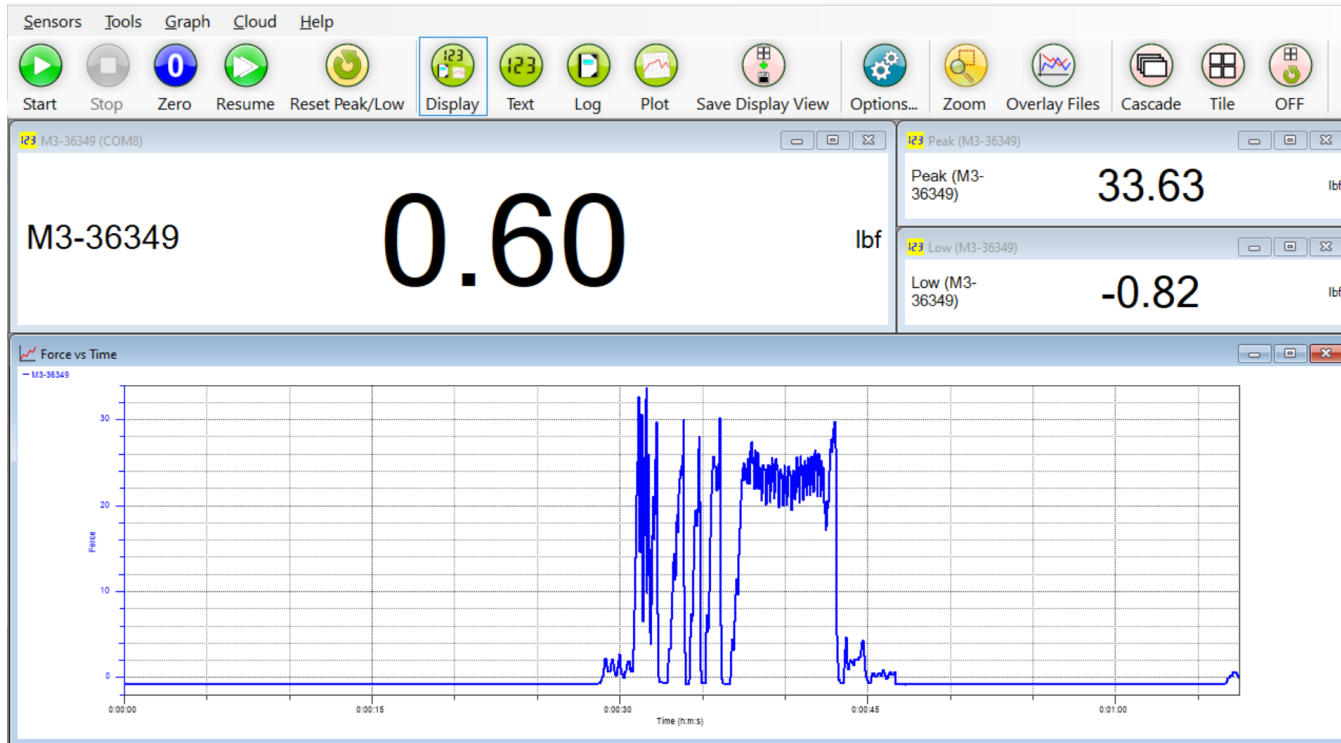


We changed the limit current for the motor settings

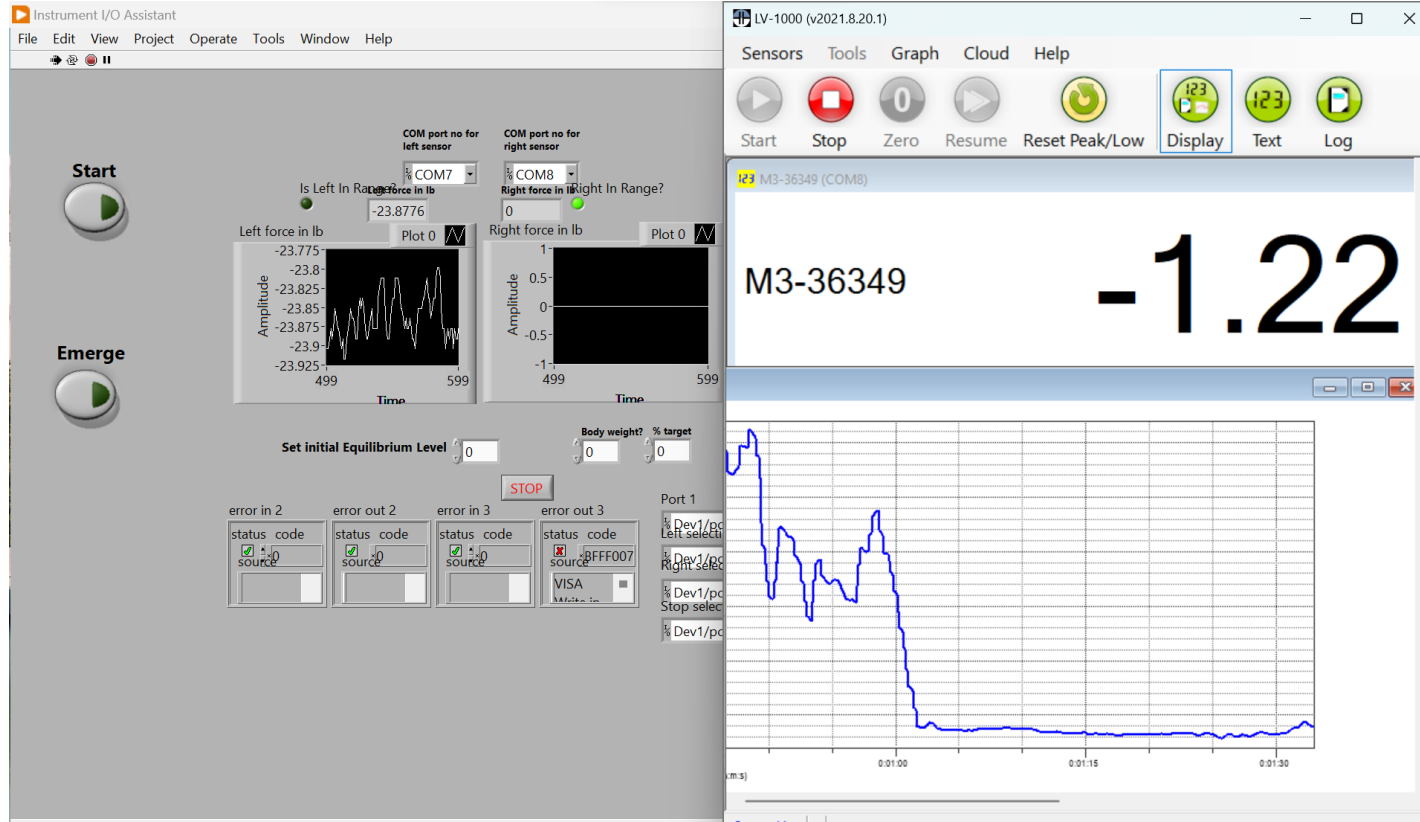




Stop at 30 (by my eye)



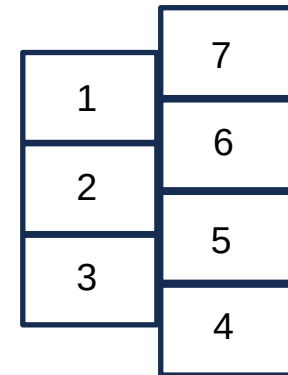
Channels could not be reread at the same time



The way to use LabVIEW to read from the force plate

	1	2	3	4	5	6	7
Fx	0	6					
Fy	1	7					
Fz	2	8	14	20	26	32	38
Mx	3						
My	4						
Mz	5						

The number from the port deck and the LabVIEW is different.
The deck numbered from 1 and LabVIEW numbered from 0.



Rewrite Q program

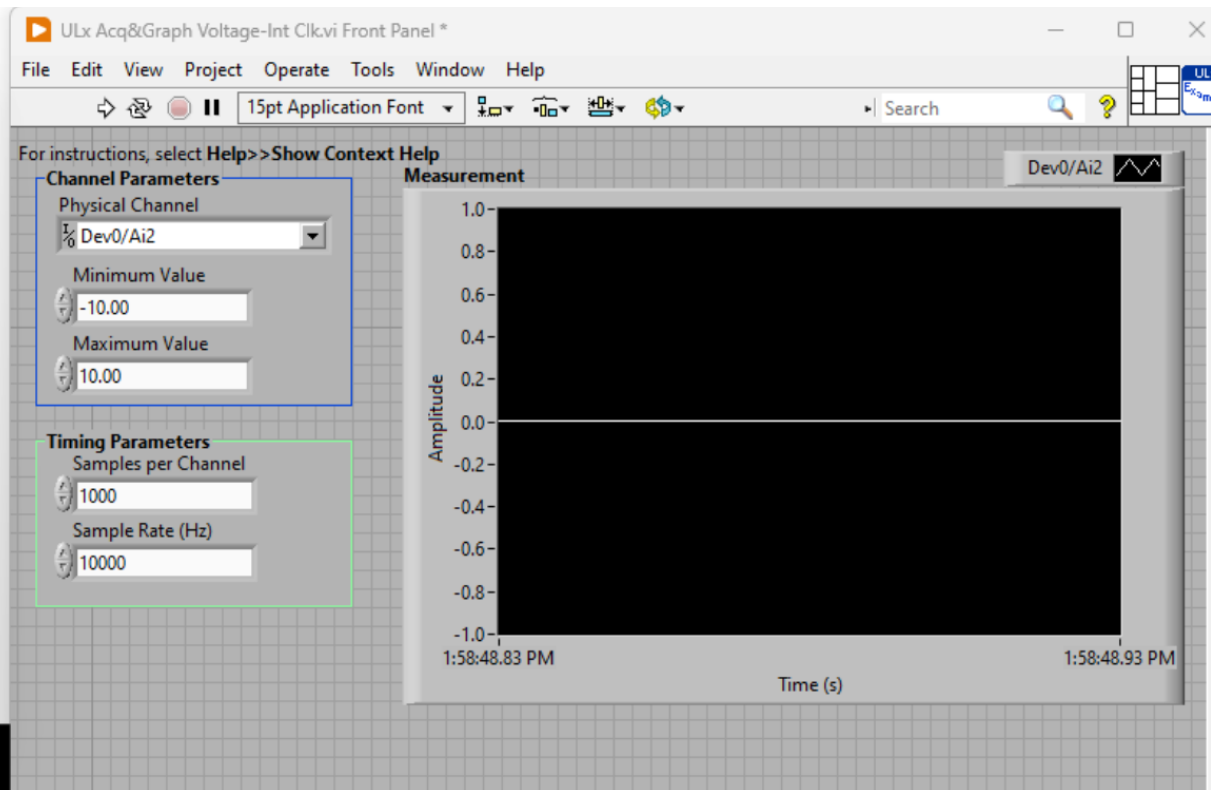
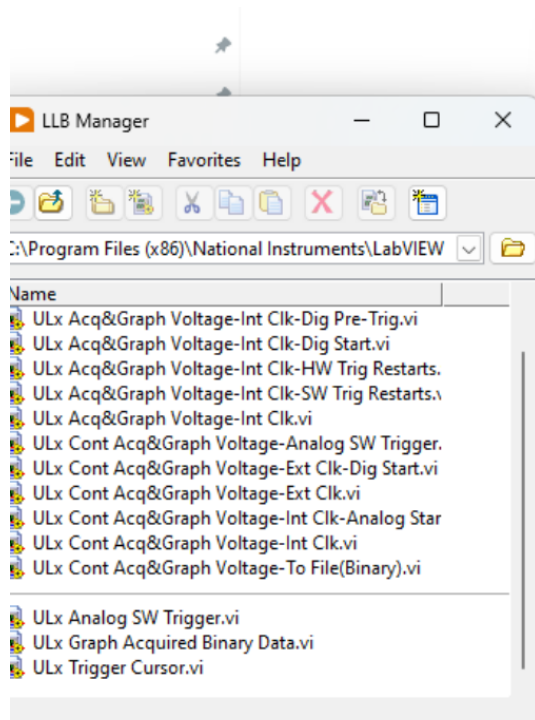
I separated the file into different segments.

Using QX to change into different segments.

17	Label4	TI	2R		
18		QJ	T	#Label1	
19		TI	3R		
20		QJ	T	#Label2	
21		TI	4R		
22		QJ	T	#Label3	
23		QG	#Label4		
24	Label1	QX	3		
25	Label2	QX	2		
26	Label3	QX	4		

Channels Table

	LEFT	RIGHT
LAB COMPUTER : Force sensor	COM 4	COM 5
LAB COMPUTER : motor	COM 6	COM 3
MY COMPUTER : Force sensor	COM 7	COM 8
my COMPUTER : motor	COM 6	COM 5



Start

Emergency
StopCOM port no for
left sensor

% COM4

Is Left In Range?



Left force in lb

2.627

COM port no for
right sensor

% COM5

Right force in lb

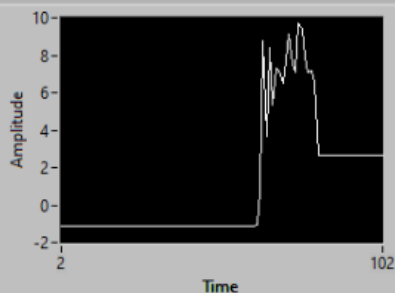
1.311

Is Right In Range?



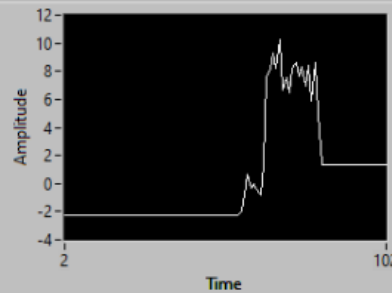
Left force in lb

Plot 0



Right force in lb

Plot 0



Both Left and Right in range?



Set initial Equilibrium Level

5

% target

0

STOP

error in 2

status	code
	x0
source	

error out 2

status	code
	x0
source	

error in 3

status	code
	x0
source	

error out 3

status	code
	x0
source	

Port 1

% Dev2/port1/line0

Triggered?



Left selection trigger 2

% Dev2/port1/line1

Triggered? 2



Right selection trigger 3

% Dev2/port1/line2

Triggered? 3

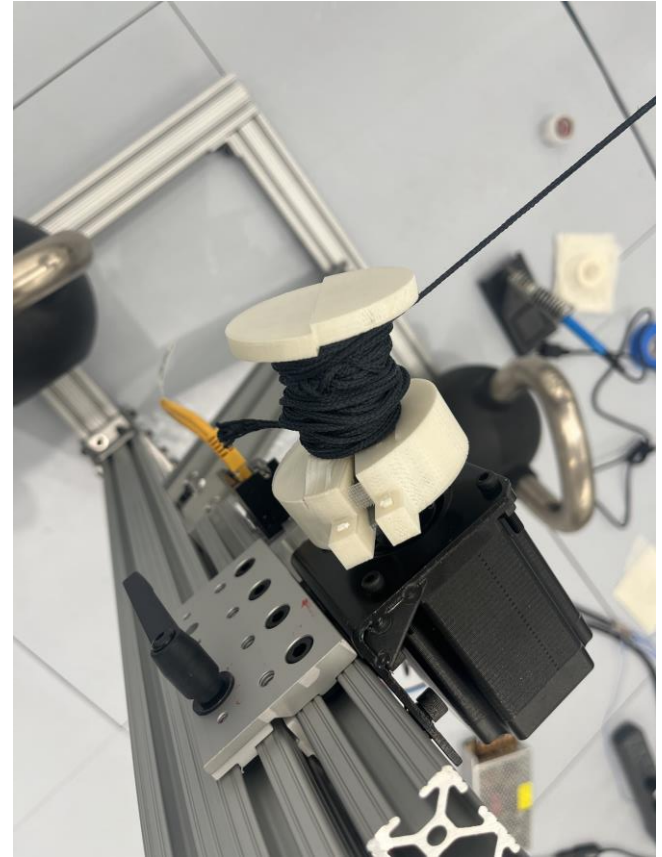


Stop selection trigger 4

% Dev2/port1/line3

Triggered? 4





Results

- The Quick Pull Method will not work for the parts we have now. The force cannot be provided neither strong enough nor quick enough.
- The Release Method cannot work as well:
 1. The motor oscillates when reaching the amount of speed we set.
 2. The motor could not provide enough force.
- The control box does not work well. If we want to change the speed of the motor, we cannot create a code to do so. We need to change the number in Q and then download it to the driver every time.

The motor we chose

$$= 3299.8 \text{ mNm}$$

$$\text{Torque} = \text{force} * r$$

$$R \text{ (radius of spool)} = 20 \text{ mm}$$

$$\text{Force} = 165 \text{ N}$$

$$\text{Take as weight (g=9.8)} = 16.84 \text{ kg}$$

$$\text{Human being: } 60 \text{ kg}$$

$$\text{Max} = 28\% \text{ body weight}$$

Continuous rated torque is the motor's continuous torque that it can output at **rated speed**, close to the max speed of the motor. This is a better judge of the motor's performance as it's the motor's torque at speed.

Continuous stall torque is the motor's continuous torque at 0 speed (at stall). This is the locked rotor torque. Manufacturers test this by locking the rotor and then monitoring the motor temperature as current is powered into the motor.

Most manufacturer's if they list a continuous torque and don't tell you if it's at stall or at speed, is typically at stall. The rated torque takes into account the spinning (magnetic) losses and thermal (I²T) losses of the motor. At 0 speed, these losses are 0 and thus the stall torque is higher than the rated torque.

Peak torque is the motor's maximum torque it can output for a short period of time, typically for acceleration/deceleration or overcoming friction. Our motors are rated for 10% duty cycle and thus the peak torque is 3.1 times the continuous stall torque.

Component	Motor
Motor Frame Size	NEMA 23
Maximum Holding Torque	467.3 in.-oz.
Maximum Speed	300 rpm
Maximum Current per Phase	2 A
Resistance per Phase	2.3 ohms
Inductance per Phase	8.1 mH
Full Step Increment	1.8°
Rotor Inertia	2 oz-in.^2
Radial Load Capacity	15 lbs.
Thrust Load Capacity	9 lbs.
Duty Cycle	Continuous
Motor Type	Hybrid Stepper
Polarity	Bipolar
Base	Two
Material	Aluminum and Steel
Ball	Ball
Ass	B
Maximum	266° F

But Actually !!!

$$= 2400 \text{ mNm}$$

Torque = force * r

R = 20 mm -> 6mm/10

Force = 120 N -> 400N

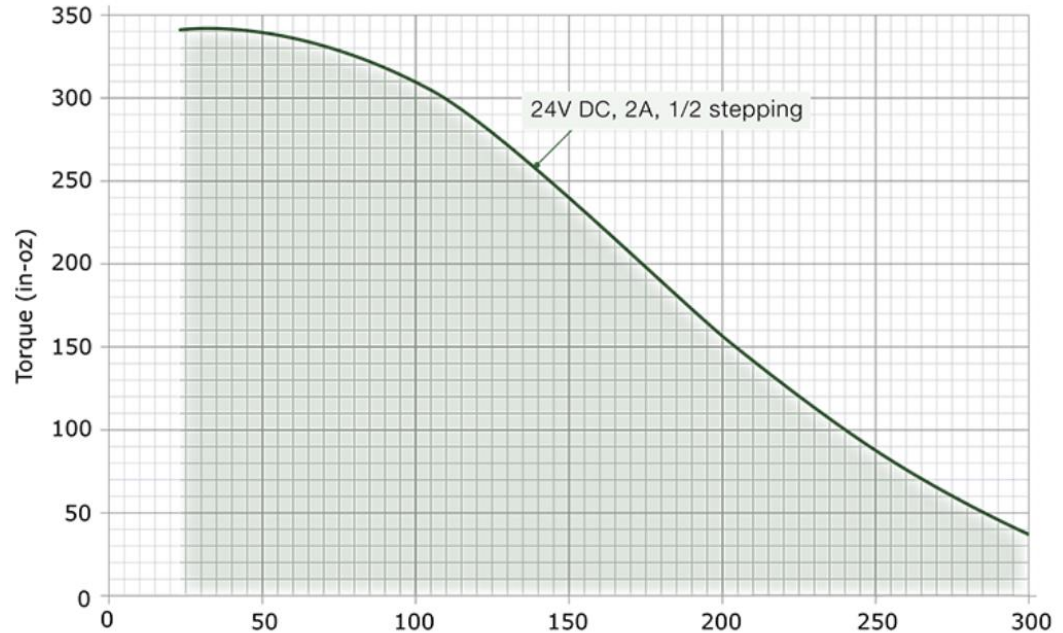
Take as weight ($g=9.8$) = 12.24 kg

Human being: 60 kg

Max = 20.4% body weight

$$120 \text{ N} < 133.45 - 146.80 \text{ N}$$

Torque-Speed Chart
for Stepper Motor (6627T923)



The motor Stanford team chose

<https://www.maxongroup.com/maxon/view/product/motor/ecmotor/ecflat/ecflat90/500267>



PRICE SCALES

	Quantity	Price per unit
Prices excluding VAT and shipping costs	1-4	€276.73
	5-19	€232.20
	20-49	€201.15
	from 50	On request

Order quantity

[Start combination](#)

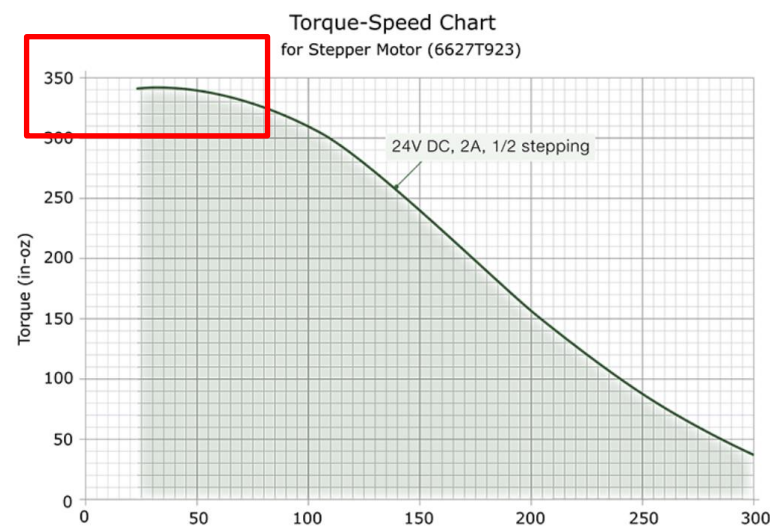
[Add to cart](#)

VALUES AT NOMINAL VOLTAGE

Nominal voltage	48 V
No load speed	1960 rpm
No load current	278 mA
Nominal speed	1670 rpm
Nominal torque (max. continuous torque)	964 mNm
Nominal current (max. continuous current)	4.06 A
Stall torque	13100 mNm
Stall current	56.9 A
Max. efficiency	86 %

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Their ability is three times stronger than ours while running

VALUES AT NOMINAL VOLTAGE

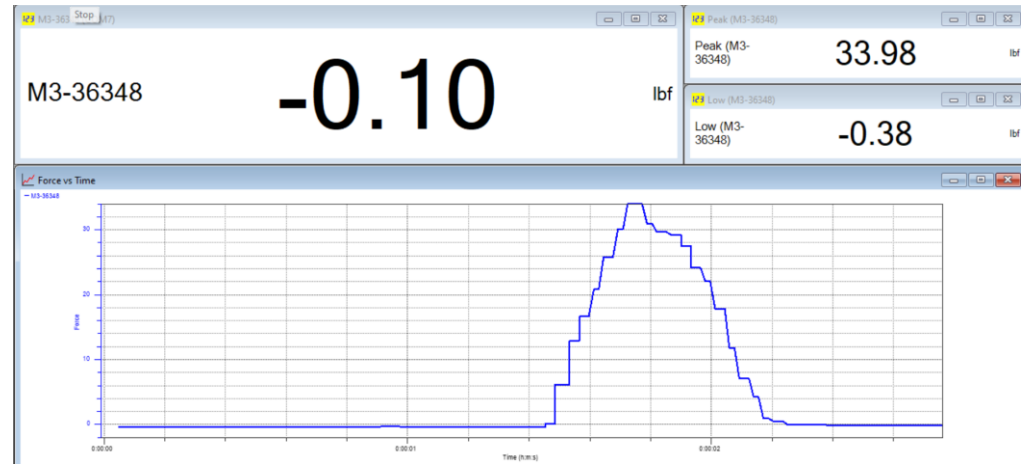
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Full Step Increment	1.8°
Rotor Inertia	2 oz-in.^2
Radial Load Capacity	15 lbs.
Thrust Load Capacity	9 lbs.
Duty Cycle	Continuous
Motor Type	Hybrid Stepper
Polarity	Bipolar
Electrical Phase	Two
Enclosure Material	Aluminum and Steel
Bearing Type	Ball
Insulation Class	B
Insulation Maximum Temperature	266° F

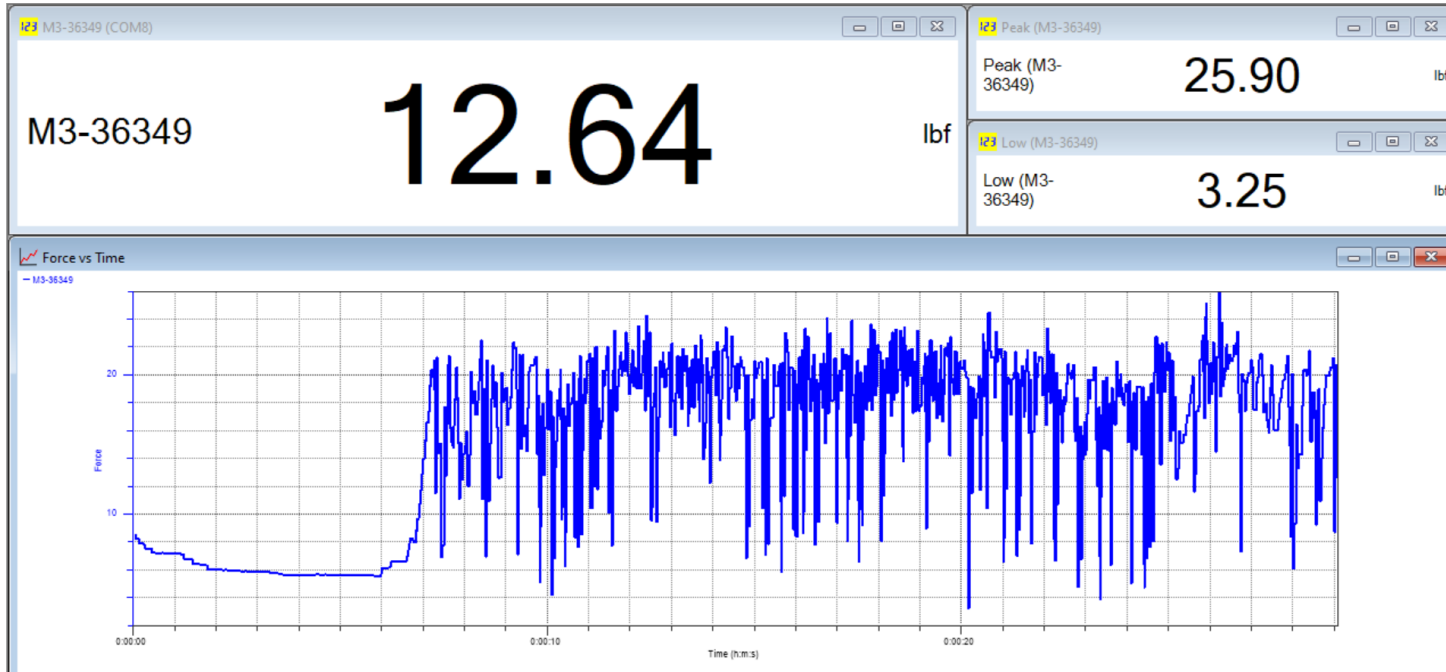
Their ability is three times stronger than ours while holding

Motor ability test – First Stage – pull by hand

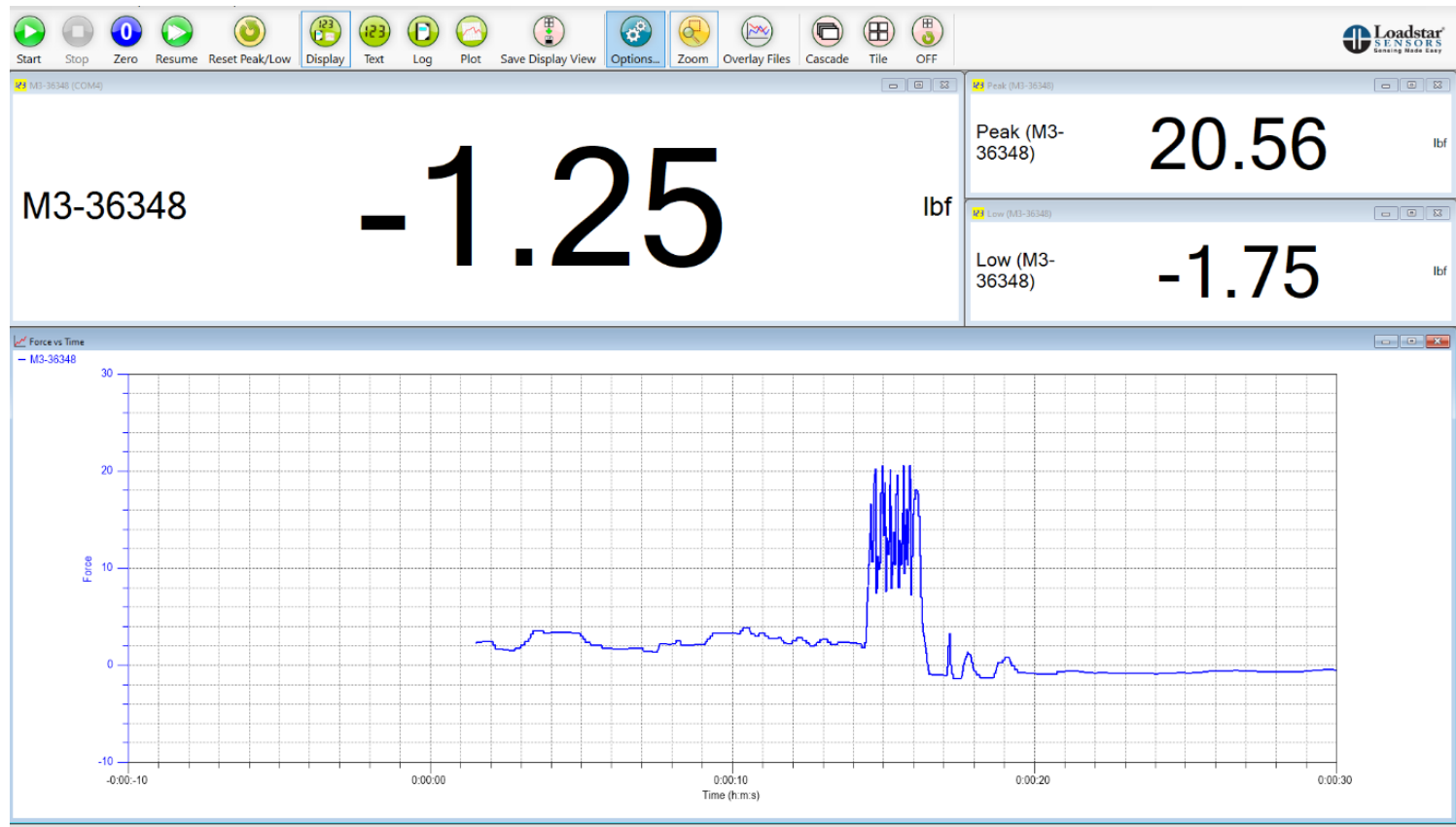
- We did the tests by pulling the participant to the side
- We found the approximate threshold as SST and MST.
- SST: about 8 -13 lbf
- = 35.58 – 57.87 N
- MST: about 30 – 33 lbf;
but sometimes 24 lbf
also drives the
movement
- = 133.45 N – 146.80 N



However, the motor could not provide enough force for MST.

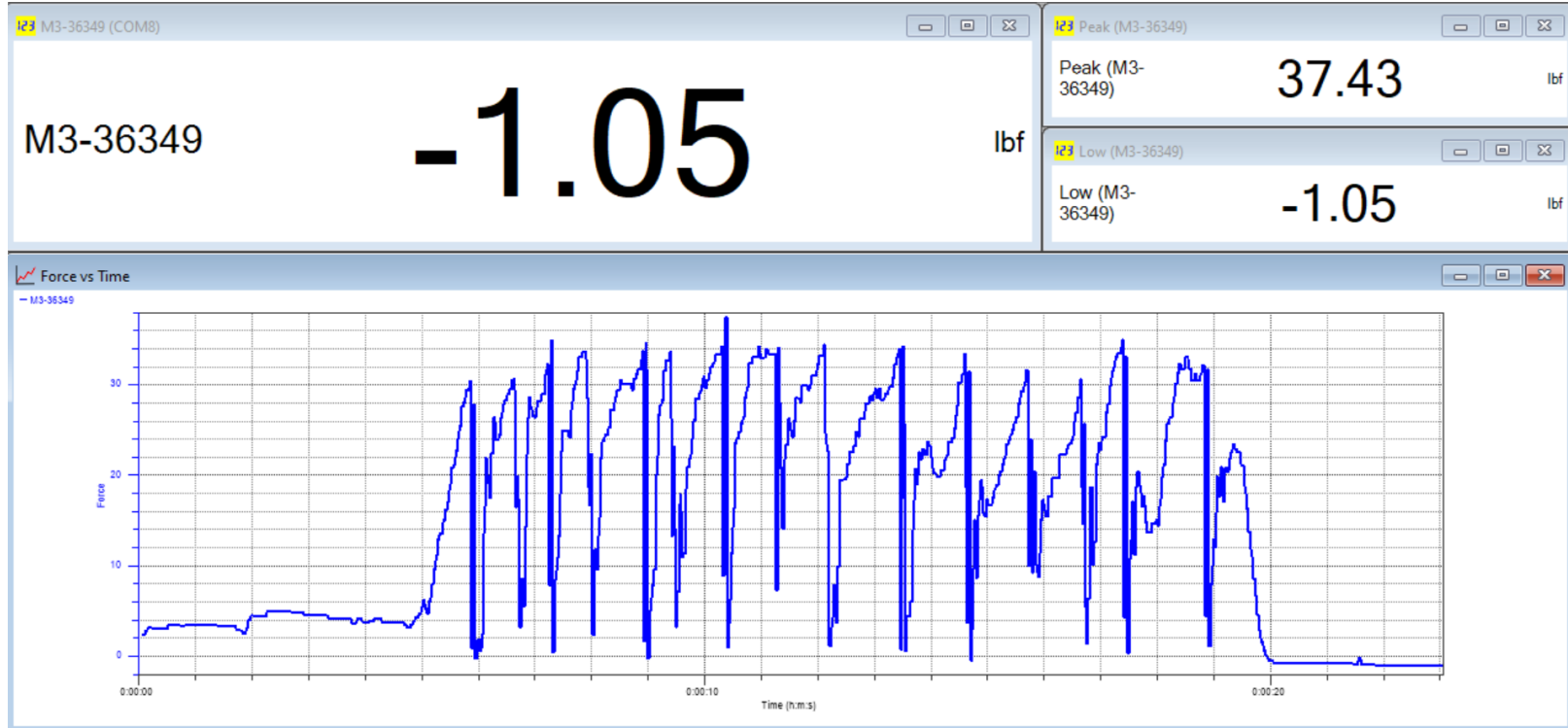


The force we get by holding by hands: 25.9 lbf = 115.2 N



The test we did this morning using Release Method: 20.56 lbf = 91.46 N

We changed the limit current for the motor settings - - It's not safe!



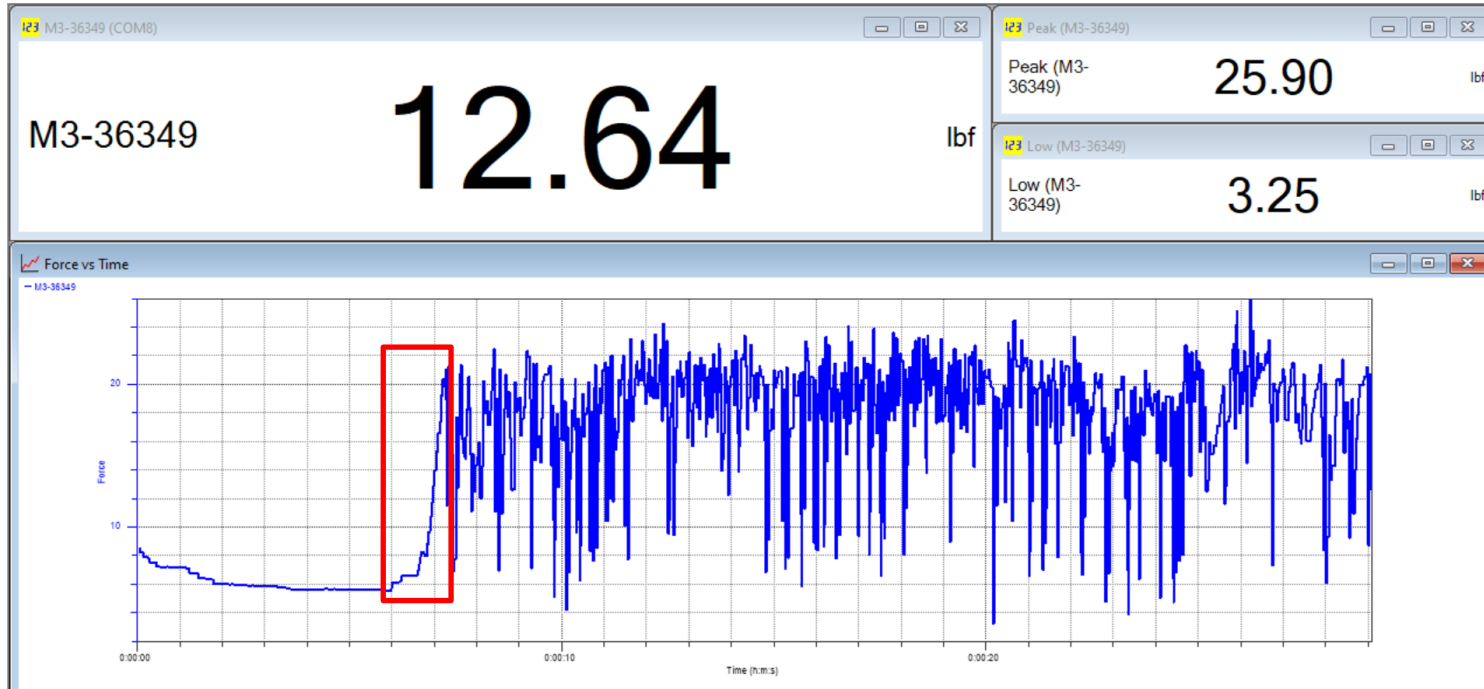
The force we get by increasing the current: 37.43 lbf = 166.5 N

Motor Oscillation makes the “holding” not possible



Also, the force is not stable. Changes from 3 lbf to 25.9 lbf

It takes time to reach the amount of force;
Stop in between could be hard.



It takes about 1.2 s to reach the amount of force, much longer than reaction time

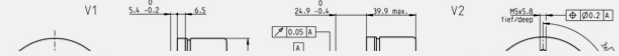
My suggestions

- If we want to keep using the method we are using recently:
We should change the motor & the control box.
- If we change the method to release: find another way to adjust the precise control on force, like the way to adjust the weight of the heavy object to release.
- Change the aim we focus, from steps to distance

New motors & design to be considered

- Maxon motor (no cable or with cable)

TECHNICAL ILLUSTRATIONS



500266	EC 90 flat Ø90 mm, brushless, 260 W, with Hall sensors	90 mm	260 W	30 V	2080 rpm	988 mNm	\$328.63
500267	EC 90 flat Ø90 mm, brushless, 260 W, with Hall sensors	90 mm	260 W	48 V	1960 rpm	964 mNm	\$328.63
500268	EC 90 flat Ø90 mm, brushless, 260 W, with Hall sensors	90 mm	260 W	60 V	1980 rpm	963 mNm	\$328.63

[Maxon EC 90 program motor overview page](#)
[brushless-DC-Motors&etcc_var=%5bus%5d%23en%23_d_&target=filter&filterCategory=EC-i](#)

no load speed	1960 rpm
No load current	227 mA
Nominal speed	1690 rpm
Nominal torque (max. continuous torque)	963 mNm
Nominal current (max. continuous current)	3.28 A
Stall torque	13300 mNm
Stall current	46.7 A
Max. efficiency	87 %

New motors & design to be considered

- Maxon motor & their control box

ESCON 70/10, 4-Q Servocontroller for DC/EC motors, 10/30 A, 10 - 70 VDC
Part number 422969



PRICE SCALES	Quantity	Price per unit
--------------	----------	----------------

Prices excluding VAT and shipping costs

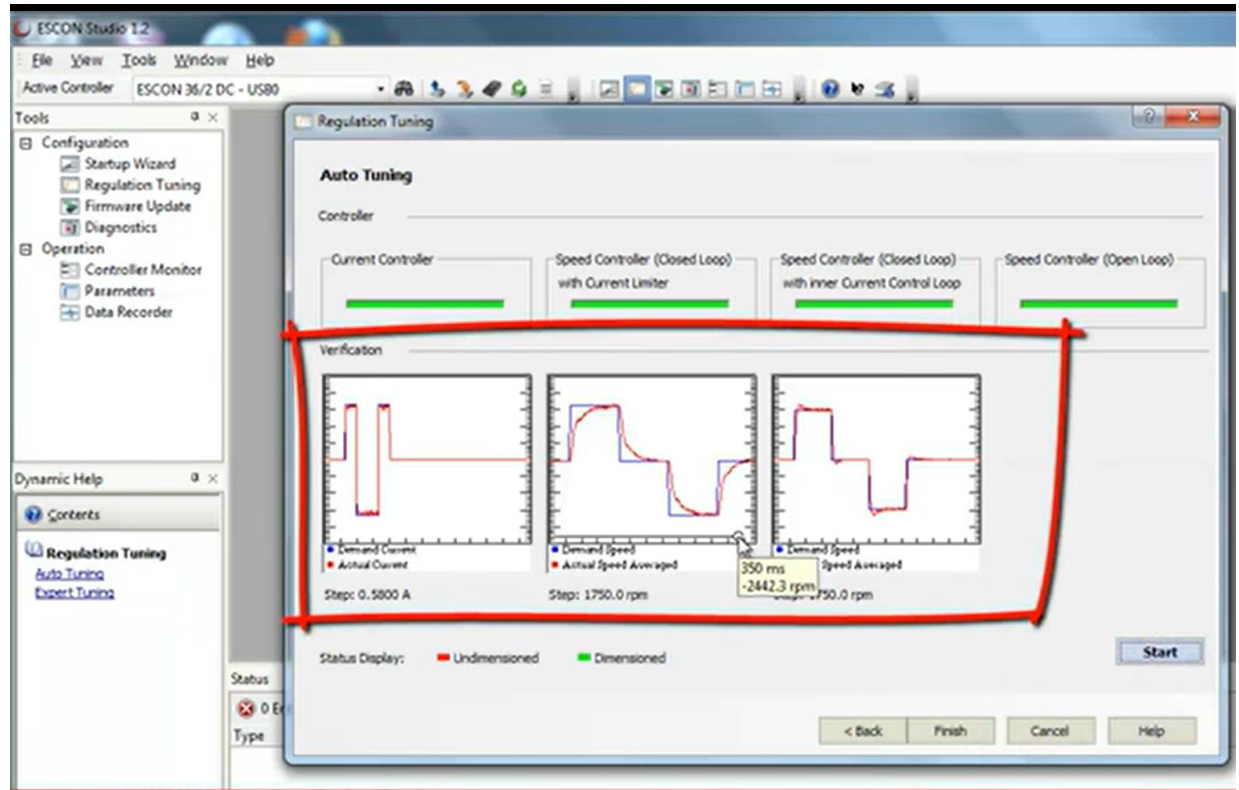
1-4

\$496.00

PART NO.	ARTICLE	TECHNICAL DATA	PRICE
275934	Encoder Cable		\$80.50
339380	Cable with Connector		\$28.00
354046	Ribbon Cable with Connector		\$26.88
403968	USB Type A - micro B Cable		\$15.25
549609	Adapter encoder connector 1.27 mm pitch to 2.54 mm pitch (DIN 41651)		\$14.13

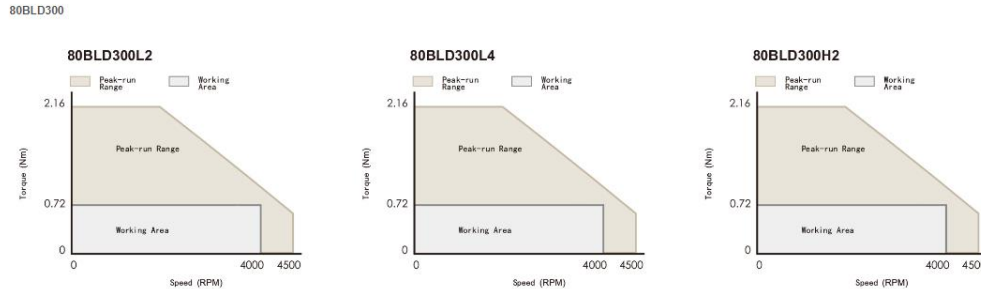
New motors & design to be considered

- The most important is that we would be able to tune the motor through their software



New motors & design to be considered

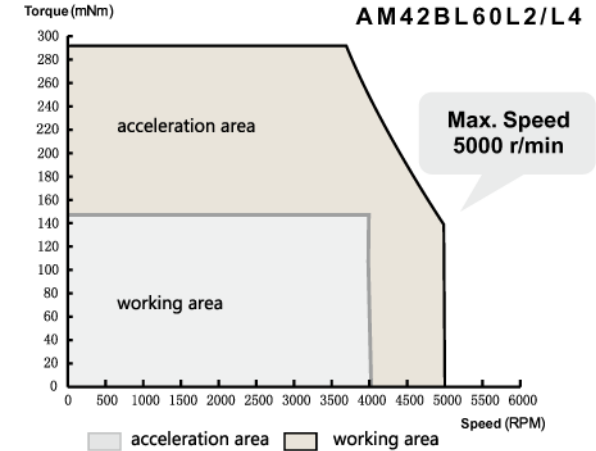
- MOONS
- The most likely one to what we have used!



<https://www.moonsindustries.com/series/brushless-dc-motor-drives-a050201>

Excellent Velocity Stability

- Velocity Regulation (under load) is $\pm 0.5\%$



Ultimate Performance

- Low heat
- Low noise
- Low vibration
- Low cogging torque
- Support RS-232&RS-485 Communication Control

New motors & design to be considered

- MOONS
- About 58 N to 180 N



80BLD300L2

Brushless DC Motor, 300Watts, Frame 80

- Wide speed range, flat torque
- Excellent speed stability
- Compact and high power
- High efficiency and energy-saving



Learn More About [S80 Series Brushless DC Motors](#)

Brand Name: [MOONS'](#)

Price: USD **240.0** EA

Quantity:

Shipping to:

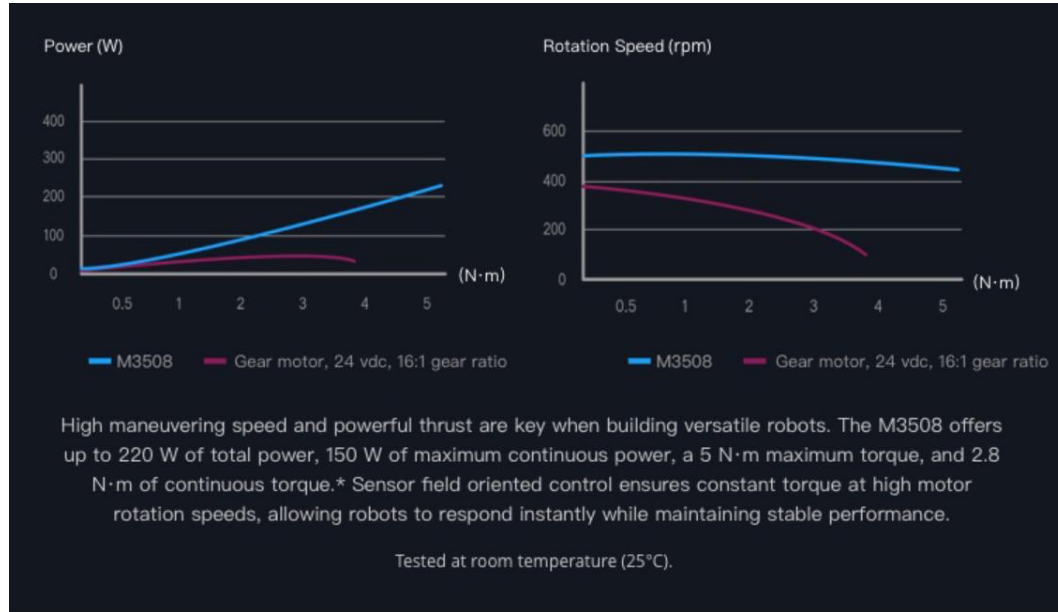
Lead Time: 5 working days

[Add to cart](#)

[Add to compare](#)

New motors & design to be considered

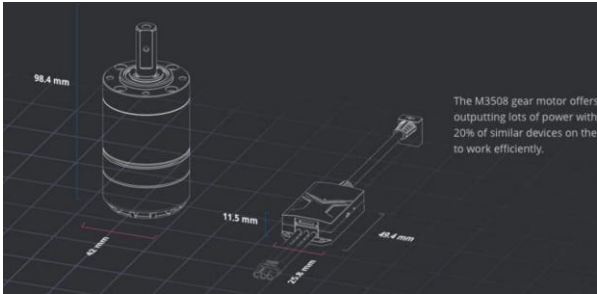
- DJI motor



v2&position=13&total_result=21&vid=32501

New motors & design to be

- DJI motor



https://store.dji.com/product/rm-m3508-p19-brushless-dc-gear-motor?from=search-result-v2&position=13&total_result=21&vid=325

	RoboMaster Development Board Cables	USD \$49	- 1 +	USD \$49	
	RoboMaster Development Board Type A	USD \$89	- 1 +	USD \$89	
	RoboMaster C620 Brushless DC Motor Speed Controller	USD \$79	- 1 +	USD \$79	
	RoboMaster M3508 Accessories Kit	USD \$59	- 1 +	USD \$59	
	RoboMaster M3508 P19 Brushless DC Gear Motor	USD \$99	- 1 +	USD \$99	

 Enjoy a 1% rebate on every purchase in the form of DJI Credit - the more you buy, the more you earn.
[Learn more about DJI Credit >](#)

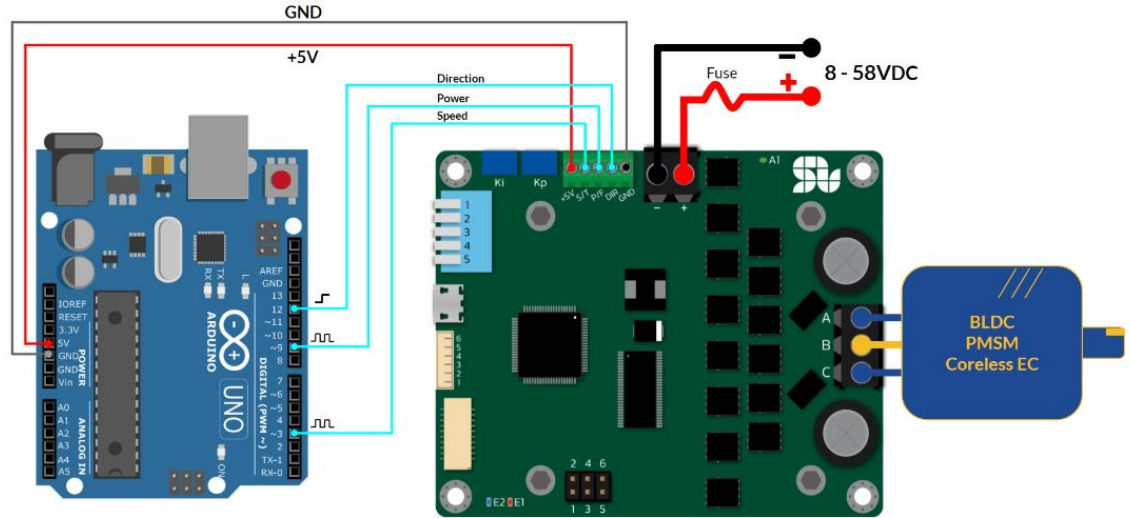
CART SUBTOTAL: USD \$375

Tax: Calculated at checkout ⓘ

Takes \$375 in total, the driver and motor

New motors & design to be considered

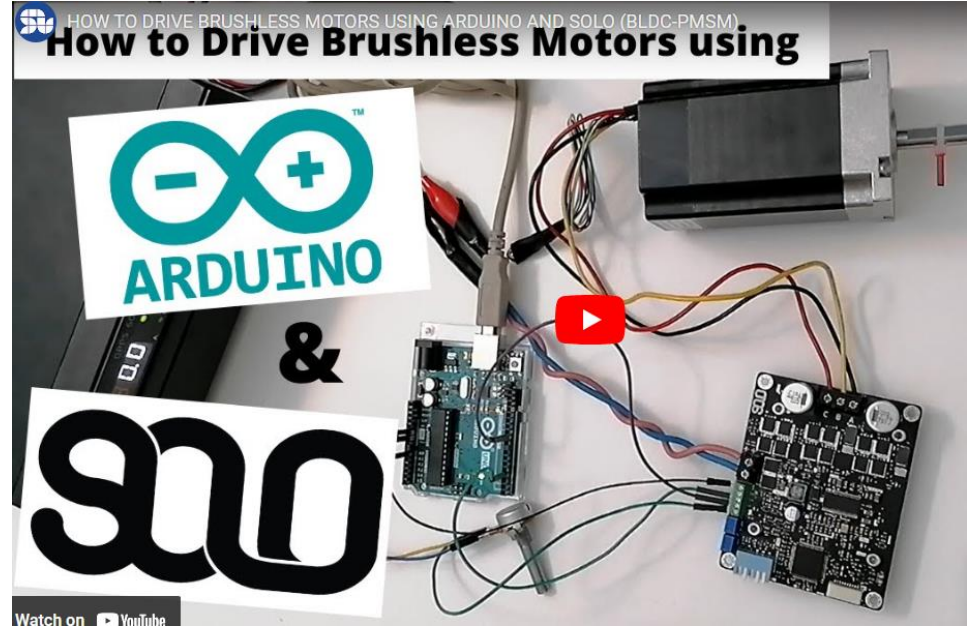
- Arduino uno + Solo + any brushless motor
- Arduino uno + ESC + any brushless motor



<https://www.solomotorcontrollers.com/blog/how-to-control-speed-or-torque-of-your-brushless-motor-with-arduino-using-solo-closed-loop/>

New motors & design to be considered

- Arduino uno + Solo + any brushless motor
- Arduino uno + ESC + any brushless motor



<https://www.solomotorcontrollers.com/blog/how-to-control-speed-or-torque-of-your-brushless-motor-with-arduino-using-solo-closed-loop/>

New motors & design to be considered

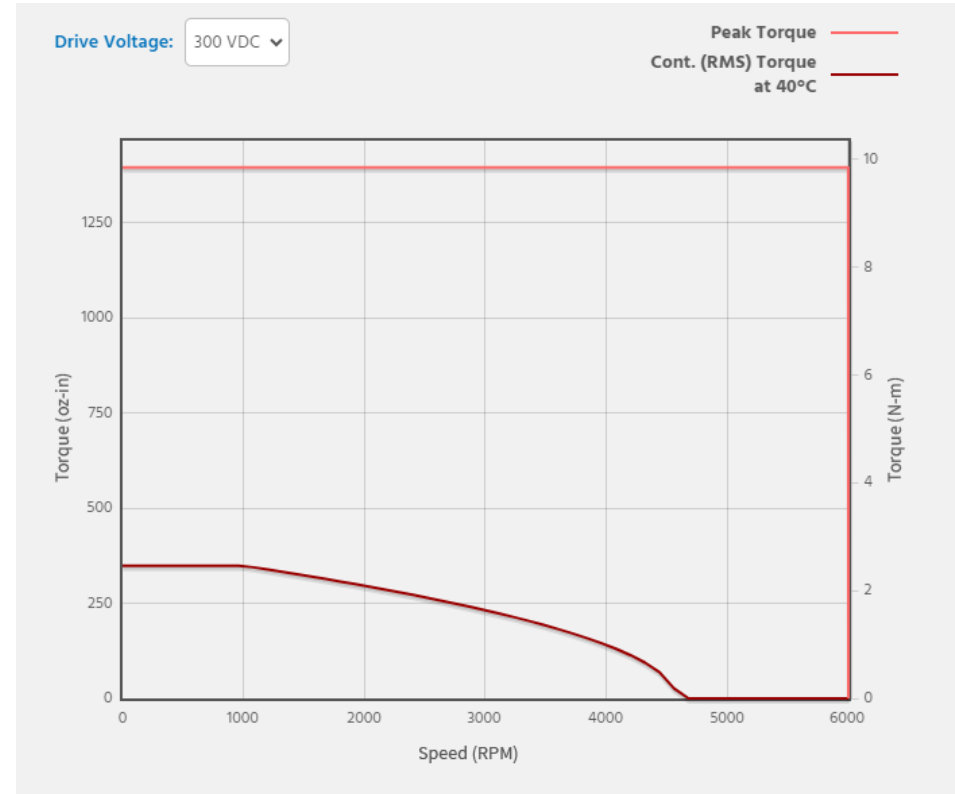
Applied motion

<https://www.alliedmotion.com/brushless-motors/brushless-servo-motors/quantum-nema-brushless-servo-motors/>

New motors & design to be considered

2.5 kg, 8 wires

https://tekninc.com/hudson-model/M-3432P-LN-08D/?model_voltage=300



New motors & design to be considered

LRPX22-042V12 (3:1 to 66:1)	3.5	5.0 to 10.8	12	PRO-A08V48B	PRO-A08V48B	CPP-A06V48A
LRPX22-042V12 (81:1)	3.2	4.0	12	PRO-A08V48B	PRO-A08V48B	CPP-B06V48A
LRPX22-042V12 (94:1 to 624:1)	0.7 to 2.8	0.9 to 3.5	12	PRO-A04V36A	PRO-A08V48B	CPP-B06V48A
LRPX22-042V24 (3:1 to 19:1)	1.8	5.5	24	PRO-A04V36A	PRO-A08V48B	CPP-A06V48A
LRPX22-042V24 (27:1 to 624:1)	0.4 to 1.8	0.4 to 4.2	24	PRO-A04V36A	PRO-A08V48B	CPP-B06V48A
LRPX22-042V48 (3:1 to 624:1)	0.2 to 0.9	0.2 to 2.8	48	PRO-A08V48B	PRO-A08V48B	CPP-B06V48A

LRPX22 Brushless DC Planetary Gear Motor

Low Noise RapidPower™ Xtreme Series



Size: 22mm (0.87 in)

Peak Torque: to 3.0 Nm (424.8 oz.in)

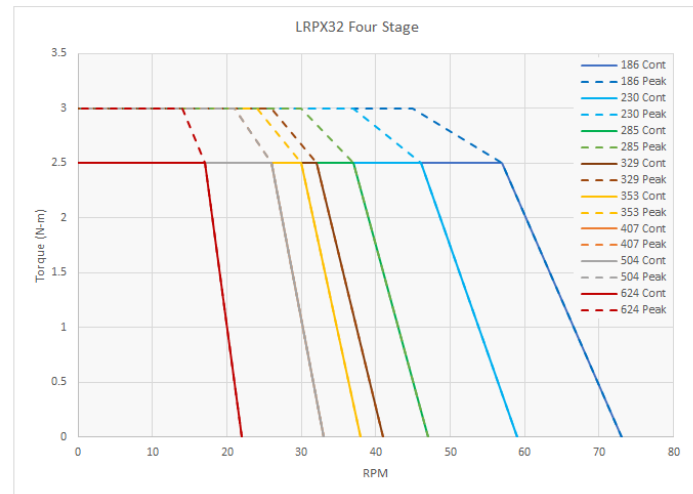
Continuous Stall Torque: to 2.5 Nm (354 oz.in)

Speed: to 2286 RPM

Data Sheets

[LRPX22 Data Sheet \(US\)](#)

[Buy Now](#)



More than expensive

\$660

<https://www.electrocraft.com/products/bl/dc/LRPX22/>

New motors & design to be considered

- Motors are not designed to do so!!!!
- Brushless motor is not easy to keep still
- Use PMSM motor: can solve every problem but need a long time to do so

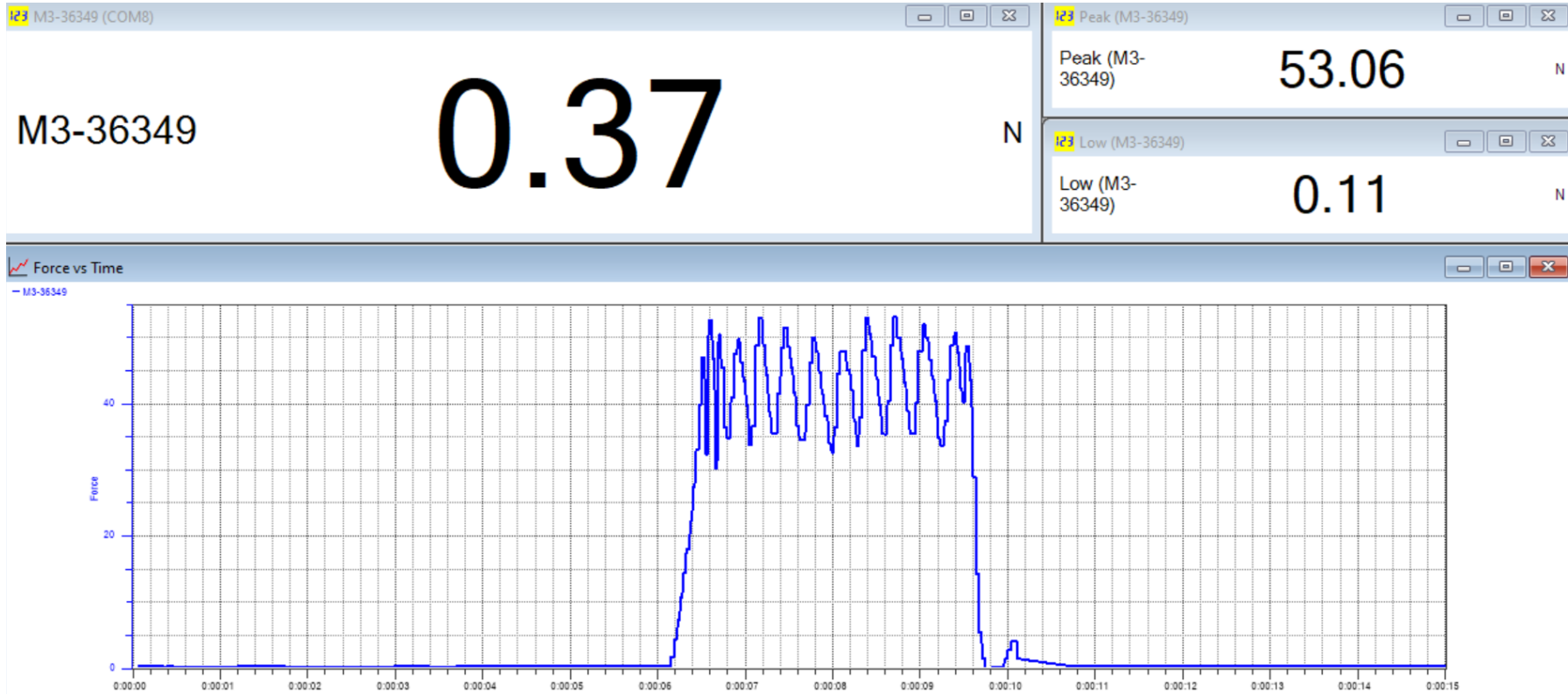
里别想那个 过载

你们老板是学控制的么

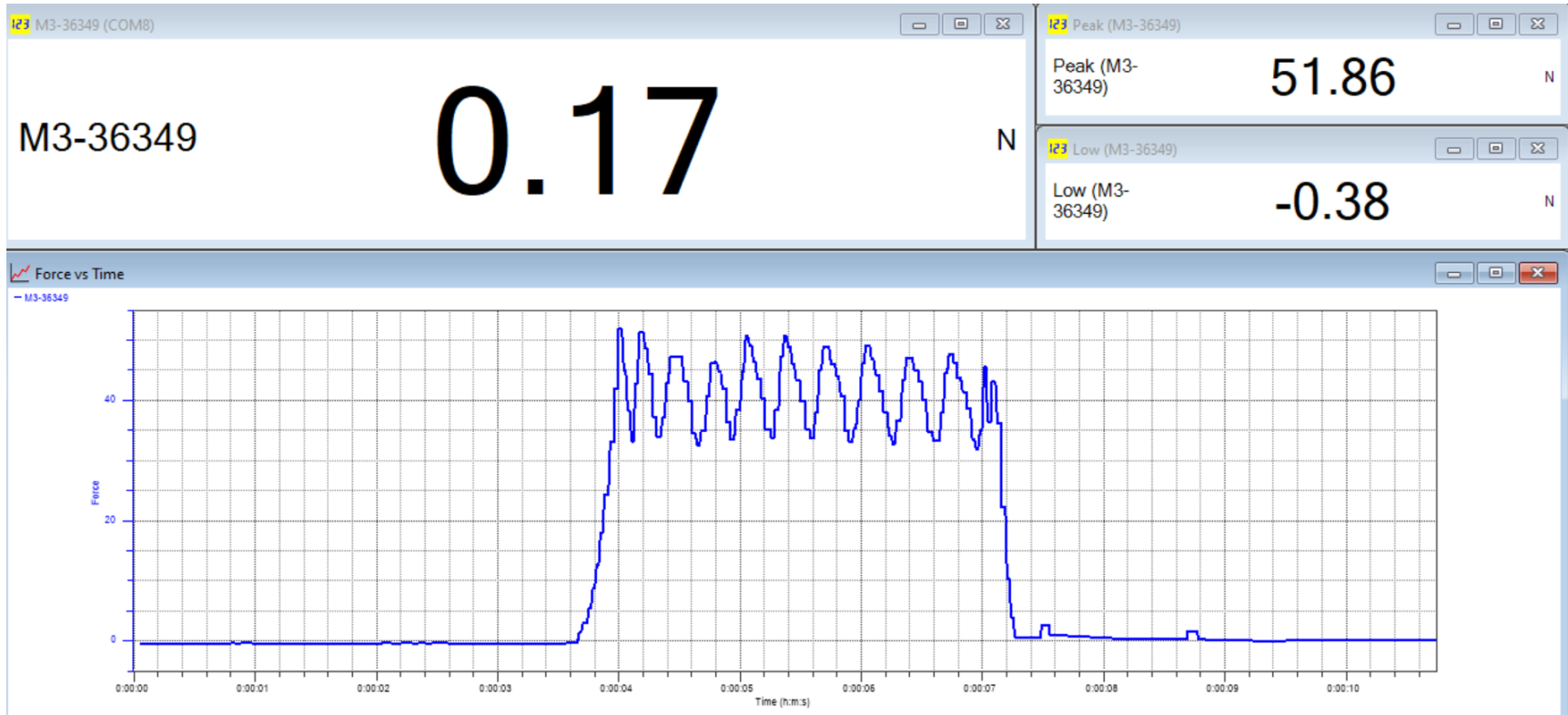
怎么能想出来这种 玩意

项目可以不用理

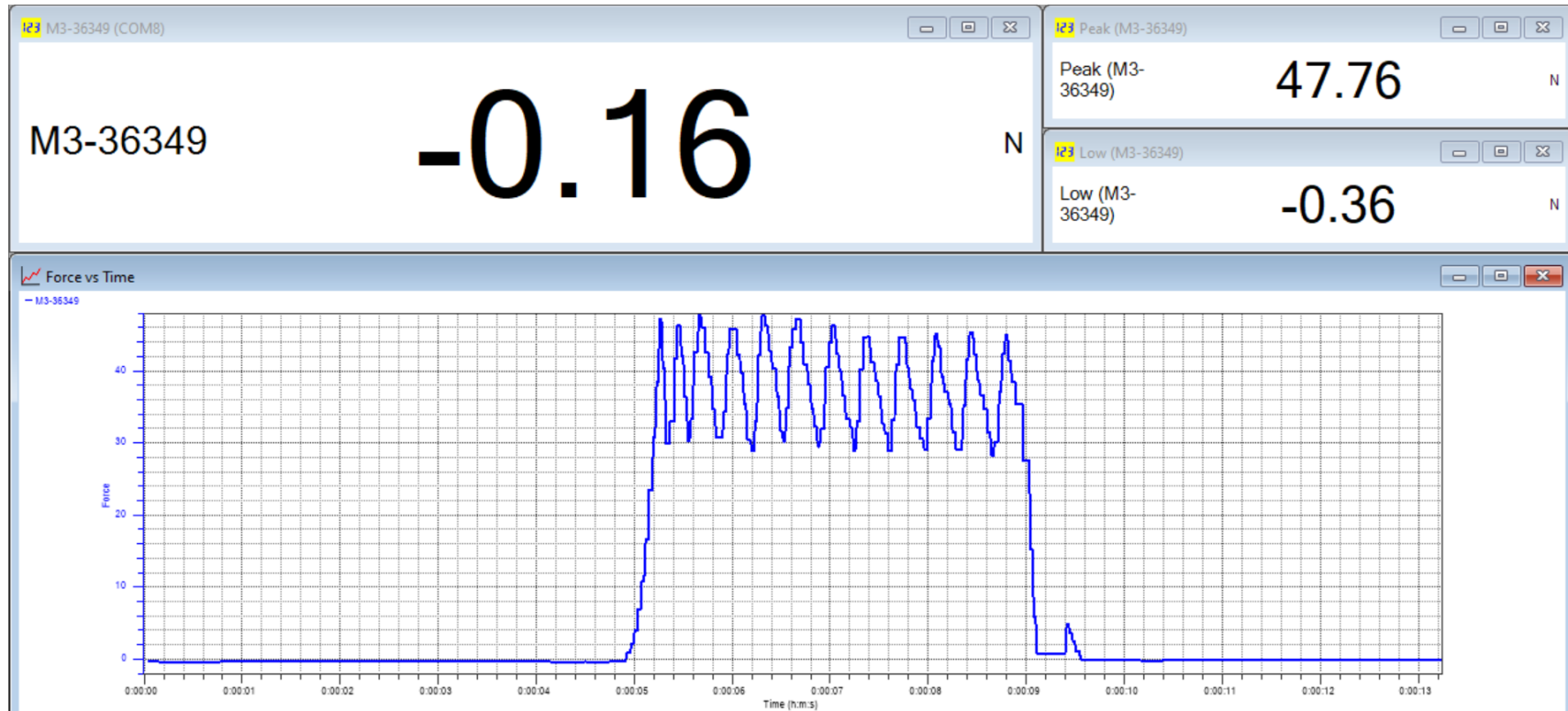
Current run as 1A, the oscillation becomes weaker; speed at -1



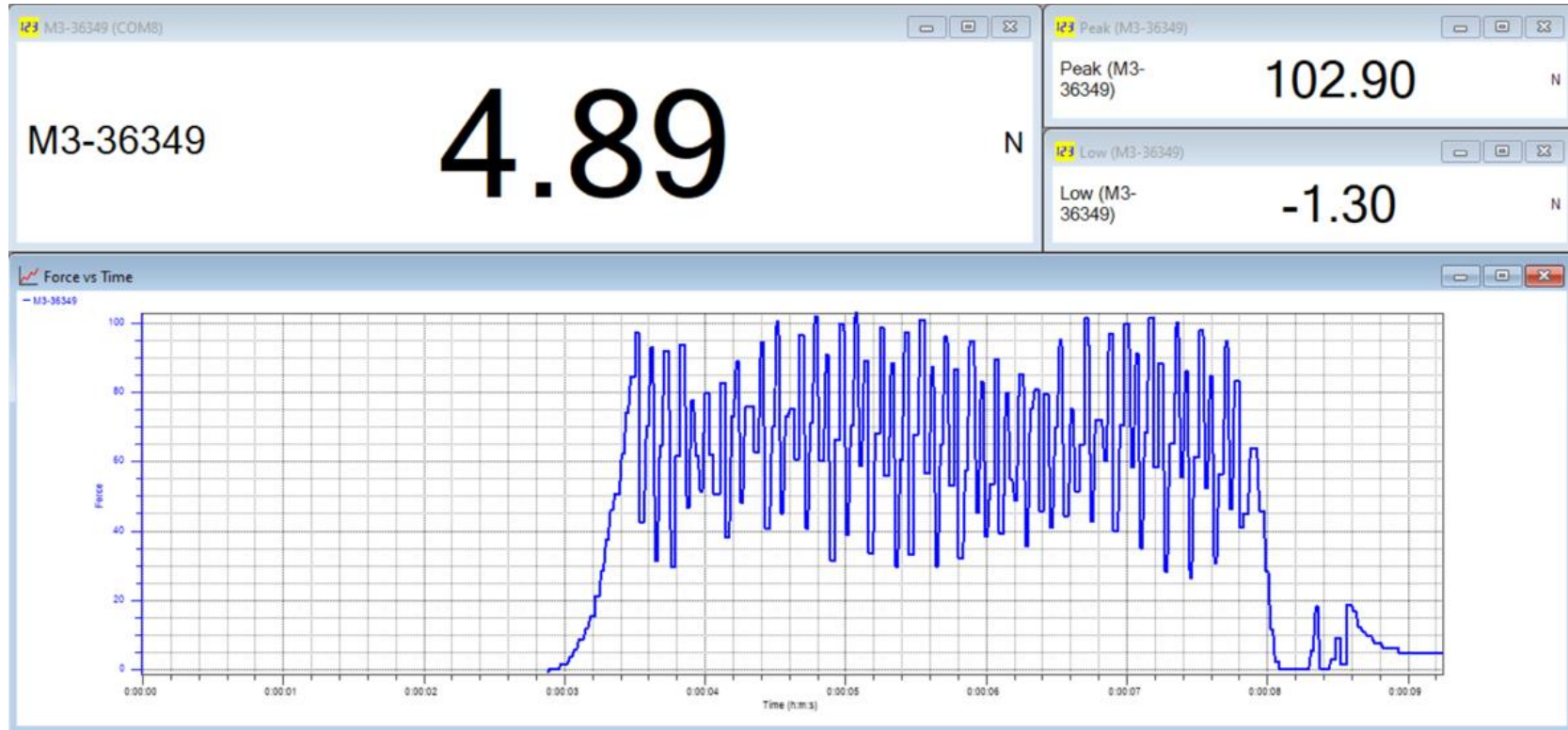
Current run as 1A, the oscillation becomes weaker; speed at -100



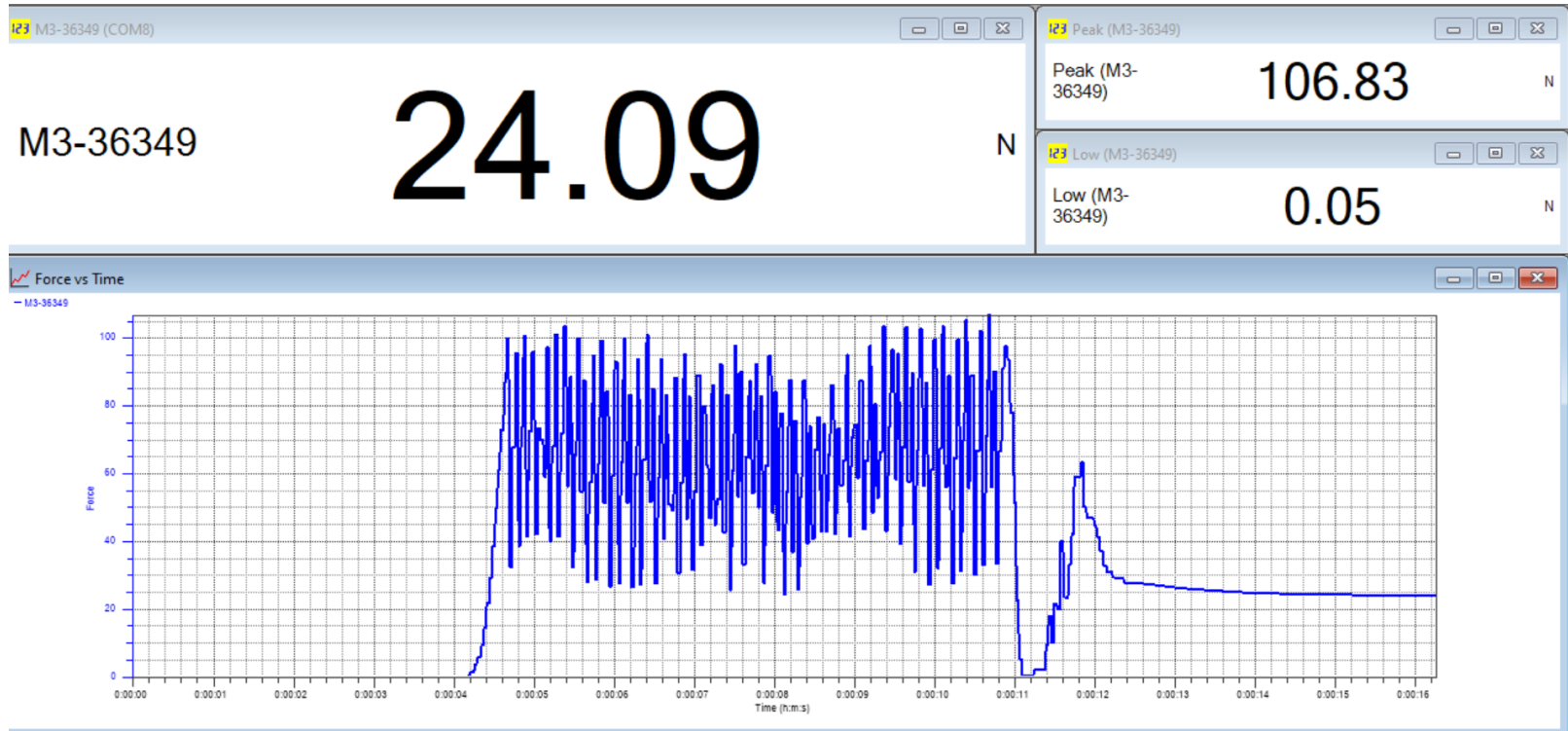
Current run as 1A, the oscillation becomes weaker; speed at -1000



Current run as 2A, the oscillation becomes stronger; speed at -100



Current run as 2A, the oscillation becomes stronger; speed at -1





The spring to choose



<https://www.mcmaster.com/5108N874/>

- From 19.05 cm extend to maximum load at 36.83 cm

Spring Type	Extension
Length	7.5"
OD	1.25"
Wire Diameter	0.135"
Extended Length @ Maximum Load	14.5"
Load, lbs.	
Min.	6.18
Maximum	68.62
Spring Rate	8.9 lbs./in.
Material	Music-Wire Steel
End Type	Loop

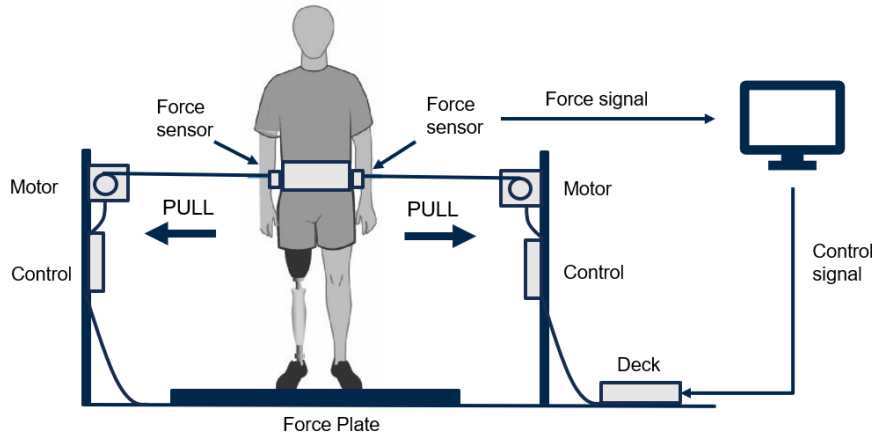
Spring Type	Extension
Length	8"
OD	1.5"
Wire Diameter	0.148"
Extended Length @ Maximum Load	17.3"
Load, lbs.	
Min.	7
Maximum	80
Spring Rate	7.9 lbs./in.
Material	Music-Wire Steel
End Type	Loop

Load = 31.12 kg -> = 305 N

ing:

force to produce; reasonable distance to change; precise control for the force

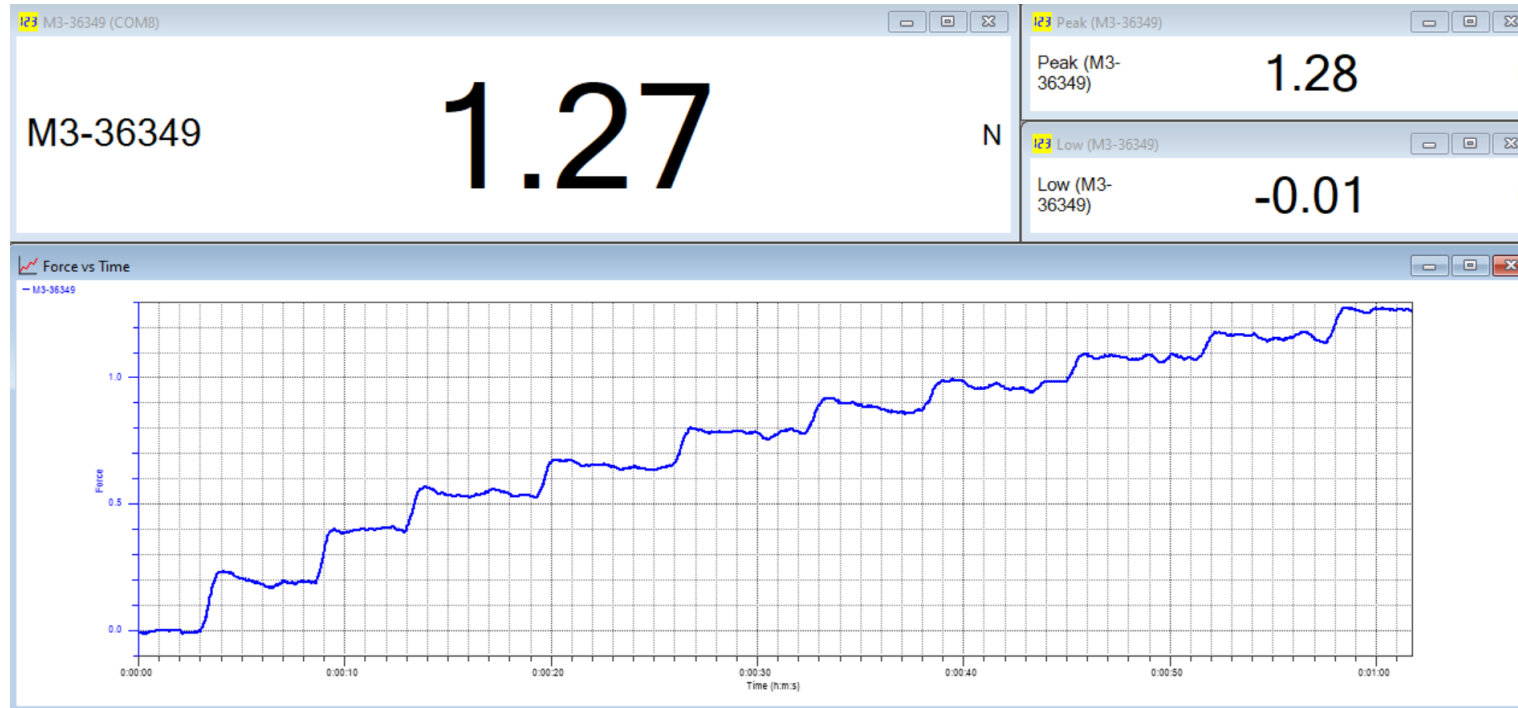
I come up with a new design:



- Problem:
- Whether the elastic cord is strong enough; fatigue of the elastic cord (but we have the force sensor)

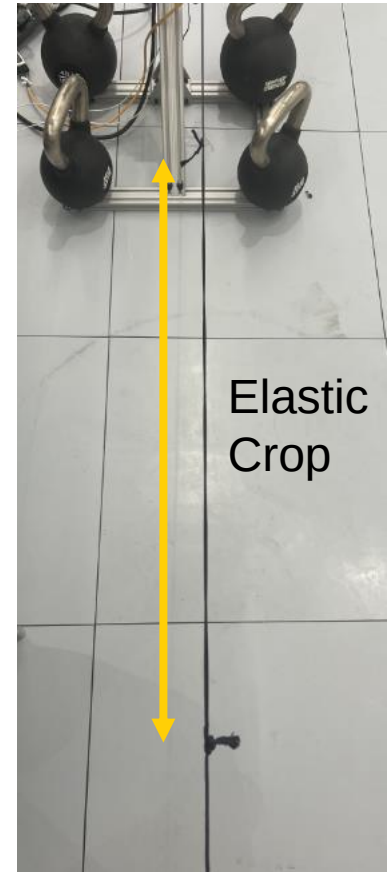
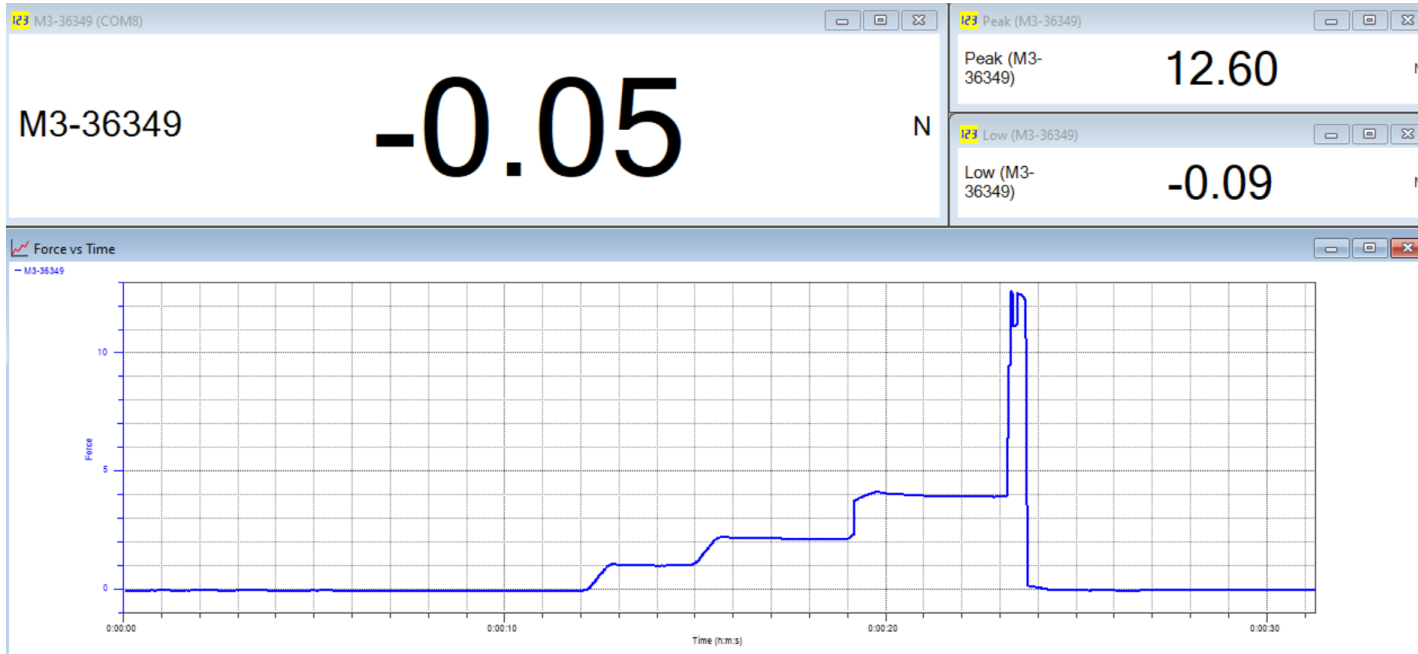
- Use an elastic cord to replace the wire
- The motor rotates and pulls the elastic cord, make it to extend to create force;
- We still use the force sensor to read the force and stop the motor when the force is reached through LabVIEW.
- Releasing the motor by quickly “rotate to the start point”, get rid of the extension in the wire.

Elastic wire principle test, increase by 5000 steps per stage



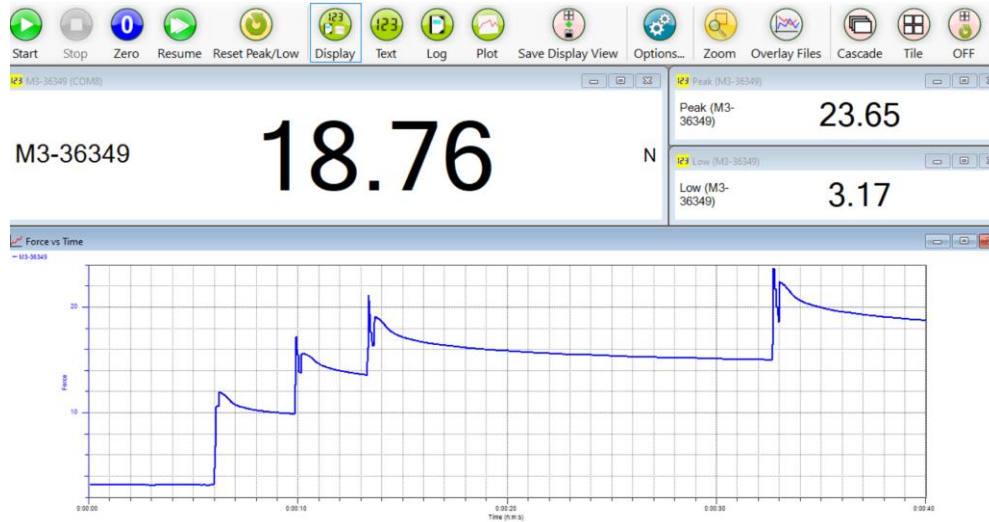
- Connect the elastic wire directly to the spool; It shows that force could be produced in this way.

Increase by 5000 steps per stage;



- Connect the wire with unextendible wire to the spool;
Provide larger and more precise control to the force;

Elastic wire principle test, increase by 5000 steps per stage



- Failed to test the maximum force because the recent elastic crop is too weak to do so. But it shows the possibility of carrying on with this method.
- After discussion, we decided to change the elastic crop to **spring**.

The spring to choose



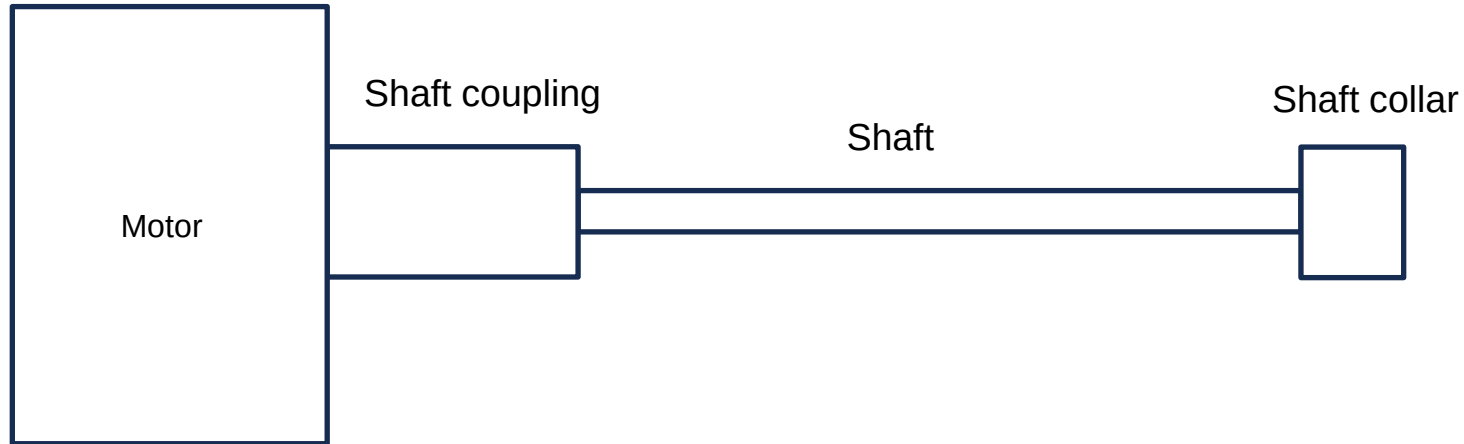
<https://www.mcmaster.com/9654K804/>

Spring Type	Extension
Length	8"
OD	1.5"
Wire Diameter	0.148"
Extended Length @ Maximum Load	17.3"
Load, lbs.	
Min.	7
Maximum	80
Spring Rate	7.9 lbs./in.
Material	Music-Wire Steel
End Type	Loop

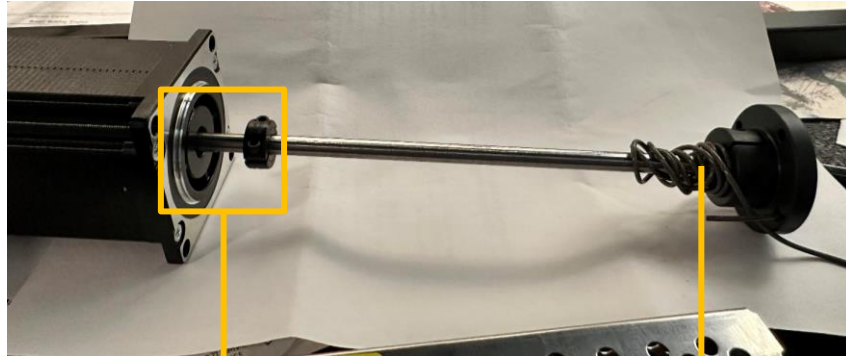
- From 20.32 cm extend to maximum load at 43.94 cm
- Maximum load = 36.29 kg -> = 355.64 N
- Considering:
- Enough force to produce; reasonable distance to change; precise control for the force

New motors & structure -- to minimize the radius of the spool

- It's hard to find the spool as we want. So, we need to combine three different parts together to reach our goal.
- Radius = $\frac{1}{4}$ inch = 6.35 mm
- While the radius of the shaft to be minimize, the force produced could be maximize.



Problem #: The structure will bend the shaft of the motor



This part is bend, and drives the force to oscillate

Bend force

- With the force applied on the shaft, there is a large force torque. In this case, especially we are doing an experiment for over 200 N.
- The inner shaft of the motor is bent. (very badly)
- The inner material might be too soft to support this design.

Problem #: The motor is over voltage

		1	2
Faults			
Reserved		☐	☐
Drive Overtemperature		☐	☐
Over Voltage		☒	☒
Internal Voltage		☐	☐
Over Current		☐	☐
Open Winding		☐	☐
Reserverd		☐	☐
Warnings			
CCW Limit		☐	☐
CW Limit		☐	☐
Under Voltage		☐	☐
Move @ Disabled		☐	☐
Reserved		☐	☐
Blank Q Segment		☐	☐
Flash Memory		☐	☐
NV Memory Error		☐	☐
Comm Error		☐	☐

Column 1 is the most recent.

 indicates a fault.  indic

- The motor, especially for the Releasing side, starts to give “Over Voltage” fault signal and stops the motor from releasing.
- It happened when the force reaches about 200 N. With the error, the motor could not run and failed to release the wires. This leads to danger for the participant. After reconnect this error is gone and appear again when the force reaches that amount.
- I have emailed the company, asking them about the case to this case but not received a feedback yet.

Motor ability

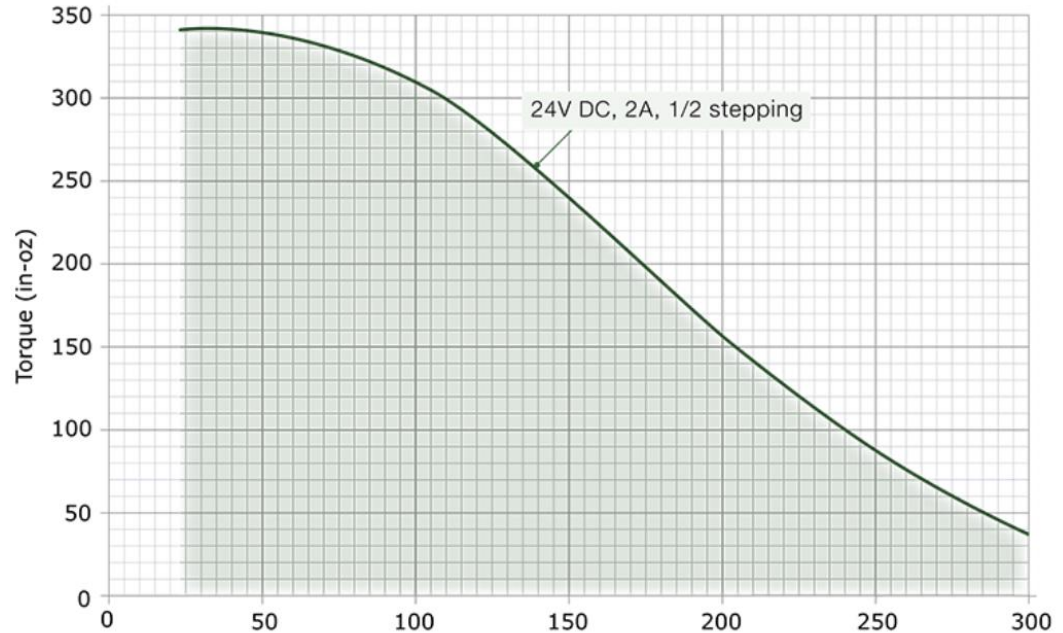
Take maximum as
 $340 \text{ in-oz} = 2400 \text{ mNm}$

Torque = force * r
 $R_{\text{old}} = 20 \text{ mm}$
Reduced to 6.35 mm up to 10 mm,

Force_{old} = 120 N
Increased to 240 up to 377.9 N.

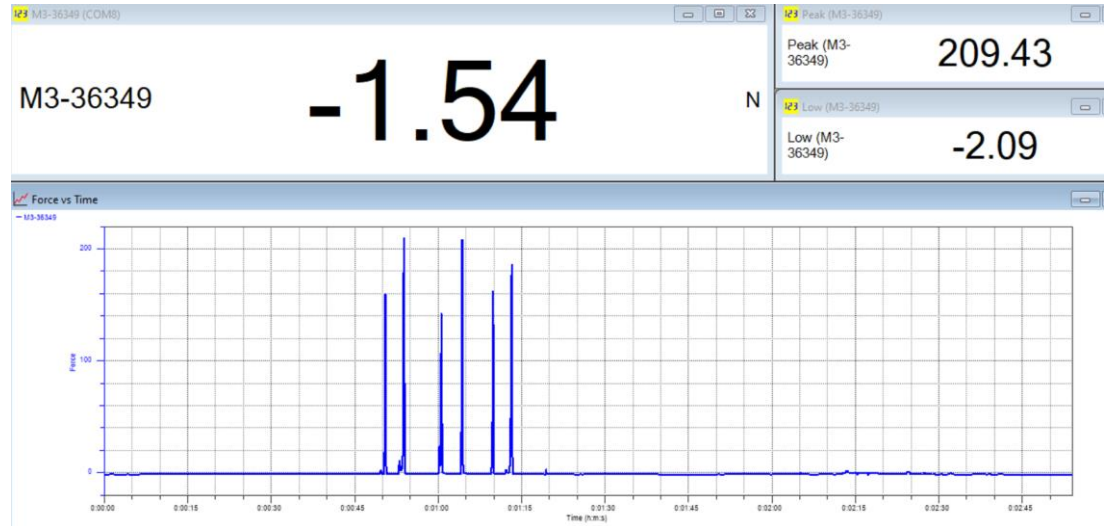
Take as weight ($g=9.8$) = 24.49 kg
to 38.56 kg

Torque-Speed Chart
for Stepper Motor (6627T923)



SST and MST

- We have redone the SST and MST test, and found that:
- (We care most about the MST since it decides the maximum force we need to provide)
- Between 150 N – 200 N: participant may take a large steps or 2 steps;
- Over 200 N: The participant definitely will take 2 steps.
- So, we decide that the force to provide must at least 250 N.



Shaft

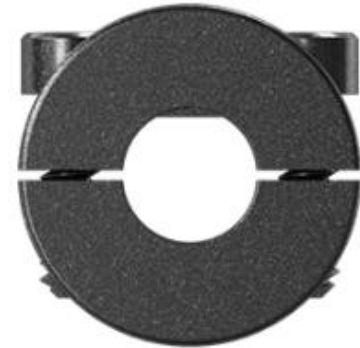
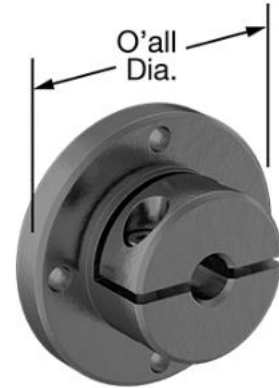
I want to buy this to connect the motor to the shat:



We have already purchased these at the very beginning



Tapped D-Profile End × D-Profile End

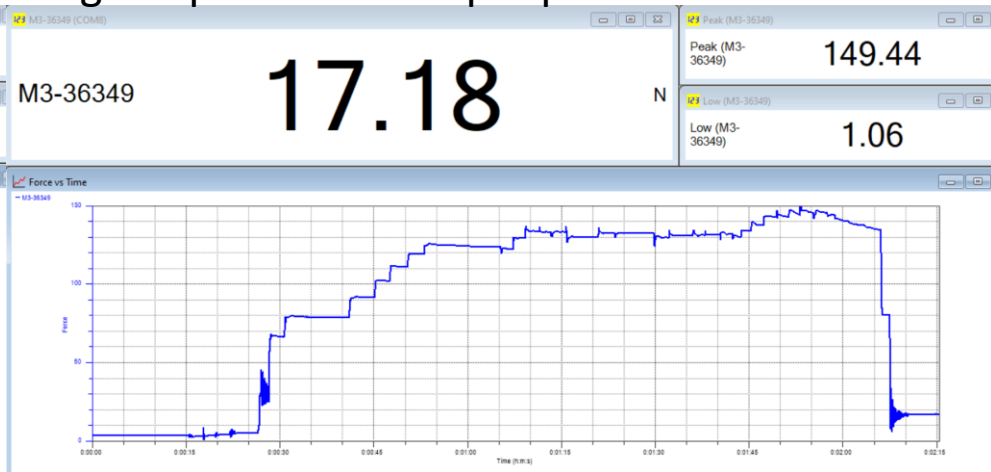
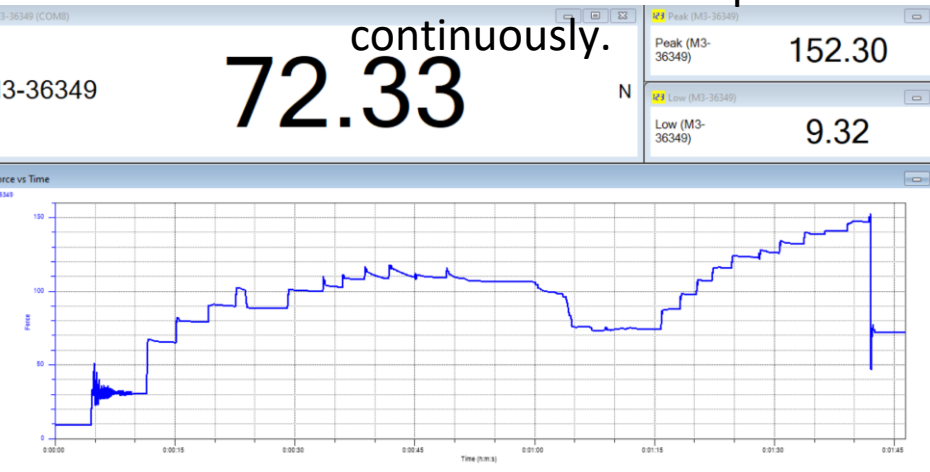


Increase by steps

The maximum value is dependent on the weight of the things to be pulled.

To initiate a step: the force applied is larger than the friction between feet and floor;

To initiate more steps: Have enough impulse to drive people to move continuously.



Findings:

- Here are the force plot of force generated by the spring system, but it is hard to generate multiple steps. Even though the force they could generate is much larger than expected and can reach what we want, the participant did not move as we wished. They always take one crossover step (around 160N) and feel that they require way more force to generate more steps.
- So, I went back to look at the values we got before and found that not only the maximum force, the magnitude of impulse ($F \cdot t$) should be considered as well. From the tests, I reached the idea that:

To initiate a step: the force applied is larger than the friction between feet and floor;

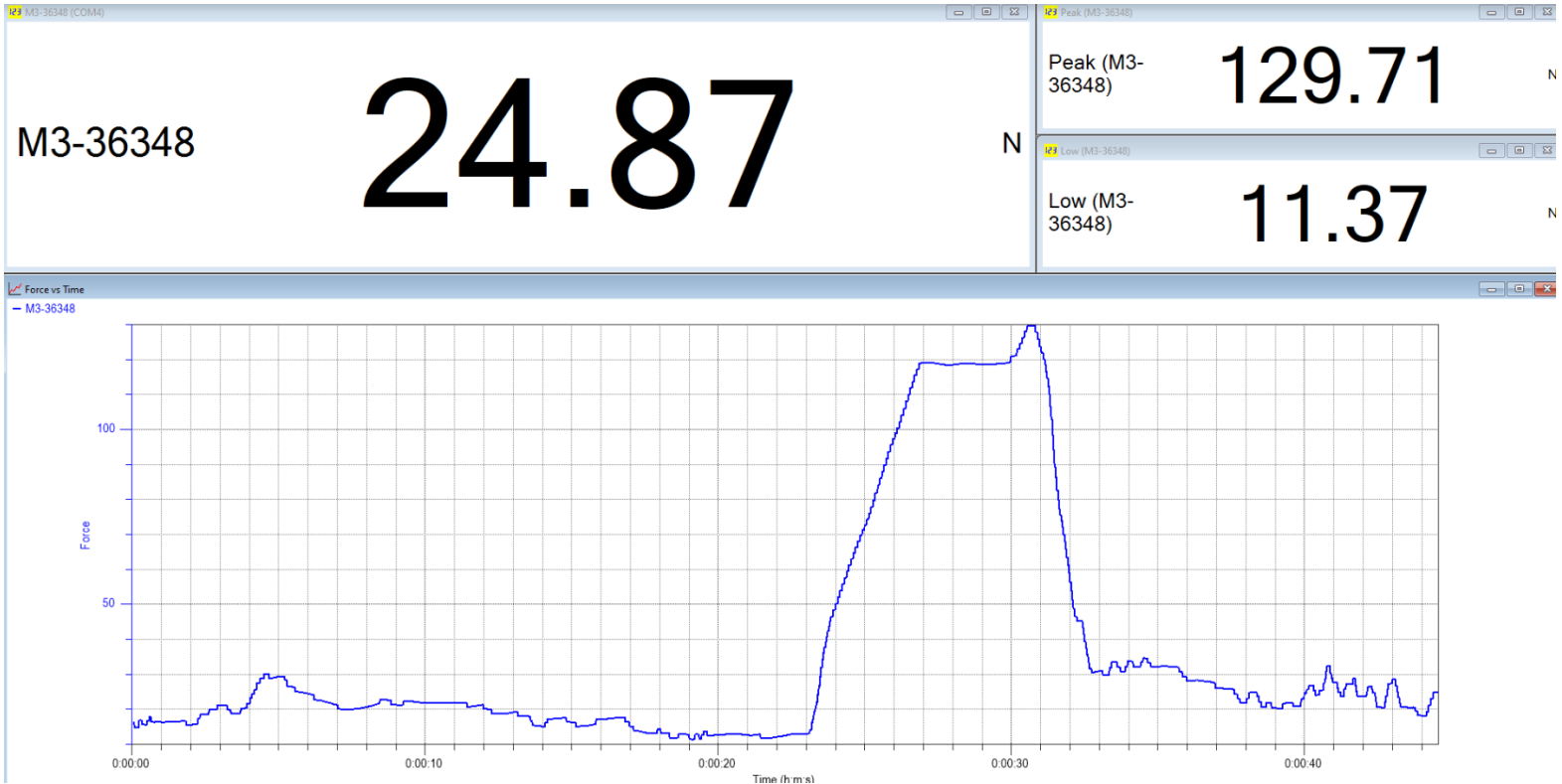
To initiate more steps: Have enough impulse to drive people to move continuously.

- The force plots are shown in the following pages:



Increase by continuous rotation & stop & release

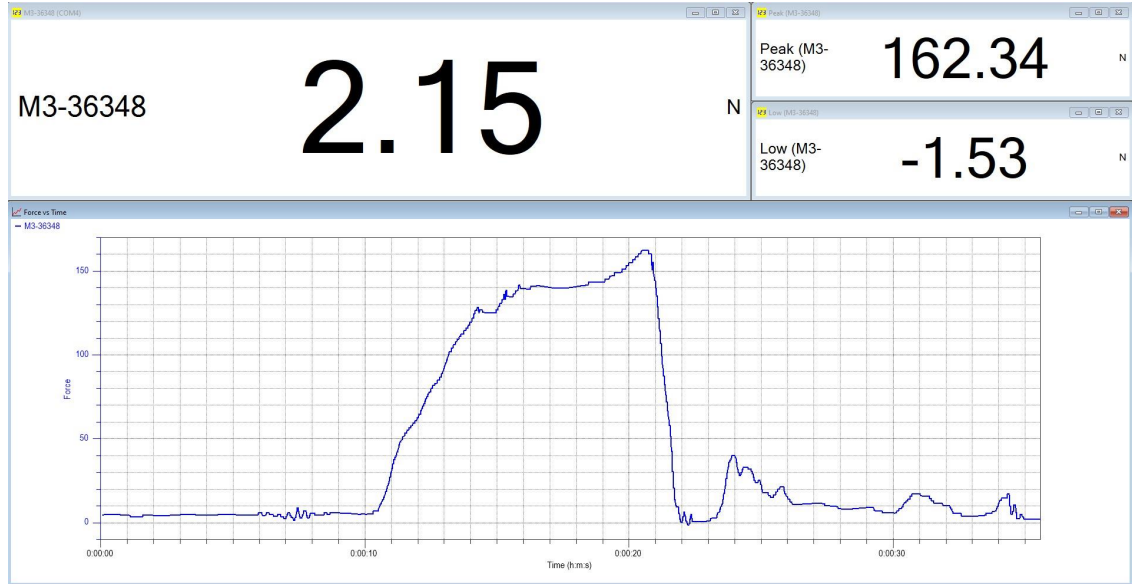
Pull side:



Increase by continuous rotation & stop & release

Pull side:

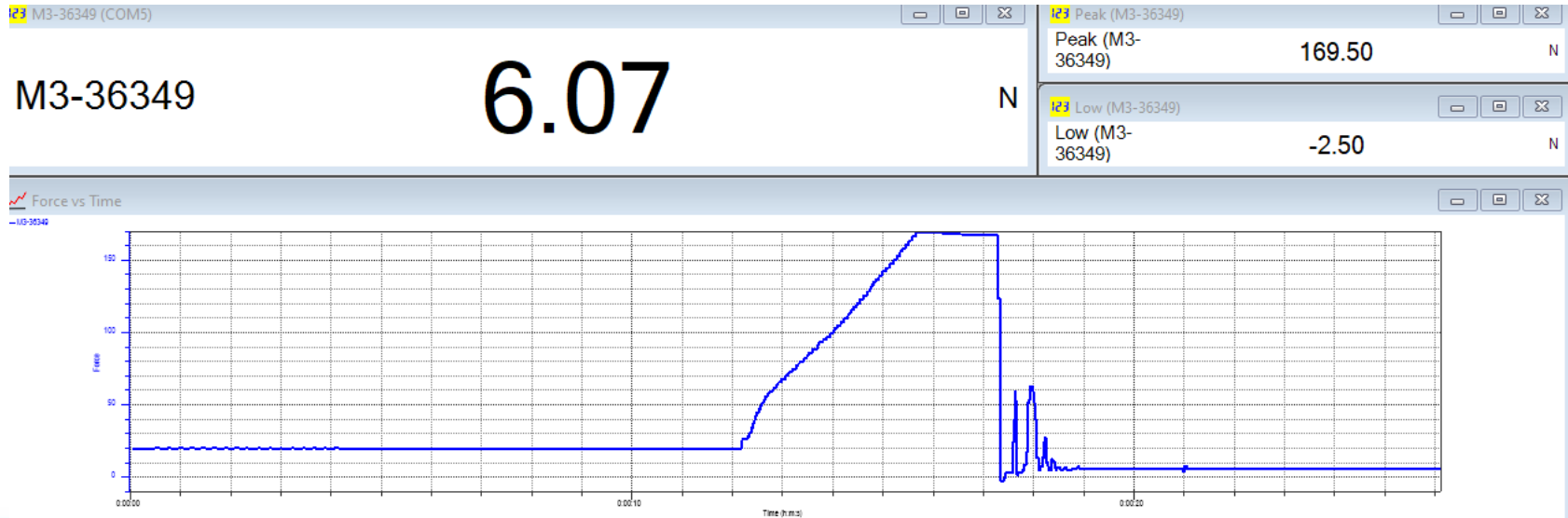
The problem is that, although the force is large enough, people make much less movement than being pulled by human using the same amount of force.



Increase by continuous rotation & stop_and_pull & release

So that, we tried first holding, and the pulling side's motor did not only stop, but rotate in the same direction with quick speed, tried to keep the force acts on the participant.

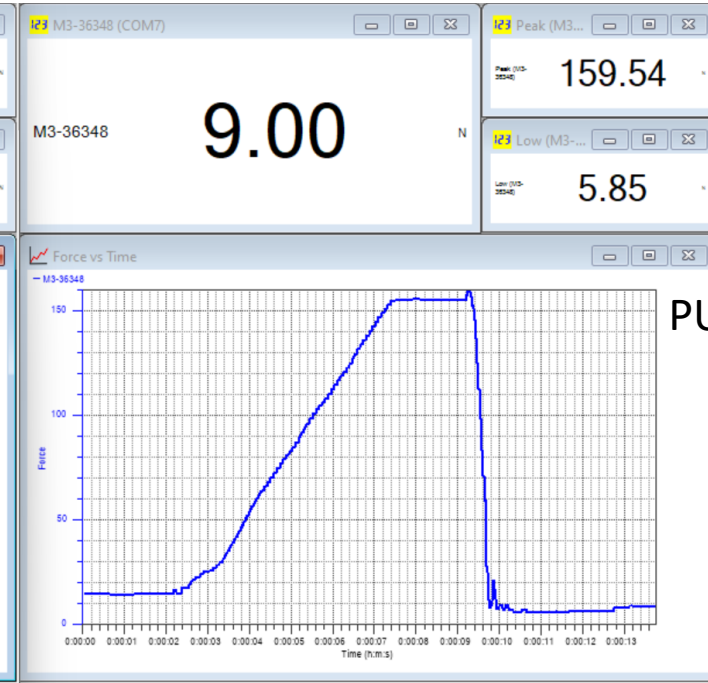
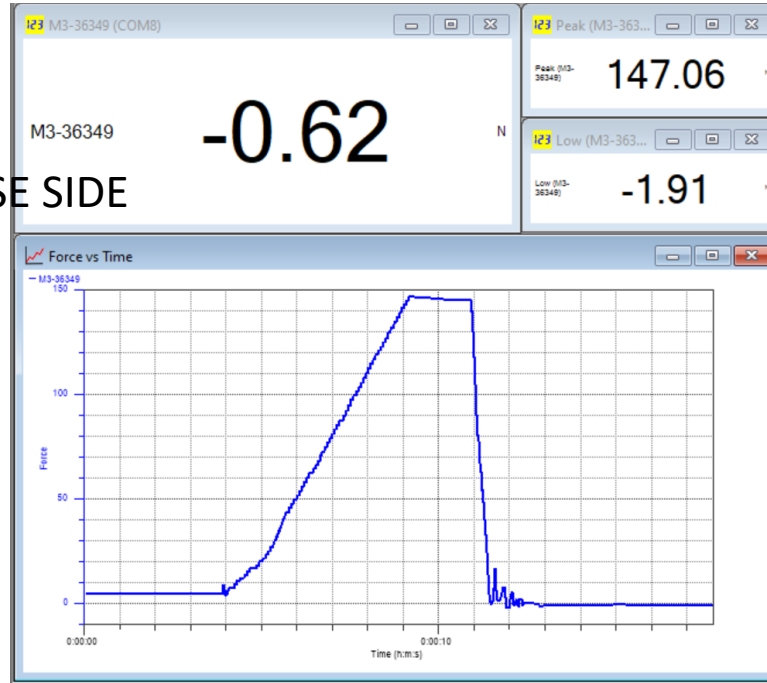
The speed to continue is hard to decide.



Increase by continuous rotation & stop_and_pull & release

People barely take one step to regain balance. They described the perturbation as “slow”

RELEASE SIDE

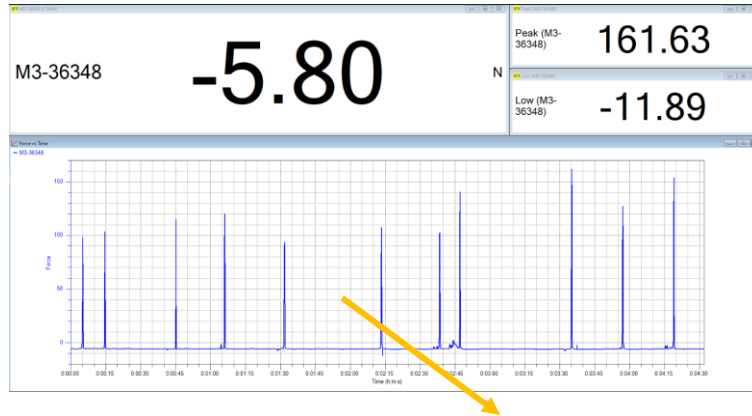


PULL SIDE

impulse

$$\mathbf{J} = \int_{t_1}^{t_2} \mathbf{F} dt = \Delta \mathbf{p} = m\mathbf{v}_2 - m\mathbf{v}_1$$

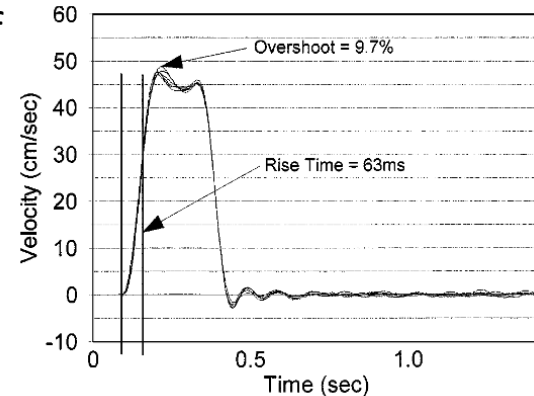
So, we need to control the time to control the magnitude of impact.



If we only looked at the force plot as these for pulling, we would think they are just instant force. But actually, they also have their work time as shown in the next page.

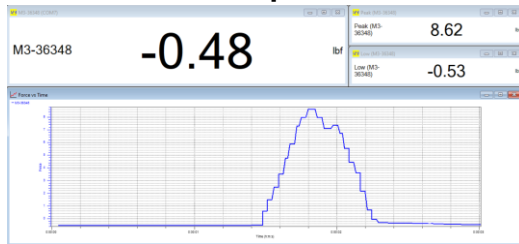
The force plot from other study to initiate steps:

Although They only listed the magnitude of the maximum force, from my perspective, the time also values.

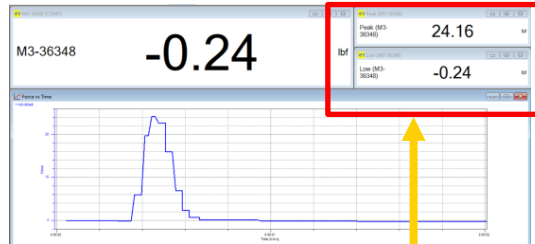


We did the experiment to decide the SST and MST for participant by pulling by hand. (unit in Lbf. In impulse calculation, I have transferred them into N) [Ns]

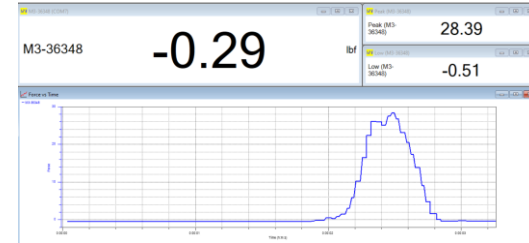
- One Step 15.336



- Larger Steps 16.1205

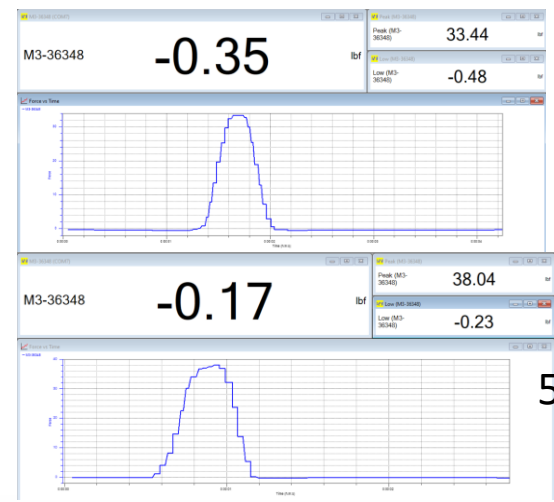
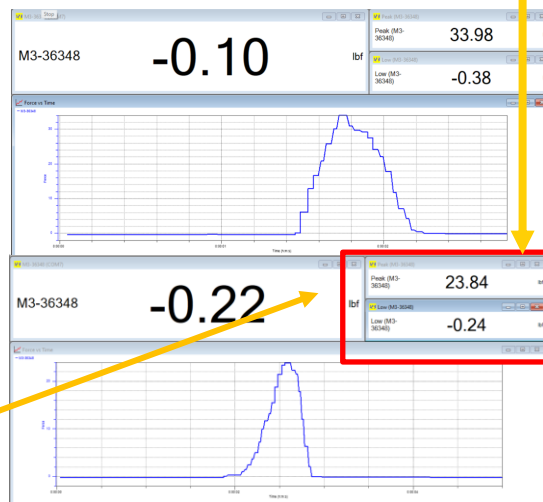


- Much Larger Steps 44.198



- Two Steps

Each impulse value is listed by the side. It solved my concern at the first stage that a small amount force could also generate two steps.



Increase by continuous rotation & stop & release

Pull side

M3-36348

2.15

N

Peak (M3-36348)

162.34

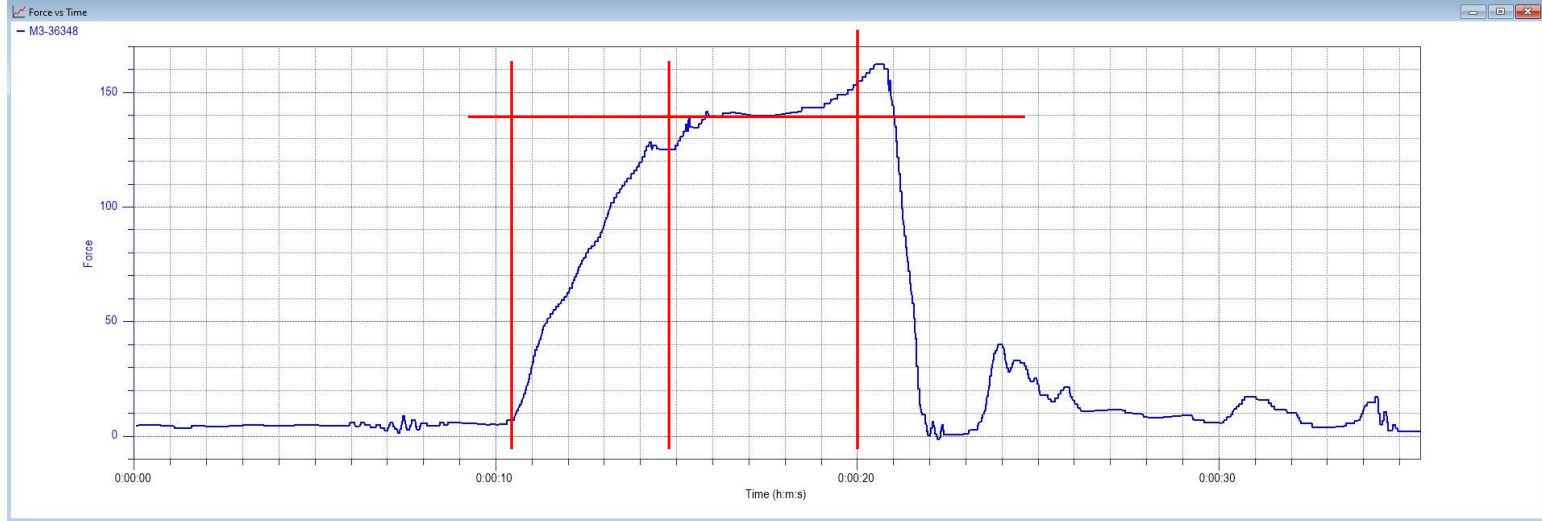
N

Low (M3-36348)

Low (M3-36348)

-1.53

N



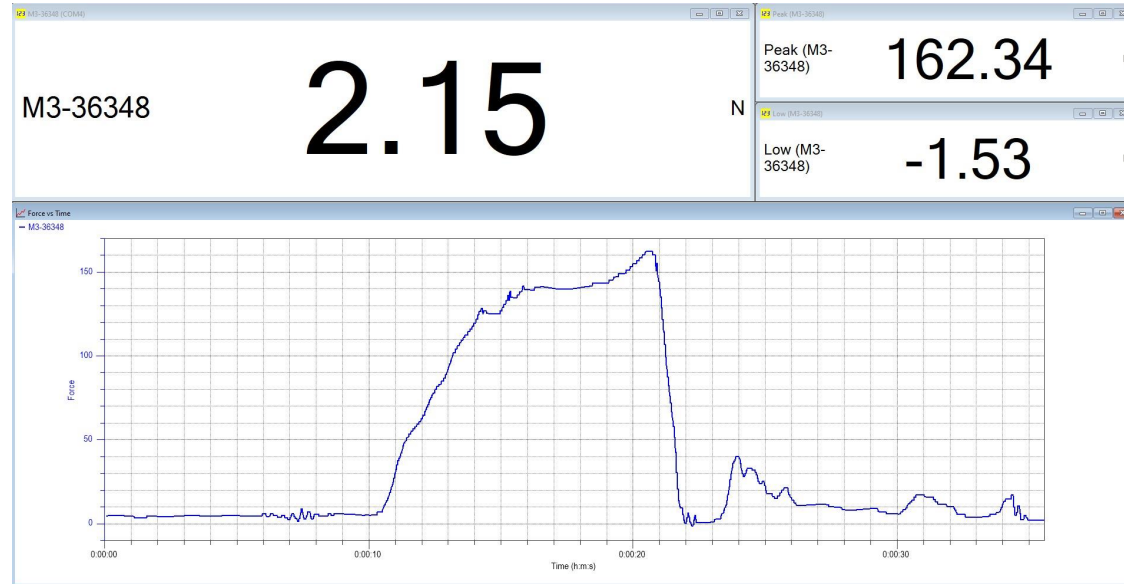
And we found that there is always a higher peak for the PULL side.

Increase by continuous rotation & stop & release

Pull side:

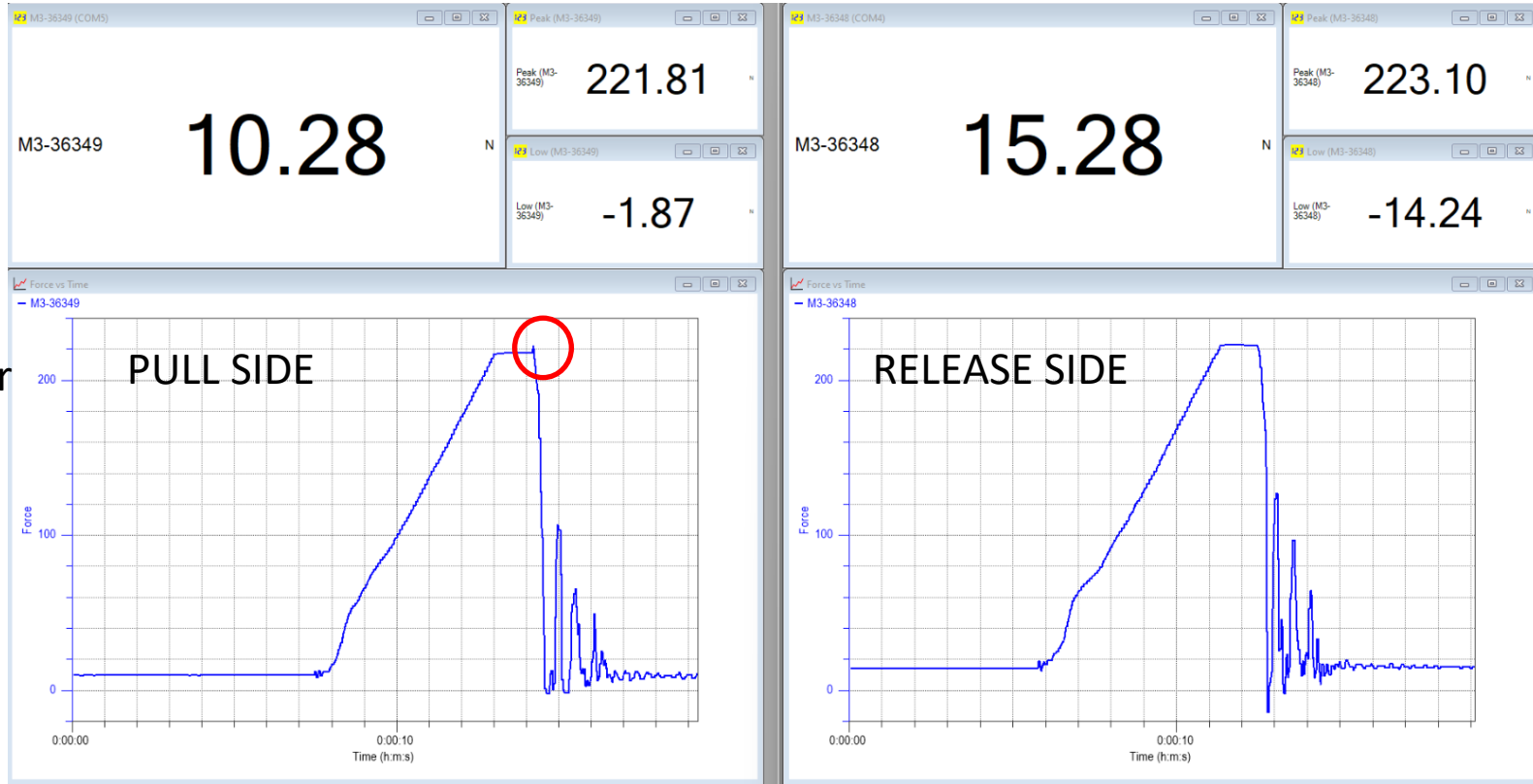
The problem for the spring system is that once people make a small movements to the pull side, the force will decrease really quickly. It's hard to pull continuously when the other side is released.

We tried to pull the pulling side continuously after reach that amount of force, but it can not be controlled very precise.

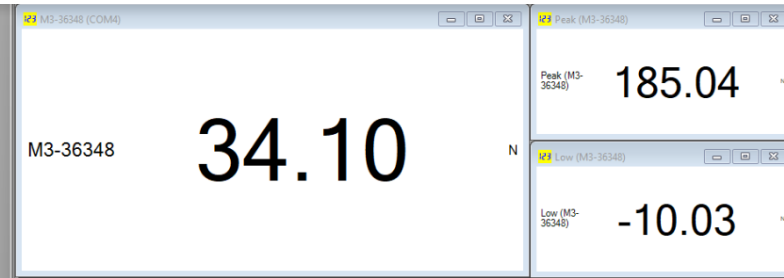
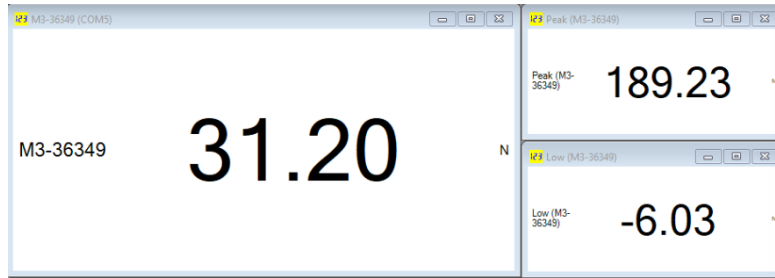


Increase by continuous rotation & stop_and_pull & release

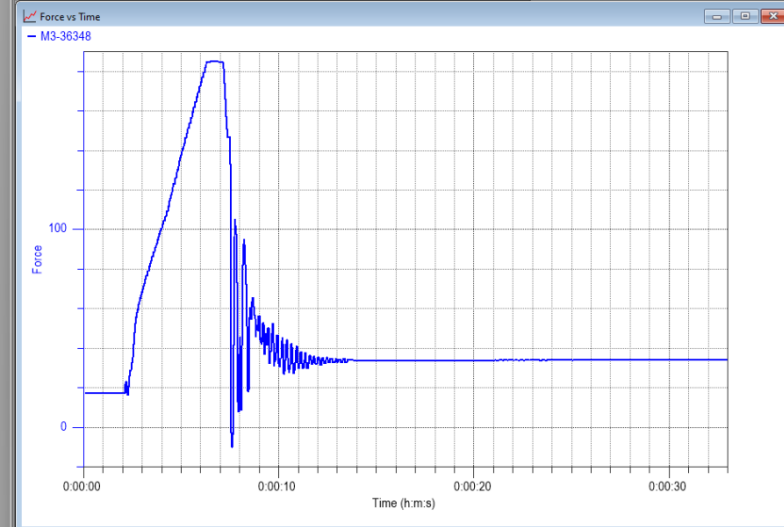
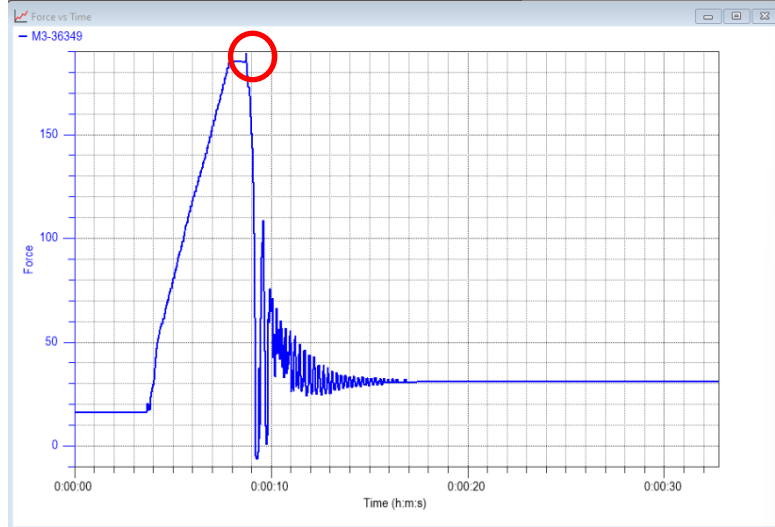
And we found that there is always a higher peak for the PULL side.



Increase by continuous rotation & stop_and_pull & release

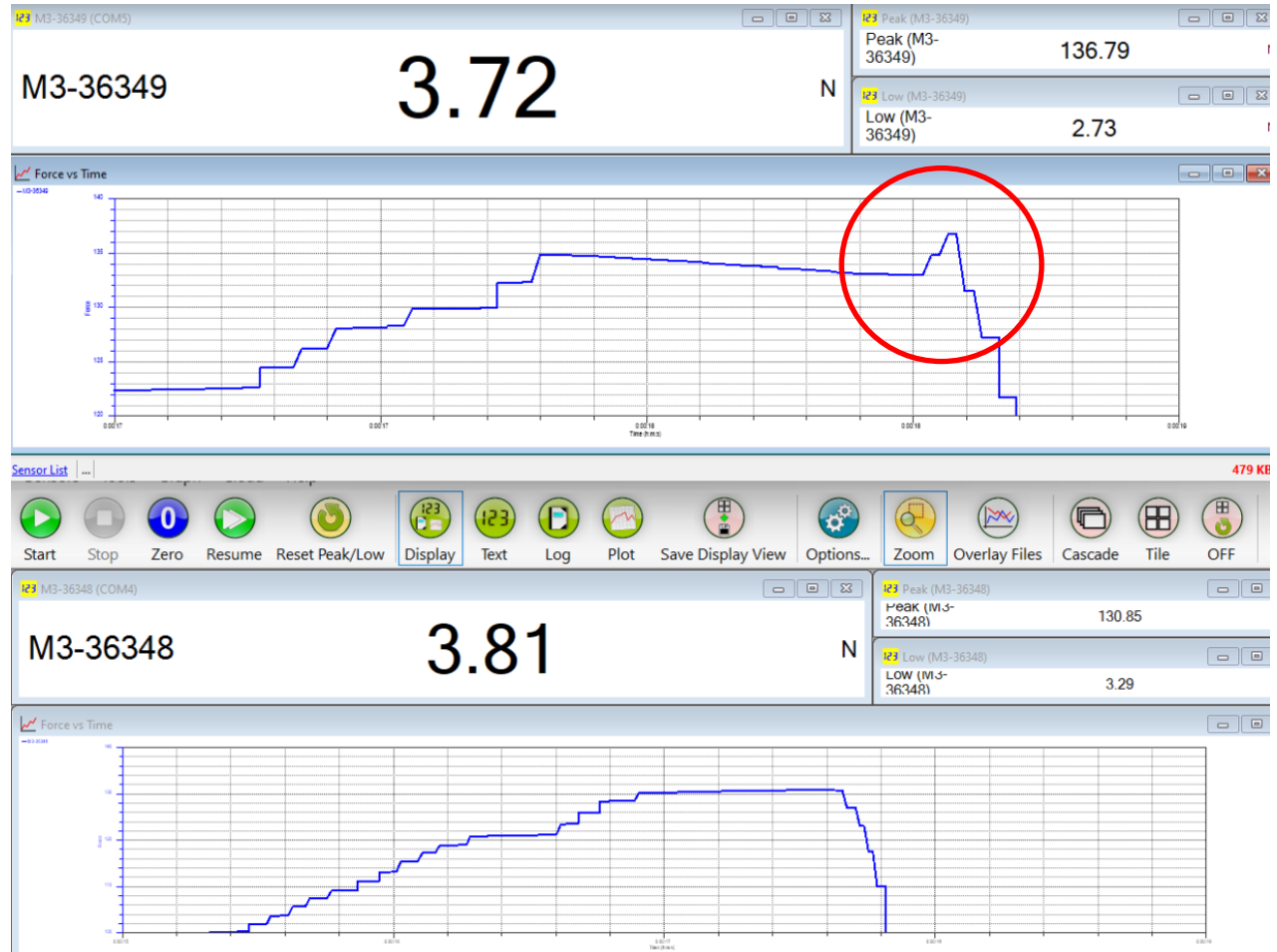


There is always a higher peak for the PULL side.



Increase by continuous rotation & stop_and_pull & release

There is always a higher peak for the PULL side.



APPENDIX 2

PROTOCOL DOCUMENT FOR HIP FUNCTION TESTING

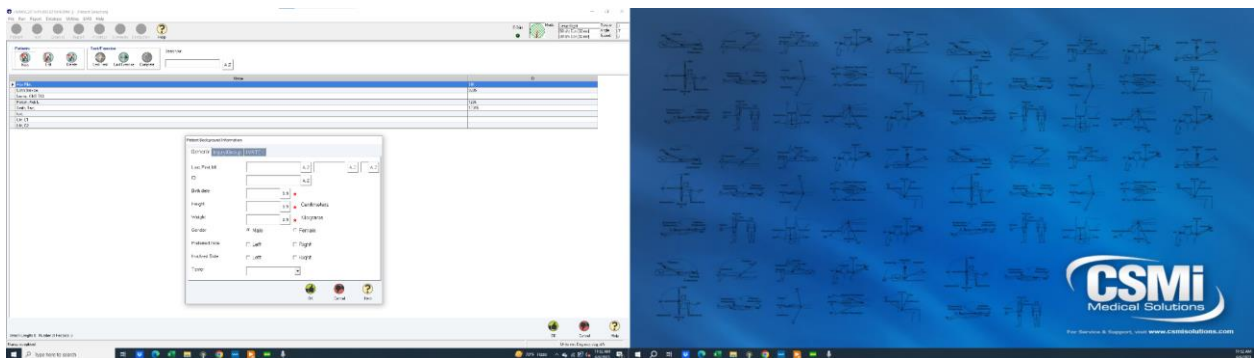
Participant testing order:

1. Hip abduction/adduction ROM
2. Hip flexion/extension ROM
3. Isometric Hip Flexion Maximal Torque
4. Hip abduction proprioception
5. Hip abduction isometric percentage torque
6. Repeat the protocol without prosthesis

☐ **Turn on gravity corrected data**

file-> preferences->data analysis->gravity corrected torque data

Establish new participant information



1. Hip abduction/adduction ROM

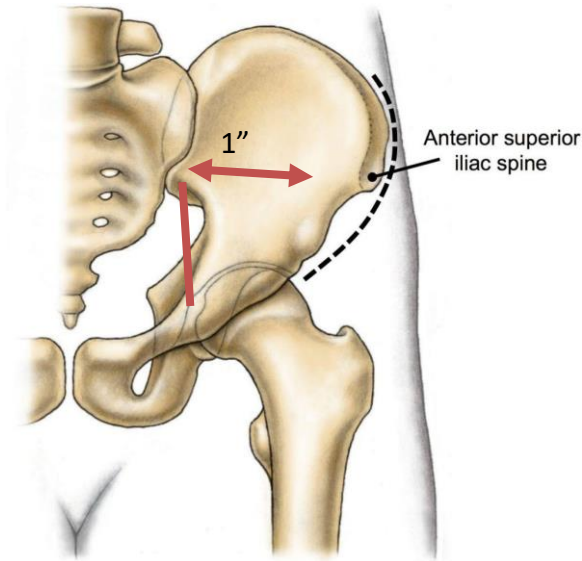
We will measure the hip's range of motion (ROM) in the frontal (abduction/adduction) and sagittal (flexion/extension) planes.

While standing beside the dyno, measure the **height of the hip joint**:

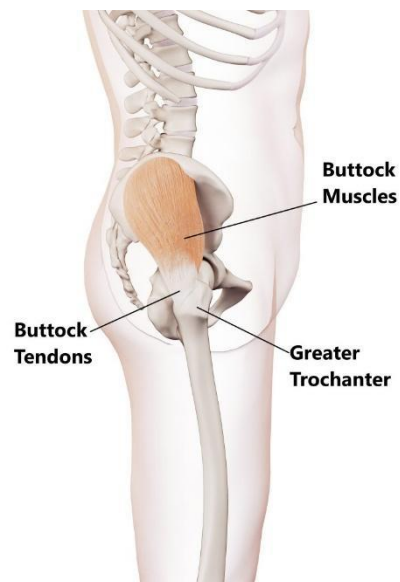
"I need to determine the position of your hip joint; for this, I want you to flex your prosthetic side hip. You will be standing on your sound side and if you need to stabilize, please hang on to the back of the chair. Is it alright if I palpate your hip to find the height measurement?"

- ☐ To locate the **hip joint center in the frontal plane**, for mediolateral, palpate the tested limb's **anterior-superior iliac spine** and move **an inch medially**. For the Vertical position, palpate **greater trochanter** and **move proximally until halfway between ASIS marker and**

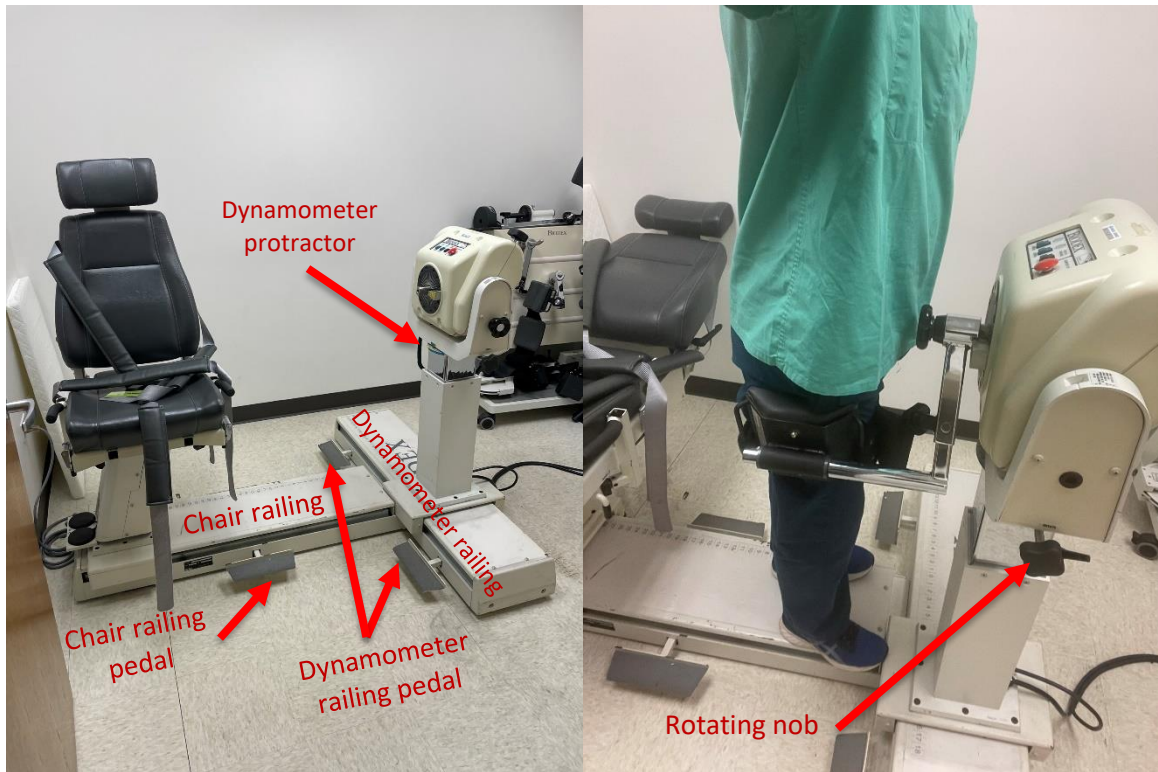
greater trochanter. Place sticker. Black dot on dyno axis will be aligned with this mark for frontal plane tests.



□ To locate the **hip joint center in the sagittal plane**, for Anteroposterior, palpate the center of the ipsilateral **femoral greater trochanter**; and vertically, **use the previously established hip height for frontal plane. Place green sticker.**



Turn the dynamometer by releasing the side nob (Rotating Nob). Turn the dynamometer, so it faces the chair. The **dynamometer protractor** should mark "0" deg.

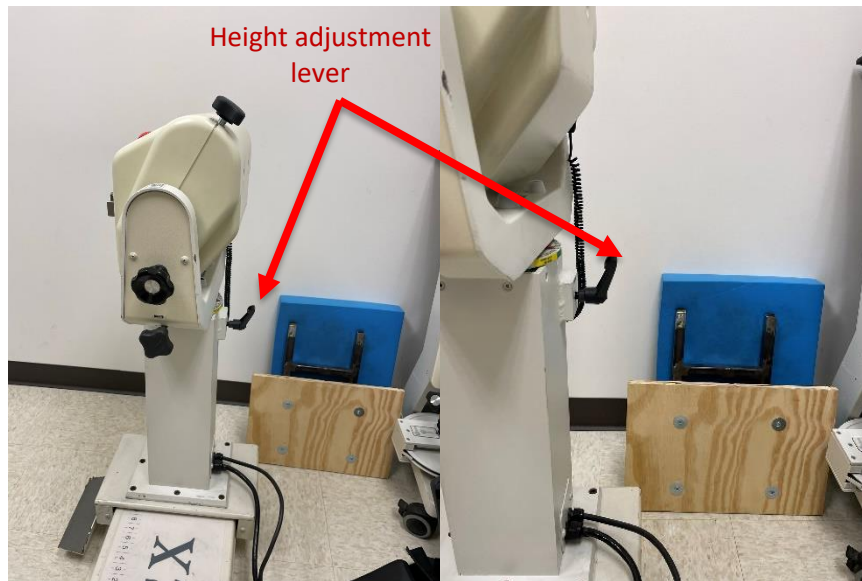


To adjust the dynamometer's height

Before raising the dynamometer, know that the device has an inch ruler. You will raise the dynamometer head to the value obtained, subtracting 30 from the height you measure for Hip joint height.

Turn and lose the **height adjustment lever** on the back of the dynamometer

Holding the head of the dynamometer, raise it to the established height



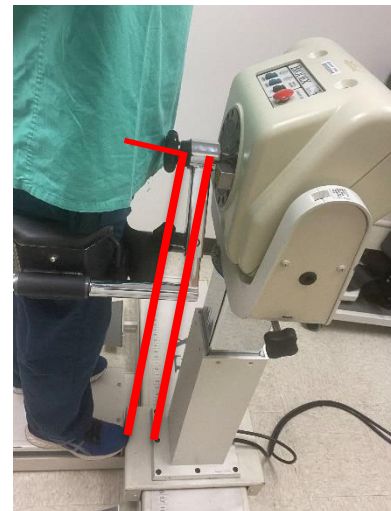
- ☐ Record dyno height on collection sheet.

Slide chair on rail close to dyno so participant can use for stability.

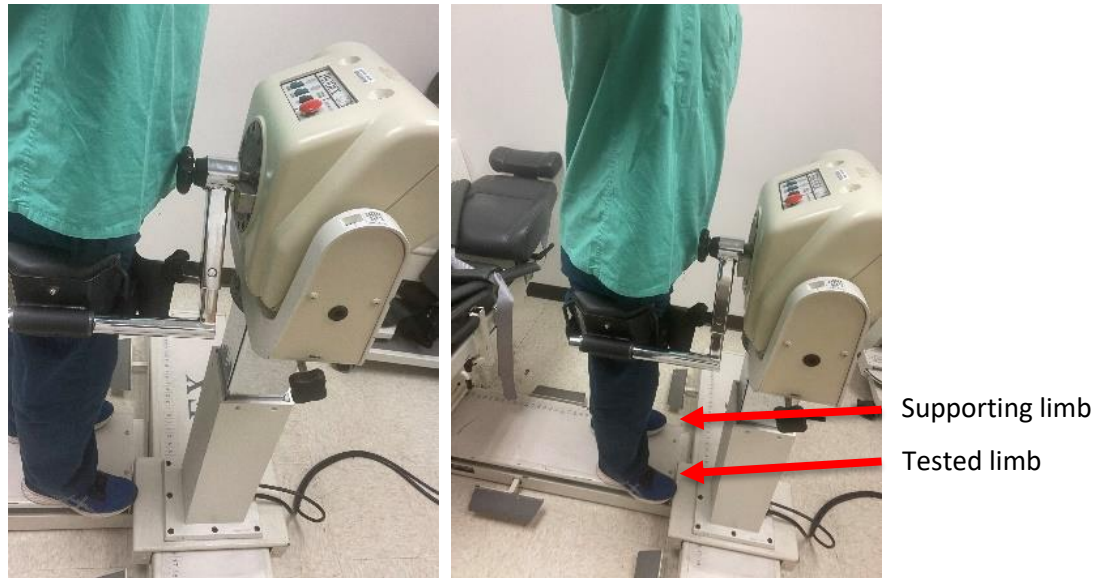
Participant Preparation

Ask the participant to step up to face the dyno using chair as support.

Once the **supporting leg** is well placed on the **ground**, align the **hip joint center (1.1)** with the **dynamometer arm's center**.



Wrap the attachment to the upper thigh so that the metallic arm is on the **lateral side of the thigh**. The attachment will not be vertical to the dynamometer. Make sure to wrap it tight but not pinch or cut blood flow, avoiding sliding movement of the limb with the padded area of the attachment on the lateral side of the limb. **Pad should be around midpoint of femur.**



"I will place this attachment on the device and strap it to your leg. Please let me know if it is too tight; it must be snug, but not pinching. Please use the back of the chair as support while I do this."

HUMAC Software Setup

From the main screen, go to **Dashboard**



Next, you will select the motion performed, and the joint tested. For this, click the **"Pattern"** button.

Dashboard Display: Isokinetic Con/Con Speed: 60/60 Con Torque: 675/675 Ecc Torque: 50/50

Pattern

☒ Knee Extension/Flexion

☐ Shoulder Internal/External Rotation in 90° Abduction

☐ Ankle Plantar/Dorsiflexion Supine

☐ Shoulder Abduction/Adduction

 Pattern

 Setup

Side

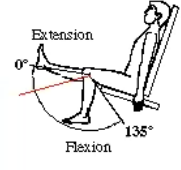
☐ Left ☒ Right

Anatomical Zero

 Set AZ

ROM Limits

Range of Motion



Software Stops

☐ Track Patient ROM

EXT 

FLX 

ROM

 Set ROM

 Clear ROM

Feedback

☒ Manual Settings

Mode and Action

Mode	Action	Speed
☐ CPM	☒ Con/Con	60
☐ Isometric	☐ Con/Ecc	60
☐ Isotonic	☐ Ecc/Con	50
☒ Isokinetic	☐ Ecc/Ecc	50

Ecc Trq

 Mode

Feedback

☐ Torque vs. Time Curves

☒ Torque vs. Position Curve

☐ Velocity vs. Time Curves

☐ Per-Rep Torque Bars

☐ Display Targets

 Feedback

Mechanical Stops

EXT FLX

Expand ROM

EXT			FLX		
☒ 0	☐ 10	???	☒ 0	☐ 10	???
☐ 20	☐ 30		☐ 20	☐ 30	

EMG

 Setup  Preview

 Exit

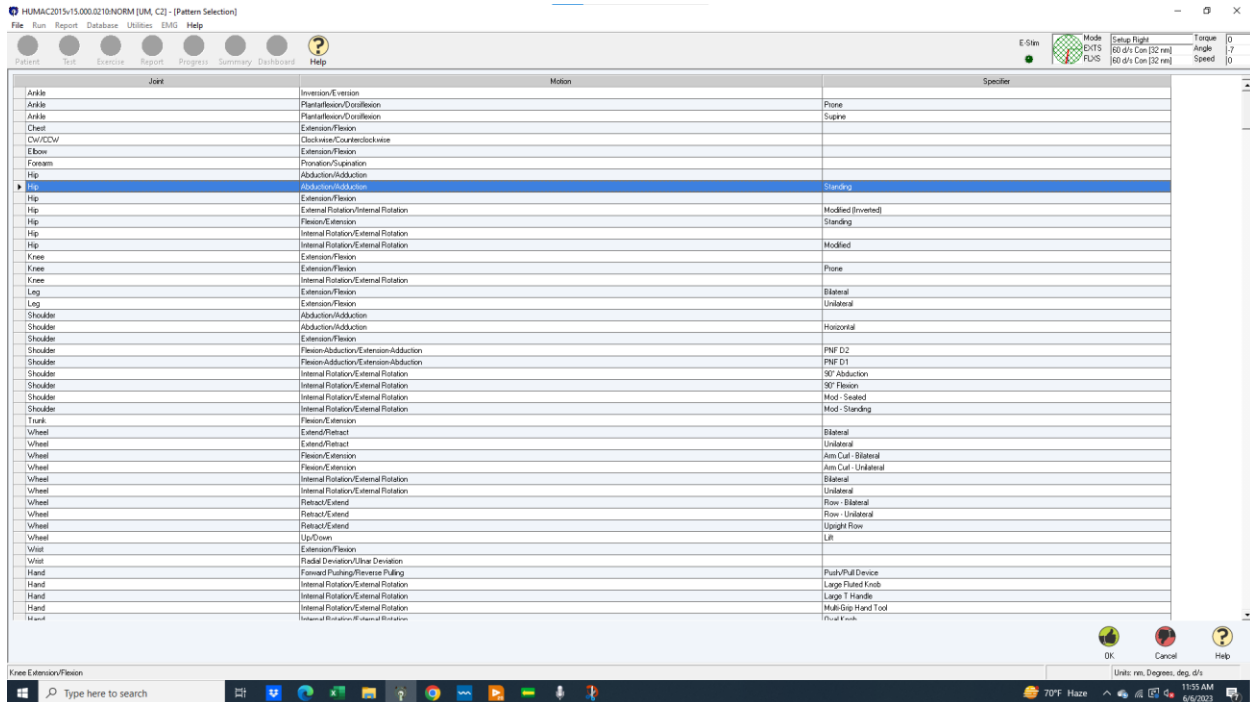
 Start

 Propriocep

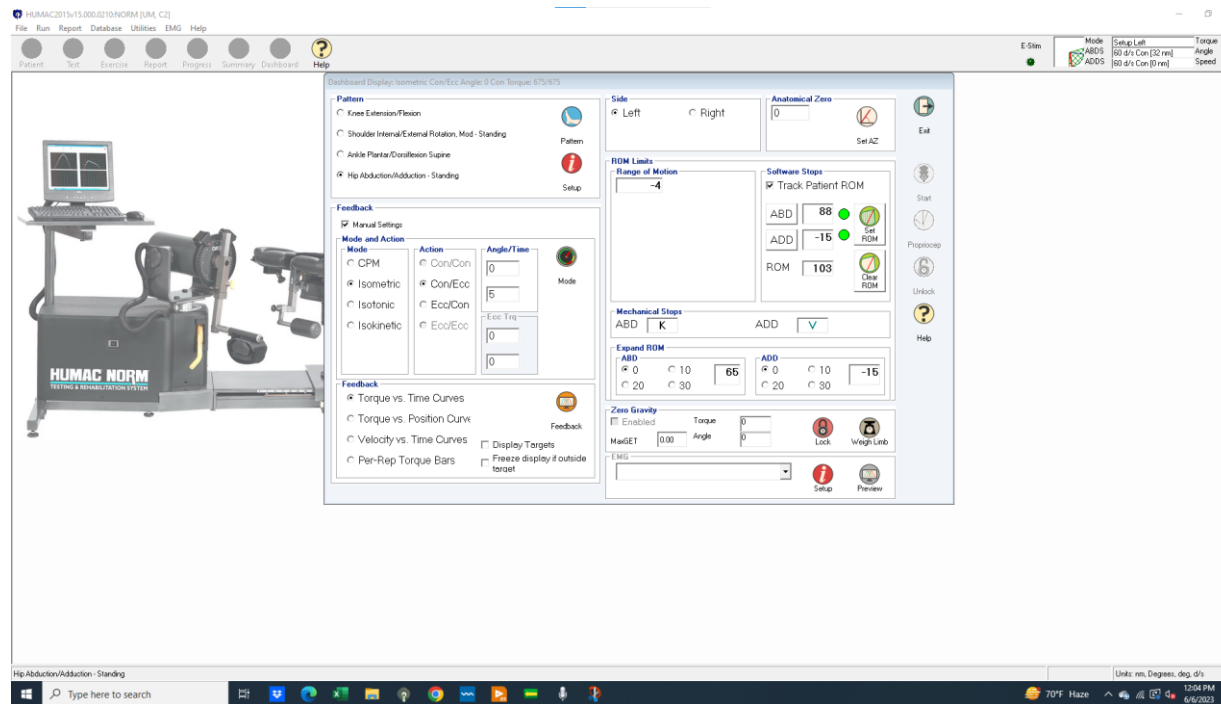
 Unlock

 Help

On the pop-up screen, select **Joint: Hip, Motion: Abduction/Adduction**



In the **Mode and Action** panel, located in the middle left of the Dashboard, select **Isometric mode**



Mode and Action			
Mode ☐ CPM ☒ Isometric ☐ Isotonic ☐ Isokinetic	Action ☐ Con/Con ☒ Con/Ecc ☐ Ecc/Con ☐ Ecc/Ecc	Angle/Time 0 5 Ecc Trq 0 0	 Mode

Then, on the top right panel, the **Anatomical Zero**, you can set up the angle for reference; the default is zero (0). Place the joint in the established position and press the "Set AZ" button. You can use a goniometer to make it consistent through the conditions

Anatomical Zero	
0	 Set AZ

The participant will be standing facing the dynamometer. Let the participant use the chair back as a support and make sure that the participant is standing straight (**not bending the trunk sideways or front to get the support**).



On the **Software**, located in the middle right of the Dashboard, check the **"Track Patient ROM."** This will allow tracking of the maximum motion of the participant's ROM. Ask the participant to abduct as far as they can and return to neutral (can do multiple times and dynamometer will track). They then can take a half step back if safe to get support leg away from the dyna arm to adduct and return to neutral position (can do multiple times and dynamometer will track).

Software Stops

☒ Track Patient ROM

ABD	???	●	
ADD	???	●	Set ROM
ROM			Clear ROM

"For this assessment, I want you to move your leg away from your body then back to center. You can do this multiple times. Each time concentrate on reaching the end of your possible motion without moving or twisting your body. Please feel free to support yourself on the machine but maintain a straight position without bending your torso sideways. "

"You will then take a slight step backward if you feel safe. You will cross your leg over your standing leg and then back to center. You can do this multiple times. Again, each time concentrate on reaching the end of your possible motion without moving or twisting your body. Please feel free to support yourself on the machine but maintain a straight position without bending your torso sideways. "

- ☐ **Record on collection sheet**
- ☐ Release thigh strap from participant.
- ☐ Relocate dyna arm to opposite side for flexion/extension testing.

2. Hip flexion/extension ROM

2.1 Participant Preparation

Ask the participant to carefully turn 90 degrees, so **the test limb** is nearest to the dynamometer.

"For this assessment, I want you to carefully turn 90 degrees, so your prosthesis side is next to the device. Make sure your supporting leg is secure and well-positioned on the ground and you can use the chair back for support."

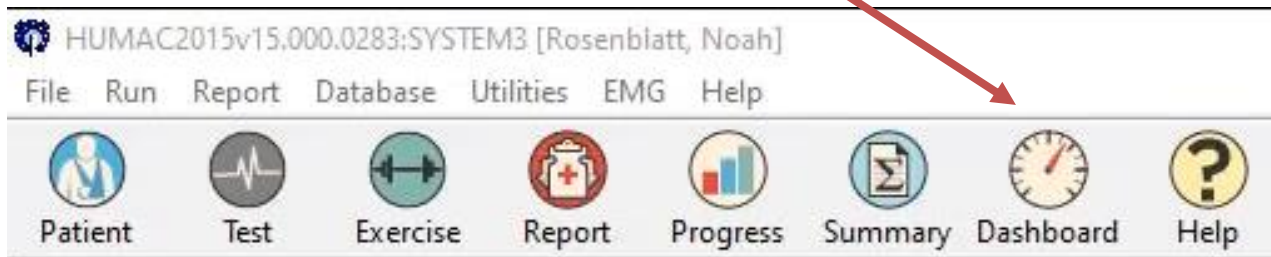
Align **the the center of the arm nob of the dynamometer** with the **hip joint center marked previously** (1.2).

"Now, I will align the dynamometer with your leg. I want you to support yourself with the chair."

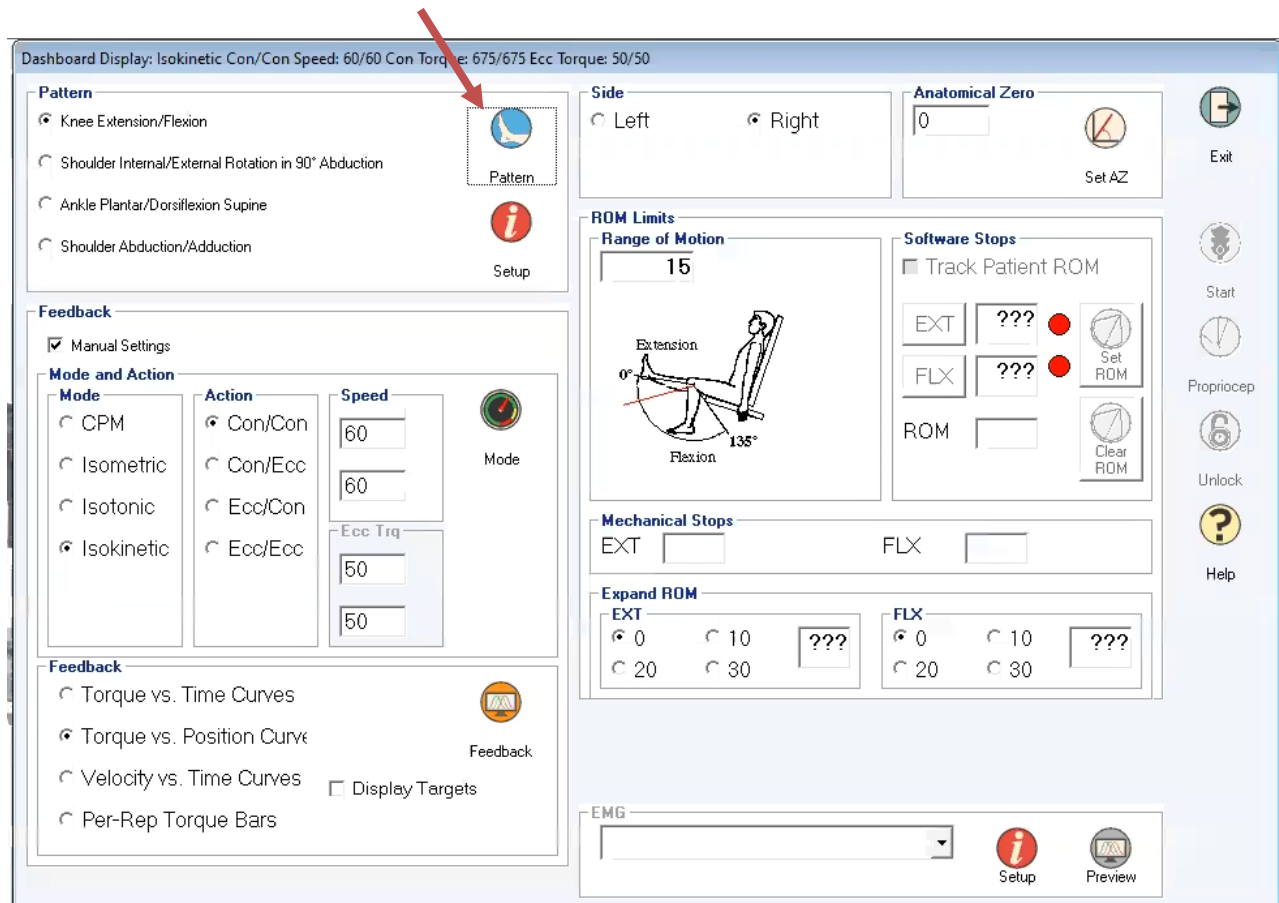
"I will place this attachment on the device and strap it to your leg. Please let me know if it is too tight; it must be snug, but not pinching. Please use the device as support while I do this."

HUMAC Software Setup

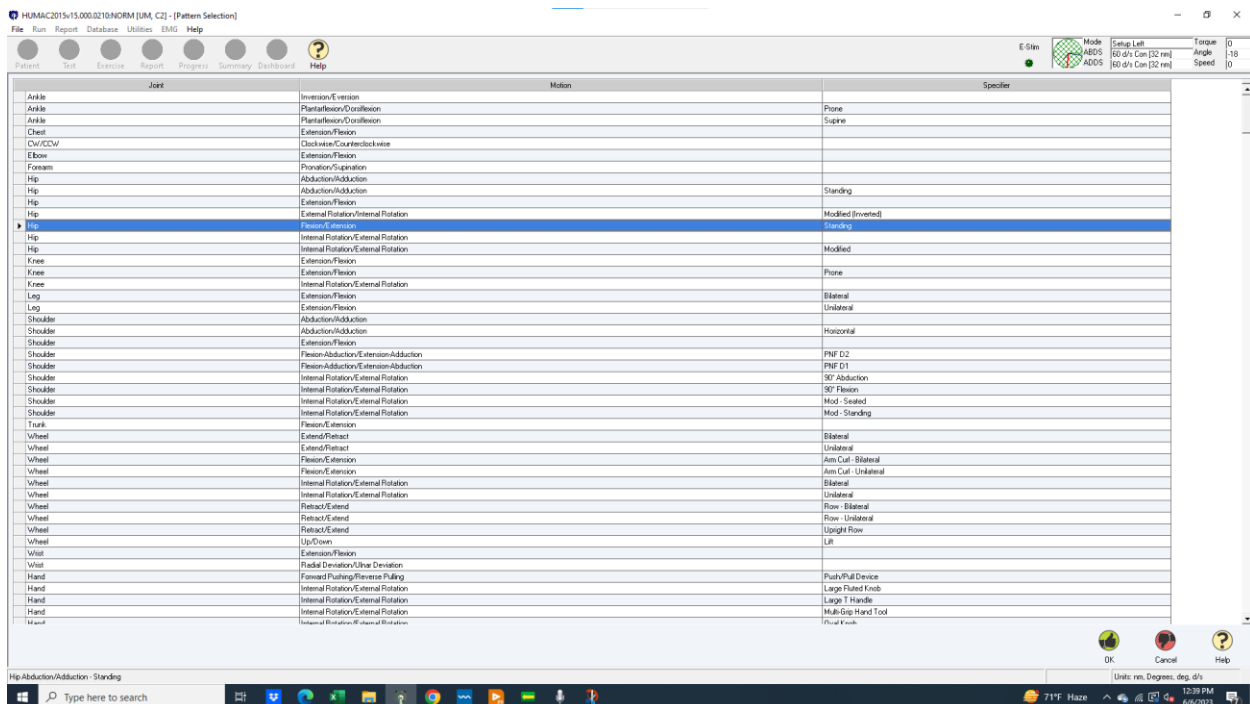
2.3 From the main screen, go to **Dashboard**



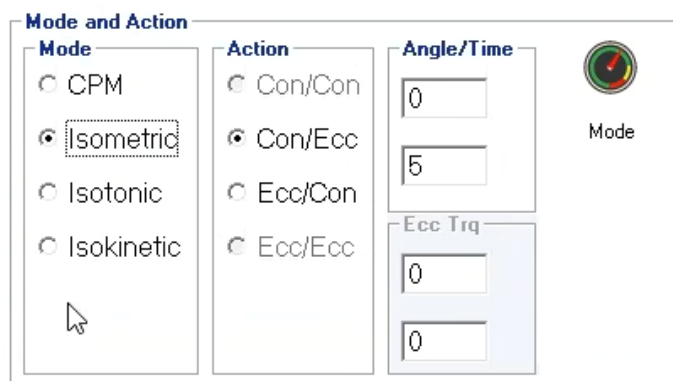
2.4 Next, you will select the motion performed, and the joint tested. For this, click the **"Pattern"** button.



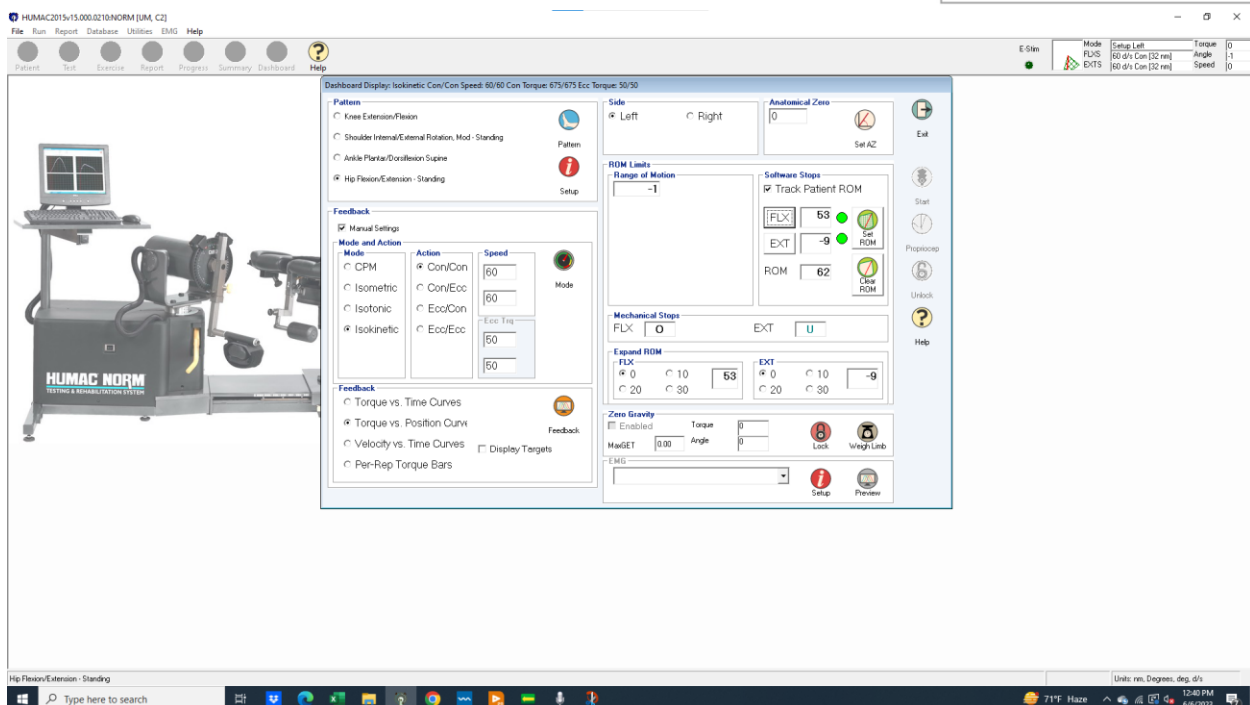
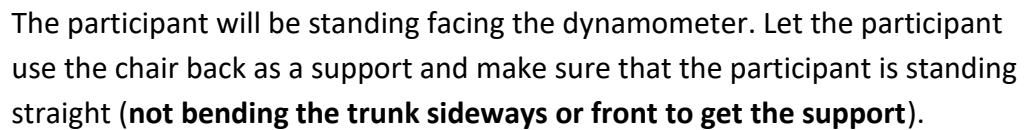
2.5 On the pop-up screen, select **Joint: Hip, Motion: Extension/Flexion**



2.6 In the **Mode and Action** panel, located in the middle left of the Dashboard, select **Isometric mode**



2.8 Then, on the top right panel, the **Anatomical Zero**, you can set up the angle for reference; the default is zero (0). Place the joint in the established position and press the **"Set AZ"** button. You can use a goniometer to make it consistent through the conditions



2.9 On the **Software**, located in the middle right of the Dashboard, check the "**Track Patient ROM.**" This will allow tracking of the maximum motion of the participant's ROM. Ask the participant to flex the hip as far as they can and return to neutral (can do multiple times and

dynamometer will track). Ask the participant to extend the hip as far as they can and return to neutral (can do multiple times and dynamometer will track).

"For this assessment, I want you to move your leg forward from your body then back to center. You can do this multiple times. Each time concentrate on reaching the end of your possible motion without moving or bending forward at the torso. Please feel free to support yourself on the machine, but maintain a straight position without bending your torso."

"Now you will extend your leg away from your body behind you and then back to center. You can do this multiple times. Again, each time concentrate on reaching the end of your possible motion without moving or bending your torso. Please feel free to support yourself on the machine, but maintain a straight position without bending your torso."

- ☐ **Record on collection sheet**
- ☐ Release thigh strap from participant.
- ☐ **RPE score**
- ☐ Break if needed

3. Isometric Hip Flexion Maximal Torque

Dyna Setup

3.1 Chair will need to be set flat and locked in. Orient head so the testing side is facing dyno arm. Lock chair rotation to 0°. Slide chair to 30. Back and seat completely flat. Participant will use step stool to get on chair and lay down. Strap upper body belts with snug fit (hip strap

around waist to ensure pelvis does not move). Lock dyno rotation at 0°, dyno arm will stay oriented with black dot on top and yellow handle on bottom, hip attachment will be slid in and locked from top, slide participant close to testing arm, can change dyno height and arm height, lock those in and record values on collection sheet, strap leg to dyno arm, can set up black stool if legs are hanging too far off the bed

Participant Preparation

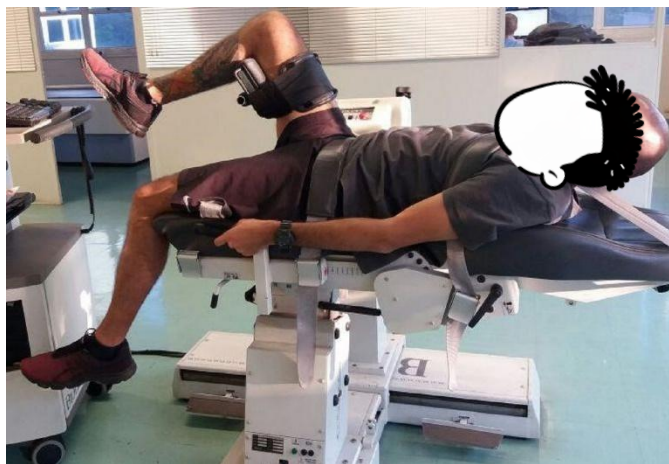
A. Ask the participant to step on stool and lay down on the flat chair, with the **Prosthesis side leg** closer to the dynamometer.

"For this test, I want to ask you to carefully climb to the chair and lay with your back down."

They may have to adjust their body position by scooting up or down to align the hip marker with the dyno arm.

B. Once the dynamometer and hip joint center are aligned, strap the participant in with the waist and shoulder straps ensuring a snug fit.

"I will put these straps on you. These straps will criss-cross your chest. Let me know if they are too tight."



C. Determine the dyno height and lock in. Secure the leg of the participant to the attachment. Ensure that the pad is over the **anterior portion** of the thigh and tight but not pinching.

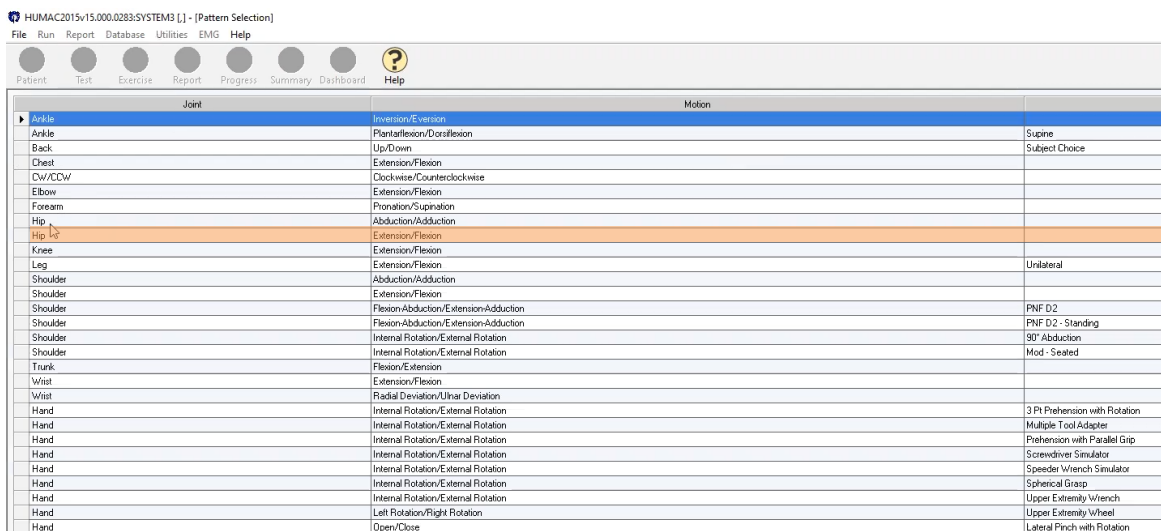
"I'm going to attach the device to your thigh. Please let me hold your leg to do it. This should be tight but not pinching, so let me know if it is too tight."

HUMAC Software Setup

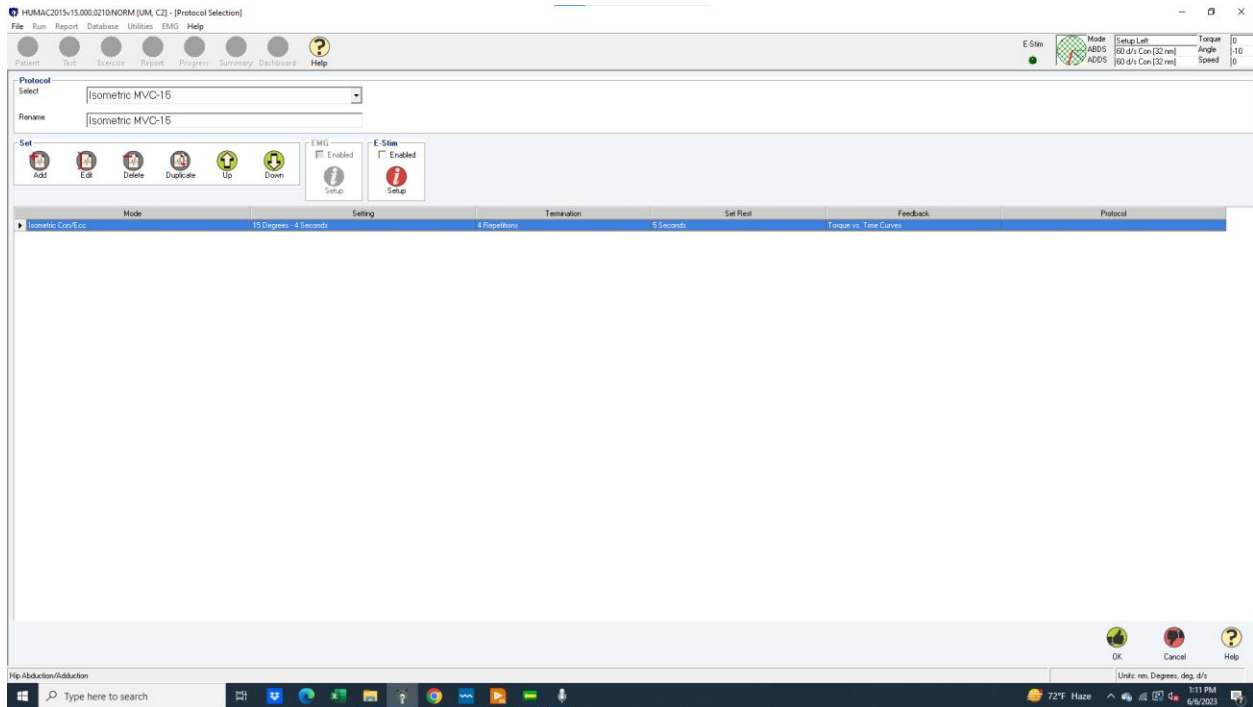
3.3 A. On the main screen, select **"Test."**



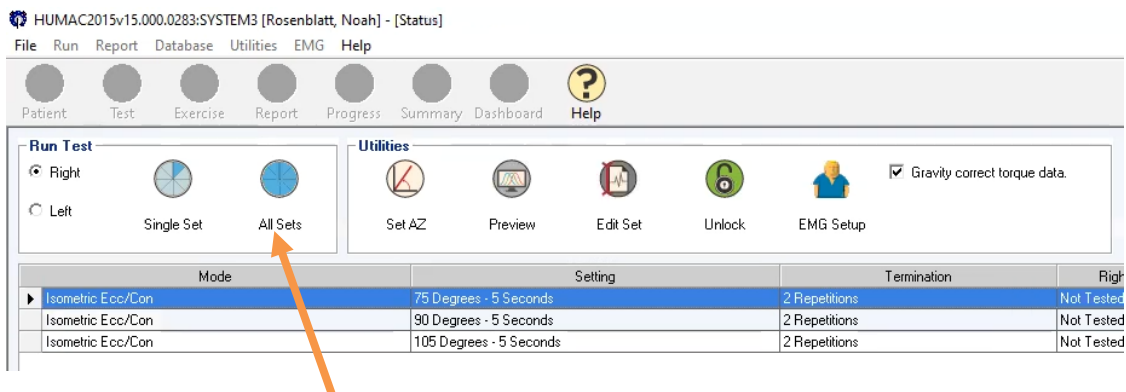
B. Select the Joint (**Hip**) and Motion (**Extension/Flexion**) from the list



C. Select the protocol **"Isometric 15 deg"** and press **"OK."**

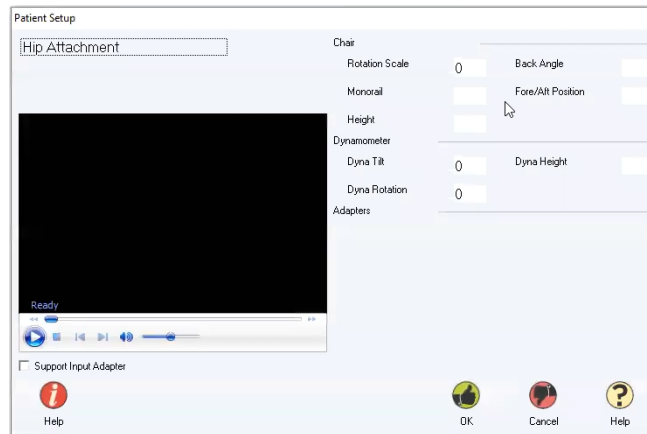


D. A new window will populate. The sets for the protocol will show here as stipulated in the protocol previously created. Press **"OK"**

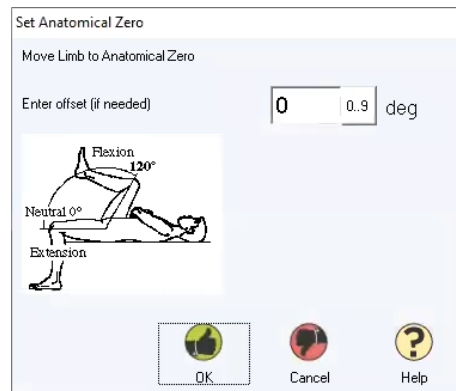


E. Press the **"All Sets"** button

F. Another window will show the configuration of the hardware. Ignore this screen and press **"OK."**



G. A new window will populate. On the participant, establish the neutral position "0" (extended leg, in a way that greater trochanter and knee are aligned and parallel to the floor) and press **"OK."** Use a goniometer to be consistent with your measurement



H. A window to set the ROM will populate. Press track patient ROM. Ask the participant to relax his leg over the chair and mark the extension by pressing the "EXT" button.

"I want you to relax your leg over the chair."

- I. Then request the participant to flex the hip to a comfortable point. You don't need a full flexion as in the ROM measurements. Make sure to have a range that complies with the minimum angle required (Flexion > 25°), but **do a functional ROM, not a full ROM**. Mark the flexion by pressing the "FLX" button. The "OK" button will turn green; push it.

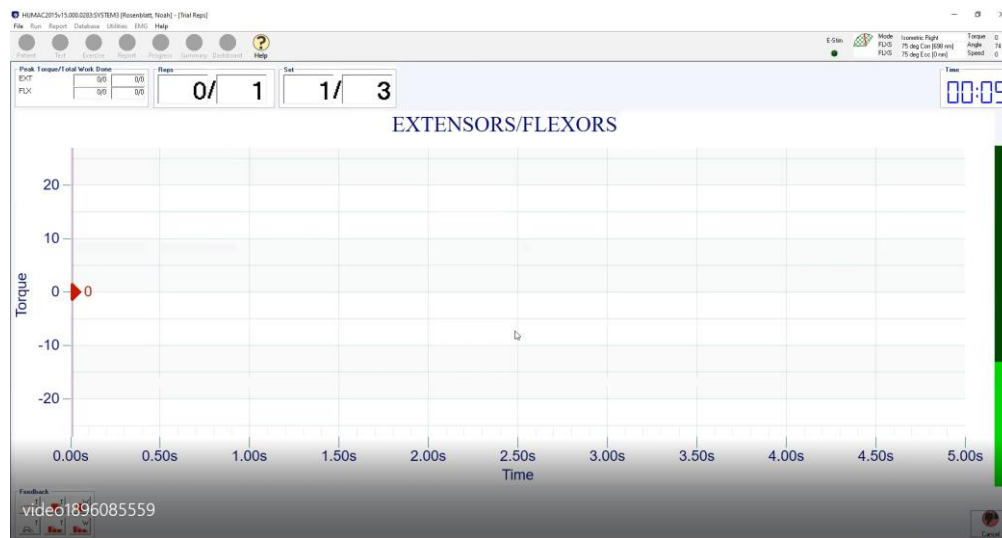
"I want you to flex your hip so your knee moves toward your chest. You will hold the leg there for 3-5 sec. You do not need to flex to your end range, just until you are comfortable. You should not feel strained during this."

J. A window will populate. The research will move the participant's leg until 15° is reached and then press the LOCK button. Ask the participant to relax the leg into the strap and press the "Weigh Limb" button.

☐ Record on collection sheet

WARNING: Give instructions to participant for next activity before pushing "OKAY" button because it will start immediately.

"I'm going to release your leg. You will drop to neutral, the computer will move you back to 15° then you will hear the beep to start your push."



Move to Next Position

Move to: 75

Current Position: -7

Cancel

Help

M. Once the test is done, you will return to the main screen (Step 5). Press the "OK"

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- ☐ Release thigh strap from participant.
- ☐ **RPE score**
- ☐ Break if needed

4. Hip abduction proprioception

Dynamometer Setup

- A. Same as above

Participant Preparation

- B. Chair same position as section 3, participant will be laying on non-testing side, position hip sticker in line with dyna testing arm. They may have to adjust their body position by scooting up or down to align the hip marker with the dyno arm.

"For this test, I want you to carefully lay on your side aligning your hip up with the black marker on the dynamometer. You will be facing the dynamometer."



- C. Adjust the dyna height to meet the joint center marked with the green sticker from section 1.

"I'm going to adjust the height of the dynamometer to your hip. For this, I will have to touch your hip. Do I have permission to do it?"

- D. Once the dynamometer and hip joint center are aligned. Strap the leg of the participant to the attachment. Ensure that the **pad is over the lateral side** of the thigh and tight but not pinching.

"I'm going to attach the device to your thigh. Please let me hold your leg to do it. This should be tight but not pinching, so let me know if it is too tight."

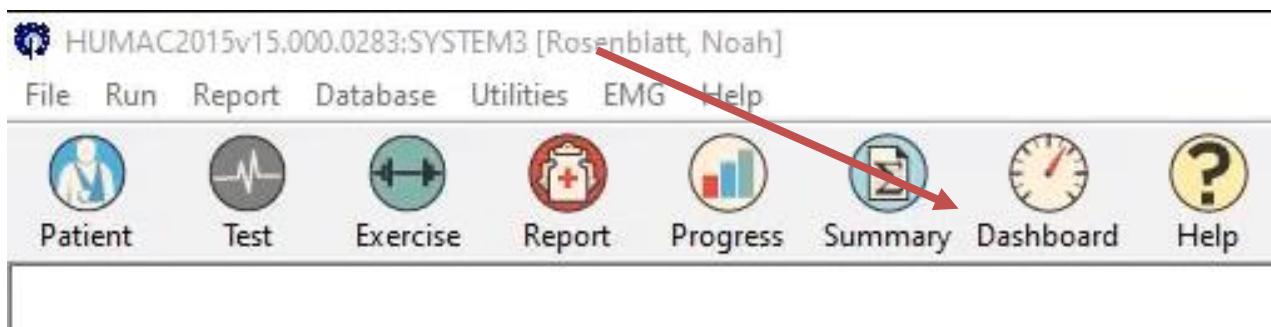
- E. Ask the participant to bend the bottom leg at the hip to 15 deg and the knee at 45 degrees partially and strap it to the chair

"I'm going to ask you to bend your bottom leg. I'm going to strap it, so it does not move. Tell me if it is too tight."

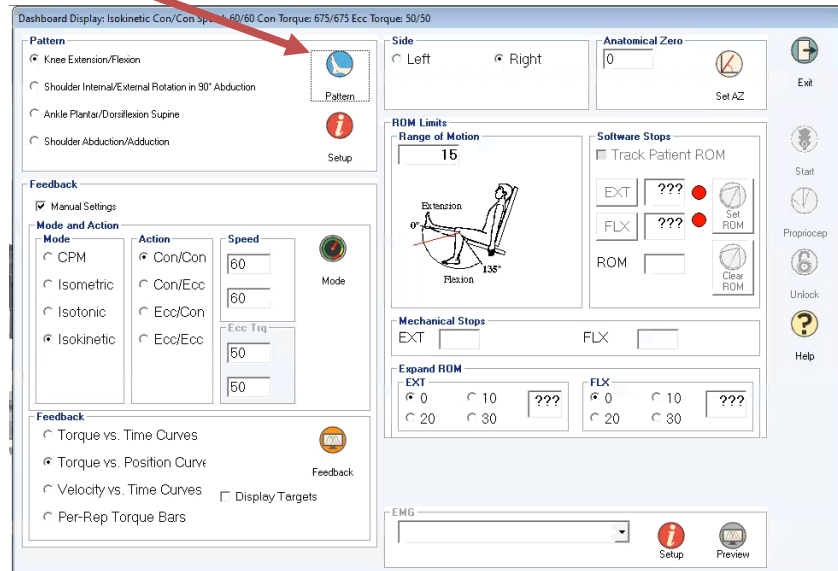
- F. Strap non-testing leg to the chair, strap back support wedge and upper body to chair.

HUMAC Software Setup

- G. From the main screen, go to **Dashboard**



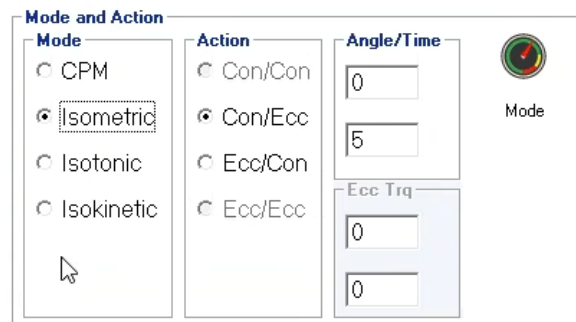
H. Click the "Pattern" button



I. On the pop-up screen, select Hip Abduction/Adduction

Joint	Motion	
Ankle	Inversion/Eversion	
Ankle	Plantarflexion/Dorsiflexion	Supine
Back	Up/Down	Subject Choice
Chest	Extension/Flexion	
Cw/CCw	Clockwise/Counterclockwise	
Elbow	Extension/Flexion	
Forearm	Pronation/Supination	
Hip	Abduction/Adduction	
Hip Int	Extension/Flexion	
Knee	Extension/Flexion	
Leg	Extension/Flexion	Unilateral
Shoulder	Abduction/Adduction	
Shoulder	Extension/Flexion	
Shoulder	Flexion/Abduction/Extension/Adduction	PNF D2
Shoulder	Flexion/Abduction/Extension/Adduction	PNF D2 - Standing
Shoulder	Internal Rotation/External Rotation	90° Abduction
Shoulder	Internal Rotation/External Rotation	Mod - Seated
Trunk	Flexion/Extension	
Wrist	Extension/Flexion	
Wrist	Radial Deviation/Ulnar Deviation	
Hand	Internal Rotation/External Rotation	3 Pt Prehension with Rotation
Hand	Internal Rotation/External Rotation	Multiple Tool Adapter
Hand	Internal Rotation/External Rotation	Prehension with Parallel Grip
Hand	Internal Rotation/External Rotation	Screwdriver Simulator
Hand	Internal Rotation/External Rotation	Speeder Wrench Simulator
Hand	Internal Rotation/External Rotation	Spherical Grasp
Hand	Internal Rotation/External Rotation	Upper Extremity Wrench
Hand	Left Rotation/Right Rotation	Upper Extremity Wheel
Hand	Open/Close	Lateral Pinch with Rotation

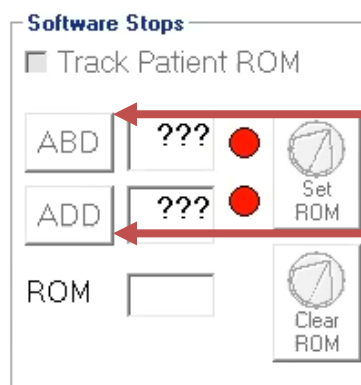
J. In Mode and Action, select Isometric mode



K. Have a helper abduct leg to neutral position then Press the **"Set AZ"** button.

L. Press the black button on the dynamometer to release the leg and ask the participant to relax the leg. On the **Software Stop**, press the **ADD** button.

"I want you to relax your leg over your other leg."

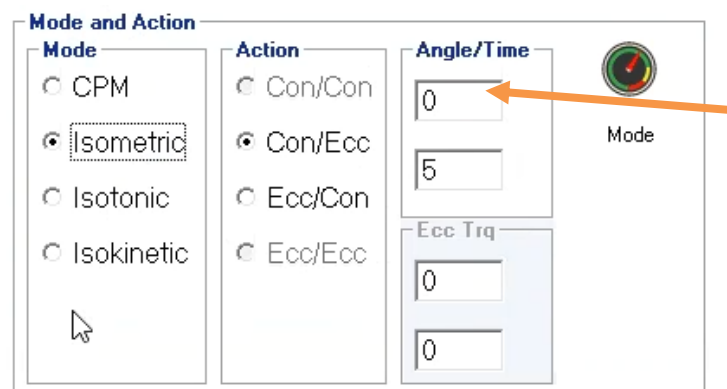


The 'Software Stops' window contains a checkbox for 'Track Patient ROM'. Below it are three rows of controls: 'ABD' with a '???' display and a red indicator light, 'ADD' with a '???' display and a red indicator light, and 'ROM' with an empty input field. To the right of these are three circular buttons: 'Set ROM' (top), 'Clear ROM' (middle), and a third button (bottom) with a circular arrow icon.

M. Grab the leg and raise less than 45 degrees, and lock it in place. Press the **ABD** button.

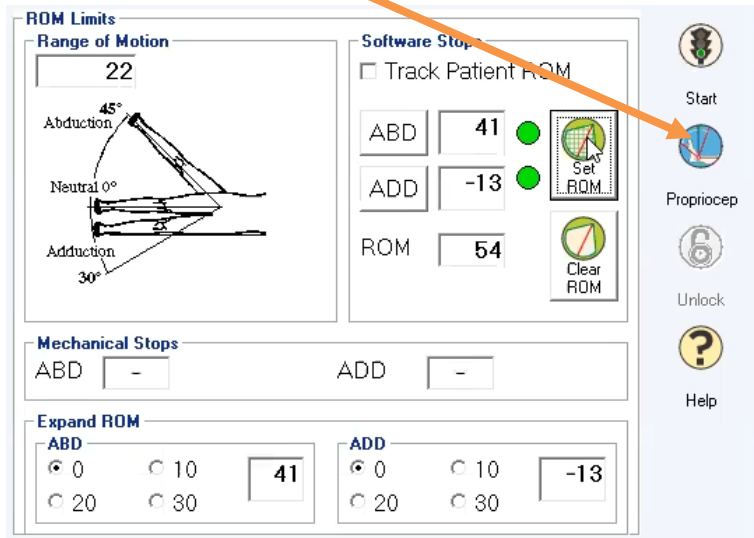
N. Press the Set ROM button. You will notice that the **"proprioception"** button activates.

O. In the Angle/Time, input the angle at which you want to establish the proprioception **(10,20,30,40)**

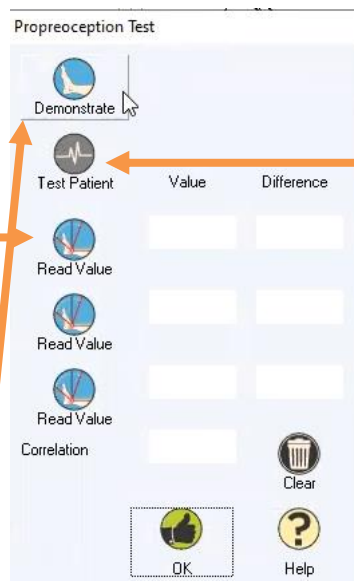


The 'Mode and Action' window is divided into three main sections. The 'Mode' section on the left has radio buttons for CPM, Isometric (which is selected and highlighted with a dashed border), Isotonic, and Isokinetic. The 'Action' section in the middle has radio buttons for Con/Con, Con/Ecc, Ecc/Con, and Ecc/Ecc. The 'Angle/Time' section on the right has two input fields: the top one is set to '0' and has an orange arrow pointing to it, and the bottom one is set to '5'. Below these are two more input fields for 'Ecc Trq', both set to '0'. A circular 'Mode' indicator is located to the right of the 'Angle/Time' section.

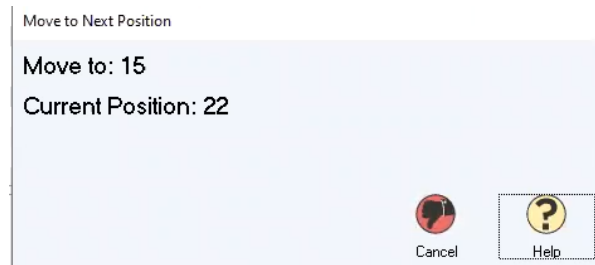
P. Press the **"Proprioception"** button. This button will be only accessible once the ROM has been established



Q. A pop-up window will show up



R. Press the **"Demonstrate"** button. This will bring a new pop-up window requesting to move the dynamometer to the angle requested. The device will lock in the position



"For this test, I want you to close your eyes. I will move your leg to a certain position and want you to try to remember how this position feels. Without opening your eyes, you will be asked to match this position afterward."

"Let me know when you are done memorizing the position so I can release your leg."

S. Let the participant feel the position with their eyes closed. Once the participant feels the position (Using internal focus), press the **"Test Patient"** button. This will release the leg

T. Request the participant to abduct to the previous position; when the participant tells you it is in place, press the lock button in the dynamometer and press the **"Read Value"** button. Release the leg from the lock position. **Repeat two more times.**

"Now I want you to move your leg to the position you just remembered and tell me when you think you have matched that position."

☐ **Record on collection sheet**

U. Change the angle value in step O. and repeat the process three more times. ***If the participant's ROM is lesser than any of these angles, please record it as non-achievable (n/a)***

V. Once you finish with the 4 positions, exit the Dashboard panel.

5. Hip abduction isometric percentage torque

Dynamometer Setup

5.1 Same as above for abduction testing

Participant Preparation

5.2 Same as above for abduction testing

HUMAC Software Setup

5.3 On the main screen, select "Test."



B. Select the Joint (**Hip**) and Motion (**Abduction/Adduction**) from the list

Joint	Motion	
▶ Ankle	Inversion/Eversion	
Ankle	Plantarflexion/Dorsiflexion	Supine
Back	Up/Down	Subject Choice
Chest	Extension/Flexion	
Cw/Ccw	Clockwise/Counterclockwise	
Elbow	Extension/Flexion	
Forearm	Pronation/Supination	
Hip	Abduction/Adduction	
Hip	Extension/Flexion	
Knee	Extension/Flexion	
Leg	Extension/Flexion	Unilateral
Shoulder	Abduction/Adduction	
Shoulder	Extension/Flexion	
Shoulder	Flexion/Abduction/Extension/Adduction	PNF D2
Shoulder	Flexion/Abduction/Extension/Adduction	PNF D2 - Standing
Shoulder	Internal Rotation/External Rotation	90° Abduction
Shoulder	Internal Rotation/External Rotation	Mod - Seated
Trunk	Flexion/Extension	
Wrist	Extension/Flexion	
Wrist	Radial Deviation/Ulnar Deviation	
Hand	Internal Rotation/External Rotation	3 Pt Prehension with Rotation
Hand	Internal Rotation/External Rotation	Multiple Tool Adapter
Hand	Internal Rotation/External Rotation	Prehension with Parallel Grip
Hand	Internal Rotation/External Rotation	Screwdriver Simulator
Hand	Internal Rotation/External Rotation	Speeder Wrench Simulator
Hand	Internal Rotation/External Rotation	Spherical Grasp
Hand	Internal Rotation/External Rotation	Upper Extremity Wrench
Hand	Left Rotation/Right Rotation	Upper Extremity Wheel
Hand	Open/Close	Lateral Pinch with Rotation

HUMAC©2015\15.000\0210NORM [JRM_C] - Protocol Selection

File Run Report Database Utilities EMG Help

Isometric Isometric Repetitive Progress Summary Dashboard ? Help

E-Stim Mode: AEDS AEDS Setup Flight: 60 d/s Con [727 nm] Torque: 1 T Angle: 38 Speed: 0

Protocol Select: Isometric 20-40-60-80% torque (4 blocks)

Reverse: Isometric 20-40-60-80% torque (4 blocks)

Set Add Edit Delete Duplicate Up Down E-MG Enabled F-Site Enabled Setup

Mode	Setting	Termination	Set Rest	Feedback	Protocol
▶ Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	60 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	60 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	60 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	
Isometric ConvEcc	15 Degrees - 2 Seconds	5 Repetitions	4 Seconds	Per Rep Torque Bars	

OK Cancel ? Help

Units: rev, Degree, deg, d/s

11:17 PM 4/6/2023

HUMAC2015v15.000.0283:SYSTEM3 [Rosenblatt, Noah] - [Status]

File Run Report Database Utilities EMG Help

Patient Test Exercise Report Progress Summary Dashboard Help

Run Test

☒ Right ☐ Left

Single Set All Sets

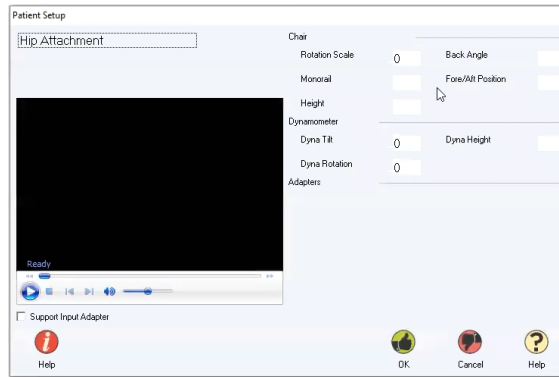
Utilities

Set AZ Preview Edit Set Unlock EMG Setup

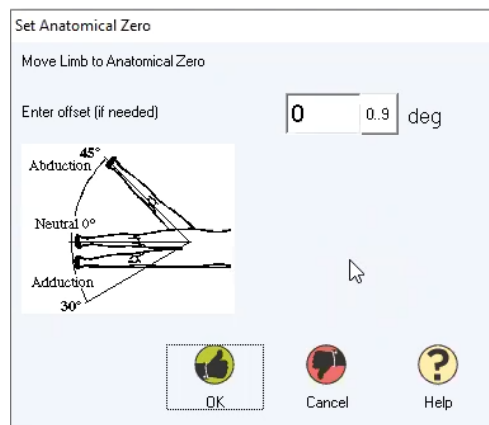
☒ Gravity correct torque data.

Mode	Setting	Termination	Right
Isometric Ecc/Con	75 Degrees - 5 Seconds	2 Repetitions	Not Tested
Isometric Ecc/Con	90 Degrees - 5 Seconds	2 Repetitions	Not Tested
Isometric Ecc/Con	105 Degrees - 5 Seconds	2 Repetitions	Not Tested

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F. Using the goniometer (inclinometer), move the leg to be straight, establishing the 0 degrees of joint position. Press the black button on the top of the dynamometer to lock the limb in place. Press the "OK" button.



G. A window to set the ROM will pop up. Ask the participant to relax his leg over the other leg and mark the adduction by pressing the **"ADD"** button.

"I want you to relax your leg over your other leg."

Set ROM Limits

Range of Motion
Position 4

45°
Abduction
Neutral
Adduction
30°

Software Stops
☐ Track Patient ROM

ABD 27 Set ROM

ADD -10 Clear ROM

ROM 37 Mirror ROM

Mechanical Stops
ABD
ADD

OK Cancel Help

H. Then request the participant to raise the leg to a comfortable point; you don't need a full abduction as in the ROM measurements. Make sure to have a range that complies with the minimum angle required (abduction > 15deg), and **do a functional ROM, not a full ROM**. Mark the abduction by pressing the **"ABD"** button. Then press the **"Set ROM"** button and then **"OK."**

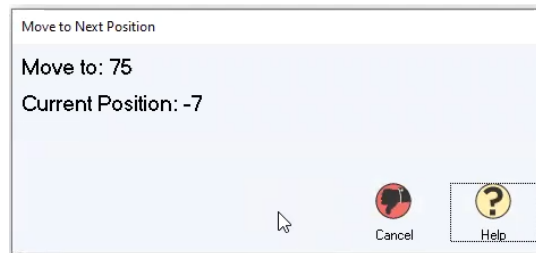
"I want you to raise your leg as high as possible without rotating your leg or body, so you still feel comfortable. Let me know when you are in that position, and I will lock it in position."

- I. A window will pop up. Set the leg at ~15 deg and press the **"Lock"** button. Ask the participant to relax the leg and press the **"Weight Limb"** button. Press the **"OK"** button

"I will move your leg to a position and lock it there. I want you to relax your leg." Need to give verbal warning that machine will move their leg into place

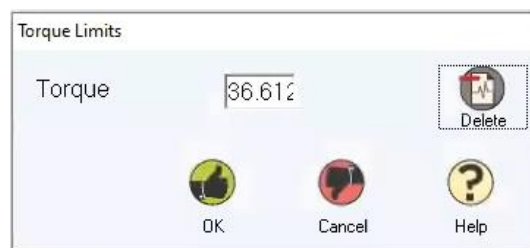


J. If the leg does not release when you press the "OK" button, release the leg by pressing the black button in the dynamometer. A window will appear to set the leg at 15 deg. The machine will move automatically, and the window may show very fast.



K. A new window will show to measure the torque limits. First, press the **"Delete"** button, and ask the participant to raise the leg as hard as possible and hold for 3 seconds. Repeat for 4 total reps with a rest in between ~ 1 minute. Record the readings on the collection sheet. The reading will only change if the current push is higher than the previous. The higher force will be maintained by the computer. Press **"OK"**

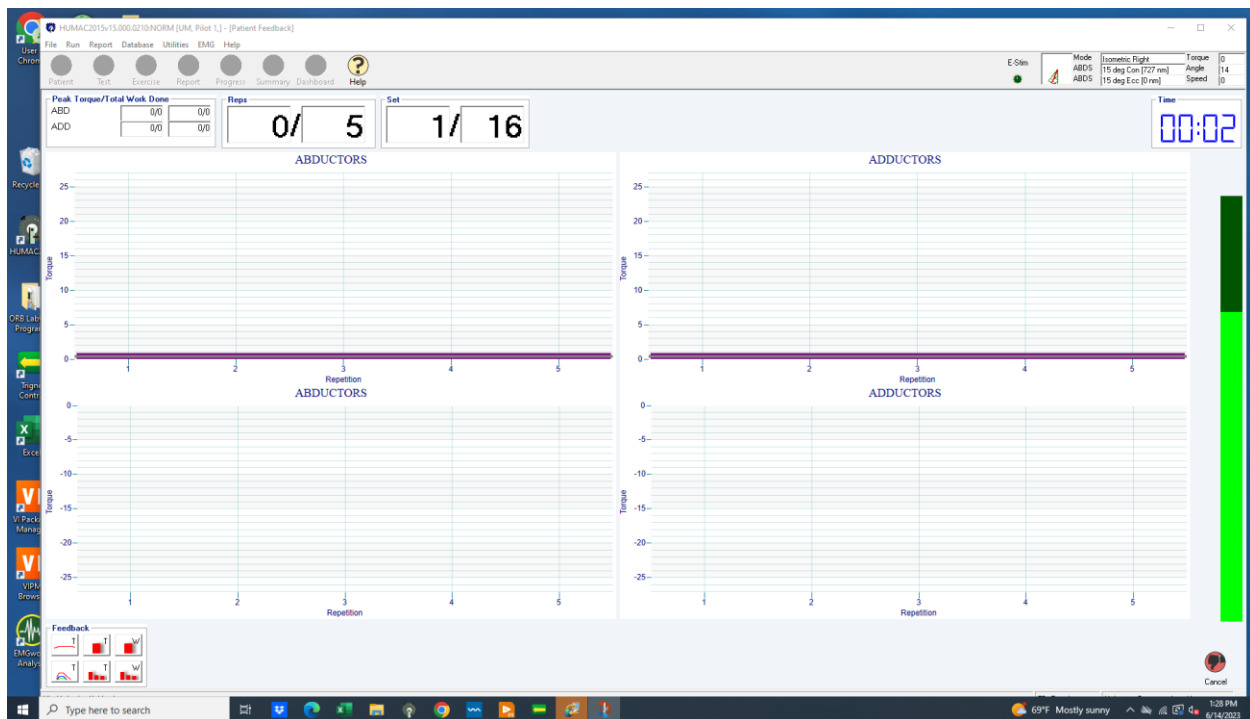
"I want you to push against the machine as hard as you can for 3 sec. Once you do this, please relax your leg."



L. ***Give instructions for next activity before pushing OK because will immediately start***

The window for the test will show up. Instruct the patient to raise the leg exerting enough force to reach the bar on the screen.

"I want you to push against the machine with enough force to reach the bar on the screen. It is not critical that you hit the bar exactly, but you must generate the force as quickly as possible. Once you have done that, you will see a 4 sec countdown on the top right of the screen. After the countdown hits zero and you hear the beep, you should repeat the task. You will have 5 repetitions at one percentage and then move up incrementally and the bar will move to a different level. After 20 reps you will have a 1 minute rest. Any questions?"



****Give reminders to be explosive throughout the blocks.**

- ☐ Release thigh strap from participant.
- ☐ **RPE score**

DATA COLLECTION SHEET FOR DYNAMOMETER TESTING

ASubject ID: _____

Date: _____

Visit Type: Socket On Socket Off Socket Type: IC SI Visit Number: #1 #2

Researcher: _____ Age: _____ Sex: M F

Height: _____(cm) Weight: _____(lbs) Involved side: R L

1. ☐ Demographic Form

2. Range of Motion Standing dyno height: _____

a. Abduction: _____(°) **select opposite side from testing limb

b. Adduction: _____(°)

c. Flexion: _____(°)

d. Extension: _____(°)

RPE: _____

Break: _____(min)

3. Hip Flexion Max Torque

Dyno height: _____

☐ Export excel sheet

Weigh Limb

Torque: _____

RPE: _____

Angle: _____

MaxGET: _____

Break: _____ (min)

4. Hip Abduction Proprioception

Dyno height: _____

**Select opposite side from testing limb

Angle	Value (°)	Difference (°)	Correlation
10°			-----

20°			-----

30°			-----

40°			-----

RPE: _____

Break: (10 min minimum): _____

☐ Falls Survey (ask for update on Visit #2) –Have you experienced a "loss of balance where your body landed on the ground or floor"

5. Hip Abduction Isometric Percentages

Weigh Limb

- e. Torque reading 1: _____
- f. Torque reading 2: _____
- g. Torque reading 3: _____
- h. Torque reading 4: _____

Torque: _____
Angle: _____
MaxGET: _____

RPE: _____

Total collection time: _____

APPENDIX 3 - IROS 2023 POSTER

Perturbation System for Studying the Influence of Socket Trim Line on Hip Musculature Utilization in Individuals with Transfemoral Amputations

B. Chen, S. Yalla, N. Rosenblatt, D. H. Gates, *Member, IEEE*

I. MOTIVATION

Limited research exists on Transfemoral Amputations (TFA) fall risk factors, including socket trimline effects. Fall prevention for people with TFA relies heavily on the prosthetic componentry underneath them coupled with the strength and coordination of their remaining hip musculature [1]. A reliable perturbation system is crucial for measurement.

II. PROBLEM STATEMENT

Precise methods for force application initiating perturbations for people with TFA are lacking. Existing approaches lack precision, require time-consuming adjustments to alter force magnitude, and disrupt natural motion [2] [3]. Unilateral force direction and participant-specific targeting require further exploration [2]. Therefore, we hypothesize that the amount the socket encompasses the residual hip musculature, specifically the socket trim line height, affects the engagement of these muscles, potentially impacting fall prevention.

III. METHODS

We developed a perturbation system (Fig. 1) to apply controlled mediolateral directed forces specified to participant characteristics, including waist height, body weight, and width of their base of support (BoS). Incremental force levels were progressively increased to identify single-step and multiple-step destabilization thresholds. Six randomized percentages above and below these stepping thresholds were chosen for both the intact and residual limbs.

A motion capture system was integrated to capture stepping responses and in-ground force plates to define step onset through a thresholding algorithm from ankle marker positions. The center of pressure position at step onset was calculated relative to the non-stepping limb ankle and normalized to the width of BoS. Recovery duration was determined for each step response.

IV. RESULTS

The perturbation system delivered controlled mediolateral perturbations. Motors, controlled through stepper driver and LabVIEW, produce force to pull the participant by extending and releasing the spring. A

waist harness with embedded force sensors was connected to ensure precise control of the force. The force plates ensured the participant reached a steady state of equal weight bearing through both limbs before the start of each perturbation. A randomization algorithm was used to control the direction and magnitude of each perturbation.

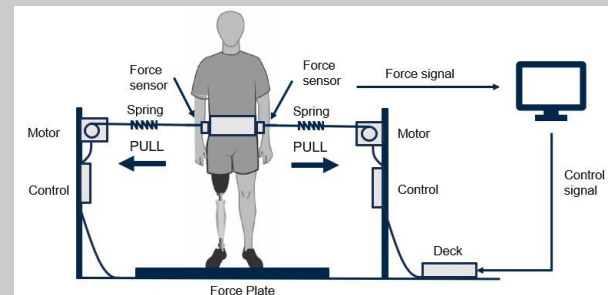


Fig. 1. Perturbation system setup.

V. DISCUSSION

This study addressed the application of accurate and specific forces to induce perturbations on individuals with TFA. Analysis of reactive stepping data explores the influence of socket trim line height on hip muscle function. This system supports future studies exploring the effects of perturbations on different planes and terrains, aiming to reduce falls and enhance the quality of life for people with TFA.

REFERENCES

- [1] Arifin N., et al. *The Scientific World Journal*, Jun. 05, 2014.
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- [3] Gray V. L., et al. *Journal of Neurologic Physical Therapy*, 41-4, pp. 222–228, Oct. 2017.