Signoff Request – 5/2 - Arm

Sunday, April 24, 2022 10:43 PM

Force Calculations

Side hardness is defined as the force needed to push a 0.444 inch ball half its diameter, or 0.222", into a piece of the wood. This is called the Janka hardness test but because there is no equation for this test, solving for the force needed with the moisture probes will take some estimation. Based on measurements made on my own wood moisture probe, it was found that the final diameter when pushed to the full 1/8" into the wood is 1/16". This means the point will have an average diameter of around 1/32" or 0.03125". Using this value as a proportion with the test value of 0.444", it can be estimated that the necessary force will be 100*(0.03125/0.44) which is about 7%. Using the side hardness of 510 lbf from the table [1], the needed force will be 35 lbf. This number can be lowered even more by realizing the depth needed here is only half of the test and the point will mean less force is required. Adjusting for this, a force of 15-20 lbf is found which is consistent with the force Dr. Canfield estimated plus a bit of margin.

Vertical Actuator

For the vertical actuation of the moisture probe, many different methods were researched. The first method looked into was using a linear actuator attached to the side of the bot. However, a standard linear actuator can only double its height and the robot must fit in a 2-block, or 16", tall crawlspace while also reaching the joist of a 6-block, or 48", crawlspace. The one type of linear actuator that could perform this is called a multi-phase or telescoping actuator. However, due to the complexity, these motors are excessively expensive for a capstone project [2].

The second idea explored was a modified scissor lift to achieve that heigh using only 1, smaller linear actuator or rotational motor. However, this mechanism would require a wide base for stability and would lose force for every crossbar which had to be added.

Finally, a cascading lift design was investigated [3]. This design uses pulleys and sliding bars to achieve exponential extension using only one motor. However, they do not provide much force and would never be able to penetrate the wood.

After hours of research, a usable method was finally developed by comping several of the methods listed above. A cascading lift design will be used to bring a small linear actuator within a few inches of the wood. This actuator will be used to drive the probes in and remove them. In this way, the height is still achieved but the force comes from the smaller actuator instead of the lift. The chosen actuator is the L16-P Miniature Linear Actuator with Feedback [4]. Specifically, the model with a 100mm stroke and 150:1 gear ratio. The specifications for this actuator are seen in figure 1. It was chosen because they weigh less than a pound, have high force values, are driven with 12V, and include analog feedback for position control. The proximity sensor described in the circuit signoff will guide the arm to the correct height at which point this feedback will be used to control the depth of wood that the actuator pushed into.

L16 Specifications

Gearing Option	35:1	63:1	150:1
Peak Power Point	50N @16mm/s	75N @10mm/s	175N @4mm/s
Peak Efficiency Point	24N @24mm/s	38N @15mm/s	75N @7mm/s
Max Speed (no load)	32mm/s	20mm/s	8mm/s
Max Force (lifted)	50N	100N	200N
Back Drive Force	31N	46N	102N
Stroke Option	**50mm**	**100mm**	**140mm**
Mass	56g	74g	84g
Repeatability (-P & LAC)	0.3mm	0.4mm	0.5mm
Max Side Load (extended)	40N	30N	20N
Closed Length (hole to hole)	118mm	168mm	208mm
Feedback Potentiometer	6kΩ±50%	11kΩ±50%	16kΩ±50%
Feedback Linearity		Less than 2.00%	
Input Voltage		0-15 VDC. Rated at 12VDC.	
Stall Current		650mA @ 12V	
Operating Temperature		-10°C to +50°C	
Audible Noise		60dB @ 45cm	
Ingress Protection		IP-54	
Mechanical Backlash		0.25mm	
Limit Switches		Max. Current Leakage: 8uA	
Maximum Static Force		250N	
Maximum Duty Cycle		20%	

Figure 1: Actuator Specs

Along with the actuator, the Servocity Cascading X-Rail Slide Kit [5] will be used for the full extension. This kit was chosen because it is able to extend to 49.8 inches in total height and collapse to 15.3 inches. This means it fits both height requirements of the robot. It also includes great instructions for assembly. Another similar kit at a lower cost was also found [6], however, it did not have documentation on load values and would be too tall at a resting height so a different kit was chosen. The chosen kit specifies that at full extension it can hold a weight of 2lbs which is more than enough for the linear actuator picked above. This part will be mounted on the side of the robot but the exact method of mounting cannot be determined until the chassis design has been completed by other group members.

The final piece needed for this mechanism is the lift's driving motor. For the main motors pulley, Servocity recommends using their motor and 2" diameter pulley to drive the system. Given this diameter and the total weight being lifted (3/4 the system weight plus the actuator linear weight), a torque of about 1.432 kg-cm will be needed. These calculations are seen in figure 2.

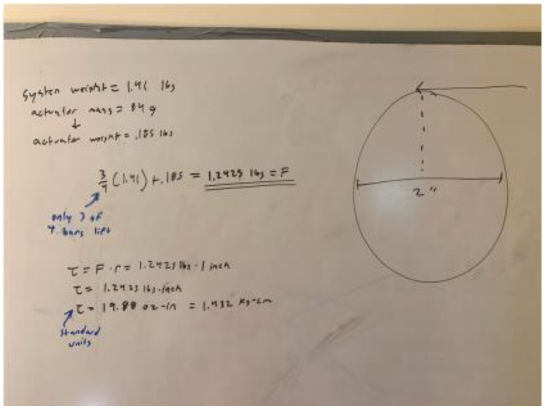

Figure 2: Torque Calculations

Based on these calculations, a motor from Pololu was chosen [6]. This motor can handle the correct amount of torque but is also smaller and cheaper than the motor Servocity sells. The pully part can also be 3D printed so that it doesn't have to be purchased and can be made to fit this motor. This model is seen in figure 3.

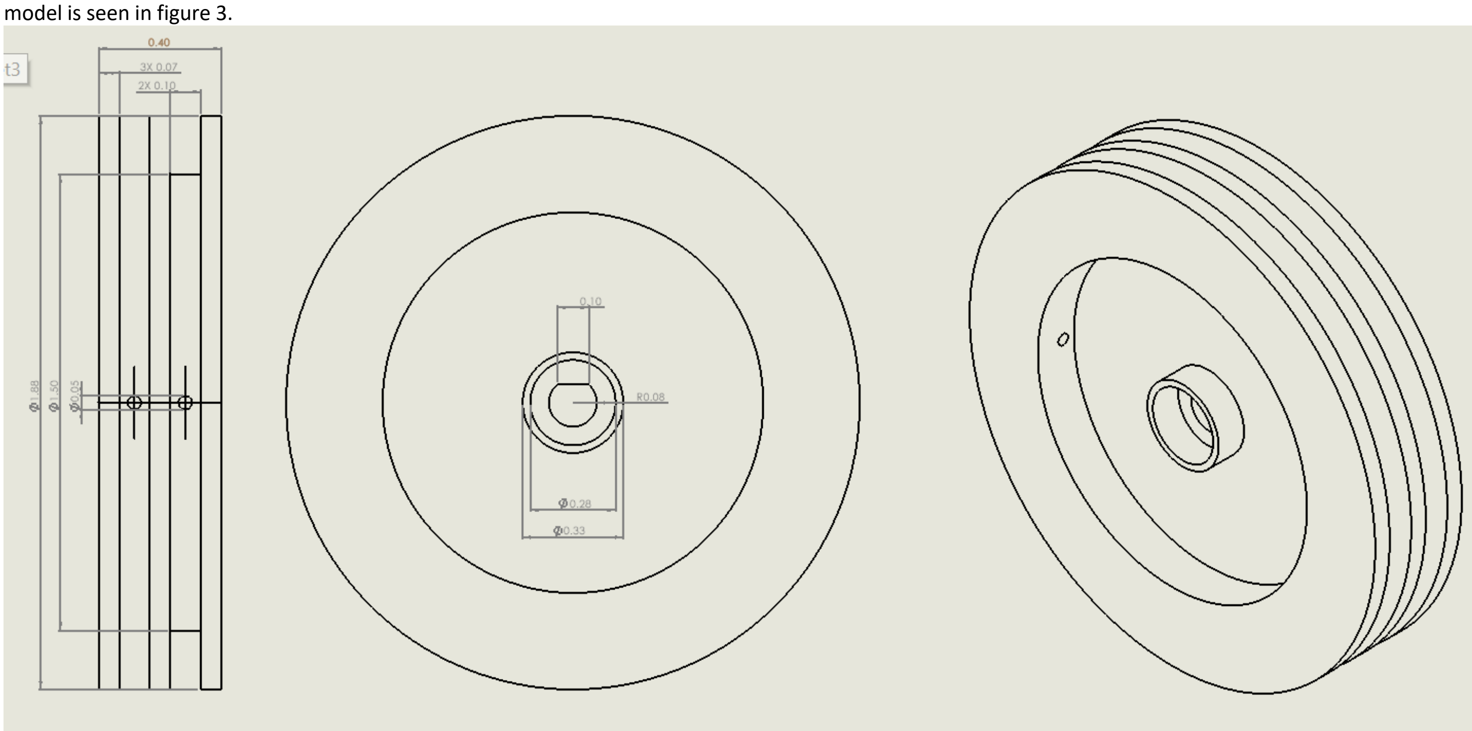

Figure 3: Pulley

Motor Driver

The L298N motor driver will be used in this system because it can control two motors at once meaning it will work for the linear actuator and arm motor [7]. It also has "high noise immunity" and has built-in filtering of back emf. This means it will be able to protect the Arduino from any back emf that is unintentionally applied to the motors by outside forces. Further information on this part can be found in its specific signoff created by Joseph Thomas. The connection of this driver as well as the motors is included in the circuit signoff.

Both the linear actuator and the rotational motor chosen are made to run off of 12 V which is within the output range of the L298N. Inspecting the datasheets also shows max currents of 650mA and 1.6 A respectively which is within the 3 Amp range of the driver (Note: these are the stall currents, real operating currents will be even lower than this). The motors will not be run simultaneously so the current pull from the driver will always be under this maximum. The rotational motor will be controlled through a simple two-wire interface with the driver handling PWM for speed control and polarity switching for direction controlAccordingng to the website, the linear actuator can be controlled in the same way using a two-wire interface. While this actuator's cable has 5 wires, the yellow, purple, and orange wires are used for position reference and feedback and won't be connected through the motor driver.

Probe

Replacement multimeter probes will be used for our probes because they are easily purchasable and already made for this purpose [8]. They also have threaded bottoms for easier attachment to the system. Finally, they will have similar dimensions to the probes on my wood moisture meter which means they should be consistent with the math performed above. These spikes will also have an attached, 3d printed part which limits it to .125 inches into the wood. The full assembly of this section is seen in the drawing in figure 4. (Note: The distance between the probes does not influence the reading [9], the distance was chosen based on owned probe)

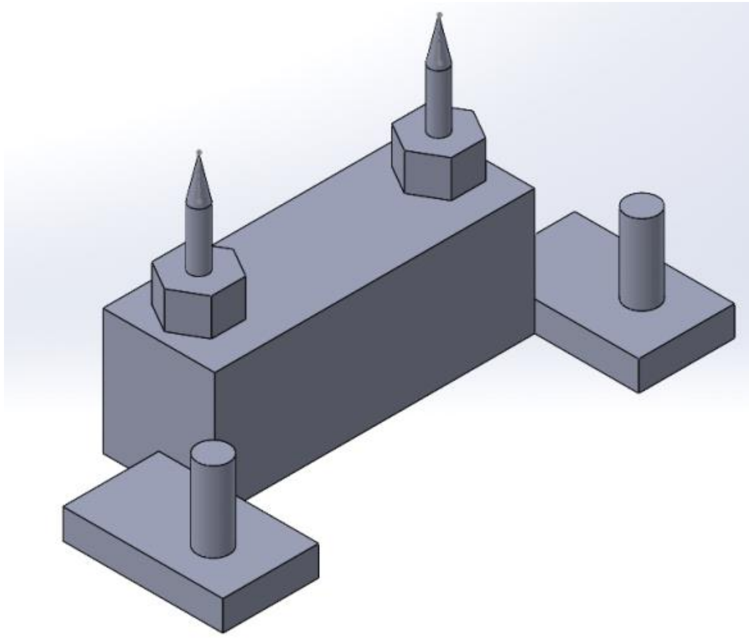

Figure 4: Probe Head

Assembly

A full model of the slide kit has not been obtained yet. The one included on the website is a broken step file that loses its links as soon as it is closed. Servocity has been contacted for a new file to use when a full robot model must be made. An x-bar was used to show how the mounting will work in the meantime and pictures/instructions for the kit assembly are found below.

The first step for assembly is to put together the arm kit. Detailed instructions for this assembly are found in the [guide] on Servocity's website. Figure 5 and 6 show assembled views of this kit. Along with this, the motor will be mounted to the chassis using the Pololu mount found in the BOM as shown in figure 7. The pulley will be attached to the shaft with a tension fit. The slide kit will also be mounted to the chassis using the screws which come with the kit. The rope will be wrapped around the main pulley and stretched up to the next pulley in accordance with the assembly instructions linked above.

The next step is to attach the bracket, probe head, and linear actuator as shown in figure 8. Magnets will be used to hold the actuator shaft to the bracket. The head is attached to the actuator by removing the head the actuator comes with and replacing it with a M6-1 threaded rod. The proximity sensor is mounted to the side of the head using the built in rods and the actuator is placed on the bracket which slides into the x-bars which come in the kit. Different colors were used to designate purchased items as opposed to designed items. The final step will be to attach the cable to the head and then back to wherever the MCU gets mounted. The cable has a max extension of 7 feet to allow for some tolerance but this can be cut if needed. Figure 8 shows the bracket removed for clarity.

Figure 5: Extended Kit View

Figure 6: Collapsed Kit View

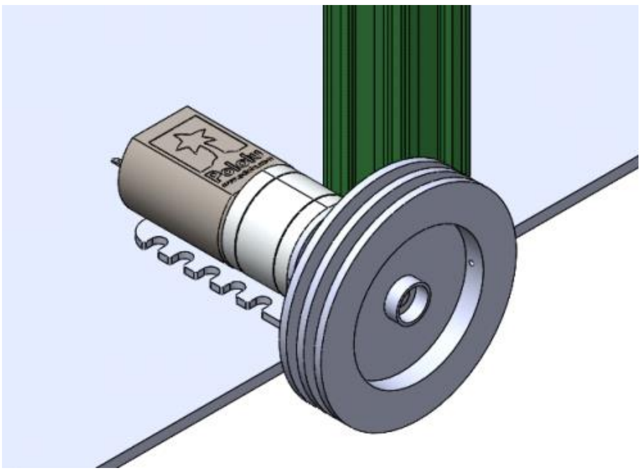

Figure 7: Motor Mounting

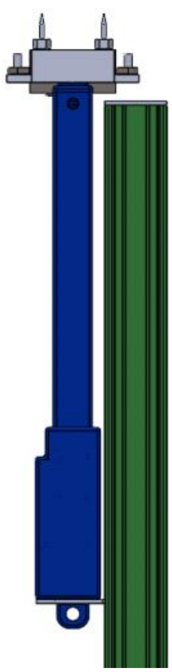

Figure 8: Bracket Mounting

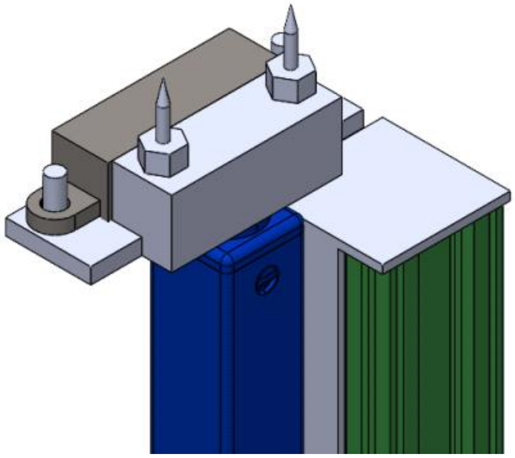
Figure 9: Bracket Mounting

The entirety of the schematic has been moved to its respective signoff dated 4/18. While these designs are intertwined, keeping mechanical and electrical on their respective signoffs keeps everything more organized.

BOM

Part Number	Price	QTY	Description	Value	Supplier
637211	$122.99	1	Cascading X-Rail Slide Kit		Servocity
31:1 Metal Gearmotor 20Dx41L mm 12V CB	$28.95	1	Rotational Motor	2.4 kg-cm	Pololu
L16-P	$80.00	1	Miniature Linear Actuator	100mm stroke	Actuonix
PIND4E	$15.58	1	Moisture Content Probes		Amazon
93805A312	9.12	1	M6 Threaded Rod		Mcmaster Carr
AT-K-C-26-8-B/7	3.83	1	Coiled Cable	3.28' - 7"	Digikey
Metal Gearmotor Bracket Pair	6.95	1	Mounting Bracket and Screws	20mm Diameter	Pololu

[1] https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch04.pdf
[2] https://www.amannesmann.de/en/products/linear-and-telescope-actuators/2-stage-telescope-actuator/
[3] https://gm0.org/en/latest/docs/common-mechanisms/linear-motion-guide/rigging.html
[4] https://www.actuonix.com/L16-Linear-Actuators-p/l16-p.htm
[5] https://www.revrobotics.com/rev-45-1507/
[6] https://www.pololu.com/product/3475
[7] https://www.sparkfun.com/datasheets/Robotics/L298_H_Bridge.pdf
[8] https://www.amazon.com/General-Tools-PIN4E-Replacement-MMH800/dp/B01LZXKTUM/ref=pd_sbs_sccl_4_3/139-8015023-9909651?pd_rd_w=ndcLF&pf_rd_p=dfec2022-428d-4b18-a6d4-8f791333a139&pf_rd_r=XHV0075MNVVT5FFHG3J6&pd_rd_r=b53869b2-e386-468c-8330-d91ac1fc2f39&pd_rd_wg=KPW0P&pd_rd_i=B01LZXKTUM&psc=1
[9] https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr06.pdf