BME Design-Spring 2021 - Riley Pieper
Complete Notebook

PDF Version generated by

Sam Schini

on

May 04, 2021 @02:53 PM CDT

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Team contact Information

Jacob Cohn - Mar 05, 2021, 12:27 PM CST

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Campagnola	Paul	Advisor	pcampagnola@wisc.edu		ECB
Puccinelli	John	Client	john.puccinelli@wisc.edu		ECB
Pieper	Riley	Leader	rgpieper@wisc.edu		
Schini	Sam	Communicator	schini@wisc.edu		
Trapp	Noah	BSAC	ntrapp@wisc.edu		
von Heimburg	Dylan	BWIG	vonheimburg@wisc.edu		
Cohn	Jacob	BPAG	jmcohn2@wisc.edu		

Project description

Jacob Cohn - Mar 05, 2021, 12:33 PM CST

Course Number: BME 402

Project Name: Low-cost Motorized Microscope Stage

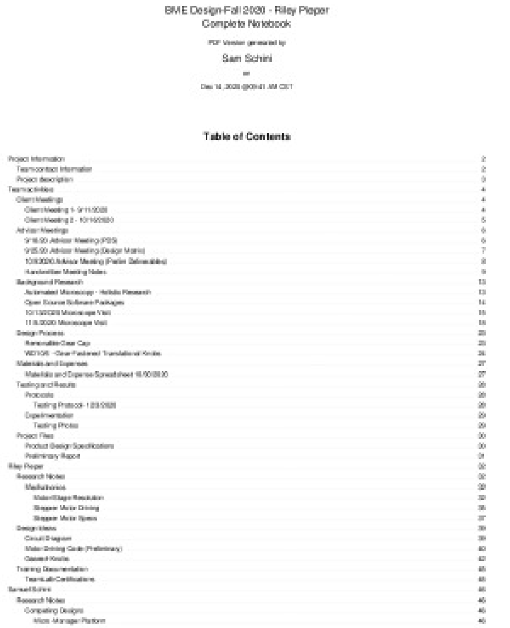
Short Name: Motorized Stage

Project description/problem statement: The goal of this project is to design a motorization system to automate the serial imaging process. This will increase image consistency as well as time efficiency. The goal for our final product is to do so with 1 micron resolution of movement and to maintain a budget of around 100 dollars.

About the client: Dr. Puccinelli is the BME Design Curriculum Coordinator as well as the Associate Chair for the BME Undergraduate Program at UW-Madison.

Fall Notebook

Riley Pieper - Feb 03, 2021, 1:53 PM CST



BME Design-Fall 2020 - Riley Pieper
Complete Notebook

PDF Version generated by

Sam Schini

on

Dec 14, 2020 @09:41 AM CST

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MicroMotor-Final_Notebook.pdf(11.3 MB) - download

2/19/21 Client meeting 1: Progress Update

Jacob Cohn - Mar 05, 2021, 12:42 PM CST

Title: Client meeting 1: progress update

Date: 2/19/21

Content by: Jacob Cohn

Present: Whole team

Goals: Update our client on our teams progress. Lay out next steps of project and explain our ideas for the mounting process.

Content:

In this meeting we talked to Dr. Puccinelli about

- Our concerns with laser cutting
    - We want thicker gears (.5 in) but are concerned with warping at that thickness
    - Solution could be to fuse multiple smaller acrylic gears together
- Our concerns with mounting of the system with respect to space and weight
    - the plan is to go forward with the mounting system with an alternate plan of a gliding system
- We should be good on the software side for now
    - will be meeting with Dr. Nimunkar about the settings for our stepper motor drivers and the motors themselves
    - Will be meeting with Dr. Elcieiri and Dr. Tsuchida about integration of arduino code with micromanager for our system

Conclusions/action items:

As for now, we are in a good place with a plan for the rest of the semester. We will meet with professors discussed above. Additionally we will meet with the makerspace laser cutting team to figure out the best way to make our acrylic gears.

1/29/21 Advisor meeting 1

Riley Pieper - Mar 12, 2021, 12:49 AM CST

Title: Advisor Meeting 1

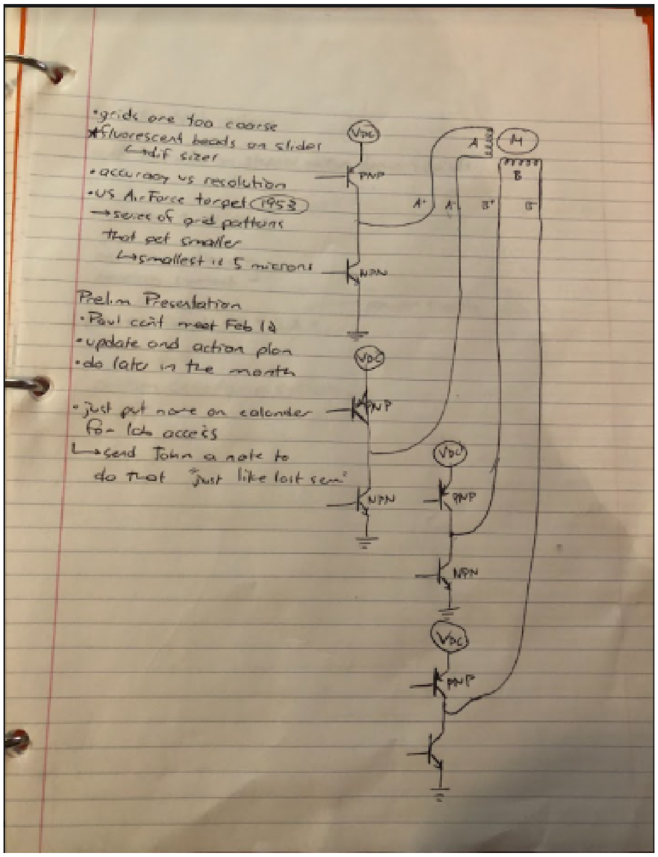
Date: 1/29/21

Content by: Riley Pieper

Present: Full Team

Goals: Document the notes taken during this meeting with our project advisor.

Content:



Conclusions/action items: The team will explore fluorescent beads and grid patterns used to validate stage translation under a microscope lens. The team will generate a prelim presentation later in the month that provides an update on progress and an action plan for moving forward with the project. To access the lab space to see the microscope, the team will continue adding events to the lab calander to signify times when they will be reserving the lab space.

2/19/21 Advisor meeting 3

Riley Pieper - Mar 12, 2021, 12:54 AM CST

Title: Advisor Meeting 3

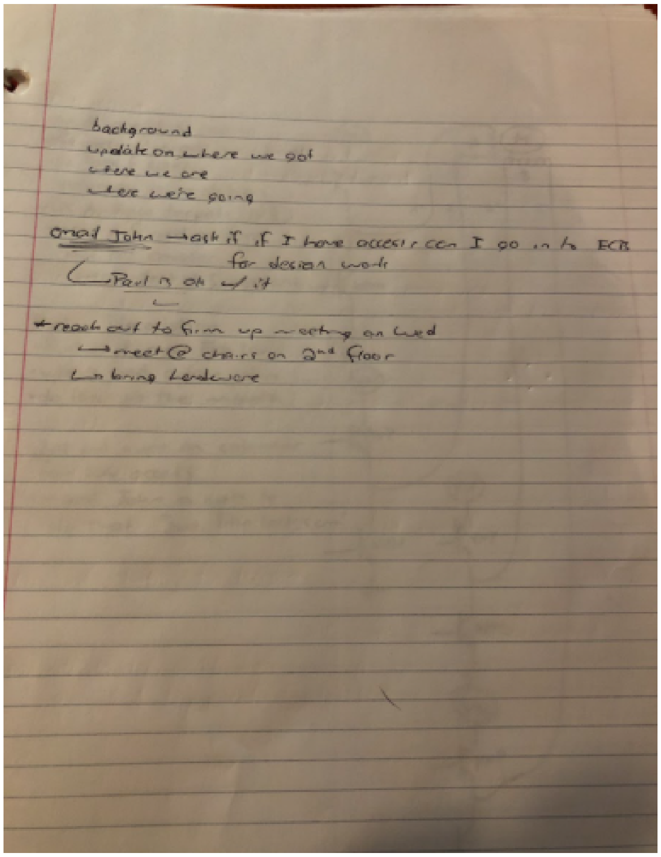
Date: 2/19/21

Content by: Riley Pieper

Present: Full Team

Goals: Document the notes taken during this meeting with our project advisor.

Content:



background
update on where we got
where we are
where we're going

email John → ask if if I have access can I go in to ECB for design work
→ Paul is ok w/ it

* reach out to firm up meeting on Wed
→ meet @ chairs on 2nd floor
→ bring hardware

Conclusions/action items: The team will include the following general sections in their preliminary presentation: background on the project, an update on where we got last semester, status on where we are with the project now, and plans for where we are heading for the remainder of this semester. We will connect with Dr. Puccinelli to determine whether we are allowed in ECB after hours (when noone is verifying Badger Badges). We are planning to meet with Dr. Campagnola again during Wednesday of next week to get into the microscope and show him exactly what we are dealing with. We will firm up this meeting with a reminder email early next week and bring our hardware to that meeting.

2/26/21 Advisor meeting 4

Riley Pieper - Mar 12, 2021, 12:58 AM CST

Title: Advisor Meeting 4

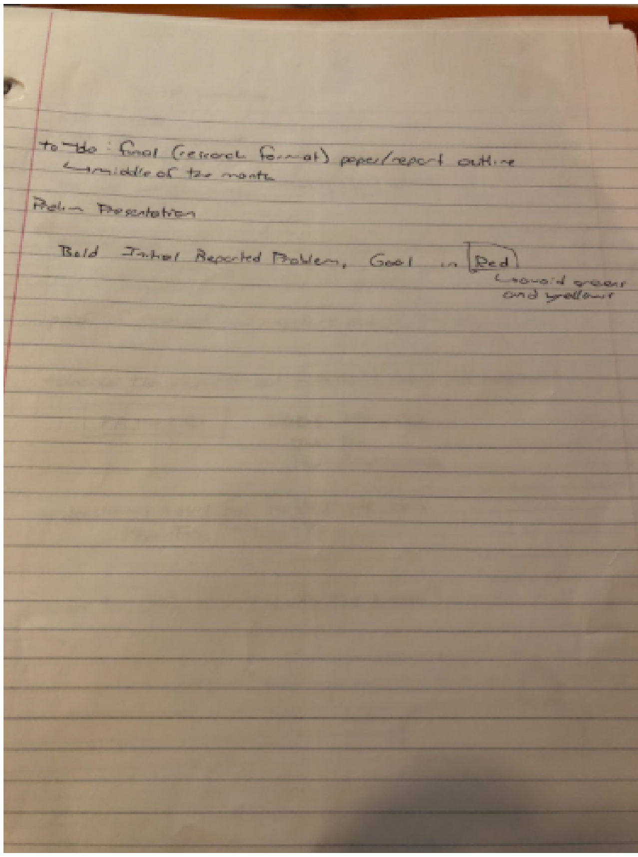
Date: 2/26/21

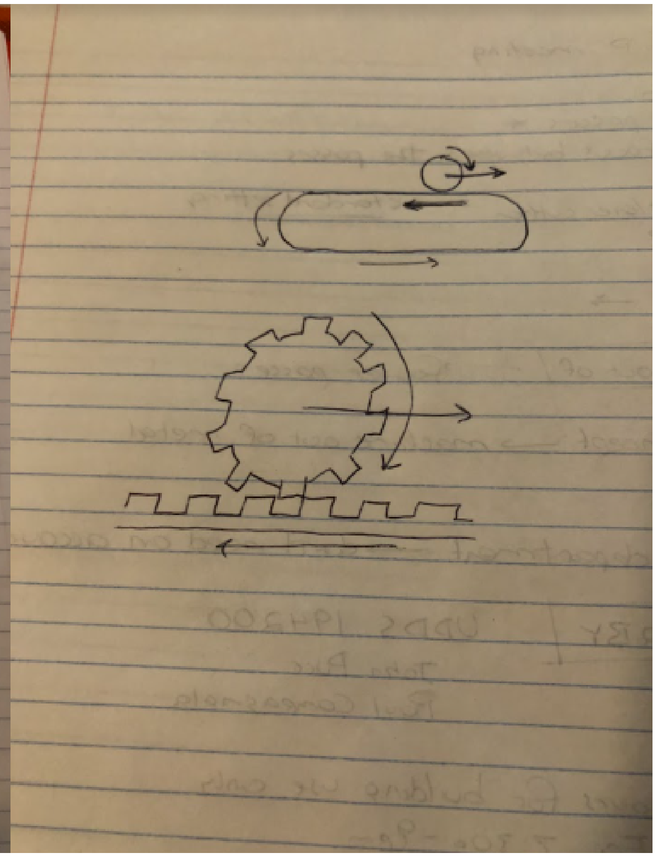
Content by: Riley Pieper

Present: Full Team

Goals: Document the notes taken during this meeting with our project advisor.

Content:





Conclusions/action items: The team will begin thinking about drafting a preliminary final report in research article format for the middle of March. In regards to feedback from the preliminary presentation, we will implement some of the suggestions in our next presentation (which will likely be our final presentation, either in poster or powerpoint format). The transmission schematic discussed in this meeting will be evaluated and considered for use to make the motors stationary while allowing the knob shaft to translate during movement.

3/5/21 Advisor meeting 5

Riley Pieper - Mar 12, 2021, 1:01 AM CST

Title: Advisor Meeting 5

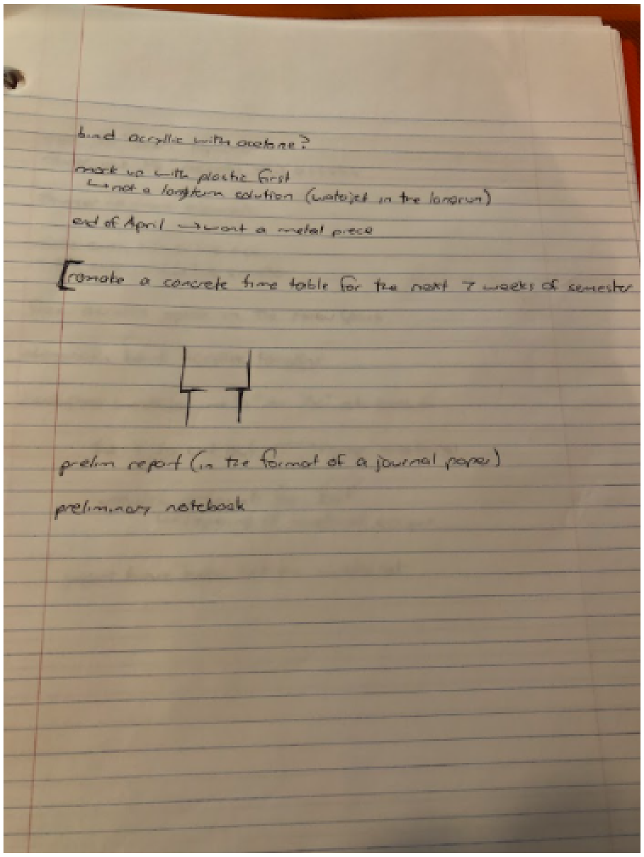
Date: 3/5/21

Content by: Riley Pieper

Present: Full Team

Goals: Document the notes taken during this meeting with our project advisor.

Content:



Conclusions/action items: The team plans to begin fabrication of the spur gears via laser cutting first. This may not be a longterm solution, but may be sufficient for primary implementation of our system with the microscope. Moving forward, the team will generate a new timetable for the remaining weeks in the semester to outline what needs to get done when. The team will also begin drafting the preliminary report in the format of a journal paper and submit LabArchives for evaluation.

3/12/21 Advisor meeting 6

Riley Pieper - Mar 15, 2021, 8:57 AM CDT

Title: Advisor Meeting 6

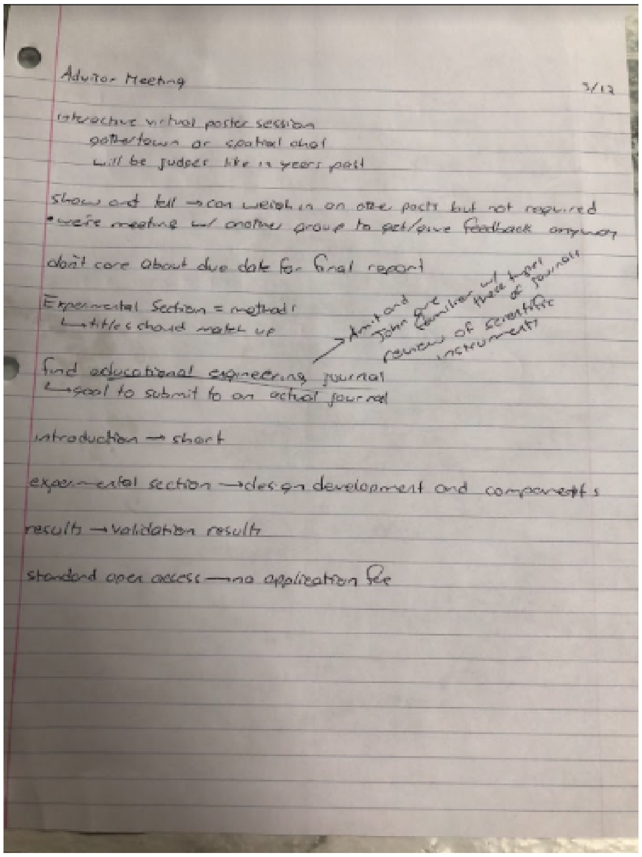
Date: 3/12/21

Content by: Riley Pieper

Present: Full Team

Goals: Document the notes taken during this meeting with our project advisor.

Content:



Advisor Meeting 3/12

interactive virtual poster session
gathertown or spatial chat
will be judged like in years past

show and tell → can weigh in on other posts but not required
• we're meeting w/ another group to get/give feedback anyway

don't care about due date for final report

Experimental Section = methods
↳ titles should match up

find educational engineering journal → Amit and John are familiar w/ these target journals of review of scientific instruments
↳ goal to submit to an actual journal

introduction → short

experimental section → design development and components

results → validation results

standard open access → no application fee

Conclusions/action items: The team will prepare for a virtual poster session that is synchronous (rather than prerecording a video) for the end of this semester. We will not, however, feel obligated to participate in the show and tell activity. In terms of the report, we will do what we can to provide our advisor with a semi-final report at the required due date at the end of this semester. However, our advisor does not care about the hard deadline for this report. Furthermore, he is willing to work through a journal article manuscript of this report to for submission to an educational engineering journal. At this point, the team will explore potential journals of this kind to target. We will use some of the information relating to organization discussed in these notes.

05.04.21 Arduino Code

Sam Schini - May 04, 2021, 12:23 PM CDT

Title: Arduino Code for Sequential Stage Movement

Date: 05.04.21

Content by: Sam Schini

Present: Sam Schini, Riley Pieper, Jake Cohn, Dylan Von Heimberg, Noah Trapp

Goals: Develop Arduino code with void loops that allow for the sequential movement of stepper motors for 2-D stage translation (x & y dimensions).

Content:

```
/*
  Stepper Motor Test
  stepper-test01.ino
  Uses MA860H or similar Stepper Driver Unit
  Has speed control & reverse switch

  DroneBot Workshop 2019
  https://dronebotworkshop.com
*/

// Defin pins

int driverX_PUL = 7;    // PUL- pin
int driverX_DIR = 6;    // DIR- pin
int driverY_PUL = 5;    // PUL- pin
int driverY_DIR = 4;    // DIR- pin

// Variables

float speedRPM = 2; // RPM
int mstep = 1; // MicroStep Setting
int pd = 1500 / (speedRPM * mstep); // Pulse Delay period (microseconds) // (min / rot) * (60sec / min) * (1,000,000us / sec) * (rot / 360deg) *
(0.018deg / step) * (step / mstep) * (mstep / 2periods)
boolean setdirX; // Set Direction
boolean setdirY; // Set Direction

int deltaFrameX = 500; // microns - movement in X between adjacent frames
int deltaFrameY = 500; // microns - movement in Y between adjacent frames
int captureDelay = 1000; // 2 seconds
int horiz_frames = 6;
int vert_frames = 6;

int xsteps = deltaFrameX * mstep * 2 / 0.9; // steps between frames
int ysteps = deltaFrameY * mstep * 2 / 1.584; // steps between frames


void setup() {

  pinMode (driverX_PUL, OUTPUT);
  pinMode (driverX_DIR, OUTPUT);
  pinMode (driverY_PUL, OUTPUT);
  pinMode (driverY_DIR, OUTPUT);

  Serial.begin(9600);

}
```

```
void loop() {

  for (int k = 0; k < vert_frames; k++){
    if (k%2 == 0){
      setdirX = LOW;
    }
    else {
      setdirX = HIGH;
    }
    digitalWrite(driverX_DIR,setdirX);
    for (int j = 0; j < horiz_frames; j++){
      for (int i = 0; i < xsteps; i++){
        digitalWrite(driverX_PUL,HIGH);
        delayMicroseconds(pd);
        digitalWrite(driverX_PUL,LOW);
        delayMicroseconds(pd);
      }
      delay(captureDelay);
      Serial.println(xsteps);
    }

    digitalWrite(driverY_DIR,HIGH);
    for (int i = 0; i < ysteps; i++){
      digitalWrite(driverY_PUL,HIGH);
      delayMicroseconds(pd);
      digitalWrite(driverY_PUL,LOW);
      delayMicroseconds(pd);
    }
    delay(captureDelay);
  }
}
```

Conclusions/action items:

The provided code is successful in operating a multi-stepper motor system so that it produces stage translation for the serial imaging process. The code accounts for translational calculations for a theoretical tissue culture display and specifies the directional stage movements of an inverted microscope.

3/8/2021 Pivot Dimensions

Riley Pieper - Mar 08, 2021, 5:33 PM CST

Title: Pivot Dimensions

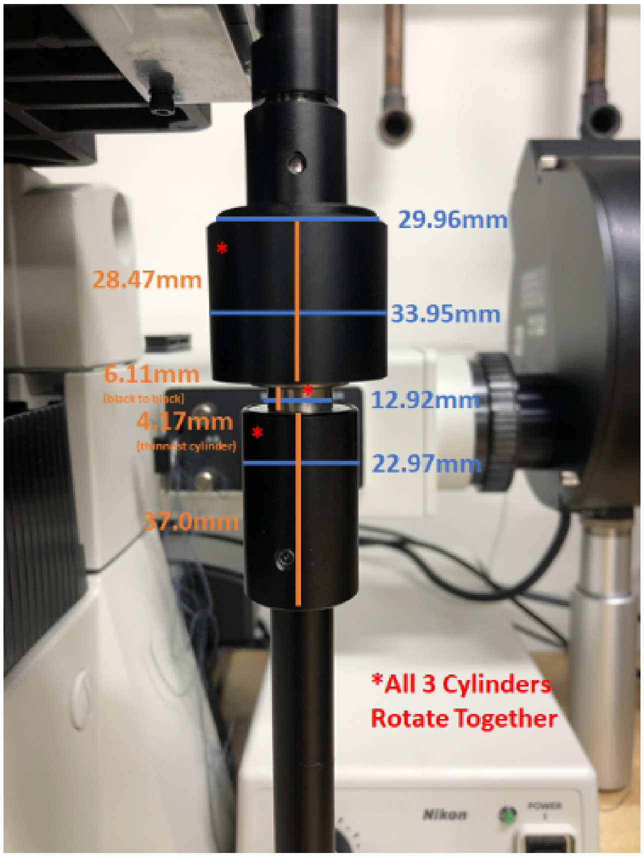
Date: 3/8/2021

Content by: Riley Pieper

Present: Dylan Von Heimburg

Goals: Record the precise dimensions of the translation knob shaft pivot point to inform the design of a pivot brace component.

Content:



Conclusions/action items: These dimensions will be used to inform a SolidWorks drawing of a brace that will prevent pivoting of the control knob shaft during motor transmission.

Meeting with Dr. Nimunkar 3/11/21

Jacob Cohn - Mar 11, 2021, 7:28 PM CST

Title: Meeting with Dr. Nimunkar

Date: 3/11/21

Content by: Jacob Cohn

Present: Whole team

Goals: Gain more insight on the settings of our motor drivers and how best to use them within our system.

Content:

Dr. Nimunkar met with us and we explained the questions we had. He had good insights on potentially finding a power source that will power our Arduino that is not a labtop or computer. Additionally, we discussed the different settings that the driver has and what has been working to drive the motor. We expressed our concern with the fractional step sizes and speed, but he seemed not to be as worried. He wants to do more research now understanding fully what our questions are and meet back up.

Conclusions/action items:

Our plan is to use the information shared with Dr. Nimunkar and do more research on the driver. At the same time, he is planning on doing more research now that he has a better understanding of our questions. We plan to meet back with him early next week and discuss each of our findings and how best to utilize the driver for our project. Finally, Dr. Nimunkar advised that we meet with another group that he has worked with that is also using stepper motors. This group is the Pill Dispenser group, and we will reach out in an email to set up a time to meet up and trade any information that we have and ask for whatever help they can provide (kind of our own little Show and Tell).

3/25/21 Dr. Nimunkar meeting 2

Jacob Cohn - Mar 26, 2021, 12:38 PM CDT

Title: Second meeting with Dr. Nimunkar

Date: 3/25/21

Content by: Jacob Cohn

Present: Whole group

Goals: Update on progress and ask about future work with serial communications as well as micromanager integration

Content:

https://www.youtube.com/watch?v=AR0un3kg-iM

https://www.youtube.com/watch?v=3LZ_v3Jldwo

https://www.arduino.cc/reference/en/language/functions/communication/serial/read/

https://startingelectronics.org/software/arduino/learn-to-program-course/19-serial-input/

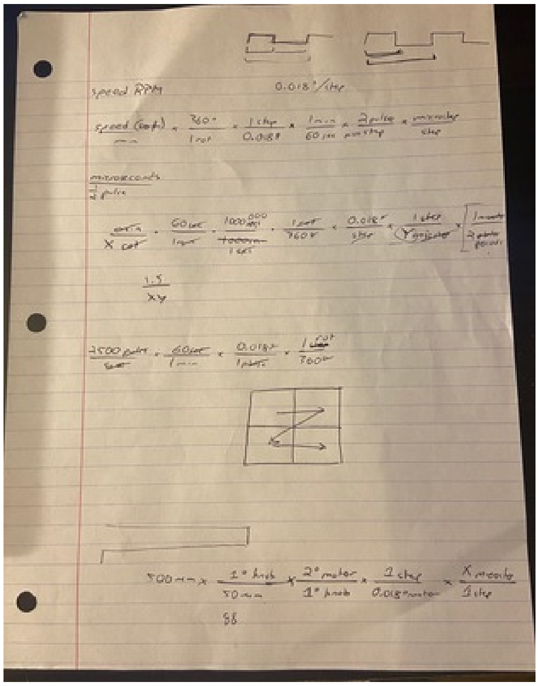
- Serial input or serial read call to stop the void loop after one set of serial imaging
- Case structure should allow for the stopping and sitting in void loop
    - https://www.arduino.cc/reference/tr/language/structure/control-structure/switchcase/

Conclusions/action items:

We plan to follow up on the links Dr. Nimunkar provided as we move forward with our code. His help with ideas surrounding the serial communications of the computer and arduino will help with the practical use of our deisgn. Moving forward we will schedule a meeting with Dr. Elcieri and Dr. Tschida to discuss MicroManager integration.

3/25/21 Pseudocode for serial imaging

Jacob Cohn - Apr 07, 2021, 3:00 PM CDT



IMG_4610.jpg(691.3 KB) - download

4/19/21 Meeting with Dr. Eliceiri

Jacob Cohn - Apr 19, 2021, 6:02 PM CDT

Title: Software meeting with Dr. Eliceiri

Date: 4/19/21

Content by: Jacob Cohn

Present: Sam Schini

Goals: Establish how we might integrate our system with software to be used in a professional manner

Content:

NEED to invert control. We are directing our commands from the arduino. Mark says that we will need to send commands from the PC to the arduino. He also suggested possibly using two arduinos, one for the x and one for the y direction. He thinks 3-4 commands will be necessary to complete what we want controlled.

1. Current location finder 2. Move to (X, Y) 3. Is it finished moving command 4. Stop all motion command

Our options as he sees it, we either write our own code, which will be involved and take nearly a month in his estimation. Could do it with a real time operating system (did not really expand on this and seemed not to be a great option). Integrate a motion control device that would replace he arduino and motor drivers or 165 (TinyG).

Micromanager integration will need to be written either way.

Could integrate an acceleration and deceleration control into the code-- easier on the microscope.

Conclusions/action items:

At the end, Kevin gave us a list of action items for Friday's presentation...

- Test and validate device if possible
- If not, speculate on data
- Give in depth paper outlook and next steps if considering continuation
- FUTURE WORK= software-- highlight the challenges rather than simply broad ideas of integration

Materials and Expense Spreadsheet 1/29/21

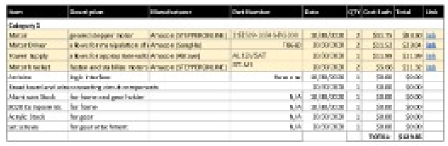
Jacob Cohn - Dec 10, 2020, 4:48 PM CST

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Category 1								
Motor	geared stepper motor	Amazon [illegible]	[illegible]	10/08/2020	[illegible]	[illegible]	[illegible]	link
Motor Driver	[illegible]	Amazon [illegible]	[illegible]	10/08/2020	[illegible]	[illegible]	[illegible]	link
Power Supply	[illegible]	Amazon [illegible]	[illegible]	10/08/2020	[illegible]	[illegible]	[illegible]	link
Motor bracket	[illegible]	Amazon [illegible]	[illegible]	10/08/2020	[illegible]	[illegible]	[illegible]	link
Arduino Uno	logic interface		Have one	10/08/2020	1	$0.00	$0.00	
Breadboard	connecting wires to components		Have them	10/08/2020	1	$0.00	$0.00	
Wires	connecting wires to components		Have them	10/08/2020	20	$0.00	$0.00	
Aluminum Stock	for frame and gear shaft [illegible]		find in lab [illegible]	10/08/2020	1	$0.00	$0.00	
8020 Components	for frame		find in lab [illegible]	10/08/2020	1	$0.00	$0.00	
Acrylic Stock	for gear		buy from makerspace	10/08/2020	1	$15.00	$15.00	
set screws	for gear attachment		find in lab [illegible]	10/08/2020	1	$0.00	$0.00	
						TOTAL:	[illegible]	

BPAG_Expense_Spreadsheet_-_Sheet1.pdf(67.9 KB) - download

4/15/21 Updated Materials

Jacob Cohn - Apr 15, 2021, 4:53 PM CDT



Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
[illegible]								
Motor	[illegible] stepper motor	Amazon (STEPPERONLINE)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	link
Motor Driver	[illegible]	Amazon [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	link
Power Supply	[illegible]	Amazon [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	link
Motor bracket	[illegible]	Amazon (STEPPERONLINE)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	link
Arduino	logic interface		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible] connecting circuit components				[illegible]	[illegible]	[illegible]	[illegible]	
Aluminum Stock	for frame and gear holder		N/A	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	for frame		N/A	[illegible]	[illegible]	[illegible]	[illegible]	
Acrylic Stock	for gear		N/A	[illegible]	[illegible]	[illegible]	[illegible]	
set screws	for gear attachment		N/A	[illegible]	[illegible]	[illegible]	[illegible]	
						TOTAL:	[illegible]	

BPAG_Expense_Spreadsheet_-_Sheet1_1_.pdf(67.5 KB) - download

3/8/21 Laser Cutting Gear Experimentation

Riley Pieper - Mar 11, 2021, 11:36 PM CST

Title: Laser Cutting Gear Experimentation

Date: 3/8/21

Content by: Riley Pieper

Present: Dylan von Heimburg

Goals: Explore the functionality and behavior of the laser cutting fabrication machine in the Makerspace in use to fabricate spur gears according to gear profile design drawings.

Content:

- Cutting in 1/4" acrylic results in minor material warping and minor gear teeth face tapering (due to laser)
- Kerf can be accounted for according to the following website/table (according to the material type and thickness):
  - http://www.cutlasercut.com/resources/tips-and-advice/what-is-laser-kerf
- Imperfections on the edge of the cut surface farthest from the laser origin impair gear mating - must be filed to produce an optimal surface/edge finish
- fabricated gears contain 25 gear teeth with a diameter of 75 mm (and a gear module of 3 mm/tooth)
  - according to preliminary, rough gear mating/transmission, this is an ideal module to maintain mating with minimal times that the gears get stuck
- the MakerSpace offers an acrylic cement solution to bind two pieces of acrylic to one another - this can be used to attach two 1/4" gears or 4 1/8" gears to produce the desired 1/2" gear
  - due to time constraints at this Makerspace visit, we were unable to try this binding solution

Conclusions/action items: We are confident in the efficacy of laser cutting to produce reasonable spur gears. Thus, a subsequent visit to the Makerspace is called for to test the efficacy of the acrylic cement solution in binding two cut gears to maximize thickness (and our ability to line these adhered gears together). We plan to laser cut gear profiles designed specifically for our application (including a motor-attached pinion and a gear with the gear holder profile cutout) at our next trip to the Makerspace.

4/20/21 Gear Holder Fabrication

Riley Pieper - May 04, 2021, 12:27 PM CDT

Title: Gear Holder Fabrication

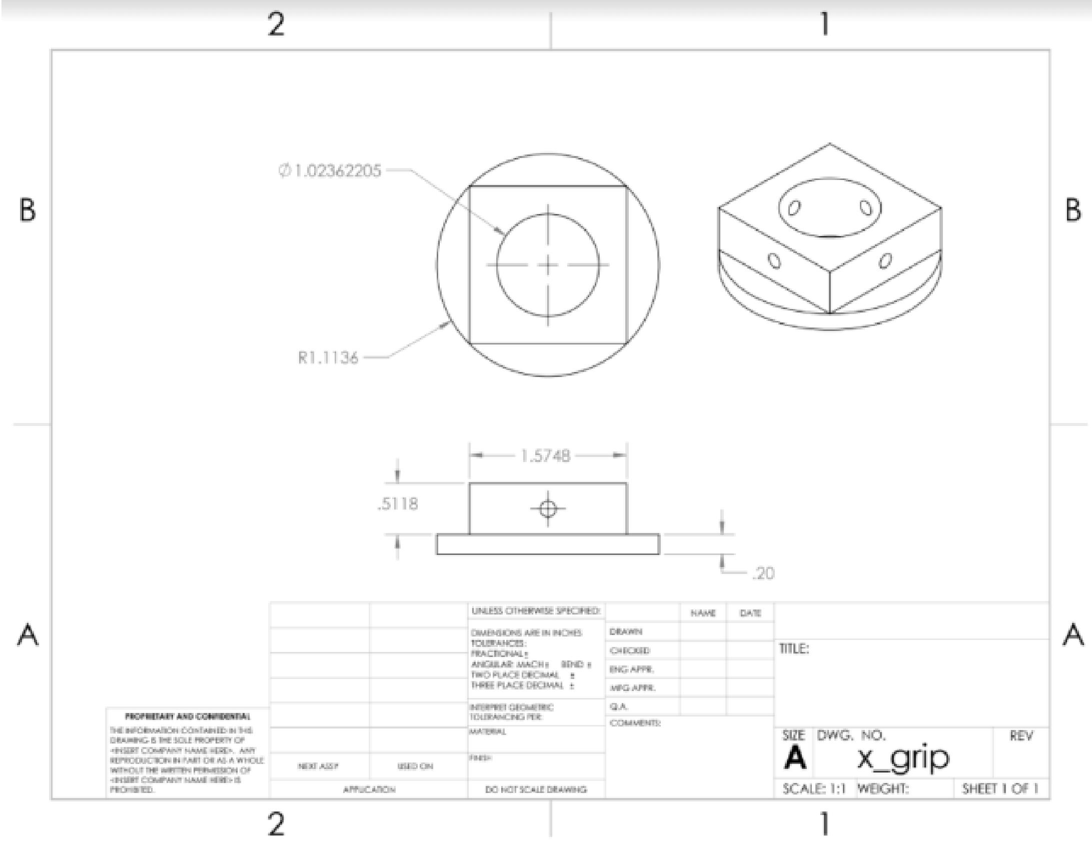
Date: 4/20/21

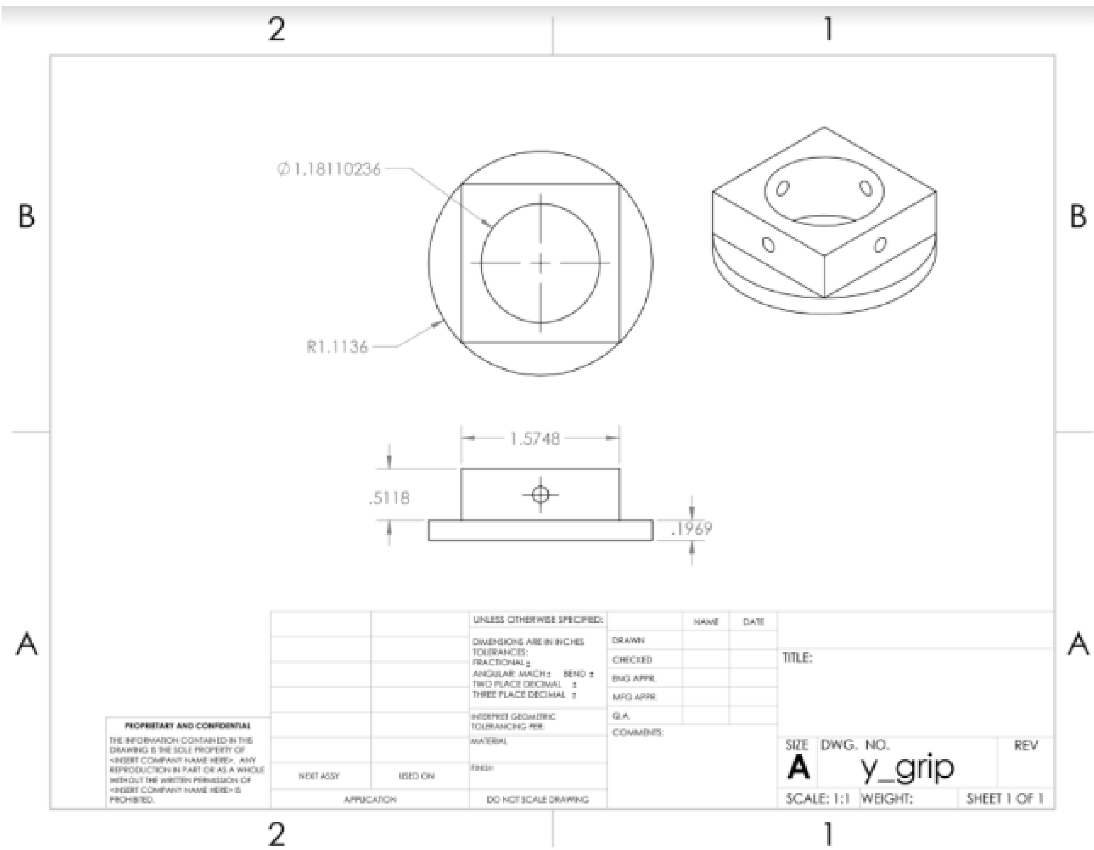
Content by: Riley Pieper

Present: Dylan von Heimburg

Goals: Detail the fabrication methods used to fabricate the gear holder components

Content:





Two gear holders were fabricated, one for each knob. The only difference between the two gear holders was the diameter of the through hole, which matched the dimensions of the knobs that we wanted to fit.

Lathe:

- turned down cylindrical aluminum stock to the desired diameter of the bottom cylindrical portion
- Drilled the center hole with a large drill on the lathe

Drop Saw:

- Cut the lathed piece off of the stock to the desired height

Mill

- Cut out the square profile on the top of the holders
- drilled four set-screw holes through the sides of the square
- tapped the set screw holes according to the threading of the selected screws

Conclusions/action items: These fabrication methods can be used and adjusted as needed to generate new gear holders for future uses of this design. If a different microscope has different sized knobs, the dimensions can be updated according to required sizes.

100 micron translation test

DYLAN VON HEIMBURG - May 04, 2021, 12:01 PM CDT

Title: 100 micron translation test

Date: 5/4/21

Content by: Dylan von Heimburg

Present: Dylan, Jacob, Sam

Goals: test our entire design fully assembled

Content:

The team input a command via Arduino code for the motor to make 100 micron steps in the x direction with a pause inbetween steps. During the pause, the team captured images of fluorescent microspheres of a known (6 micron) diameter as seen below. Consecutive images were analyzed using Image J to determine the actual measured translation of each step. The raw data for 11 consecutive steps are as follows (in microns):

110

199

108

110

88

107

80

107

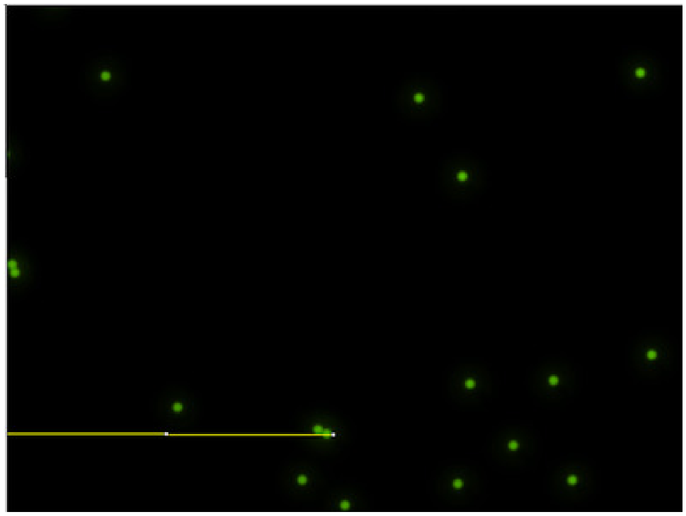
79

115

79

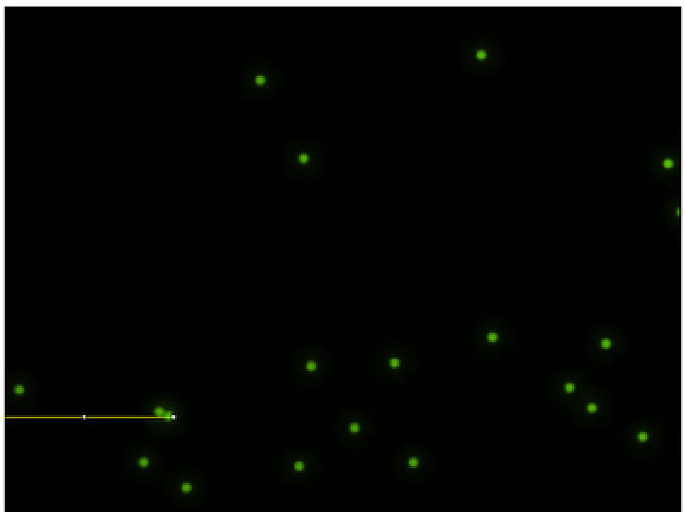
Conclusions/action items: We now have a baseline for the accuracy and resolution of our stage. Further testing would be required to analyze both smaller step sizes, and the use of both motors/directions together.

DYLAN VON HEIMBURG - May 04, 2021, 12:02 PM CDT



402_translation_testing_sample_1.png(18.6 KB) - download

DYLAN VON HEIMBURG - May 04, 2021, 12:02 PM CDT



402_translation_testing_sample_2.png(21 KB) - download

Preliminary Presentation

Jacob Cohn - Mar 05, 2021, 1:01 PM CST

Google logo

Sorry, unable to open the file

Preliminary Report

3/11/21 Final Schedule

Riley Pieper - Mar 11, 2021, 11:25 PM CST

Title: Final Schedule

Date: 3/11/21

Content by: Riley Pieper

Present: None

Goals: Draft a schedule that outlines target deadlines for the remainder of the project action items in order to complete the project prior to the end of the semester.

Content:

	18-Mar	25-Mar	1-Apr	8-Apr	15-Apr	23-Apr	28-Apr
Transmission Fabrication	laser cutting gears	milling holders					
Mounting/Support Design	draw schematic (mount and brace)	plan fabrication					
Software Writing (SI Code)	draft SI skeleton code	refine code with rot-trans calcs	prep for Microman. integration				
Mounting/Support Fabrication		print/acquire parts	assemble on scope				
Micromanager Integration			meet with Microman. contact	integrate SI software	incorporate imaging procedures		
Testing					acquire testing tools	conduct testing	
Final Poster Presentation							
Final Report/Manuscript							

Conclusions/action items: The team will refer to this schedule to determine which activities are the most pertinent at any given time. This flow of actions is critical based on the fact that many of the action items require completion of a prior action item. This schedule will be modified as needed moving forward.

3/10/21 3D Printable Joints

Riley Pieper - Mar 11, 2021, 11:59 PM CST

Title: 3D Printable Joints

Date: 3/10/21

Content by: Riley Pieper

Present: None

Goals: Learn about methods for incorporating snap-type joints into 3D printed components for easy assembly of separate components in order to design a brace for the pivoting mechanism of the stage control shaft that is printed as two halves that snap together around the pivoting point.

Content:

How to 3D Print Joints - Simply Explained

https://all3dp.com/2/3d-printed-joints-the-basics/

- joint types include:
  - Interlocking Joints: don't allow movement except in one direction; keeps parts together with friction
  - Snap-fit joints: require the part to bend to snap into place
    - Cantilever Joints: protruding piece of plastic deflects as the joint is assembled
    - Annular Joints: i.e. pen cap on a pen
    - Ball-and-socket Joints: useful if parts need to flex/rotate
- Incorporating clearance is critical to ensure the physical parts will fit together after 3D printing
  - 0.3mm of clearance is good for most 3D printers
- for parts that bend, incorporate fillets and chamfers to minimize stress concentrations that lead to part failure
- This site also provides tips on printing setup (i.e. orientation, overhangs, supports, etc)

Snap-Fit Joints for Plastics: a design guide

(see PDF of this guide attached to this entry)

This guide provides specific information regarding different snap joint types including:

- Cantilever Snap Joints
- Torsion Snap Joints
- Annular Snap Joints

Snap Fits

http://infocenter.3dsystems.com/bestpractices/mjp-best-practices/projet-mjp-2500/snap-fits

- Deflection-strain formulas for cantilever snap joints
- Common problems and solutions to snap fit designs

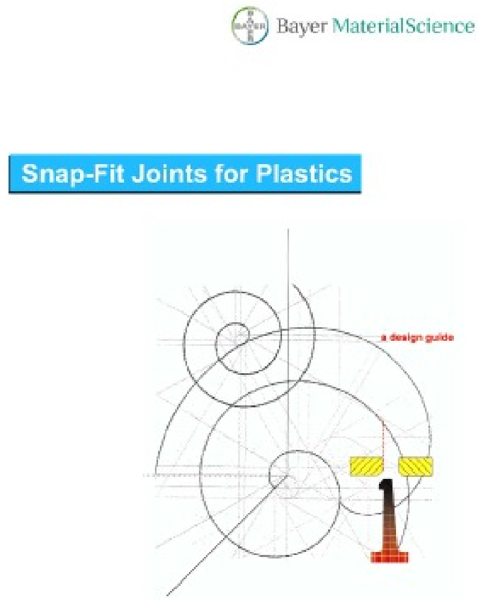
How to connect two parts with printed joints and snap fits

https://www.sculpteo.com/blog/2018/04/25/how-to-connect-two-parts-with-3d-printed-joints-and-snap-fits/

This resource provides similar examples of snap fits as the other resources, but specificially exemplifies them as used to fit two parts that compose an enclosed shell, similar to the use that we want to get out of these snap fitting joints.

Conclusions/action items: The principles, ideas, and tips presented in these resources will be used to design snap fit joint components on the pivot brace that will be 3D printed in two halves and snapped together around the pivoting point on the control knob shaft. It seems that the most applicable snap fit joint is the cantilever snap joint. This will be implemented in SolidWorks and some preliminary 3D printing testing will be done to determine whether it will be effective in fixing the brace together.

Riley Pieper - Mar 11, 2021, 11:53 PM CST



Plastic_Snap_fit_design.pdf(2.5 MB) - download

3/11/21 TB6600 Motor Driver Tutorial

Riley Pieper - Mar 12, 2021, 12:17 AM CST

Title: TB6600 Motor Driver Tutorial

Date: 3/11/21

Content by: Riley Pieper

Present: None

Goals: Explore the Stepper Motor Driver with Arduino tutorial, specific to our purchased stepper motor driver, shared with us by Dr. Nimunkar.

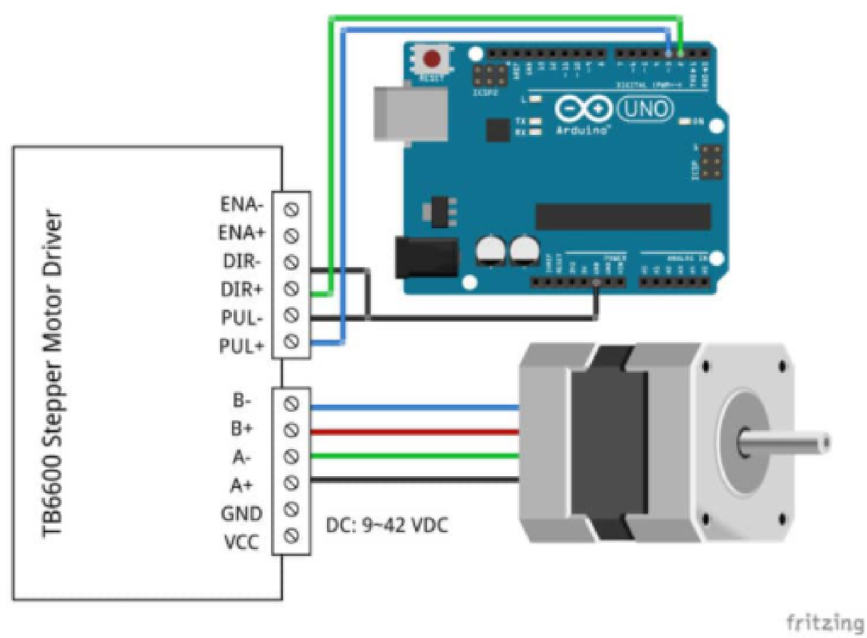
Content:

TB6600 Stepper Motor Driver with Arduino Tutorial (3 Examples) (makerguides.com)

This tutorial provides some specifications of the motor driver module that were not presented to us on Amazon (where we purchased the driver):

Operating voltage	9 – 42 V
Max output current	4.5 A per phase, 5.0 A peak[1]
Microstep resolution	full, 1/2, 1/4, 1/8 and 1/16[2]
Protection	Low-voltage shutdown, overheating and over-current protection
Dimensions	96 x 72 x 28/36 mm
Hole spacing	88, ⌀ 5 mm
Cost	Check price

The wiring schematic presented in this tutorial confirms that the wiring schematic that we are using is correct (ours matches the tutorial):



The microstep table presented in the tutorial confirms our suspicions regarding the settings of the motor driver module (corresponding to full step, 1/2 step, etc)

S1	S2	S3	Microstep resolution
ON	ON	ON	NC
ON	ON	OFF	Full step
ON	OFF	ON	1/2 step
OFF	ON	ON	1/2 step
ON	OFF	OFF	1/4 step
OFF	ON	OFF	1/8 step
OFF	OFF	ON	1/16 step
OFF	OFF	OFF	1/32 step

In regards to the current settings on the driver, the tutorial explains that these settings adjust the current that goes to the motor when it is running. The tutorial recommends starting with a current level of 1A (which is not the rated current of the motor in use). Thus, it seems that the current setting is not dictated by the rating of the motor but rather by the desired current (potentially corresponding to the torque output expected).

The code presented in this tutorial is essentially the same as the basic pulsing code that we have been using to test out mechatronic system up to this point. The tutorial does go into detail about each section of the code, which may be useful if anyone is unclear about what each portion of the code is doing.

The tutorial also makes use of the AccelStepper library via Arduino that is capable of accelerating and decelerating the stepper motor. This functionality does not seem useful to our project at this time, but it may become useful in the future.

Conclusions/action items: After reviewing this tutorial given to us by Dr. Nimunkar, I realize that we already have a general understanding for much of the information that is covered. It was reassuring to learn that the microstep settings are doing what we expect them to do (in terms of adding addition steps in between the full steps) and give us a slighly better idea about the current setting. This tutorial, however, did not inform me about why our motor tends to stall at certain current and microstep settings. Hopefully our upcoming follow-up meeting with Dr. Nimunkar will clarify a few of the final confusions that we have regarding the stepper motor driver that we are using.

3/10/21 Pivot Brace 0.9

Riley Pieper - Mar 12, 2021, 12:36 AM CST

Title: Pivot Brace 0.9

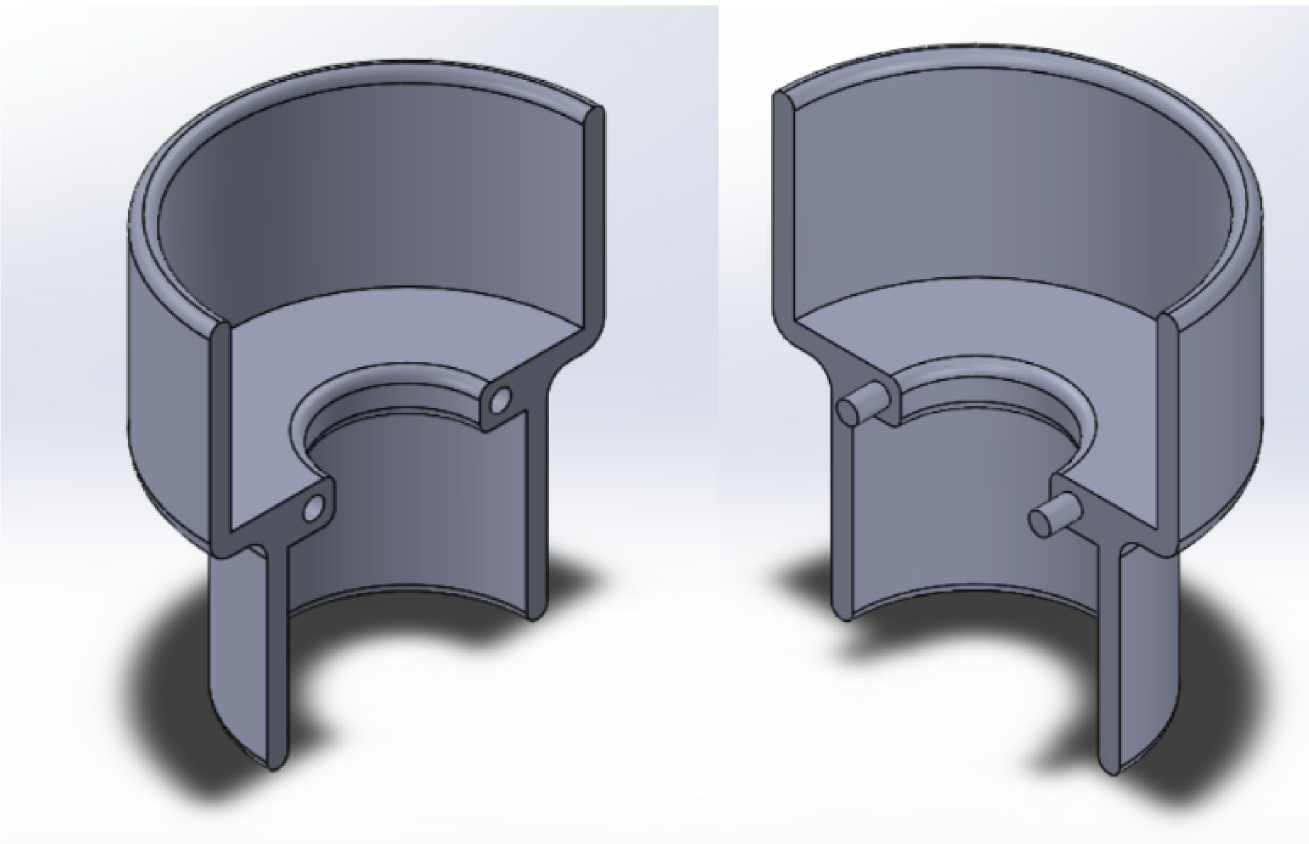
Date: 3/10/21

Content by: Riley Pieper

Present: None

Goals: Design a 3D-printable brace for the pivoting mechanism of the control knob shaft composed of two parts that fit together around the pivoting point.

Content:



Displayed above are the two halves of the pivot brace component. The larger diameter area fits around the larger cylinder directly above the pivot point. The smaller diameter area fits around the smaller cylinder below the pivot point. The extended ridge between the smaller and larger cylinders fits in the area between the cylinders on the shaft and will prevent the brace from moving axially along the shaft when fit in place. The design incorporates pins on one side of the brace that fit into holes on the other side to help maintain positioning of the brace halves relative to one another.

Conclusions/action items: This brace design is not yet complete. It still requires a mechanism of attachment between the two halves. I have been researching methods for implementing 3D-printable snap fit joints that can be used to fix two 3D printed pieces together. One of these snap joints will be incorporated into this design so that the two halves can snap together around the pivot point of the control shaft to prevent pivoting. Once this snap mechanism is implemented, the parts will be 3D printed in resin (for the improved surface finish).

Stepper Motor Explained

Sam Schini - Mar 05, 2021, 1:52 PM CST

Title: Stepper Motor Functionality Explained in Video

Date: 03.04.21

Content by: Sam Schini

Present: Sam Schini

Goals: Understand the mechanical foundation of a stepper motor and how it operates.

Content:

https://www.youtube.com/watch?v=eyqwLiowZiU

Conclusions/action items:

This resource provides an explanation video of how a stepper motor operates. Highlighted is a "hybrid stepper motor" with a clever rotor and stator arrangement of teeth and stator coils to allow for various manipulations of the rotor. Moreover, the synchronous energizing of coil sets can provide half stepping capabilities. Our chosen stepper motor iterates with incredible precision - 0.018 degree step angle.

04.19.21 Meeting w/ Dr. Eliceiri & Dr. Tsuchida (MicroManager)

Sam Schini - Apr 21, 2021, 8:46 PM CDT

Title: MicroManager Integration with Arduino Code Discussion

Date: 04.19.21

Content by: Sam Schini

Present: Sam Schini & Jake Cohn

Goals: Further understand the application of open source microscopy software for our intended design purposes.

Content:

- Weakness of current design is that it is uniquely tailored to the Nikon scope in lab 2005 of ECB
- Control should be inverted: computer --> serial port --> Arduino
    - Simple serial syntax to ask where the stage is, command to see where the stage is, command to ask if the stage is moving, command to stop the stage
- Approach
    - Arduino or real-time operating system
    - Possibly have 2 Arduinos
    - Incorporate Arduino Motion Control
        - Could use a TinyG CNC Controller (which would replace Arduino and motor driver) although it requires Gcode from a serial port and would need a MicroManager interface to be rewritten
- Could consider next steps to refine acceleration/deceleration
- For poster presentation on Friday:
    - Spend time testing and validating - speculate what could be found
    - Determine the challenges that are currently at hand with the software - how do we integrate?
    - Determine a plan for continuing work on this and pursuing a journal publication - find an educational journal

Conclusions/action items:

These are the notes that were taken during the 04.19.21 meeting with Dr. Eliceiri and Dr. Tsuchida. These notes are used to assist future work and direction of project.

03.05.21 Arduino Code

Sam Schini - Mar 05, 2021, 1:40 PM CST

Title: Arduino Code for Basic Circuit

Date: 03.05.21

Content by: Sam Schini

Present: Sam Schini

Goals: Create an Arduino code that spins the stepper motor appropriately.

Content:

```
/*
  Stepper Motor Test
  stepper-test01.ino
  Uses MA860H or similar Stepper Driver Unit
  Has speed control & reverse switch

  DroneBot Workshop 2019
  https://dronebotworkshop.com
*/

// Defin pins

int driverPUL = 7;    // PUL- pin
int driverDIR = 6;    // DIR- pin

// Variables

float speedRPM = 7; // RPM (4 <= SHAKING THRESHOLD <= 11)
int pd = 1500 / speedRPM; // Pulse Delay period (microseconds)
boolean setdir = LOW; // Set Direction

// Interrupt Handler

void revmotor (){

  setdir = !setdir;

}


void setup() {

  pinMode (driverPUL, OUTPUT);
  pinMode (driverDIR, OUTPUT);

}

void loop() {

    //pd = map((analogRead(spd)),0,1023,2000,50); //not needed
    digitalWrite(driverDIR,setdir);
    digitalWrite(driverPUL,HIGH);
    delayMicroseconds(pd);
    digitalWrite(driverPUL,LOW);
    delayMicroseconds(pd);

}
```

Conclusions/action items:

This simplistic code block was taken from the DroneBot Workshop website and allows for the integration of an Arduino, breadboard, Microstep Driver, AC/DC converter (not purchased power supply), and the Stepper Motor. This code produces a fluid rotation and will act as the proof of concept skeleton code for further development of specificity.

04.21.21 Arduino Code

Sam Schini - Apr 21, 2021, 8:22 PM CDT

Title: Arduino Code for Sequential Stage Movement

Date: 04.21.21

Content by: Sam Schini

Present: Sam Schini, Riley Pieper, Jake Cohn, Dylan Von Heimberg, Noah Trapp

Goals: Develop Arduino code with void loops that allow for the sequential movement of stepper motors for 2-D stage translation (x & y dimensions).

Content:

```
/*
  Stepper Motor Test
  stepper-test01.ino
  Uses MA860H or similar Stepper Driver Unit
  Has speed control & reverse switch

  DroneBot Workshop 2019
  https://dronebotworkshop.com
*/

// Defin pins

int driverX_PUL = 7;    // PUL- pin
int driverX_DIR = 6;    // DIR- pin
int driverY_PUL = 5;    // PUL- pin
int driverY_DIR = 4;    // DIR- pin

// Variables

float speedRPM = 2; // RPM
int mstep = 1; // MicroStep Setting
int pd = 1500 / (speedRPM * mstep); // Pulse Delay period (microseconds) // (min / rot) * (60sec / min) * (1,000,000us / sec) * (rot / 360deg) *
(0.018deg / step) * (step / mstep) * (mstep / 2periods)
boolean setdirX; // Set Direction
boolean setdirY; // Set Direction

int deltaFrameX = 500; // microns - movement in X between adjacent frames
int deltaFrameY = 500; // microns - movement in Y between adjacent frames
int captureDelay = 1000; // 2 seconds
int horiz_frames = 6;
int vert_frames = 6;

int xsteps = deltaFrameX * mstep * 2 / 0.9; // steps between frames
int ysteps = deltaFrameY * mstep * 2 / 1.584; // steps between frames


void setup() {

  pinMode (driverX_PUL, OUTPUT);
  pinMode (driverX_DIR, OUTPUT);
  pinMode (driverY_PUL, OUTPUT);
  pinMode (driverY_DIR, OUTPUT);

  Serial.begin(9600);

}
```

```
void loop() {

  for (int k = 0; k < vert_frames; k++){
   if (k%2 == 0){
    setdirX = LOW;
   }
   else {
    setdirX = HIGH;
   }
   digitalWrite(driverX_DIR,setdirX);
   for (int j = 0; j < horiz_frames; j++){
    for (int i = 0; i < xsteps; i++){
     digitalWrite(driverX_PUL,HIGH);
     delayMicroseconds(pd);
     digitalWrite(driverX_PUL,LOW);
     delayMicroseconds(pd);
    }
    delay(captureDelay);
    Serial.println(xsteps);
   }

   digitalWrite(driverY_DIR,HIGH);
   for (int i = 0; i < ysteps; i++){
    digitalWrite(driverY_PUL,HIGH);
    delayMicroseconds(pd);
    digitalWrite(driverY_PUL,LOW);
    delayMicroseconds(pd);
   }
   delay(captureDelay);
  }
}
```

Conclusions/action items:

The provided code is successful in operating a multi-stepper motor system so that it produces stage translation for the serial imaging process. The code accounts for translational calculations for a theoretical tissue culture display and specifies the directional stage movements of an inverted microscope.

Microstep Driver

Sam Schini - Mar 05, 2021, 2:33 PM CST

Title: Understanding the Microstep Driver

Date: 03.05.21

Content by: Sam Schini

Present: Sam Schini

Goals: Understand how to initiate and correctly set up our stepper motor with the microstep driver so that it works correctly.

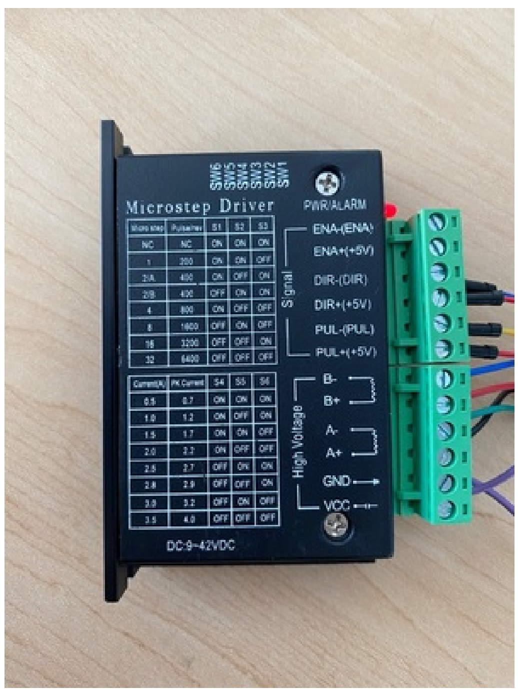
Content:

Per the image attached below, it is necessary to interpret the microstep setting and current setting for our stepper motor. The readings are carried out via the 6 DIP switches and how they correspond to the ideal functionality. Because the motor has a rated current/phase of 1.68A, we will set the driver to produce current of 1.5A with a PK current of 1.7A. Further, we need to better understand the pulse/rev setting, although with this current, a microstep of "2/A" and pulse/rev of 400 seems to work.

Conclusions/action items:

This is a topic for discussion with Dr. Nimunkar in our upcoming meeting. We will be asking about label interpretation and optimal functioning conditions so that the motor is used apppropriately.

Sam Schini - Mar 05, 2021, 2:27 PM CST



Microstep_Driver.jpg(199.1 KB) - download

Motor Driver Research 3/5/21

Jacob Cohn - Mar 11, 2021, 7:15 PM CST

Title: Jacob Cohn

Date: 3/5/21

Content by: Jacob Cohn

Goals: Gather as much information about the team's motor driver as possible to understand how to use it properly for our purposes

Content:

In this article, they used a motor with a smaller gearbox, but used the same stepper motor driver that our team is working with. The driver supports up to 1/16 microstepping which allows for our motor's movement to be extremely fine. Based on the wiring set up, our group appears to have the correct wiring for the motor and the driver.

There is good steps outlined for troubleshooting wiring problems.

1. Try to spin the shaft of the stepper motor by hand and notice how hard it is to turn.
2. Now pick a random pair of wires from the motor and touch the bare ends together.
3. Next, while holding the ends together, try to spin the shaft of the stepper motor again

The microstep setting section will be most useful as we move forward. Based on this document, we probably could have used motors with a smaller gear reduction, but we will be fine with the motors we have. They attribute a **smaller step setting to achieving quieter, smoother operation** while sacrificing speed. It is difficult to know what setting we want to use without testing with the microscope, but this will be something to play with when we get the system set up. For **stalling problems**, they say to increase the current level.

They use a slightly different arduino code that we can use to model how our code operates. They also have further code that introduces speed, rotation, and direction. Within Arduino, they use AccelStepper which is a zip library and this manages the acceleration and deceleration of the stepper motor.

```
/* Example sketch to control a stepper motor with TB6600 stepper motor driver and Arduino without a library:
continuous rotation. More info: https://www.makerguides.com */

// Define stepper motor connections:
#define dirPin 2
#define stepPin 3

void setup() {
  // Declare pins as output:
  pinMode(stepPin, OUTPUT);
  pinMode(dirPin, OUTPUT);

  // Set the spinning direction CW/CCW:
  digitalWrite(dirPin, HIGH);
}

void loop() {
  // These four lines result in 1 step:
  digitalWrite(stepPin, HIGH);
  delayMicroseconds(500);
  digitalWrite(stepPin, LOW);
  delayMicroseconds(500);
}
```

TB6600	Connection
VCC	9 – 42 VDC
GND	Power supply ground
ENA-	Not connected
ENA+	Not connected
DIR-	Arduino GND
DIR+	Pin 2 Arduino
PUL-	Arduino GND
PUL+	Pin 3 Arduino
A-, A+	Coil 1 stepper motor
B-, B+	Coil 2 stepper motor

Operating voltage	9 – 42 V
Max output current	4.5 A per phase, 5.0 A peak[1]
Microstep resolution	full, 1/2, 1/4, 1/8 and 1/16[2]
Protection	Low-voltage shutdown, overheating and over-current protection
Dimensions	96 x 72 x 28/36 mm
Hole spacing	88, ⌀ 5 mm

information from https://www.makerguides.com/tb6600-stepper-motor-driver-arduino-tutorial/

Conclusions/action items:

The information found in this resource will help to troubleshoot motor, code and integration issues that the team may face with the system once testing begins. Keeping this resource in mind, the team plans to move forward using the code they provide, the suggestions they make, and the troubleshooting tips they give to guide us with integration and logically driving our motors. The first order of business will be to find the settings we want to use and optimize our code to maximize movement efficiency with that.

Gliding track idea 3/11/21

Jacob Cohn - Mar 11, 2021, 7:49 PM CST

Title: Gliding track idea

Date: 3/11/21

Content by: Jacob Cohn

Goals: Get a better idea of Dr. P's idea with using the product that he mentioned via email as an alternative to our mounting system.

Content:

In our preliminary presentation, the team posed an alternative to our mounting system that entailed modeling a wheel-like system to carry our motors with the movement of the stage so that they can continuously mate with the translational control knobs of the microscope. Dr. P suggested this, a track-like system to connect to the microscope and serve the same purpose as our proposed alternative. The caveat being that this system is commercially available and we would not have to build it from scratch.

It is commercially available for just under $7 from Grainger, and comes in a two pack. The glide mechanism is through a ball bearing, similar to our proposal, but in this, we would mount our motors to the track and fasten the track to the microscope for stability. The length is 14 in which is likely longer than we would need, but may rule out its use based on spatial considerations. We would be able to repurpose our mounting brackets that we currently have to fix the motors to the gliding surface.

https://www.grainger.com/product/GRAINGER-APPROVED-Side-Drawer-Slide-33GN78

Conclusions/action items:

This option seems relatively feasible if our mounting system fails in any way. The main concern would be the length consideration taking up more space than we are afforded. If the design process brings us to this point, we certainly should consider this as a primary option to address moving our motors with the stage.

Green Card Documentation

Jacob Cohn - Mar 11, 2021, 7:51 PM CST

Title: Green Card Documentation

Date: 1/29/21

Content by: Jacob Cohn

Goals: Demonstrate training

Content:

Conclusions/action items:

Use this training to help fabricate gear holders

3/11/21 Microscope Testing Options

DYLAN VON HEIMBURG - Mar 12, 2021, 12:27 AM CS

Title: Microscope Testing Options

Date: 3/11/21

Content by: Dylan von Heimburg

Present: Dylan von Heimburg

Goals: Explore more in-depth options for testing our fabricated complete final design.

Content:

The first and most basic option for measuring with a microscope is to use a stage micrometer. A stage micrometer is a microscope stage with markings similar to a ruler on its surface. Stage micrometers are relatively inexpensive (~$10), but I was only able to find ones with markings down to .01 mm or 10 micron increments. This will be suitable for an accuracy along the lines of "how accurately can our system execute the command of moving 100 microns in the x direction" for example, but not precise enough for our resolution tests.

https://www.microscopeworld.com/t-microscope_measuring.aspx

To combat this challenge, our advisor, Dr. Campagnola, steered the team towards utilizing some fluorescent beads. Something similar to the Flow Cytometry Sub-Micron Particle Size Referen Kit would be more suitable for our resolution tests. If, for example, we know a particle in our field of view is 2 microns in diameter, then comparing consecutive images of that reference sphere before and after a single step using Image J will result in an estimation of our stage system's resolution.

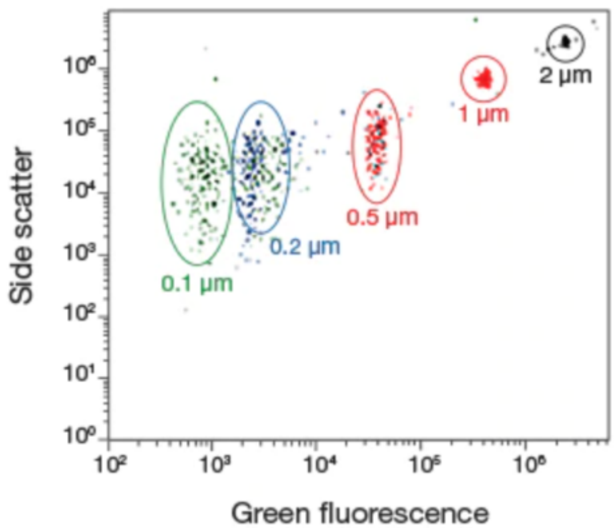


Figure 3. Separation of differently sized microspheres from the Flow Cytometry Sub-Micron Particle Size Reference Kit. Five microsphere suspensions from this reference kit were analyzed using the Attune® Acoustic Focusing Cytometer (Blue/Violet). The diameters of the green-fluorescent microspheres are as marked.

https://www.thermofisher.com/us/en/home/references/newsletters-and-journals/bioprobes-journal-of-cell-biology-applications/bioprobes-70/fluorescent-microspheres-for-calibration.html

Conclusions/action items: Ideally, each component of our system will be fabricated in time to test the accuracy and resolution according to the methods described above. Howev if this is not the case, other methods will have to be developed to test components in isolation.

3/4/21 Laser 1 Upgrade

DYLAN VON HEIMBURG - Mar 11, 2021, 11:54 PM CST

Title: Laser 1 Upgrade

Date: 3/4/21

Content by: Dylan von Heimburg

Present: Dylan von Heimburg

Goals: Obtain the laser upgrade necessary to use the laser cutter to fabricate our initial gear prototypes.

Content:

EMU

Welcome, Dylan von Heimburg
You are logged in to the
EMU Reservation System

Reserve a Machine | My Reservations | My Status

Materials Fee is paid through 2021-06-30. See Receipt

You may apply for the following upgrades:

Name
Welding 1
CNC Mill 1
Woodworking 1
Ironworker 1
Cold Saw 1
CNC Lathe Haas 1

You have the following permits and upgrades:

Name	Date
Green Permit	02/27/2019
Red Permit	02/13/2018
Laser 1	03/04/2021

Conclusions/action items: I am now able to reserve time in the UW MakerSpace to use the laser cutter to make the initial gear prototypes. We will experiment with the precision of the laser at varying acrylic thicknesses.

Notes from Stepper Motor with Arduino Tutorial

NOAH TRAPP - Mar 11, 2021, 12:37 PM CST

Title: Notes from Stepper Motor with Arduino Tutorial (makerguides.com)

Date: 3/11

Content by: Noah Trapp

Present: Noah Trapp

Goals: Learn more about how we can best control the DC motors with Arduino pulsing code

Content:

- fairly simple wiring schematic for Arduino (photo included below)
- 1/2 step mode should provide 400 steps per revolution (pair this with gear reductions for increased precision)
- could even use 1/32 step mode
- lower step does result in much slower operation
- start with 1 A current level
- example pulsing code to control stepper motor:

```
#define dirPin 2
#define stepPin 3

void setup() {
// Declare pins as output:
pinMode(stepPin, OUTPUT);
pinMode(dirPin, OUTPUT);

// Set the spinning direction CW/CCW:
digitalWrite(dirPin, HIGH);
}

void loop() {
// These four lines result in 1 step:
digitalWrite(stepPin, HIGH);
delayMicroseconds(500);
digitalWrite(stepPin, LOW);
delayMicroseconds(500);
```

- need to determine steps per revolution constant in order to have more control over speed and precision
- for loops control how many steps the motor takes (integrate with Micro-Manager?)

source: https://www.makerguides.com/tb6600-stepper-motor-driver-arduino-tutorial/ (shown to us by Dr. Nimunkar)

Conclusions/action items: determine the step mode that is most suitable for our project and implement

3/17 Work on Stepper Motor

NOAH TRAPP - Apr 13, 2021, 2:27 PM CDT

Title: Stepper Motor Control Via Arduino

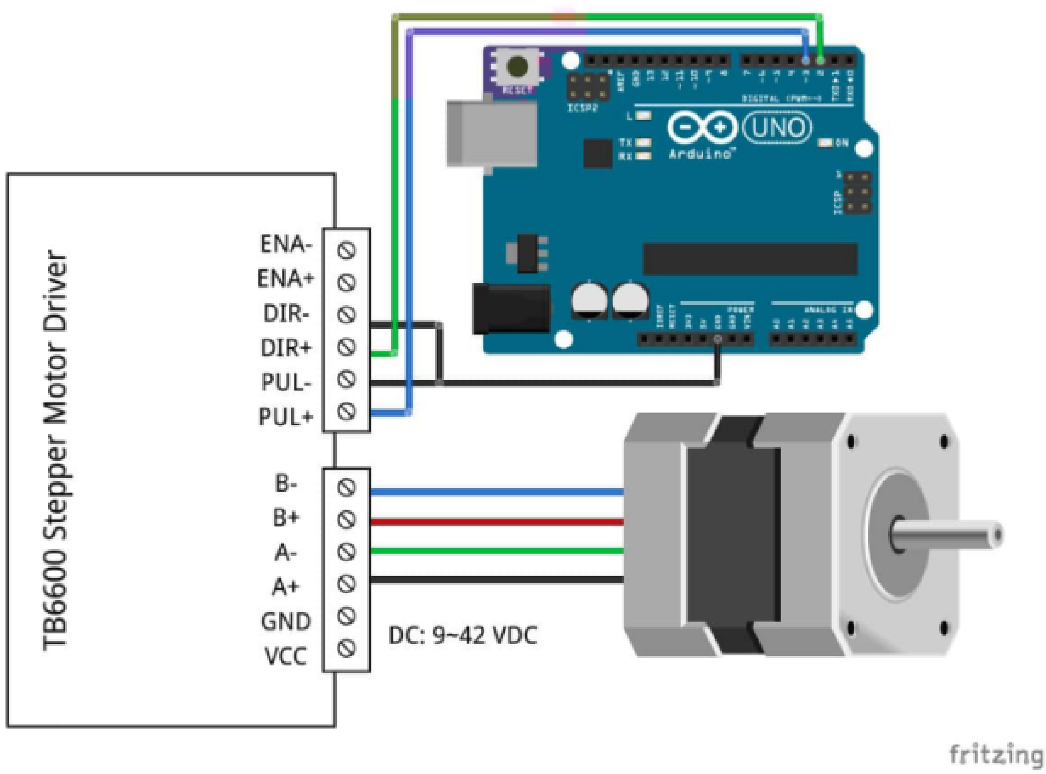
Date: 3/17

Content by: Noah

Present: Sam

Goals: Work on better control of stepper motor via Arduino code

Content:



- Wiring schematic for the Arduino code we will be using (https://www.makerguides.com/tb6600-stepper-motor-driver-arduino-tutorial/)

- Code lets us control:
    - rotation
    - speed
    - direction
- steps per revolution is based on which micro-stepping constant we use

- unfortunately we were unable to get the stepper motor working properly despite using code which seemed to have no errors. Hopefully our meeting with Amit will help clear out some of the potential issues with the stepper motors or our code

Conclusions/action items: Meet with Amit, refine code, look at wiring attachments

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: