BME Design-Spring 2024 - MAXWELL NASLUND
Complete Notebook

PDF Version generated by

Amber Schneider

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Team contact Information

Jamie Flogel - Jan 26, 2024, 12:34 PM CST

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Project description

Amber Schneider - Apr 25, 2024, 5:37 PM CDT

Course Number: BME 402

Project Name: MRI compatible motion platform

Short Name: nonmagnetic_mover

Project description/problem statement:

Tissue phantoms used for the testing and calibration of quantitative magnetic resonance imaging (qMRI) are typically static replicas of the human body. However, these static models fall short in accurately capturing the continuous motion due to natural physiological processes, such as respiration and digestion. To address this limitation, a specialized MRI-compatible device capable of positioning a phantom and replicating physiological movements was developed to enhance the accuracy of qMRI evaluations.

About the client: Mr. Jiayi Tang - UW School of Medicine and Public Health Department of Medical Physics

2024/01/31 Client Meeting 1

Jamie Flogel - Jan 31, 2024, 3:58 PM CST

Title: First Client Meeting of the Semester

Date: 1/31/2024

Content by: Jamie

Present: Amber, Max, Kendra, Caspar

Goals:

-Redefine goals for the semester

-Check in on project

Content:

-Client is open to different directions

-Baseline goal was movement provided that is MR safe

-Client has concerns with the friction problem

-Client was hoping to have mechanical issues resolved

-More testing/validation should be done

-Testing within the MRI setting to determine presence of artifacts

-Client is not expecting perfection within the mechanical control

-Given appropriate modifications and testing there are already many applications

-Two directions of motion would be good but is not the primary motion (only a 10-15% improvement)

-Another possible direction (control theory) - attempt to characterize the transfer function - be able to account for arbitrary waveforms

-Want to be able to model/measure difference between anatomical motion and platform output

-In general client is open to the interests of the team

-Client anticipates that a significant time commitment will be needed to do testing

Conclusions/action items:

We should begin working on the checklist to be able to test withing the MRI setting. We should continue to make modifications to optimize our current design rather than focusing on adding another direction of motion.

2024/03/11 Client Meeting 2

Amber Schneider - Mar 11, 2024, 8:21 AM CDT

Title: Client Meeting 2

Date: 3/11/2024

Content by: Amber Schneider

Present: Jiayi Tang, Max, Jamie, Caspar

Goals: get better understanding of client requirements for frequency and amplitude

Content:

- Previous Max Specifications
  - 60 number -- infants
- New Max Specifications
  - 60 cycles per minute --> 1 or 2 cm
- If we arent interested in ADC problem, we can pick tha amplitude and frequency range

https://www.researchgate.net/figure/Amplitudes-of-respiration-induced-liver-motion-of-each-liver-segment-during-expiration_tbl2_324210979

Segment	Average amplitude ± SD (mm)		
	LR	AP	SI
S1	−2.0 ± 2.6	1.0 ± 1.3	5.5 ± 2.6
S2	0.3 ± 2.2	1.2 ± 3.5	6.3 ± 4.2
S3	−0.3 ± 1.9	2.4 ± 1.4	5.8 ± 2.8
S4a	−1.4 ± 3.3	1.5 ± 2.4	3.0 ± 2.6
S4b	− 1.2 ± 1.6	2.0 ± 1.9	5.3 ± 3.4
S5	− 0.2 ± 2.1	3.2 ± 2.0	5.5 ± 2.4
S6	− 0.1 ± 4.6	2.2 ± 2.3	6.5 ± 3.5
S7	− 1.4 ± 3.8	3.5 ± 2.5	8.6 ± 3.4
S8	1.0 ± 2.6	3.3 ± 2.3	5.0 ± 3.3
mean	−0.6 ± 3.0	2.3 ± 2.4	5.7 ± 3.4

Positive values denote excursion in the left, posterior, or superior directions; Negative values, right, anterior, or inferior
Abbreviations: LR left-right, *AP* anterior-posterior, *SI* superior-inferior, *SD* standard deviation

- 6 cm is a lot, probably extends use into modeling other things
- does'nt want to lose resolution at a lower amplitude
  - ensure accuracy at adult frequency & amplitude
- **Value lower amplitudes more**
- 60 breaths per minute isnt necessary for the lab
- Engineering contest
  - more people will find project interesting with greater range
- 20 breaths per minute would be great

Amplitude Range: 1 - 3 cm (6 cm **max**)

MRI

- 3 Scanners
  - 2 available all day
  - 1 available after 3pm
- MR Physicist
  - strong hand magnet
  - pass over design
- Generally- good availability
- *Try to test within the next 2-3 weeks*
- Aluminum coupling on motor
  - should be fine
  - brass would be better
- Copper sheet
  - should be fine
  - not moving

Conclusions/action items:

Met with the client to discuss the maximum specifications for the device. Update motor control and gear ratio based on new specifications. Test to see if the motor can accurately reproduce these values.

2024/04/02 Client Meeting 3

Kendra Besser - Apr 02, 2024, 10:01 AM CDT

Title: Client Meeting 3

Date: 4/2/2024

Content by: Kendra

Present: Jiayi Tang, Amber, Kendra

Goals: Update the client of motor complications and evaluate advice he might have

Content:

problems:

- error in the RPM output
- can't get a clean signal from the microcontroller to the motor controller
- noisy signal, reached out to company to see if this was meeting their constraints
- tried calling company but the number didn't work (international?)

questions:

1. In the starter code, where does the hexaVelocity conversion (hexaVelocity = 0.0063*rpmVelocity) come from? Can this value be improved somehow?
2. How can we get the RPM to be more precise? Is there a specification for the precision of the RPM?
3. Do people typically edit the starter code? If so, are other hardware changes typically made as well?

notes:

- from Yanis: hexaVelocity = 0.0063*rpmVelocity; = **coefficient used to link speed in RPM to a numerical speed setpoint**
- **the error was consistent amoung trials but the standard deviation varied as speed varied**
- **contact marin and engineer carl.nassif@tekceleo.fr Carl Nassif he's the one who sent original code**
- **unplug analog pin and just look at analog output controller**
    - **is the microcontroller noisy (analog voltage) - use different microcontroller (they have an external digital to analog converter)**
    - **or the noise is coming from converter board - question for the company about why that is**
    - **encoder was used to count number of revolutions - PID scheme with closed loop code**
    -
    - **if the filter does not work, the implement the closed loop solution**

Conclusions/action items:

Met with the client to discuss the motor complications. Work on cleaning up the signal with the multiple contacts and apply the amplifier/ LP filter. If that does not work then consider working on the PID control aspect to refurbish the signal.

2024/01/26 Advisor Meeting 1

Amber Schneider - Jan 26, 2024, 1:54 PM CST

Title: Advisor Meeting 1

Date: 1/26/2024

Content by: Amber Schneider

Present: Kendra, Jamie, Dr. Trevathan, Caspar, Max

Goals: discuss format of the semester, project ideas, and future work

Content:

1st Day Activities

- Progress Report has changed
  - Keep simple and easy to understand
- Change course sections
- Update website and notebook

Administrative Items

- No design matrix
- Preliminary Presentation -- coming up in 2 weeks
  - Advisor is going to get more info by next week to discuss
  - present to advisor & client
- Final Report
  - writing a "journal article"
  - pick a journal, write within requirements
  - can submit if team chooses to
    - **discuss with client, can possibly work with him to help**
- Notebook
  - focus on entries related to continuing the design
  - include some new research notes for biology and physiology

Project Discussion

- Mechanical Design
  - Improving gears (less play between them)
  - Increasing gear ratio for more torque
  - Belt drive?
- Motor Control
  - Understand values that were included in the original code
  - Delays in motor control can cause the velocity to lag
    - Causes total position to be less than expected
  - Solution:
    - Implement PID control system
    - Get position feedback from encoder

Conclusions/action items:

The team met with our Advisor, Dr. Trevathan, for the first time this semester. He began the meeting by going over logistics of the course, including future deliverables and course schedule. Next, we discussed the project in terms of Mechanical Design and Motor Control. Future action items include meeting with the client to get insight into his expectations for the semester.

2024/02/02 Advisor Meeting 2

Kendra Besser - Feb 02, 2024, 1:54 PM CST

Title: Advisor Meeting 2

Date: 2/22024

Content by: Kendra Besser

Present: Amber, Jamie, Dr. Trevathan, Caspar, Max

Goals: Discuss the progress made so far, a more detailed idea of what we want to do with the prototype, and expectations for the presentation

Content:

Overviewed Client meeting:

- we need to ask for bound of frequency to understand gear ratio
- we are replacing the metal schools

motor

- the motor company updated documentation so we have revised this
- they have new control specifications
- PID and transfer functions
- used proportional control (position control)
- we want to reach out to the company and get info about implementing position control
- Trevathan suspects that we are not hitting our velocity (speed response time 50 ms)
- the way we are measuring time in the code could be more efficient
- discuss how PID control can be implimennted
    - write algorithm to read value then adjust is to what you would expect

journal submission:

- getting something published takes a few years
- the end of semester goal is to get a draft
- at the end of the semester we have to have a draft of the whole semester (not expected to be submittable) - just on the platform
- abstract could be done as a side work to get to the conference
- we will likely be co-authors on his research journal if the platform is used

goals:

- focus on the 1D device
- revise errors in design
- more user friendly product (control software)
- at the end of the semester
- use a lot of the semester to test and user interface
    - upload csv file for user interface
    - transfer function
- MRI saftey testing by the end of February

presentation

- it will just be the group and advisor in the room
- the client can be invited
- no design matrix but it is more so discussion of current prototype, what we learned from it, and a detailed timeline of the work we are planning on doing
- plan on a discussion at the end of the presentation
- 10min presentation? - he said that is his understanding
- specifics on how to test and quantitative
    - how we learned from those and how to update the testing schedule

Conclusions/action items:

The team met with our Advisor, Dr. Trevathan, for the second time this semester. We discussed were we want to take the project and the steps we have made to work in that direction. We discussed what he excepts for the upcoming presentation next week.

2024/02/16 Advisor Meeting 3

Amber Schneider - Feb 16, 2024, 1:55 PM CST

Title: Advisor Meeting 3

Date: 2/16/2024

Content by: Amber

Present: Jamie, Dr. Trevathan, Caspar, Max

Goals: Discuss the progress made this week

Content:

Physical Prototype

- Plastic screws are **ORDERED**
- Working on gearing ratio
  - Amplitude = 6cm
  - Frequency: 20/60
- understanding motor code
  - met with coding team to understand equations from last semester

Motor

- Encoder
  - 1 or 2 pins used to read
  - number of rotations vs ticks
  - *How is it updated?*
- Interrupt vs wait statements
  - wait statements continue to run code (NOT IDEAL)
- RPM to Voltage
  - updated and ran test
  - seems to be more accurate
    - only tried at 60 RPM value

Troubleshoot Motor in Next Advisor Meeting

- Send Dr. Trevathan code to review ahead of the meeting

Paper

- Midterm version due in a few weeks
- BME 402 Guidelines --> Writing a research paper
  - https://bmedesign.engr.wisc.edu/files/course/report/BME402-Whitesides_writing_research_paper.pdf
- Expectations for Midterm Draft
  - Data from last year as **example**
  - Description of the device
  - Outline for sections we dont have data for
    - Whitesides outline
- Choosing journal article
  - Variety of different types of scientific journals
    - Science, Nature: broad audience, important and exciting results, cited by a lot of other articles, high impact factor (rating 30+)
    - Domain specific journals (IEE biomedical engineering): more engineering oriented, not much validation required
    - Journals that specify in methods
  - Focus on what audience we want to target
    - MRI researchers -- what journals are they publishing in? reading?
  - Many have author requirements / guidelines to follow
  - Finding
    - find articles that use similar technology
    - what journals are they publishing in?
- **Project Goal: Open source methods project that can be used accross many MRI applications**

Conclusions/action items:

Met with advisor to discuss 2 aspects of the project: prototype & motor. Discussed updates, challenges, and future work. Began discussing midterm report.

2024/02/23 Advisor Meeting 4

Amber Schneider - Feb 24, 2024, 11:39 AM CST

Title: Advisor Meeting 4

Date: 2/23/2024

Content by: Amber

Present: Jamie, Dr. Trevathan, Caspar, Max, Brandon Coventry

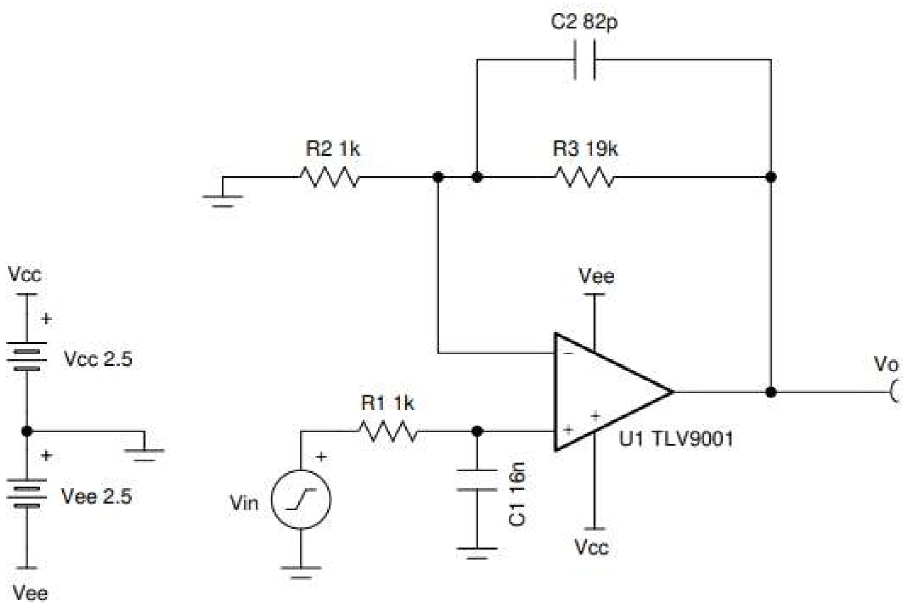
Goals: Discuss the progress made this week, review motor code & output

Content:

Microcontroller

- There could be a pre-scalar on the nucleo board
    - typically ~1.5 if it exists
- V_ref = 3.3 V
- V_out = 3.3 V / 2^12 * AnalogValue
- **Op Amp (step down) filter**
    - better to use the full resolution range of the microcontroller than just a little bit
    - can add a op amp circuit to step down the gain by a certain factor (10?)
    - Reccomended op amp: TL071 or TL072
        - typical to find in an instrumentation lab
- **Low Pass filter**
    - get rid of high frequency noise (as seen on oscilliscope)
    - must find adequate cutoff frequency

Circuit Design: low-pass filter combined with a non-inverting amplifier

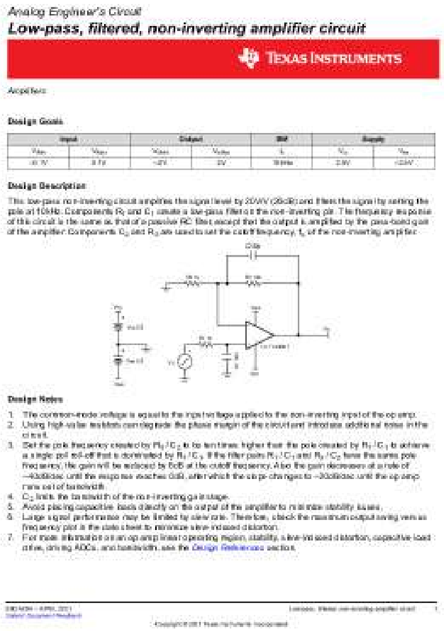


- V_in = Nucleo Output
- Future Mathematics: https://www.ti.com/lit/an/sboa294/sboa294.pdf
    - Steps:
        - calculate gain
        - find necessary R values (ratio, let R_1 = 1k)
            - Good to have in the range of 1k to 10k
        - use value to find cutoff frequency
            - 10x highest desired frequency

Conclusions/action items:

Briefly discussed activities from last week involving the prototype improvements. Reviewed rough outline of preliminary report. Amber discussed the motor progress and challenges from the past week. Brandon Coventry and Dr. Trevathan helped troubleshoot issues with the microcontroller. The team concluded that an additionall step-down amplifier circuit along with a low-pass filter is necessary to get a better signal from the microcontroller to the motor control board. Action items include finishing the preliminary report, building the prototype, and creating the correct circuit.

Amber Schneider - Feb 24, 2024, 11:39 AM CST


Analog Engineer's Circuit

Low-pass, filtered, non-inverting amplifier circuit

TEXAS INSTRUMENTS

Design Goals

Design Description

Design Notes

Download

BME402_LP_and_nonInverting_Circuit.pdf (505 kB)

2024/3/1 Advisor Meeting 5

Kendra Besser - Mar 01, 2024, 1:46 PM CST

Title: Advisor Meeting 5

Date: 3/1/2024

Content by: Kendra

Present: Jamie, Dr. Trevathan, Caspar, Max, Amber

Goals: Discuss the progress made this week

Content:

- preliminary deliverable, submitted this morning
- meeting next week, then the week after is the tong lecture (can meet after), then show and tell, then next week
- show and tell
    - we are not showing, only telling, we are only giving feedback to juniors
    - juniors get the chance to get information from more experienced seniors
- progress
    - redesigned the gear box and printed by the end of the day
    - circuit is designed in LT spice
    - to convert to rpm we convert to 1/175
    - max amplitude
        - 6cm is our max distance = 22 velocity code
        - 22/175 is gain in circuit, then divide by 22 in code
        - chose something that is a little less than that for gain because resistor values may be limited
        - cutoff frequency = 10 x highest frequency in sin wave
            - if we have cutoff of 5 hz it is possible to get that bandwidth (limiting factor is the resistors)
            - could have op amps that drift (not stable) - we probably wont have issues with that because of our low range
            - definitely cutoff before 60 hz (that's were a lot of noise come from)
            - 32uF capacitor is a larger capacitor but available (5% accuracy)
            - calibrate the capacitor and resistors to use the precision in the code
            - can look for components on digikey to see if the are accessible on market
            - higher cutoff makes capacitor smaller
            - goal is to output higher wave forms which will reduce noise
        - the high frequency noise is coming from microcontroller, digital to analog converter, etc
    - we will build circuit by end of next week and implement in full code

Conclusions/action items:

work on mechanical assembly and build the low pass op amp circuit then prepare for show and tell.

2024/3/8 Advisor Meeting 6

Amber Schneider - Mar 08, 2024, 2:17 PM CST

Title: Advisor Meeting 6

Date: 3/8/2024

Content by: Amber

Present: Jamie, Dr. Trevathan, Caspar, Max

Goals: Discuss the progress made this week

Content:

Updates

- prototype gearbox and rails were newly printed
- assembled with plastic screws
- circuit was created and initially tested
    - issues with amplifier
        - How to power?
    - issues with LP filter
        - When to cutoff? How much should gain be at 60 Hz?
- Potential Solutions
    - add another inverting op amp to the circuit (gain -1)

TL-072: https://www.ti.com/product/TL072

Conclusions/action items:

Team discussed progress made during the week with the physical prototype and the motor control circuit. Next steps include improving the circuit and testing.

2024/4/5 Advisor Meeting 7

Kendra Besser - Apr 05, 2024, 2:19 PM CDT

Title: Advisor Meeting 7

Date: 4/5/2024

Content by: Kendra

Present: Jamie, Dr. Trevathan, Caspar, Max, amber

Goals: Discuss the progress made this week

Content:

- discussion of inverting voltage conversion circuit
    - opened pinout diagram to check circuit
    - we have a dual output chip - only designed to do both outputs
    - it takes voltage of 4.5-5 volts and converts
    - the microcontroller (nucleo-F446RE) has a 5 v input, we should have plenty of current to pull from this
    - 0v vs ground - it is an isolated system so they are not at the same potential (we could connect them together for our purpose)
    - designed for dual rails
- we rebuild inversion circuit
    - not necessarily built on bread board because there is a lot of capacitance and can cause noise (shouldn't be a huge deal of our system but could be a source of error)
    - we will have almost no capacitance in the load
    - specs: 5 volt in, dual out 3.3, 4.7 uF on input, 4.7 uF on output
    - dual output configuration
    - input going to pin 1 and 2, on opposite side of chip (keep capacitors close to chip) between vin and ground (input capacitor)
    - negative output is -3.3
    - the output is a ratio of input voltage, should be a clean signal; however
- to do
    - in filter swap electric capacitors with ceramic ones
    - use 1x probe to measure signal

Conclusions/action items:

Team discussed progress made during the week with the inverting voltage conversion circuit. Next steps include completing the circuit design and testing device.

2024/4/12 Advisor Meeting 8

Jamie Flogel - Apr 12, 2024, 2:17 PM CDT

Title: Advisor Meeting 7

Date: 4/12/2024

Content by: Jamie

Present: Kendra, Dr. Trevathan, Caspar, Max, amber

Goals: Discuss the progress made this week

Content:

- discussion of issues with power inversion circuit
  - Motor seemed to function fine with out the circuit in the MRI
  - If we can correct the mismatch in the sinusoid then maybe its not worth our time to continue working with the circuit
- Discussed meeting with motor company
  - They told us to change the value for the conversion
  - Determine the value experimentally
  - We ran tests and altered the coefficient to get closer to correct RPM
  - We think we are pretty close but need to test in sinusoid rather than constant output
  - The code is cleaner and clearer now
  - Changing the gear ratio probably helped a lot with cleaning up the signal
  - Discussed issue with varying the mass impacting the speed we reach the correct acceleration
    - We should look at this over different masses
    - Want to make sure that we are achieving the expected velocities
- Discussed testing in the MR room
  - We will be able to track motion of the phantom in the platform
  - Discussed issues with the wire
  - We need to cut the PVC pipe shorter
- Discussed design excellence award criteria
  - Focused on engineering progress and the data and validation
  - Really try to capture the importance of what we are doing
  - What did you do and what's the data you got
  - Did you achieve your goals
  - Make sure to get across the potential and impact for your design
  - Circle back to the impact at the end
  - We need to cut back the draft
  - We also will need to include the data
  - Are we able to accurately get the velocity and positions we expect
  - Wants to see data across multiple masses
    - Adjust the calibration factor
    - Show we can do this reliably across different masses

Conclusions/action items:

Team discussed progress made during the week with the power inverting circuit, GitHub, and the calibration factor. We also discusses our MR room testing and future testing. We should continue to do more testing.

2024/4/22 Advisor Meeting 9

Kendra Besser - Apr 22, 2024, 12:51 PM CDT

Title: Advisor Meeting 9

Date: 4/22/2024

Content by: Kendra

Present: Jamie, Dr. Trevathan, Caspar, Max, amber

Goals: Discuss the results and implications of testing

Content:

- we showed the testing results to trevathan
- no direct relationship from weight to percent error
- recalibrated conversion factor
  - still no direct relationship with weight
- no direct relationship with weight
  - motor is not limited by torque required
  - error is likely form operating at a small motor amplitude acceleration
  - cant control motors ability to accelerate that mass (limited by control software that controls the velocity of the system)
  - velocity is not being fully reached (lower amplitude)
  - operating at small portion of input range (variability in error)
  - if we have calibrated to account for error then we should be getting something random error instead of like always under
  - **there was no relationship with weight, error is likely from operating at a small input range to the motor driver**
    - max voltage is 2.8 V out of 3V
    - **future work: changing the motor driver that better matches amplitudes or using feedback to control position**
- how accurate when changing f and A
  - baseline was recalibrated 0 kg
  - did all testing at 0kg
  - the period when varying frequency there was a low percent error - period is good
  - error is clearly in amplitude all about 30% error
  - conversion from calculated sin wave (integral of velocity in code to convert to rpm/ position) we are not sure if this is accurate when changing A or f
  - diameter of pinon part of the calculation could be wrong
  - we are taking the position and calculating velocity required at each time point
  - motor works on one equation - velocity (we only input the velocity into the motor) but we are hand calculating the position to graft the results
  - **we externally calculate the velocity at each time point**
    - **not sure the position to velocity calculation is accurate**
    - we need equation that goes from position we want to achieve to the velocity we want to achieve
    - the conversion seems like the constant issue that gets 30% error
    - **future work: we need to confirm that the equation we are using and how we are getting the velocity is correct**
  - address this error in presentation and possibly backtrack the velocity

Conclusions/action items:

Team discussed testing results and potential discussion about that. We have an idea about where the errors may be coming form and we will adress these on our poster. Additionally, we may backtrack the f and A test to find the values we should be comparing to in the grafts.

2024/02/02 Motor Meeting 1

Amber Schneider - Feb 02, 2024, 1:35 PM CST

Title: Motor Meeting 1

Date: 2/2/2024

Content by: Amber Schneider

Present: Amber, Kendra

Goals: review new Tekceleo resources

Content:

Tekceleo Resource Center

- Ultrasonic Motor: WLG-75-R
- Maximize your WLG-75 experience with our accessible resources hub. Navigate through insightful and instructional guides, crafted to assist you at every step.
- Contains **User Guide** and **Catalog**

User Guide

- Conditions of Use
    - To operate continuously, the motor needs to dissipate heat. It is advisable to mount it on a metal cooling plate.
    - Performances are ensured as long as the temperature of the motor remains under 45 degrees.
    - We highly recommend to use a flexible coupling between the WLG75 motor and the load in order to ensure performances.
    - The controller can be shared through license agreement for customers who want to incorporate the electronics into their own systems.
    - All our controller can directly control continuous movement with switches.
    - Software can be shared and/or customized on demand.
    - For precise motion control it is necessary to use a microcontroller connected to the controller. In our evaluation kit we offer specific STM32 microcontroller with embedded demo software for easily handle our motors.
    - The motor shaft must absolutely not be loaded by radial load more than specified : 60 N.
    - The motor must be mounted on cooling plate designed in order to better dissipate the heat emanating from the motor.
    - Optimal size is aluminum plate with the specified dimensions: 100 x 150 x 8 mm.
    - Make sure to screw the motor using the right screw length (M4x0.7 – 6 mm deep MAX in the motor).
    - Please respect the recommended tightening torque for M4 screws : 3.5 Nm.
- Parts


WLG-75-R


WLG-75 ECU


STM32 MICROCONTROLLER


HEAT DISSIPATION PLATE

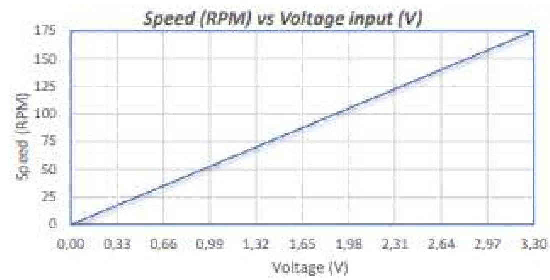

24V POWER SUPPLY

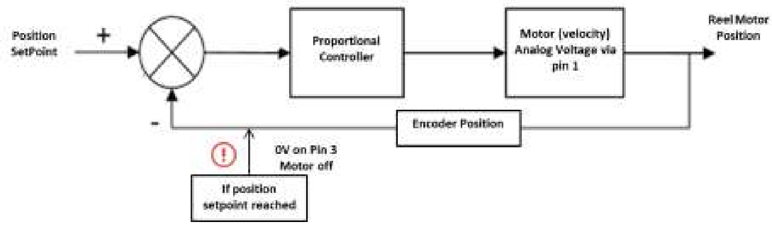

CABLE ECU-MOTOR (30CM)


FREE DEMO SOFTWARE

- Control Specifications

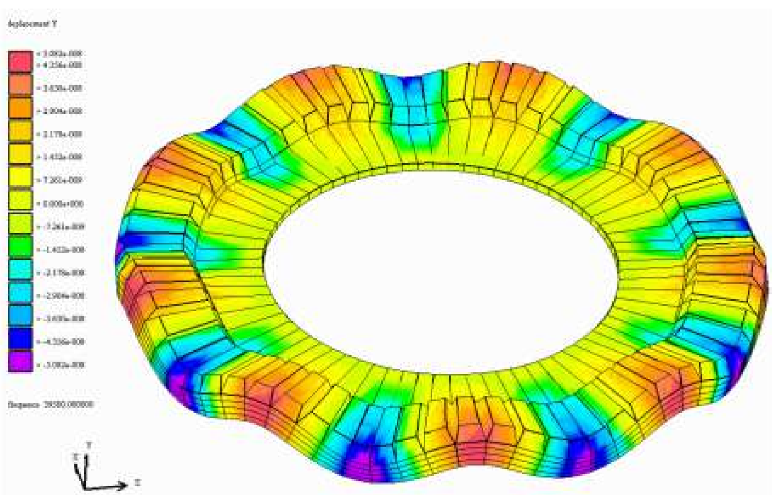
CHARACTERISTICS	VALUES
On / Off response time (Pin 3)	< 500 µs
Speed change response time	< 50 ms
Closed loop position controller (see figure below)	P control proportional
In case you need to control the position of the motor : In order to take advantage of the on / off response time of the motor, it is preferable to send a 0V on pin 3 once the motor has reached its position (see figure below)	
ENCODER DATA	**VALUES**
Two channel quadrature digital outputs for direction sensing : A and B	5760 increments per revolution each
One channel, Index digital output I (Z)	1 increment per revolution





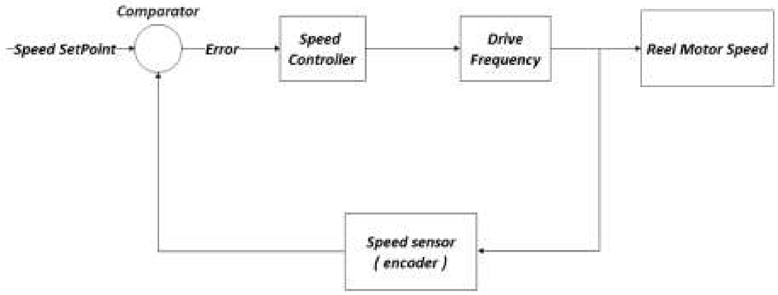
Catalog

- Mechanical Properties
  - wave actuator technology
  - integrated control sensors
  - efficient torque to weight ratio
  - 3 Key elements:
    - • A piezoelectric ceramic with segmented electrodes
      • A vibratory stator
      • A rotor pressed on the combtooth shaped stator

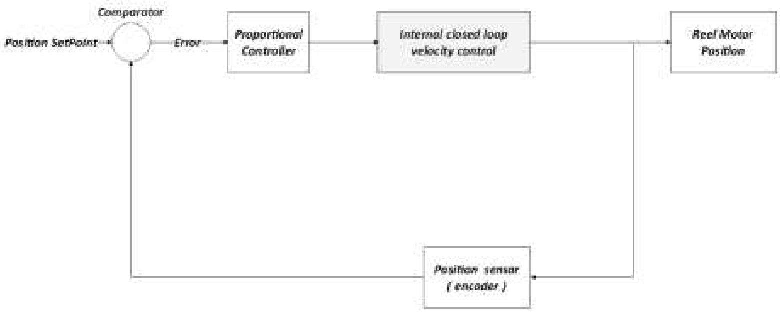


SIMULATION OF TRAVELLING WAVE MODULATION ON A WLG-75 STATOR

- Control Principles
  - closed loop control mechanism
    - use control linear or angular position, velocity, and acceleration
  - the closed loop control system measures the position and then converts it into an electrical signal with our embedded encoder technology
  - motors are able to have a speed setpoint as well as a position set point
  - Signals used to control motor:
    - For the rotative-direction change of CW-CCW, and a Stop of the motor, two signals of a TTL level are required
    - For speed change, an analog signal of DC 0 [V] - 3.3 [V] is required
  - In order to stabilize the speed of a motor, an internal closed loop control is integrated in the controllers of the motors. Speed control of the motor is defined by its drive frequency.
  - **Position of the motor is controllable by using the encoder signals**
    - To achieve smooth position control and optimize precision, customer can use a proportional control. It allows to correct the controlled variable and proportionally correct the difference between desired value (e.g. position setpoint) and the measured value (e.g. real motor position).



INTERNAL CLOSED LOOP VELOCITY PRINCIPLE THAT IS INTEGRATED IN THE CONTROLLER ITSELF



SIMULATION OF TRAVELLING WAVE MODULATION ON A WLG-75 STATOR

Conclusions/action items:

Over winter break, Tekceleo launched a new Resources page. Its aim is to index all the documentation our customers need to easily integrate our technologies and produce tomorrow's solutions. During the meeting, we viewed and took notes on the updated catalogs and user guides.

Action Items

- Use diagrams in control specifications slide to incorporate PID control and possibly determine transfer function.
- Understand the control principles outlined in the catalog and how to use them.

Kendra Besser - Feb 02, 2024, 1:07 PM CST

```
/**
 * @author Aaron Berk
 *
 * @section LICENSE
 *
 * Copyright (c) 2010 ARM Limited
 *
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 * LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
 * OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN
 * THE SOFTWARE.
 *
 * @section DESCRIPTION
 *
 * Quadrature Encoder Interface.
 *
 * A quadrature encoder consists of two code tracks on a disc which are 90
 * degrees out of phase. It can be used to determine how far a wheel has
 * rotated, relative to a known starting position.
 *
 * Only one code track changes at a time leading to a more robust system than
 * a single track, because any jitter around any edge won't cause a state
 * change as the other track will remain constant.
 *
 * Encoders can be a homebrew affair, consisting of infrared emitters/receivers
 * and paper code tracks consisting of alternating black and white sections;
 * alternatively, complete disk and PCB emitter/receiver encoder systems can
 * be bought, but the interface, regardless of implementation is the same.
 *
 *               +-----+     +-----+     +-----+
 * Channel A     |  ^  |     |     |     |     |
 *            ---+  ^  +-----+     +-----+     +-----
 *               ^  ^
 *               ^  +-----+     +-----+     +-----+
 * Channel B     ^  |     |     |     |     |     |
 *            ------+     +-----+     +-----+     +-----
 *               ^  ^
 *               ^  ^
 *               90deg
 *
 * The interface uses X2 encoding by default which calculates the pulse count
 * based on reading the current state after each rising and falling edge of
 * channel A.
 *
 *               +-----+     +-----+     +-----+
 * Channel A     |     |     |     |     |     |
 *            ---+     +-----+     +-----+     +-----
 *               ^     ^     ^     ^     ^
 *               ^  +-----+  ^  +-----+  ^  +-----+
 * Channel B     ^  |  ^  |  ^  |  ^  |  ^  |     |
```

[Download]

QEI.cpp (9.27 kB)

Kendra Besser - Feb 02, 2024, 1:07 PM CST


```
/**
 * @author Aaron Berk
 *
 * @section LICENSE
 *
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 * THE SOFTWARE.
 *
 * @section DESCRIPTION
 *
 * Quadrature Encoder Interface.
 *
 * A quadrature encoder consists of two code tracks on a disc which are 90
 * degrees out of phase. It can be used to determine how far a wheel has
 * rotated, relative to a known starting position.
 *
 * Only one code track changes at a time leading to a more robust system than
 * a single track, because any jitter around any edge won't cause a state
 * change as the other track will remain constant.
 *
 * Encoders can be a homebrew affair, consisting of infrared emitters/receivers
 * and paper code tracks consisting of alternating black and white sections;
 * alternatively, complete disk and PCB emitter/receiver encoder systems can
 * be bought, but the interface, regardless of implementation is the same.
 *
 *               +-----+     +-----+     +-----+
 * Channel A     |  ^  |     |     |     |     |
 *            ---+  ^  +-----+     +-----+     +-----
 *               ^  ^
 *               ^  +-----+     +-----+     +-----+
 * Channel B     ^  |     |     |     |     |     |
 *            ------+     +-----+     +-----+     +-----
 *               ^  ^
 *               ^  ^
 *               90deg
 *
 * The interface uses X2 encoding by default which calculates the pulse count
 * based on reading the current state after each rising and falling edge of
 * channel A.
 *
 *               +-----+     +-----+     +-----+
 * Channel A     |     |     |     |     |     |
 *            ---+     +-----+     +-----+     +-----
 *               ^     ^     ^     ^     ^
 *               ^  +-----+  ^  +-----+  ^  +-----+
 * Channel B     ^  |  ^  |  ^  |  ^  |  ^  |     |
```


[Download]

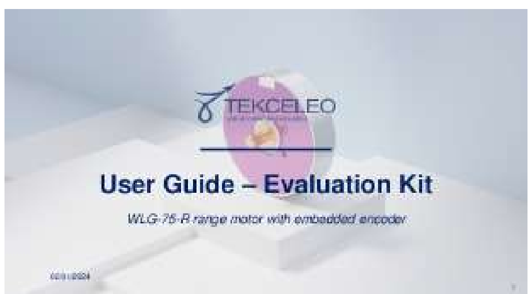
QEI.h (8.29 kB)

Amber Schneider - Feb 02, 2024, 1:10 PM CST

[Download]

Catalog-WAVELLING-WLG-R-2023-2024.pdf (1.83 MB)

Amber Schneider - Feb 02, 2024, 1:10 PM CST



[Download]

1-TEKCELEO-User-Guide-WLG-75-R.pdf (994 kB)

2024/03/19 Motor Meeting w/ Tekceleo

Amber Schneider - Mar 19, 2024, 1:01 PM CDT

Title: Motor Meeting w/ Tekceleo

Date: 3/19/2024

Content by: Amber Schneider

Present: Kendra

Goals: meet with representative to get a better idea of how to improve motor accuracy

Content:

Summary:

- Working on a design project for an MRI motion platform
- Want to use the motor for sinusoidal motion
- have programmed the microcontroller to produce the sinusoidal motion, but so far there has been a lot of error
    - expected RPM not equal to actual RPM
- We think its due to problems with getting a clean signal from the microcontrolller to the motor controller?
- **Any suggestions on how to better accomplish this task?**

Questions:

<u>Where does the hexaVelocity conversion come from? Can this value be improved somehow?</u>

hexaVelocity = 0.0063*rpmVelocity;

<u>How can we get the RPM to be more precise? Is there a specification for the precision of the RPM?</u>

<u>Do people typically edit the starter code? How to manipulate for our needs?</u>

Conclusions/action items:

Tried to call contact phone number. Unsuccessful. Emailed with team CCd.

2024/04/11 Motor Meeting w/ Tekceleo 2

Kendra Besser - Apr 11, 2024, 9:01 AM CDT

Title: Motor Meeting w/ Tekceleo

Date: 4/11/2024

Content by: Kendra Besser

Present: Amber

Goals: meet with representative over zoom to get a better idea of how to improve motor accuracy and demonstrate our problems

Content:

Summary:

- Working on a design project for an MRI motion platform
- Want to use the motor for sinusoidal motion
- have programmed the microcontroller to produce the sinusoidal motion, but so far there has been a lot of error
    - expected RPM not equal to actual RPM
    - when coded to 60 RPM, output was 67
- We think its due to problems with getting a clean signal from the microcontroller to the motor controller?
- **Any suggestions on how to better accomplish this task?**

- accuracy of speed the main board, new driver is not perfect
    - not very accurate on its own
    - difference are similar but not exactly the same for each trial, errors where slightly off when we ran multiple trials
    - the error we are getting is linked to the hexavalue coefficient
    - we can alter the value a little and test that and repeat
- where value comes from
    - there is an encoder in motor that accounts for the hexavelocity
    - the values of this range from 0 to 1.1 which is linked to the RPMs from 0 to 175s
    - reduce coefficient a little bit and test
    - 1.1 / max velocity of motor (175)
        - absolute value (to make it the most precise)
        - 0.006285 is the actual value
- PID
    - motor is capable of PID
    - this is a good way to have good accurate position
    - we do not need to implement the PID, changing the coefficient

Conclusions/action items:

We should run multiple tests while changing the hexavelocity number to trial and error the closest hexavelocity what we need.

2024/04/11 Motor Coefficient Calibration (Medium RPM)

Amber Schneider - Apr 25, 2024, 5:12 PM CDT

Title: Motor Coefficient Calibration (Medium RPM)

Date: 4/11/2024

Content by: Amber Schneider

Present: Kendra

Goals: experimentally determine new RPM to Voltage coefficient

Content:

Constant RPM

- Program RPM to be 60
- Run 6 trials
- Average number of revolutions counted on encoder
- Repeat for RPM = 50
- Find the slope between the averages and the expected values
  - (Avg_60-Avg_50)/(60-50)
- RESULT: multiply current coefficient by 1/1.016

Time Test

- Program RPM = 60
- Run 5 trials
- Time how long it takes to complete 60 revolutions
- Calculate experimental RPM and take the average
- Repeat for RPM = 50
  - Measure time to complete 50 revolutions
- Find the slope between the averages and the expected values
  - (Avg_60-Avg_50)/(60-50)
- RESULT: multiply current coefficient by 1/0.98

Conclusions/action items:

Updating the coefficient causes the motor to run more accurately. Future calibration is necessary for low RPM values.

Amber Schneider - Apr 25, 2024, 5:17 PM CDT

Download

Motor_Coefficient_Calibration_Medium_RPM_.pdf (49.3 kB)

2024/04/18 Motor Coefficient Calibration (Low RPM)

Amber Schneider - Apr 25, 2024, 5:14 PM CDT

Title: Motor Coefficient Calibration (Low RPM)

Date: 4/18/2024

Content by: Amber Schneider

Present: Kendra

Goals: experimentally determine new RPM to Voltage coefficient

Content:

Time Test

- Program RPM = 7
- Run 5 trials
- Time how long it takes to complete 7 revolutions
- Calculate experimental RPM and take the average
- Repeat for RPM = 15
    - Measure time to complete 15 revolutions
- Find the slope between the averages and the expected values
    - (Avg_15-Avg_7)/(15-7)
- RESULT: multiply current coefficient by 1/0.98

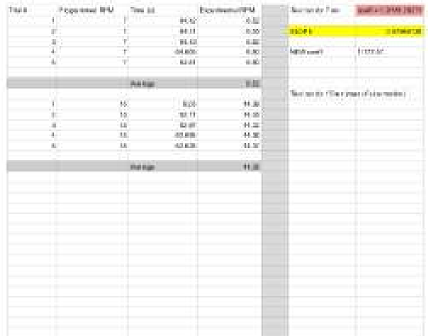
Time Test 2

- Coefficient was updated in mbed
- Time Test was performed again for further calibration at low RPM

Conclusions/action items:

Updating the coefficient causes the motor to run more accurately. The performance of the new coeficient should be tested against the old coefficient during a sinusoidal motion test when the motor is connected to the platform.

Amber Schneider - Apr 25, 2024, 5:18 PM CDT



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Motor_Coefficient_Calibration_Low_RPM_.pdf (46.4 kB)

2024/02/22-Improved Gearbox

Jamie Flogel - Feb 22, 2024, 6:02 PM CST

Title: Improvements to Gearbox

Date: 2/22/24

Content by: Jamie

Present: Max

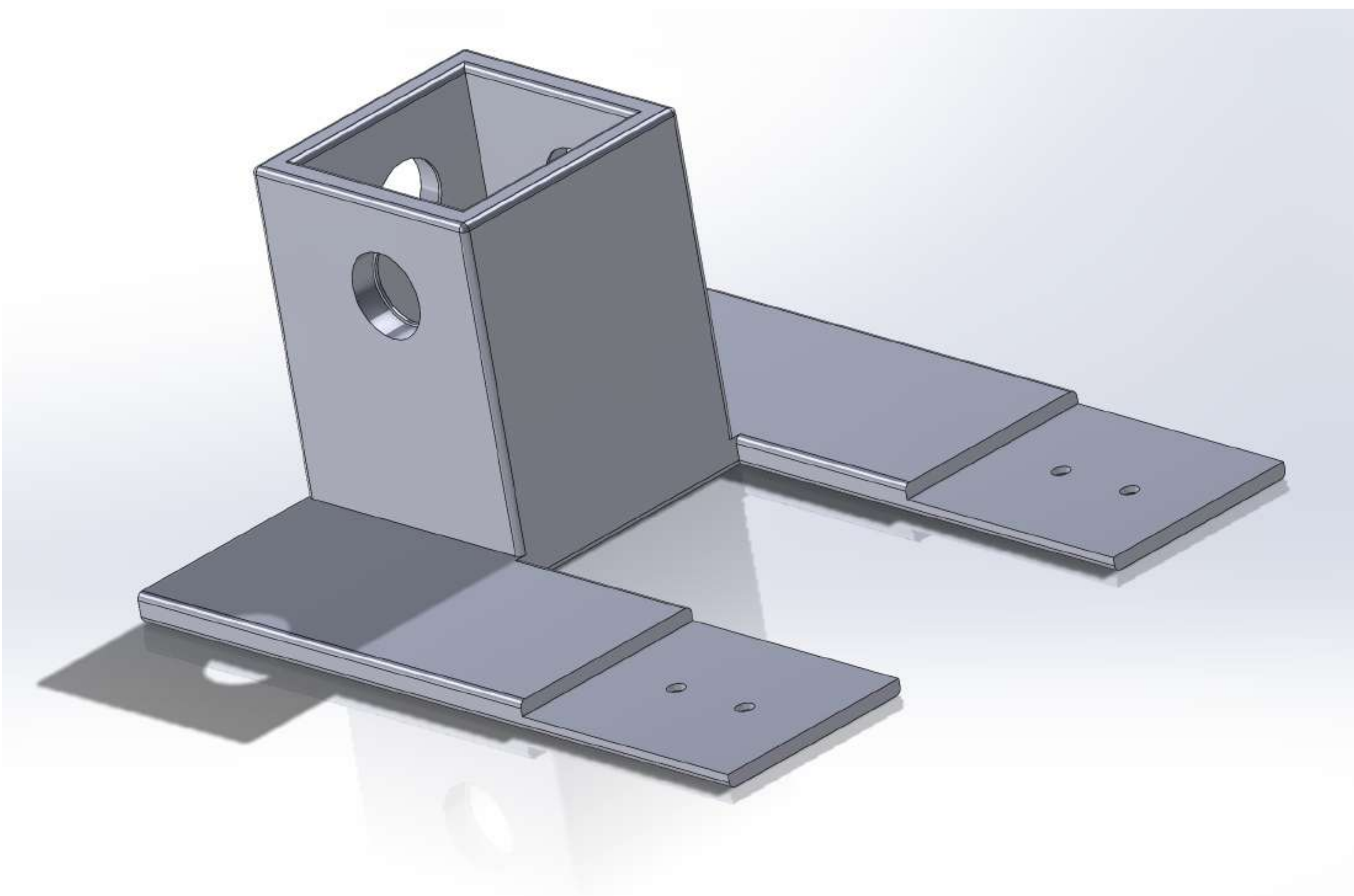
Goals:

-Document changes to the gearbox design

Content:

-We filleted the edges of the gearbox to make them less sharp

-We flipped the extension pieces



Conclusions/action items:

We will continue to make updates as necessary to the gearbox and other mechanical components

Jamie Flogel - Feb 23, 2024, 2:19 PM CST

Download

extension.STL (16.3 kB)

Jamie Flogel - Feb 22, 2024, 6:01 PM CST

Download

spring_gearbox.SLDPRT (257 kB)

MAXWELL NASLUND - Apr 20, 2024, 4:31 PM CDT

Download

extension.SLDPRT (99.1 kB)

Jamie Flogel - Feb 22, 2024, 6:01 PM CST

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spring_gearbox.STL (167 kB)

2024/12/23-1.5 Gear ratio Gears

Jamie Flogel - Feb 23, 2024, 2:28 PM CST

Title: Updated gears

Date: 2/23/24

Content by: Jamie and Max

Present: Amber

Goals:

-Document new gears

Content:

-We need a new gear ratio or 1.5 to increase torque output

Conclusions/action items:

We will continue to make modifications as needed to our design. We will 3D print these gears along with the new gearbox.

Jamie Flogel - Feb 23, 2024, 2:37 PM CST

Download

2-1_BevelGear_new.STL (248 kB)

Jamie Flogel - Feb 23, 2024, 2:37 PM CST

Download

1-1_BevelGear_new.STL (292 kB)

2024/04/29- Expense Table

Jamie Flogel - Apr 29, 2024, 8:23 AM CDT

Title: Final Expense Table

Date: 4/29/24

Content by: Jamie

Present: N/A

Goals:

-Document all of our team's expenses

Content:

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1 - Gearbox Prints								
Ultimaker PLA (118 g)	3D printed support for the driveshaft	Ultimaker	RAL-9005	11/17/2023	1	$9.44	$9.44	N/A
Ultimaker PLA (126 g)	3D printed gearbox extension pieces	Ultimaker	RAL-9005	2/27/2024	1	$6.30	$6.30	N/A
Ultimaker PLA	3D Printed Gears	Ultimaker	RAL-9005	3/7/2024	1	$2.56	$2.56	N/A
Ultimaker PLA	3D Printed Gearbox and motor stand	Ultimaker	RAL-9005	3/14/2024	1	$19.60	$19.60	N/A
Component 2 - Linear Rails								
Linear Rails	400 mm linear rails	igus	CWS-06-30-400	11/13/2023	2	$167.69	$335.38	Link
Component 3 - Linear Slides								

Linear Slides	Slides to support platform on linear slides	igus	WWPL-06-30-06	11/13/2023	2	$18.25	$36.50	Link
Component 4 - Driveshaft								
Driveshaft	Connection piece between motor and gearbox	Grainger	H0400075PW1000	11/16/2023	1	$8.00	$8.00	Link
Component 5 - Platform								
Platform	1/4 black acrylic sheet provided by Makerspace	MSC	MSC# 63391700 (no part number given similar example)	11/17/2023	1	$20.00	$20.00	N/A
Component 6 - Glass Ball Bearings								
Glass Ball Bearings	Glass ball bearings to allow for frictionless rotation	Grainger	MSN0459939	12/1/2023	5	$17.07	$85.35	N/A
Component 7 - Fastners								
M5 Plastic Screws	Used to assemble final prototype	Grainger	50M050080H016	2/15/24	1	$1.65 per package of 25	$1.65	Link
M4 Plastic Screws	Used to assemble final prototype	Grainger	50M040070N035	2/15/24	2	$5.92 per package of 25	$11.84	Link
Plastic Screws and Nuts	Plastic hardware from the makerspace	Makerspace	N/A	3/6/2024	1	$1.30	$1.30	N/A
Component 8 Power Components								

Power Inverter	Power supply inverter to improve circuit	DigiKey	PDM1-S5-D3-S	3/22/2024	2	$5.12	$10.24	Link
Component 9 - unused features due to reprints/redesigns								
Ultimaker PLA	3D printed Gearbox	Ultimaker	RAL-9005	10/26/2023	1	$19.36	$19.36	N/A
Ultimaker PLA	Motor to driveshaft adapter piece	Ultimaker	RAL-9005	12/1/2023	1	$1.12	$1.12	N/A
Ultimaker PLA	Motor to driveshaft adapter piece reprint	Ultimaker	RAL-9005	12/4/2023	1	$2.84	$2.84	N/A
Ultimaker PLA	Motor to driveshaft adapter piece reprint	Ultimaker	RAL-9005	12/5/2024	1	$2.65	$2.65	N/A
Ultimaker PLA (37.0 g)	3D printed gears to translate and facilitate motion	Ultimaker	RAL-9010	10/26/2023	1	$2.96	$2.96	N/A
Ultimaker PLA (325.0 g)	3D printed gears and gearbox	Ultimaker	RAL-9005	11/03/2023	1	$26.00	$26.00	N/A
Bamboo Labs PLA (127.34 g)	3D printed gearbox extension pieces	Bambu Lab	#000000	11/15/2023	1	$12.19	$12.19	N/A
Ultimaker PLA (27 g)	3D printed racks	Ultimaker	RAL-9005	11/29/2023	1	$2.16	$2.16	N/A
Ultimaker PLA (126 g)	3D printed Motor Stand	Ultimaker	RAL-9005	12/01/2023	1	$10.08	$10.08	N/A

Ultimaker PLA	3D printed gears and gearbox	Ultimaker	RAL-9005	2/23/24	1	$14.60	$14.60	N/A
TOTAL:	**$642.12**							

Conclusions/action items:

Overall we were able to stay well under budget on our project.

2024/4/30 - Final Gearbox Assembly

MAXWELL NASLUND - Apr 30, 2024, 6:17 PM CDT

Title: Final Gearbox Assembly

Date: 2024/4/30

Content by: Maxwell

Present: n/a

Goals: Detail all SOLIDWORKS files for gearbox assembly

Content:

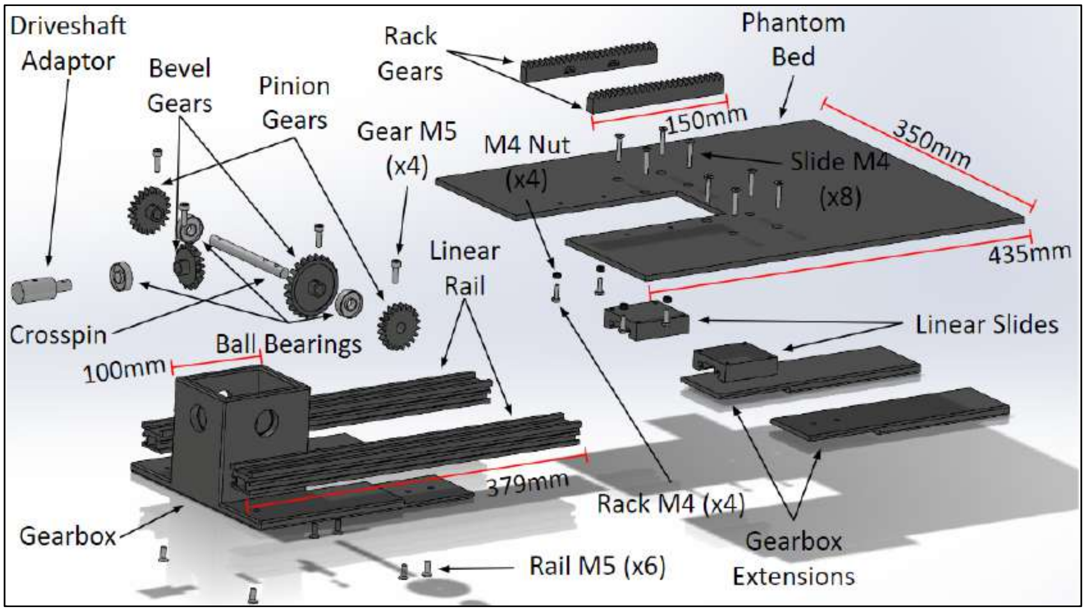

Figure 1: Full Gearbox assembly

Figure 1 above illustrates all the components of the gearbox assembly and how they fit together.

Conclusions/action items:

Attached here are all related SOLIDWORKS files to replicate the illustrated figure above.

MAXWELL NASLUND - Apr 30, 2024, 6:18 PM CDT

Download

1.5-1_BevelGear.SLDPRT (681 kB)

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1-1_BevelGear.SLDPRT (1.06 MB)

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3D_Printed_Components.SLDASM (518 kB)

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BallBearing.SLDPRT (101 kB)

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crosspin_new.SLDPRT (138 kB)

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Driveshaft_pin_new.SLDPRT (141 kB)

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extension.SLDPRT (113 kB)

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Download

Final_Assembly.SLDASM (1.18 MB)

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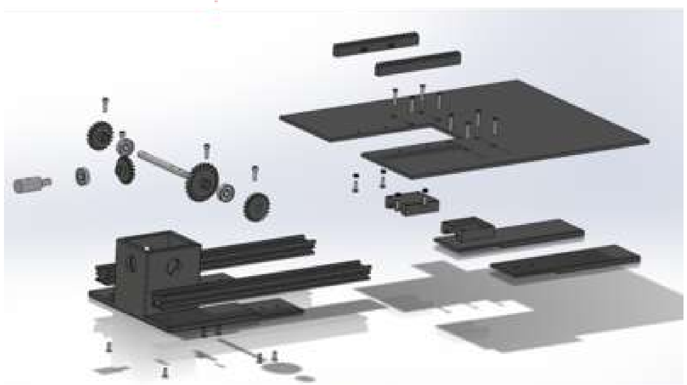

Download

final_exploded.png (389 kB)

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Gear_M5.SLDPRT (107 kB)

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M4_Nut.SLDPRT (104 kB)

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NewPlatform.SLDPRT (131 kB)

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Rack.SLDPRT (307 kB)

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Rack_M4.SLDPRT (115 kB)

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rail.SLDPRT (162 kB)

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Rail_M5.SLDPRT (94.1 kB)

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slide.SLDPRT (132 kB)

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Slide_M4.SLDPRT (91 kB)

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spring_gearbox.SLDPRT (305 kB)

2024/4/30 - Final Motor Assembly

MAXWELL NASLUND - Apr 30, 2024, 6:21 PM CDT

Title: Final Motor Assembly

Date: 2024/4/30

Content by: Maxwell Naslund

Present: N/A

Goals: Detail all the related SOLIDWORKS files for the Motor Assembly

Content:

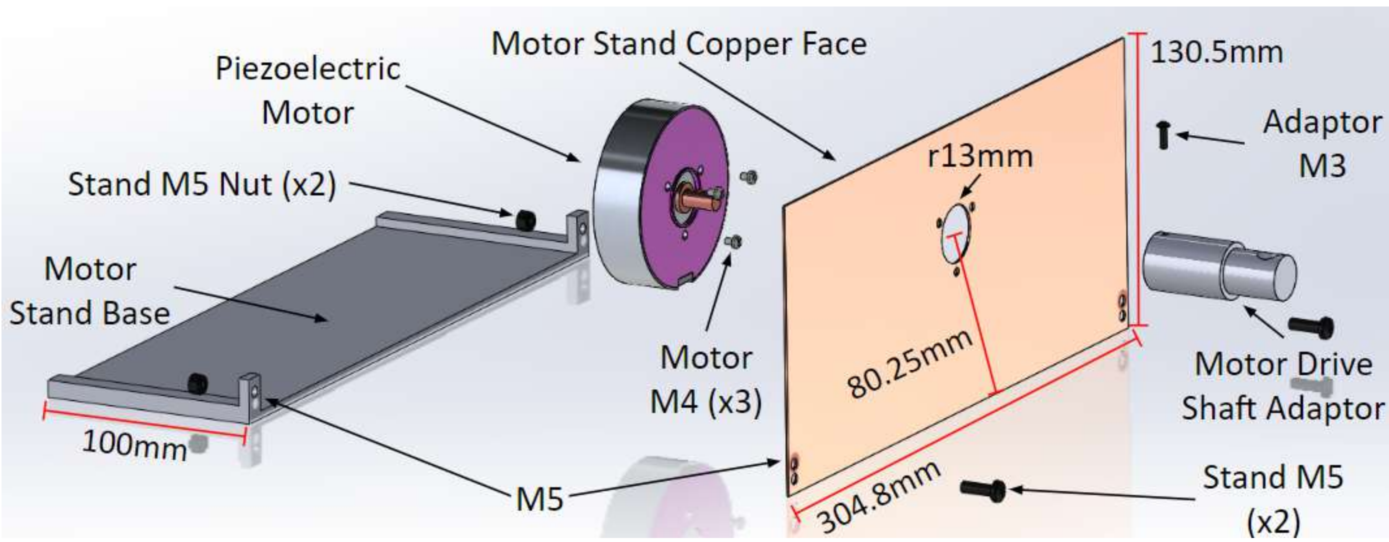

Figure 1: Final Motor Assembly components

Figure 1 above illustrates all the components used within the final motor assembly and how they fit together.

Conclusions/action items:

Attached here are all the SOLIDWORKS files used in the assembly illustrated in the figure above.

MAXWELL NASLUND - Apr 30, 2024, 6:21 PM CDT

Download

Adaptor_M3.SLDPRT (114 kB)

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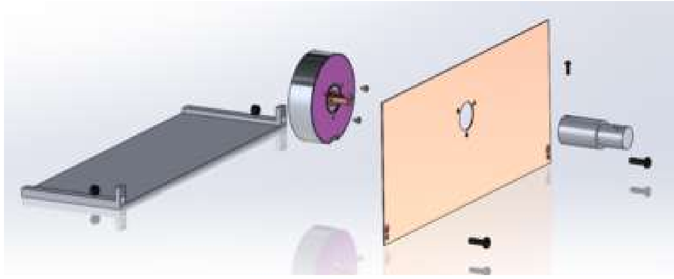

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Final_Motor_Assembly.png (174 kB)

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DATA

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Final_Motor_Assembly.SLDASM (410 kB)

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DATA

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Motor.SLDPRT (230 kB)

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Motor_M3.SLDPRT (123 kB)

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DATA

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MotorCopperFace.SLDPRT (123 kB)

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MotorDriveshaft_Adaptor.SLDPRT (155 kB)

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MotorStand.SLDPRT (135 kB)

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Stand_M5.SLDPRT (112 kB)

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Stand_M5_Nut.SLDPRT (106 kB)

2024/4/30 - Fabrication Protocol

MAXWELL NASLUND - Apr 30, 2024, 6:26 PM CDT

Title: Fabrication Protocol

Date: 2024/4/30

Content by: Maxwell Naslund

Present: N/A

Goals: Attach full final assembly fabrication protocol

Content:

Please see the attached pdf for the full fabrication protocol in case images do not load properly here.

Motor Assembly

Copper Face

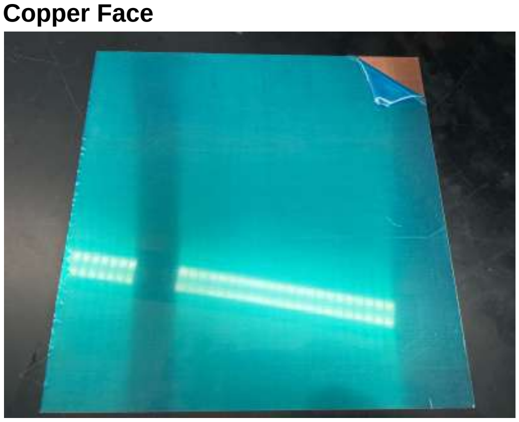


Figure 1: Uncut 1’ x 1’ copper sheet

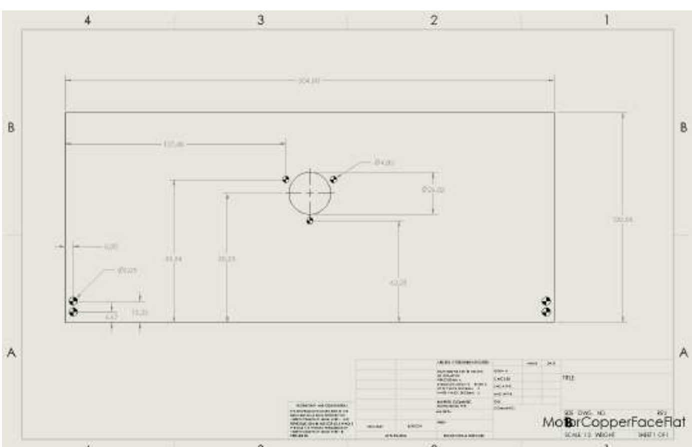


Figure 2: Copper face drawing

1. Starting from the 1’ x 1’ copper sheet illustrated in figure 1, on the metal shear in the. TEAM Lab, cut a piece to 130.58cm tall.
2. Drill a pilot hole in the cut copper sheet at 152.4mm in the x-dimension, and 88.84mm in the y-direction as illustrated in figure 2.
3. Using a 1” hole saw, drill a 1” hole centered at the previously drilled pilot hole.
4. Drill three 3mm holes 120 degrees apart around the previously drilled 1” hole as illustrated in figure 2.
5. Drill four 5mm holes at the locations illustrated in figure 2.

Motor Stand

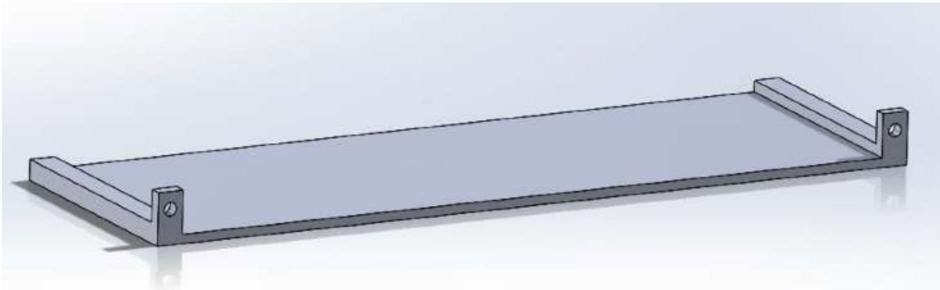


Figure 3: Motor stand SOLIDWORKS

1. 3D print attached motor stand .stl file at the Makerspace with 20% infill.

Motor to Driveshaft Adapter

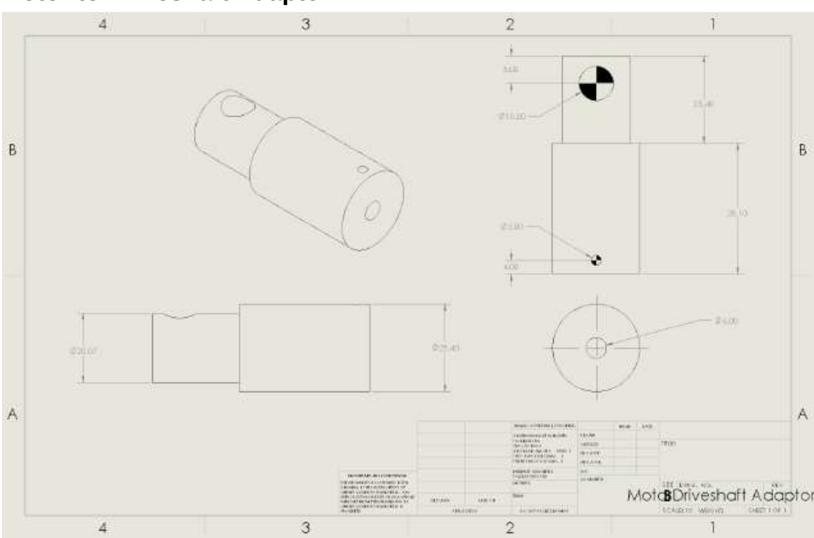


Figure 4: Driveshaft to Driveshaft Adapter drawing

1. Starting from 1” cylindrical aluminum stock, lathe one side down to a 20.07mm diameter 25.4mm in the TEAM Lab, as illustrated in figure 4.
2. Using a 6mm bit, drill a center hole 19mm deep on the side of the stock that is 25.4mm, as illustrated on figure 4.
3. Part the cylindrical aluminum stock off at 63.5mm, as illustrated in figure 4.
4. On the mill, drill a 3mm hole 4mm from the end of the 25.4mm end of the part. Drill down to the center hole drilled on the lathe, as illustrated on figure 4.
5. On the mill, drill a 10mm hole 8mm from the end of the 20.07mm end of the part. Drill all the way through the part, as illustrated on figure 4.

Full Motor Assembly

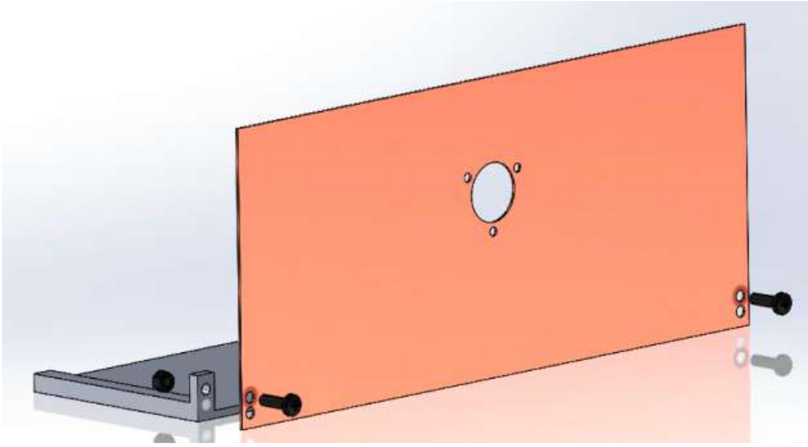


Figure 5: Motor stand and Face connected via two M5 screws

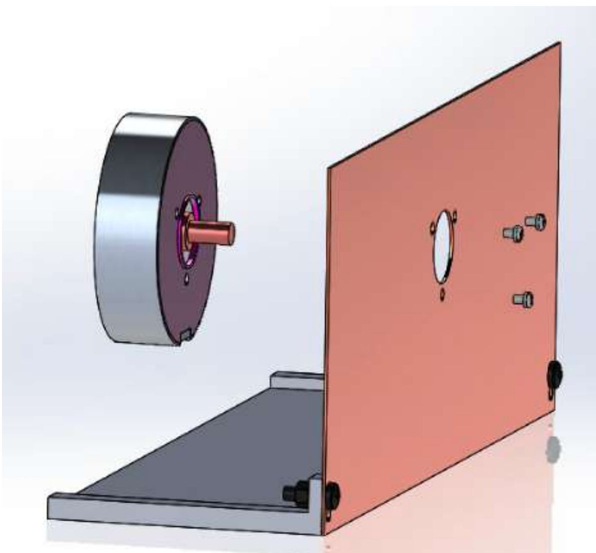


Figure 6: Motor connected to Motor stand via three M4 screws

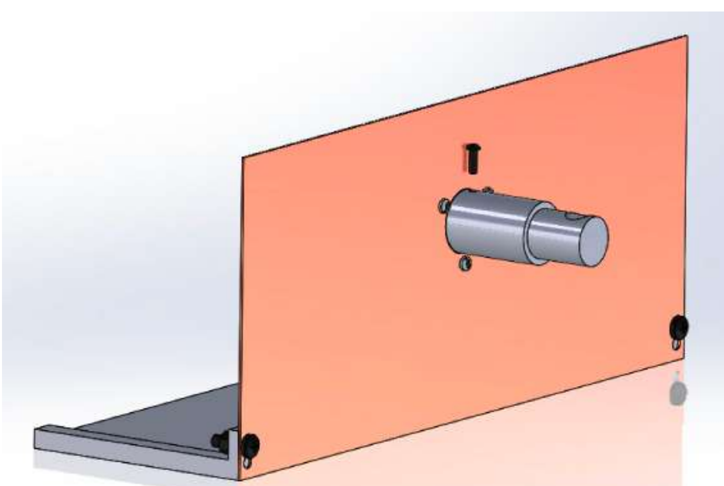


Figure 7: Motor to Driveshaft Adapter connected to motor via a M3 set screw

1. Using two M5 screws, attach copper face to copper stand. One screw on each side staggered, as illustrated in figure 5.
2. Using three M4 and three M4 washers, connect the piezoelectric motor to the copper face. Motor cable connection should point down, as illustrated in figure 6.
3. Slide the Motor to Driveshaft Adapter over the motor stud. Using a M3 screw, screw down onto one of the two flat sides of the motor stud to secure the adapter to the motor, as illustrated in figure 7.

Gearbox Assembly

3D Print Components

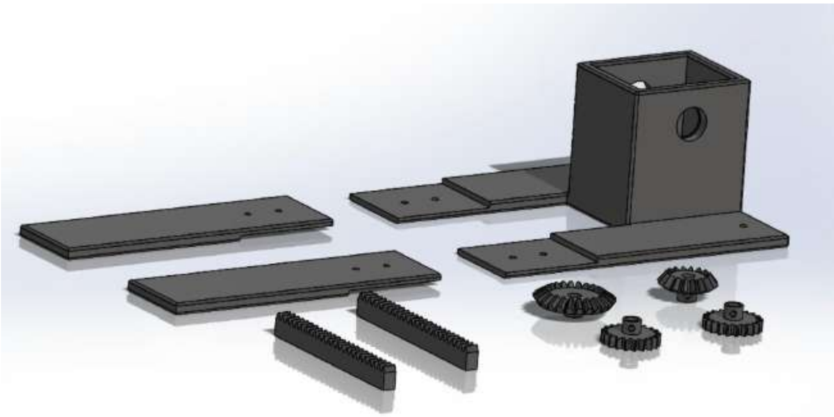


Figure 8: Gearbox 3D printed components

At the Makerspace, 3D print the Gearbox, Gearbox Extensions, Bevel Gears, Pinion Gears, and Rack Gears at 20% infill, as illustrated in figure 8.

Crosspin

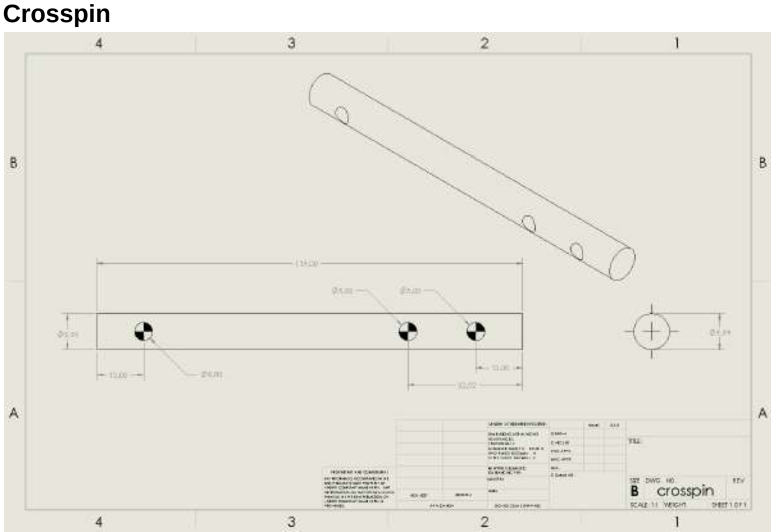


Figure 9: Crosspin drawing

1. In the TEAM Lab, start with 1” HDPE cylindrical stock. Lathe the piece down to 10mm diameter.
2. Using a 5mm bit, on the mill drill three holes in the crosspin in the locations illustrated in figure 9.

Gearbox to Driveshaft Adapter

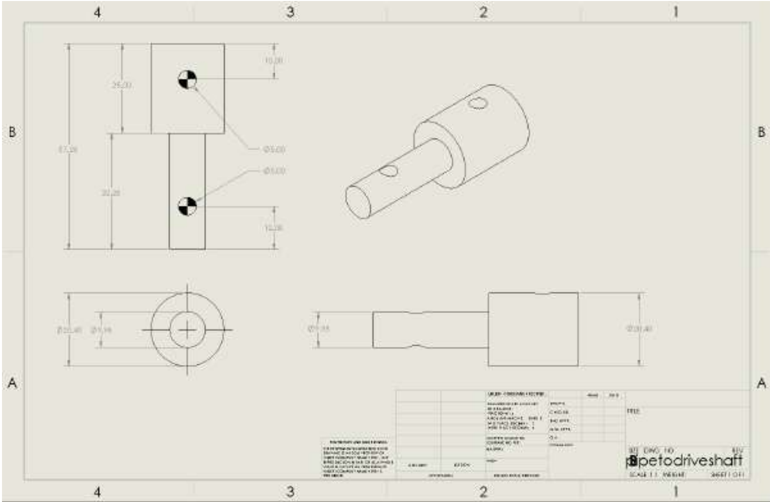


Figure 10: Gearbox to Driveshaft Adapter

1. In the TEAM Lab, start with 1” HDPE cylindrical stock. Lath 32.28mm length to 10mm diameter.
2. Lathe the next 25mm down to 20.4mm diameter.
3. Part the piece off to a 57.28mm length.
4. Using a 5mm bit, on the mill drill two holes in the adapter in the locations illustrated in figure 10.

Phantom Bed

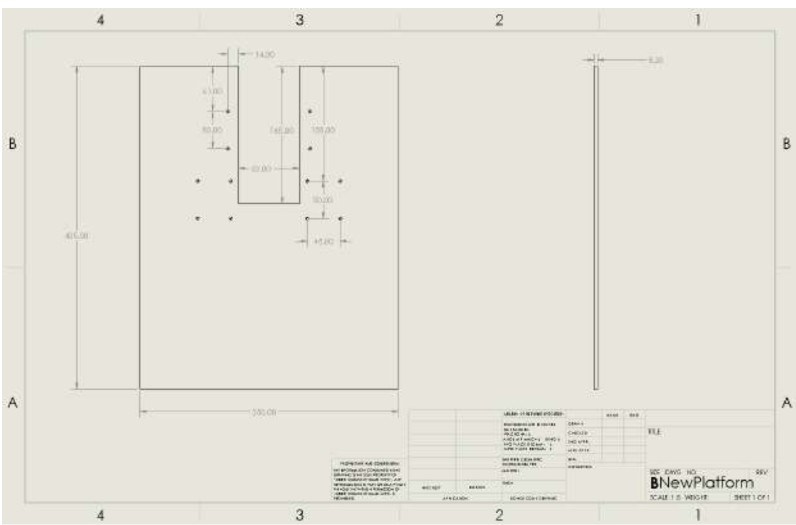


Figure 11: Phantom Bed drawing

1. In the TEAM Lab, cut an acrylic sheet to 350mm by 435mm on a table saw.
2. Using a bandsaw, cut a 83mm by 185mm rectangle from the center of the 350mm side, as illustrated in figure 11.
3. Using a drill press, drill 12 M4 holes according to the drawing illustrated in figure 11.

Full Gearbox Assembly

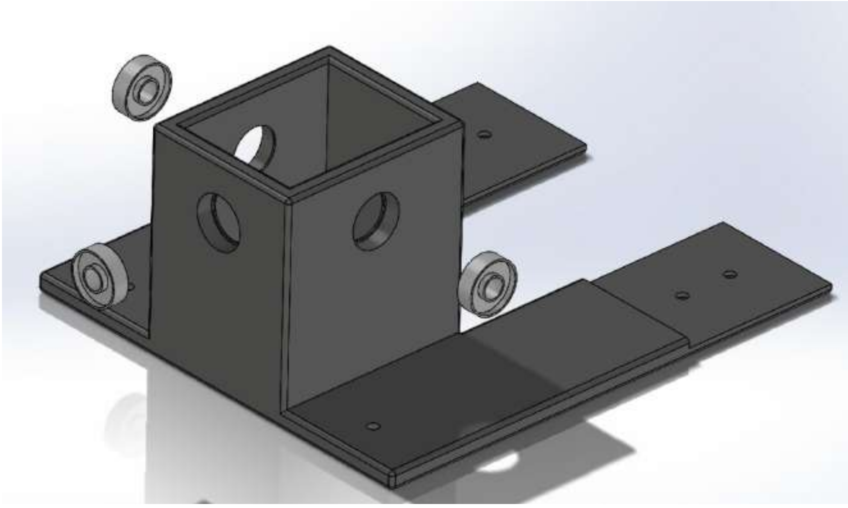


Figure 12: Adding bearings to gearbox

1. Insert three glass ball bearings into the gearbox as illustrated in figure 12.

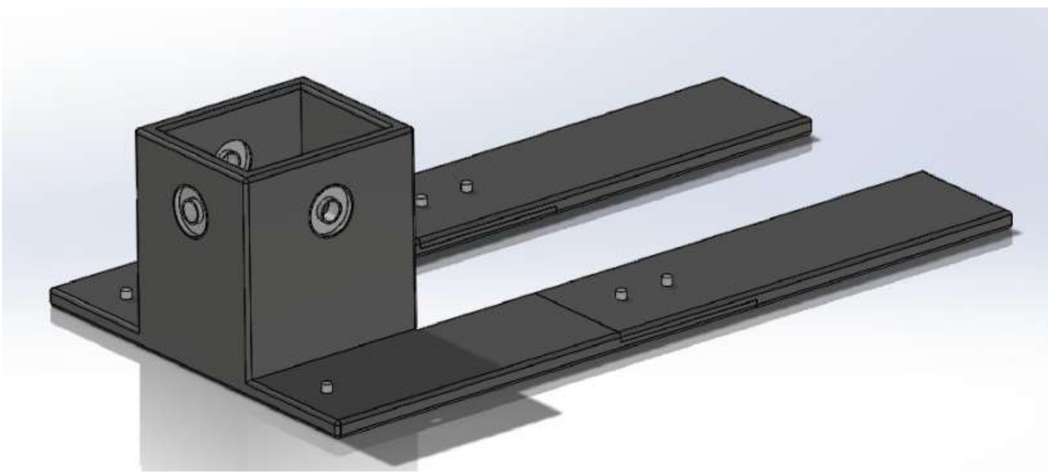


Figure 13: Adding Gearbox extensions

2. Connect 3D printed gearbox extension pieces to the gearbox via six M5 screws, as shown in figure 13. Screws should be screwed in from the bottom up.

Figure 14: Adding internal components to gearbox

3. Add Gearbox to Driveshaft adapter, Crosspin, and bevel gears in the configuration illustrated in figure 14.
4. Using two M5 screws, anchor the bevel gears to the crosspin and adapter.

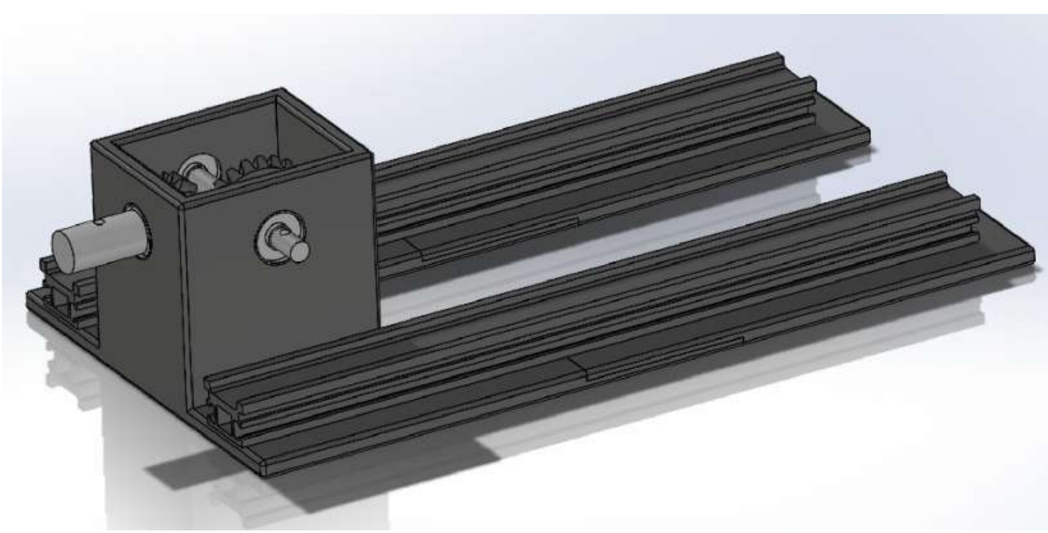


Figure 15: Adding linear rails to assembly

5. Using the same six M5 screws to connect the gearbox to the gearbox extensions, connect two linear rails as illustrated in figure 15.

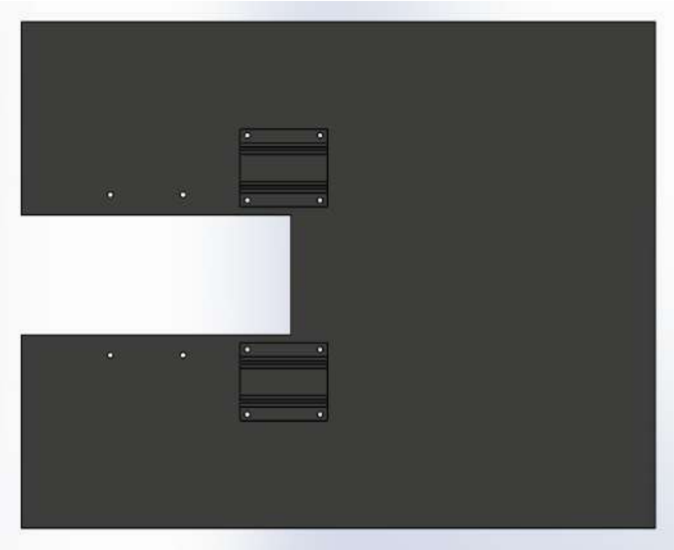


Figure 16: Adding linear slides to assembly

6. Using eight M4 screws, attach two linear slides to the bottom of the phantom bed as illustrated in figure 16.

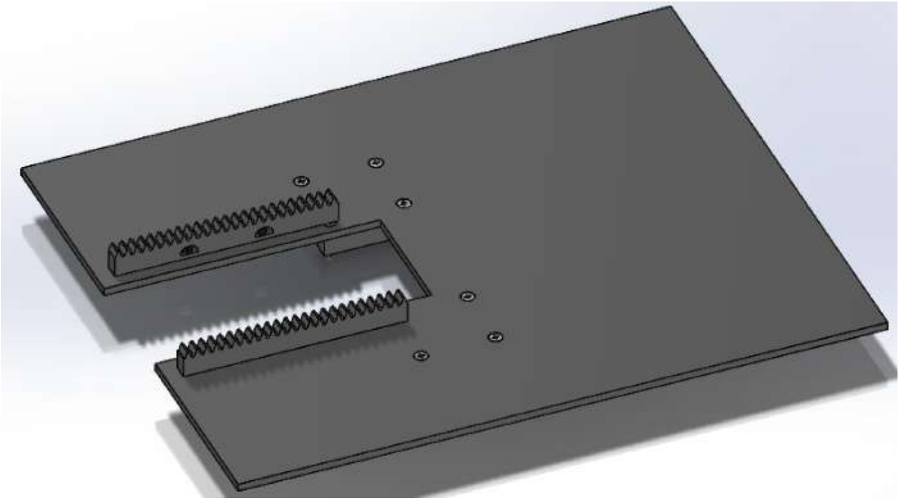


Figure 17: Adding rails to phantom bed

7. Using four M4 screws and nuts (two per rail) attach rails to the phantom bed as illustrated in figure 17.

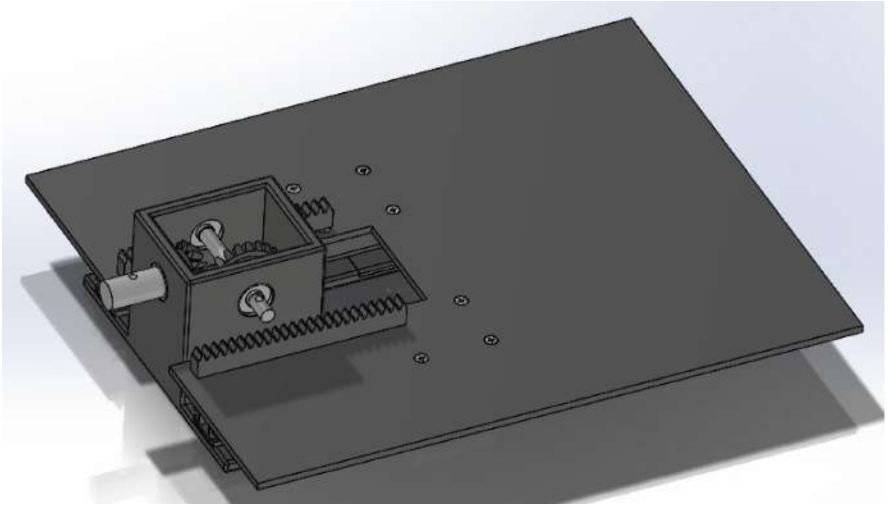


Figure 18: Adding phantom bed to gearbox

8. Slide the linear slides on the bottom of the phantom bed on top of the linear rails attached to the gearbox as illustrated in figure 18.

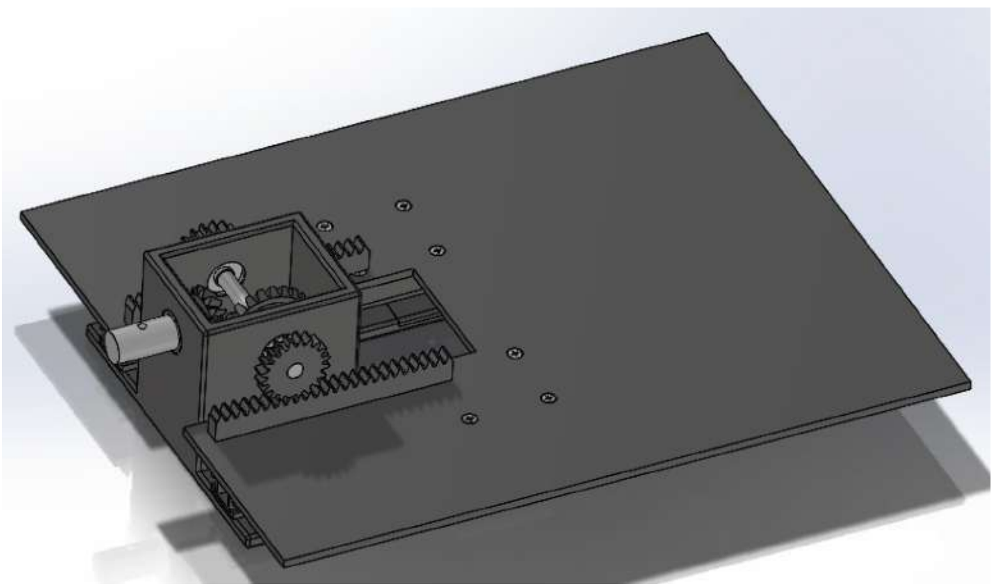


Figure 19: Adding pinion gears to assembly

9. Slide pinion gears onto both sides of the crosspin as shown in figure 19.
10. Using two M5 screws, anchor pinion gears to crosspin.

Driveshaft

1. Cut a 10’ long ¾” pvc pipe into two pieces. One measuring 4’ and the other 6’. Only the 4’ long pieces will be used in the full prototype assembly.
2. In the TEAM Lab, using a drill press, drill a 10mm hole 8mm from one end of the pipe.
3. Using a drill press, drill a 5mm 10mm from the other end of the pipe.

Full Prototype Assembly

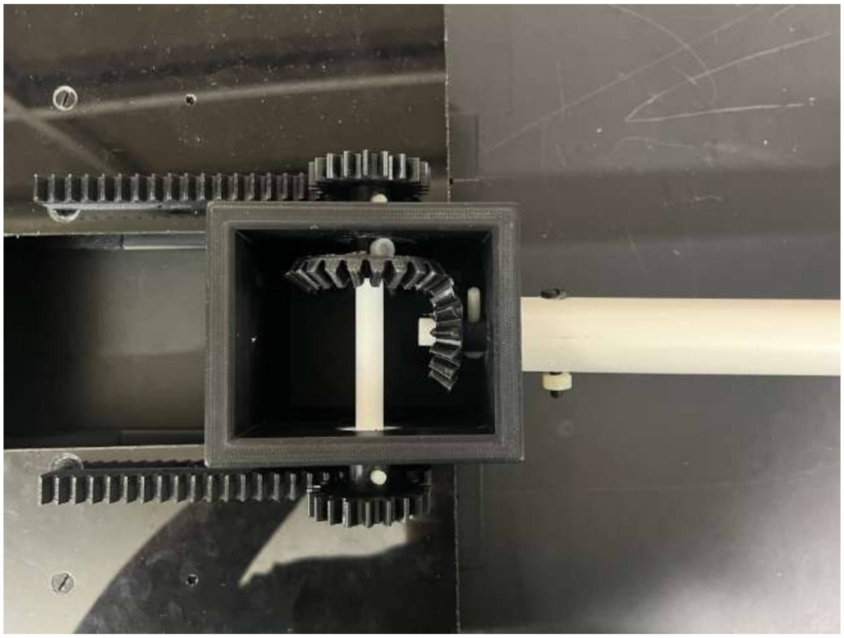


Figure 20: Attaching driveshaft to gearbox

1. Connect one side of the 4’ driveshaft to the gearbox to driveshaft adapter via a M5 screw.

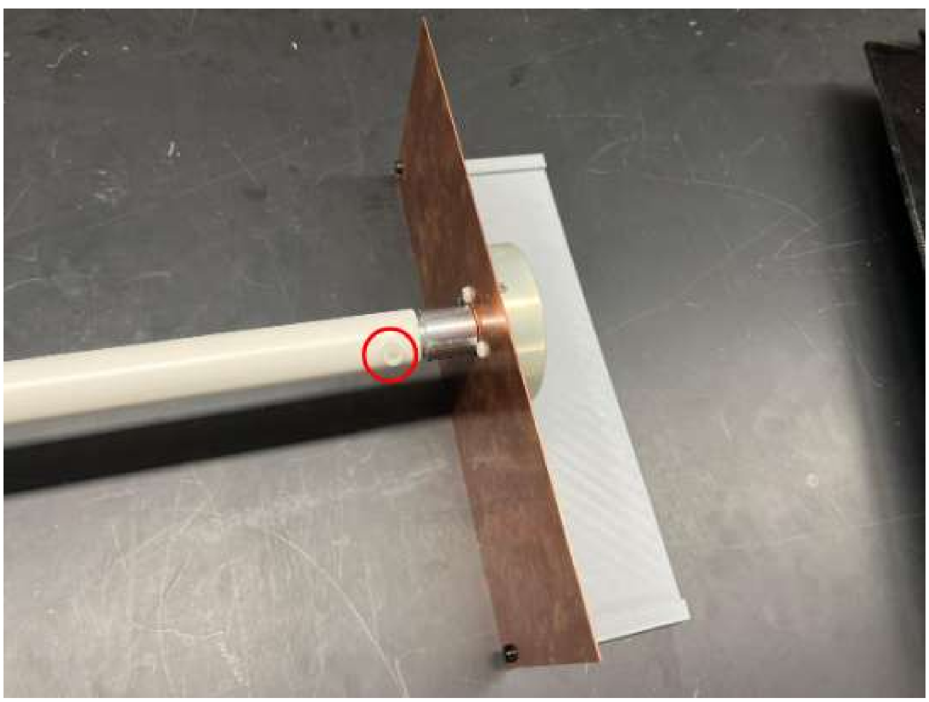


Figure 21: Attaching driveshaft to Motor assembly

2. Connect the other side of the 4’ driveshaft to motor assembly via a M10 screw and nut as illustrated in figure 21.

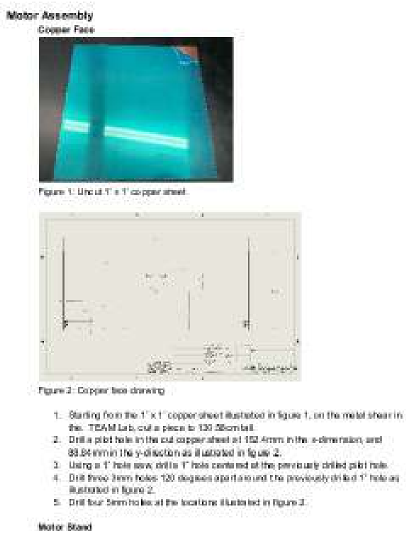
Figure 22: Full prototype assembly

3. Full prototype has been completed.

Conclusions/action items:

If images have not loaded correctly, please see attached pdf.

MAXWELL NASLUND - Apr 30, 2024, 6:27 PM CDT



Motor Assembly

Copper Face

Figure 1: Uncut 1' x 1' copper sheet.

Figure 2: Copper face drawing

1. Starting from the 1' x 1' copper sheet illustrated in figure 1, on the metal shear in the TEAM Lab, cut a piece to 130.58cm tall.
2. Drill a pilot hole in the cut copper sheet at 152.4mm in the x-dimension, and 88.84mm in the y-direction as illustrated in figure 2.
3. Using a 1" hole saw, drill a 1" hole centered at the previously drilled pilot hole.
4. Drill three 3mm holes 120 degrees apart around the previously drilled 1" hole as illustrated in figure 2.
5. Drill four 5mm holes at the locations illustrated in figure 2.

Motor Stand

Download

Fabrication_Protocal.pdf (8.32 MB)

Platform Sinusoidal Motion Test

Amber Schneider - Apr 25, 2024, 5:35 PM CDT

Platform Sinusoidal Motion Test

Description:

This test is performed to determine if the platform is moving at the expected displacement of the sine wave. Multiple trials will be conducted at different weights. The motor velocity will be constant throughout trials.

Materials:

1. Fully assembled prototype
2. Bright marker
3. Camera
4. Kinovea software

Procedure:

1. Assemble complete prototype.
2. Connect the motor to the microcontroller and plug into power.
3. Connect the microcontroller to a laptop with the required files.
4. Ensure that the latest version of the active program is uploaded to the motor.
   a. The latest main.cpp can be downloaded from GitHub.
5. Place a bright marker on the platform to mark the initial position.
6. Set-up camera in full view of the platform and begin recording a video from the top view.
7. Run the function "sinusoidalSpeedVariation()" by pressing 2.
   a. This program will set the velocity of the motor to a sine wave with amplitude of 10 RPM, frequency of 8/60 Hz, and offset of 0. It will run for 60 seconds.
8. Once complete, stop recording the video.
9. Upload the video to Kinovea. Calibrate by drawing a line of known length on the video.
10. Track the displacement of the bright marker throughout the entire time the platform is moving.
11. Export the data to excel to perform statistical analysis.
12. Repeat steps 5-11 with different weights on the platform, ranging from 0-4 kg.

Download

V2._Platform_Sinusoidal_Motion_Test.pdf (40.6 kB)

2024/02/22 Sinusoidal Function w/ Interrupts

Amber Schneider - Feb 24, 2024, 12:14 PM CST

Title: Sinusoidal Function w/ Interrupts

Date: 2/22/2024

Content by: Amber Schneider

Present:

Goals: identify if code produces correct sine wave

Content:

Relevant Motor Code:

Setup

```
#include "QEI.h"
#include "math.h"
#include "mbed.h"
#include <chrono>
#include <cstdio>
#include <math.h>
#include <stdlib.h>
#include <time.h> /* time_t, struct tm, difftime, time, mktime */

BufferedSerial pc(USBTX, USBRX); // how to connect to terminal

// Setup for Encoder
QEI motorEncoder(D2, D3, D4, 5760, QEI::X4_ENCODING);

// Pin Setup
// Analog: 0.0 - 1.0 values --> converted to voltage
// Digital: 0 or 1
AnalogOut velocityControl(A2);
DigitalOut motorDirection(A0);
DigitalOut motorState(A1);
DigitalOut Flag(LED1); // Interrupt Flag at LED pin

// Definitions
#define pi 3.14159265
#define SAMPLING_RATE
  20833 // Sampling Rate in microseconds (8/60*360=48 samp/s)

void samp_out(); // Prototype for call to interrupt service routine (ISR)

// NEW: 2/5
Ticker samp_rate;
double conversion_factor = 1.0 / 175.0; // still off by 1 rev at 60 RPM
```

Sinusoidal Motion Function

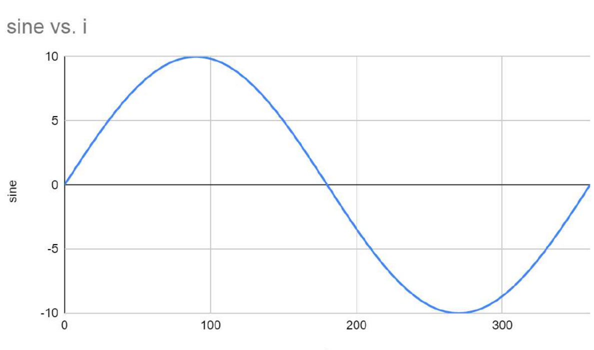
```
void sinusoidalSpeedVariation() {
```

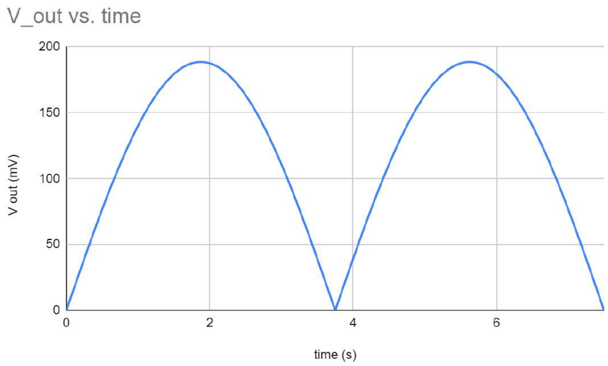
```
    float amplitude = 10.0;
    float offset = 0;
    float frequency = 8.0 / 60; // Future: Adjustable frequency

    auto t = chrono::microseconds(SAMPLING_RATE);
    samp_rate.attach(&samp_out, t);
    float sinewave = 0;
    while (true) {
      if (Flag) { // how to choose upper bound of i?
        // Calculate the output velocity using a sinusoidal function
        if (i < 360) { // Want to have an analog output value for every 1° of the
                       // sine wave
          sinewave = amplitude * sin(2 * pi * 1 / 360 * i) + offset;
          i++;
        } else { // case when i = 360
          i = 0;
          sinewave = amplitude * sin(2 * pi) + offset;
        }
        // Convert velocity to voltage
        hexaVelocity = conversion_factor * sinewave;

        if (hexaVelocity < 0) {
          motorDirection.write(1); // CCW
          hexaVelocity = hexaVelocity * -1.0;
        } else {
          motorDirection.write(0); // CW
        }
        velocityControl.write(hexaVelocity);
        motorState.write(1);

        Flag = !Flag;
      } // End of if
    }   // end of while loop
    printf("End of Function \n\n");
    motorState.write(0);
  } // end of main loop
```

Interrupt Service Routine

```
// Interrupt Service Routine.
void samp_out() { Flag = !Flag; }
```

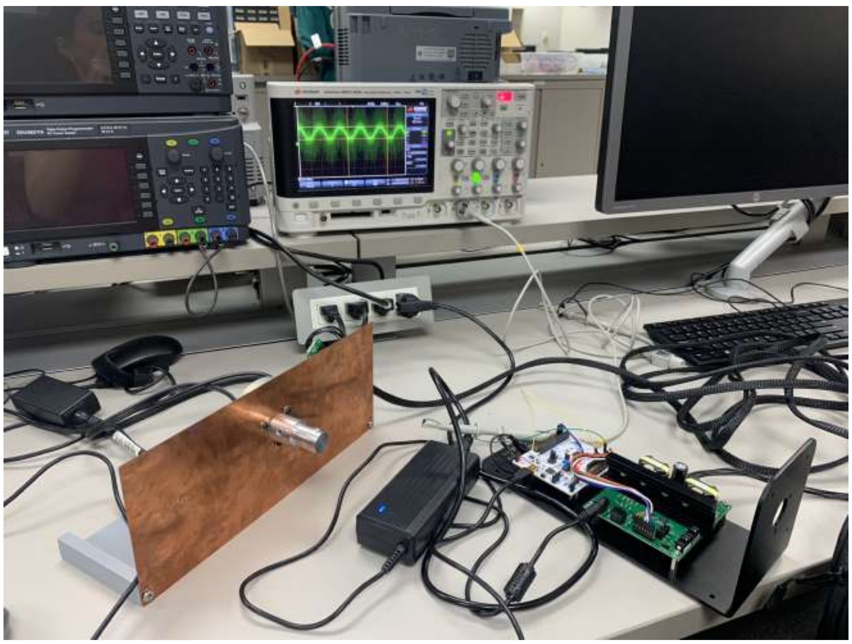
<u>Theoretical Output:</u>



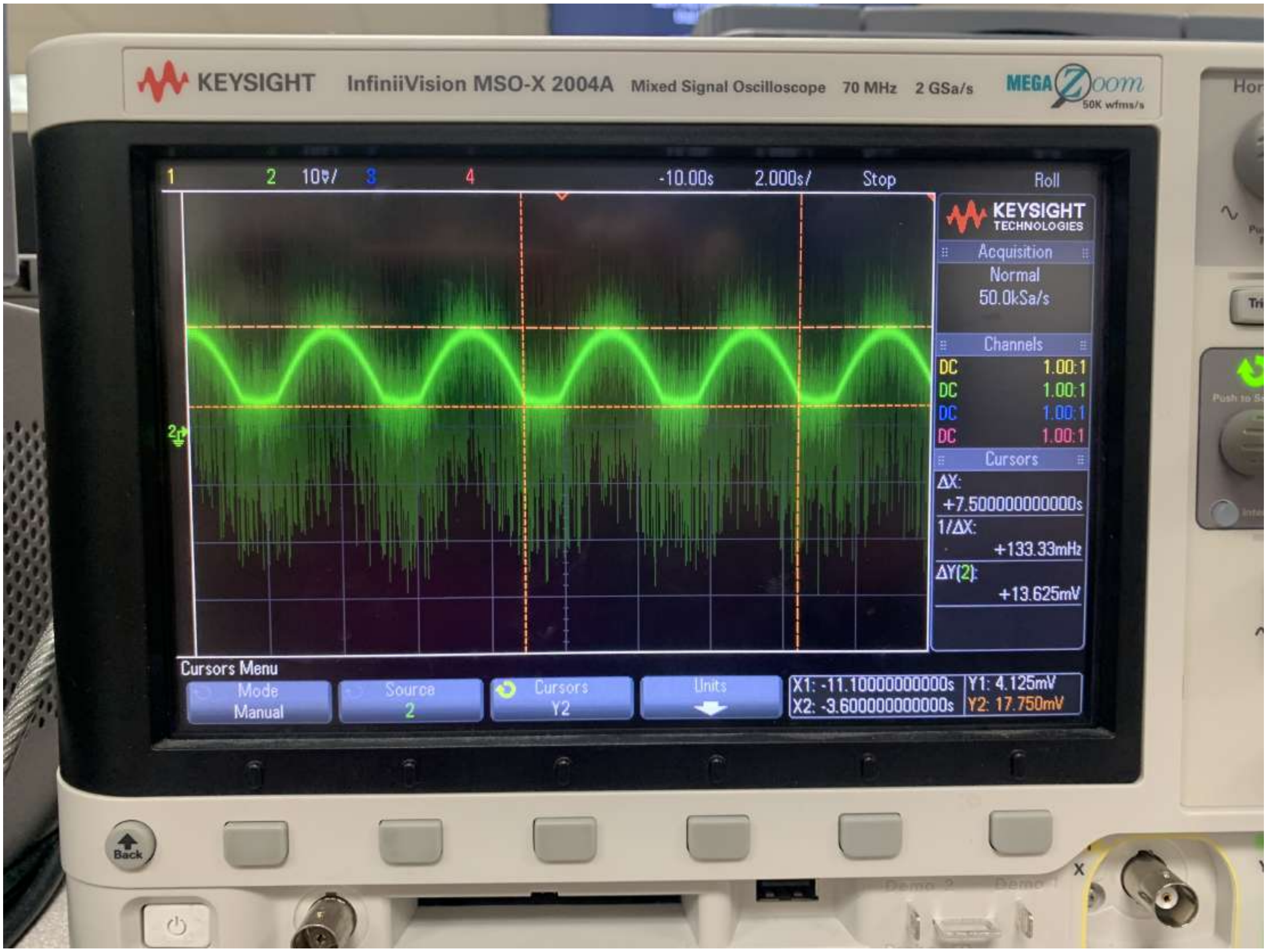


Note: *V_out will always be positive; however, when the sine wave is a negative value, the motor will switch direction.*

Experimental Output:



Test Setup: Measurement of A2 pin on oscilliscope.



Oscilliscope Output

- *Period: 7.5 s*
- *Amplitude: 13.625 mV*

Conclusions/action items:

Visually, the output of the sine wave is correct. It is always positive, but the motor direction changes depending for half the period. The period & frequency are also correct for the desired 8 cycles per minute testing condition. This is due to the sampling rate, which calls the ISR. The amplitude is not what is expected, but it is not entirely clear why. The signal also has a lot of noise. After discussion with the teams advisor and another research associate, a LP filter and step-down amplification circuit should be implemented to utilize the full range of the microcontroller, while also limiting the high-frequency noise passed to the motor controller.

2024/04/16- Sinusoidal Motion Test

Jamie Flogel - Apr 25, 2024, 12:27 PM CDT

Title: Sinusoidal Motion Test Data

Date: 4/16/2024

Content by: Jamie

Present: Amber

Goals:

-Present results from Sinusoidal Motion Test

Content:

-We ran 3 trials for 3 different weights

-We ran trails for 0kg, 1.5 kg and 4kg

-After looking at the data on Kinovea there were major issues with both the 1.5 kg and 4 kg trials

-There was significant slipping of the gears and issues with the setup which caused us to get very inaccurate data

-For 0 kg we got an average period of 7.47 with a stdev of 0.525

-We go an average P-P value of 3.79 cm with a stdev of 0.077

-Percent error for the period was 0.44 and for the amplitude was 3.48

-All of these are within the values specified in the PDS

Conclusions/action items:

We will redo the tests for some of the weights to get a more accurate sense of how the platform motion varies with weight. However our 0kg results looked very promising.

2024/04/18- Sinusoidal Motion Weight Redo

Jamie Flogel - Apr 25, 2024, 12:41 PM CDT

Title: Sinusoidal Motion Test Data

Date: 4/17/2024

Content by: Jamie

Present: Amber, Kendra

Goals:

-Present results from rerun Sinusoidal Motion Test

Content:

-To have 3 different weights we redid the test with 1.5 kg and 3.6 kg

-We did 3 trials for both weights

-For 1.5 kg we got an average period of 7.60 with a stdev of 0.568

-For 1.5 kg the average P-P value was 3.57 cm with a stdev of 0.056

-Percent error for the period was 1.38 and for the amplitude was 2.51

-For 3.6 kg we got an average period of 7.55 with a stdev of 0.547

-For 3.6 kg the average P-P value was 3.41 cm with a stdev of 0.155

-Percent error for the period was 0.71 and for the amplitude was 7.03

-All of the periods were within the tolerance outlined in the PDS

-The period for 0 kg and 1.5 kg are within the tolerance outlined in the PDS

-There does not appear to be a clear relationship between weight and accuracy of the amplitude

-Since all levels are very close to the tolerances outlined in the PDS this variation is likely due to the small input range currently being used by the motor driver

-This variation also could be due to a faulty RPM to voltage conversion factor as it was provided in the code but can also be experimentally determined

Conclusions/action items:

Many of the results we are having so far fit within the tolerances outlined in our PDS. We can try retesting after determining the RPM to voltage conversion factor experimentally.

2024/04/18- Sinusoidal Motion Recalibration Test

Jamie Flogel - Apr 25, 2024, 12:46 PM CDT

Title: Sinusoidal Motion Test Data

Date: 4/18/2024

Content by: Jamie

Present: Amber, Kendra

Goals:

-Present results from recalibrated Sinusoidal Motion Tests

Content:

-We recalibrated the RPM to voltage conversion factor experimentally and reran sinusoidal motion tests for 0 kg and 1.5 kg to improve accuracy of the motor

-We ran 3 trials for each weight and averaged our results

-Below is a summary of the pre and post calibrated tests

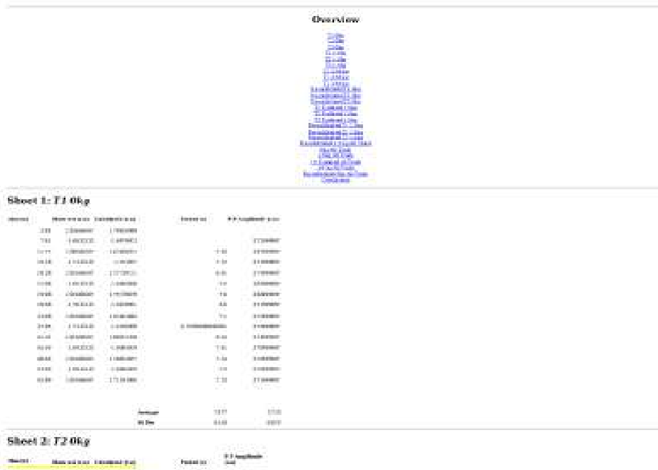
	Average Period (s)	Period Stdev	Average P-P	P-P Stdev	Percent error period	Percent error amplitude
0 kg	7.47	0.525	3.79	0.077	0.44	3.48
1.5 kg	7.60	0.568	3.57	0.056	1.38	2.51
3.563 kg	7.55	0.547	3.41	0.155	0.71	7.03
Recalibrated 0 kg	7.50	0.588	3.78	0.048	0.06	3.12
Recalibrated 1.5 kg	7.50	0.383	3.67	0.212	0.02	0.10

-The full data spreadsheet is attached below

Conclusions/action items:

Many of the results we are having so far fit within the tolerances outlined in our PDS. We found that recalibrating the motor significantly improved the percent error in both the period and amplitude.

Jamie Flogel - Apr 25, 2024, 12:47 PM CDT


Overview

Sheet 1: T1 0kg

Sheet 2: T2 0kg

Download

Kinovea_Data_Analysis.xlsx (57 kB)

2024/04/19- Frequency and Amplitude Testing

Jamie Flogel - Apr 25, 2024, 12:56 PM CDT

Title: Sinusoidal Motion Test Data

Date: 4/19/2024

Content by: Jamie

Present: Entire Team

Goals:

-Present results from Sinusoidal Motion Tests where we varied Amplitude and Frequency

Content:

-We wanted to characterize the ability of our prototype at extreme amplitude and frequencies

-We wanted to test out the full range of what is outlined in our PDS

-To do this we tested out amplitudes of 1 cm and 6 cm

-We also tested frequencies of 4 cycles per minute and 20 cycles per minute

-We compared these to a baseline of 3.6 cm amplitude at 8 cpm which served as the controls

-A table of our findings is outlined below

	Average Period (s)	Period Stdev	Average P-P	P-P Stdev	Percent error period	Percent error amplitude
Baseline (8/60, 3.6 cm)	7.50	0.588	3.78	0.048	0.06	4.83
1 cm Amplitude	7.53	0.574	1.29	0.065	0.42	29.19
6 cm Amplitude	7.46	0.281	7.77	0.252	0.55	29.58
Low Frequency (4/60)	15.03	0.634	4.64	0.194	0.21	28.65
High Frequency (20/60)	3.01	0.177	4.64	0.114	0.32	28.67

-In seeing these results it looked like our period was very accurate but something was off with the period

-We saw a similar percent error for all the trials so we wondered if it had something to do with an error in our calculations or process

-We discovered that in our set up the camera angle was slightly shifted likely leading to this significant error in the amplitude

Conclusions/action items:

While the percent error of the period in these tests was very accurate there was a clear issue with the amplitude. After correcting the set-up we should retest and re-analyze the data.

2024/04/22- Frequency and Amplitude Retest

Jamie Flogel - Apr 25, 2024, 1:05 PM CDT

Title: Sinusoidal Motion Test Data

Date: 4/19/2024

Content by: Jamie

Present: Amber, Kendra

Goals:

-Present results from redo of the Sinusoidal Motion Tests where we varied Amplitude and Frequency

Content:

-We corrected the setup for the test and redid trials for each of the amplitudes and frequencies

-For the 1 cm amplitude 2/3 trials failed due to play within the gears and an undetected driveshaft detachment

-At this point in the semester we did not have time to rerun the trial so we analyzed the data we were able to collect

-A summary table is included below but note there was only one trial used for the 1cm amplitude Redo

	Average Period (s)	**Period Stdev**	**Average P-P**	**P-P Stdev**	**Percent error period**	**Percent error amplitude**
Baseline (8/60, 3.6 cm)	7.50	0.588	3.78	0.048	0.06	4.83
1 cm Amplitude	7.53	0.574	1.29	0.065	0.42	29.19
6 cm Amplitude	7.46	0.281	7.77	0.252	0.55	29.58
Low Frequency (4/60)	15.03	0.634	4.64	0.194	0.21	28.65
High Frequency (20/60)	3.01	0.177	4.64	0.114	0.32	28.67
4 cpm Redo	15.07	0.682	4.11	0.101	0.45	12.06
6 cm Amplitude Redo	7.56	0.552	6.48	0.231	0.81	6.16
20 cpm Redo	3.02	0.184	3.94	0.036	0.51	7.35
1 cm Amplitude Redo (one trial only)	7.437	0.843	0.736	0.042	0.84	27.63

-In this rerun we saw much lower percent errors in the amplitude while the percent error for the period remained small

-Though the percent errors in amplitude are not within the tolerances specified in the PDS the large amplitude and frequency trials are quite close

-We believe that the play in the gears and the issue with the drive shaft could have contributed significantly to the error observed

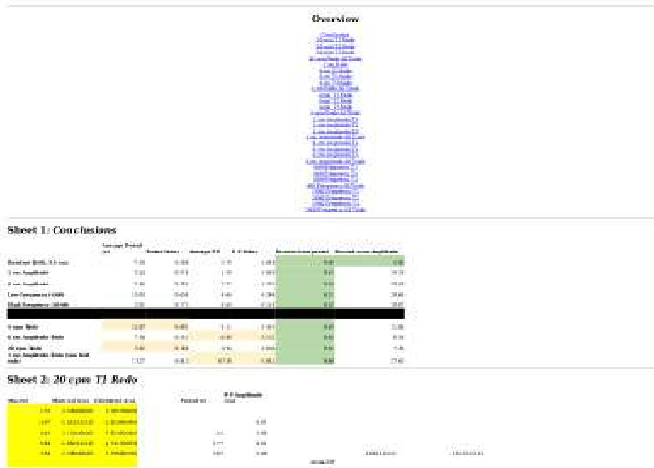
-Additionally similar to the earlier tests working with the small range of the motor driver also likely led to these sub-optimal results

-The full testing excel sheet for the frequency and amplitude testing is included below

Conclusions/action items:

In the future there is more work to be done in reducing some of the mechanical errors that were seen after running many tests. Additionally more work could be done to use a wider range of input values in the motor driver.

Jamie Flogel - Apr 25, 2024, 1:05 PM CDT



[Download](#)

Freqency_and_Amplitude_Testing.xlsx (77.4 kB)

2024/04/25 Final Motor Code

Amber Schneider - Apr 25, 2024, 5:40 PM CDT

Title: Final Motor Code

Date: 4/25/2024

Content by: Amber Schneider

Present:

Goals: document final main.cpp file of motor code and attach .bin file of compiled code

Content:

```
#include "QEI.h"

#include "math.h"

#include "mbed.h"

#include <chrono>

#include <cstdio>

#include <math.h>

#include <stdlib.h>

#include <time.h> /* time_t, struct tm, difftime, time, mktime */


BufferedSerial pc(USBTX, USBRX); // how to connect to terminal


// Setup for Encoder

QEI motorEncoder(D2, D3, D4, 5760, QEI::X4_ENCODING);


// Pin Setup

// Analog: 0.0 - 1.0 values --> converted to voltage

// Digital: 0 or 1

AnalogOut velocityControl(A2);

DigitalOut motorDirection(A0);

DigitalOut motorState(A1);
```

```
DigitalOut Flag(LED1); // Interrupt Flag at LED pin


// Definitions

#define pi 3.14159265

#define SAMPLING_RATE  20833 // Sampling Rate in microseconds (8/60*360=48 samp/s)


void samp_out(); // Prototype for call to interrupt service routine (ISR)


Ticker samp_rate;

double conversion_factor = 1.0 / 175.9283227; // BEST 4/18

// 1.0 / 181.29371; Result of tests on 4/11


int encoderIncrementsPerRev = 5760;

double hexaVelocity = 0.0;

float rpmVelocity;

float increment = 0;

float presicion = 0.015625;

float angle;

int demo;

int direction;

int state;

float sum;

float speed;

int i = 0;


// Define rack and pinion values

const float pinionDiameter = 43.45; // in mm


// Interrupt Service Routine.
```

```
void samp_out() { Flag = !Flag; }


// Function to vary the motor speed sinusoidally
void sinusoidalSpeedVariation() {
  // TODO:
  // 1. Re-incorporate user interaction (puTTy)
  // ensure input values are within SAFE range


  printf("Sinusoidal Function (runs for 60 seconds) \n\n");
  clock_t start = clock();
  // printf("Enter desired Frequency \n\n");
  // char f;
  // pc.read(&f, 1);
  // int frequency = f - '0';


  // printf("Enter desired Amplitude \n\n");
  // char a;
  // pc.read(&a, 1);
  // int amplitude = a - '0';


  // GEAR RATIO
  float gear_ratio = 1.5; // 1.5:1 gear ratio


  // WITHOUT CIRCUIT
  float amplitude = 10.;
  // Original: 10.0
  float circuit_gain = 1.0; // none


  // WITH CIRCUIT
```

```
// float amplitude = 1.0;

// IDEAL: 1.0 / amplitude / conversion_factor/ gear_ratio

// float circuit_gain = 29.4 / 355.3;

// adjust for actual circuit gain


//float frequency = 8.0 / 60.0; //NOT USED

// Original 8.0 / 60;

float offset = 0.0;


auto t = chrono::microseconds(SAMPLING_RATE);

samp_rate.attach(&samp_out, t);


float sinewave = 0.0;


bool condition = true;

while (condition) {

 clock_t end = clock();

 double currentTime = static_cast<double>(end - start) / CLOCKS_PER_SEC;


 if (Flag) {

  // Calculate the output velocity using a sinusoidal function

  if (i < 360) { // Analog output value for every 1° of sine wave

   sinewave = amplitude * sin(2 * pi * 1 / 360 * i) + offset;

   i++;

  } else { // Case when i = 360 => restart

   i = 0;

   sinewave = amplitude * sin(2 * pi) + offset;

  }
```

```
      // Convert velocity to voltage

      hexaVelocity = gear_ratio * conversion_factor / circuit_gain * sinewave;


      if (hexaVelocity < 0) {

        motorDirection.write(1); // CCW

        hexaVelocity = hexaVelocity * -1.0;

      } else {

        motorDirection.write(0); // CW

      }

      velocityControl.write(hexaVelocity);

      motorState.write(1);


      Flag = !Flag;

    } // End of if

    if (currentTime > 60.0) {

      condition = false;

    }

  } // end of while loop

  printf("End of Function \n\n");

  motorState.write(0);

} // end of main loop


// EXAMPLE

void incrementWrite() {

  // printf("Enter a desired angle with a precision of 0.015625 degrees \n");

  // scanf("%f", &angle);

  angle = 360; // hardcode angle

  increment = rint(angle / presicion);
```

```
  // scanf("%f", &rpmVelocity );

  rpmVelocity = 10; // hardcode rpmVelocity

  hexaVelocity = 0.0063 * rpmVelocity;

  velocityControl.write(hexaVelocity);

  // printf("Enter 1 to start the motor rotation \n");

  // scanf("%d", &state);

  state = 1; // start motor rotation

  while (motorEncoder.getPulses() != increment) {

    if (motorEncoder.getPulses() < increment) {

      motorDirection.write(0); // clockwise

      motorState.write(1);

    }

    if (motorEncoder.getPulses() > increment) {

      motorDirection.write(1); // counter-clockwise

      motorState.write(1);

    }

    if (motorEncoder.getPulses() == increment) {

      motorState.write(0);

    }

  }

  motorState.write(0);

  printf(" Motor arrived at desired position \n\n");

}


// EXAMPLE

void continuousMode() {

  // printf("Enter a rotational speed between 5 and 175 rpm \n");

  // scanf("%f", &rpmVelocity);

  rpmVelocity = 10; // hardcoded
```

```
  hexaVelocity = 0.0063 * rpmVelocity;

  velocityControl.write(hexaVelocity);

  // printf("Enter a rotational direction : 0 clockwise and 1 counterclockwise

  // \n"); scanf("%d", &direction);

  direction = 0; // clockwise

  motorDirection.write(direction);

  // printf("Enter 1 to start the motor rotation \n");

  // scanf("%d", &state);

  state = 1;

  // printf("The motor will turn in the direction and the speed you chose

  // \n\n");

  int i = 0; // run for 10 seconds

  while (state == 1) {

    motorState.write(state);

    // printf("Enter 0 to stop the motor \n\n");

    // scanf("%d", &state);

    wait_us(1000000); // wait 1 s

    if (i == 10) {

      state = 0;

    } else {

      i = i + 1;

    }

  }

  printf("%d", motorEncoder.getRevolutions());

  printf("%d", motorEncoder.getPulses());

  printf("\n\n");

  motorState.write(0);

  printf(" Motor stopped \n\n");

}
```

```
// Last Updated: 4/10
void testVolRPM() {
  rpmVelocity = 7;                  // hardcoded
  hexaVelocity = conversion_factor * rpmVelocity; // coeff between 0-1.1
  velocityControl.write(hexaVelocity);
  direction = 0; // clockwise
  motorDirection.write(direction);
  motorState.write(1);
  bool a = true;
  while (a) {
    ThisThread::sleep_for(60s);
    a = false;
  }
  printf("The encoder counted %d revolutions", motorEncoder.getRevolutions());
  motorState.write(0);
}


// Written 4/11
void timeRPMTest() {
  // printf("Enter a desired angle with a precision of 0.015625 degrees \n");
  // scanf("%f", &angle);
  rpmVelocity = 7;       // hardcode rpmVelocity
  angle = 360 * rpmVelocity; // num revolutions
  hexaVelocity = conversion_factor * rpmVelocity;

  increment = rint(angle / presicion);
  // scanf("%f", &rpmVelocity );
  velocityControl.write(hexaVelocity);
```

```
  // printf("Enter 1 to start the motor rotation \n");

  // scanf("%d", &state);

  state = 1; // start motor rotation

  while (motorEncoder.getPulses() != increment) {

    if (motorEncoder.getPulses() < increment) {

      motorDirection.write(0); // clockwise

      motorState.write(1);

    }

    if (motorEncoder.getPulses() > increment) {

      motorDirection.write(1); // counter-clockwise

      motorState.write(1);

    }

    if (motorEncoder.getPulses() == increment) {

      motorState.write(0);

    }

  }

  motorState.write(0);

  printf(" Motor arrived at desired position \n\n");

}


int main() {

  bool isOn = true;

  while (isOn) {

    printf("Enter 0 to Exit, Enter 1 for timeRPMtest() hardcoded demo, "

           "Enter 2 for sinusoidal demo, Enter 4 for Voltage to RPM \n\n");

    char c;

    pc.read(&c, 1);

    int demo = c - '0';
```

```
    if (demo == 1) {
      printf("Demo 1 Selected \n\n");
      timeRPMTest();
      // continuousMode();
      motorEncoder.reset();
    }
    if (demo == 2) {
      printf("Demo 2 Selected \n\n");
      sinusoidalSpeedVariation();
      motorEncoder.reset();
    }
    if (demo == 0) {
      printf("Exiting loop \n\n");
      isOn = false;
      motorState.write(0);
    }
    if (demo == 4) {
      printf("Demo 4 Selected \n\n");
      testVolRPM();
      motorEncoder.reset();
    }
  }
  printf("This is the end of the code \n\n");
}
```

Conclusions/action items:

The above code is accessible through putty.

Amber Schneider - Apr 25, 2024, 5:41 PM CDT

Download

mbed-os-Spring-Design.NUCLEO_F446RE_40_.bin (46.8 kB)

04/25/2024 GitHub Link

Amber Schneider - Apr 25, 2024, 5:53 PM CDT

Title: GitHub Link

Date: 4/25/2024

Content by: Amber Schneider

Present:

Goals: add link to github for future reference and use

Content:

https://github.com/JamieF2024/nonmagentic_mover

Conclusions/action items:

This github was developed to begin the transition into an open source MRI platform prototype.

2024/02/29 - Gearbox RPM and Torque Calculation

MAXWELL NASLUND - Feb 29, 2024, 7:18 PM CST

Title: Gearbox RPM and Torque Calculation

Date: 2024/02/29

Content by: Maxwell Naslund

Present: n/a

Goals: Outline the process of calculating max Motor RPM requirements and torque placed on the motor.

Content:

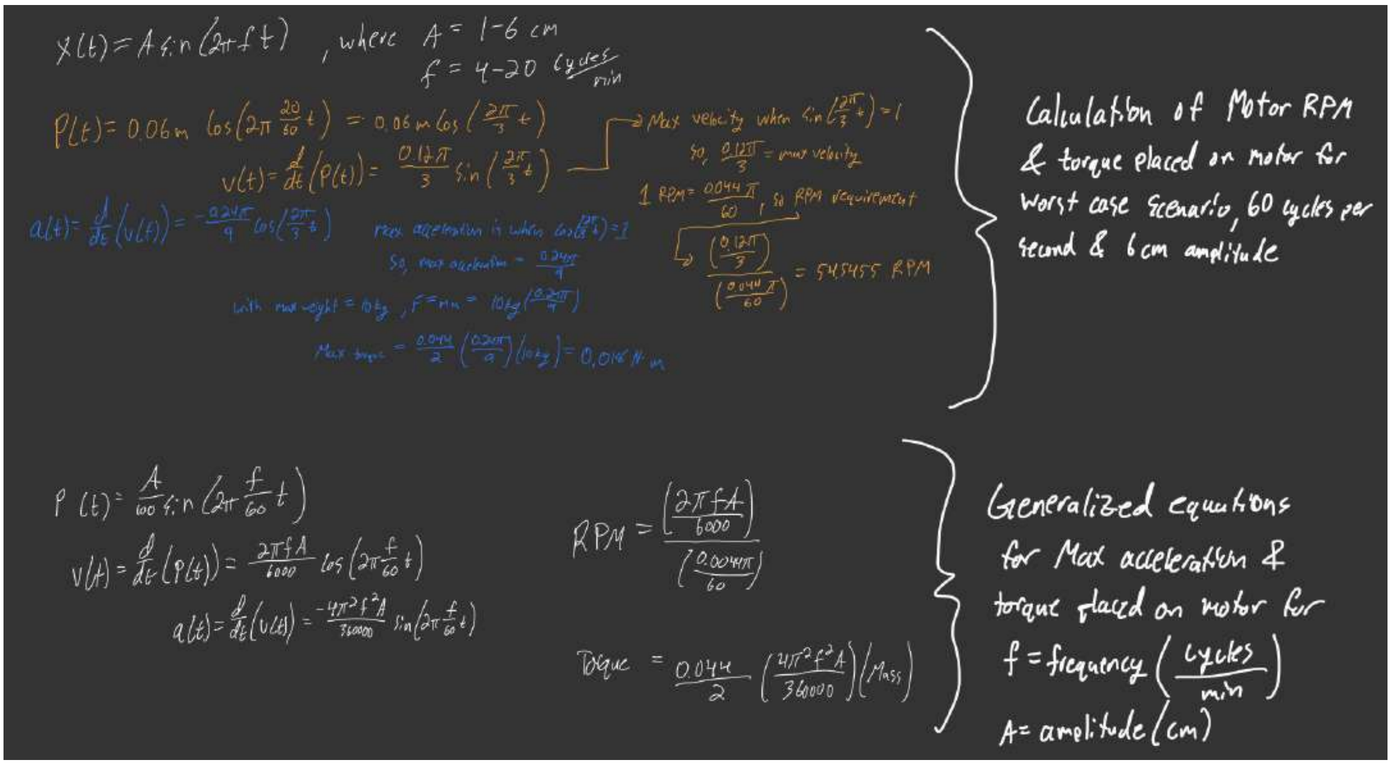


Figure 1: RPM & Torque Calculations

Figure 1 above illustrates the derivation of the worst case scenarios for Motor RPM's and torque placed on the motor.

As defined in our PDS, the prototype should be able to replicate a sinusoid of 4-20 cycles/min, at amplitudes of 1-6 cm. With these requirements, we can calculate the worst case scenario for the motor to assure that we can actually replicate these requirements. In this case, the worst case scenario would be creating a sinusoid with a frequency of 20 cycles/min and an amplitude of 6cm. Using the equations shown in the figure 1, it was derived that the motor would have to deliver a maximum of RPM of 54.55 which would place a torque of 0.018 Nm on the motor. These are well within the motors specifications.

Equation 1: RPM Calculations

RPM = (2*π*frequency*amplitude6000)(0.044*π60*gear_ratio)

Equation 2: Torque placed on motor

Torque = gear_ratio*mass*0.044*2*π2*frequency2*amplitude360000

Conclusions/action items:

We will be able to use these derived equations to understand what the motor will need to deliver.

2024/02/29 - MATLAB Motor Requirements Script

MAXWELL NASLUND - Feb 29, 2024, 7:27 PM CST

Title: MATLAB Motor Requirements Script

Date: 2024/02/29

Content by: Maxwell Naslund

Present: n/a

Goals: Outline the Matlab script I created to easily derive the motor requirements

Content:

The following is the script we are using to understand what RPM's are required by the motor for the desired outputs, along with the induced torque placed on the motor.

```
function [torque,rpm] = gearbox(mass,freq,ampli,ratio)

rpm = (2*pi*freq*ampli/6000)/((0.044*pi)/(60*ratio));

torque =  ratio*mass*0.044*0.5*4*(pi^2)*(freq^2)*ampli/360000;

end
```

The function is very simple and quickly applies the equations that we have derived for the motor requirements.

This function takes the inputs Phantom mass, desired frequency (cycles/min), desired amplitude, and gear ratio. With these inputs, it becomes very easy to understand the boundaries we are limited to in the gearbox design. As we move forward with trying to reduce friction in the gearbox design, we might want to increase the gear-ratio of the box to allow for more force to be passed to the phantom bed in attempt to smooth the sinusoid created.

Conclusions/action items:

Attached here is the matlab code that we will use to help understand gearbox boundries and potential gear-ratios to move forward with.

MAXWELL NASLUND - Feb 29, 2024, 7:27 PM CST

```
function [torque,rpm] = gearbox(mass,freq,ampli,ratio)
%UNTITLED3 Summary of this function goes here
%   Detailed explanation goes here

rpm = (2*pi*freq*ampli/60000)/((0.044*pi)/(60*ratio));
torque = ratio*mass*0.044*0.5^2*(pi^3)*(freq^2)*ampli/360000;

end
```

Download

gearbox.m (258 B)

2024/02/29 - Graphical Representation of Gearbox Limitations

MAXWELL NASLUND - Feb 29, 2024, 7:39 PM CST

Title: Graphical Representation of Gearbox Limitations

Date: 2024/02/29

Content by: Maxwell Naslund

Present: n/a

Goals: Document graphical representations developed

Content:

Below I've attached some graphical representations I was able to create using our derived equations. These establish curves that we are able to use when we are pinned at the maximum of one of our variables, whether its pinned at 6cm amplitude, or at 20 cycles/min.

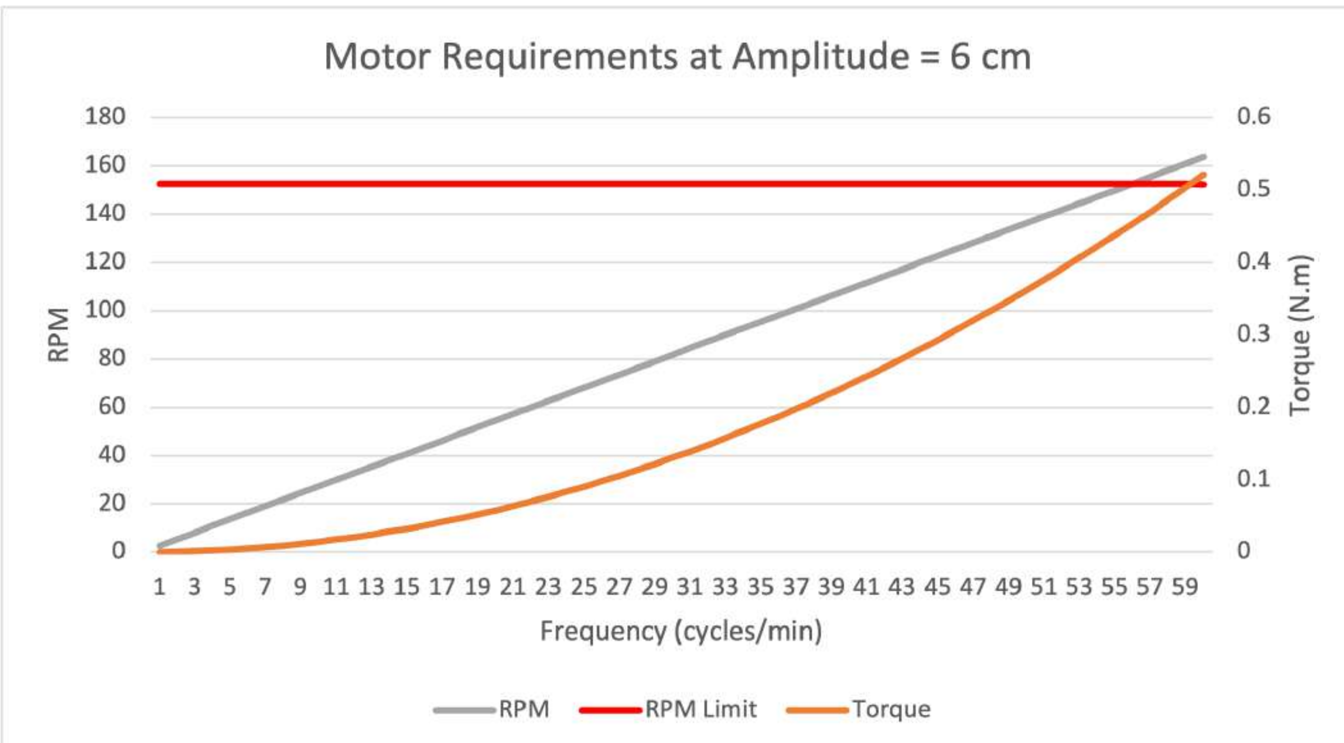


Figure 1

Figure 1 illustrates the associated curves of required motor RPM and induced torque on motor when pinned at the maximum variable 6cm. This curve was developed with a 1:1 gear ratio. The red curve illustrates the maximum RPM the motor can output.

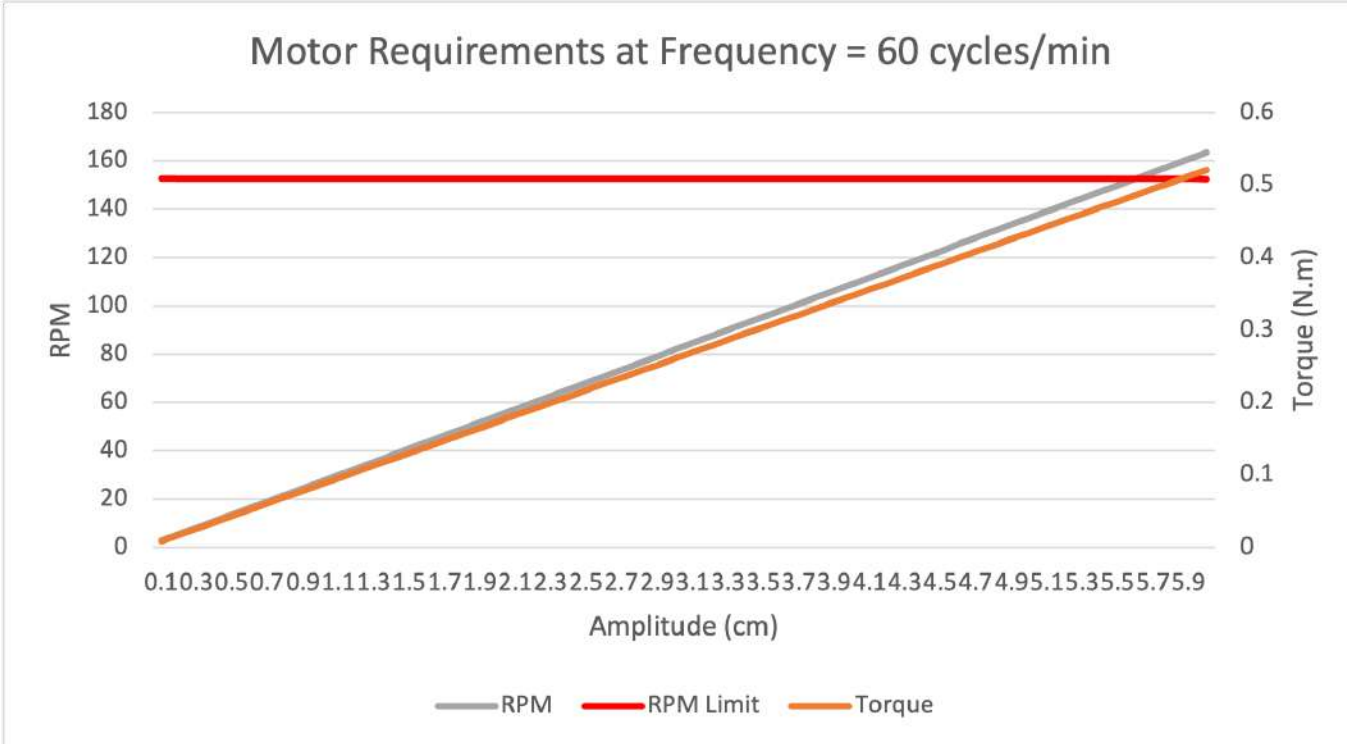


Figure 2

Figure 2 illustrates the associated curves of required motor RPM and induced torque on motor when pinned at the maximum frequency of 20 cycles/min. This curve was developed with a 1:1 gear ratio. The red curve illustrates the maximum RPM the motor can output.

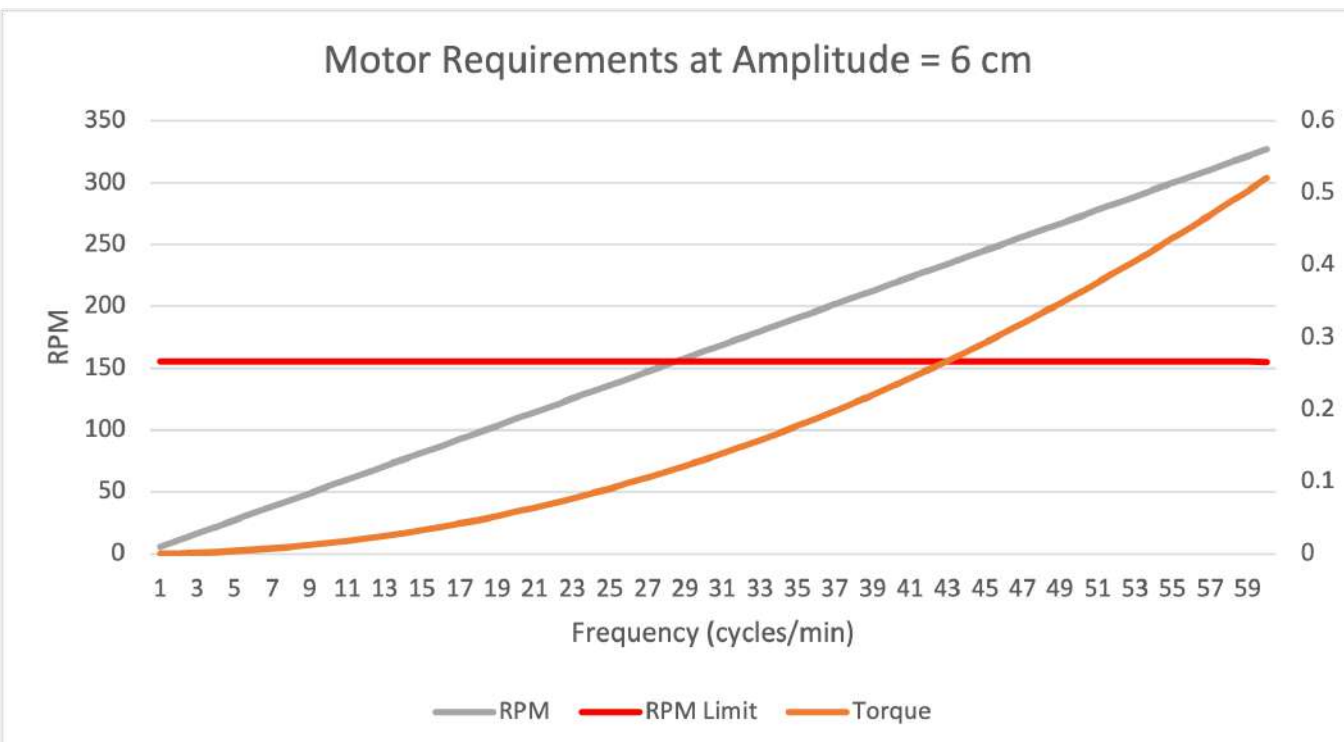


Figure 3

Figure 3 illustrates the associated curves of required motor RPM and induced torque on motor when pinned at the maximum variable 6cm. This curve was developed with a 1.5:1 gear ratio. The red curve illustrates the maximum RPM the motor can output.

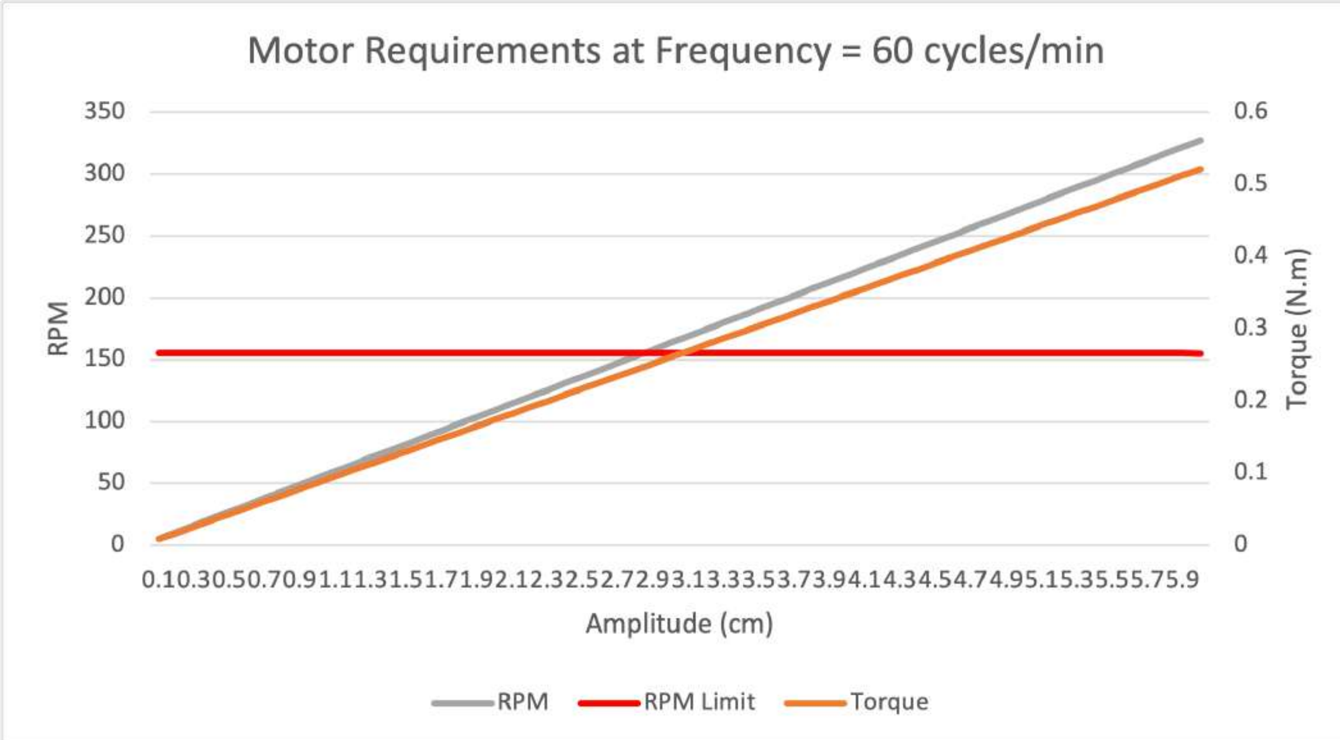


Figure 4

Figure 4 illustrates the associated curves of required motor RPM and induced torque on motor when pinned at the maximum variable frequency 20 cycles/min. This curve was developed with a 1.5:1 gear ratio. The red curve illustrates the maximum RPM the motor can output.

Conclusions/action items:

These give a nice graphical representation of the limitations we have associated with the gearbox.

2024/02/02 - Flexible Coupling

MAXWELL NASLUND - Feb 02, 2024, 1:18 PM CST

Title: Flexible Coupling

Date: 2024/02/02

Content by: Maxwell Naslund

Present: n/a

Goals: Outline the company to contact for quote on flexible motor coupling

Website: http://acces.cc/technical-data.html

Content:

Company: A.C.C.&S.

Ref: A2533

Email: infos@acces.cc

Conclusions/action items:

We will have to in the near future reach out to this company for a quote for a flexible coupling for the ultrasonic motor

2024/02/29 - Proposed Swappable Gear-Ratio Gearbox

MAXWELL NASLUND - Feb 29, 2024, 7:50 PM CST

Title: Proposed Swappable Gear-Ratio Gearbox

Date: 2024/02/29

Content by: Maxwell Naslund

Present: n/a

Goals: Outline one of my preliminary ideas to test different gear-ratios with a swappable design

Content:

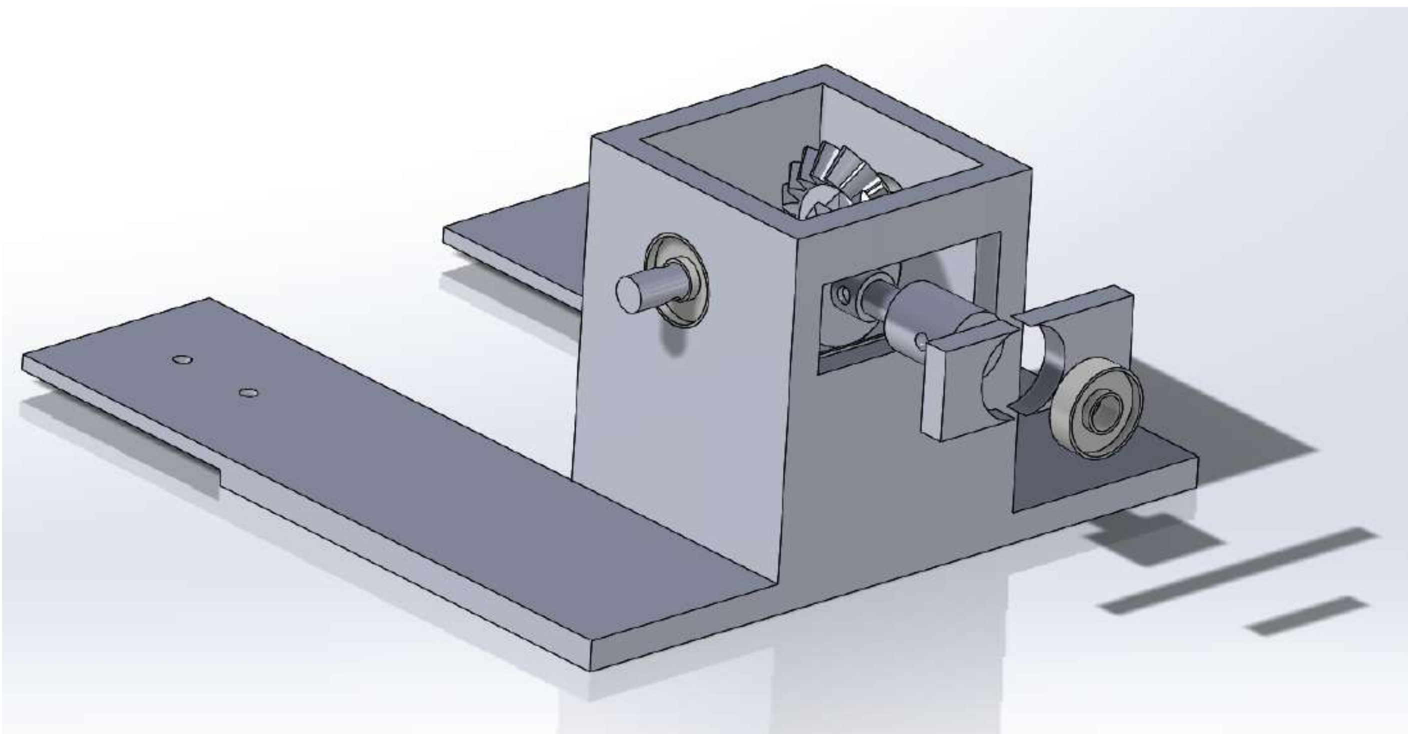


Figure 1: Swappable Gear-ratio design

Figure 1 above illustrates one of the preliminary ideas to test different gear-ratios in the gearbox.

The design contains a modified gearbox SOLIDWORKS part with a section removed where the driveshaft connects. This allows for different sized pieces to be slotted into to move the first gear in the bevel gear assembly. With a smaller initial gear, we would increase the gear-ratio of the assembly and increase the torque output. This would require the gear itself to moved closer to the second gear. With this swappable insert, we could print whatever size is required to physically move the initial drive gear towards the secondary gear.

Conclusions/action items:

We ended up deciding not to pursue this idea further. With the development of reliable equations for gearbox output we no longer need to trial and error whether changing the gear-ratio of the design would provide any benefit.

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

1_1_BevelGear.SLDPRT (711 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

1_1_Gearbox.SLDASM (318 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

1_1_insert_L.SLDPRT (68.9 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

1_1_insert_R.SLDPRT (73.5 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

1-1_BevelGear_new.SLDPRT (777 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

crosspin_new.SLDPRT (137 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

gearbox_adjust.SLDPRT (191 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

pipetodriveshaft_new.SLDPRT (141 kB)

MAXWELL NASLUND - Feb 29, 2024, 7:51 PM CST

Download

BallBearing.SLDPRT (99.7 kB)

2024/01/31-Organ Motion and its Management

Jamie Flogel - Feb 01, 2024, 5:21 PM CST

Title: Notes on Organ Motion and its Management

Date: 1/31/2024

Content by: Jamie

Present: N/A

Goals:

-Further understand the motion of organs in MRI

Content:

https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S0360301601014535

-Treatment can vary due to patient movement.

-Actual dose can vary from planned dose due to inaccurate quantifications

-This discrepancy can cause poorer clinical results

-The amount of motion varies depending on the organ

-A study was done to better understand prostate and seminal vesicle motion

-Anterior-posterior motion was found to be directly correlated with fractional changes in rectal volume

-There was also a study done on bladder motion

-Another study was done to investigate liver motion

-Under deep breathing liver movement ranged from 12-75 mm

-They also quantified the movements of a few other organs

-This data could be useful in programing alternate waveforms to mimic other organs

Conclusions/action items:

Overall the motion of many different organs due to respiration has been quantified. We can use the findings from these studies to generate waveforms to mimic anatomical motion.

2024/02/21-Magnetic Resonance in Medicine

Jamie Flogel - Feb 21, 2024, 3:54 PM CST

Title: Magnetic Resonance in Medicine Notes

Date: 2/21/24

Content by: Jamie

Present: N/A

Goals:

-Learn more about another potential journal

Content:

Link: https://onlinelibrary-wiley-com.ezproxy.library.wisc.edu/page/journal/15222594/homepage/author-guidelines

-Magnetic Resonance in Medicine is an international journal for the publication of investigations concerned with all aspects of the development and use of nuclear magnetic resonance and electron paramagnetic resonance techniques for medical applications

-Impact factor 3.3

-Manuscript types include research articles, technical notes, rapid communications, letters to the editor and replies, reviews, mini reviews, review symposiums, and guidelines

-Technical notes are complete accounts of technical work of a limited scope, nut may also describe methodologically-oriented clinical studies of a limited scope or other such limited studies

-Use 1.5 line spacing on A4 format with 1 inch margins on all sizes in a basic font of at least 11 pt

-Research article max of 5000 words and 10 total figures/tables

-Technical notes max of 2800 words and 5 total figures/tables

-Structured abstract format (Purpose, methods, results, conclusion)

Conclusions/action items:

This journal is very relevant to the project we are doing. The technical notes format might better fit our project since it is so early on in the device's use in research.

2024021/21-Journal of Magnetic Resonance Imaging

Title: Physiologic Motion Phantom for MRI applications Research Notes

Date: 2/21/24

Content by: Jamie Flogel

Present: N/A

Goals:

-Look at journal articles for similar devices

-Investigate potential journals for submission

Content:

Link: https://onlinelibrary-wiley-com.ezproxy.library.wisc.edu/doi/epdf/10.1002/jmri.1880060315

-This article was submitted to the Journal of Magnetic Resonance Imaging

-This article discusses similar issues of motion artifact on MR scans

-In this article a phantom is used to simulate physiologic motion

-This phantom is a model of a heart

-This design utilizes a lead screw

-Based on the similar aim of the project this is definitively a journal to consider

https://onlinelibrary-wiley-com.ezproxy.library.wisc.edu/page/journal/15222586/homepage/forauthors.html?
utm_source=google&utm_medium=paidsearch&utm_campaign=R3MR425&utm_content=Medicine&gad_source=1&gclid=CjwKCAiA29auBhBxEiwAnKcSq
lF2U3tgIJ66ia0yLcbJGYMxRoCkkYQAvD_BwE

-The Journal of Magnetic Resonance Imaging (JMRI) is an international journal devoted to the timely production of basic and clinical research, educational information related to the diagnostic applications of magnetic resonance

-JMRI is owned by the international Society for Magnetic Resonance in Medicine (ISMRM)

-Types of Manuscripts include research articles, case reports, reviews, editorial/commentary, guidelines, and letters to the editor

-For research articles you can have up to 20 manuscript pages (5,000 words), 40 references, 10 figures and tables

-Should be double-spaced in 12 pt font with 2.5 cm margins

-Acceptable fonts include arial, times new roman, and bookman old style

-Each component should begin on a new page in the main document in this order:

-Full Title page with acknoledgements

-Title/Abstract/Keywords

-Text

-References

-Tables

-Figure Legends

-Figures

-The abstract should be no more than 300 words

-Research articles should include background, purpose/hypothesis, study type, phantom type and numbers, field strength/sequence, assessment, statistica

Conclusions/action items:

JMRI is a journal we could consider for our article. We have access to the requirements for this journal and it seems relevant to the work we are doing.

2024/04/29-ASTM F2503

Jamie Flogel - Apr 29, 2024, 8:45 AM CDT

Title: ASTM F2503 Notes

Date: 4/29/24

Content by: Jamie

Present: N/A

Goals:

-Ensure our device is meeting MRI specific codes and standards

Content:

-This standard addresses safety concerns regarding bringing medical devices into the MR environment

-This aims to address the injuries and deaths of patients related to medical devices in the MR environment

-Before being brough in items should be assessed for static magnetic field interactions

-Also assess potential RF field interactions

-MR marking should be included in the labeling

-Make sure to adhere to proper labeling systems

-Different symbols and colors are used to denote key information about the safety and use of medical devices

-This marking should be displayed on the packaging or the device itself

-Image artifacts are not a direct safety issue and are thus not included in this standard

-https://compass.astm.org/document/?contentCode=ASTM%7CF2503-23E01%7Cen-US

Conclusions/action items:

When we brought our device into the MR environment we first had it inspected by a medical radiologist at WIMR. In his inspection he determined that our device would not create any significant concerning static magnetic field interactions or RF interactions. In the future marking should be added to the device to ensure researchers know it is MR safe.

2024/04/29-ASTM F2213-17

Jamie Flogel - Apr 29, 2024, 9:00 AM CDT

Title: ASTM F2213-17 Standard Test Method for Measurement of Magnetically Induced Torque on Medical Devices in the Magnetic Resonance Environment.

Date: 4/29/24

Content by: Jamie

Present: N/A

Goals:

-Ensure our device meets standards required for the MR environment

Content:

-This standard does not address safety concerns related to RF and magnetically induced torque

-This would likely only be needed to be done for the motor component of our design

-Since there are no metallic parts in the rest of the design they would not be impacted

-This testing likely would've been done by the manufacturer prior to gaining FDA approval

-Since no other aspects of our design would need to be tested we are compliant with this standard

-In this test you determine the coefficient of friction and compare the sliding of the device to calculated expectations

-Ideally no motion is observed

-https://compass.astm.org/document/?contentCode=ASTM%7CF2213-17%7Cen-US

Conclusions/action items:

Our device meets the criteria defined in this standard because the motor is the only part of our design that would need to be considered. The manufacturer as well as our client have already introduced it into the MR environment and determined that magnetically induced torque is not a concern.

2024/03/13 - Updated Motor Stand

Jamie Flogel - Mar 13, 2024, 5:10 PM CDT

Title: Motor Stand

Date: 12/1/2023

Content by: Jamie and Max

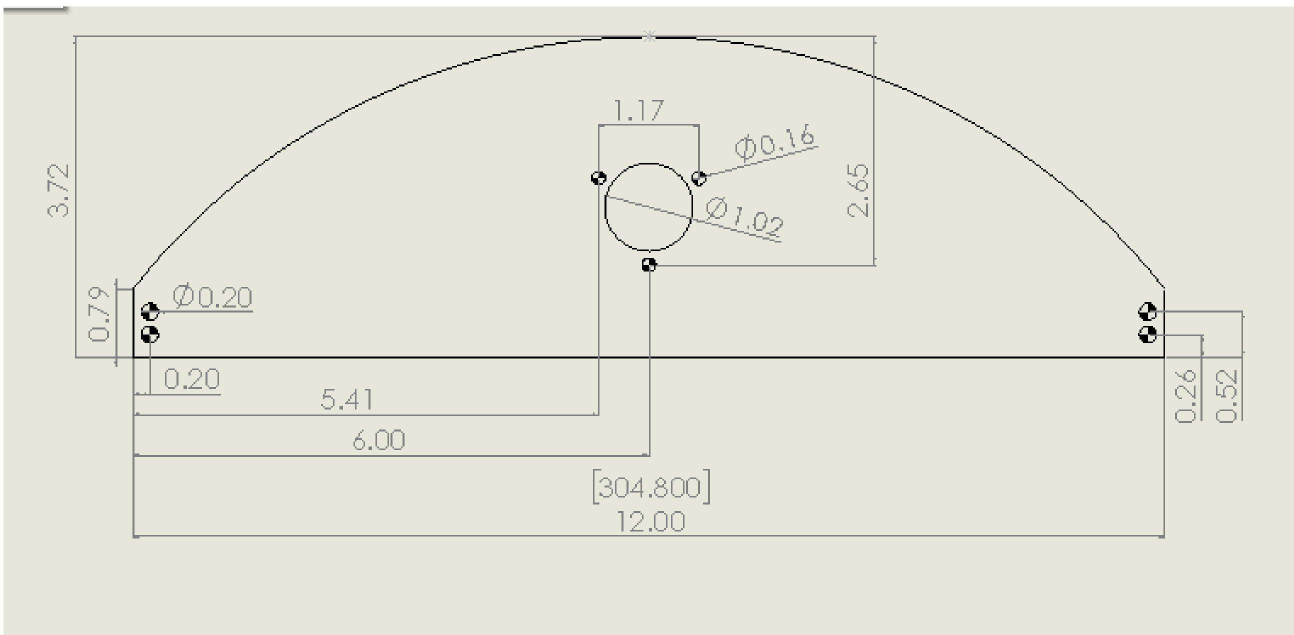
Present: N/A

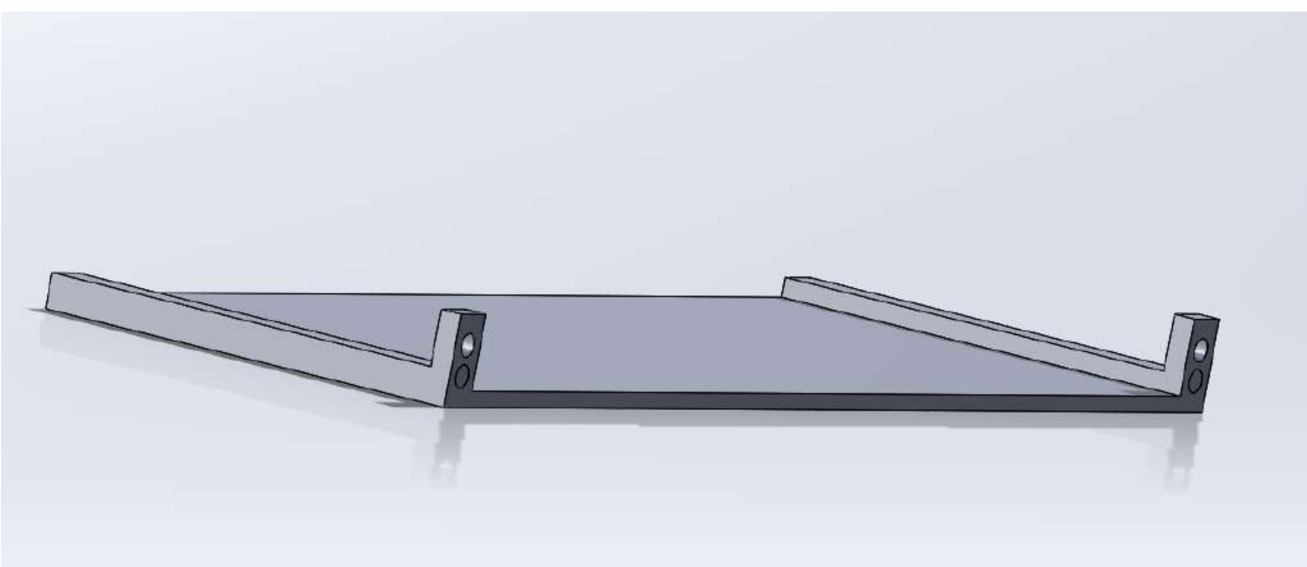
Goals:

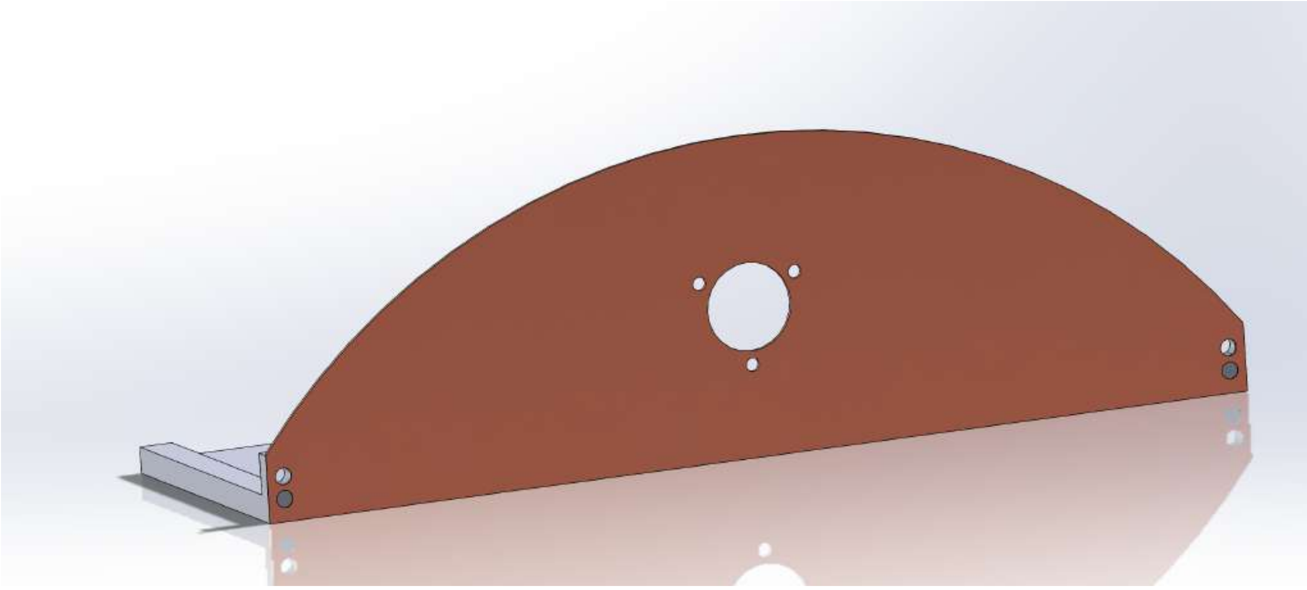
-Develop a stand to hold the motor in the right position at the right height

Content:

Drawing of copper piece:







We modified the motor stand to allow for an added nut. This will allow us to better secure the copper face holding the motor to the motor stand.

Conclusions/action items:

We will 3D print the plastic piece and attach it to the the current copper/motor assembly. This will better secure the motor in place during operation.

Jamie Flogel - Dec 01, 2023, 3:12 PM CST

Download

MotorCopperFace.SLDPRT (125 kB)

Jamie Flogel - Dec 01, 2023, 3:12 PM CST

Download

MotorCopperFace.SLDDRW (127 kB)

Jamie Flogel - Mar 13, 2024, 5:07 PM CDT

Download

MotorStand.SLDPRT (129 kB)

Jamie Flogel - Mar 13, 2024, 5:08 PM CDT

Download

MotorStand.STL (55 kB)

2024/01/27-Training Documentation

Jamie Flogel - Sep 13, 2023, 1:47 PM CDT

Title: Training Documentation

Date: 9/13/2023

Content by: Jamie Flogel

Present: N/A

Goals: To demonstrate completion of biosafety and chemical training

Content:

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

This certifies that Jamie Flogel has completed training for the following course(s):

Course	Assignment	Completion	Expiration
Biosafety Required Training	Biosafety Required Training Quiz 2022	1/23/2022	1/23/2027
Chemical Safety: The OSHA Lab Standard	Final Quiz	1/23/2022	

Data Last Imported: 09/13/2023 01:42 PM

Conclusions/action items:

I have completed all required biosafety and chemical safety training.

2024/01/27-Green Permit Documentation

Jamie Flogel - Sep 13, 2023, 1:48 PM CDT

Title: Green Permit Documentation

Date: 9/13/2023

Content by: Jamie Flogel

Present: N/A

Goals: Document completion of green permit.

Content:

Conclusions/action items:

I have completed my green and red permit training.

Jamie Flogel - Mar 30, 2022, 7:24 AM CDT

Download

Green_Permit.jpg (64.6 kB)

2024/02/28 HIPAA Privacy & Security Training

Jamie Flogel - Apr 29, 2024, 9:05 AM CDT

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

This certifies that Jamie Flogel has completed training for the following course(s):

Expand All **Collapse All**

Course	Assignment	Completion	Expiration
2023-24 HIPAA Privacy & Security Training	HIPAA Attestation	2/28/2024	
Animal Biosafety Level 2	ABSL2 Quiz 2024	1/31/2024	1/31/2025
Biosafety 102: Bloodborne Pathogens for Laboratory and Research	Biosafety 102: Bloodborne Pathogens Safety in Research Quiz 2024	1/31/2024	1/31/2025
Biosafety 105: Biosafety Cabinet Use	Biosafety 105: Biosafety Cabinet Use Quiz	1/31/2024	No Expiration
Biosafety 106: Autoclave Use	Biosafety 106: Autoclave Use: Safety and Efficacy - Verification Quiz	2/1/2024	No Expiration
Biosafety 107: Centrifuge Safety	Biosafety 107: Centrifuge Safety Verification Quiz	2/1/2024	No Expiration
Biosafety Required Training	Biosafety Required Training Quiz 2022	1/23/2022	1/23/2027
Chemical Safety: The OSHA Lab Standard	Final Quiz	1/23/2022	
Environmental & Occupational Health	Animal Contact Risk Questionnaire	2/23/2024	2/22/2025
Risk Communication in Animal Facilities	Risk Communication in Animal Facilities Quiz 2024	2/19/2024	2/19/2027
Safety for Personnel with Animal Contact	Animal Contact Personnel Quiz 2024	2/19/2024	2/19/2029

[VCRGE Look-up Tool: https://apps.research.wisc.edu/TILT](https://apps.research.wisc.edu/TILT)

2024/04/16-Motion Phantom in MR Analysis

Jamie Flogel - Apr 16, 2024, 5:30 PM CDT

Title: Analysis of in MR Room Testing Data

Date: 4/16/24

Content by: Jamie

Present: Max

Goals:

-Determine what the amplitude of our sinewave was based on the MRI scans taken

Content:

-On Friday we took our prototype to the WIMR to validate it in an MRI environment

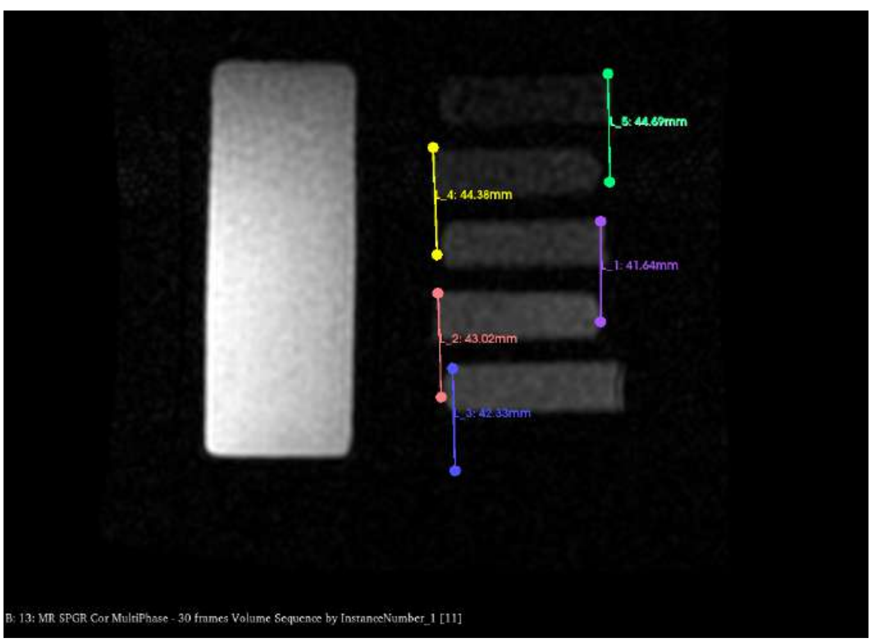
-It was concluded that our device was safe to bring into the MR room and we ran our code and the platform moved as normal

-Our client helped us take images using various scan protocols

-Our client sent us the images and we loaded them into a 3D viewing software Slicer

-Using the features of slicer we measured the experimental amplitude of our sinewave based off the images taken

-Points were difficult to track but gave us an experimental amplitude of around 43.2 mm



Conclusions/action items:

We should compare this to the Kinovea software tracking to get a better understanding of the current amplitude of our prototype. This will tell us if the motion output by the platform matches what is in the software.

2024/4/30 - MRI Artifacts

Kendra Besser - Apr 30, 2024, 3:23 PM CDT

Title: MRI Artifacts

Date: 4/30/24

Content by: Kendra

Present: Kendra

Goals: Record what artifacts populate with a motor introduced during MRIs

Content:

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6541879/

Method:

- The behavior of an ultrasonic motor (USM), the most common MRI-safe actuator, in a high-field scanner was investigated
- The motor was located in three orientations with respect to the bore axis with the power on or off
- The induced image artifacts were compared across four sequences
- Three artifact reduction methods (employing ultrashort sequences, slice thickness reductions, and bandwidth increments) were tested

Results:

- Signal voids, pileups, and geometric distortions were observed when the motor was off
- The artifact size was minimal when the motor shaft was aligned with the bore axis
- zipper and motion artifacts were noted when the motor was running, and these artifacts increased with increasing motor speed
- Increasing the bandwidth slightly reduced the artifacts
- decreasing the slice thickness from 5 mm to 3 mm and from 5 mm to 1 mm reduced artifact size from 30% to 40% and from 60% to 75%, respectively

conclusion:

- The image artifacts were due to the non-homogenous nature of the static and gradient fields
- caused by the motor structure
- The operating motor interferes with the RF field, causing zipper and motion artifacts

Conclusions/action items:

After reading this research paper, I concluded that respitory motion along with other physiological motion during MRIs causes severe artifacts. To prevent this, patients have to hold their breath but this can be very difficult for certain populations and causes short acquisition times.

2024/3/1 - MRI platform 1D motion article

Kendra Besser - Mar 01, 2024, 7:34 AM CST

Title: MRI platform 1D motion research article

Date: 3/1/24

Content by: Kendra

Present: Kendra

Goals: record the methods and background this research article used for a MRI motion platform

Content:

Source: https://onlinelibrary.wiley.com/doi/full/10.1002/mrm.25903

introduction:

- Motion of the intra-abdominal organs as well as the abdominal wall results in image artifacts such as blurring, aliasing, and ghosting
- artifacts lead to reduced conspicuity of pathology on MRI images, thus compromising its diagnostic performance
- different stratigies to avoid artifcats:
    - averaging of multiple acquisitions
    - respiratory triggering
    - sorting through the use of abdominal bellows
    - pencil beam navigator triggering
    - prospective and retrospective motion correction
    - alternative acquisition strategies such as periodically rotating “blades” in k-space
- may have an effect on quantitative MRI measures (eg, longitudinal relaxation time T1, transverse relaxation time T2, effective transverse relaxation rate T2*, apparent diffusion coefficient)
- Studies of respiratory patterns in healthy human subjects under well-controlled conditions indicate a coefficient of variation between 10% and 17% for important variables such as respiratory frequency and tidal volumes, which translates into motion artifacts on MR images
- A motion platform that can reproducibly replicate the motion of abdominal organs in the MRI environment, combined with a variety of phantoms, would provide the means for developing and testing different diagnostic and therapeutic MRI strategies for specific clinical scenarios and needs
- abdominal organ motion (up to 5 cm in the head–foot direction and 3 cm in the anterior–posterior direction)
- accommodate a variety of phantoms up to the size of a torso, to operate within the bore of an MRI under any imaging condition, and to deliver periodic, random, and also physiologic motion trajectories

Conclusions/action items:

This research article was a good example of article formatting; we will be using this as an example to write our own research article.

2024/2/1 - Transfer Function

Kendra Besser - Mar 01, 2024, 7:03 AM CST

Title: Transfer Function

Date: 2/1/2024

Content by: Kendra

Present: Kendra

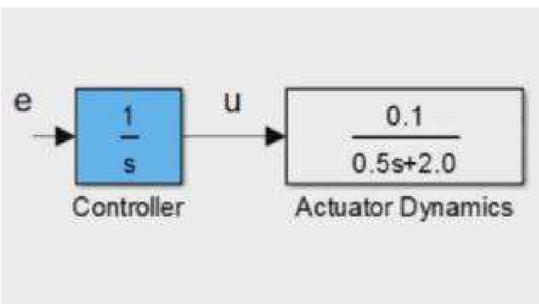
Goals: work on how to create a transfer function

Content:

source: https://www.mathworks.com/discovery/transfer-function.html

A transfer function is a convenient way to represent a linear, time-invariant system in terms of its input-output relationship. It is obtained by applying a Laplace transform to the differential equations describing system dynamics, assuming zero initial conditions. In the absence of these equations, a transfer function can also be estimated from measured input-output data.

Transfer functions are frequently used in block diagram representations of systems and are popular for performing time-domain and frequency-domain analyses and controller design. The key advantage of transfer functions is that they allow engineers to use simple algebraic equations instead of complex differential equations for analyzing and designing systems



transfer function v PID control

PID control:

PID control respectively stands for proportional, integral and derivative control, and is the most commonly used control technique in industry. The following video explains how PID control works and discusses the effect of the proportional, integral and derivative terms of the controller on the closed-loop system response. To learn how to design and implement PID controllers, check out the resources below the video. Matlab is a great place to easily implidemnt PID control

functions of PID:

- Selecting an appropriate PID algorithm (P, PI, or PID)
- Tuning controller gains
- Simulating the controller against a plant model
- Implementing the controller on a target processor

Conclusions/action items:

Instead of inserting a transfer function in our code, we will move forward with a PID control. this will hopefully help midigatae the error we are recieving form the motor input.

2024/2/29 - LP noninverting amp circuit

Kendra Besser - Mar 01, 2024, 7:22 AM CST

Title: LP noninverting amp circuit

Date: 2/29/24

Content by: Kendra

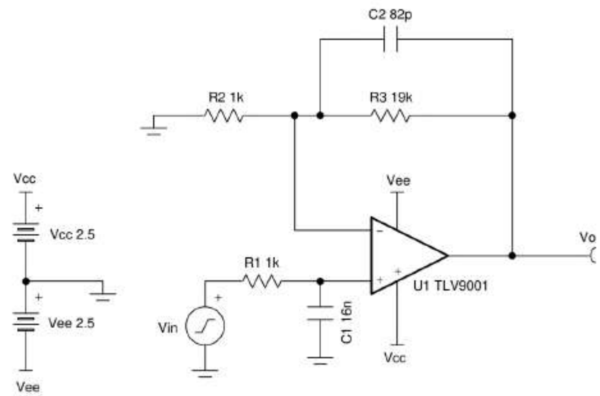
Present: Kendra

Goals: develop a circuit that can clean out our output to the motor

Content:

source: https://www.ti.com/lit/an/sboa294/sboa294.pdf

the goal would be to create a circuit that looks like the one below but adjust the resistor and capacitor values to fit with the output the motor requires.



this is the math used to find the appropriate values of R and C

Design Steps

The DC transfer function of this circuit follows:

$$V_o = V_{in} \times \left(1 + \frac{R_3}{R_2} \right)$$

1. Calculate the gain.

$$\text{Gain} = \frac{V_{oMax} - V_{oMin}}{V_{iMax} - V_{iMin}} = \frac{2V - (-2V)}{0.1V - (-0.1V)} = 20\frac{V}{V}$$

2. Calculate values for R_2 and R_3.

$$\text{Gain} = 1 + \frac{R_3}{R_2} = 20\frac{V}{V} \rightarrow \text{(26dB)}$$

Choose $R_2 = 1k\Omega$:

$$R_3 = (\text{Gain} - 1) \times R_2 = 19k\Omega$$

3. Calculate the component values R_1 and C_1 to set the cutoff frequency, f_c. Pick the value of R_1 and then calculate C_1 to set the location of f_c.

Choose $R_1 = 1k\Omega$:

$$C_1 = \frac{1}{2\pi \times R_1 \times f_c} = \frac{1}{2\pi \times 1k\Omega \times 10kHz} = 15.92nF \approx 16nF \text{ (Standard Value)}$$

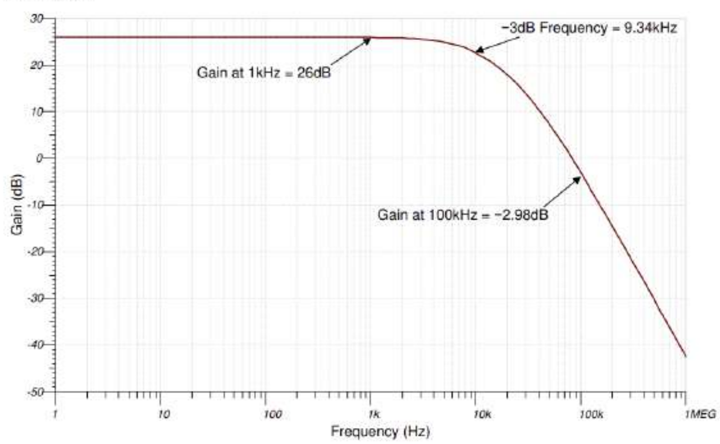
4. Calculate C_2 value to set the cutoff frequency (f_c) of the op amp. Select the corner frequency to be at least ten times larger than f_c.

$f_c = 10kHz$; $10 \times f_c = 100kHz$

$$C_2 = \frac{1}{2\pi \times R_3 \times 100kHz} = \frac{1}{2\pi \times 19k\Omega \times 100kHz} = 83.77pF \approx 82pF \text{ (Standard Value)}$$

Below is the gain bode plot that we will want to replicate with our circuit but at different values.

AC Simulation Results



We will be using op amp TL270 or TL271 because of their easy access and abundance

Conclusions/action items:

We will be using a low pass resistor capacitor circuit with a non-inverting op amplifier to digest and clean the output function to the motor. This was the motor uses its full range and has a clear signal on how to move.

2024/2/2 - Motor documentation

Kendra Besser - Feb 02, 2024, 1:23 PM CST

Title: Motor Documentation

Date: 2/2/24

Content by: Kendra

Present: Kendra

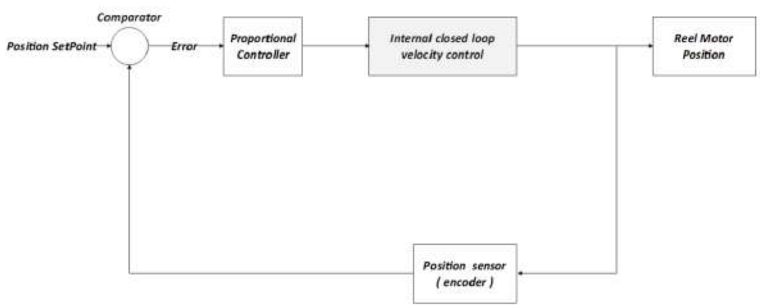
Goals: Update new information from the new motor specifications

Content:

Source: https://www.tekceleo.com/wp-content/uploads/2024/01/Catalog-WAVELLING-WLG-R-2023-2024.pdf

Attached is the new CATALOGUE MOTEURS WAVELLING.

- the motor can be ran via controlling the velocity (voltage supply) or positioning
- position: To achieve smooth position control and optimize precision (proportion control)
- position: allows to correct the controlled variable and proportionally correct the difference between desired value



- position:

below is the specs for the microcontroller

5.1.1.WLG-75-R SERIES Technical Specification

		WLG-75-R	WLG-75-R AMAG (Non-Magnetic)
Performances	No Load Speed	175 RPM	175 RPM
	Nominal Speed	150 RPM	150 RPM
	Max Torque	1.2 N.m	1.2 N.m
	Nominal Torque	0.75 N.m	0.75 N.m
	Holding Torque	1.5 N.m	1.5 N.m
Precision	Built-in encoder	Yes, optical with quadrature output	Yes, optical with quadrature output
	Max Encoder Resolution	0,0156° / 273 µr	0,0156° / 273 µr
	Possible Max encoder Resolution (custom)	0,0039° / 68 µr	0,0039° / 68 µr
Operations	Operating Voltage	24 VDC	24 VDC
	Maximal Power Consumption	24 VDC / 2.9 A	24 VDC / 2.9 A
	Weight	282 g	282 g
	Operating Temperature	0°C – 45°C	0°C – 45°C
	Connector	Molex ref. 87438-0843	Molex ref. 87438-0843

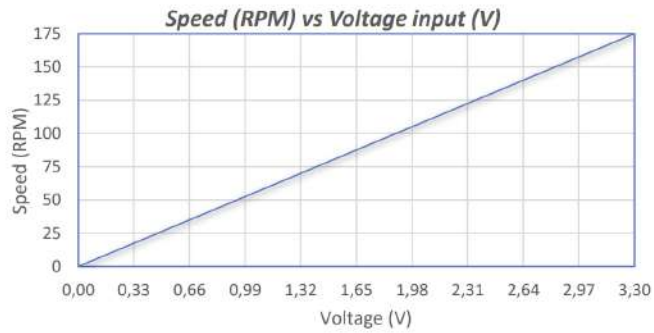
Source: https://www.tekceleo.com/wp-content/uploads/2024/01/1-TEKCELEO-User-Guide-WLG-75-R.pdf

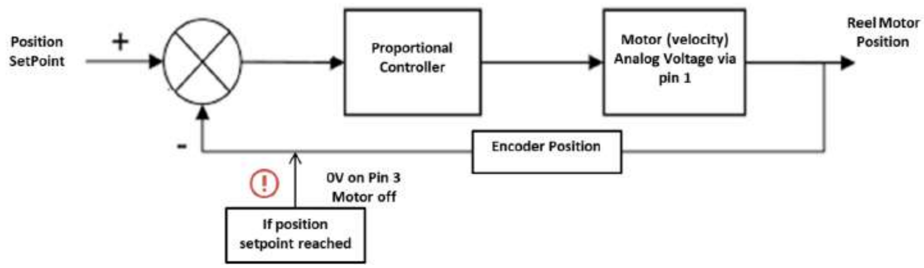
This is the new user guide for the WLG-75R.

- contains characteristic and operating specifications

- control specifications:

CHARACTERISTICS	VALUES
On / Off response time (Pin 3)	< 500 µs
Speed change response time	< 50 ms
Closed loop position controller (see figure below)	P control proportional
In case you need to control the position of the motor : In order to take advantage of the on / off response time of the motor, it is preferable to send a 0V on pin 3 once the motor has reached its position (see figure below)	
ENCODER DATA	**VALUES**
Two channel quadrature digital outputs for direction sensing : A and B	5760 increments per revolution each
One channel, Index digital output I (Z)	1 increment per revolution





TEKCELEO
We Accelerate Innovation

12

Conclusions/action items:

The new TEKCELEO documentation helps convey that the motor can be controlled via velocity or positions. We will likely be moving forward and changing the code to

2024/4/30 - Termite

Kendra Besser - May 01, 2024, 2:31 PM CDT

Title: Termite

Date: 4/30/24

Content by: Kendra

Present: Kendra

Goals: Record the information I learned about termite and how it can be applied here

Content:

source: https://readthedocs.org/projects/termite/downloads/pdf/latest/

- Termite uses the yaml format to define commands and tasks. The wikipedia has a good description of the format.
- The mains entry point is a yaml file, called termite.yaml, Which should be in your current working directory.
- In termite we have two basic elements, the commands, and the tasks. A command is a list of tasks, and should have a name, which is basically an identifier. Let's see a basic termite.yaml file:
-
```
- command:
    name: dev
    tasks:
        - shell:
            command: echo "Hello world!!"
```
- Global Tasks:
-
```
- shell: &some_id
    command: echo "Hello world!!"

- command:
    name: hello
    tasks:
        - shell: *some_id

- command:
    name: bye
    tasks:
        - shell: *some_id

        - shell:
            command: echo "Goodbye!!"
```
- commands:
-
```
- command:
    name: hello
    tasks:
        - shell:
            command: echo "Hello world!!"

- command:
    name: bye
    tasks:
        - shell:
            command: echo "Goodbye!!"
```

Conclusions/action items:

Based on the research of termite, this program will not be used for the prototype because of the time it would take to install, learn, and teach others how to use.

2024/2/29 - LP amp circuit

Kendra Besser - Mar 01, 2024, 7:16 AM CST

Title: LP noninverting amp circuit

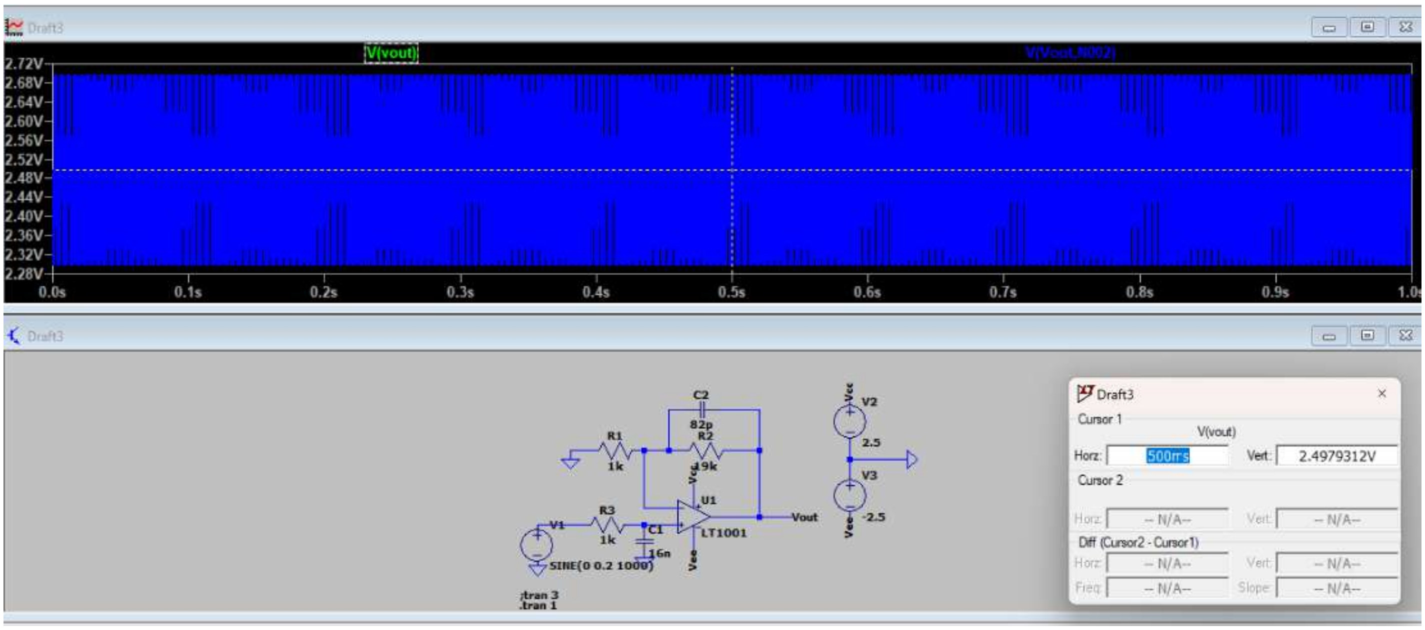
Date: 2/29/24

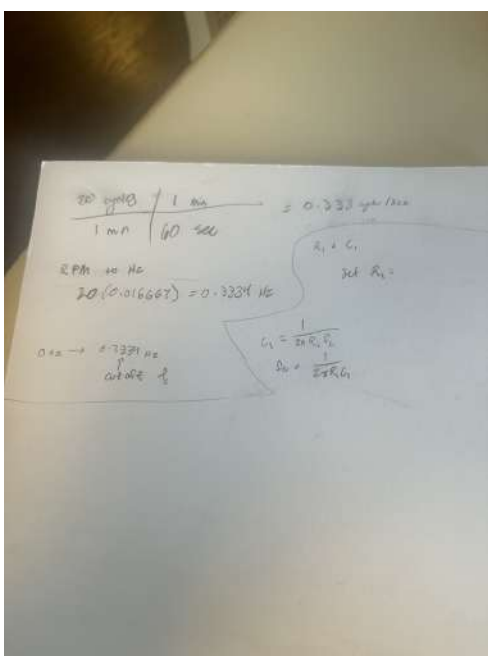
Content by: Kendra

Present: Kendra

Goals: develop a circuit that can clean out our output to the motor

Content:





Conclusions/action items:

This low pass resistor capacitor circuit with a non-inverting op amplifier will be used within our circuit. This way the motor uses its full range and has a clear signal on how to move. Final values on resistors and capacitors will come later as wee clarify our signaling.

2024/4/30 -Team Lab Training

Kendra Besser - Apr 30, 2024, 3:03 PM CDT

Title: Team Lab Training

Date: 4/30/24

Content by: Kendra

Present: Kendra

Goals: Record my certificates for the red and green permit in team lab and the makerspace.

Content:

see attachment for certificate

Conclusions/action items:

I have completed the red and green permit training and have received a certificate in each of them. I have the skills and ability to use the equipment in the team lab and makerspace in order to fabricate a prototype for the project.

Kendra Besser - Jan 31, 2023, 10:49 PM CST

You have the following permits and upgrades:

Name	Date
Green Permit	03/21/2022
Red Permit	03/11/2022

You have used the following:

Type	Machine	Hours
Lathe	Lathe 5	3.0
	Lathe 3	2.0
Lathe Total		**5.0**
Mill	Mill 6	2.5
	Mill 2	1.0
Mill Total		**3.5**
Grand Total		**8.5**

Download

Screenshot_20230131_104851.png (96.1 kB)

2024/4/30-Lab Safety Training

Kendra Besser - Apr 30, 2024, 3:03 PM CDT

Title: Lab Safety Training

Date: 4/30/2024

Content by: Kendra

Present: Kendra

Goals: Record my completion in the chemical safety and biosafety training courses.

Content:

see attachment for certificate

Conclusions/action items:

I have completed the chemical safety and biosafety training courses. I have the certification to use the bio and chem labs.

2024/4/30 - MRI Safety Training

Kendra Besser - Apr 30, 2024, 3:06 PM CDT

Title: MRI Safety Training

Date: 4/30/2024

Content by: Kendra

Present: Kendra

Goals: Record my completion in the MRI Safety Training.

Content:

Conclusions/action items:

I have completed the MRI Safety Training. I have the checklist 1 complete which allows me to go into the MRI Control room and the MRI room itself with a supervisor.

2024/02/01 Characterizing and Modeling Breathing Dynamics

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Amber Schneider - Feb 02, 2024, 11:22 AM CST

Title: Characterizing and Modeling Breathing Dynamics: Flow Rate, Rhythm, Period, and Frequency

Date: 2/1/2024

Content by: Amber Schneider

Present:

Goals: understand how breathing is currently modeled

Content:

N. J. Napoli, V. R. Rodrigues, and P. W. Davenport, “Characterizing and Modeling Breathing Dynamics: Flow Rate, Rhythm, Period, and Frequency,” Frontiers in Physiology, vol. 12, Feb. 2022, doi: https://doi.org/10.3389/fphys.2021.772295.

Purpose

- provides researchers and clinicians the ability to differentiate respiratory compensation, impairment, disease progression, ventilator assistance, and the onset of respiratory failure
- important to have at our disposal efficient metrics and techniques that can better discriminate the onset of respiratory failure, the progression of respiratory diseases, and ventilatory adaptation
- discuss one fundamental modeling of breathing and how modeling imprecise assumptions decades ago regarding breathing are still propagating into our quantitative analysis today, limiting our characterization and modeling of breathing

Assumption

- breathing is a continuous sinusoidal wave that can consist of a single frequency which is composed of a stationary time-invariant process has limited our expanded discussion of breathing dynamics, modeling, functional testings, and metrics
- address misnomers regarding breathing dynamics (rate, rhythm, frequency, and period)
- demonstrate how these misnomers impact the characterization and modeling through the force equations that are linked to the Work of Breathing (WoB) and our interpretation of breathing dynamics through the fundamental models and create possible erroneous evaluations of work of breathing

Current Airflow Methods for Modeling Breathing

- modeling using sinusoidal waveforms must be modified to account for real-time airflow patterns that have a more complex waveform
- transition from pure sinusoidal airflow to the non-sinusoidal waveforms pattern of breathing commonly found in normal breathing is necessary

Foundational Flow Model for Breathing Dynamics

- WoB (work of breathing) is a representation of the amount of energy required to overcome the elastic and resistive elements of the respiratory system that move gas into and out of the lung during breathing
- work performed consisted of elastic (~70%) and inelastic components (~30%)
- To calculate the WoB that was formally modeled and still used today requires the measurement of pleural pressure

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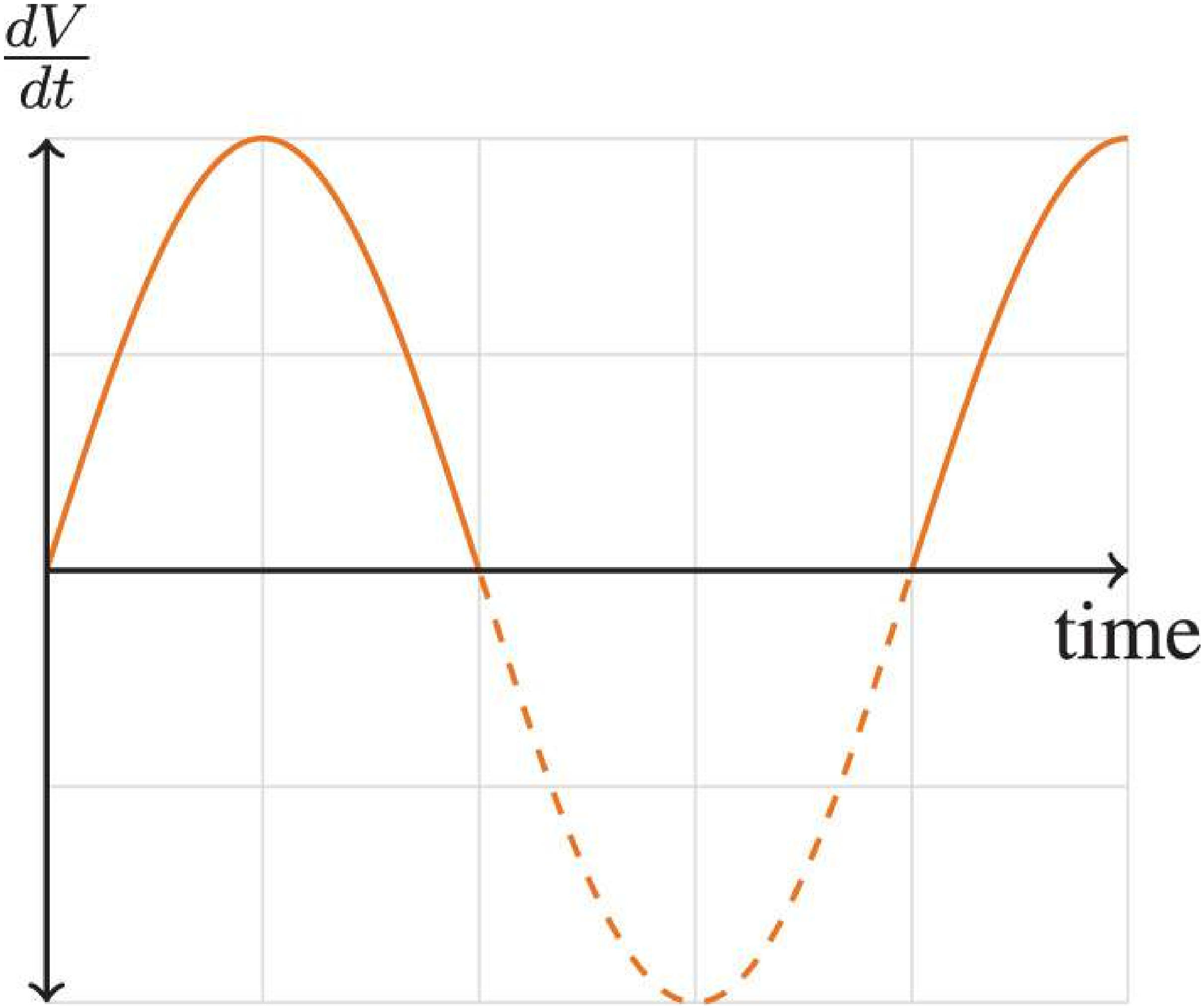

Figure 1. Flow Velocity Pattern: dV/dt = a*sin(bt)

Equation of work for a single inspired breath using the airflow velocity data:

$$W = \frac{1}{2}KV_T^2 + \frac{1}{4}K'\pi^2 fV_T^2 + \frac{2}{3}K''\pi^2 f^2 V_T^3.$$

- This model serves its purpose perfectly when estimating the forces of an “ideal” breath
    - a breath that has only one frequency, and only for a single breath

Frequency

- airflow velocity of a breath is described by frequency
- unlike an ideal spring that would continue oscillating, the exhalation stage of the breath does not continue the same harmonic (frequency)
- breath is paused or slowed down during the expiration stage of the breath, altering our rhythm of breathing
- unlike an ideal spring that has one frequency (a single harmonic), a single breath is linked to the sum output of all our respiratory muscles acting together to alter our chest cavity and to generate the forces for our breath
- **multiple frequency flow components within a single breath can be generated**

Conclusions/action items:

Modeling breathing dynamics is important in the field of medicine because it can help people understand the human body and pathology better. Humans do not breathe in a sinusoidal pattern; however, much research is being done examining and modeling breathing as sinusoidal. This paper showed errors could be between 41% and 314% when modeling breathing as sinusoidal.

2024/02/25 MRI-compatible platform for one-dimensional motion management studies in MRI

Amber Schneider - Feb 25, 2024, 4:26 PM CST

Title: MRI-compatible platform for one-dimensional motion management studies in MRI

Date: 2/25/2024

Content by: Amber Schneider

Present:

Goals: understand similarities and differences to our project, identify journal article structure for MR in Medicine

Content:

- Challenges in MRI because of respiratory motion
- Compensation strategies vary widely based on patient
- System: programmable motorized linear stage
- tested in MRI
- No interference between the motion platform and the MRI
- Motion-related artifacts commensurate with motion amplitude, frequency, and waveform were observed
- The motion platform can produce reliable linear motion within a whole-body MRI
- The system can serve as a foundation for a research platform to investigate and develop motion management approaches for MRI

Details are in the caption following the image

Figure 1. (A) Rendering of an MRI-compatible motion platform capable of producing linear motion within a clinical MRI scanner. (B) Photograph of the setup used for this study.

Conclusions/action items:

The motion platform was used in this study to produce linear motion within an MRI. This Journal setup consisted of Purpose, Methods, Results, and Conclusion. Methods and Results shared the same subheadings. Future work includes drafting a journal article to follow a similar style.

2024/02/01 Transfer Function of Control System

Amber Schneider - Feb 02, 2024, 11:30 AM CST

Title: Transfer Function of Control System

Date: 2/1/2024

Content by: Amber Schneider

Present:

Goals: understand the basics of transfer functions

Content:

Electrical4U, “Transfer function of Control System,” Electrical4U, https://www.electrical4u.com/transfer-function/#google_vignette (accessed Feb. 2, 2024).

Transfer Function: represents the relationship between the output signal of a control system and the input signal, for all possible input values

- For any control system, there exists a reference input known as excitation or cause which operates through a transfer operation (i.e. the transfer function) to produce an effect resulting in controlled output or response

Laplace Transform: $$G(s) = \frac{C(s)}{R(s)} \Rightarrow R(s).G(s) = C(s)$$

- R(s) = input
- C(s) = output

Procedure for determining the transfer function of a control system:

1. Form the equations for the system
2. Take Laplace transform of the system equations, assuming initial conditions as zero
3. Specify system output and input
4. Take the ratio of the Laplace transform of the output and the Laplace transform of the input which is the required transfer function

Methods of Obtaining a Transfer Function

- **Block Diagram Method**: It is not convenient to derive a complete transfer function for a complex control system. Therefore the transfer function of each element of a control system is represented by a block diagram. Block diagram reduction techniques are applied to obtain the desired transfer function.
- **Signal Flow Graphs**: The modified form of a block diagram is a signal flow graph. Block diagram gives a pictorial representation of a control system. Signal flow graph further shortens the representation of a control system.

Conclusions/action items:

Transfer functions are useful to characterize how a system works. It describes exactly how an input of a system will be converted to the output of a system. It may be complex to find the transfer function of our device; however, it may be more simple if we use the block diagram method.

2024/02/01 Basics of PID Controllers

Amber Schneider - Feb 02, 2024, 12:52 PM CST

Title: Transfer Function of Control System

Date: 2/1/2024

Content by: Amber Schneider

Present:

Goals: understand the basics of PID control

Content:

T. Yuldashev and A. Solovev, “Basics of PID Controllers: Working Principles, Pros & Cons,” www.integrasources.com, Apr. 26, 2023. https://www.integrasources.com/blog/basics-of-pid-controllers-design-applications/

What is a PID Controller?

- PID: proportional-integral-derivative
- **mechanism used in feedback control loops to automatically maintain a process parameter at a certain level**
- applications in almost any area where automatic control is required
- PID algorithm regulates a process variable by calculating a control signal that is the sum of three terms (proportional, integral, derivative)
    - Result --> return a process variable into the acceptable range

How does a PID Controller Work?

- need to identify what is happening inside a closed loop system first
- **PID controller** is placed in the core of a closed loop system
    - can be a device or an algorithm running on a ***microcontroller***
- The **plant/system** refers to the object under control
    - can be an industrial furnace, ***a motor***, or anything else
- The plant is controlled with an **actuation device**
    - can be a ***motor drive***, a heater, a cooler, or anything else that can drive the system
- The parameter that needs to be controlled is called the **process variable**.
    - can be temperature, flow rate, pressure, ***rotation speed***
- The process variable is measured with a sensor that sends the signal back to the controller, thus providing **feedback**
- The controller receives a **desired process value** or **set point**
    - It is the value that the system must achieve.
- This parameter is always set from outside – manually or automatically by a high-level control system
- OVERALL BASIC WORKING PRINCIPLE: The controller compares the measured process variable and the set point. Based on the difference between them, the algorithm computes a control signal and sends it to the actuation device. It, in turn, drives the plant to the desired process value (set point).

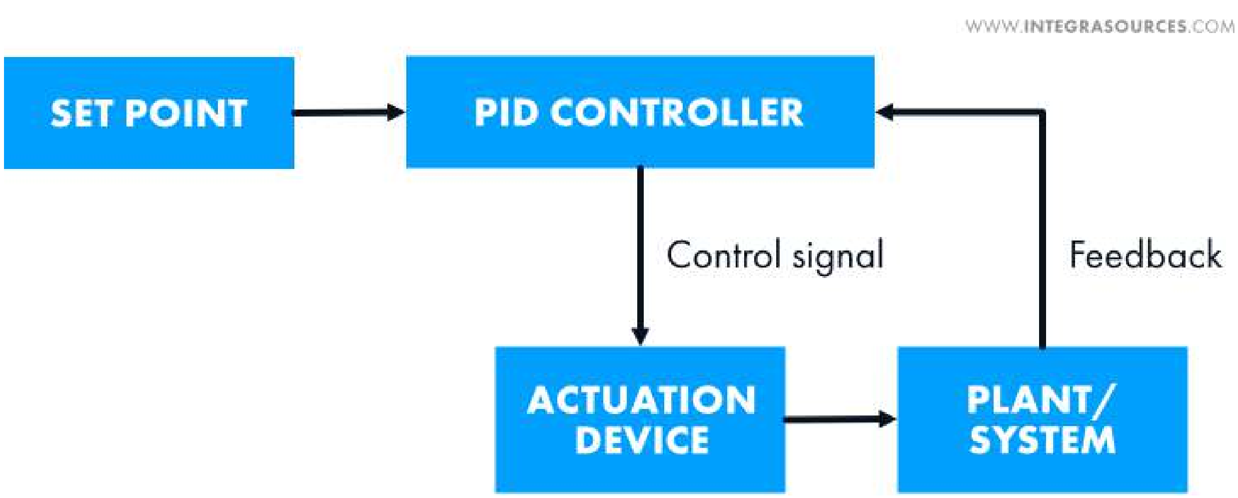

Figure 1. Control System Diagram

Proportional, Integral, and Derivative Terms

$$\text{Control signal} = P + I + D = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt}.$$

$$e(t) = SP(t) - PV(t),$$

where $SP(t)$ is the set point (desired process value),

and $PV(t)$ is the process variable

- If a gain is set to zero, the whole term becomes zero
- This way, the PID mechanism can be turned into a P controller, a PI controller, and other modifications

Proportional Term

- Difference between the set point (SP) and the measured process variable (PV) multiplied by the P gain (Kp)
    - This difference is referred to as the error value, or e(t)
- The error value represents how far the system is from the desired value
    - The higher it is, the higher the value of the manipulated variable and the faster the system will drive the process variable to the desired value

$$SP = SP(t)$$

$$PV = PV(t)$$

$$P = K_p e(t) = K_p\ (SP - PV).$$

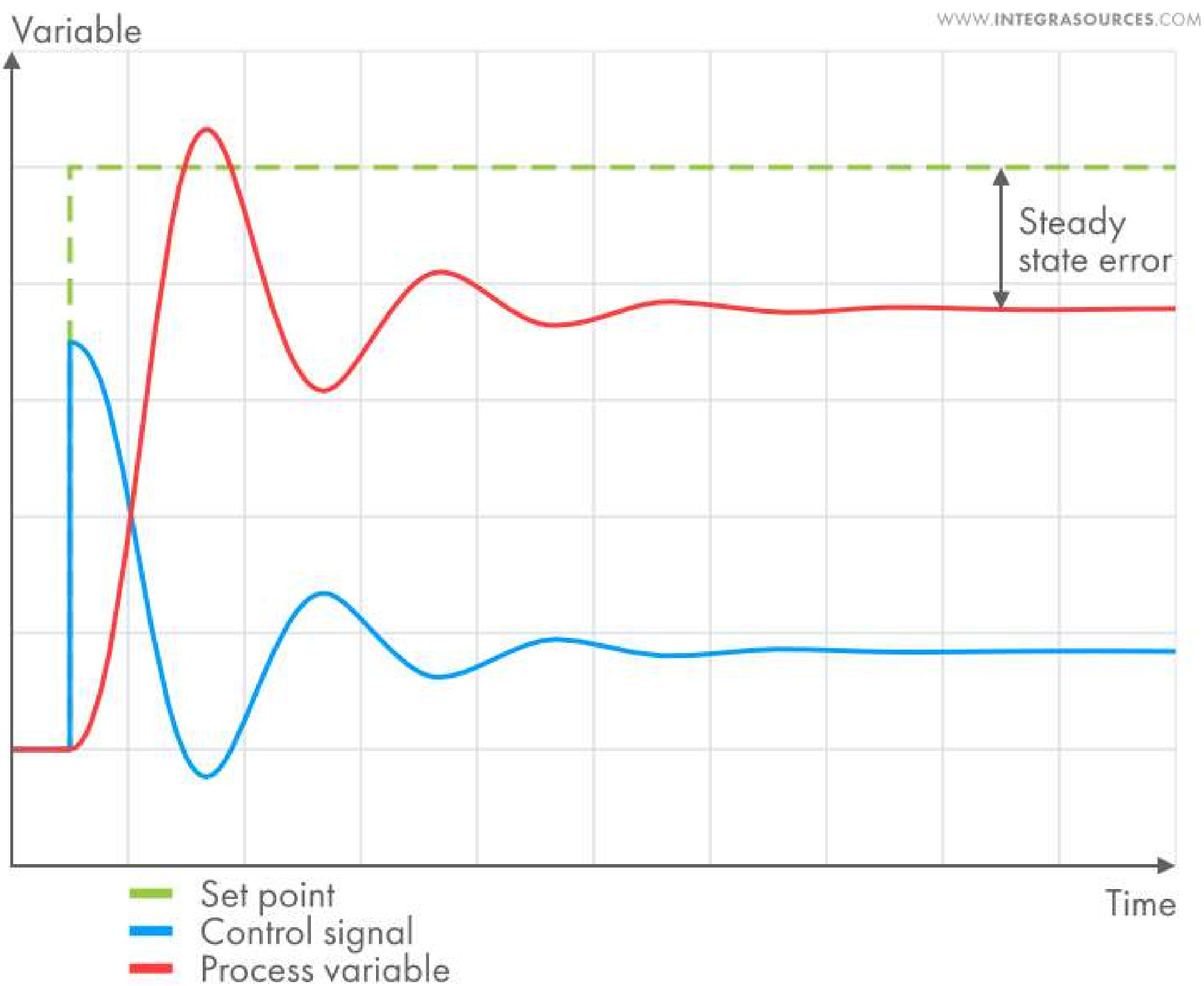

Figure 1. P Controller

- The proportional gain (Kp) defines the speed of the control system response.
    - **If it is too large**, the process variable starts to oscillate and can even oscillate out of control
- In certain systems, **using only the P term cannot reduce the error value to zero**.
- The remaining difference between the set point and process variable is called the **steady-state error**. In such cases, we need to add the integral term to the equation.

Integral Term

- The integral term is proportional to the time integral of the error value. It means the I component considers the history of the error. The integral gain (Ki) increases the weight of this component in the actuating output.

$$I = K_i \cdot \int_0^T (SP - PV)d\tau.$$

- If there is even a small error, the integral term will increase continuously (or decrease if the error is negative) until the steady state error equals zero.

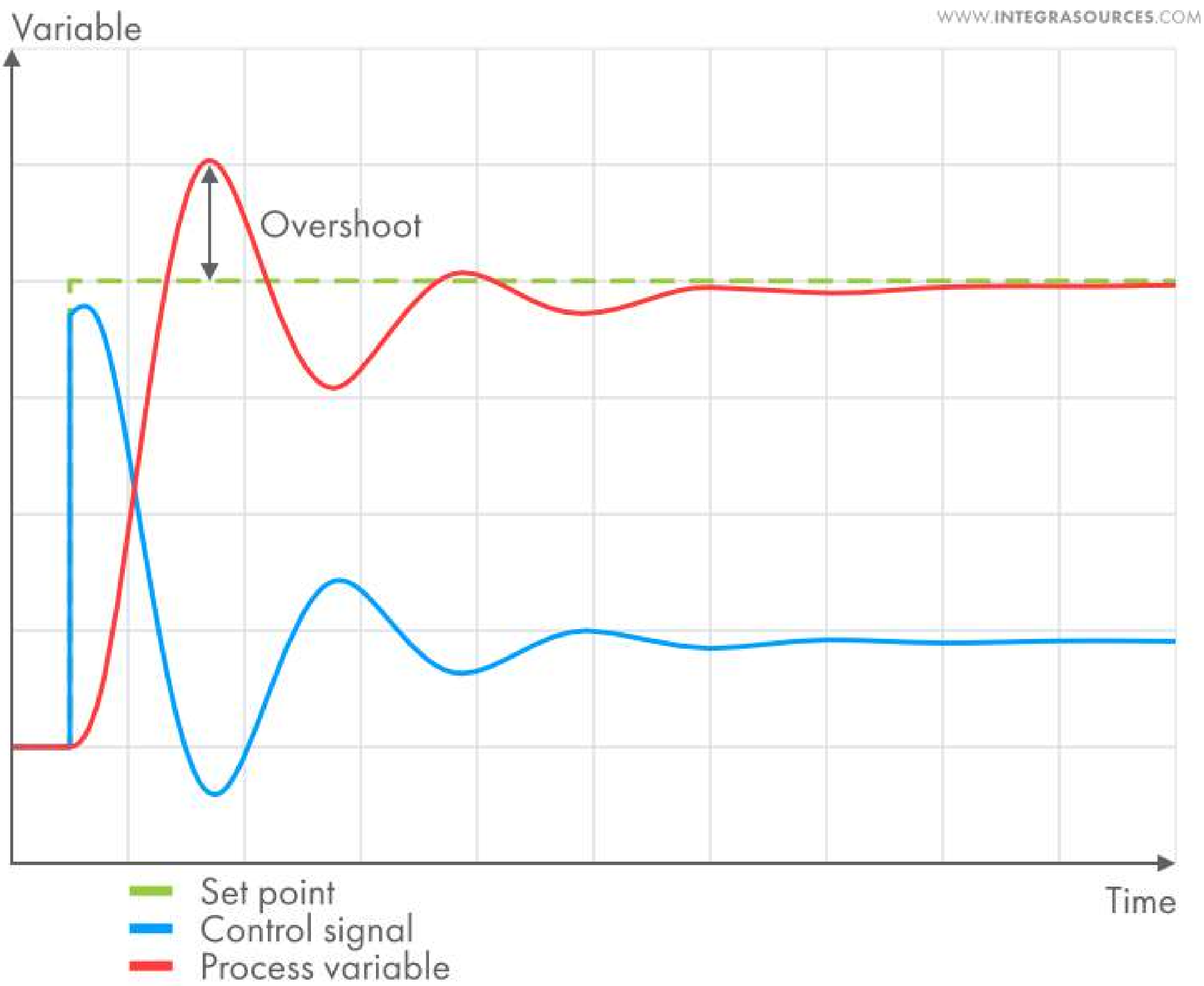

Figure 2. I controller. *A pure I controller is very slow and typically causes the process variable to overshoot the set point. That's why engineers use PI or PID controllers more often.*

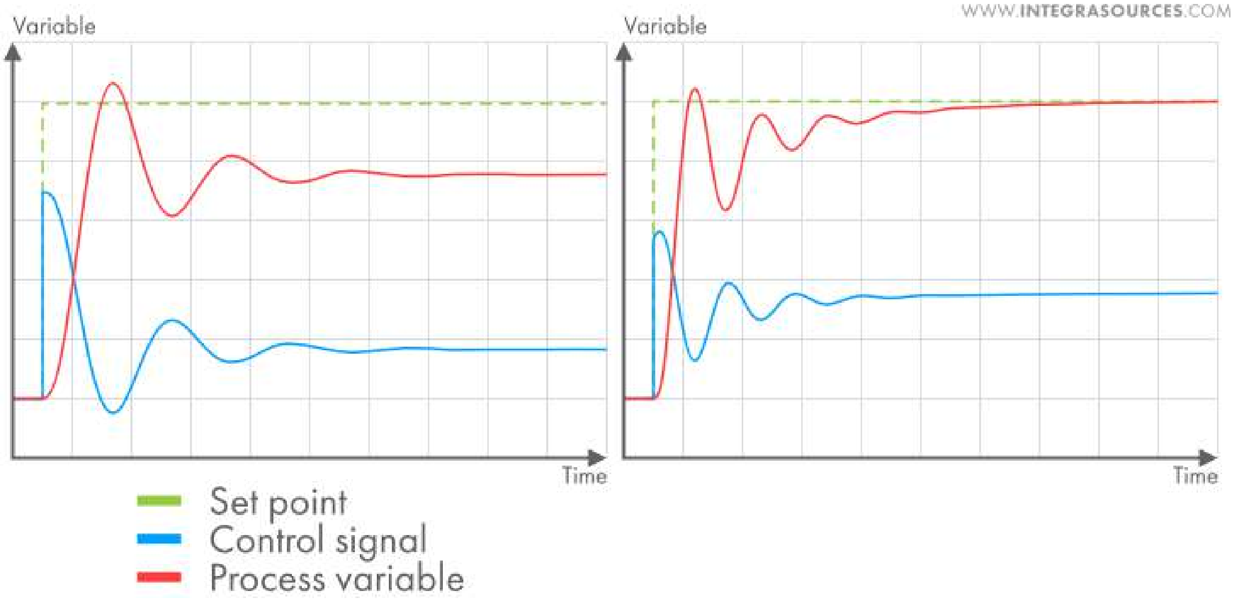

Figure 3. Work of a P controller (on the left) and a PI controller (on the right) with the same P gain. The process on the left causes a steady-state error, but adding the I term eliminates the error (graph on the right).

Derivative Term

- The derivative term uses the difference between the current and previous error values divided by the time between measurements (dt)

$$D = K_d \frac{d}{dt}(SP - PV) = K_d \frac{d(error)}{dt} = K_d \frac{\text{current error - previous error}}{\Delta t}$$

- It is proportional to the rate of change of the process variable.
    - P term fixes the current error
    - I term considers previous errors
- Derivative term takes into account future error values, compensates for the sharp fluctuations in the system, prevents it from strong overshoot, and decreases oscillations
- The derivative gain (Kd) changes the weight of this component in the control signal

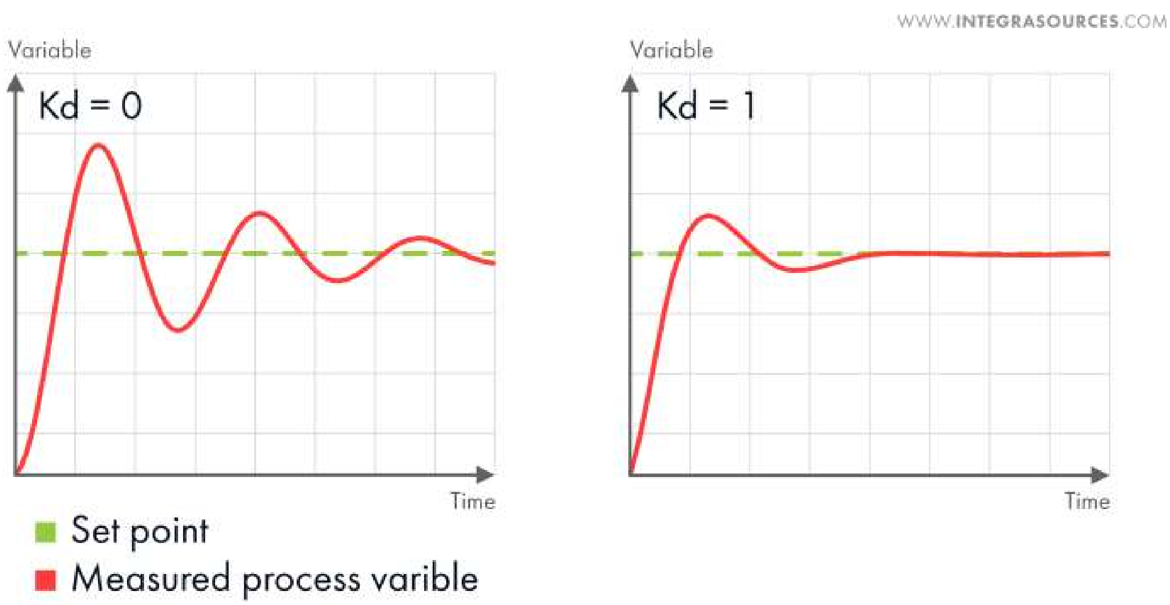

Figure 4. Adding the derivative term and setting the Kd to 1 decreases the oscillations in the process. Often, the D term is left out when dealing with slow systems.

Application -- Controlling a Motor

- Using a PID controller for DC motor control is another frequent application. Our team applied this algorithm when developing a DC motor controller for a company that makes robots and robot kits.
- The PID algorithm was implemented on the microcontroller of the device.
- Its task was to regulate the rotation speed of DC motors.
- The process variable is measured with a quadrature encoder.
- The solution allows for a smooth start/stop, stabilizes the speed of a robot, and even provides distance control.
- Since the DC motor controller was supposed to be used with different robot models, we also created a desktop application for setting the parameters of the device. The app also allows for tuning the PID gains.

Conclusions/action items:

A PID controller is a closed feedback loop system that can control a system based on the measurement of the process variable. Applications include controlling a motor with an encoder from a microcontroller. Future work includes figuring out an alforithm to implement into our system.

2024/02/06 PID Mbed Library

Amber Schneider - Feb 06, 2024, 6:23 PM CST

Title: PID Mbed Library

Date: 2/6/2024

Content by: Amber Schneider

Present:

Goals: outline the PID library for future reference and implementation

Content:

https://os.mbed.com/users/aberk/code/PID/docs/tip/classPID.html

API Documentation

- Proportional-integral-derivative controller
- #include <PID.h>

Public Member Functions

	PID (float Kc, float tauI, float tauD, float interval) Constructor.
void	**setInputLimits** (float inMin, float inMax) Scale from inputs to 0-100%.
void	**setOutputLimits** (float outMin, float outMax) Scale from outputs to 0-100%.
void	**setTunings** (float Kc, float tauI, float tauD) Calculate **PID** constants.
void	**reset** (void) Reinitializes controller internals.
void	**setMode** (int mode) Set **PID** to manual or auto mode.
void	**setInterval** (float interval) Set how fast the **PID** loop is run.
void	**setSetPoint** (float sp) Set the set point.
void	**setProcessValue** (float pv) Set the process value.
void	**setBias** (float bias) Set the bias.
float	**compute** (void) **PID** calculation.

Figure 1. Public Member Fucntions

```
PID ( float Kc,
      float taul,
      float tauD,
      float interval
    )
```

Constructor.

Includes.

Sets default limits [0-3.3V], calculates tuning parameters, and sets manual mode with no bias.

Parameters:

Kc	- Tuning parameter
taul	- Tuning parameter
tauD	- Tuning parameter
interval	PID calculation performed every interval seconds.

Figure 2. Constructor Documentation

float compute (void)

PID calculation.

Returns: The controller output as a float between outMin and outMax.

Definition at line 223 of file PID.cpp.

void reset (void)

Reinitializes controller internals.

Automatically called on a manual to auto transition.

Definition at line 162 of file PID.cpp.

void setBias (float bias)

Set the bias.

Parameters: bias The bias for the controller output.

Definition at line 216 of file PID.cpp.

void setInputLimits (float inMin,
float inMax
)

Scale from inputs to 0-100%.

Parameters:

InMin	The real world value corresponding to 0%.
InMax	The real world value corresponding to 100%.

Definition at line 80 of file PID.cpp.

void setInterval (float interval)

Set how fast the PID loop is run.

Parameters:

interval	PID calculation peformed every interval seconds.

Definition at line 192 of file PID.cpp.

void setMode (int mode)

Set PID to manual or auto mode.

Parameters:

mode	0 -> Manual Non-zero -> Auto

Definition at line 180 of file PID.cpp.

void setOutputLimits (float outMin,
float outMax
)

Scale from outputs to 0-100%.

Parameters:

outMin	The real world value corresponding to 0%.
outMax	The real world value corresponding to 100%.

Definition at line 104 of file PID.cpp.

void setProcessValue (float pv)

Set the process value.

Parameters: pv The process value as a real world value.

Definition at line 210 of file PID.cpp.

void setSetPoint (float sp)

Set the set point.

Parameters: sp The set point as a real world value.

Definition at line 204 of file PID.cpp.

void setTunings (float Kc,
float taul,
float tauD
)

Calculate PID constants.

Allows parameters to be changed on the fly without ruining calculations.

Parameters:

Kc - Tuning parameter
taul - Tuning parameter
tauD - Tuning parameter

Figure 3. Member Function Documentation

Conclusions/action items:

Got a better understanding of what the mbed PID library has to offer. Next steps include determining how to incorporate a PID algorithm into the sinusoidal motion function.

Amber Schneider - Feb 06, 2024, 6:23 PM CST

```
/**
 * @author Aaron Berk
 *
 * @section LICENSE
 *
 * Copyright (c) 2010 ARM Limited
 *
 * Permission is hereby granted, free of charge, to any person obtaining a copy
 * of this software and associated documentation files (the "Software"), to deal
 * in the Software without restriction, including without limitation the rights
 * to use, copy, modify, merge, publish, distribute, sublicense, and/or sell
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 * LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
 * OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN
 * THE SOFTWARE.
 *
 * @section DESCRIPTION
 *
 * A PID controller is a widely used feedback controller commonly found in
 * industry.
 *
 * This library is a port of Brett Beauregard's Arduino PID library:
 *
 *  http://www.arduino.cc/playground/Code/PIDLibrary
 *
 * The wikipedia article on PID controllers is a good place to start on
 * understanding how they work:
 *
 *  http://en.wikipedia.org/wiki/PID_controller
 *
 * For a clear and elegant explanation of how to implement and tune a
 * controller, the controlguru website by Douglas J. Cooper (who also happened
 * to be Brett's controls professor) is an excellent reference:
 *
 *  http://www.controlguru.com/
 */

#ifndef PID_H
#define PID_H

/**
 * Includes
 */
#include "mbed.h"

/**
 * Defines
 */
#define MANUAL_MODE 0
#define AUTO_MODE   1

/**
 * Proportional-integral-derivative controller.
 */
```

Download

PID.h (5.53 kB)

Amber Schneider - Feb 06, 2024, 6:23 PM CST

```
/**
 * @author Aaron Berk
 *
 * @section LICENSE
 *
 * Copyright (c) 2010 ARM Limited
 *
 * Permission is hereby granted, free of charge, to any person obtaining a copy
 * of this software and associated documentation files (the "Software"), to deal
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 * THE SOFTWARE.
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 *
 * For a clear and elegant explanation of how to implement and tune a
 * controller, the controlguru website by Douglas J. Cooper (who also happened
 * to be Brett's controls professor) is an excellent reference:
 *
 *  http://www.controlguru.com/
 */

/**
 * Includes
 */
#include "PID.h"

PID::PID(float Kc, float tauI, float tauD, float interval) {

    usingFeedForward = false;
    inAuto           = false;

    //Default the limits to the full range of I/O: 3.3V
    //Make sure to set these to more appropriate limits for
    //your application.
    setInputLimits(0.0, 3.3);
    setOutputLimits(0.0, 3.3);

    tSample_ = interval;
```

Download

PID.cpp (7.59 kB)

2024/02/22 Whitesides' Group: Writing a Paper

Amber Schneider - Feb 22, 2024, 3:06 PM CST

Title: Whitesides' Group: Writing a Paper

Date: 2/22/2024

Content by: Amber Schneider

Present:

Goals: understand what is expected for a general research paper

Content:

[1]G. M. Whitesides, “Whitesides’ Group: Writing a Paper,” Advanced Materials, vol. 16, no. 15, pp. 1375–1377, Aug. 2004, doi: https://doi.org/10.1002/adma.200400767.

Definition of a Scientific Paper

- organized description of hypotheses, data, and conclusions
- intended to instruct the reder
- objective in research:formulate and test hypotheses, draw conclusions from tests, tech conclusions to others
  - NOT to "collect data"
- Structure for planning research in progress, and storing a completed research program

Reason for Outlines

- most efficient to write papers from outlines
- **Outline**: written plan of the organization of a paper
  - ***includes data***
- carefully organized and presented set of data
- attendant objectives, hypotheses, and conclusions
- much of the TIME goes into the text
- most of the THOUGHT goes into organization of the data and its analysis

Construction of an Outline

- Important ideas
- Questions to ask:
  - Why did I do this work?
  - What does it mean?
  - What hypotheses did I mean to test?
  - What ones did I actually test?
  - What were the results?
  - What measurements did I make?
- Equations, figures, schemes
- Pick the best combination of hypotheses, objectives, and data

3 Major Categories

1. Introduction

- Why did I do the work?
- What were the central motivations and hypotheses?

2. Results and Discussion

- What were the results?
- How were compounds made and characterized?
- What was measured?

3. Conclusions

- What does it all mean?
- What hypotheses were proved or disproved?
- What did I learn?
- Why does it make a difference?

Finer Organization

- organize the data
- construct figures, tables, and schemes to present the data **clearly and compactly**
- put outline of sections, tables, sketches, equations, and more in good **order**

Components of an Outline

1. Title
2. Authors
3. Abstract
    1. *This can be done when the paper is complete*
4. Introduction
    1. Opening sentence: state concisely the objective of the work, indicate why this objective is important
    2. Elements:
        1. objectives of the work
        2. justification for these objectives (why is the work important)
        3. background (who else has done what? how what have we done previously?)
        4. guidance to the reader (what should the reader watch for in the paper? what are the interesting high points? what strategy did we use?)
        5. summary/ conclusion (what should the reader expect as conclusion?)
5. Results and Discussion
    1. organized according to major topics
    2. separate parts should have subheadings in boldface to make organization clear and to help the reader scan through the final text for parts of interest
    3. make section headings as specific and information rich as possible
6. Conclusions
    1. Summarize the conclusions of the paper as alist of short phrases or sentences
    2. Do not repeat what is in the Results section unless special emphasis is needed
    3. The Conclusions section should not be a summary
    4. It should add a new, higher level of analysis, and should indicate explicitly the significance of the work
7. Experimental
    1. Include, in the correct order to correspond to the order in the Results section, all of the paragraph subheadings of the Experimental section

Summary

- Organize the outline and the paper around easily assimilated data tables, equations, figures, schemes rather than around text
- Organize in order of importance, not in chronological order
  - Start with the most important results, and put the secondary results later, if at all.

Conclusions/action items:

A scientific paper is a organized document containing hypotheses, data, and conclusions. Outlining is crucial for efficient paper writing, focusing on data organization and analysis. Action items include begining the outline for our projects preliminary research paper.

2024/02/22 MRI In Medicine Author Guidelines

Amber Schneider - Feb 22, 2024, 3:22 PM CST

Title: MRI In Medicine Author Guidelines

Date: 2/22/2024

Content by: Amber Schneider

Present:

Goals: understand the requirements by MRI In Medicine Journal

Content:

https://onlinelibrary.wiley.com/page/journal/15222594/homepage/author-guidelines

Similar (Example) Article: https://onlinelibrary.wiley.com/doi/full/10.1002/mrm.25903

Overview

- Magnetic Resonance in Medicine (Magn Reson Med) is an international journal devoted to the publication of original investigations concerned with all aspects of the development and use of nuclear magnetic resonance and electron paramagnetic resonance techniques for medical applications.
- Reports of original investigations in the areas of mathematics, computing, engineering, physics, biophysics, chemistry, biochemistry, and physiology directly relevant to magnetic resonance will be accepted, as well as methodology-oriented clinical studies.

Copyright Assignment, and Criteria for Authorship and Submission

- **Main criteria** for acceptance of papers: significance, originality, clarity, and quality of the work reported
- Manuscripts are accepted for review with the understanding that the same work has not been published, it is not under consideration for publication elsewhere, and its submission for publication has been approved by all persons listed as authors
- submission for publication is approved by the appropriate authority at the institution where the work was carried out

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- The journal strongly encourages authors to facilitate the reproducibility of their research by sharing publicly the source code or scripts that are used to generate results presented in their articles via a Data Availability Statement at the end of their paper.
- This statement must appear in the main manuscript in order for it to appear in the final paper.

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- **Research Article** (formerly Full Paper) is the default manuscript type. Manuscripts submitted in conjunction with the ISMRM's Young Investigator Award competition may be submitted as Research Articles or Rapid Communications.
- **Technical Notes** are complete accounts of technical work of a limited scope, but may also describe methodologically-orientated clinical studies of a limited scope or other such limited studies.
- **Rapid Communications** are preliminary accounts of topical work that has high importance. If there should exist a backlog of accepted articles that have been electronically published in Early View but have not yet appeared in a print issue, Rapid Communications will be preferentially placed in the next available issue prior to other manuscript types. Consequently, the Referees' scores for accepted Rapid Communications generally tend to be higher than for Technical Notes, particularly in the areas of originality and importance. Manuscripts submitted in conjunction with the ISMRM's Young Investigator Award competition may be submitted as Research Articles or Rapid Communications.

- **Reviews** are scholarly reports on a field of particular interest to the journal's readership. Reviews are submitted based on editorial invitation, although contributed Reviews are also considered. Authors intending to submit a Review article should contact the Editor-in-Chief with their proposal prior to preparing the article. All Reviews are peer reviewed.

Organization

- Title Page
- Abstract
- Manuscript Body
- Subheadings
- Tables
- Acknowledgements
- Footnotes

Conclusions/action items: The website outlines requirements for submission. Additionally, a style guide is provided for consistency across the journal. Action items include discussing the format of similar journals and determining which one we would like to draft our preliminary report based off of their requirements.

Amber Schneider - Feb 22, 2024, 3:11 PM CST

Revised November 2022

Updated Style Guide

Magnetic Resonance in Medicine

[illegible]

Article Organization and Presentation

Title Page

[illegible]

[illegible]

[illegible]

[illegible]

Abstract

[illegible]

Purpose:
Methods:
Results:
Conclusion:

[Download](#)

MRM_Style_Guide_Nov-2022.pdf (290 kB)

2024/02/05 Sinusoidal Function Update

Amber Schneider - Feb 06, 2024, 6:01 PM CST

Title: Sinusoidal Function Update

Date: 2/5/2024

Content by: Amber Schneider

Present:

Goals: improve sinusoidal function

Content:

Past

- Sinusoidal wave function used time variables to track progress through a for loop
- unknown hexa velocity "conversion factor" = 0.0063

Updates

- new conversion factor = 1.0/175.0
  - Linear slope
  - Max AnalogValue (1.0) / Max Speed (175 RPM)

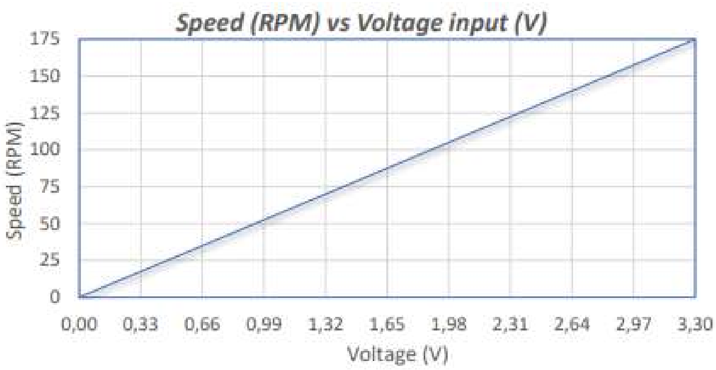


Figure 1. Control Specifications from [TEKCELEO - User Guide (p.12)](#)

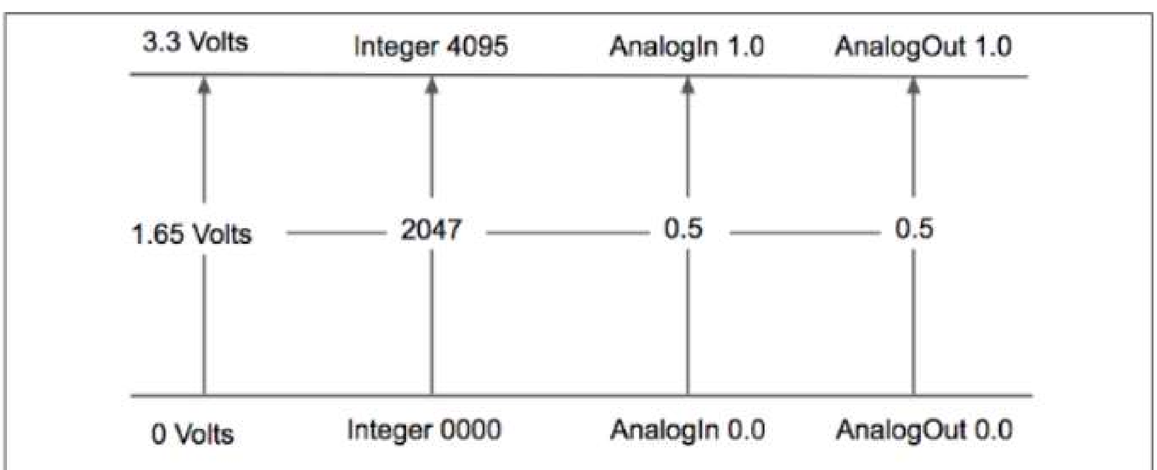


Figure 1.5 Maximum and minimum analog input and output voltage values, ADC values and values for AnalogIn and AnalogOut mbed functions.

Figure 2. Maximum and Minimum analong input and output voltage values, ADC values, and values for AnalogIn and AnalogOut mbed functions.

- improved clock management to use wait_us
    - Added variables: sampling_rate, dt, t

```
// Generation of 1 Hz sine wave at 360 samples/per second using wait statement

#include "mbed.h"

#define pi (3.14159)
#define PERIOD (2778)  //360 samples/sec
AnalogOut sinewave(A3);  //create an analog output on pin A3

int i;

int main() {
    while(1) {

        for (i = 0; i < 360; i++) {
           sinewave = sin( i * (pi/180.0) );
           wait_us(PERIOD);

            }  // End of for ()
     }         // End of while()
}
```

Figure 3. Example Mbed Code from BME463 Lec 2 Slides

```
include "mbed.h"
include <math.h>

alogOut sine_wave(A3); // Define AnalogOut object for pin A3

t main() {
  const float frequency = 1.0f; // Frequency of the sine wave in Hz
  const int sample_rate = 360; // Sample rate in samples per second
  const float amplitude = 0.5f; // Amplitude of the sine wave

  const float dt = 1.0f / sample_rate; // Time interval between samples

  while(1) {
      for(int i = 0; i < sample_rate; i++) {
          float t = i * dt; // Time for current sample
          float sine_val = amplitude * sin(2 * M_PI * frequency * t); //

          sine_wave.write(sine_val); // Write sine value to pin A3

          wait(dt); // Wait for next sample
      }
  }
```

Figure 4. Output from ChatGPT. Used to validate and improve robustness of code from Figure 2.

Current Code:

```
float amplitude = 10; //What does this do?
float offset = 0;
float frequency = 8.0/60; // Adjust the frequency as needed
float sampling_rate = 2.2*frequency; // Speed Change response time = 50ms
float dt = 1.0/sampling_rate;

while(1) {
    for(int i=0; i<sampling_rate; i++){
        // Calculate the output velocity using a sinusoidal function
        float t = i*dt;
        float sinewave = amplitude * sin(2 * pi * frequency * t) + offset;

        // Convert velocity to voltage
        hexaVelocity = conversion_factor * rpmVelocity;

        if(hexaVelocity<0) {
            motorDirection.write(1); //CCW
            hexaVelocity = hexaVelocity*-1.0;
        } else {
            motorDirection.write(0); //CW
        }
        velocityControl.write(hexaVelocity);
        motorState.write(1);
        wait_us(dt*pow(10.0,6.0));
        } // end of for loop
} // end of while loop
printf("End of Function \n\n");
motorState.write(0);
```

Testing

- Measure electrical output on pin using an oscilliscope
- Use code below to validate Speed to Voltage Conversion:

```
// Last Updated: 2/5
void testVolRPM(){
    rpmVelocity = 60; // hardcoded
    hexaVelocity = conversion_factor*rpmVelocity;
    velocityControl.write(hexaVelocity);
    direction = 0; //clockwise
    motorDirection.write(direction);
    motorState.write(state);
}
```

Conclusions/action items:

Updated conversion factor between analog out variable and desired speed (RPM). Implemented new sampling/ time management in sinusoidal function code. Action items include testing the code to validate the changes.

2024/02/06 PID Control Algorithm - V1

Amber Schneider - Feb 06, 2024, 6:41 PM CST

Title: PID Control Algorithm - V1

Date: 2/6/2024

Content by: Amber Schneider

Present:

Goals: write a draft of a PID Control Algorithm

Content:

Libraries

#include "mbed.h"

#include "QEI.h"

Definitions

// Define motor velocity and direction pins

AnalogOut velocityControl(A2);

DigitalOut motorDirection(A0);

DigitalOut motorState(A1); // on or off

// Define encoder pins

QEI motorEncoder (D2, D3, D4, 5760,QEI::X4_ENCODING); // from sample code

// Define PID constants

const float Kp = 0.5;

const float Ki = 0.2;

const float Kd = 0.1;

// Define target velocity

const float targetVelocity = 0; // Update in for loop

// Define PID variables

```
float error_integral = 0;

float prev_error = 0;
```

PID Function

```
float calculatePID(float target, float current) {
    float error = target - current;
    error_integral += error;
    float derivative = error - prev_error;
    prev_error = error;
    float output = Kp * error + Ki * error_integral + Kd * derivative;
    return output;
}
```

Sinusoidal Function -- to add

```
    while(1) {
        // Read current velocity from encoder
        float currentVelocity = encoder.getPulses() * 5760; // Assuming 5760 pulses per revolution

        // Calculate PID output
        float pidOutput = calculatePID(targetVelocity, currentVelocity);

        // Apply PID output to motor control
        if(pidOutput >= 0) {
            motorDirection = 1; // Forward direction
            motorPWM = pidOutput;
        } else {
            motorDirection = 0; // Reverse direction
            motorPWM = -pidOutput;
        }
```

```
        // Wait for a small time interval

        wait(0.05);

    }
```

Conclusions/action items:

Successfuly wrote a draft PID control algorithm. Future work includes presenting it to the team, making edits, and debugging.

2024/02/24 Expected Sinusoidal Motion

Amber Schneider - Apr 25, 2024, 5:28 PM CDT

Title: Expected Sinusoidal Motion

Date: 2/24/24

Content by: Amber Schneider

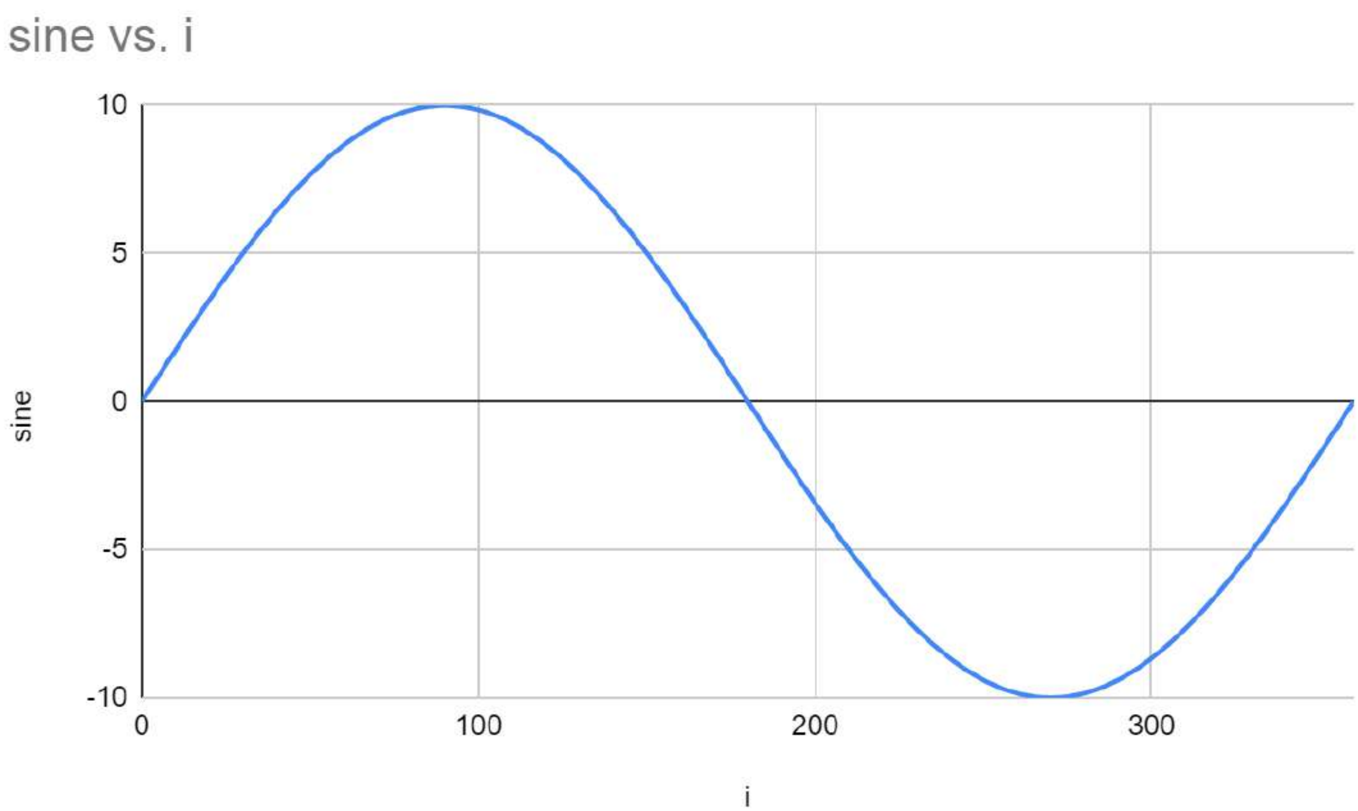
Present:

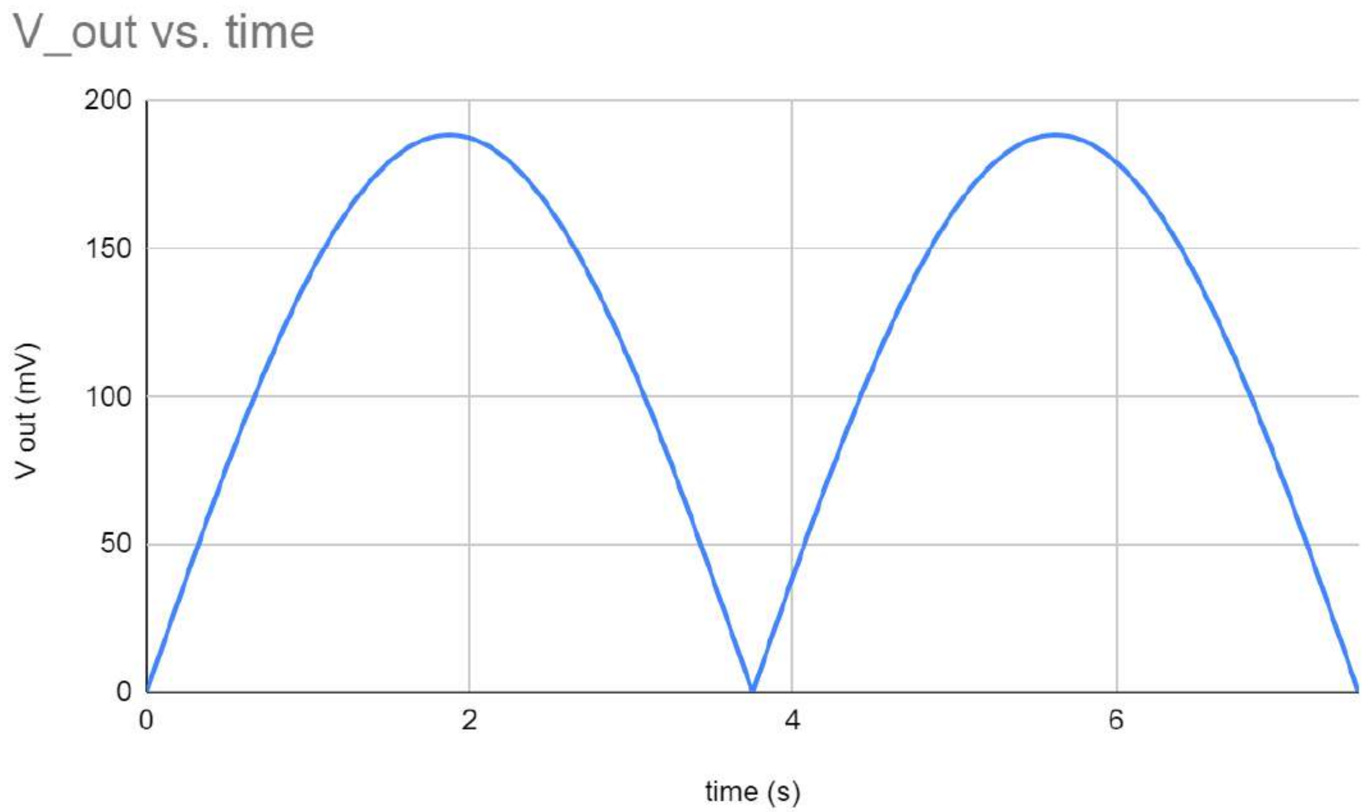
Goals: understand what the theoretical motion should be for the sine wave and compare to oscilliscope output

Content:

Theoretical:

- sinewave = amplitude * sin(2 * pi * frequency / sampling_rate * i) + offset;
- RESOLUTION = 3.3/2^12*10^3 = 0.8056640625 mV



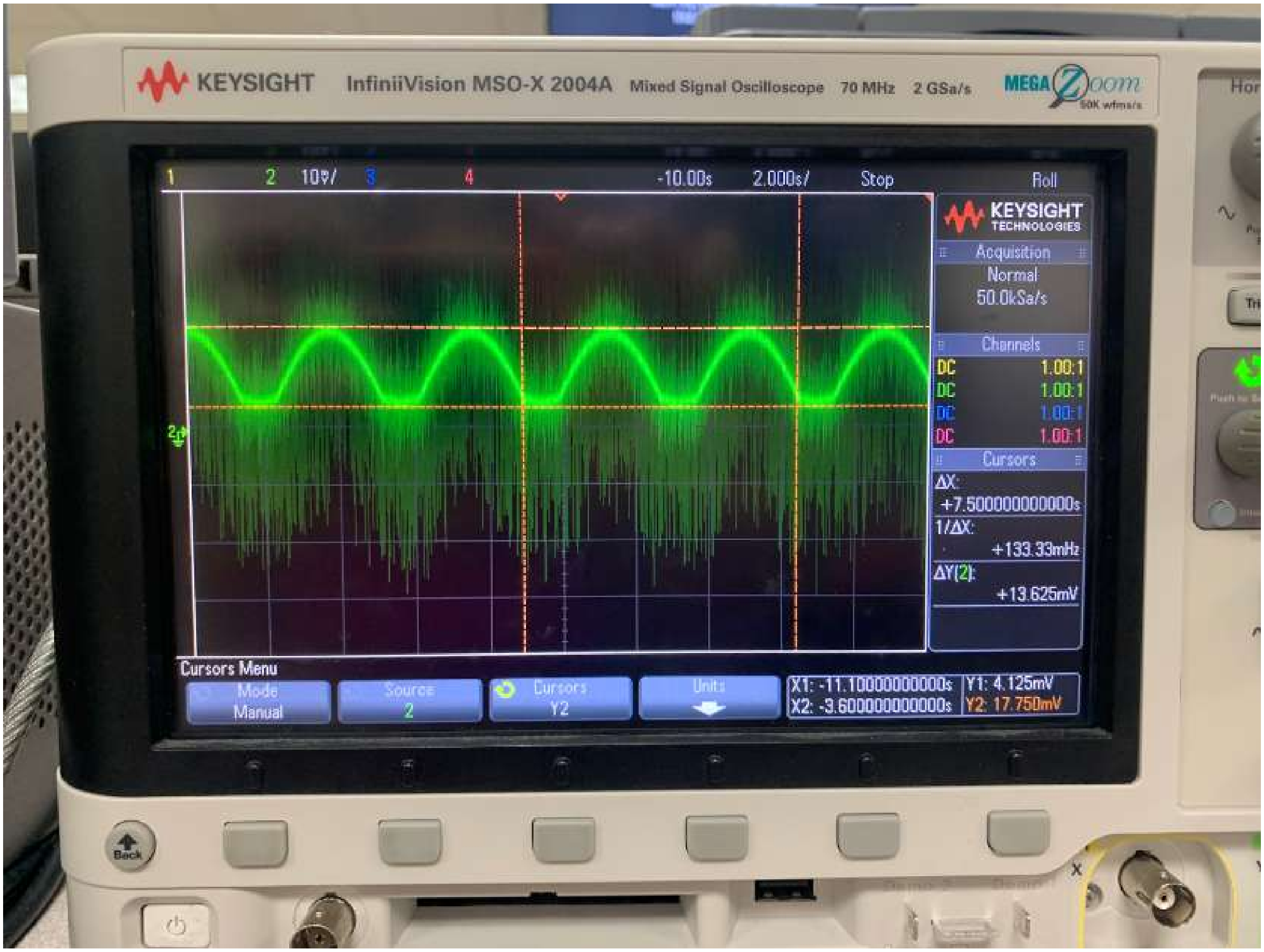


* Note: code never goes negative, instead switches direction

<u>Experimental:</u>

Updated Code w/ Interrupts

- sinewave = amplitude * sin(2 * pi * 1/360 * i) + offset;
- SAMPLING RATE = 20833 micro seconds (f=8/60)



Conclusions/action items:

Signal appears to have the correct period of 7.5 seconds. However, there is a lot of noise around the signal. After discussing with the team and advisor, we may want to introduce a low pass filter to reduce this noise (likely 60Hz).

2024/02/28 Low-Pass Inverting Amplifier Circuit

Amber Schneider - Feb 28, 2024, 4:38 PM CST

Title: Low-Pass Inverting Amplifier Circuit

Date: 2/28/2024

Content by: Amber Schneider

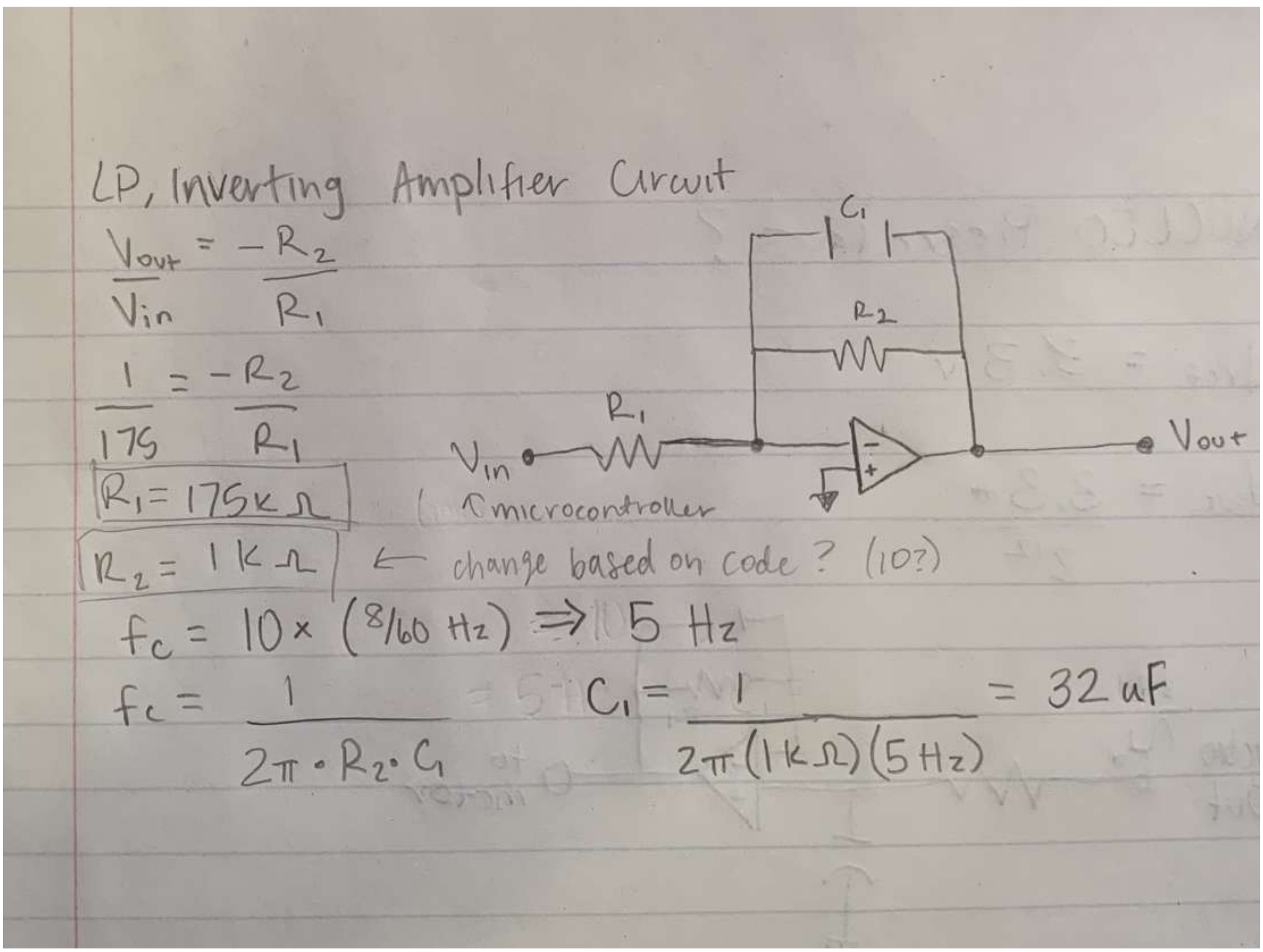
Present:

Goals: design a LP inverting amplifier circuit in LT Spice

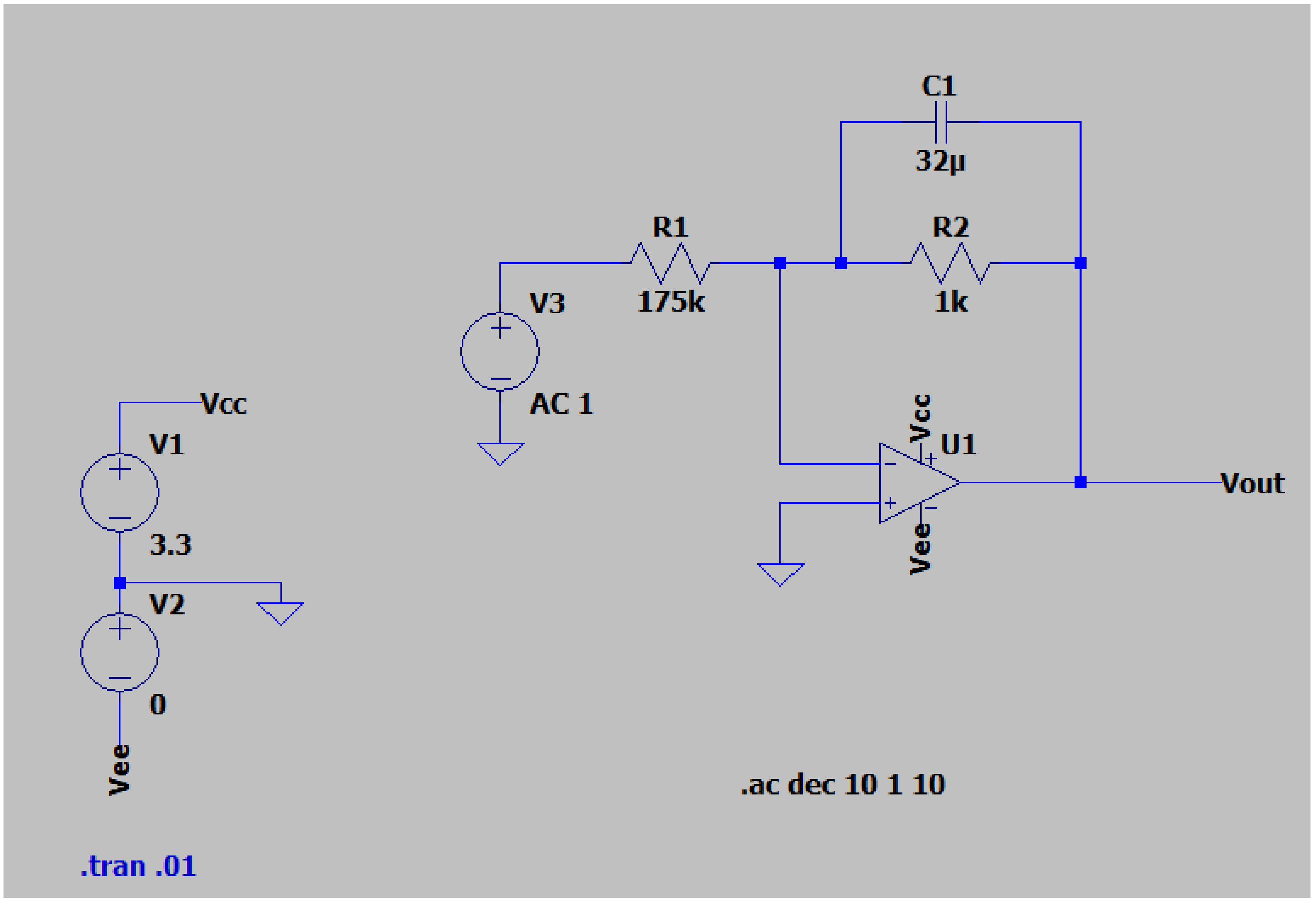
Content:

Circuit Design & Calculations

- Gain: 1/175
  - R1 = 175 kΩ
  - R2 = 1 kΩ
- Cutoff Frequency: 5 Hz
  - C1 = 32 μF

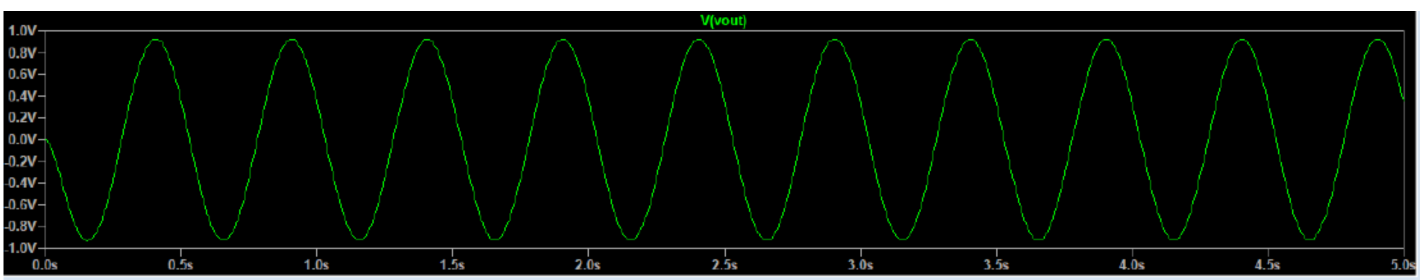


Relevant Calculations

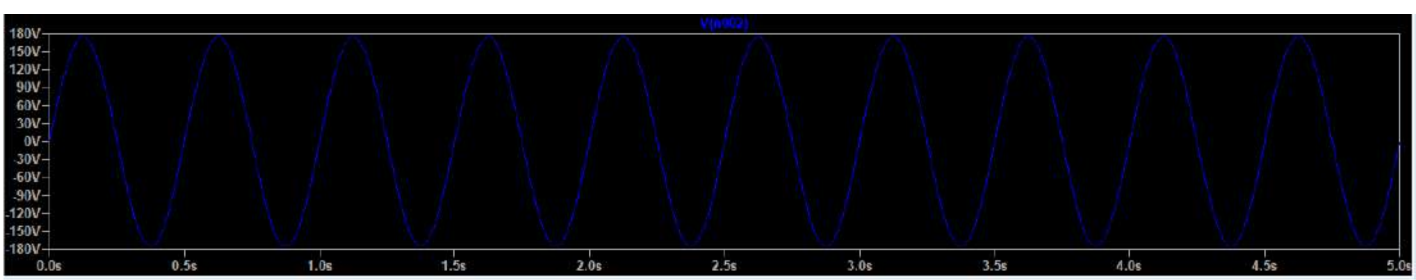


Circuit Designed in LT Spice

<u>Amplification Graphs</u>

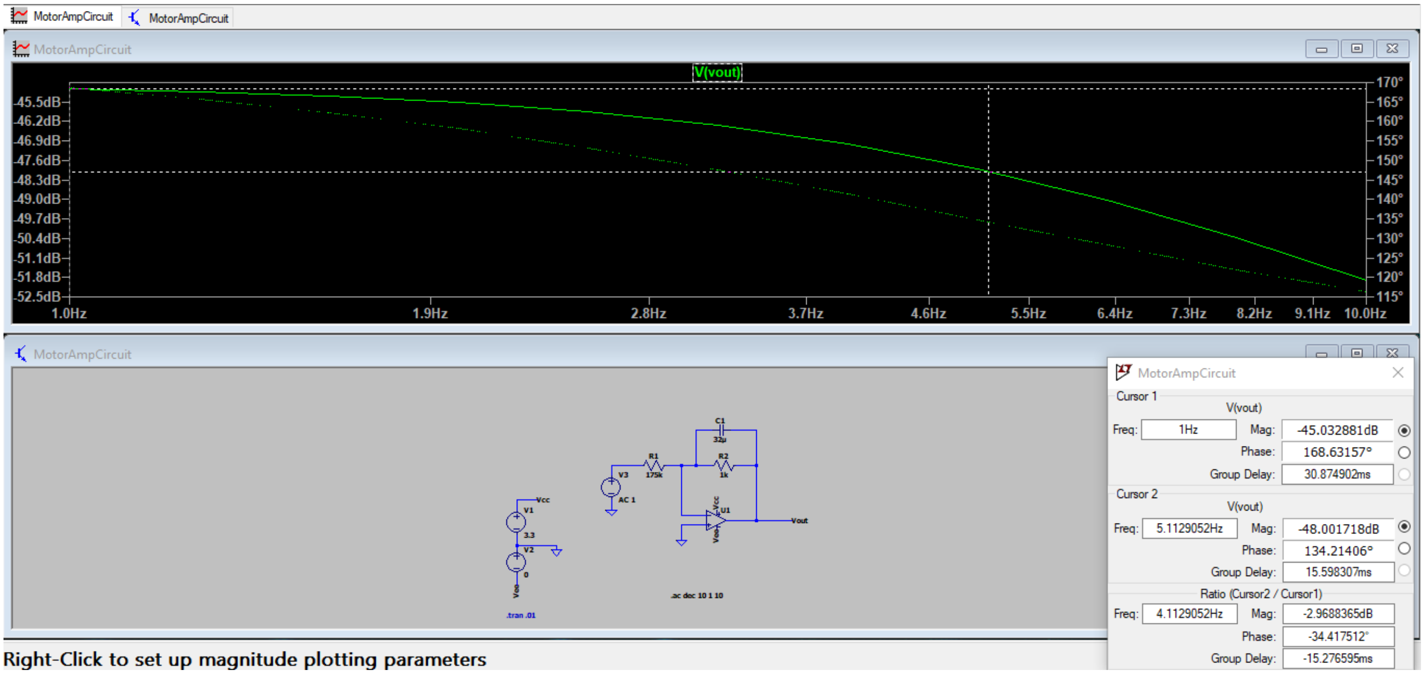


V out = negative sine wave with amplitude of 1 V



V in = posiitve sine wave with amplitude of 175 V

<u>Bode Plot</u>

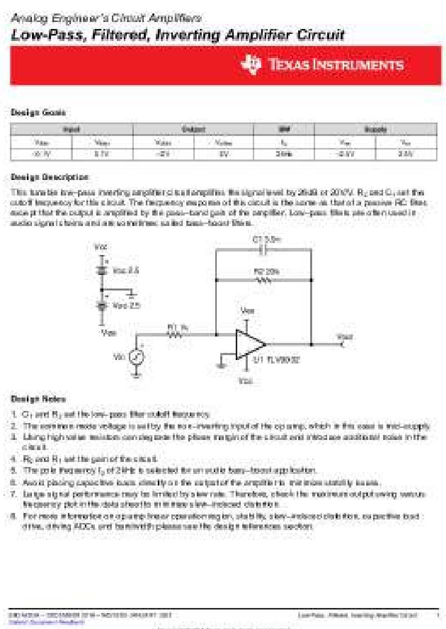


The "Ratio Curser" shows a difference in magnitude of approx. -3dB at 5Hz, indicating that is the cutoff frequency.

Conclusions/action items:

A low pass inverting amplifier circuit was created in LT spice based off an example from Texas Intruments. Action items include verifying the desired gain and cutoff frequency with the team and the client.

Amber Schneider - Feb 28, 2024, 4:24 PM CST


Analog Engineer's Circuit Amplifiers
Low-Pass, Filtered, Inverting Amplifier Circuit
Texas Instruments

Design Goals

Design Description

Design Notes

Download

Texas_Instruments_Low-Pass_Inverting_Amplifier_Circuit_Example.pdf (744 kB)

Amber Schneider - Feb 28, 2024, 4:35 PM CST

Download

MotorAmpCircuit.asc (1.47 kB)

2024/03/11 Voltage Divider & LP Filter

Amber Schneider - Mar 11, 2024, 8:52 AM CDT

Title: Voltage Divider & LP Filter

Date: 3/11

Content by: Amber Schneider

Present:

Goals: outline new passive filter design idea

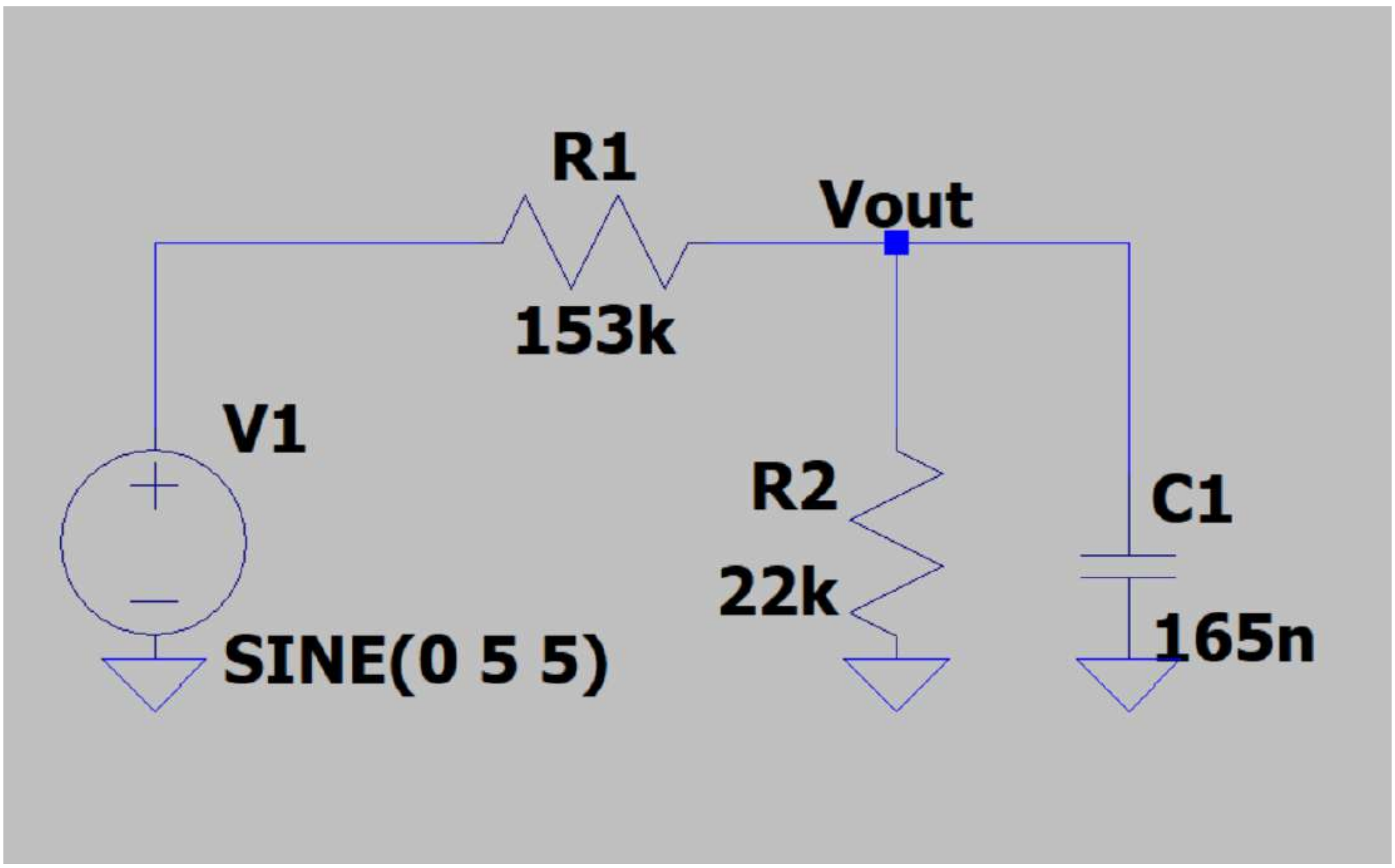
Content:

Similar Concept: https://electronics.stackexchange.com/questions/281391/divider-and-lowpass-combined

Theory

- Voltage divider -- reduce microcontroller output
- Lowpass filter -- remove high frequency noise
- $fc = \frac{(R_1+R_2)\sqrt{(10^{3/10}-1)}}{2\pi * R_1 * R_2 * C_1} \approx \frac{(R_1+R_2)}{2\pi * R_1 * R_2 * C_1}$

Model in LT Spice



Gain = 22/175, fc = 50Hz

Conclusions/action items:

The circuit seems to theoretically work. Next steps include verifying with our advisor that it will work for our application. Then, we can move ahead with building and testing the circuit.

Amber Schneider - Mar 11, 2024, 8:53 AM CDT

Download

voltage_divider_and_LP.asc (642 B)

2024/04/11 Low-Pass Inverting Amplifier (x2) Circuit

Amber Schneider - Apr 11, 2024, 4:41 PM CDT

Title: Low-Pass Inverting Amplifier Circuit (x2) Circuit

Date: 4/11/2024

Content by: Amber Schneider

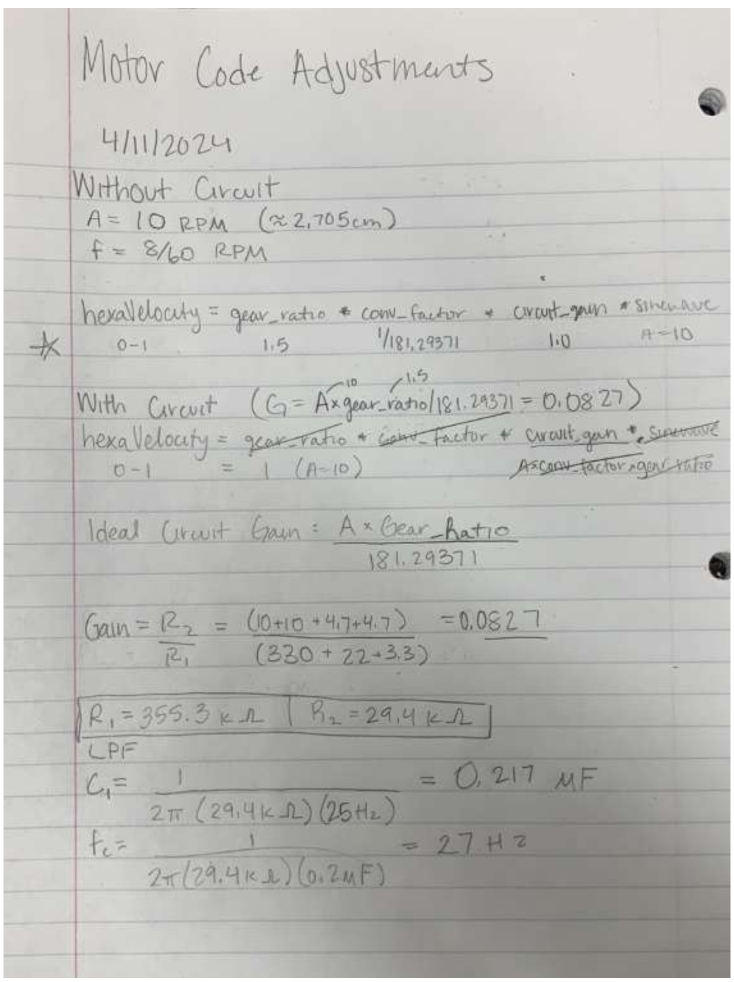
Present:

Goals: design a LP inverting amplifier cascaded circuit in LT Spice

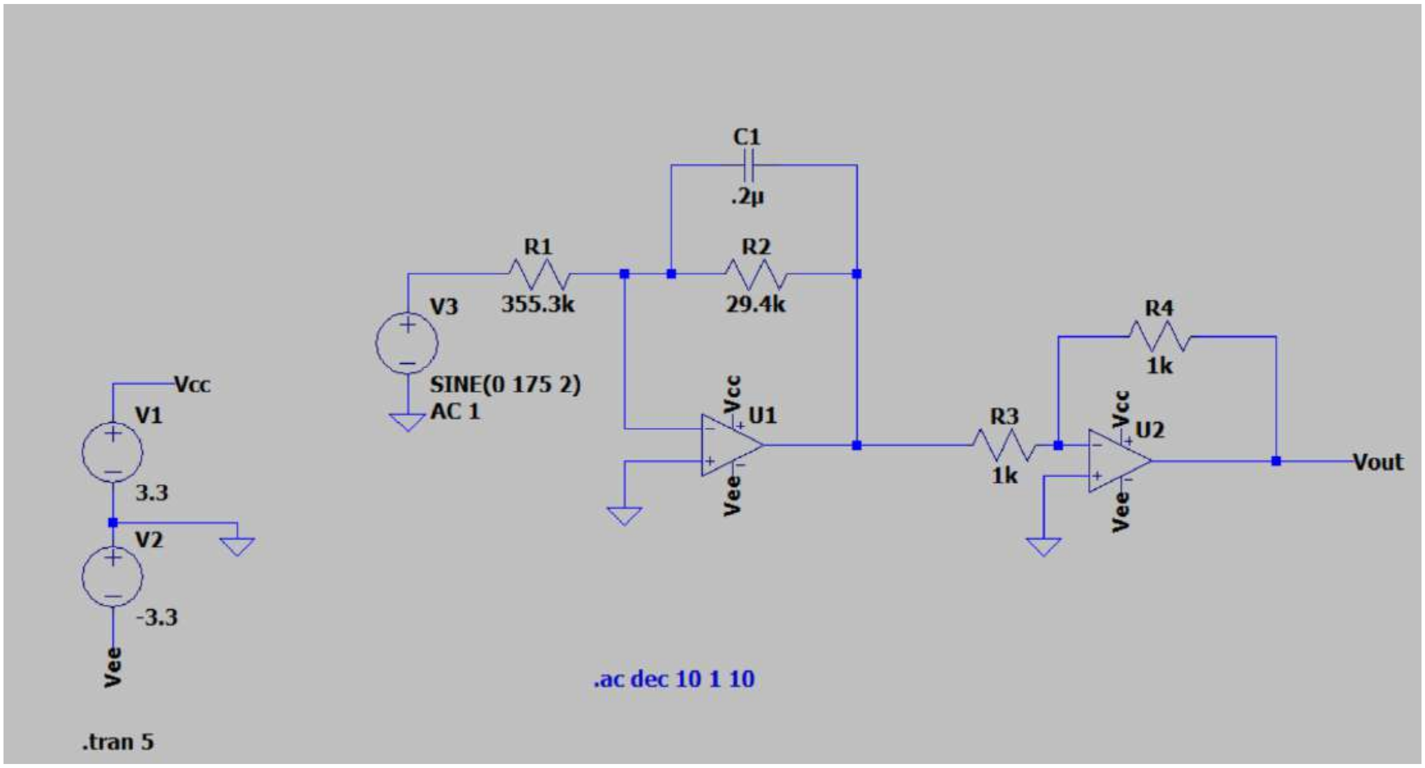
Content:

Circuit Design & Calculations

- Gain: 0.0827
  - R1 = 335.3 kΩ
  - R2 = 29.4 kΩ
- Cutoff Frequency: 27 Hz
  - C1 = 2 μF
- Gain: -1
  - R1 = R2 = 1kΩ



Relevant Calculations



Circuit Designed in LT Spice

Conclusions/action items:

A low pass inverting amplifier circuit was created in LT spice based off the previous design, with the addition of a second amplifier to make the signal positive again. Action items include verifying the gain and cutoff frequency on an oscilliscope.

Amber Schneider - Apr 11, 2024, 4:43 PM CDT

Download

MotorAmpCircuit2.asc (2.02 kB)

2024/04/19 Extreme Code Calculations

Amber Schneider - Apr 25, 2024, 5:47 PM CDT

Title: Extreme Code Calculations

Date: 4/19/2024

Content by: Amber Schneider

Present:

Goals: calculate extreme amplitude and frequency variables to input to the code during extreme testing

Content:

Amplitude

3.6 cm P-P

- A = 10

1 cm P-P

- A = 2.77264

6 cm P-P

- A = 16.63586

Frequency

8/60 s

- SR = 20833
- A = 10 (P-P stays at 3.6cm)

4/60 s

- SR = 41667
- A = 5 (P-P stays at 3.6cm)

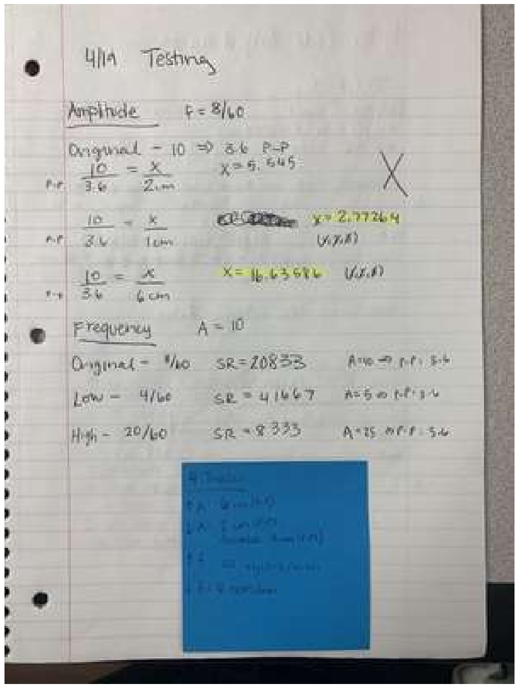
20/60 s

- SR = 8333
- A = 25 (P-P stays at 3.6cm)

Conclusions/action items:

For the extreme testing, the code must be updated for each case. The calculations above were verified to be correct by another team member before testing.

Amber Schneider - Apr 25, 2024, 5:48 PM CDT



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ExtremeTestingSampleCalculations.jpg (2.12 MB)

2022/02/17 EMU Account Status

Amber Schneider - Feb 17, 2022, 11:15 PM CST

You have the following permits and upgrades:

Name	Date
Green Permit	01/25/2022
Lab Orientation	09/22/2020
Red Permit	10/14/2021
Laser 1	10/06/2020

Amber Schneider - Mar 06, 2022, 4:13 PM CST

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greenPass.pdf (280 kB)

2024/02/25 HIPAA Privacy & Security Training

Amber Schneider - Feb 25, 2024, 4:29 PM CST

VCRGE Training Information Lookup Tool **University of Wisconsin-Madison**

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

This certifies that Amber Schneider has completed training for the following course(s):

Expand All Collapse All

Course	Assignment	Completion	Expiration
2023-24 HIPAA Privacy & Security Training	HIPAA Attestation	2/24/2024	
Biosafety Required Training	Biosafety Required Training Quiz 2022	1/12/2022	1/12/2027
Biosafety Required Training	Biosafety Required Training Quiz	9/26/2021	9/26/2026
Chemical Safety: The OSHA Lab Standard	Final Quiz	1/12/2022	

Data Last Imported: 02/25/2024 03:14 PM

VCRGE Look-up Tool: https://apps.research.wisc.edu/TILT

Loading [MathJax]/extensions/Safe.js

Movement in MRIs - 2-1-2024

CASPAR UY - Mar 01, 2024, 9:40 AM CST

Title: Movement in MRIs

Date: 2-1-2024

Content by: Caspar Uy

Goals: Understand additional motion effects in the MR Imaging process

URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4517972/

Content:

- Particle motion or blood flow is useful with image contrast but not helpful with bulk motion
- Various methods are required to alleviate the image distortion
- K-space is the spectrum of spatial frequencies for the imaged object
    1. Small features and smooth intensities are closer to the k-space origin
- Typical Motion-induced deterioration
    1. Blurring
    2. Ghosting – both coherent and incoherent from moving structure
    3. Signal loss
    4. Undesired strong signals
- Slow gradual movement is less detectable from sequential k-space due to its insensitivity to slow motion
    1. Standard periodic motions like breath, blood pulsation, cardiac motion, and tremors are enough to cause artefacts given the sudden type of motion
- Switched on gradients *in vivo* during pulse sequences cause motion artefacts given that MRI relies on creating gradient echoes.

Conclusion: The typical motion deterioration are somewhat quantifiable but identifiable. We can use these types of motion to confirm such artefacts.

Plastic Screws - 2-2-2024

CASPAR UY - Feb 14, 2024, 5:14 PM CST

Title: Plastic Screws Needed

Present: Caspar, Max, Jamie

Date: 2-2-2024

Goals: Find the type of screws needed to make the device more MR compatible than the proof of concept

URLs:

1. https://www.grainger.com/product/4DEV1?gucid=N:N:PS:Paid:GGL:CSM-2295:4P7A1P:20501231&gad_source=1&gclid=EAIaIQobChMIitOs3aiNhAMVb0NHAR1SrA3NEAQYBiABEgI9tvD_BwE&gclsrc=aw.ds
2. https://www.grainger.com/product/Machine-Screw-M5-Thread-Size-447C51
3. https://www.grainger.com/product/Machine-Screw-M4-Thread-Size-4DFC5
4. https://www.grainger.com/product/Machine-Screw-M4-Thread-Size-4DFC2
5. https://www.grainger.com/product/Machine-Screw-M5-Thread-Size-447C75
6. https://www.grainger.com/product/Machine-Screw-M5-Thread-Size-31JP94
7. https://www.grainger.com/product/Machine-Screw-M5-Thread-Size-4DJK4
8. https://www.grainger.com/product/Machine-Screw-M4-Thread-Size-4AGX9
9. https://www.grainger.com/product/TEI-FASTNERS-Hex-Head-Cap-Screw-Nylon-808AM5
10. https://www.grainger.com/product/TEI-FASTNERS-Hex-Head-Cap-Screw-Nylon-808AM7
11. https://www.grainger.com/product/TEI-FASTNERS-Hex-Head-Cap-Screw-Nylon-808AM9

Content:

Current Situation: The team requires primarily M4 (approximately 10, 20mm and 8, 12mm and 5, 5mm) and M5 (approximately 10, 12mm) plastic screws. For the motor 3 M4 that are approximately 3-5mm in length.

Name	Source Number	Screw Size	Fastener Length (in -> mm)	Screw Type	Main Material	Package Amount	Cost/Package	Manufacturer Part Number
Machine Screw: #4-40 Thread Size, 1/4 in Lg, Polycarbonate, Plain, Pan, Phillips, Inch, 5 PK	1	4	(1/4in) 25.4mm	Phillips	Polycarbonate	5	$2.71	010440W025PC
Machine Screw: M5 12mm	2	5	12mm	Phillips	PEEK	10	$25.86	PKM508-12PHP-01
Machine Screw: M4 8mm	3	4	8mm	Phillips	Nylon	25	$4.75	50M040070P008
Machine Screw: M4 35mm*	4	4	35mm	Slotted	Nylon	25	$4.92	50M040070N035
Machine Screw: M5 12mm	5	5	12mm	Slotted	PEEK	10	$25.86	PKM508-12FHS-01
Machine Screw: M5 12mm	6	5	12mm	Slotted	Brass	25	$19.05	M48040.050.0012
Machine Screw: M5*	7	5	13.3mm	Slotted	Nylon	25	Actual: $8.71 Clearance: $1.65	50M050080H016

Machine Screw: M4	8	4	12mm	Slotted	Nylon	25	$3.74	50M040070D012
Machine Screw: M4	9	4	8mm	Hex Cap	Nylon	25	$4.78	NYM407-8HH-UF01
Machine Screw: M4	10	4	12mm	Hex Cap	Nylon	25	$5.57	NYM407-12HH-UF02
Machine Screw: M4	11	4	20mm	Hex Cap	Nylon	25	$6.37	NYM407-20HH-UF02

Conclusion:

Send a condensed list to Kendra and Client for preferences.

Chosen Screws - 2/14/2024

CASPAR UY - Feb 14, 2024, 5:19 PM CST

Title: Chosen Screws for Use

Present: Caspar, Max, & Jamie

Date: 2-14-2024

Content:

There are two screws that will be used for the MR safe component of the device.

SITE 1: https://www.grainger.com/product/Machine-Screw-M4-Thread-Size-4DFC2

SITE 2: https://www.grainger.com/product/Machine-Screw-M5-Thread-Size-4DJK4

Site, Screw Size; Type; material; length; price

Site	Screw Size	Screw Type	Material	Fastener Length	Price
1	M4	Slotted	Nylon	35mm	$5.92per package of 25
2	M5	Slotted	Nylon	13.3mm	Actual: $8.71 per package of 25 Clearance: $1.65 per package

For the M4 we are going to cut them down to the respective fastener lengths.

The respective lengths for the M4 are 10mm, 12mm, 20mm and for M5 12mm.

Hex Nuts for the M4 - package of 25, $4.94/pack

https://www.grainger.com/product/Hex-Nut-M4-0-70-Thread-4AGK1

Conclusion:

We are going to need to 3D print M5 hex nuts with a thread pitch of 0.8mm.

Machine Certified - Green Permit

CASPAR UY - May 01, 2024, 5:42 PM CDT

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Front.jpg (96.5 kB)

CASPAR UY - May 01, 2024, 5:42 PM CDT

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Back.jpg (87.5 kB)

Machine Reservations

CASPAR UY - May 01, 2024, 5:45 PM CDT

Caspar Uy

ID Number: [redacted]

Eligibility: CoE Students

Profile

Bookings

Memberships

Bookings

Name	Day	Time
Mill Reservation - Mill 1	Fri, Mar 22 2024	8:30 - 9:00 AM
Mill Reservation - Mill 1	Fri, Mar 22 2024	9:00 - 9:30 AM
Mill Reservation - Mill 1	Fri, Mar 22 2024	9:30 - 10:00 AM
Mill Reservation - Mill 1	Fri, Mar 22 2024	10:00 - 10:30 AM
Lathe Reservation - Lathe 2	Fri, Mar 15 2024	8:30 - 9:00 AM
Lathe Reservation - Lathe 2	Fri, Mar 15 2024	9:00 - 9:30 AM
Lathe Reservation - Lathe 2	Fri, Mar 15 2024	9:30 - 10:00 AM
Lathe Reservation - Lathe 2	Fri, Mar 15 2024	10:00 - 10:30 AM

HIPAA Grades

CASPAR UY - May 01, 2024, 5:46 PM CDT

Name	Due	Submitted	Status	Score	
2023-24 HIPAA Privacy & Security Training - OLD Assignments				-	
2023-2024 HIPAA Privacy & Security Training Assignments		Mar 1 at 11:34am		✓	
HIPAA Attestation Assignments		Mar 1 at 11:37am		2 / 2	
Assignments				100%	12.00 / 12.00
Total				12.00 / 12.00	12.00 / 12.00

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Certifications

CASPAR UY - May 01, 2024, 5:48 PM CDT

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This certifies that Caspar Uy has completed training for the following course(s):

Course	Assignment	Completion	Expiration
2023-24 HIPAA Privacy & Security Training	HIPAA Attestation	3/1/2024	
Biosafety Required Training	Biosafety Required Training Quiz 2022	1/31/2022	1/31/2027
Chemical Safety: The OSHA Lab Standard	Final Quiz	2/1/2022	

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1885/11/03-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.

1885/11/03-Template

Jamie Flogel - Feb 02, 2024, 1:17 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

BME Design-Fall 2024 - notebook

MAXWELL NASLUND - Feb 05, 2024, 8:41 PM CST


BME Design-Fall 2023 - MAXWELL NASLUND
Complete Notebook

Kendra Besser

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