

MRI compatible motion platform

Date: 04/05/2024 – 04/11/2024

Client: Jiayi Tang

Advisor: Dr. Trevathan

Team:

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Jamie Flogel

Amber Schneider

Problem statement

MRI phantoms used to test and calibrate MRI's are often static models of the human body. These static models don't give a good representation of the constant motion created from natural processes such as respiratory and digestive functions. To solve this, our team will work on a MR compatible device that will hold a phantom and simulate the movements found within the human body.

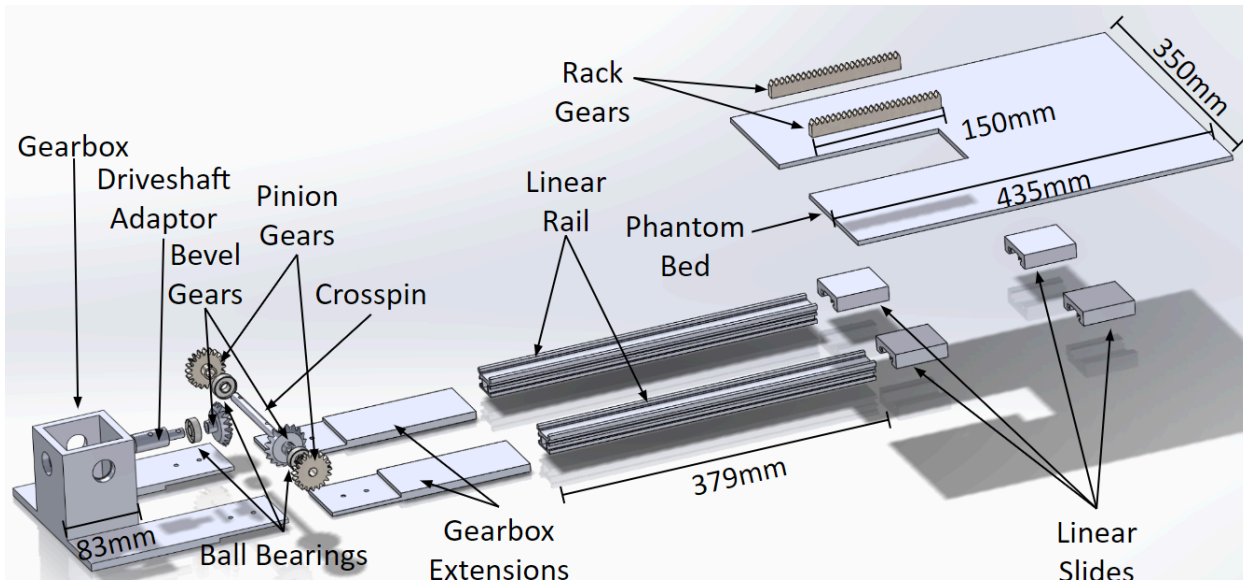
Brief status update

On Friday, the team met to assemble the negative power rail component into the circuit. We were successful in completing this with the help of our advisor. We also determined that we will submit our work for the ISMRM conference. During the week, Kendra and Amber met with Tekceleto to get more information on the motor RPM inaccuracy issue. They suggested we experimentally determine the coefficient to convert RPM to Voltage. Amber and Kendra ran several tests and came up with a new coefficient of ~ 0.0055 which seems to be accurate with constant RPM inputs. More tests need to be done with the full assembly to determine any further modifications of this value. Jamie began working on the outreach reflection and set the layout for the team GitHub repository. Caspar and Max worked on creating the low pass filter in the circuit, adjusting the gain based on Amber and Kendra's new coefficient, and cascading the inverting amplifier with a gain of -1 to rectify the signal.

Difficulties / advice requests

N/A

Current design



Materials and expenses

| Item | Description | Manufacturer | Part Number | Date | QTY | Cost Each | Total | Link |
|-----------------------|---------------------------------------|--------------|-------------|------------|-----|-----------|--------|------|
| Component 1 | | | | | | | | |
| 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 | 400 mm linear rails | igus | CWS-06-30-4 00 | 11/13/2023 | 2 | \$167.69 | \$335.38 | Link |
| Component 3 | | | | | | | | |
| 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 | Connection piece between motor and gearbox | Grainger | H0400075PW 1000 | 11/16/2023 | 1 | \$8.00 | \$8.00 | Link |
| Component 5 | | | | | | | | |
| 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 to allow for frictionless rotation | Grainger | MSN0459939 | 12/1/2023 | 5 | \$17.07 | \$85.35 | N/A |
| Component 7 | | | | | | | | |
| M5 Plastic Screws | Used to assemble final prototype | Grainger | 50M050080 H016 | 2/15/24 | 1 | \$1.65 per package of 25 | \$1.65 | Link |
| M4 Plastic Screws | Used to assemble final prototype | Grainger | 50M040070N 035 | 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 | | | | | | | |

Major team goals for the next week

1. Finish Senior Outreach reflection and Executive Summary
2. Test the prototype in the MR room
3. Update circuit and motor code
4. Continue adding material to GitHub

Next week's individual goals

- Max
 - Test Prototype in the MR room
 - Work to solidify design
 - Complete outreach and executive summary
- Amber
 - Test the prototype in the MR room
 - Make updates to the motor based on testing outcomes
 - Finalize the executive summary, ISMRM conference submission, and the outreach summary
- Jamie
 - Test the prototype in the MR room
 - Finalize the executive summary, ISMRM conference submission, and the outreach summary
 - Make updates to the prototype based on testing outcomes
- Kendra
 - Finalize the executive summary, ISMRM conference submission, and the outreach summary
 - Work with team to test the prototype in the MRI room
 - Improve the code and circuitry of the prototype to give more accurate results
- Caspar
 - Finalize the executive summary, ISMRM conference submission, and the outreach summary
 - Finalize

Timeline

| Task | Jan | Feb | | | | March | | | | | April | | | | May | |
|------------------------|-----|-----|---|----|----|-------|---|----|----|----|-------|----|----|----|-----|----|
| | 26 | 2 | 9 | 16 | 23 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 | 3 | 10 |
| Project R&D | | | | | | | | | | | | | | | | |
| Empathize | | X | X | X | X | | | | | | | | | | | |
| Background | | X | X | | | | | | | | | | | | | |
| Prototyping | | | X | X | X | X | X | X | X | | X | | | | | |
| Testing | | | | | | | | | | | | | | | | |
| Deliverables | | | | | | | | | | | | | | | | |
| Progress Reports | | X | X | X | X | X | X | X | X | | X | X | | | | |
| Prelim presentation | | | X | | X | | | | | | | | | | | |
| Final Poster | | | | | | | | | | | | | | | | |
| Meetings | | | | | | | | | | | | | | | | |
| Client | | X | | | | | X | | | | X | | | | | |
| Advisor | X | X | X | X | X | X | | | | | X | | | | | |
| Website | | | | | | | | | | | | | | | | |
| Update | X | X | X | X | X | X | X | X | X | | X | | | | | |

Filled boxes = projected timeline
 X = task was worked on or completed

Previous week's goals and accomplishments

- Max
 - Met with advisor to implement negative power rail on circuit
 - Connected to Keil Studio for code development
 - Continued work on low-pass gain filter
- Amber
 - Met with team to combine mechanical and software teams and reassign tasks
 - Met with advisor and team to implement negative power rail on circuit
 - Tested motor RPM before meeting with Tekceleo
 - Met with Jamie to begin adding motor files to the GitHub repository
 - Met with Tekceleo to discuss RMP accuracy concerns
 - Ran tests to determine new RPM to Voltage conversion
- Jamie
 - Met with team to combine mechanical and software teams and reassign tasks
 - Met with advisor and team to implement negative power rail on circuit
 - Worked on outreach summary
 - Worked on creating and updating GitHub
 - Updated expenses
- Kendra
 - Meet with Tekceleo to discuss hexavelocity conversion
 - Team meet to assemble inverting amplifier
 - Met with team to combine mechanical and software teams and reassign tasks
- Caspar
 - Worked on Learning mBed and KeliStudio to function

BME Design: 402

- Combined the mechanical and software work of each team
- Met with advisor and team to implement negative power rail on circuit

Activities

| Name | Date | Activity | Time (h) | Week Total (h) | Sem. Total (h) |
|-------|---------|--|----------|----------------|----------------|
| Max | 1/26/24 | Semester planning with team | 1.5 | 4 | 37.5 |
| | 1/31/24 | Client meeting | 0.5 | | |
| | 2/2/24 | Team meeting to review future fabrication | 1.0 | | |
| | 2/2/24 | Team presentation assignments | 0.5 | | |
| | 2/6/24 | Modeled future design in solidworks | 1.5 | | |
| | 2/6/24 | Worked on preliminary presentation | 1.0 | | |
| | 2/7/24 | Reviewed preliminary presentation with team | 1.0 | | |
| | 2/12/24 | Reidentified desirable producible sinusoid | 1.0 | | |
| | 2/14/24 | Met with team to order screws, and calculate gearing ratio | 2.0 | | |
| | 2/16/24 | Team meeting to clarify torque transmission | 1.0 | | |
| | 2/20/24 | Gearbox outputs algorithm | 1.0 | | |
| | 2/22/24 | Watched MRI Safety Video | 1.0 | | |
| | 2/22/24 | Solidworks modifications to gears | 2.5 | | |
| | 2/23/24 | Drafted report and printed prototype with team | 1.5 | | |
| | 2/26/24 | Wrote 'MRI-Compatible Motion Platform' section in 'Methods' & 'Results & Discussion' for Preliminary Journal entry | 1.0 | | |
| | 2/27/24 | Edit Preliminary Journal with team | 2.0 | | |
| | 2/28/24 | HIPPA Training | 1.0 | | |
| | 2/28/24 | Reprint Gearbox | 0.5 | | |
| | 3/1/24 | Checklist I Screening | 1 | | |
| | 3/6/24 | Meeting to start gearbox assembly | 2 | | |
| | 3/7/24 | Rack Solidworks redesign | 1 | | |
| | 3/11/24 | Client Meeting | 0.5 | | |
| | 3/13/24 | Team meeting to assemble gearbox | 0.5 | | |
| | 3/13/24 | Gearbox redesign | 2 | | |
| | 3/15/24 | Voltage divider design testing | 2 | | |
| | 3/20/24 | Gearbox Assembly | 2 | | |
| | 4/3/24 | Negative rail assembly | 2 | | |
| | 4/5/24 | Worked with advisor to implement negative power rail | 1.5 | | |
| | 4/5/24 | Met with team to connect to Keil Studio | 1 | | |
| | 4/11/24 | Worked on low-pass gain filter | 1.5 | | |
| Amber | 1/26/24 | Semester planning with team | 1.5 | 7.5 | 44.5 |
| | 1/31/24 | Client meeting | 0.5 | | |
| | 2/1/24 | Controls research | 1.0 | | |
| | 2/2/24 | Review Motor Documentation | 1.0 | | |
| | 2/2/24 | Create preliminary presentation slides | 0.5 | | |
| | 2/5/24 | Implement changes to code | 1.0 | | |
| | 2/6/24 | Draft PID algorithm | 0.5 | | |
| | 2/7/24 | Review and practice preliminary presentation w/ team | 1.0 | | |
| | 2/14/24 | Started MRI certification | 0.50 | | |
| | 2/15/24 | Ran motor code test | 0.50 | | |
| | 2/15/24 | Analyzed results | 0.50 | | |
| | 2/15/24 | Updated code | 0.50 | | |
| | 2/16/24 | Team meeting to clarify sinusoidal motion | 1.0 | | |

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|-------|---------|---|-----|-----|------|
| | 2/19/24 | equation (Velocity & Position) Meeting with Dr. Nimuncar to discuss sinusoidal motion function | 0.5 | | |
| | 2/20/24 | Edited sinusoidal motion function | 1.0 | | |
| | 2/21/24 | Tested & edited sinusoidal motion function | 2.0 | | |
| | 2/21/24 | Watched GEHC MRI safety video | 1.0 | | |
| | 2/22/24 | Test sinusoidal motion function | 1.0 | | |
| | 2/22/24 | Background research on Journal Article | 1.0 | | |
| | 2/23/24 | Drafted report and printed prototype with team | 1.5 | | |
| | 2/24/24 | HIPPA Training | 0.5 | | |
| | 2/25/24 | Wrote Motor and Testing sections of report | 0.5 | | |
| | 2/25/24 | Competing Design Journal Research | 0.5 | | |
| | 2/27/24 | Circuit Design Meeting | 0.5 | | |
| | 2/27/24 | Edit Preliminary Report | 2.0 | | |
| | 2/28/24 | Circuit Calculations | 1.0 | | |
| | 2/29/24 | MRI Safety Book | 1.5 | | |
| | 3/1/24 | Checklist I Screening | 1.0 | | |
| | 3/5/24 | Circuit Testing | 2.0 | | |
| | 3/8/24 | Circuit Testing w/ Team | 1.5 | | |
| | 3/11/24 | Client Meeting | 0.5 | | |
| | 3/11/24 | Circuit Redesign | 1.0 | | |
| | 3/15/24 | Voltage Divider Circuit assembly & testing | 2.0 | | |
| | 3/19/24 | Conversation with Tekceleo | 0.5 | | |
| | 4/2/24 | Meeting with Client | 0.5 | | |
| | 4/3/24 | Meeting with Team (executive summary & circuit construction) | 2.0 | | |
| | 4/4/24 | Communication with Tekceleo | 0.5 | | |
| | 4/5/24 | Team meeting to explain motor and assign new roles/tasks | 1.5 | | |
| | 4/5/24 | Implement negative power rail w/ team & advisor | 1.0 | | |
| | 4/10/24 | Ran RPM accuracy test | 0.5 | | |
| | 4/10/24 | Updated GitHub with motor code documentation | 2.0 | | |
| | 4/11/24 | Met with Tekceleo to discuss RMP accuracy concerns | 1.0 | | |
| | 4/11/24 | Ran tests to calculate new RPM to Voltage conversion | 1.5 | | |
| Jamie | 1/26/24 | Semester planning with team | 1.5 | 6.5 | 38.5 |
| | 1/31/24 | Client meeting | 0.5 | | |
| | 1/31/24 | Researched organ motion | 0.5 | | |
| | 2/2/24 | Worked on Preliminary presentation | 0.5 | | |
| | 2/5/24 | Completed budget slide | 0.5 | | |
| | 2/6/24 | Completed timeline slide | 1.0 | | |
| | 2/7/24 | Review and practice prelim presentation | 1.0 | | |
| | 2/8/24 | Researched Plastic Screws | 0.5 | | |
| | 2/14/24 | Met with team to order screws, and calculate gearing ratio | 2.0 | | |
| | 2/16/24 | BPAG meeting | 0.5 | | |
| | 2/16/24 | Team meeting to clarify torque transmission | 1.0 | | |
| | 2/21/24 | Researched potential journals | 1.5 | | |
| | 2/21/24 | Watched MRI Safety Video | 1.0 | | |
| | 2/22/24 | Solidworks modifications to gears | 2.5 | | |
| | 2/23/24 | Drafted report and printed prototype with | 1.5 | | |

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|--------|---------|--|-----|---|------|
| | 2/26/24 | team Wrote characterization of motion and sinusoidal motion test sections of report | 0.5 | | |
| | 2/27/24 | HIPPA Training | 0.5 | | |
| | 2/27/24 | MRI safety reading | 0.5 | | |
| | 2/27/24 | Edit preliminary report | 2.0 | | |
| | 3/1/24 | Checklist I Screening | 1.0 | | |
| | 3/6/24 | Meeting to start gearbox assembly | | | |
| | 3/8/24 | Circuit Testing w/ Team | 1.5 | | |
| | 3/11/24 | Client Meeting | 0.5 | | |
| | 3/13/24 | Began assembly of new prototype redesigned motor stand | 1.5 | | |
| | 3/14/24 | Updated expense table | 0.5 | | |
| | 3/15/24 | Voltage divider design testing | 2.0 | | |
| | 3/20/24 | Gearbox Assembly | 2.0 | | |
| | 4/3/24 | Meeting with Team (executive summary & circuit construction) | 2.0 | | |
| | 4/5/24 | Team meeting to combine teams and redirect efforts | 1.5 | | |
| | 4/5/24 | Worked on negative power rail with advisor | 1.0 | | |
| | 4/9/24 | Worked on outreach | 1.0 | | |
| | 4/10/24 | Created and updated GitHub | 2.0 | | |
| | 4/11/24 | Updated Expenses | 1.0 | | |
| Kendra | 1/26/24 | Semester planning with team | 1.5 | 5 | 32.5 |
| | 1/31/24 | Client meeting | 0.5 | | |
| | 2/1/24 | Researched transfer function | 0.5 | | |
| | 2/2/24 | Review motor documentation | 1.0 | | |
| | 2/5/24 | Edited preliminary slides | 1.0 | | |
| | 2/7/24 | Review and practice prelim presentation | 1.0 | | |
| | 2/14/24 | HIPPA training | 0.5 | | |
| | 2/26/24 | Caught up on meetings | 0.5 | | |
| | 2/26/24 | Downloaded, read, and ran new code | 0.5 | | |
| | 2/26/24 | Wrote introduction to preliminary report | 1.0 | | |
| | 2/27/24 | Circuit design meeting | 0.5 | | |
| | 2/27/24 | Edited preliminary report | 2.0 | | |
| | 2/28/24 | Watched MRI safety video | 1.0 | | |
| | 2/29/24 | Read MRI safety manual | 1.5 | | |
| | 2/29/24 | LP non inverting amp circuit equations and circuit draft | 1.0 | | |
| | 2/29/24 | Completed design journal research | 2.0 | | |
| | 3/1/24 | MRI checklist screening | 1.0 | | |
| | 3/4/24 | Gathered materials & built LP/ amp circuit | 1.0 | | |
| | 3/5/24 | Circuit Testing | 2.0 | | |
| | 3/12/24 | Catch up on meeting notes | 0.5 | | |
| | 3/14/24 | New circuit calculations | 1.0 | | |
| | 3/15/24 | Voltage Divider Circuit assembly & testing | 2.0 | | |
| | 3/19/24 | Conversation with Tekceleo | 0.5 | | |
| | 4/2/24 | Meeting with Client | 1.0 | | |
| | 4/3/24 | Meeting with Team (executive summary & circuit construction) | 2.0 | | |
| | 4/4/24 | Communication with Tekceleo | 0.5 | | |
| | 4/5/24 | Team meeting to combine teams and redirect efforts | 1.5 | | |
| | 4/5/24 | Worked on negative power rail with advisor | 1.0 | | |

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|---------|-------------------------|--|------|--|-------|
| | 4/11/24 | Meeting with Tekceleo | 2.5 | | |
| Caspar | 1-26-24 | Semester planning with team | 1.5 | | 33.88 |
| | 1-31-24 | Client Meeting | 0.5 | | |
| | | Researched organ movement in MRIs | 0.75 | | |
| | 2-2-24 | Team Meeting | 1 | | |
| | 2-6-24 | Worked on Presentation Slides | 1.25 | | |
| | 2-7-24 | Preliminary Presentation team meeting | 1 | | |
| | 2-8-24 | Researched Plastic Screws | 0.75 | | |
| | 2-14-24 | Finalizing Plastic Screw and Nut | 1.25 | | |
| | | Research, Met to work on gearbox | | | |
| | 2-16-24 | Team Meeting | 1.0 | | |
| | 2-17-24 | Journal Types Review | 0.33 | | |
| | 2-25-24 | Preliminary Report | 1.0 | | |
| | 2-29-24 | Watched MRI Safety Video | 1.5 | | |
| | 2-29-24 | MRI Checklist Readings | 1.0 | | |
| | 3/1/24 | MRI checklist Screening | 1.0 | | |
| | 3-6-24 | Meeting to work on gearbox assembly | 2 | | |
| | 3-8-24 | Circuit Testing and Screw modifying | 2 | | |
| | 3-11-24 | Client Meeting | 0.5 | | |
| | 3-13-24 | Began Assembly for next prototype | 1.5 | | |
| | 3-14-24 | Worked on Driveshaft | 2.5 | | |
| | 3-20-24 | Gearbox assembly | 1.75 | | |
| | 3-22-24 | Worked on Driveshaft | 2 | | |
| | 4-5-24 | Get briefed on Tekceleo and electronics team | 1.5 | | |
| | 4-9-24 | Introduction to mBed and KeliStudio | 2 | | |
| 4-10-24 | KeliStudio learning | 0.5 | | | |
| 4-10-24 | Research Capacitor Gain | 0.75 | | | |
| 4-12-24 | Low Pass Filter Build | 3 | | | |