PiezoBot: Partial Design Report

Monqiue Parrish and Brayden Riggs

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Introduction

Brayden Riggs - Team Lead: Responsibilities include managing due dates, main coder for the project, soldering, and meeting with the client weekly.

Monique Parrish - Treasurer: Responsibilities include managing the budget for the project, filling out purchase orders, 3D printing, web design, and weekly meetings.

Add pictures later

Intro to the Piezobots Project:

This project is an improvement to the Kilobots created at Harvard. Dr. Cunha has challenged us to construct a small, low-budget robot. Instead of incorporating a bulky vibration motor, we are trying to cut down on that weight with a piezo disk. Applications for these robots can be applied in search and rescue, collective transport, and cleaning oil spills. However, this is still an early stage prototype for these robots that will have a lot of potential and more fine-tuning to be done.

Our project is focused on designing a cheaper and low energy "kilobot" using a piezo disk to try and improve onto the kilobot design to instead create a "piezobot". This project targets programming and designing with collective behavior using an autonomous swarm.

Problem Statement

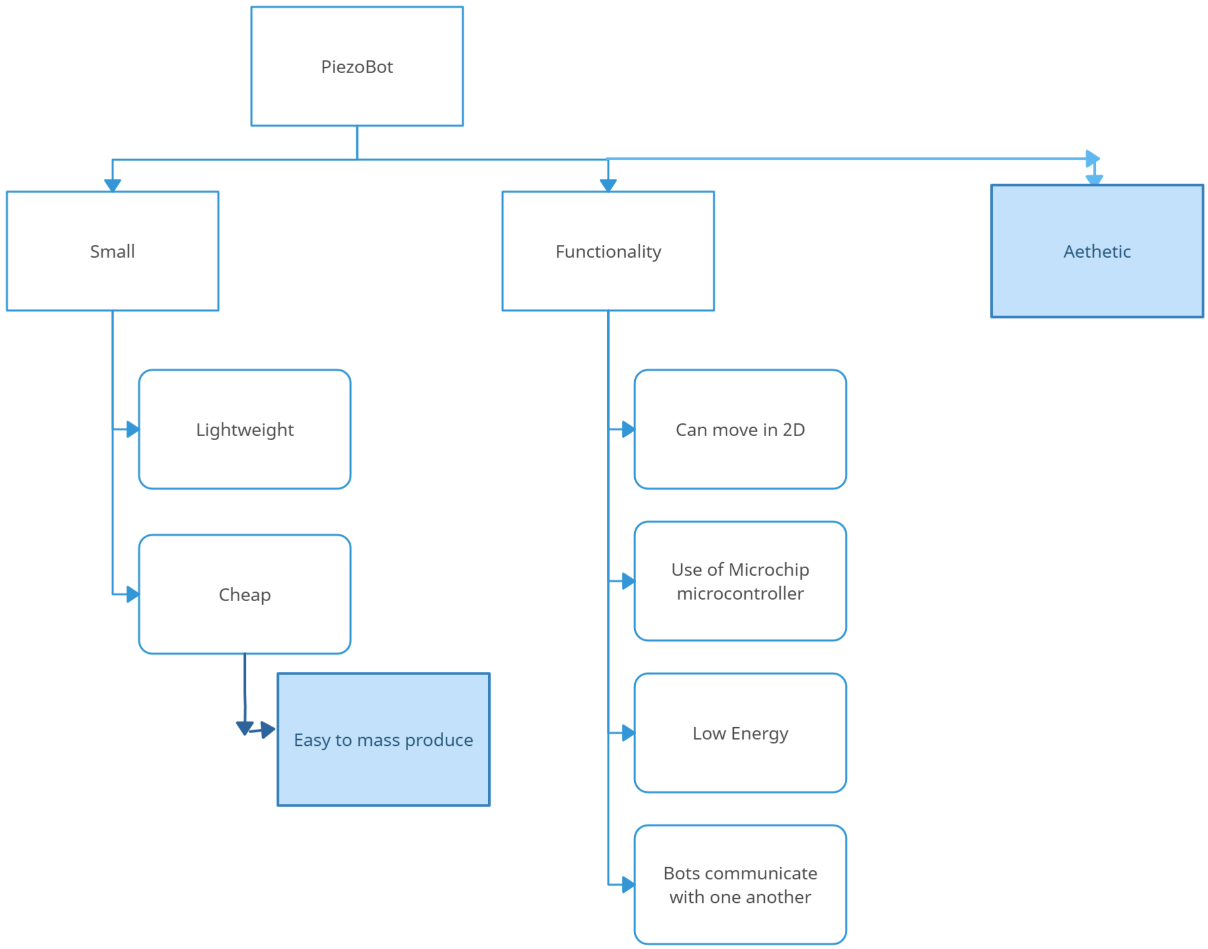
Statement of Needs:

In this Section, we will analyze the client's needs for the project and team objectives for the project.

Marketing Requirements

- Small as possible
- Light weight
- Easy to manufacture/mass produce.
- Use Microchip microcontroller since they are sponsoring the project
- AVR 128 nano Board
- Low energy
- Use piezo disk

Diagram:



	2D	Energy	Communication	Light	Cheap	Sum	Weight
2D	1	5	4	3	3	16	0.414
Energy	0.2	1	3	2	0.5	6.7	0.173
Communication	0.25	0.33	1	2	0.25	3.83	0.099
Light	0.33	0.5	0.5	1	0.5	2.83	0.073
Cheap	0.33	2	4	2	1	9.33	0.241
						38.69	1

This matrix is subjective to what our group rated each category compared to the other categories we thought important. This helps explain in numerical values how valuable we thought each requirement was.

Expectations:

When we first met with the client, Dr. Cunha, he clearly stated that the final robot is functional in that it moves in the 2-dimensional plane for at least 3 feet. He wants to make it as small as possible with the option to make a communication system between multiple robots. When building the robot, we need to keep in mind that Dr. Cunha wants to mass produce these robots so selecting expensive parts for our robot would not be optimal for his requirements. Still, selecting some parts that might cost a little more but be smaller and/or perform better is something that we would keep in mind and possibly strive for when purchasing parts.

Statement of Objectives

The purpose of this project is to design and physically cut the disk to achieve 2D movement. Since it is still in the early stages, our goals are to meet the client's needs for creating a basic, functioning piezobot that is capable of movement using a joystick.

We expect to achieve this by following our timeline which we created in our project management section. We first aim to find the ideal cut to achieve 2D movement using 3 hemi-sphere legs that will be glued onto our robot, or the piezo disk. Then following the schematic we will create a circuit to help apply a differential voltage that will move the robot in any direction.

Other objectives include finishing our bibliography and report fully by the end of the semester along with our other final submittals which include: the video pitch, poster, and website.

System Requirements

Technical:

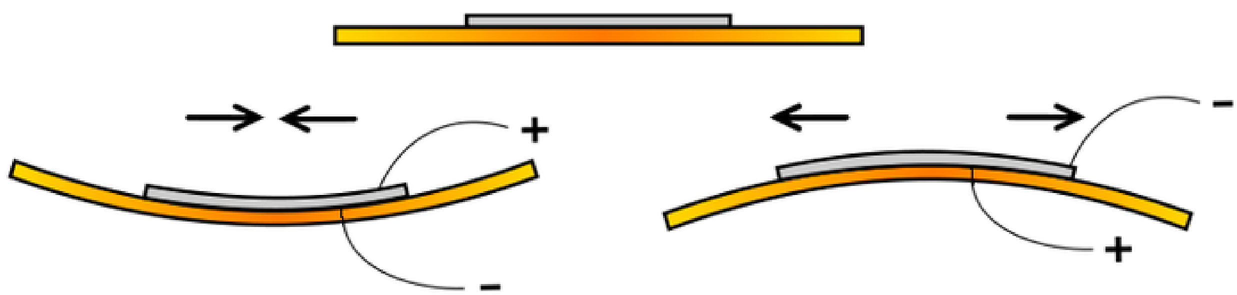
- Low Energy
- Small as possible
- 2D Movement (at least "3 Feet")
- Low cost
- Bots Communicate

Hardware and Software:

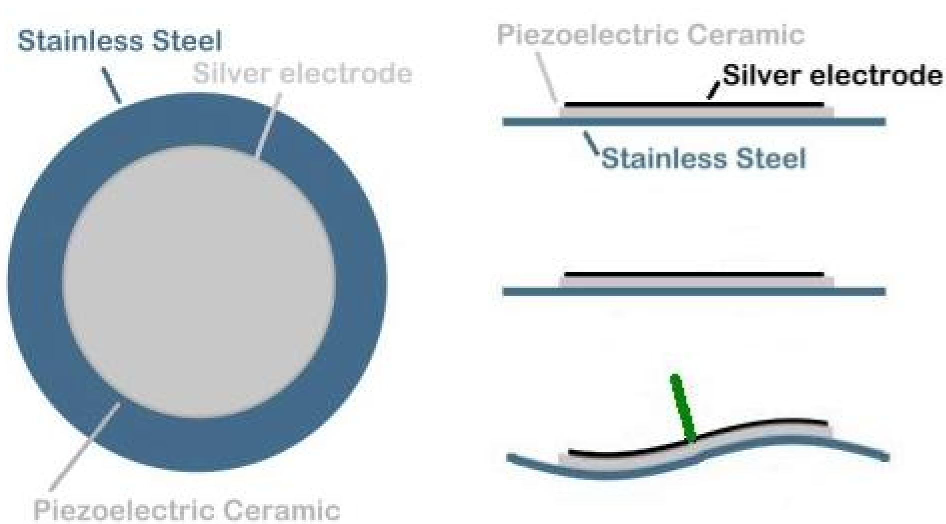
- Use MPLAB X software
- Use Microchip microcontroller (AVR128DB48-C Nano

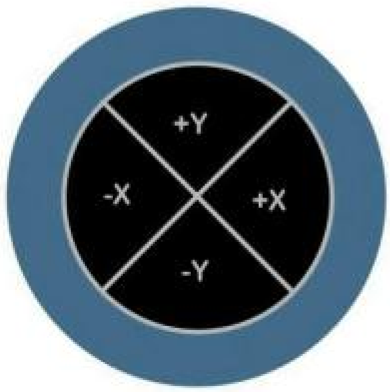
Concept

Our solution to improving onto the Kilobot design is to reduce the weight and complexity by installing a piezo disk instead of a vibration motor. Using this disk we will cut it into a specific design and apply 3 half-sphere legs onto certain cuts in order to achieve movement.



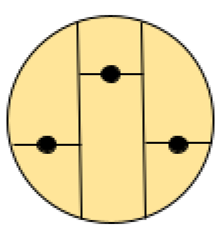
The basic functionality of using the piezo disk is that when you apply a differential voltage to the electrode and the stainless steel plating, then you achieve this bowing motion.





Cutting the disk in some sort of specific way will result in a unique movement that can allow the 2D movement we're looking for. Achieving a cut that can result in control over forward and lateral movement is what we're essentially trying to achieve. In this example cut, it is cut in 4 even sections where applying certain differential voltages across the disk can result in the peg in the middle of the disk to direct towards the +x, -x, +y, or -y sections on the disk. Our cut is more complex.

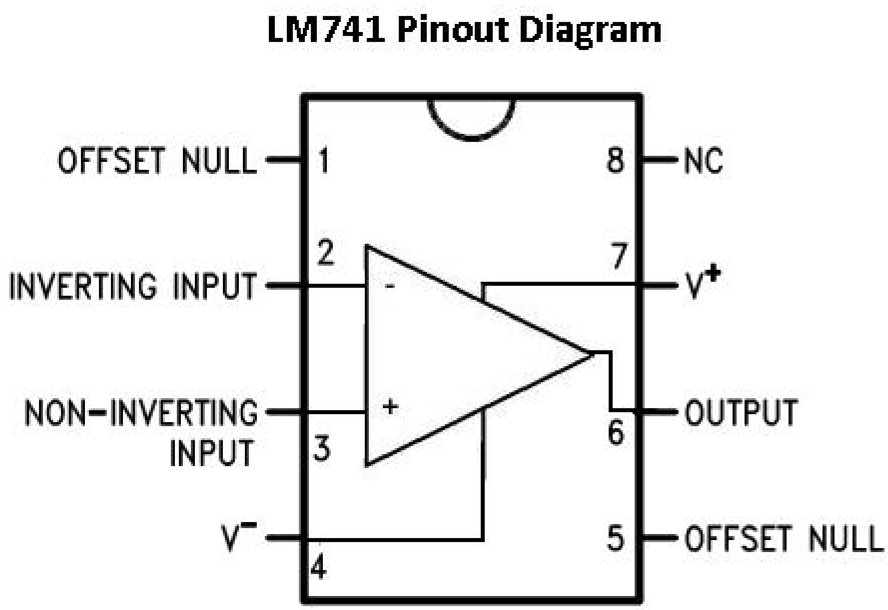
Cut designs and Schematic:



For our cut, we made 5 total cuts where each leg falls onto a horizontal cut. All legs would move forward due to the horizontal cut and using the 2 vertical cuts we can move the disk laterally.

After setting up an AC square wave signal using a timer, sending a differential voltage to the disk will create a certain flex in the disk that can create 2D movement to achieve a minimum of 3 feet of movement. Future plans will incorporate a joystick for demonstration of movement.

LM741 Inverter:



The inverter will allow us to get a differential voltage to apply to the disk simultaneously.

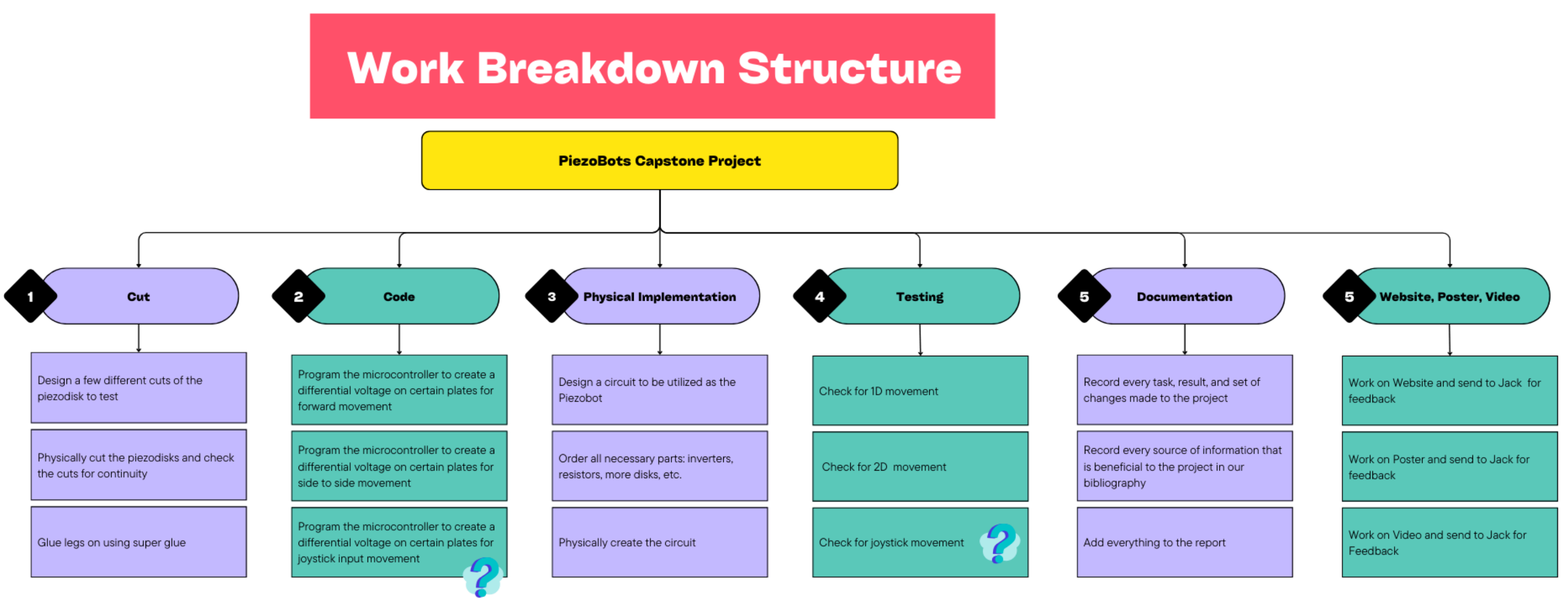
Bill of Materials:

Vendor	Description	Unit	Cost
Amazon	Piezo Disc 50 pieces	1	12.54
Micheals	Super glue	1	7.99
Amazon	Half circle acrylic spheres	1	obsolete

Microchip	AVR 128DB48 Curiosity Nano Board	1	$24
Amazon	Arduino Analog Joystick	1	$6.29
Amazon	LM 741 Inverter Op Amp	1	$0.50

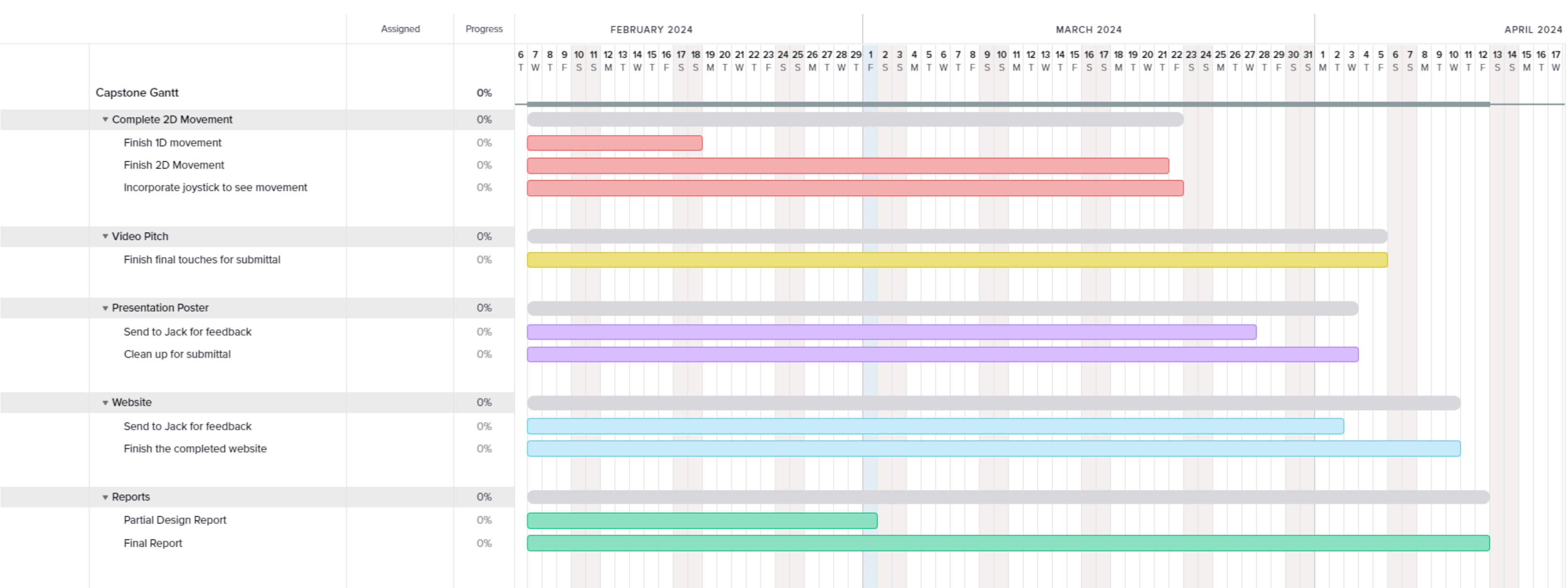
Project Management

WBS:



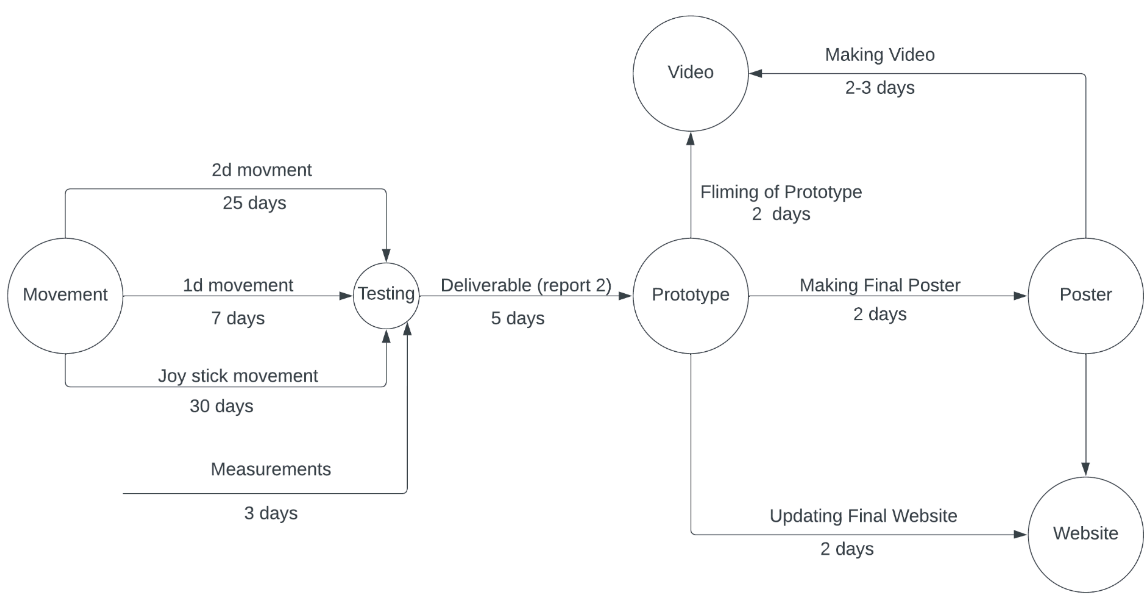
In our WBS chart, we broke it down into 6 main overall tasks for the project. First, we started designing, which we started looking at the different ways to cut the disk and how to assemble the circuit. Then we shifted over to getting the timer and code set up to generate a PWM signal. Then using the finalized designs we physically implemented the prototype legs and circuits. After all this, we tested to see if the code, circuit, and cut on the piezo disk functioned properly. So far, we're still tweaking the code and testing sections heavily. Then, obviously we're documenting sources and changes made to the project onto our report and bibliography. In its own section I included the website, poster, and video which we will need to finish by the end of the semester.

Gantt:



Our gantt chart focuses on 3 main sections we have for the 2D 3 feet minimum that Dr. Cunha has assigned us. We broke it into getting the forward movement first and having that finished by February 18. Then the 2D movement was another subtask we had planned to finish by March 21 and the final subtask was to add the joystick which kind of goes along with the 2D movement but we decided that we would add a day or two if we need to iron things out with it. Other sections include the timelines for the video pitch, poster, website, and report sections which all are pretty self explanatory, but as a note that they do have subtasks that only ask for feedback from Dr. Cunha or Jack prior to the final submission.

PERT:



PERT Diagram

Most Likely	March 22, 2024	37 days

Optimistic	March 15, 2024	30 days
Pessimistic	April 10, 2024	56 days

Optimistic/Pessimistic/Most Likely Table

Standard Deviation: (30 - 56) / 6 = -4.333

Tc = (30 + (4*37) + 56) / 6 = 39

For the Optimistic/Pessimistic/Most Likely Table the date it was made was February 14th, 2024. The most likely date is March 22, 2024 which is about 2-3 weeks before we need to be done by. The court Activity we are on is the 1D movement but looking at the diagram it is parallel with the 2D movement, joystick movement, and reading measurements. The measurement activity is related to testing as well as the movements. Looking at the activities we can see what are parallel and that can be done at the same time but not filming the prototype because by then all the other activities will be complete because to be able to film we have to finish all other activities.

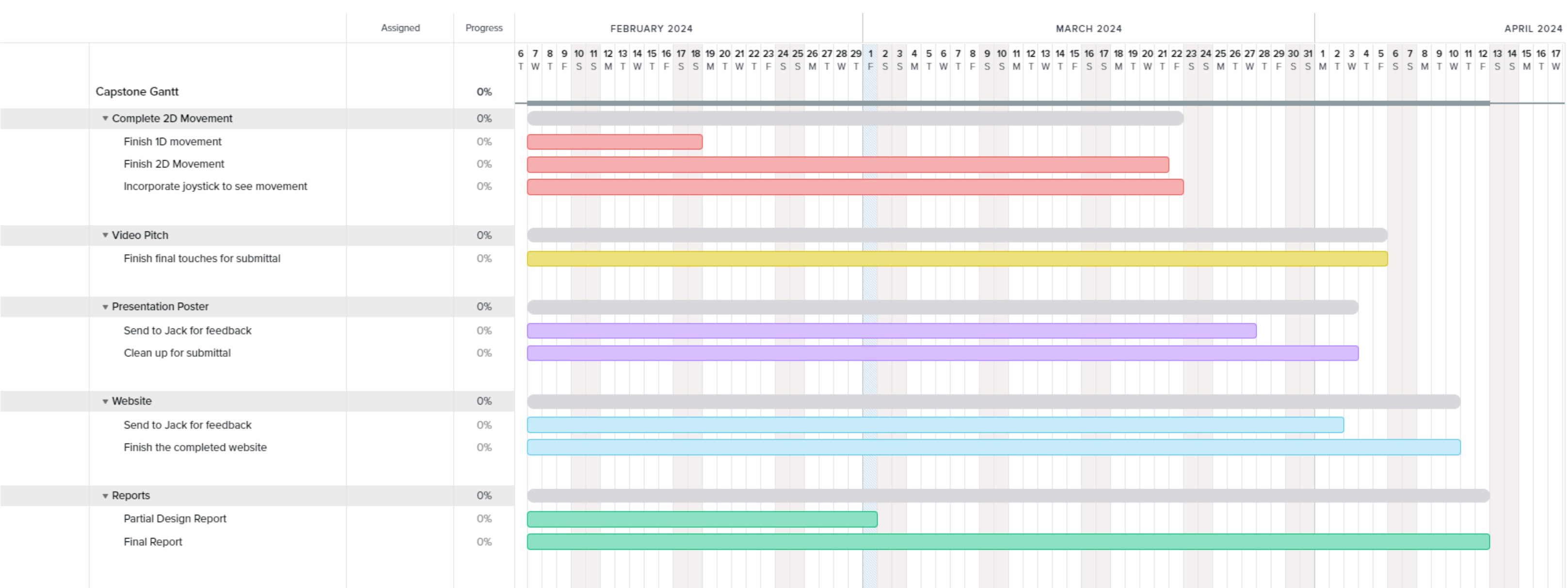
Testing

We plan on testing more capacitances, frequencies, and load resistances. We want to have low power robots that can be multiplied into a swarm. We plan on starting with around 100k ohms and then observe it in an oscilloscope. We should be obtaining an abrupt increase and then an exponential decrease since the disk is essentially a capacitor. If we don't see the waveform then we can try other possible resistor values. We have to keep in mind low power consumption. When looking at the resonance frequency, the closer to the resonance frequency of the piezo, the more it will bend, but it will also drive more displacement current so finding the right frequency is important. Measurement of the capacitance in our project will be with a capacitance meter and we'll need to measure the capacitance of each segment after cutting the disk. Also using continuity we will need to make sure there is no crosstalk between sections. From all these measurements, we can find the relaxation time for the robot's legs using 2.pi.f = R.C. We also need to measure the capacitance with and without the legs connected. We can also measure this capacitance with the legs free floating and with the legs on a surface supporting the weight of our robot. The capacitance of each segment should be close to each other. Otherwise, the legs will have different displacements and do a biased walk.

To measure the resonance frequency, we can insert a shunt resistor in series with our circuit and measure the voltage across it as a function of the excitation frequency. If we divide the measured voltage by the constant resistance value of this shunt resistance, we get the current our piezo is driving. The current will peak at the resonant frequency. This peak can be very sharp, so we should sweep the frequency by small amounts close to the resonant frequency. Also, we need to measure the quality factor of the resonance peak: full width at half-maximum (FWHM) over resonant frequency. We should measure it for every condition: with and without legs, full disk, each segment of the cut disk, floating legs, legs on surface, etc.

Conclusion

The next step we want to achieve is to fully automate the joystick to function as the input for our piezobot's movement. We expect to get that completely incorporated into our piezobot by the end of the month. Also, with the fine-tuning of the project we plan to test way more and get more information and data for our report. We also plan on finishing our poster for the FEST we have coming up in mid April. In the 2 minute video pitch, we want to showcase the movement of our piezobot with the joystick along with basic information on the project.



Referring back to the Gantt chart, for the next 3-4 weeks maximum, we want to completely finish Dr. Cunha's project needs to require at least 3 feet of 2 dimensional movement for our piezobot. To showcase how our piezo disk can move, we again, want that user-control of using an analog joystick. 2D movement would finish at the end of the week on March 22. The video pitch and poster would be roughly finished by the end of the week on April 5 so we can get feedback from Dr. Cunha and Jack before ironing out any discrepancies for the final submittal. Our final report including our bibliography, testing, materials, requirements, etc. will be finalized and ready for submission by April 12.

Bibliography