Tactile Simulation Sprint 5 Report

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Executive Summary of Progress Until 5/11/2022 Design Review

We have been working on Sprint 5, the Dove prototype. We will restate the goal of our project in order to give context to the goals for the Dove prototype: to create a system capable of realistically simulating tactile sensation via electric stimulation, and to integrate the system into an ergonomic and user-friendly glove. We had two goals for the Dove prototype (Sprint 5). The first was to create simulations of the electrode cross-capacitance and a theoretical wiring diagram of the full system, and the second was to implement a functional electrode driving circuit.

We encountered some limitations on the circuit requiring us to redesign it to operate at a higher voltage. Because of this, the circuit is considered incomplete. Both simulations have been considered complete by the team and should aid in selecting wave forms for stimulus. Going into the Sprint 6 we will be focusing heavily on the development of the circuit.

List of Project Backlog Items Undertaken

Task Name	Anticipated Hours (Total)	Progress Made	Responsible Party	Actual Hours
5.1.1 Sim of Six Electrode Cross Capacitance	4	Completed	Eli	10
5.1.2 Sim of Full Skin/Electrode Interaction	4.5	Completed	Eli	12
5.1.3 Real Testing W/O Skin	2.5	Completed	Eli	2
5.1.4 Testing On Skin for Desired Effects	5	Incomplete	Eli	N/A
5.2.1 Power Supply Powered Current Source	3	Completed	Jacob	3
5.2.2 XTR110KP Powered Circuit	3	Completed	Jacob	8
5.2.3 Custom Biphasic Current Circuit	5	Completed	Jacob	13
5.2.4 HV513 Powered Circuit	3	Incomplete	Jacob	N/A

Crow Prototype Task Descriptions

5.1.1 Sim of Six Electrode Cross Capacitance (Eli)

This task involved updating the capacitance simulation document based on the changes in the electrode array. I was required to analyze the effect of the capacitive coupling between adjacent electrodes, as well as with the slightly farther electrodes.

5.1.2 Sim of Full Skin/Electrode Interaction (Eli)

This task involved creating a representation of the whole electrode system. It was required to account for the pathways through the skin and different electrodes acting as ground.

5.1.3 Real Testing W/O Skin (Eli)

This task involved testing the circuit over a potentiometer in order to test the circuit's ability to maintain a constant current.

5.1.4 Testing On Skin for Desired Effects (Eli)

This task involved executing the tasks defined in the quality control methodology document and laid out in the spreadsheet. Results were recorded and analyzed. This task was considered to be done when all the questions described by the methodology had been answered.

5.2.1 Power Supply Powered Current Source (Jacob)

In order for Eli to start work on the real testing of the electrodes, he needs a circuit capable of biphasic current. This can be done using the power supply more simply. It was not as easily controllable as one made for use with the microcontroller so this was only a stepping stone to allow him to continue testing while I continued work on the main circuit.

This was implemented using the previously simulated circuit which utilized the INA126PA In-Amp chip.

5.2.2 XTR110KP Powered Circuit (Jacob)

This was just one potential solution to the problem of creating our driving circuit. This chip which we have on hand and previously purchased is capable of sending a negative current source through the load which is controllable by a voltage input source. This input source could be controlled with the microcontroller onboard DAC 0V-3.3V signal.

The problem with this IC was the amount of supporting hardware required for it and the fact that we only have 1 which makes it difficult to build more of these drivers. We later found that it also had too low of a voltage maximum.

5.2.3 Custom Biphasic Current Circuit (Jacob)

We have purchased two different integrated circuits which may or may not be capable of implementing what we need. We also have the custom circuit idea which initially relied on the H-bridge hooked up with a V-I converter. I really wanted to make a custom circuit because it provided more control over our output signal.

This task ended up being implemented with the Howland Current Pump as it allowed us to implement the waveform we wanted with a much simpler circuit.

5.2.4 HV513 Powered Circuit (Jacob)

The final potential solution was our Serial to Parallel converter integrated circuit. This theoretically would be the ultimate solution to our problem as it should be capable of driving all of our electrodes as well as switching the polarity at will. One problem we have however is a lack of understanding about how to implement it exactly because no simulation models exist for it. Another problem we face is the fact that it is still in transit and we do not have it on hand to begin testing.

This task also required the fine soldering attachment to an adapter so we could prototype with it on a breadboard. This task should really have been split into many that add up to much longer estimated hours except that would have ruined the sprint velocity. I did not work on this task anyway because the IC did not come in on time. If I did, this task and 5.2.3 were mutually exclusive.

Sprint Velocities

Overall Team Velocity

$$\text{Overall Team Velocity} = \frac{\text{Total anticipated hours on completed tasks}}{\text{Total anticipated hours for sprint}} = \frac{22}{30}$$

$$0.73 = 73\%$$

We had a couple tasks incomplete due to either shipping delays or our circuit development issues which accounts for the missing 21% in team velocity.

Individual Velocities

Jacob

$$\text{Team Member Velocity} = \frac{11}{14}$$

$$0.79 = 79\%$$

Eli

$$\text{Team Member Velocity} = \frac{11}{16}$$

$$0.69 = 69\%$$

The velocity is higher this time around, due to the fact that we completed the majority of the circuit development tasks, despite the shortcomings of the overall design which will be addressed in the tasks next sprint. This did however prevent us from completing the skin testing task to satisfaction, which is the main source of velocity loss. Another loss in velocity is because one of our ICs took several weeks to arrive so we were not able to complete the task that would have been using it this sprint.

Team and Instructor Feedback on Deliverables

5.1.1 Sim of Six Electrode Cross Capacitance (Eli)

Instructor Feedback

The slides demonstrating the cross capacitance should include any work done in solving for the cross capacitance. You must show the formulas and the derivation of the capacitance values rather than just the end result.

Intra-team Feedback

I do agree with the professors. A formula on the slide would have been easy enough and could provide much more context as to how it was calculated.

Team Response to Feedback

I see your point. However, once you go under the hood of the math behind the capacitance, the equation in fact involves a rather complicated integral. It would not be evident from looking at it. That said, I could have put in just the base equation without substituting in the distance integral or any other values. I do have that information in detail in the writeup though.

5.1.2 Sim of Full Skin/Electrode Interaction (Eli)

Instructor Feedback

This doesn't seem like a simulation that was well executed. First of all it was poorly presented, and lacks backup from the engineering notebook. The model is not fitted very well to the data so you should look for a better model. You also need to account for the probe impedance when you are doing this.

Intra-team Feedback

I liked seeing the full circuit as a reference more than anything practical. I am intrigued by your measurements on real skin impedance and would like to continue these tests to give a better understanding of the required frequency and voltage relationship. I did get the feeling that you had not spent too much time on that part because it was not a task initiative on the sprint planning board so it would be worth it to spend more time and research.

Team Response to Feedback

I admit that this part was pretty poorly prepared, I had prioritized the capacitance analysis so I did not have as much time as I would have needed to do a more thought out analysis of this. I also realized at a very late point that part of my model I had constructed from these measurements was flawed and I had to redo it. Overall I am not really satisfied with the output of this task but I don't think it makes sense to keep working on it. In response to the probe impedance question, I know the AD2 has a $1M\Omega$ or so scope impedance, but given that the impedance analyzer setup uses separate channels I don't know if that impedance would apply across channels as well. If there is only a $1M\Omega$ scope impedance then the low frequency values are likely inaccurate, though it should be accurate for higher frequencies where the relative load impedance is lower. In response to the model fit, I think the fit looks bad because of the log-log scale, maybe it would work better if I fitted the log of the impedance but I don't think that would be useful. The same amount of error at a different area on the log scale can look a lot bigger when in reality it is probably pretty similar. Overall I would agree with the professors feedback that this task was not well presented or methodically executed. The poor approach I took is a weakness I am looking to improve in Sprint 6.

5.1.3 Real Testing W/O Skin

Instructor Feedback

Not presented

Intra-team Feedback

I think this task was done satisfactorily, given that by the time we did it we already knew that we would have to be changing the design. The circuit performed as expected in the context that we designed it for, which I would call a success. Obviously, it failed when we subjected it to conditions exceeding what it had been designed for.

Team Response to Feedback

The true shame lies in our failure to fully characterize the signal. We should have known from the start that the voltage must be higher. I suppose it is a good thing we tested this physical circuit with the lower voltage for verification before stepping up the output. We have laid and tested the groundwork and all we need to do is raise the voltage capabilities.

5.2.1 Power Supply Powered Current Source (Jacob)

Instructor Feedback

Not presented

Intra-team Feedback

This circuit was not very good, it did not remain stable at moderately high loads. There was not enough documentation or organization of the wiring for me to use the circuit effectively for testing. I think we probably should have abandoned this one a bit earlier, but now that we have a better circuit we can just take the lessons learned and move on. With future circuits we should document the utility and the development process more thoroughly.

Team Response to Feedback

I did focus too much on the deliverable being more of an explanation of the process including the calculations for the values of the voltage and resistor values. This distracted me from the main goal of the deliverable which should have had more of a focus on how to use the circuit.

5.2.3 Custom Biphasic Current Circuit (Jacob)

Instructor Feedback

Be wary of using high voltage in this circuit. A high voltage DC-DC step-up converter should not be required. The voltages you need can be produced by a DC desktop power supply. In addition to this, a high voltage op-amp can be replaced with an A/B amplifier placed at the output of your Howland Current Pump circuit.

Intra-team Feedback

I think this was a good end result for what the task set out to do, but not necessarily what the project needed. I think the leads we have been given will be helpful in improving on this circuit.

Team Response to Feedback

If the goal was solely to create a biphasic current source, we did it. Unfortunately we also require a high voltage output in order to overcome the high impedance of the skin. I am thankful for the expert ideas from Professor Petersen and I will implement test out if that will work as quickly as I can. I do worry about this affecting the Howland Current Pump's ability to maintain a constant current output but I will test this in simulation first.

Description of Team Process Improvements Identified During Sprint Retrospective

We need to have sharper focus on the goals of each task. Going into Sprint 5, we knew that each of our tasks were too large to fit under the 5 hour limit. Because we don't specifically know how to break up these tasks until we start them, we should focus more on the overarching goal and break that down into subtasks once we start. We ended up spending a lot more time on tasks than we had planned to because in several cases we failed to estimate tasks that should really have been 10-15 hours and break those up. Another goal

is to improve the quality of our deliverables. We will approach this in two ways. One will be to direct the work done in the task more efficiently by outlining the deliverable beforehand, adding an additional layer of Sprint planning beyond the taskboard and in more depth. The second will be in the final output of the tasks, making sure the process used is clear and replicable to the other team member. This part should be easier being implemented in conjunction with the outlining.

Sprint 6 Goals and Objectives

We are in the process of redefining Sprint 6 to be in line with our priorities for the project. Currently, our plan is to direct all our attention into improving the circuit and establishing the device as a proof of concept for tactile electrostimulation. Our first priority will be adding an AB amplifier to the current source in order to let it operate at higher voltages, constrained by the transistors instead of the op amp. As a backup we have received the HV513 IC that had been delayed from last sprint, so it may prove worthwhile to implement that. Lastly if we finish the circuit with time to spare we can get it all integrated into the glove and clean up the design a bit. We will decide how to go about this in our next planning meeting.