Task 2.2.2 / 4.1.1

Tactile Stimulation Team

Microcontroller To Electrode Circuit Design Write-up

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1 Introduction and Overview

This document will serve as a walk through of all decisions made in the 2.2.2 task. It will serve as a guide as to how the decisions were made and everything that may need to be remembered and documented moving forward. It will be broken down into sub-tasks, and each sub-task will be explained as thoroughly as possible.

Each of these sub-tasks will start by describing the predetermined goal of it, as well as the estimated work time. It will then describe the process of going through the task, and the final result. Overall, this document will serve as a deliverable for each of the sub-tasks in the 2.2.2 task.

2 Sub-Tasks

I. Design the Circuit (Est. Hrs: 20)

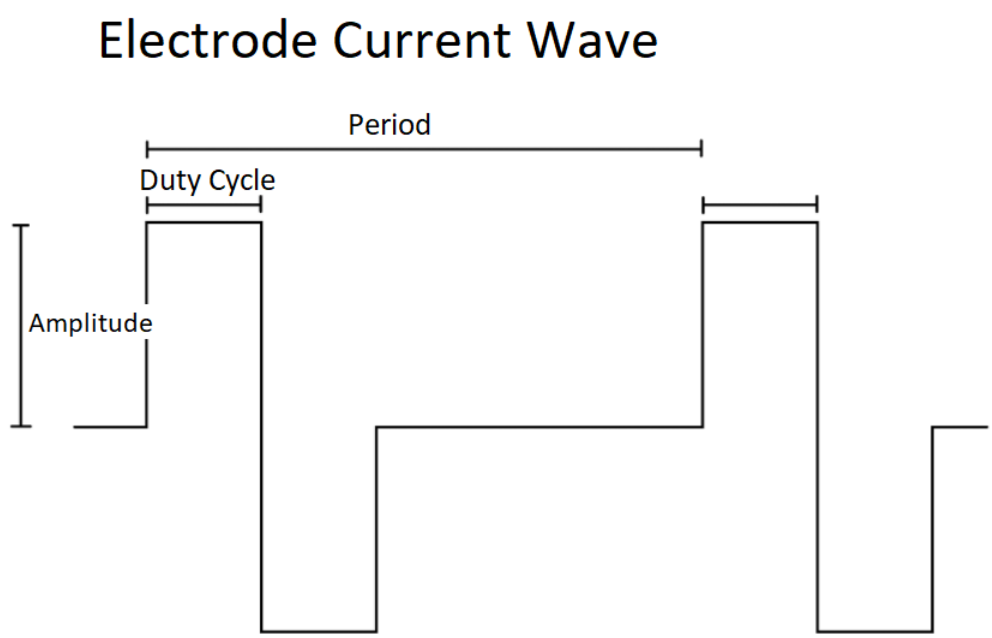
Description

This sub-task is easily the largest part of this whole task. This sub-task is where the actual design was going to take place. All we know is the signal the microcontroller PWM can output and what the electrode needs. We are responsible for finding out how to build the circuit to make the two work. This task required a lot of research, design, simulation, and testing in order to complete.

It earned the estimated work hours of 20, and it may even be an underestimation. It's impossible to know before starting research, how long it will take you to find what you need. This tasks deliverable was to be this write up as well as the graphs produced in PSpice.

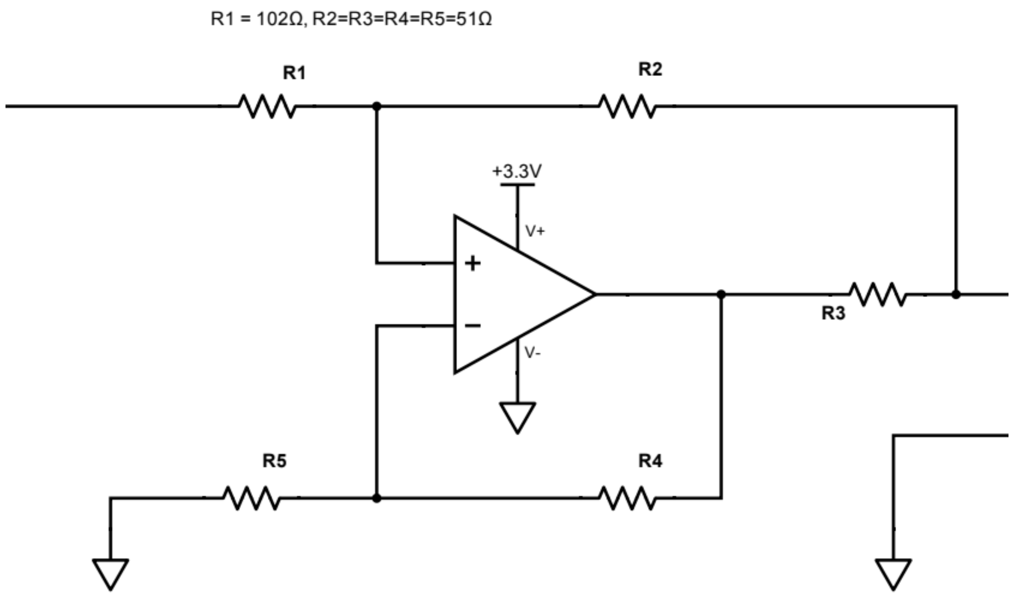
Walk-Through

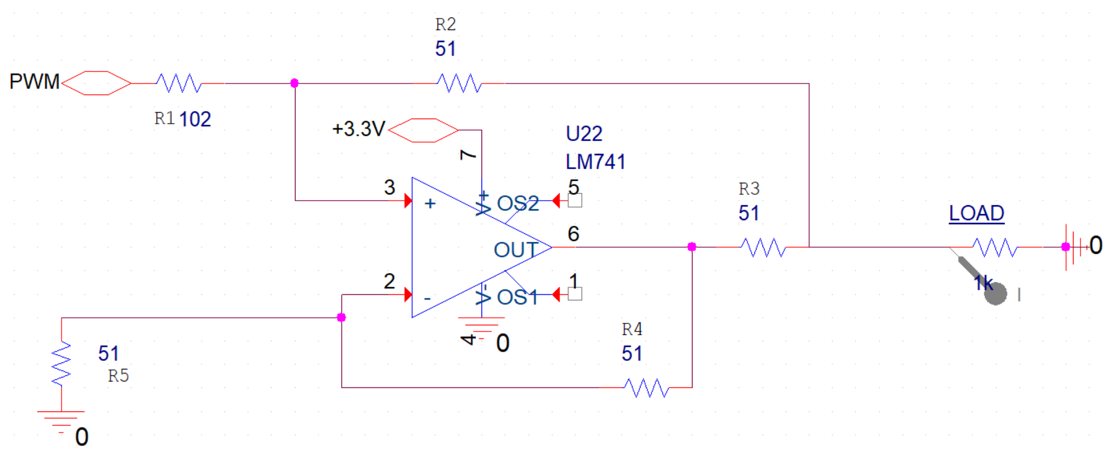
To start with, we know that we wanted the following signal to be carried to the electrode:



Each component; the amplitude, period, and duty cycle, we wanted to be able to control through software. This was the exact signal though that we wanted to start with. Now that I am working on the circuit to adapt the signal, I wanted to start by simulating everything with PSpice. I started by creating the V-I circuit that we used with the Albatross prototype:

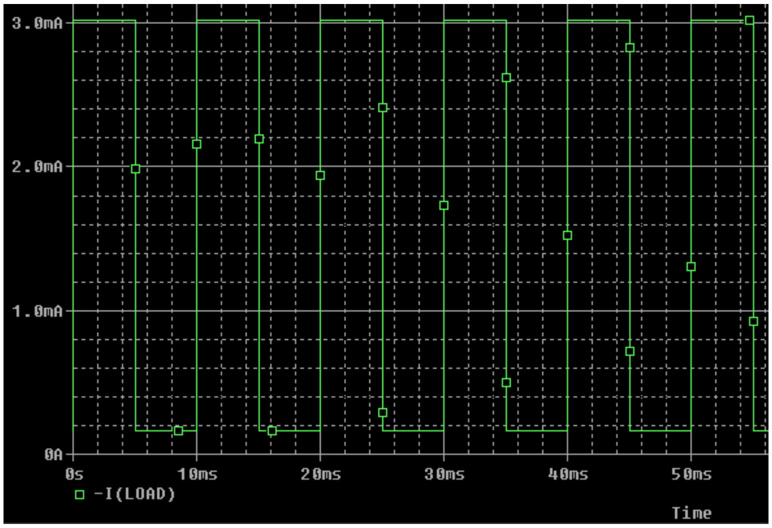
V-I Converter



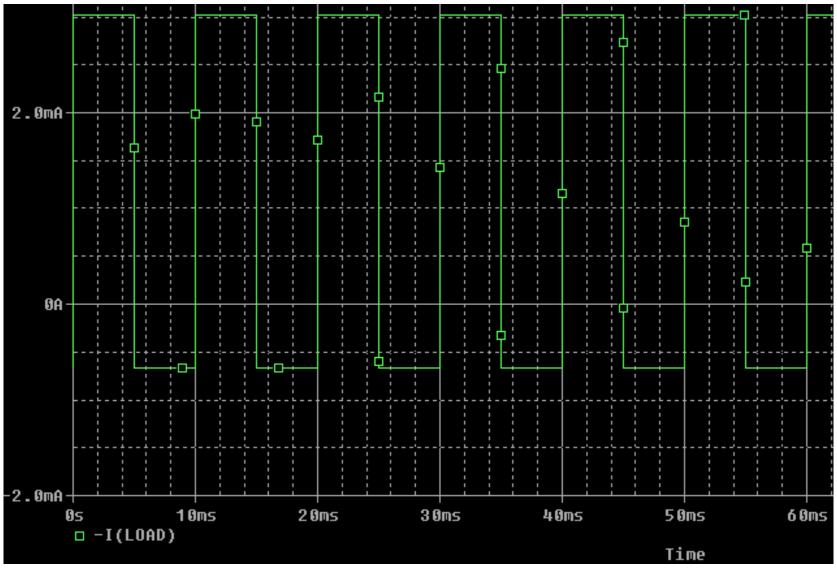


The load was arbitrary because it will be extremely variable and all we care about is the current which should be the same, no matter the load impedance.

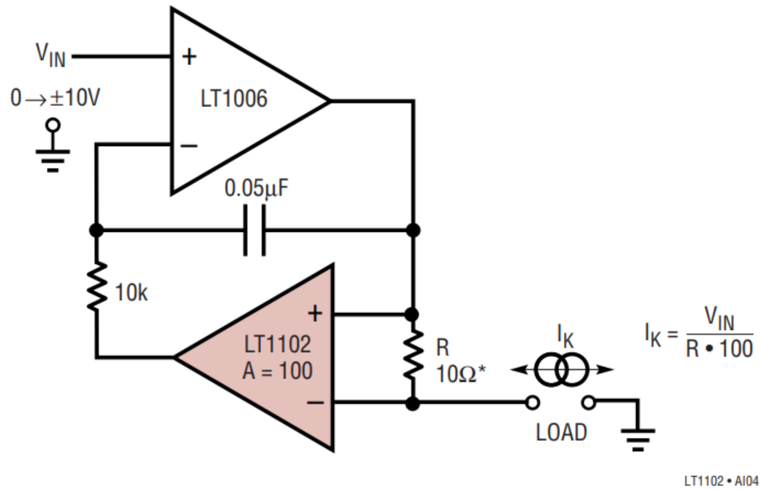
We observed the same frequency response as we did with Albatross on the AD2.



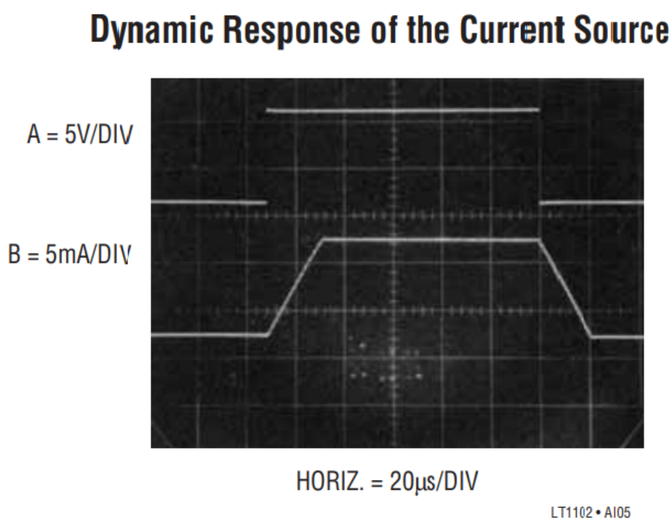
The problem with this circuit however, is that if we applied a biphasic square wave signal to the input pin, we would not receive a symmetrical biphasic current wave coming out. Instead we got the following:



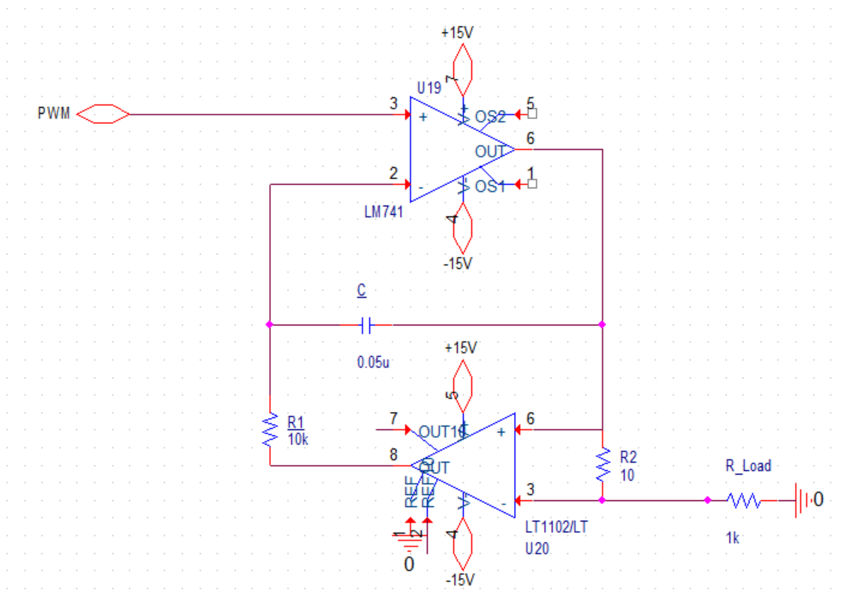
In order to remedy this, I turned to Google for a proper biphasic voltage controlled current source. I found an instrumentation amplifier (In-Amp) called the LT1102 which gave an example of how to build one in it's data sheet. This was the schematic



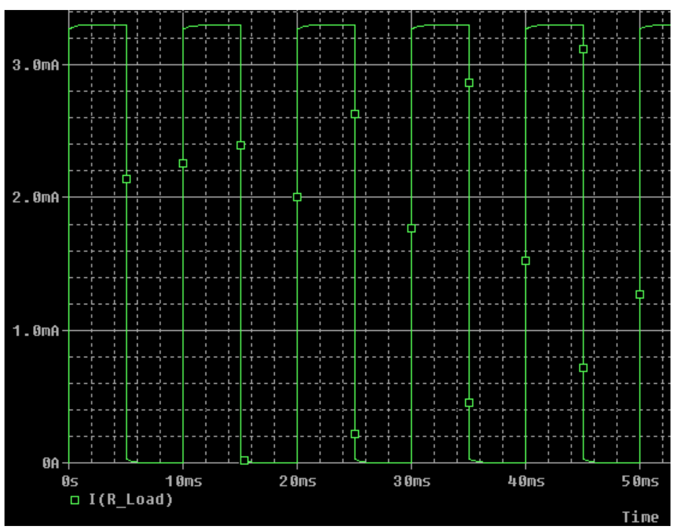
This gives the equation, $I_X = \frac{V_{IN}}{R*100}$ Where 100 is just the gain of the In-Amp in it's current configuration. This resulted in the following graph taken from their data sheet:



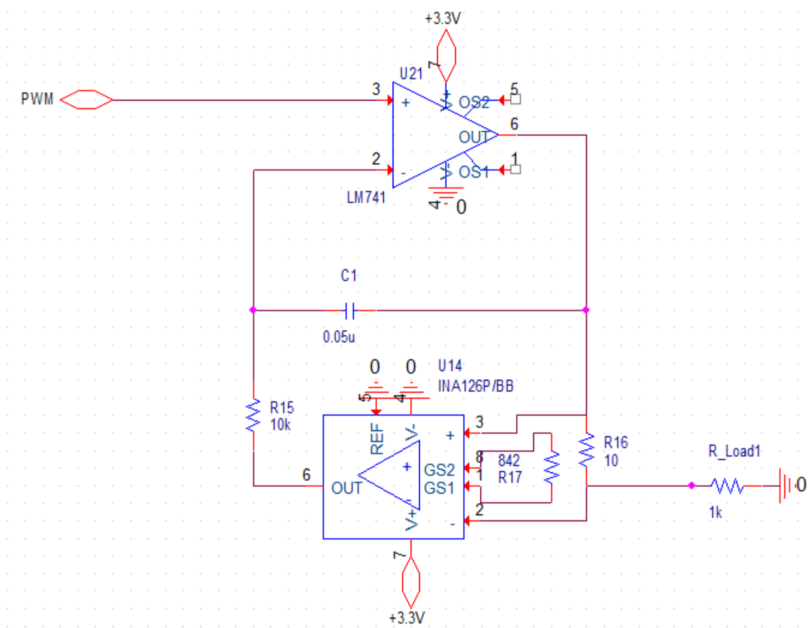
I focused on mimicking the output they got with a PSpice model.



Which gave us the following graph with impulse input 0 to +3.3V waves.



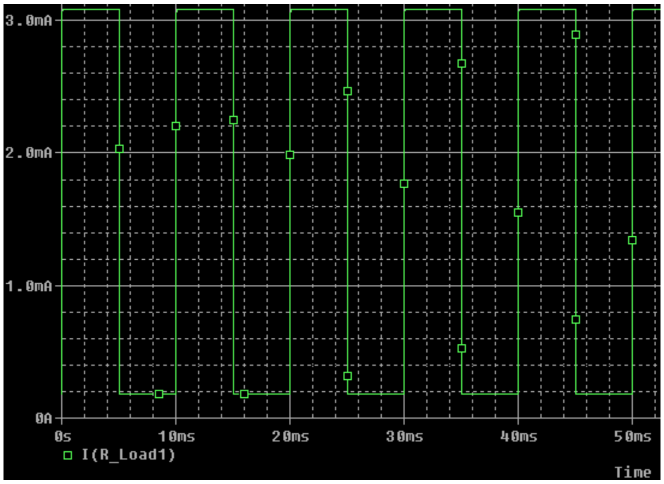
I then recreated this with the only In-amp that BELS has available, the INA126PA. This is the schematic:



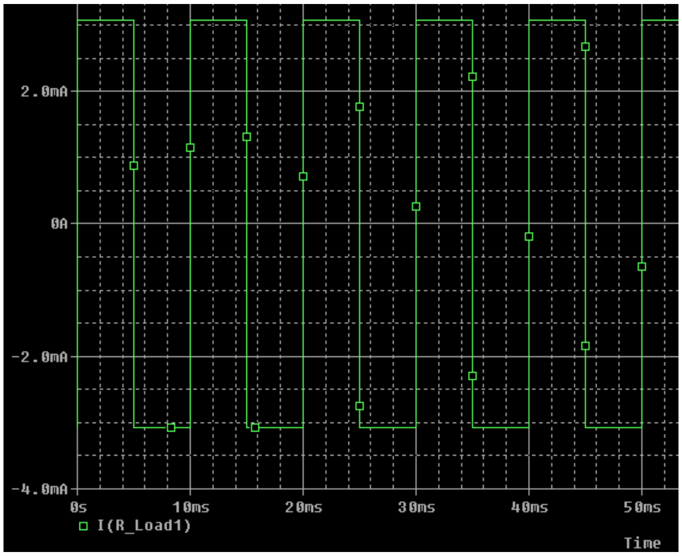
With this In-Amp, the gain is controlled by the resistor, R17 using the following table:

DESIRED GAIN (V/V)	R_G (Ω)	NEAREST 1% R_G VALUE
5	NC	NC
10	16k	15.8k
20	5333	5360
50	1779	1780
100	842	845
200	410	412
500	162	162
1000	80.4	80.6
2000	40.1	40.2
5000	16.0	15.8
10000	8.0	7.87

In order to match the output signal we used for the Albatross V-I converter, I made set the gain to 100 which corresponds to a 842Ω resistance between the reference pins, pin 1 and 8. This gives the In-Amp version of our V-I converter the added benefit of a single resistance value determining the gain, rather than all the external R2 to R5 resistance values from the previous circuit. This makes it easy to change the gain with a potentiometer for more signal range. This was the resulting graph using the same 0-3.3V impulses:

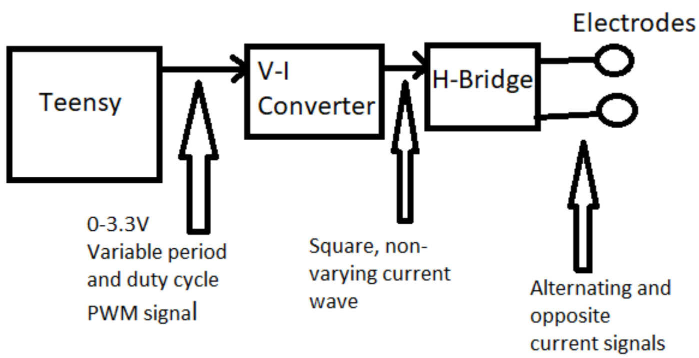


Once again a very similar result. Now however, watch when we apply a negative voltage:



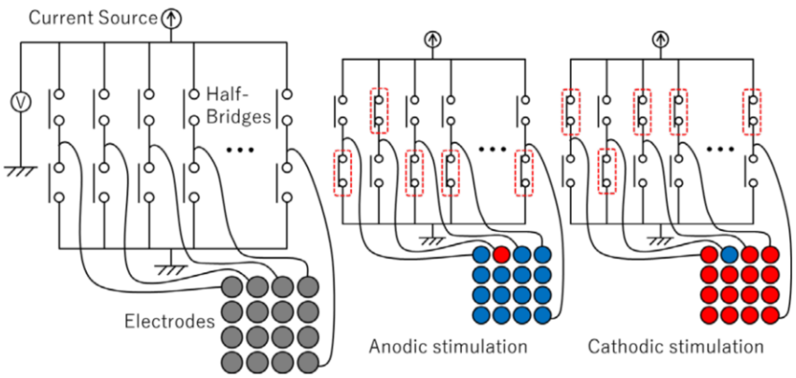
We get a perfectly symmetrical output signal.

The problem we now encountered is applying this negative voltage with the PWM output signal. This seemed like it would require a H-Bridge set up to switch the voltage midway through the PWM High signal. We also decided that we would be better off having the H-Bridge switching circuit between the V-I and the electrode rather than between the PWM and V-I converter. This is because it would be easier to directly switch which electrode is the anode (negative) and which is the cathode (positive). This gives us the following super basic block diagram:

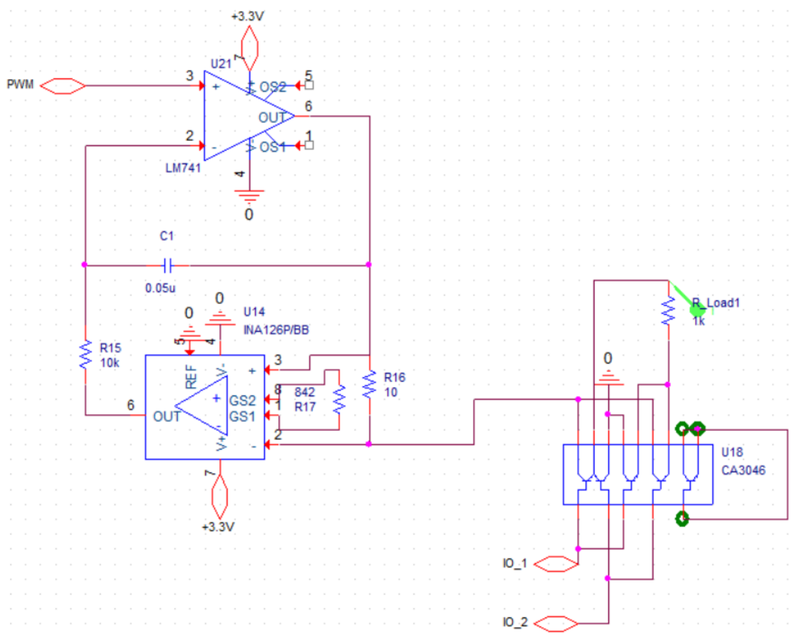


With this setup, we no longer even need the V-I converter to be capable of outputting a biphasic current signal but it is still worth using because of how much easier it is to adjust the gain.

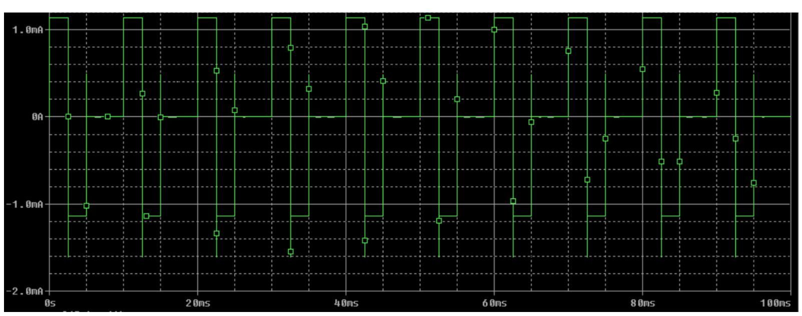
With an H-bridge, rather than switching the polarity of the current going through the electrode, we can simply switch which electrode acts as the cathode and which as the anode. Using the design in this simple graphic by Hiroyuki Kajimoto, I implemented it in simulation.



(a) Simple reference design by Kajimoto



(b) Schematic with H-Bridge setup.



(c) Resulting current output at the load resistor.

We are now capable of adapting the signal to exactly what we want. The problem is that for each PWM signal, we will need the V-I component. For each pair of electrodes (Anode and Cathode) that we power, we require four BJTs. The next step would be to achieve similar results with less components. In Hiroyuki Kajimoto's paper, he manages to power his entire electrode array using a 64-channel serial-to-parallel converter. I found a breadboard compatible, 32-channel IC called the HV5523 by Microchip which supports the high voltage. The 74164 by TI is supplied by BELS, and more ubiquitous but it does not support high voltage output.

II. Source Circuit Components (Est. Hrs: 2)

Description

This task is much easier than the last. With all the specific circuit components decided on with the completion of simulation of our desired circuit, no hard decisions should be required. This task involves sourcing all components necessary for our circuit. The main function of this task is to describe which ICs we decided on, as well as other circuit component values and why we chose them. An example would be the part number of the Op-amp we used and if the current limits are high enough. It will also require finding out how to acquire any missing components.

Walk-Through

III. Implement the Signal (Est. Hrs: 5)

Description

This task involves building the circuit and testing to ensure we get the expected output at the electrode. With all the sub-tasks leading to this, the hope is that this task should be trivial.

Walk-Through