Week of Sept. 6th

After having a second meeting with Dr. Ara as a group, we:

- Set up individual research goals for each member.
- Established a date/time to meet with Textron Aviation to discuss questions/concerns.
- Began creating a timeline of when each step of our design needs to be accomplished to bring to our Textron meeting.
- Created our team project proposal and detailed our projects requirements.

Individually, I have begun by part of the group research into DC brushless motors. I found information related to the voltage, current, and torque characteristics of BLDC motors and helpful equations for future design calculations.

Research: https://www.integrasources.com/blog/bldc-motor-controller-design-principles/

Week of Sept. 20th

After having a meeting with Textron Aviation last week, we have begun to research each area of our circuit based on recommendations from Dr. Ara. In the meeting with Textron Aviation, they recommended we use LTspice to design circuits digitally. I have begun to experiment with LTspice to understand how the program works.

For research, I have begun to investigate voltage regulators and filter circuits. Based on research, our team is thinking of using a simple Zener Diode voltage regulator. Regarding the filter, we believe a low pass filter will suit our needs the best due to it having a range of 0 to a critical frequency.

Research: https://sciencing.com/function-voltage-regulator-5380230.html

https://www.electronics-tutorials.ws/filter/filter_2.html

Week of Oct. 11th

During the period of our Midterm presentations, my main tasks were to create my individual slides for the presentation and make sure I cited any materials I included in the slides. The materials I was responsible for covering were the RC filter components and logic and the overall summary of our project.

After our midterm presentation and some meetings with Dr. Ara, we were suggested to investigate a comparison circuit that could identify the leading of ending edge of each square wave pulse from the tachometer. I was assigned to investigate integrator op-amps, as integration will allow us to evaluate the voltage received across a period of time.

From my research I found some helpful equations that will benefit our tests and calculation for circuit values:

$$V_{out} = -\frac{1}{R_{in}C}\int_0^t V_{in}\,dt = -\int_0^t V_{in}\frac{dt}{R_{in}.C}$$

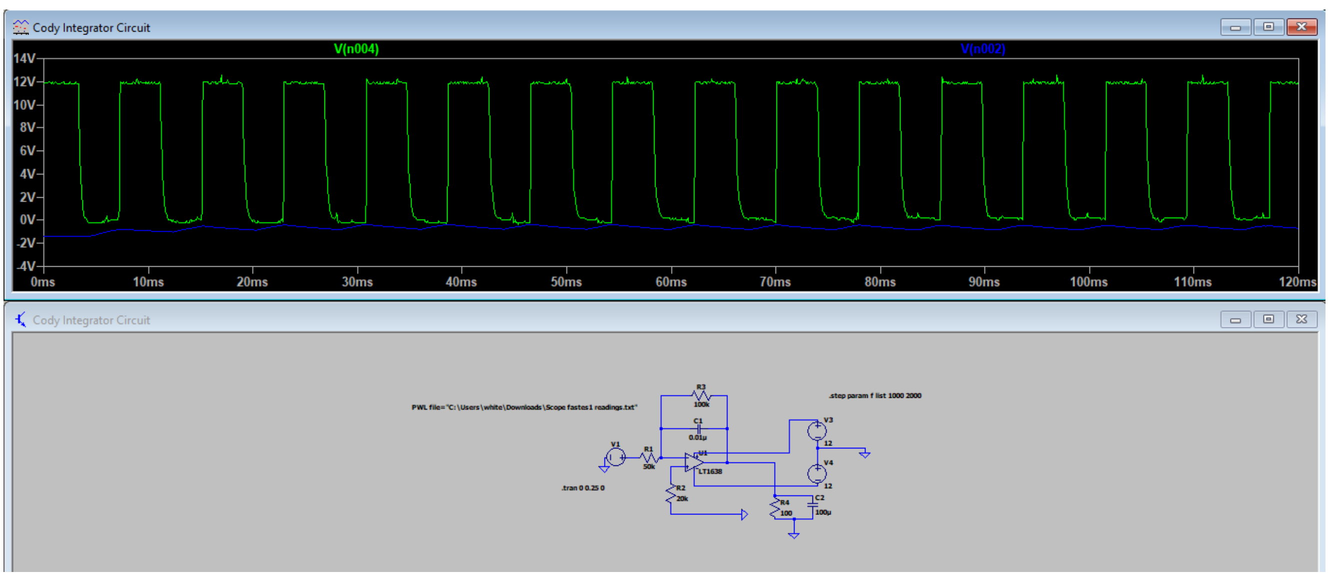
$$V_{out} = -\frac{1}{j\omega RC}V_{in}$$

https://www.electronics-tutorials.ws/opamp/opamp_6.html

Week of Oct. 25th

During this period, I have been largely working on getting a good design for the Integrator circuit we plan to implement. This circuit will allow us to grab a leading/lagging edge of each pulse of our square wave input, without using any memory or storage (ie. Programmable devices). We need this in order to identify if the current frequency being read is beyond our threshold or below the threshold minus the hysteresis.

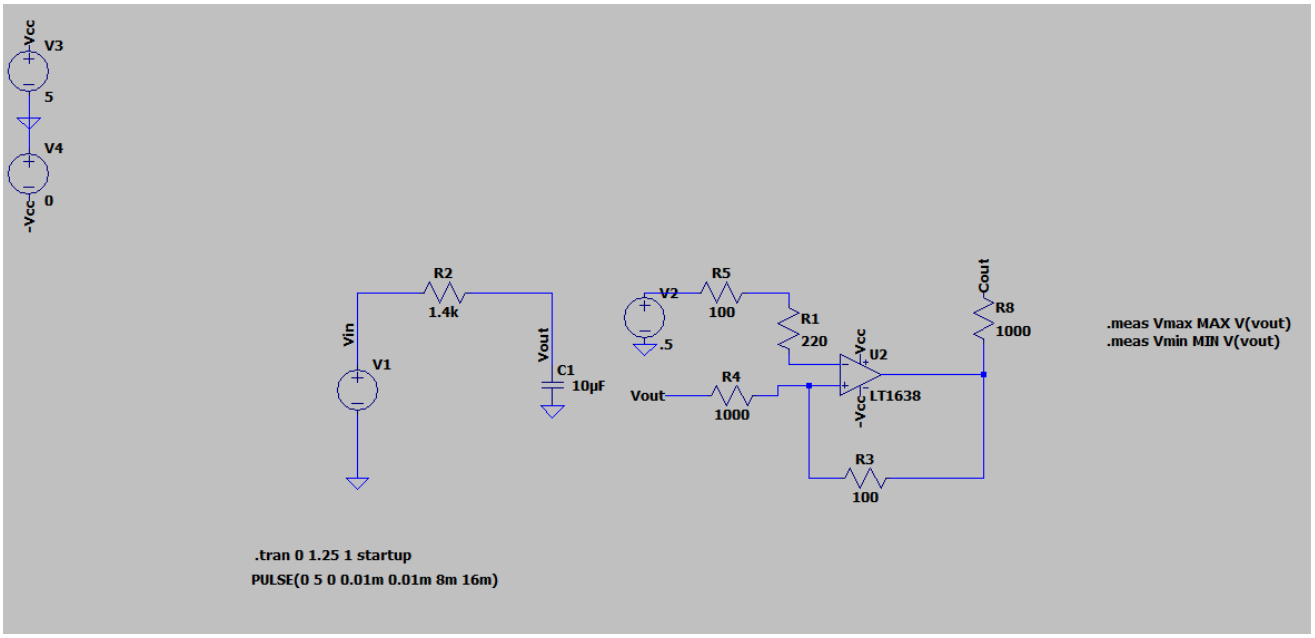
I did some testing in LTSpice, and after tweaking the circuit for a while, I came up with this design:



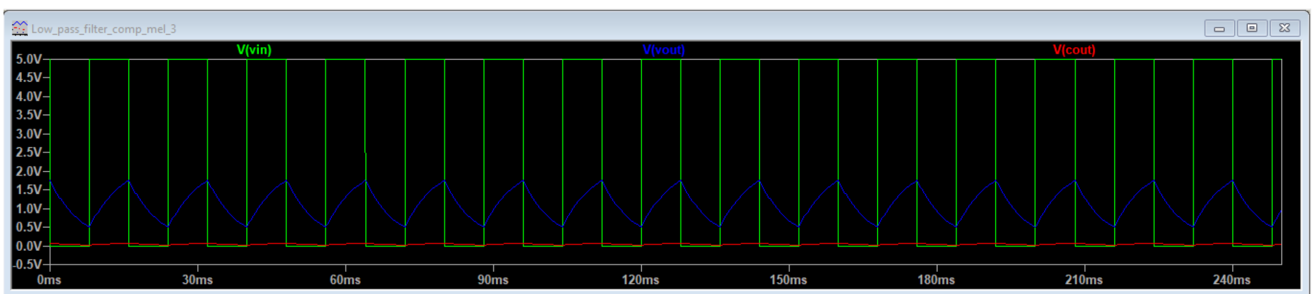
The integrator acts as a function generator, which transforms the square wave into a sawtooth signal, and inverts the output voltage so that it is negative. During each positive half cycle, the capacitors charge up and then during the negative half cycles the discharge, giving the constant increase and decrease in output voltage.

Week of Nov. 8th

For this week, me and my team have largely been trying to tweak our current circuits to give us the desired output that we are seeking. I have largely been investigating Integrator op amp circuits, but me and my team recently found an easier way to implement our integrator to easily connect to our comparator circuit. However, we have been having the most problems getting the comparator circuit to trigger when it should. This week, I was able to get the values to a starting point that gets this comparator to switch on and off when desired. This circuit looks like:



The main issue we were experiencing was caused by our C1 capacitor above. Originally, it was 100 uF, which was too high of a capacitance causing the output to become a near DC signal. By lowering the capacitance, we began to get more of a switching effect as seen below:



While it is only slight, we want this switching effect to be close together as to give us the threshold range that we need to create a hysteresis effect. By continuing to lower the capacitance, we should experience a large threshold, and by lowering the total resistance we'll get a larger Vmax from the pulse wave.

Product Reflection:

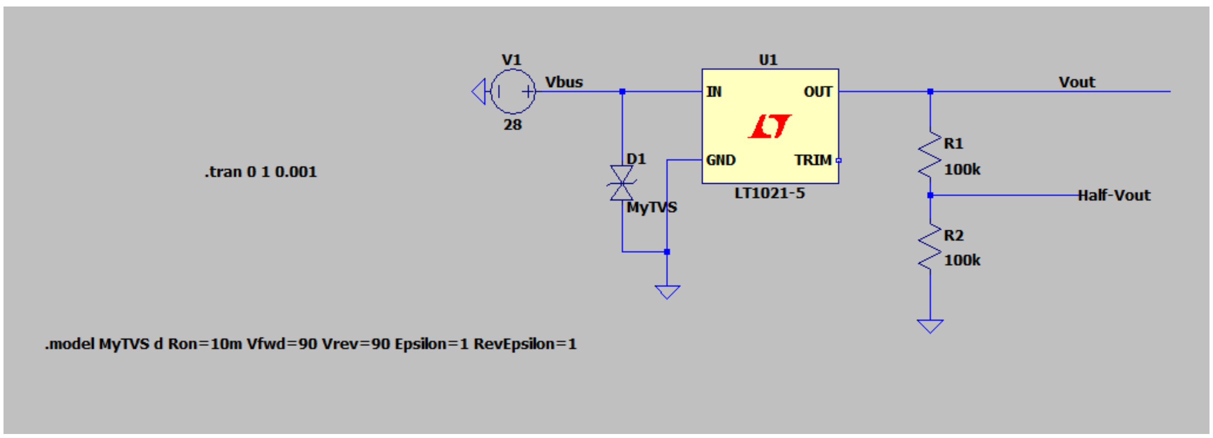
For my team's project, we are trying to address the problem of adding a cooling fan to an airplane's wire bundle. This fan will be used to monitor additional testing that does not currently exist for airplanes during test flights. This problem is worth addressing because airplanes are a vehicle that people greatly value the safety of. A crash from an airplane can be far more catastrophic than a car crash, so creating more parts to monitor additional data will allow engineers to create even safer and more efficient airplanes for consumers. Based on the requirements specified to us by Textron Aviation, we know that the frequency being provided by a motor will need to be monitored to see if it is operating outside of the threshold set for it. We have decided to accomplish this by implementing an integrator circuit. This circuit will be used to change the square wave form into a sawtooth wave form, where each triangle has a specific area that can be observed. If this area gets too large, then we know that the frequency is getting lower and into a range that may not be optimal. If this happens, then the comparator circuit will receive this area and see that the area (voltage) is too large and should be grounded out. If the area is optimal, then the signal can simply be passed through. This logic has been getting us quite close to solving the main function of the circuit, but we still have not addressed a few parts. We still need to establish a good voltage regulating circuit that can manage the voltage provided by our power bus, as well as a way to manage the current that is in the output. We know we need to be able to provide up to 1 amps constantly, so we are assuming that a MOSFET or Transistor can accomplish this part very easily, while something like a Metal Oxide Varistor could accommodate the varying voltage and a voltage regulator will set it to a lower constant voltage.

Second Semester

Week of 2/7/22:

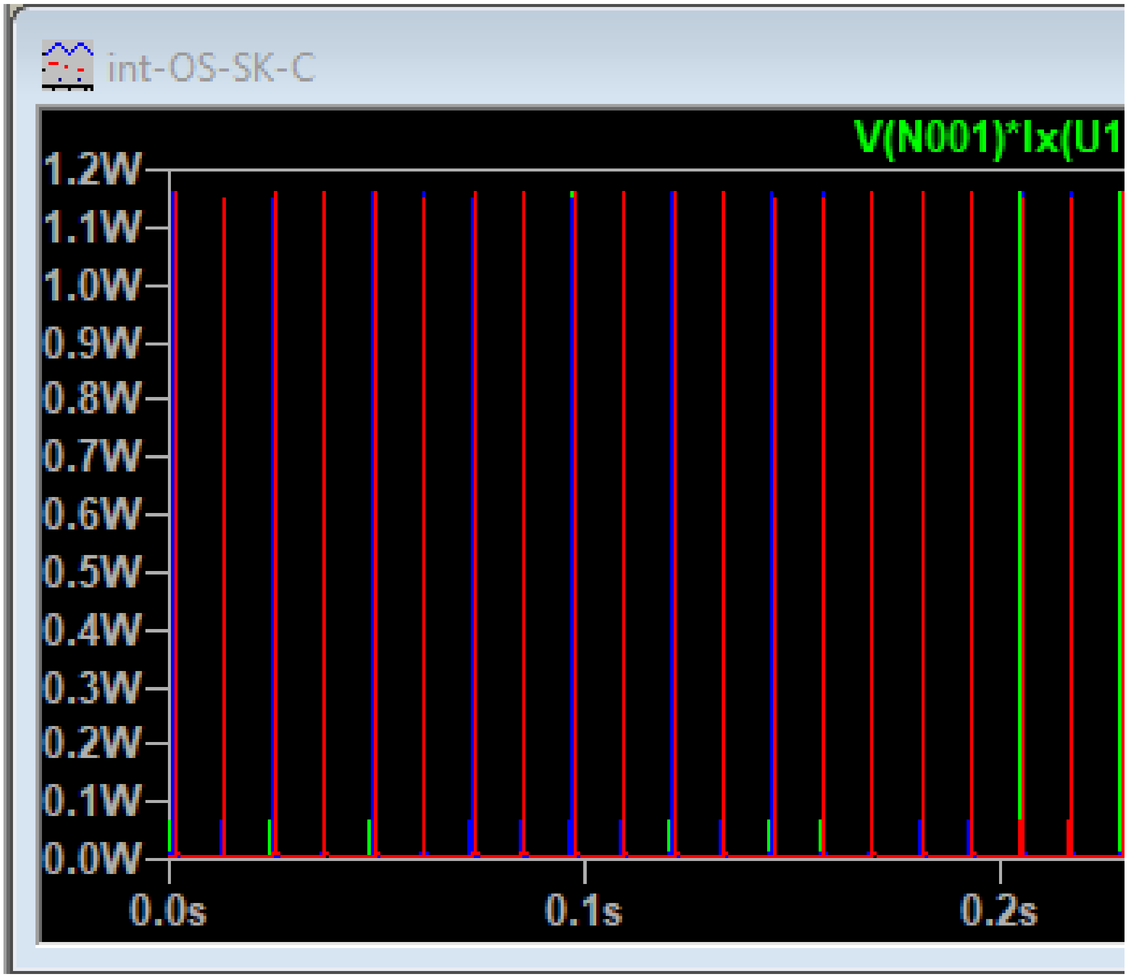
Currently me and my team are working to get a fully finished protype from start to finish. The main issues we are working to address are the output section where we need to sink 1 A continuously, and PCB design, and the effects of heat on the circuit. I am currently working to understand the effects of heat on the circuit and have been working on the design of our power section input.

Regarding the power section input, I have created the design below:

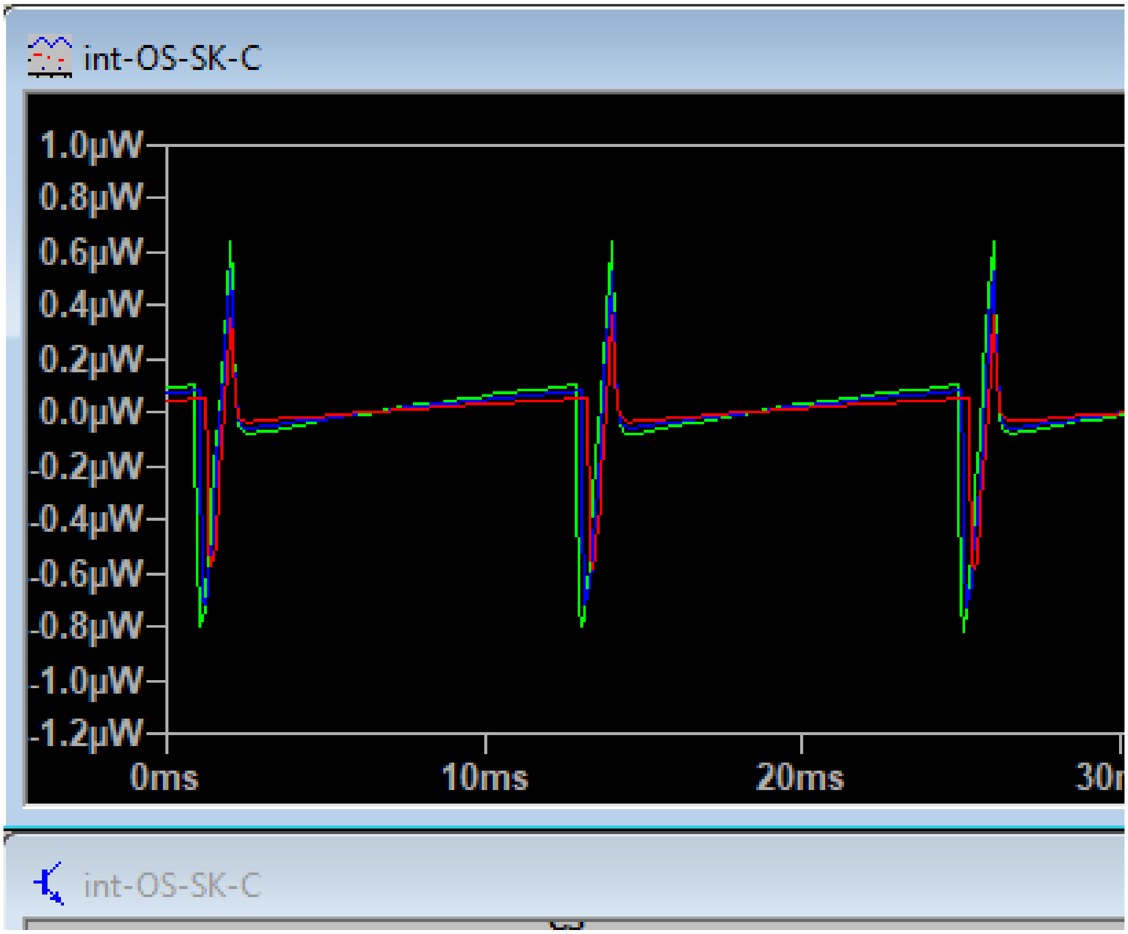


This design uses a 5-volt linear voltage regulator with a TVS diode rated for 90 V. The regulator is used to maintain the power busses input voltage to 5-volt, and the TVS diode is used to protect against voltage spikes from lightning, which is one of our DO requirements. There is also a voltage divider circuit included to provide 2.5-volts to the comparator circuit later in the main circuit.

Regarding the effects of temperature, I ran the following tests in LTspice:



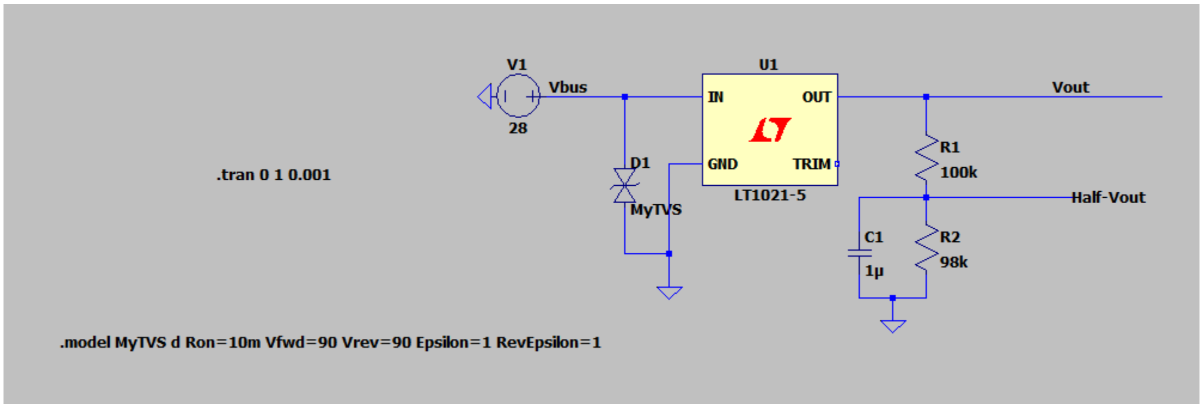
By evaluating the change in power for different temperatures, I can see how much the temperature is affecting the performance of the circuit. In this case I ran for three temperatures (-40, 27, and 125 degrees Celsius) where the green lines are the coldest temperatures, and the red lines are the hottest temperatures. For this example, I was evaluating a NE555 timer in the PWM part of our circuit which does not have much change with temperature at all. However, below is the response for a feedback capacitor in our integrator circuit section:



Colder temperatures require more power is used to reach the desired performance, while hotter temperatures use far less power. Resistors will have a similar response as resistors will have to get hotter to maintain their values properly in a circuit.

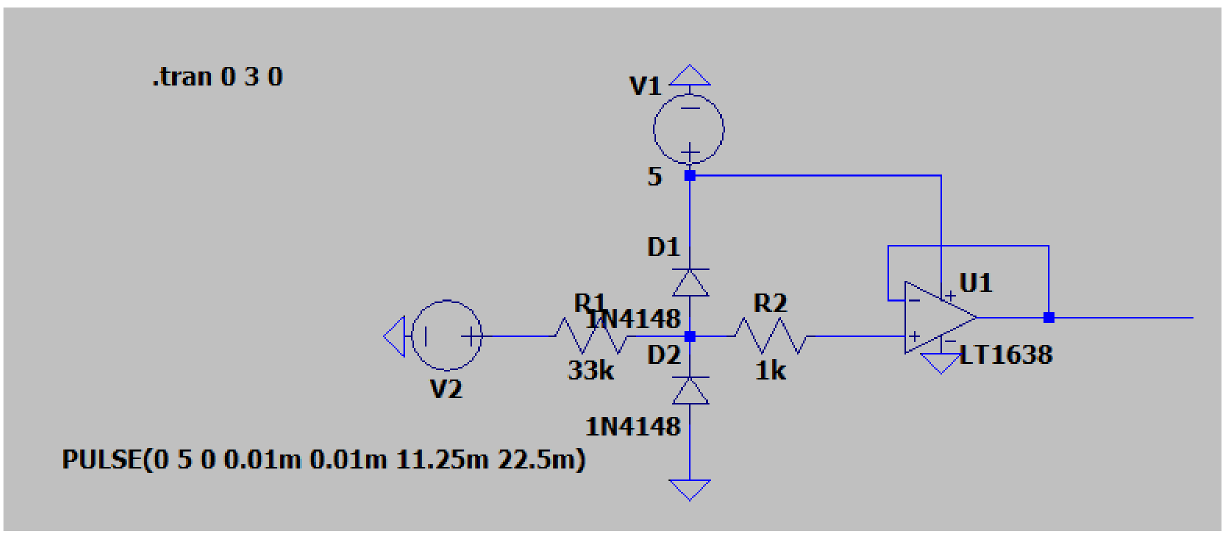
Week of 2/21/22:

For this week, I primarily focused on finishing the last parts of our circuit. Because I have designed the power bus regulator to include a TVS diode, we have lightning protection in our power section:



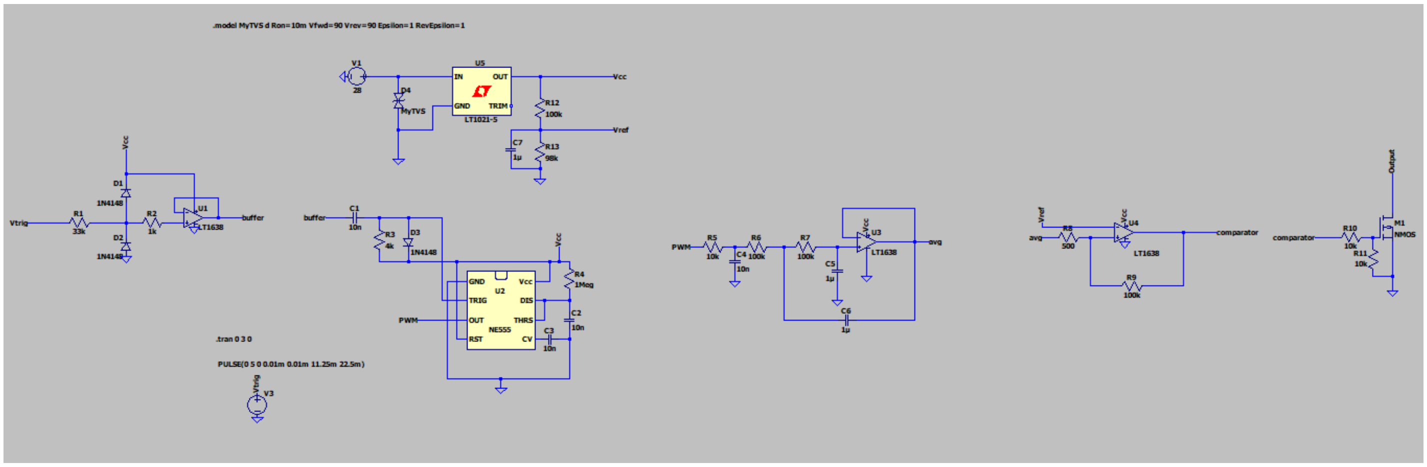
TVS diodes are great at taking large voltages and grounding them out to prevent circuit damage. Since a lightning strike will create huge voltage spikes, this diode will activate once that large voltage enters the voltage section and ground it out.

Since the output section uses a MOSFET, there is already lightning protection as MOSFETS have a natural protection against lightning. This thus left our input section to be protected against lightning. To accomplish this, we were recommended to use a buffer circuit by Clinton (our Textron tasking engineer). After researching buffer circuits, specifically using a Schmitt Trigger, I created the following circuit:



This circuit uses the feedback loop to compare the previously recorded input versus the next recorded input. If the input that comes after the feedback is drastically different (ie. in the case of high voltage spikes from lightning), the op amp will prevent the flow of electricity by turning off and the remaining voltage will ground out through the 1N4148 diode, after the current is lowered by going through R1.

After this, I went ahead and combined all parts of the circuit together to make sure the circuit worked as a finished product, and this is what that circuit looks like:



.model MyTVS d Ron=10m Vfwd=90 Vrev=90 Epsilon=1 RevEpsilon=1
V1
28
D4
MyTVS
U5
IN
OUT
GND
TRIM
LT1021-5
Vcc
R12
100k
Vref
C7
1µ
R13
98k
Vcc
D1
1N4148
Vtrig
R1
33k
R2
1k
U1
LT1638
buffer
D2
1N4148
buffer
C1
10n
R3
4k
D3
1N4148
Vcc
R4
1Meg
GND
U2
Vcc
TRIG
DIS
PWM
OUT
THRS
NE555
RST
CV
C2
10n
C3
10n
.tran 0 3 0
PULSE(0 5 0 0.01m 0.01m 11.25m 22.5m)
Vtrig
V3
PWM
R5
10k
C4
10n
R6
100k
R7
100k
C5
1µ
Vcc
U3
LT1638
avg
C6
1µ
Vref
avg
R8
500
Vcc
U4
LT1638
comparator
R9
100k
comparator
R10
10k
R11
10k
M1
NMOS
Output