



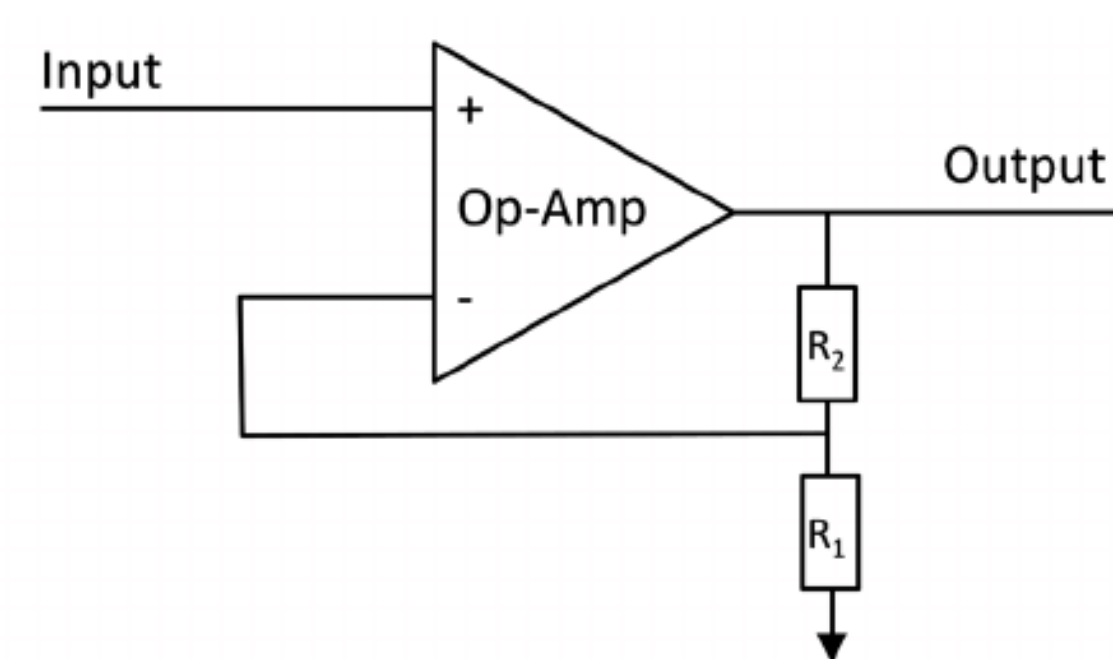
PROBLEM

- Piezoelectric mirrors are used to test the attitude control system of the spacecraft
- Available voltage to supply to the mirrors is 0 – 3V
- The mirrors require a range of 0 – 10V supplied
- Create a non-inverting amplifier capable of scaling up the available voltage to the desired 0 – 10V

APPROACH

- Research op amps to learn more about how they function and how they can be designed.
- Knowing desired values, fabricate custom op amp
- Gain is the ratio of the input to output voltage, round up to ensure proper supplied voltage:

$$\frac{10}{3.3} = 3.1 \text{ (Gain)}$$



$$\text{Gain} = G = 1 + \frac{R_2}{R_1}$$

- In a non-inverting op amp, gain can be calculated using the equation below.

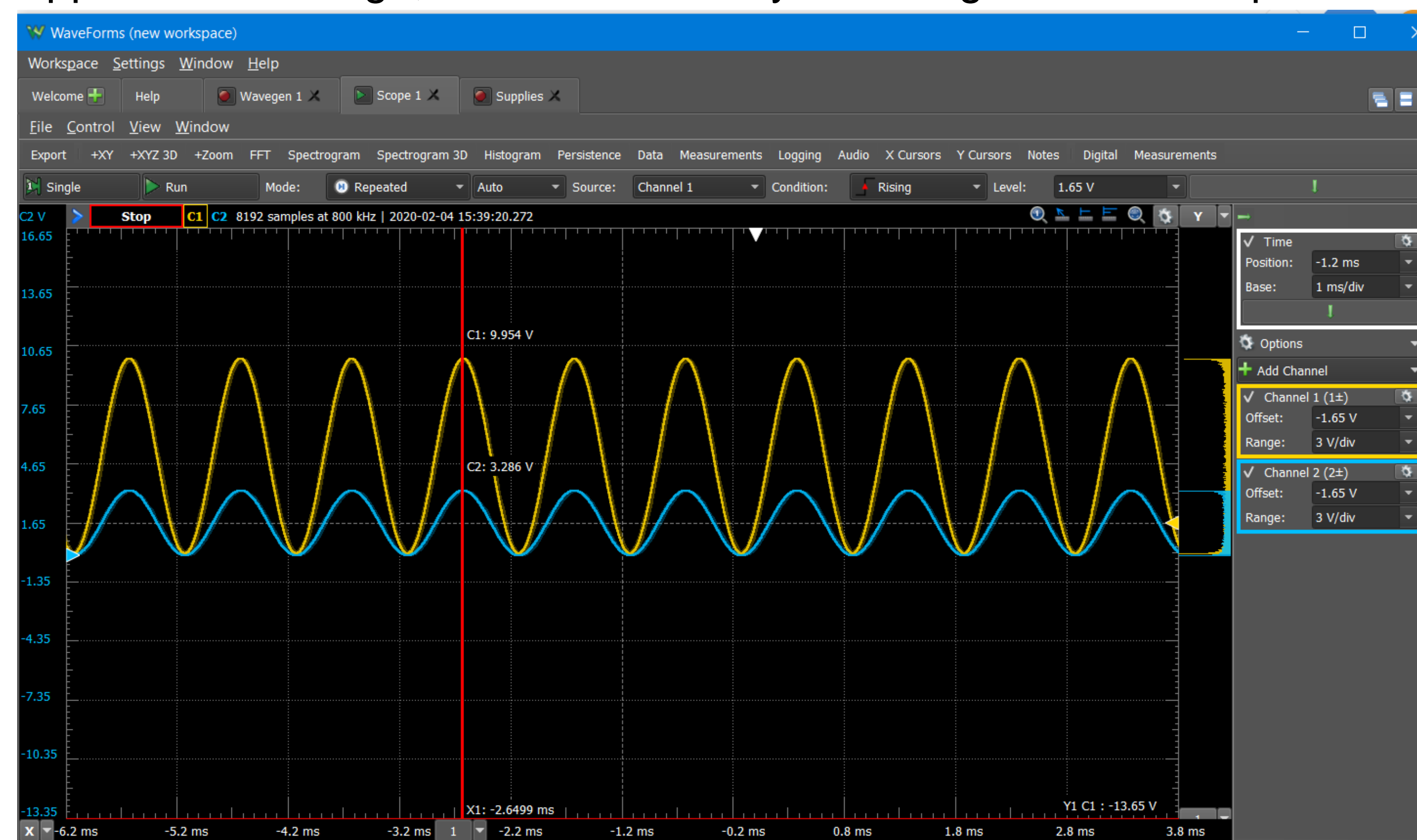
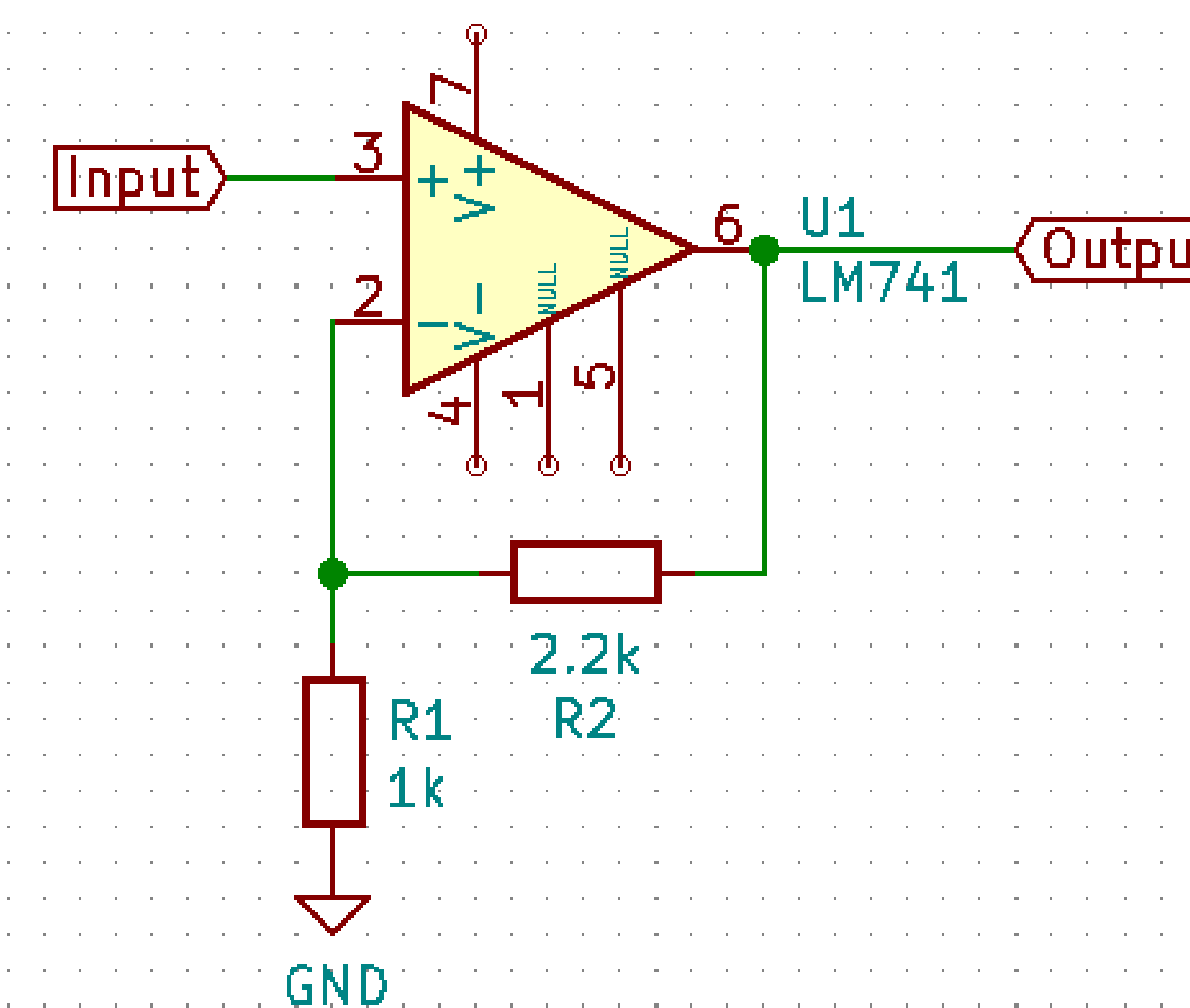
$$\frac{R_2}{R_1} + 1 = 3.1 \text{ (Gain)}$$

- Resistance ratio of 2.03, R2 must be double R1

METHODS/ RESULTS

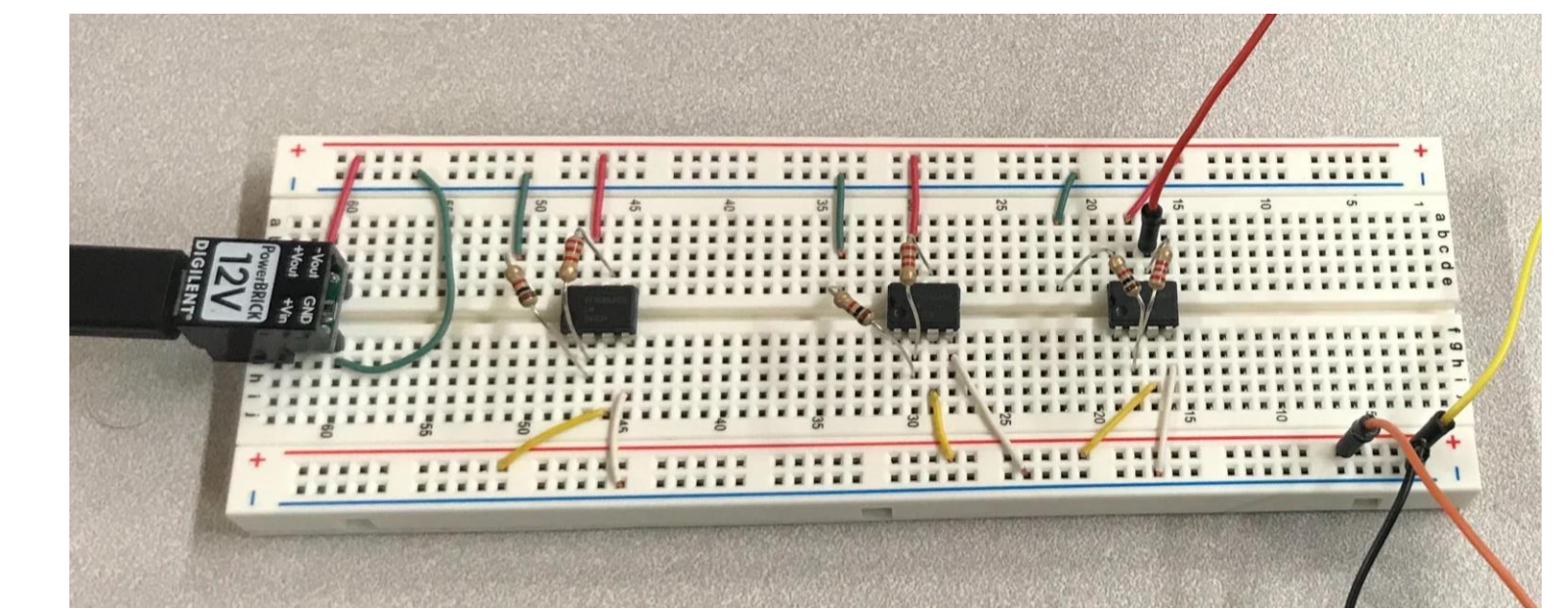
- The primary characteristics of an operational amplifier include high input impedance, low output impedance, and high open-loop gain. All contribute to the ability to control closed-loop gain through feedback and input impedance.
- To ensure enough voltage is supplied, R2 is set to 2.2kΩ and R1 to 1kΩ

$$\frac{2.2k}{1k} + 1 = 3.2 \text{ (Gain)}$$
- The schematic for the circuit is drawn up in KiCad
- The input draws no current, meaning the current flowing through R1 and R2 is the same
- The voltage at the negative, inverting, terminal is equal to the voltage across R2, found using voltage division
- The inverting voltage is equal to the non-inverting input voltage
- This means $V_{in} = V_{out} * \frac{R_1}{(R_1+R_2)}$ which can be written as the equation above in terms of gain.
- The circuit is built on to a solderless breadboard for testing
- Supplied with voltage, the circuit is analyzed using an oscilloscope



- The blue wave, channel 2, is the input, 0 – 3.3V, while the yellow wave, channel 1, is the output of the op amp, 0 – 9.954V
- With a desired max voltage of 10V, 9.954V is only 0.46% off

RESULTS



- The desired output voltage has been achieved
- Circuit is remade two more times to allow for further testing

CONCLUSIONS

- A non-inverting operational amplifier with a gain of 3.2 was created
- The op amp brings the present 0 – 3.3V to the desired 0 – 10V
- Calibration of the piezoelectric mirrors to ensure proper function is required before further testing is possible
- The next step is to test the operational amplifier hand in hand with the piezoelectric mirrors
- I was able to get industry-like experience working in a rapid design environment
- Given a chance to complete every step in the circuit's fabrication: research, design, prototyping and testing

ACKNOWLEDGEMENTS

Sunip Mukherjee
Sanjeev Mehta