ASEN 3300, Fall 2023: Lab 6 Report Submission

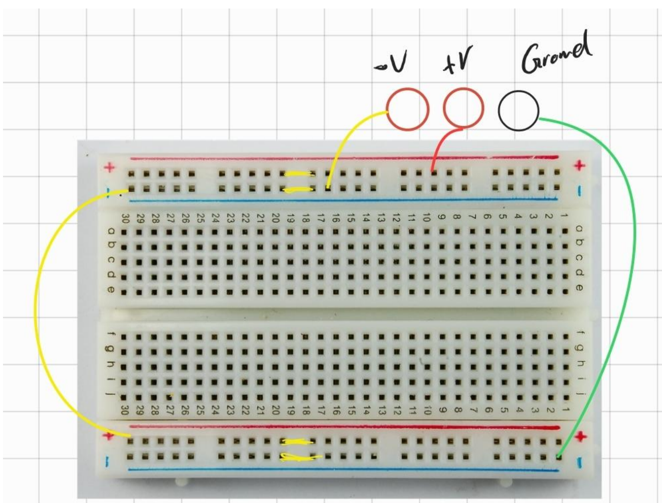
Names:	Joshua Geeting
	Brady Sivey
	Jared Steffen
Section:	012

---

4. Experiment (30 pts)

4.0. Breadboard layout (3 pts)

Red: +V
Yellow: -V
Green: Ground
Orange: Signal (not drawn)



4.1. Inverting Amplifier (5 pts)

a. Record your responses to 4.1.a in the table below:

R1:	10 kΩ
Rf (Feedback resistor):	20 kΩ

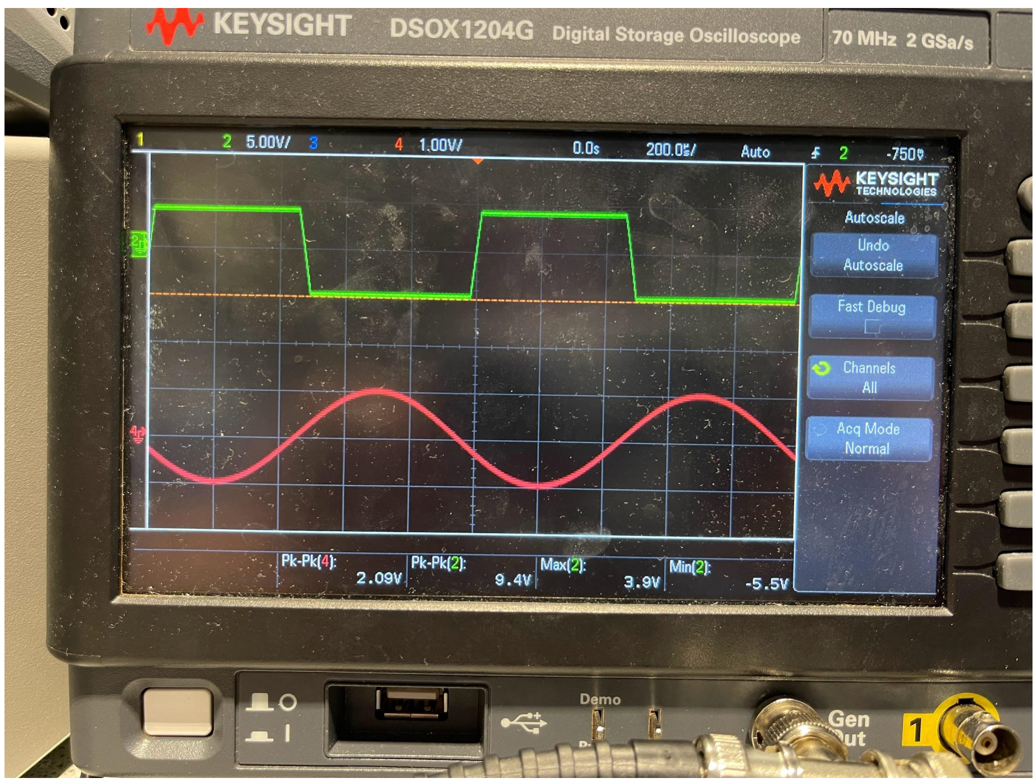
b. Record your responses to 4.1.b below:

+V:	+5.01V
-V:	-5.01 V

d. Record your responses to 4.1.d below:

V_{PK} (output **amplitude - not V_{PP})**	4.3 V
Computed gain	6 dB

e. Record your responses to 4.1.e below:

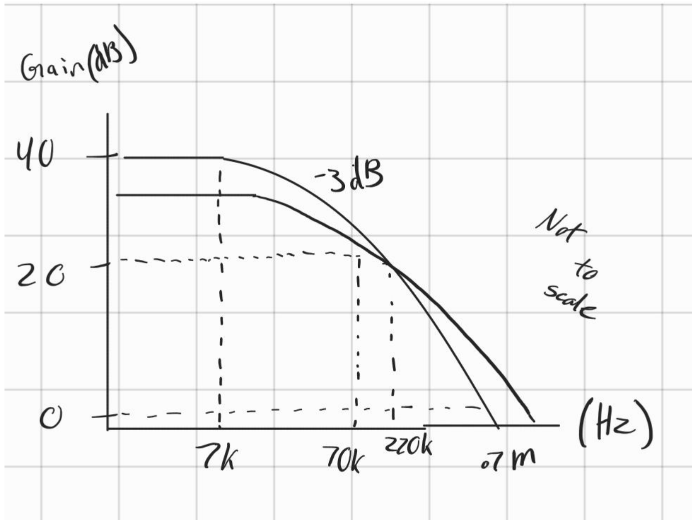


$+V_{SATURATION}$ (max voltage):	3.9 V
$-V_{SATURATION}$ (min voltage):	-5.5 V

4.2. Amplifier Limitations (5 pts)

a. Record your responses to 4.2.a below:

Predicted -3dB frequency:	220 kHz



b. Record your responses to 4.2.b below:

Amplifier actual bandwidth (-3 dB frequency):	169.5 kHz

c. Record your responses to 4.2.c below:

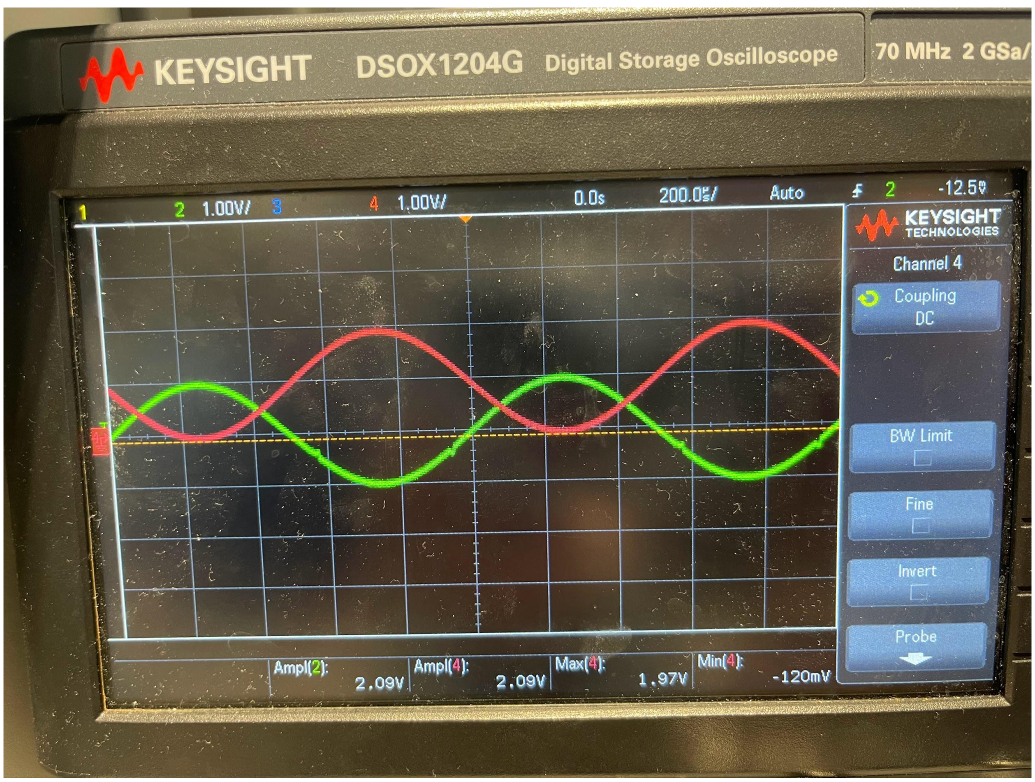
Gain dB:	-1.64 dB
Linear amplitude ratio V_O/V_I:	0.82

4.3. Summing Amplifier (5 pts)

d. Record your response to 4.3.d below:

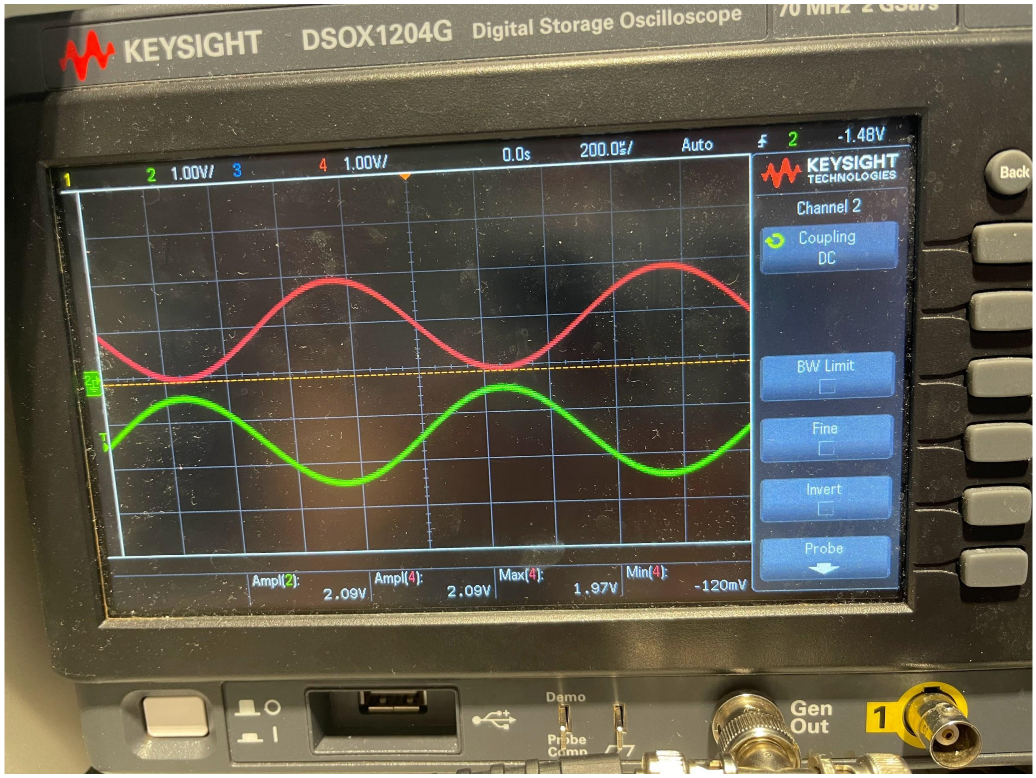
DC offset:	0 V
Gain V_1:	1

e. Record your response to 4.3.e below:



g. Record your responses to 4.3.g below:

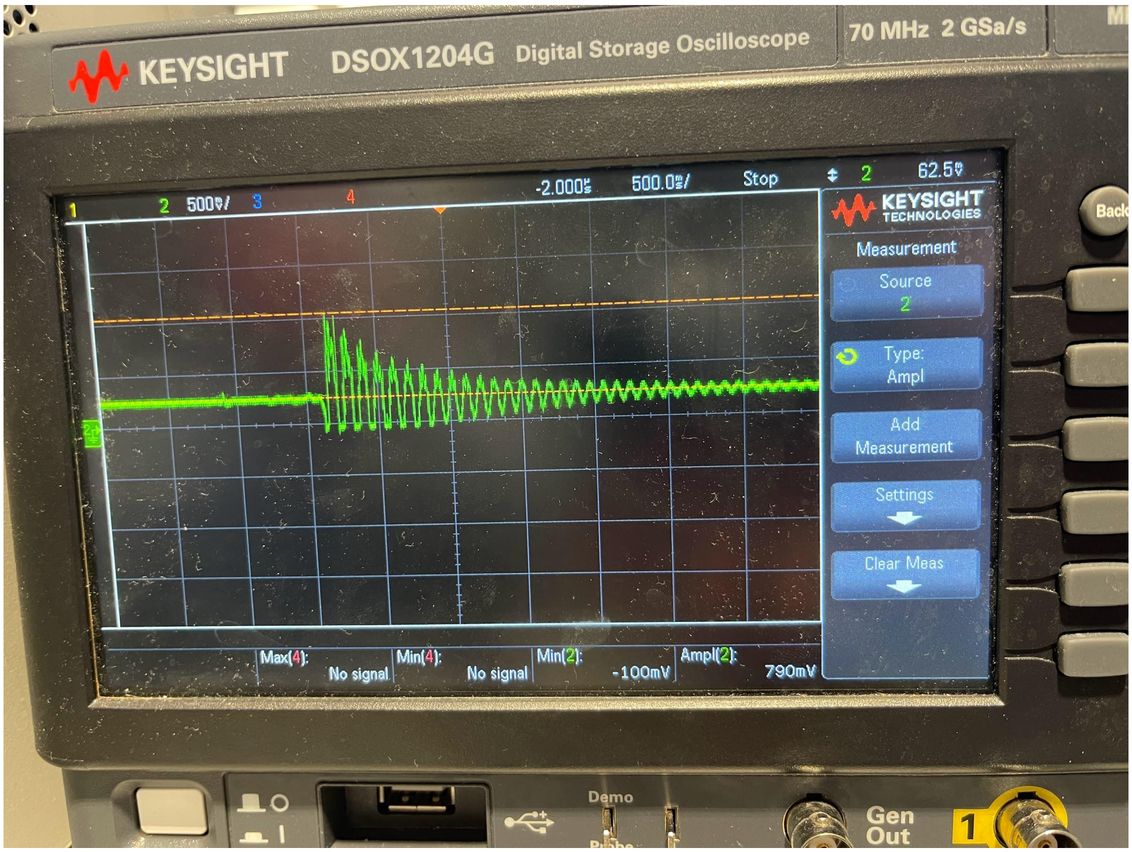
DC Offset: Change in DC offset goes from 1V to -1.5V (-2.5 V total)



4.4. Vibrating Beam (4 pts)

c. Record your responses to 4.4.c below:

Beam length used for this part (in):	14”



The oscilloscope shows a negative sinusoidal wave (due to the way the beam was deflected). While there was some noise in the signal captured, it had decaying oscillations over time.

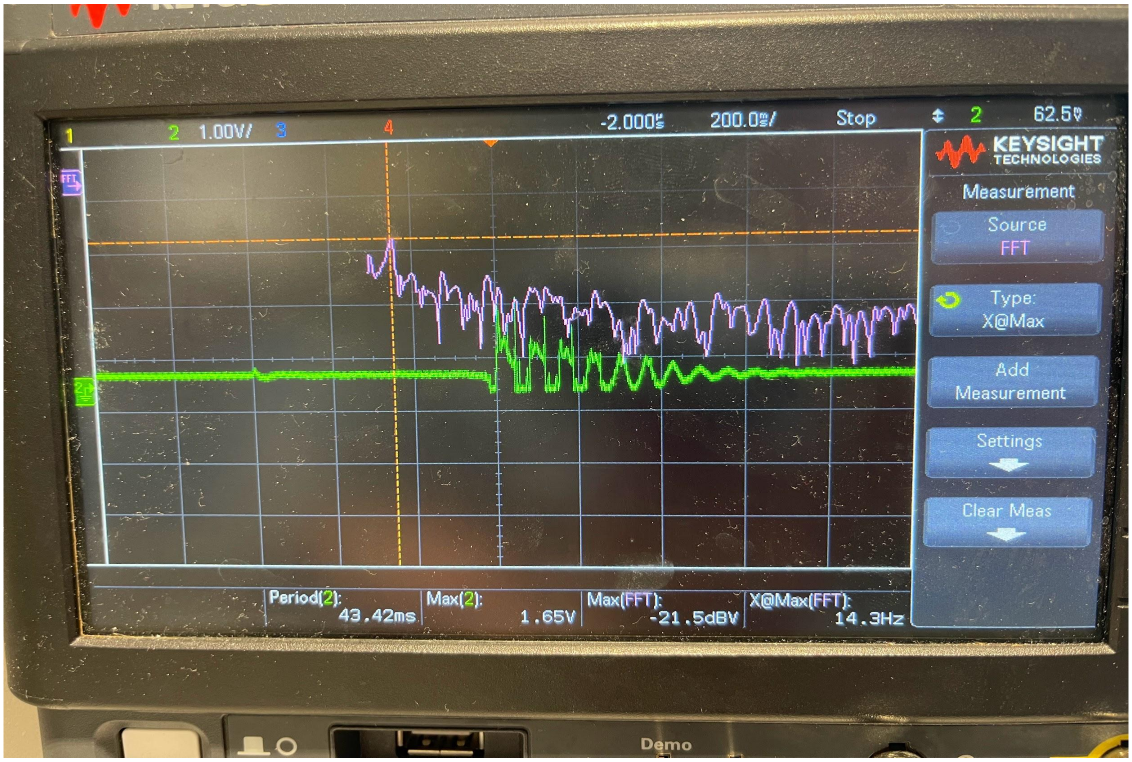
Period of oscillations:	13.9 ms
Amplitudes of oscillations:	790 mV

1st peak - 790 mV
2nd peak - 569 mV

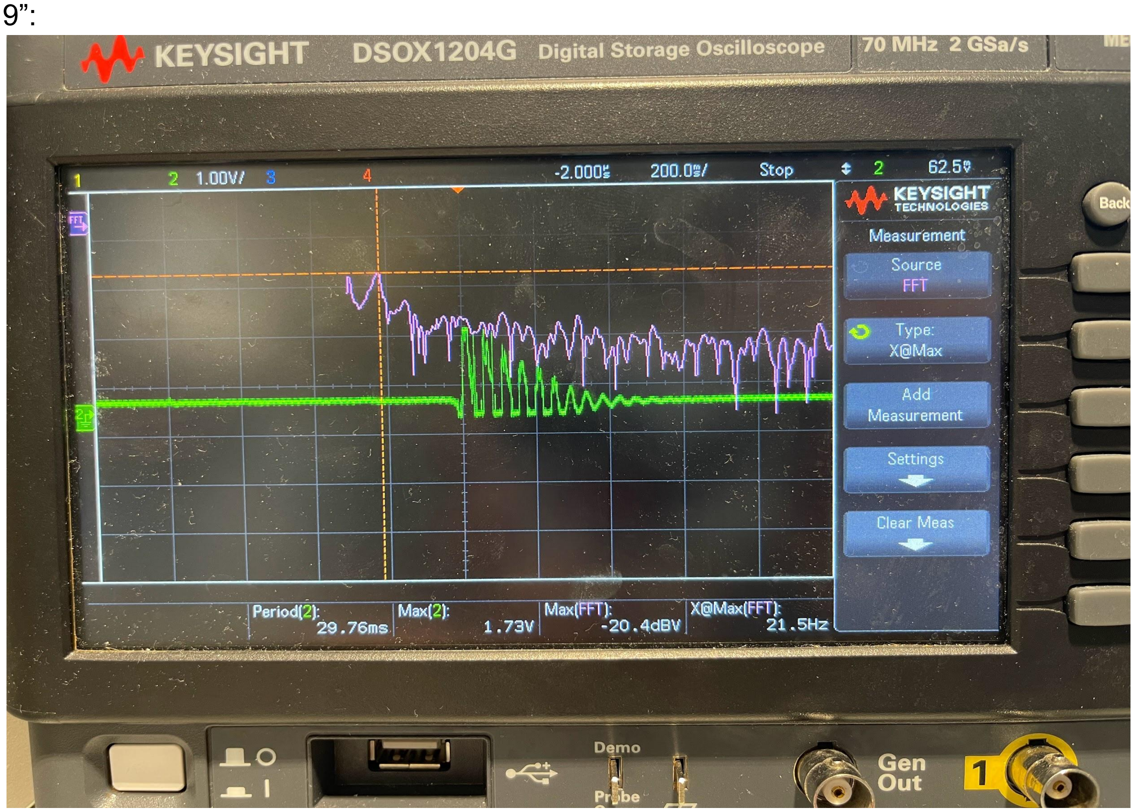
Damping ratio: 0.052

d. Record your responses to 4.4.d below:

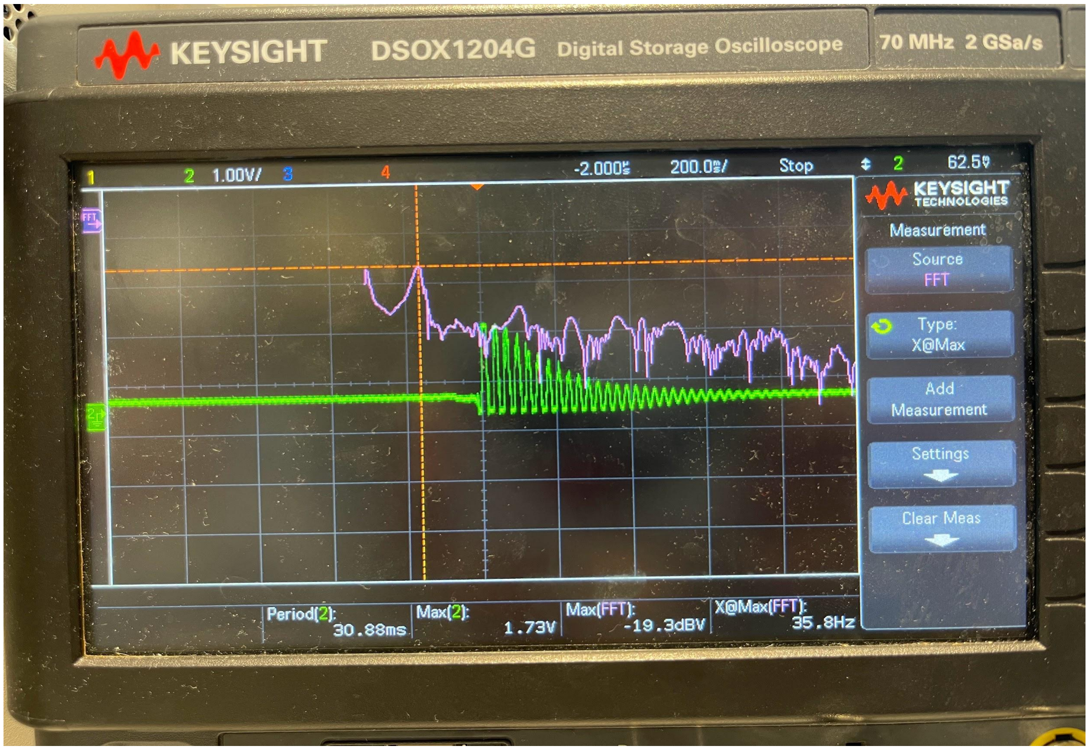
11":



9":



7”:



11”: 0.306 V 9”: 0.347 V 7”: 0.395 V
11”: 14.3 Hz 9”: 21.5 Hz 7”: 35.8 Hz

e. Record your response to 4.4.e below:

As beam length gets shorter, the resonant frequency increases.

4.5. Accelerometer Signal Conditioning DC:

To help with a smooth design process of the signal conditioning circuit, this section will have you setup and verify intermediate stage outputs. Before beginning, please check your signal conditioning circuit, designed in prelab Q 9, with a TA or Professor. Your goal is to provide (V_{out} = 0 ± 1 V/g) for the ADXL at the output of your signal conditioning circuit.

b. Record your responses to 4.5.b below:

$V_{OutDivider} = V_{R2} =$	3.607 V
$R_1 =$	330 Ω
$R_2 =$	1 kΩ

c. Record your responses to 4.5.c below:

Sensitive axis chosen (X or Y):	X axis
V_{out} (Sensitive axis up):	1.101 V
V_{out} (Sensitive axis down):	1.215 V
V_{out} (Flat on table w/ solder mask up):	1.161 V
V_{out} (Flat on table w/ solder mask down):	1.591 V
V_{out} to g relation (V_{out} = offset [V] + sensitivity [V/g or mV/g]):	1.158 V + 52.2 mV/g

e. Record your responses to 4.5.e below:

Expected Gain (V_{out}/V_{in} linear gain)	3.61

Sensitive axis chosen (X or Y):	X axis
V_{out} (Sensitive axis up):	198 mV
V_{out} (Sensitive axis down):	-197 mV
V_{out} (Flat on table w/ solder mask up):	-10 mV
V_{out} (Flat on table w/ solder mask down):	10 mV

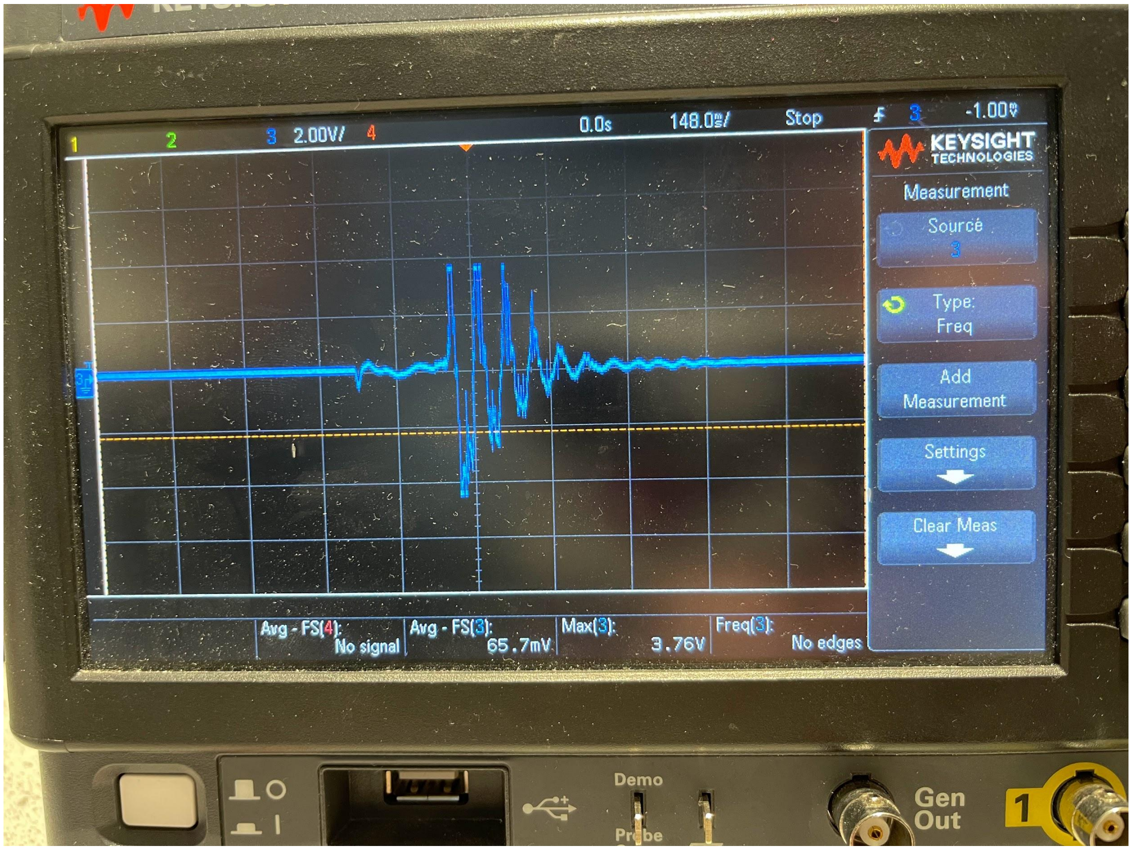
V_{out} to g relation (V_{out} = offset [V] + sensitivity [V/g or mV/g]):	0 V + 198 mV/g
Actual Gain (V_{out}/V_{in} linear)	3.77

f.

The results are expected. There is some discrepancy due to resistor values not being the same as calculated resistor values, but they are within an acceptable range.

4.6. Accelerometer Signal Conditioning Vibrating Beam:

c. Record your responses to 4.6.c below:



Frequency of oscillations:	25 Hz
Amplitudes of oscillations:	3.67 V
DC Offset:	0 V

5. Analysis (20 points)

5.1. Inverting amplifier

a. Record your response to 5.1.a below:

There are many reasons why you would not want to do that. With a 20dB gain, the voltage gain corresponds to 10. So the output voltage would be 10 times greater than the input voltage. And with a 1k ohm resistor as the feedback resistor, you would need a very high input voltage which could possibly damage the amplifier or circuit. Also even a small input noise would be amplified and lead to a noisy output.

b. Record your response to 5.1.b below:

After removing the feedback resistor, the inverting amplifier outputs a square wave instead of a sine wave. When you remove the feedback resistor, you break the feedback loop that determines the gain and stability of the amplifier. In result, getting an undesired behavior like a square wave.

5.2. Amplifier limitations

a. Record your response to 5.2.a below:

An input amplitude of approximately 2.393 V will cause the inverting amplifier to clip. This is determined by computing the linear gain (A) to be 5.012 given the dB gain. This can then be used to compute Vin through the equation Vout=A*Vin, where Vout = 12 V.

b. Record your response to 5.2.b below:

No. The inverting amplifier we used is essentially a low pass filter, so higher frequency waves will see little dB gain.

c. Record your response to 5.2.c below:

Yes it's possible to model the output of an inverting amplifier as a simple RC low pass filter with a gain(A).

RC = 1 / (2π*f_inv_amp * A)

F_inv_amp = 169.5 kHz
A = gain = V_O/V = 0.82

RC = 0.00115

d. Record your response to 5.2.d below:

Inverting amplifiers can be seen in many electronics. They are commonly found in audio implications as they are able to correct phase shifts of the signal.They are also used commonly in active filters.By using a capacitor in the feedback loop, they can be changed into low-pass, high-pass or band-passs filters. But there are limitations to inverting amplifiers. They are not suitable for high-frequency applications as they have limited bandwidth from internal limitations. And as mentioned in 5.1, noise is also amplified. So they are not suitable for low noise applications.

5.3. Summing amplifier (no analysis questions)

5.4. Vibrating Beam

NOTE: For 4a-4c please clarify the beam length you are referring to and keep it consistent throughout the 3 questions.

a. Record your response to 5.4.a below:

The beam length used was 14’’ And we observed a negative sinusoidal oscillation over time. This makes sense as the beam was in oscillatory motion, therefore producing various g values and voltage responses.

b. Record your response to 5.4.b below:

$W_0 = 2\pi\left(\frac{1}{T}\right)$ $T = 13.9\ ms = 0.0139\ s$

$\boxed{W_0 = 452.03\ \frac{rad}{s}}$

$A_i = A_0 e^{\eta w_n t_i}$

$A_1 = 790\ mV$ @ $t = 13.9\ ms$

$A_2 = 569\ mV$ @ $t = 27.8\ ms$

$.790 = A_0 e^{-\eta(452.03)(0.0139)}$ $0.569 = A_0 e^{-\eta(452.03)(0.0278)}$

$x_1 = 0.79 = A_0 e^{-6.283\eta}$ $x_2 = 0.569 = A_0 e^{-\eta(12.566)}$

$\frac{x_1}{x_2} = 1.3884 = e^{\eta(6.283)}$

$6.283\eta = \ln(1.3884)$

$\boxed{\eta = 0.052}$

The damping ratio and natural frequency were determined from the above equations.

c. Record your response to 5.4.c below:

In order to find the maximum acceleration, we can do the peak amplitude (790 mV)/ the slope of the accelerometer output (52.2 mV/g) this then produces a result of 15.13 gs which is equivalent to a 148.31 m/s^2 acceleration.

d. Record your response to 5..d below:

If you were to clamp the end closer to the tip of the beam we would see a change in period of oscillation. We would have a much quicker response. As a result, the damping ratio and natural frequency would change.This is because there is less deflection when bending a smaller beam when compared to a longer beam.

5.5. Accelerometer Signal Conditioning

a. Record your response to 5.5.a below:

Our signal conditioning circuit involved various design elements to get the intended output signal between 150 and 300 mV/g. First, we created a voltage divider in order to get the voltage going into the accelerometer to be around 3.6 V. This was done using a 330 ohm resistor as R1 and a 1 kilo ohm resistor as R2 connected to a 5V voltage source. With this input voltage, the accelerometer outputs a signal of 1.158 V + 52.2 mV/g. We then decided to put this signal through a voltage follower to account for the accelerometer's high output impedance. Finally, the signal passes through the summing amplifier. Part of this summing amplifier was designed to cancel out the DC offset voltage. This was done by connecting a voltage divider to a -5 V power supply in order to drop the voltage as close to -1.158 V as possible. The other part of the summing amplifier involved amplifying the signal through the 10 kilo ohm feedback resistor connected to the summing op amp. This ultimately produced a signal of approximately 0 V + 198 mV/g. These results showed that the DC offset was removed and the 52.2 mV/g signal was amplified from the original output of the accelerometer before the signal conditioning.

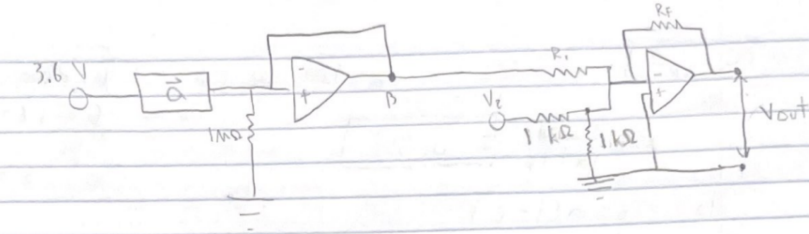
b. Record your response to 5.5.b below:

We would not have been able to achieve the same results without the buffer circuit. Due to the accelerometer's high output impedance, without the voltage follower, we would have only been reading around 0.23*V accelerometer. With the high input impedance and low output impedance of the op amp, we are able to minimize the output impedance of the accelerometer and produce a voltage reading of about 0.97*V accelerometer.

c. Record your response to 5.5.c below:

ADXL326 output $= 0.9\text{ V} \pm 52.2 \frac{\text{mV}}{g}$

Desired output $= \frac{1\text{ V}}{0.01 g} = 0\text{ V} \pm 100000 \frac{\text{mV}}{g}$



$V_B = 0.97 V_{acc}$

$V_B = 0.873\text{ V} + 50.634 \frac{\text{mV}}{g}$

$V_2 = -0.873 \times 2$

$\boxed{V_2 = -1.746\text{ V}}$

$V_{out} = -R_F\left(\frac{V_2}{R_2} + \frac{V_1}{R_1}\right)$

$R_2 = 1\ \Omega$
$V_2 = -1.746\text{ V}$
$V_1 = 0.873\text{ V} + 50.634 \frac{\text{mV}}{g}$
$V_{out} = 100000 \frac{\text{mV}}{g}$
$R_1 = 1\text{ k}\Omega$

$100000 = R_F\left(\frac{-1.746}{1\text{ k}\Omega} + \frac{0.873 + 50.634}{1\text{ k}\Omega}\right)$

$100000 \frac{\text{mV}}{g} = R_F\left(50.634\left(\frac{\text{mV}}{g\text{ k}\Omega}\right)\right)$

$R_F = 1974.95\text{ k}\Omega \approx 2\text{ M}\Omega$