

Su22-ENGR-40M-01 Lab 4

Jannah Sabic El-Rayess

TOTAL POINTS

55 / 55

QUESTION 1

Lab 20 pts

1.1 L1. Vout Amplitude 2 / 2

✓ - 0 pts Correct

- 1 pts Not within reasonable range
- 2 pts Incomplete
- 0.25 pts Peak to Peak instead of Amplitude

1.2 L2. Empirical Gain 2 / 2

✓ - 0 pts Correct

- 1 pts Some error in calculation / out of acceptable range
- 2 pts Incorrect answer; work unclear
- 0.5 pts Does not compare with theoretical
- 0.25 pts other errors

1.3 L3. Screenshot 3 / 3

✓ - 0 pts Correct

- 3 pts Incomplete or missing
- 2 pts Incorrect shape
- 1 pts Taking Values from noise
- 0.5 pts Error (see comments)

1.4 L4. Table and Bode Plot 6 / 6

✓ - 0 pts Correct

- 1 pts All values a little low
- 2 pts Strange values in places lead to non-realistic plot
- 1 pts Gain in passband not close enough to 20dB
- 2 pts Incorrect corner frequencies
- 3 pts Incorrect plot shape
- 6 pts Incomplete/missing
- 0.5 pts Did not plot points and then draw a line through those points

1.5 L5. Offset 2 / 2

✓ - 0 pts Correct

- 2 pts Somehow managed to observe an output offset
- 1 pts Does not state if behavior is consistent or explains why
- 2 pts Incomplete/missing

1.6 L6. Empirical Gain 2 / 2

✓ - 0 pts Correct

- 1 pts Error in measurement/calculation
- 2 pts Incorrect - several errors
- 2 pts Incomplete/missing
- 0.5 pts Does not compare with theoretical
- 0.5 pts Calculates correct gain, but does not mention amplitude
- 0.2 pts Incorrect gain mentioned

1.7 L7. Screenshot 3 / 3

✓ - 0 pts Correct

- 1.5 pts Output clipped
- 3 pts Missing/Incomplete
- 3 pts Incorrect
- 0.5 pts wrong input signal

QUESTION 2

2 Analysis 10 / 10

✓ - 0 pts Correct

- 3 pts No suggestion for adding/changing circuit components
- 3 pts Doesn't explain downside
- 2 pts Right idea but not sufficiently specific (didn't state which direction to shift capacitor or resistor values)
- 10 pts Not completed

- **4 pts** No suggestion to filter out the noise using the filters from the circuit
- **3 pts** Incorrect filter reasoning

QUESTION 3

3 Build Quality 20 / 20

- + **5 pts** plus
- ✓ - **0 pts** Check Plus
- **5 pts** Check
- **10 pts** Check Minus
- **15 pts** minus
- **3 pts** Late

QUESTION 4

4 Cleanup 5 / 5

- ✓ - **0 pts** Correct
- **2 pts** missed a spot
- **5 pts** did not clean up

- *Before you measure, ask yourself:* What amplitude do you expect on the output of the instrumentation amplifier? What offset do you expect? If your oscilloscope doesn't show what you expect to see, debug this before continuing!

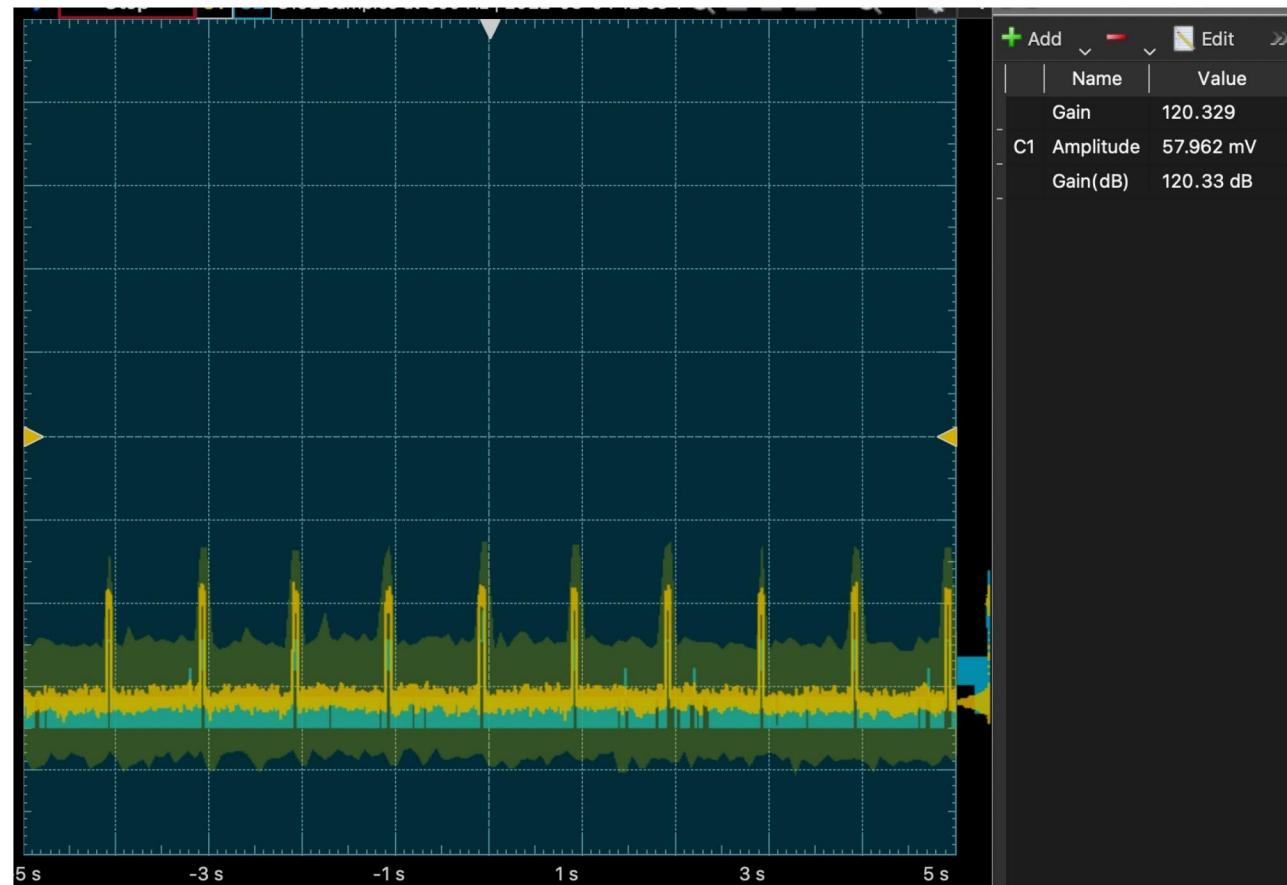
L1: Measure the amplitude of the output signal v_{out} of your instrumentation amplifier.

62.498 mV

L2: Use your measured amplitude to calculate the empirical gain of the instrumentation amplifier stage. How does this compare to what you expected?

123.78 is the value we got and we expect a value close to 143.

L3: Take a picture or screenshot of the output, and attach it to your lab report.



1.1 L1. Vout Amplitude 2 / 2

✓ - 0 pts Correct

- 1 pts Not within reasonable range

- 2 pts Incomplete

- 0.25 pts Peak to Peak instead of Amplitude

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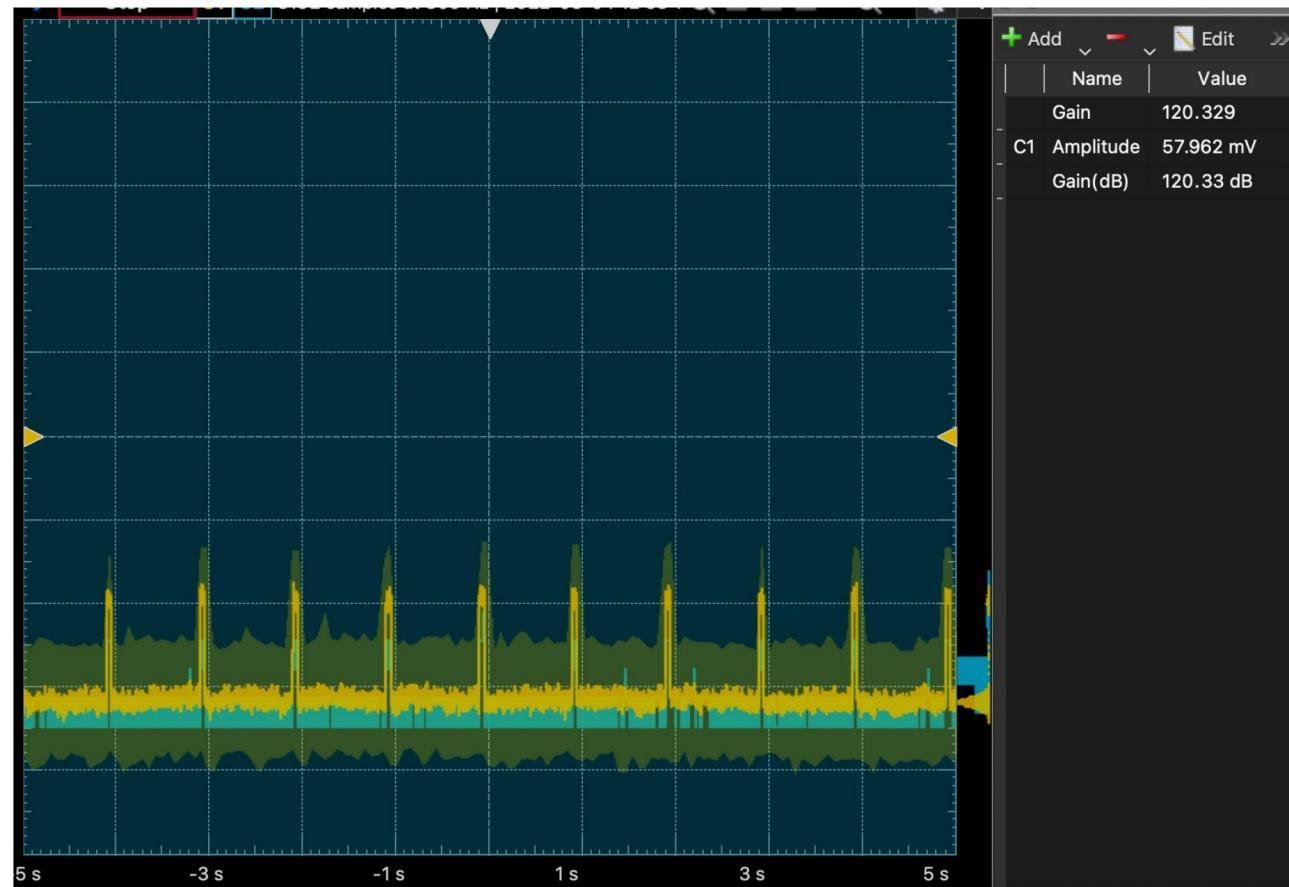
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1.2 L2. Empirical Gain 2 / 2

✓ - 0 pts Correct

- 1 pts Some error in calculation / out of acceptable range
- 2 pts Incorrect answer; work unclear
- 0.5 pts Does not compare with theoretical
- 0.25 pts other errors

- *Before you measure, ask yourself:* What amplitude do you expect on the output of the instrumentation amplifier? What offset do you expect? If your oscilloscope doesn't show what you expect to see, debug this before continuing!

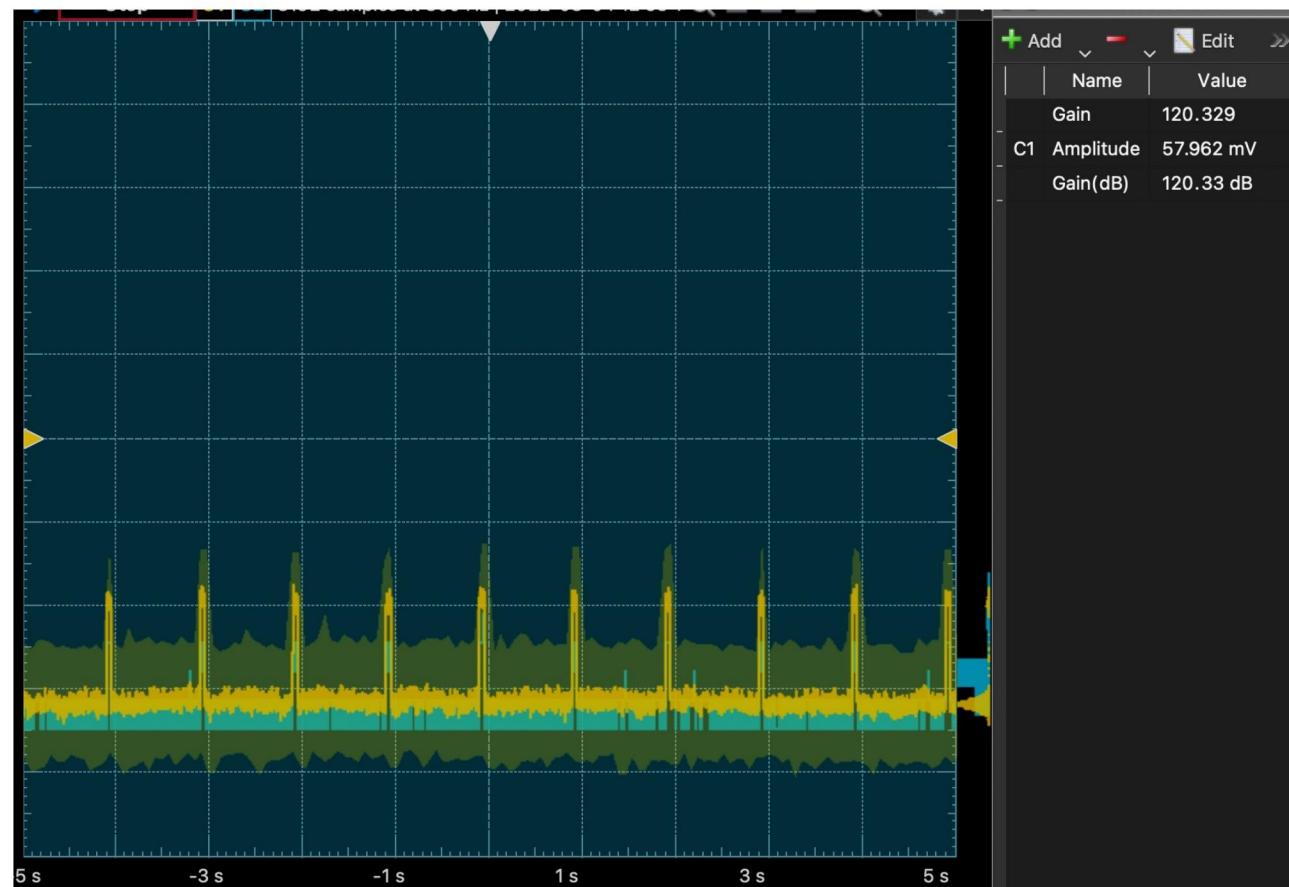
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1.3 L3. Screenshot 3 / 3

✓ - 0 pts Correct

- 3 pts Incomplete or missing

- 2 pts Incorrect shape

- 1 pts Taking Values from noise

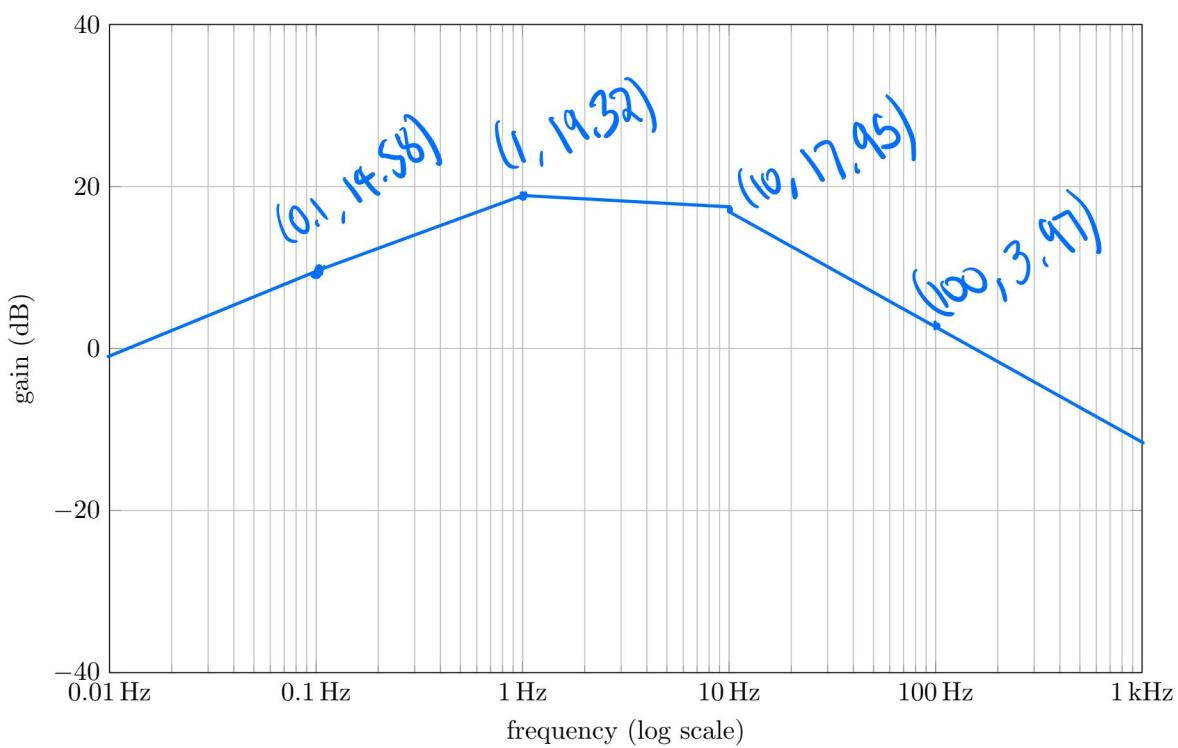
- 0.5 pts Error (see comments)

L4: Using a test signal of 200 mVpp, find the amplitude of the output at each frequency in the table below. (On a log scale, 1, 2, 5 and 10 are about equally spaced, so these values make the plots more evenly sampled.) Use these data points to draw an empirical Bode magnitude plot of your filter.

Tip: Before each measurement, ask yourself: What do you expect to see? If it doesn't match, fix this before recording measurements, and save yourself having to do the whole thing all over again.

Tip: Measuring low frequencies can take a really long time, so you might like to start with the high frequencies, so that if your circuit isn't working, you'll notice quickly.

Frequency	Output amplitude (V)	$\frac{V_{\text{out}}}{V_{\text{in}}}$	gain in dB
0.1 Hz	33.245 mV	5.35818	14.580 dB
0.2 Hz	151.45 mV	5.33615	14.545 dB
0.5 Hz	0.84222 V	8.20135	18.278 dB
1 Hz	0.94749 V	9.24222	19.316 dB
2 Hz	0.97704 V	9.51142	19.565 dB
5 Hz	461.74 mV	9.35854	19.424 dB
10 Hz	487.60 mV	7.89627	17.948 dB
20 Hz	0.61504 V	5.88695	15.398 dB
50 Hz	301.06 mV	2.92585	9.3250 dB
100 Hz	156.99 mV	1.57925	3.9690 dB



1.4 L4. Table and Bode Plot 6 / 6

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- 1 pts All values a little low
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- 1 pts Gain in passband not close enough to 20dB
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- 3 pts Incorrect plot shape
- 6 pts Incomplete/missing
- 0.5 pts Did not plot points and then draw a line through those points

L5: Add a 1 V offset on the signal generator, so that your new input signal is 200 mVpp, 1 Hz with a 1 V DC offset. What do you notice about the offset at the output? What about with a -1 V DC offset? Is this consistent with your analysis in the prelab?

Hint: What is the frequency of a DC signal? What should your circuit do to signals at this frequency?

The frequency of a DC signal is 0, therefore it will not affect the output at all. Whether the offset is 1V or -1V, it has no affect on the output. This is consistent with the analysis because the only variable is frequency and this does not change the frequency.

4.4 Putting it all together

Once you're satisfied that both your IA and bandpass filter stages are working, disconnect the signal generator, and connect the output of the instrumentation amplifier to the input of the bandpass filter. Your circuit should now be the one from page 13, with the test input signal of the circuit on page 13 going into IA input terminals.

Test the entire circuit by configuring the signal generator to 1 mV, 1 Hz pulses with a 5% duty cycle. Check that the output does what you expect.

Then, try changing the frequency up to 100 Hz and down to 0.1 Hz, and verify that the output matches expected behavior. Finally, try adding an offset of a few millivolts, and check the output.

L6: Once everything looks good, measure and record the amplitude of the output signal (after the bandpass filter) when the signal generator is set to 1 mV amplitude, 1 Hz pulses with a 5% duty cycle. Use this to calculate the combined empirical gain of the IA and bandpass filter stages. Does this match what you expect?

The amplitude is 0.57895 V and the gain is 1289.1. The gain matches what we approximately what we expected as it should be around 143×10 . 1289.1 is very close to 1430.

L7: Take a picture or screenshot of your final output with the test input signal (a simulated sinusoidal "heartbeat", if you will), and attach it to your lab report.

4.5 Next week

Next week, we will connect this circuit to your wrists to measure your heart. To provide addition safety, we will add resistors to our circuit to limit current, provide an isolation board that will separate the circuit and AD2 from your laptop, and run the laptop on battery. It should be fun.

1.5 L5. Offset 2 / 2

✓ - 0 pts Correct

- 2 pts Somehow managed to observe an output offset

- 1 pts Does not state if behavior is consistent or explains why

- 2 pts Incomplete/missing

L5: Add a 1 V offset on the signal generator, so that your new input signal is 200 mVpp, 1 Hz with a 1 V DC offset. What do you notice about the offset at the output? What about with a -1 V DC offset? Is this consistent with your analysis in the prelab?

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1.6 L6. Empirical Gain 2 / 2

✓ - **0 pts** Correct

- **1 pts** Error in measurement/calculation

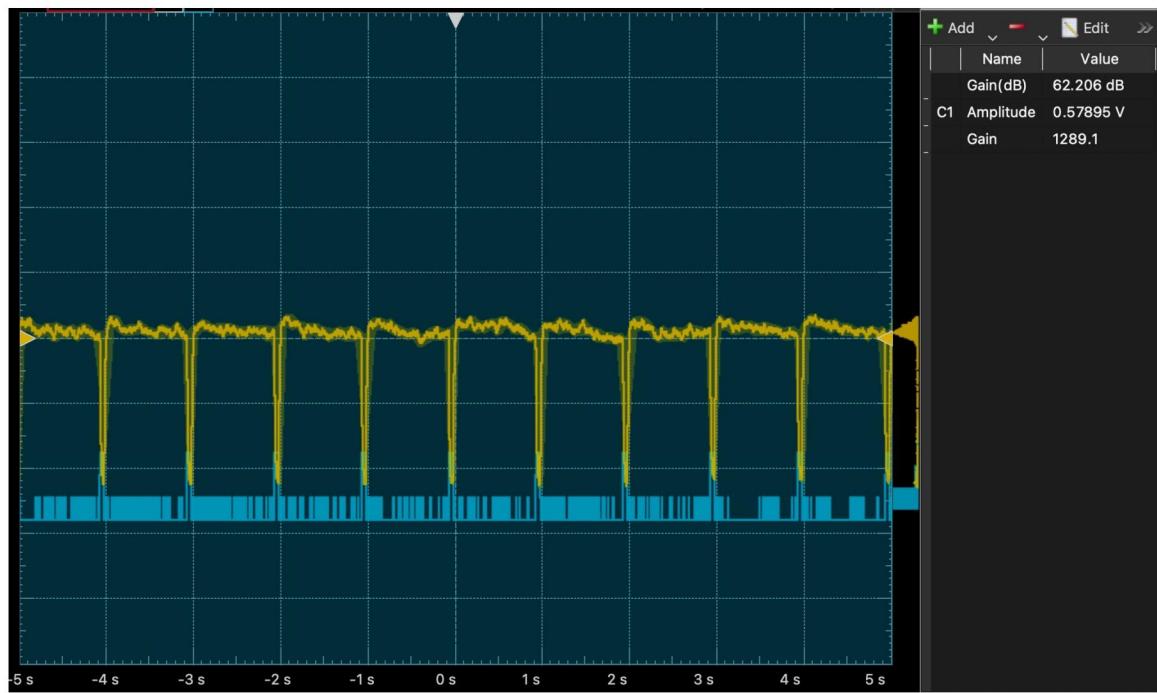
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- **0.2 pts** Incorrect gain mentioned



1.7 L7. Screenshot 3 / 3

✓ - 0 pts Correct

- 1.5 pts Output clipped

- 3 pts Missing/Incomplete

- 3 pts Incorrect

- 0.5 pts wrong input signal

5 Analysis

A1: We can still see some noise at the output of this circuit. Suppose we wanted to try to reduce this noise by changing the filter stages. Could we reduce this noise further? Which components would we need to add or change? Since the heart beat is not a sine wave (it has a spike in it), do you think there might be a downside of doing this?

There is a lot of noise because the band pass filter lets in frequencies between .3Hz and 16Hz even though heart rate is between .4Hz and 2Hz. The corner frequency of 16Hz comes from the low pass part of the filter, so we can reduce noise by bringing this corner frequency to the left. The capacitor has a very low value of .1mF, which makes the corner frequency so large. Thus, if the capacitor had a higher value, the corner frequency would be lower. The downside is if the corner frequency is pushed too far to the left then it might not capture all the spikes in the heart beat, so it should be reduced to 4Hz or 5Hz and not all the way down to 2Hz.

2 Analysis 10 / 10

✓ - 0 pts Correct

- 3 pts No suggestion for adding/changing circuit components

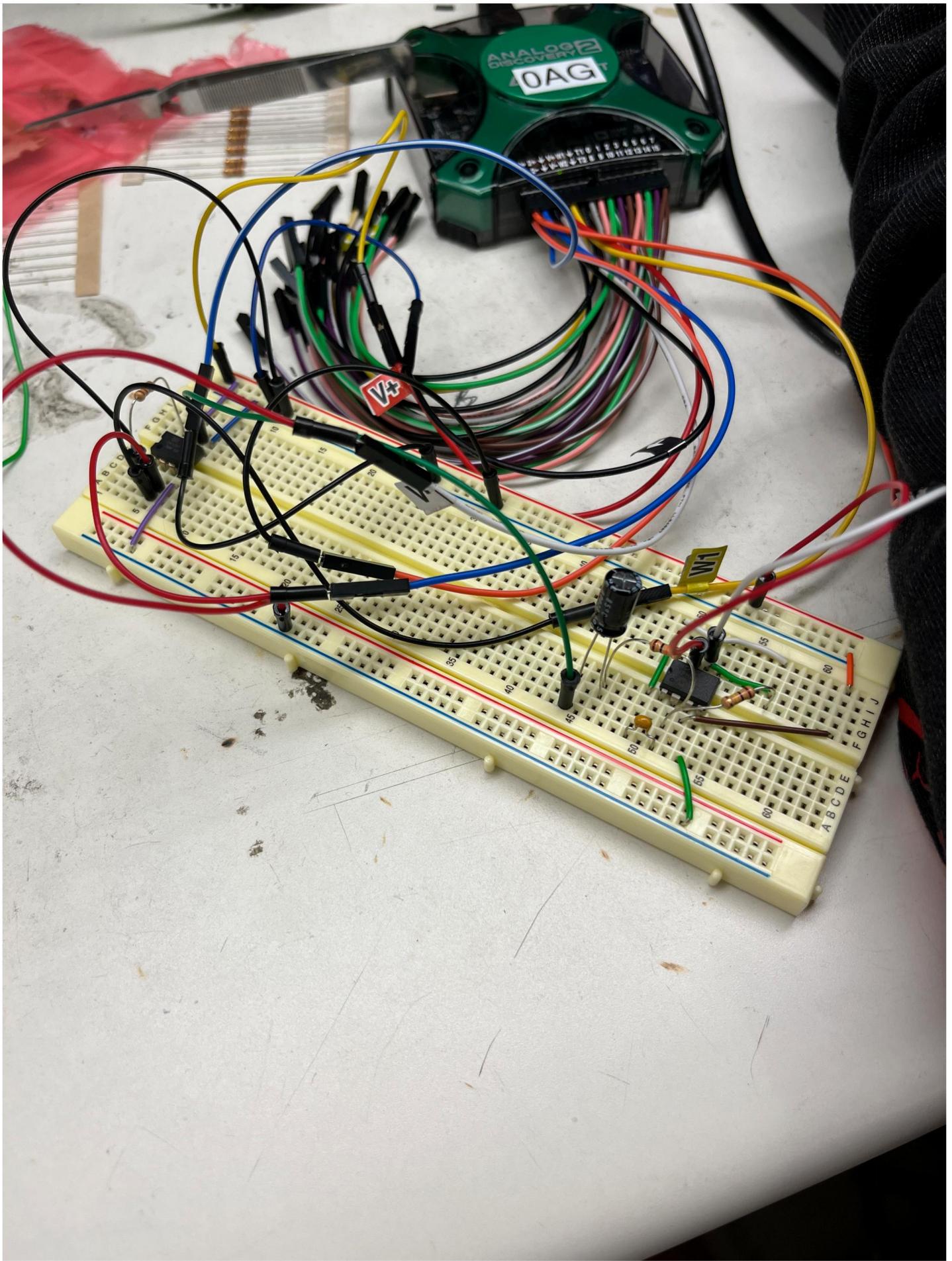
- 3 pts Doesn't explain downside

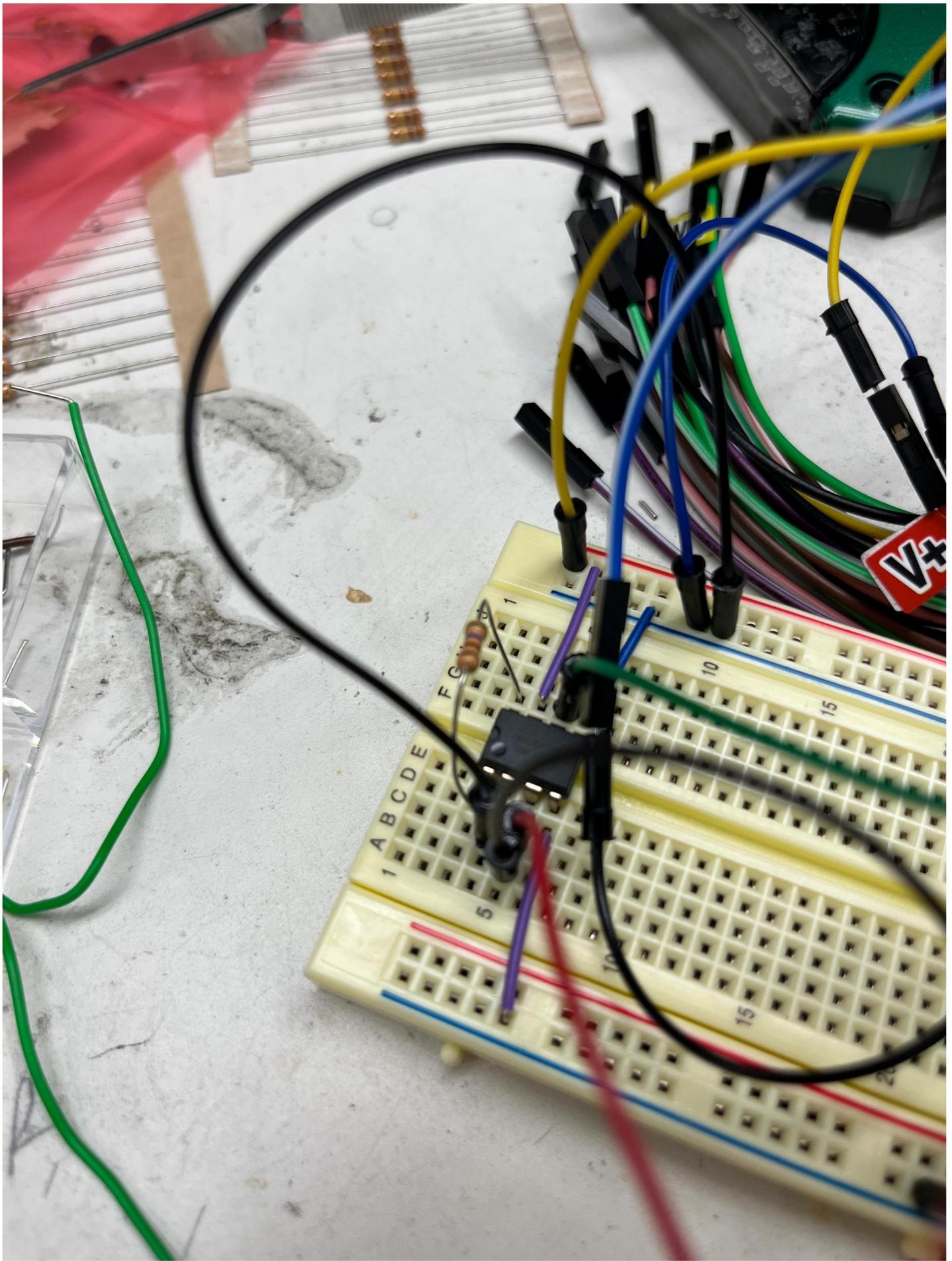
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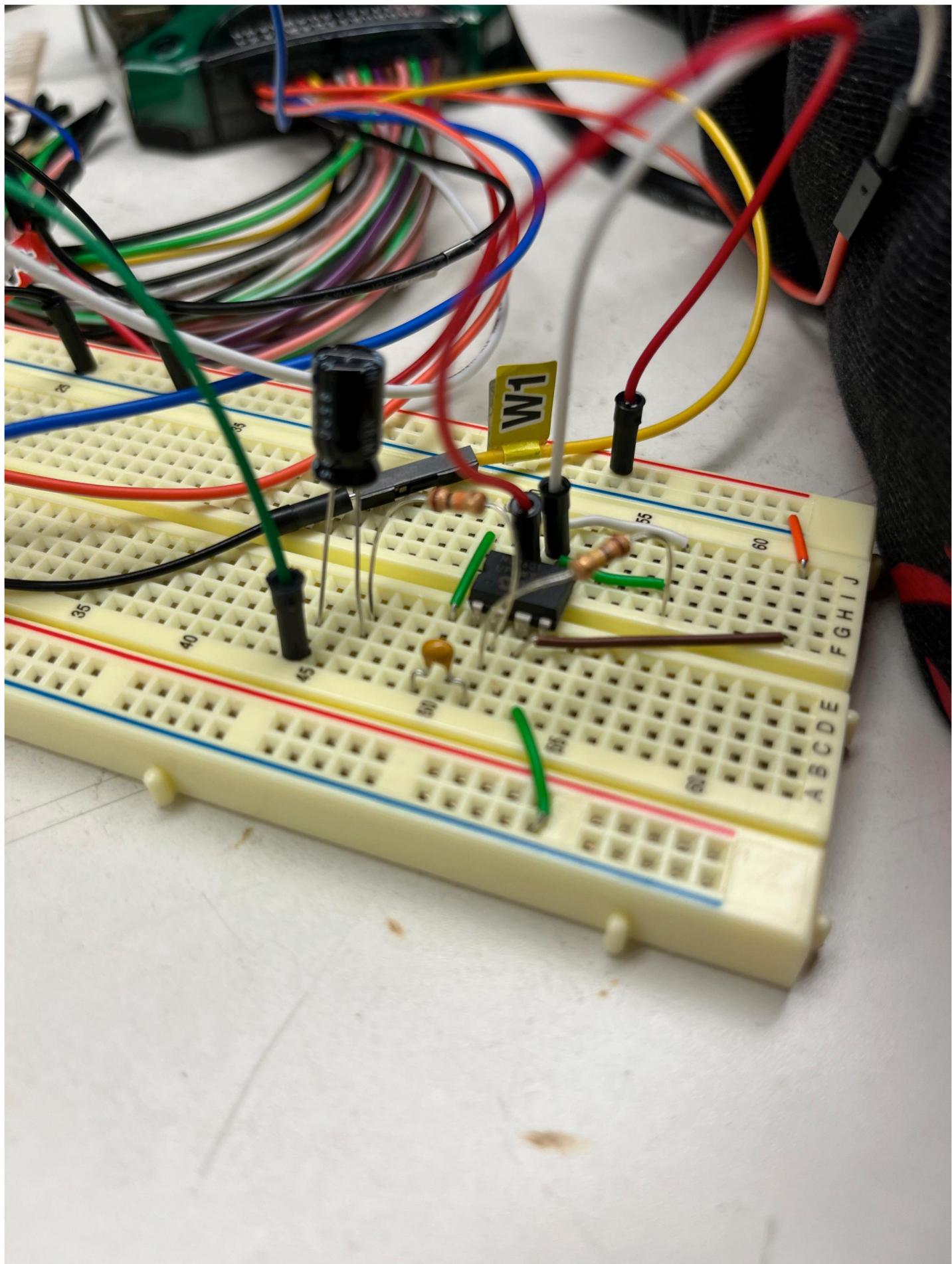
- 10 pts Not completed

- 4 pts No suggestion to filter out the noise using the filters from the circuit

- 3 pts Incorrect filter reasoning

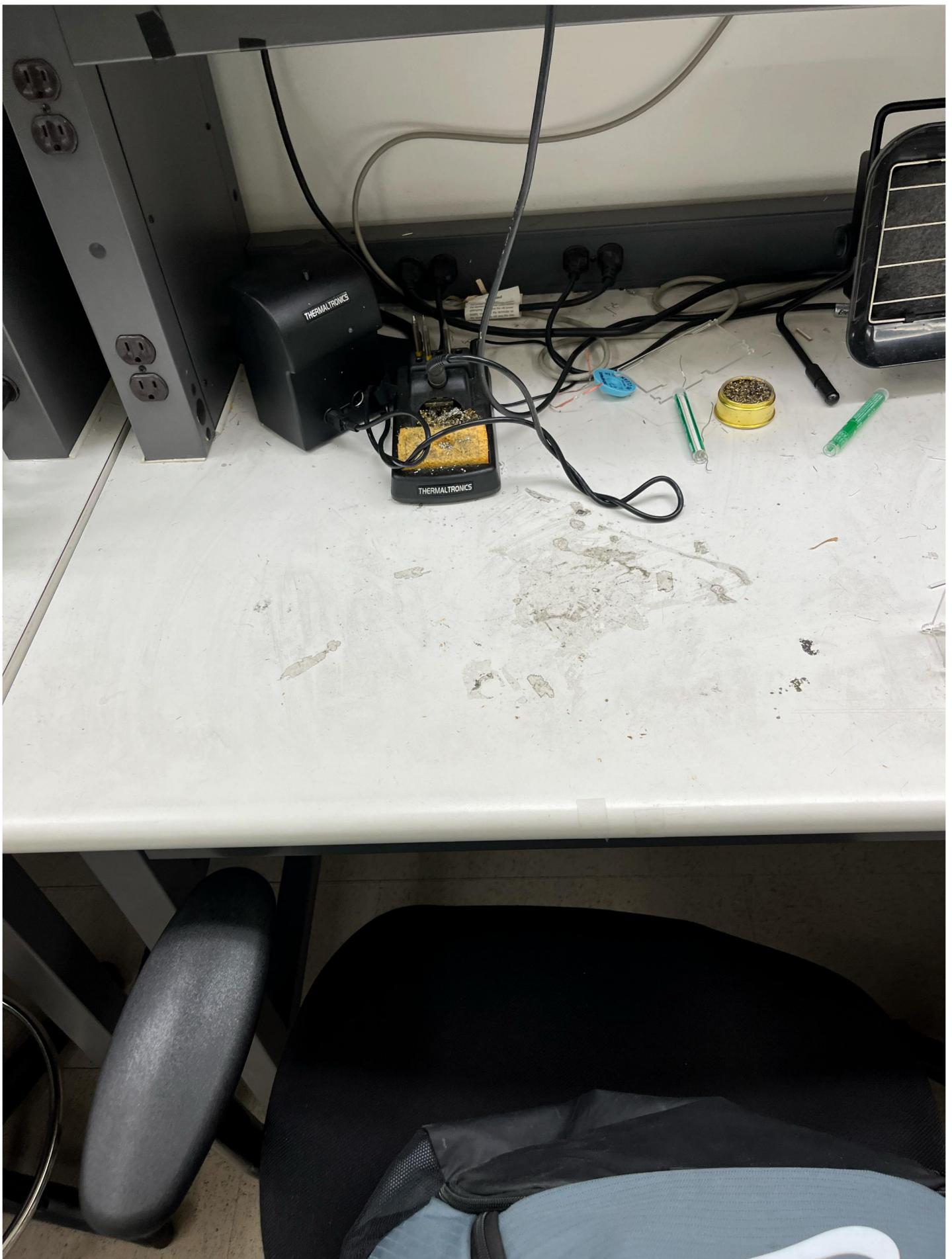






3 Build Quality 20 / 20

- + 5 pts plus
- ✓ - 0 pts Check Plus
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- 15 pts minus
- 3 pts Late



4 Cleanup 5 / 5

✓ - 0 pts Correct

- 2 pts missed a spot

- 5 pts did not clean up