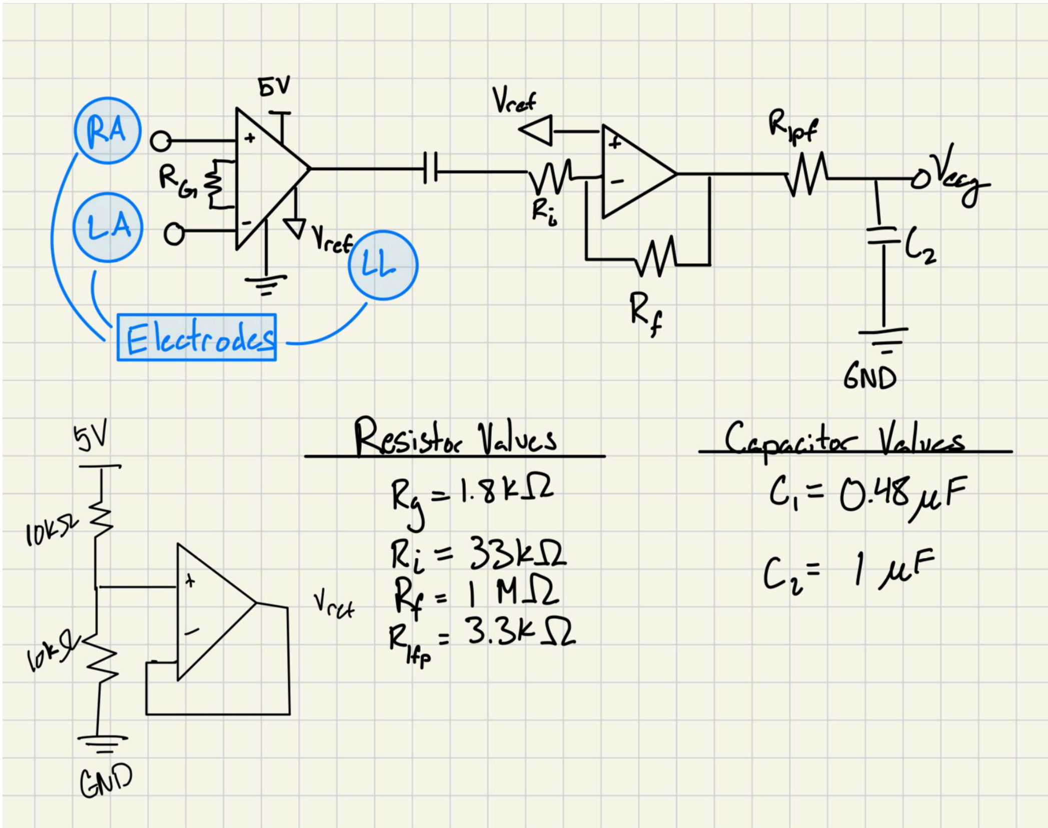
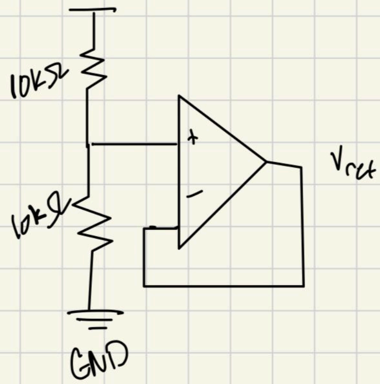
Exercise 1: hand or computer-drawn schematic, annotated with electrode leads and resistor/capacitor values.





Solve for R_1

Given

$$\boxed{G_1 = 1 + \frac{50k}{R_G} \approx 30}$$

$$\frac{50k}{R_G} \approx 29 \Rightarrow \frac{50k}{29} = R_g$$

$$\boxed{1.8k\Omega = R_g}$$

Assign R_i, solve for C_1

$$f_c = 0.1\,Hz = \frac{1}{2\pi R_i C_1}$$

$$\boxed{R_i = 33k\Omega}$$

$$0.1\,Hz = \frac{1}{2\pi(33k)C_1}$$

$$C_1 = \frac{1}{2\pi(33k)0.1}$$

$$\boxed{C_1 = 0.48\,\mu F}$$

Solve for R_f

$$G_2 = -R_f \approx -30R_i$$

$$R_f \approx 990000\,\Omega$$

$$\boxed{R_f \approx 1M\Omega}$$

Assign R_{LFP}, Solve for C_2

$$f_c = 50Hz = \frac{1}{2\pi R_{LFP} C_2}$$

$$\boxed{R_{LFP} = 3.3k\,\Omega}$$

$$f_c = 50Hz = \frac{1}{2\pi(3.3k)C_2}$$

$$\boxed{C_2 = 1\mu F}$$

Check f_c's & G_{tot}

Ideal = 0.1 Hz
0.107 within 20%

$$f_c = \frac{1}{2\pi R_i C_1} = \frac{1}{2\pi(33000)(47\times10^{-6})} = \boxed{0.107\ Hz}$$

$$f_c = \frac{1}{2\pi R_{lpf} C_2} = \frac{1}{2\pi(3.3k)(0.1\times10^{-6})} = \boxed{48\ Hz}$$

Ideal = 50 Hz
48 Hz within 20%

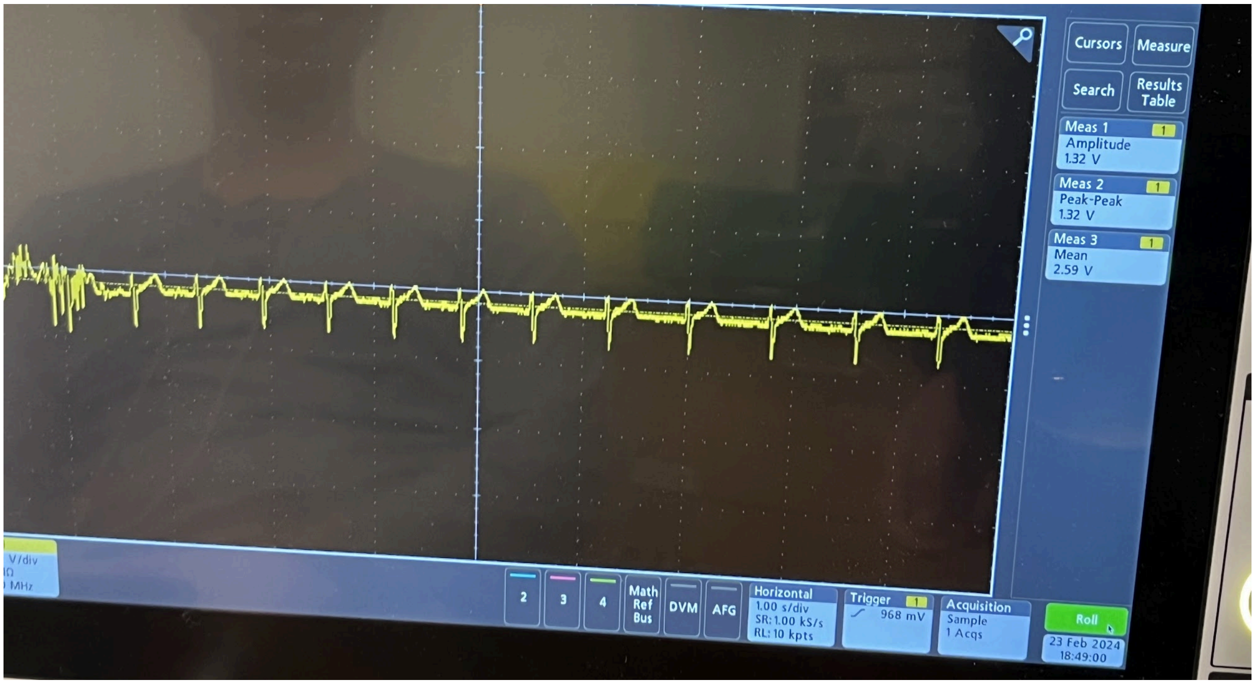
$$G_1 = 1 + \frac{50k\Omega}{1.8k} = 28.8$$

$$G_2 = -30.3$$

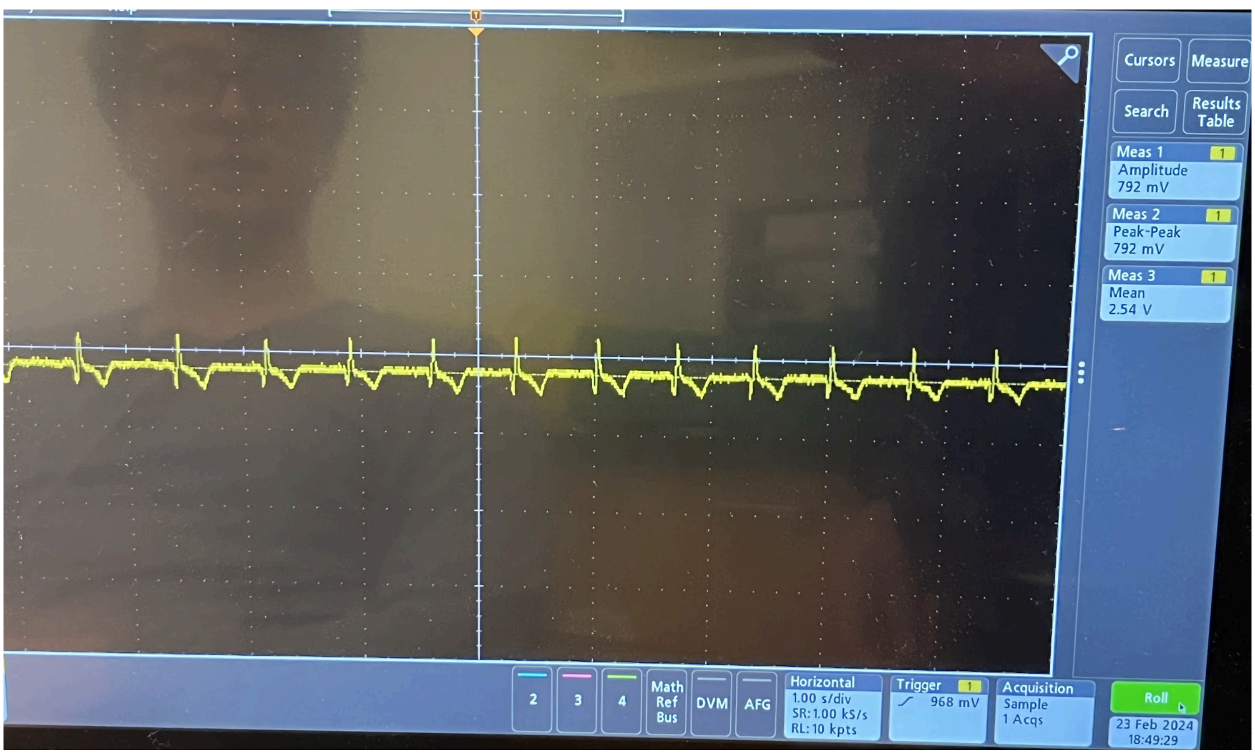
Ideal G_{tot} = 1000
872 is within 20%

$$\boxed{G_{tot} = -872.64}$$

Exercise 2: Screen captures showing the circuit working as expected, along with answers to the four questions in the exercise.



Original waveform



Flipped waveform to show clearer peaks

1. **What is the actual input signal amplitude based on the measured output? Is it smaller or larger than 1 mV? If your output amplitude is too small, adjust your gain and try again.**

The input signal amplitude is 0.91 mV, calculated using the amplitude measured on the oscilloscope and the gain for the circuit calculated in exercise 1.

2. **How does your measured ECG waveform compare to the waveforms presented in class? Comment on the noise and morphology (shape) of the waveform.**

Our waveform shown in the pictures above is upside down, because the electrode pins were switched. Besides this, there is a good amount of noise, such that the P & U peaks are not really distinguishable from the noise, only the QRS interval, and the T peak are visible.

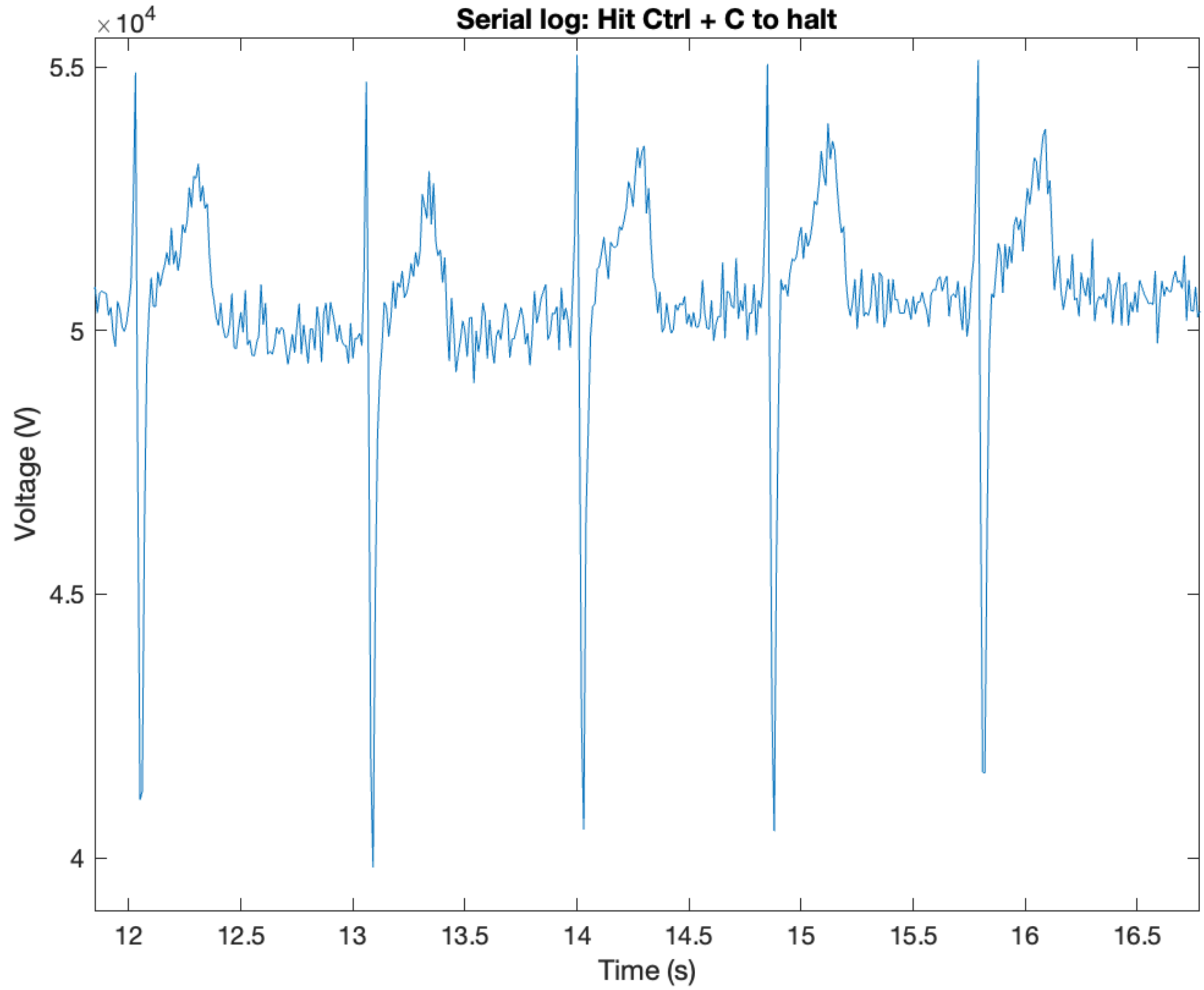
3. What is the DC (average) level of your signal, and how does it change over time?

The mean signal voltage is 2.54 V, it remains unchanged over time unless the circuit or electrode-wearer are disturbed.

4. If we wanted to reduce the tolerance of the different design parameters, how would we go about doing so?

To reduce the tolerance of design parameters we could choose different values for our resistors and capacitors, as these are the variables that affect the gain, V_{ref}, and circuit bandwidth.

Exercise 3: Answers to the three questions listed in the exercise:



1. Approximately how many bits is your signal?
   16 bits.

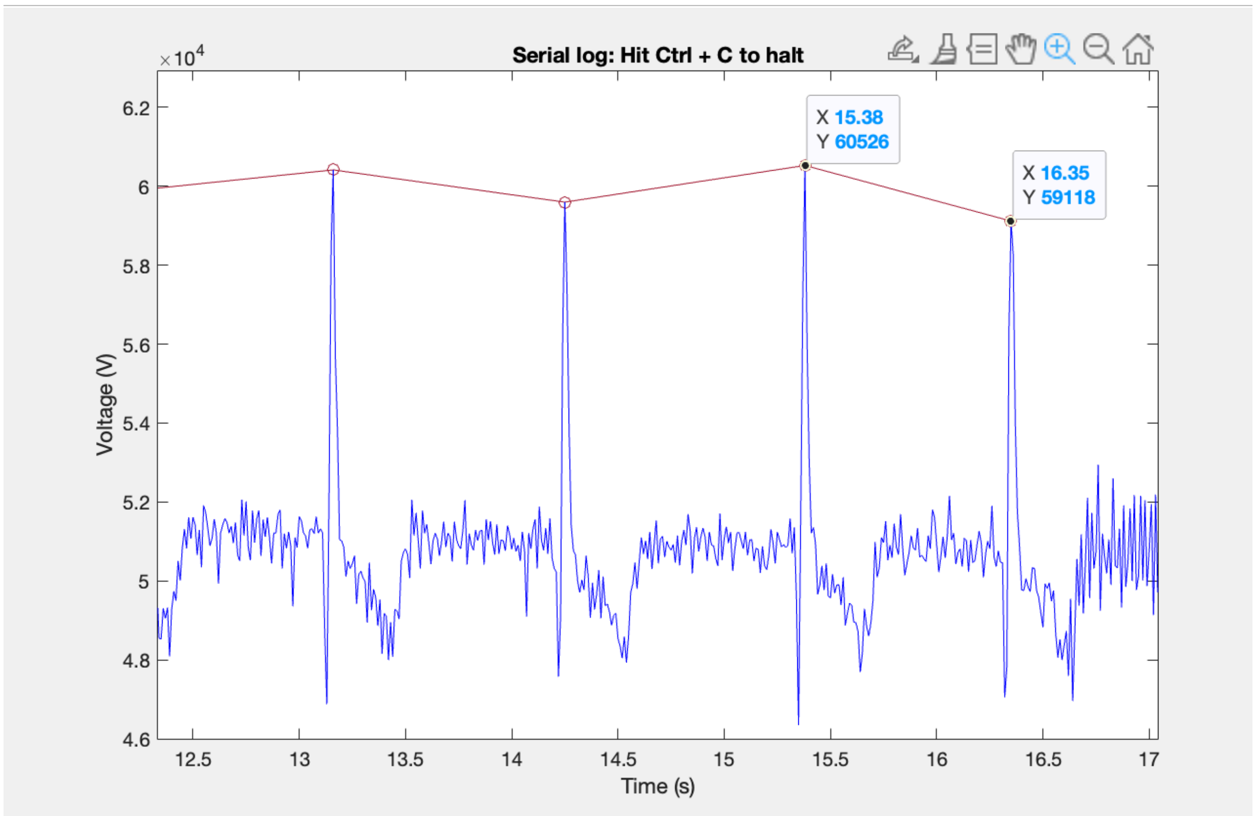
2. Approximately how many samples do you have per beat?
   At a heart rate of roughly 60 bpm, and 100 hz sample rate, there are about 100 samples per beat.

3. How does your measured ECG waveform compare to the waveforms presented in class?
   The waveform in class has a much larger R wave peak than ours, but our S wave has a much lower trough. To correct for this we decided to flip the leads, allowing for a much clearer peak that can be measured.

Exercise 4: Video demonstrating peak detector code works with LED1
https://drive.google.com/file/d/1ZXrIgs0_HNBXRkd5Ry5cZ2JlkmAYRZSf/view?usp=sharing

Exercise 5: Commit code with IHR matching those from ecgTrim.csv

Exercise 6: Commit code and include screenshots demonstrating the IHR output with cross-verification to the MATLAB data




```
ɔ details available
IHR =

   61.2245
```

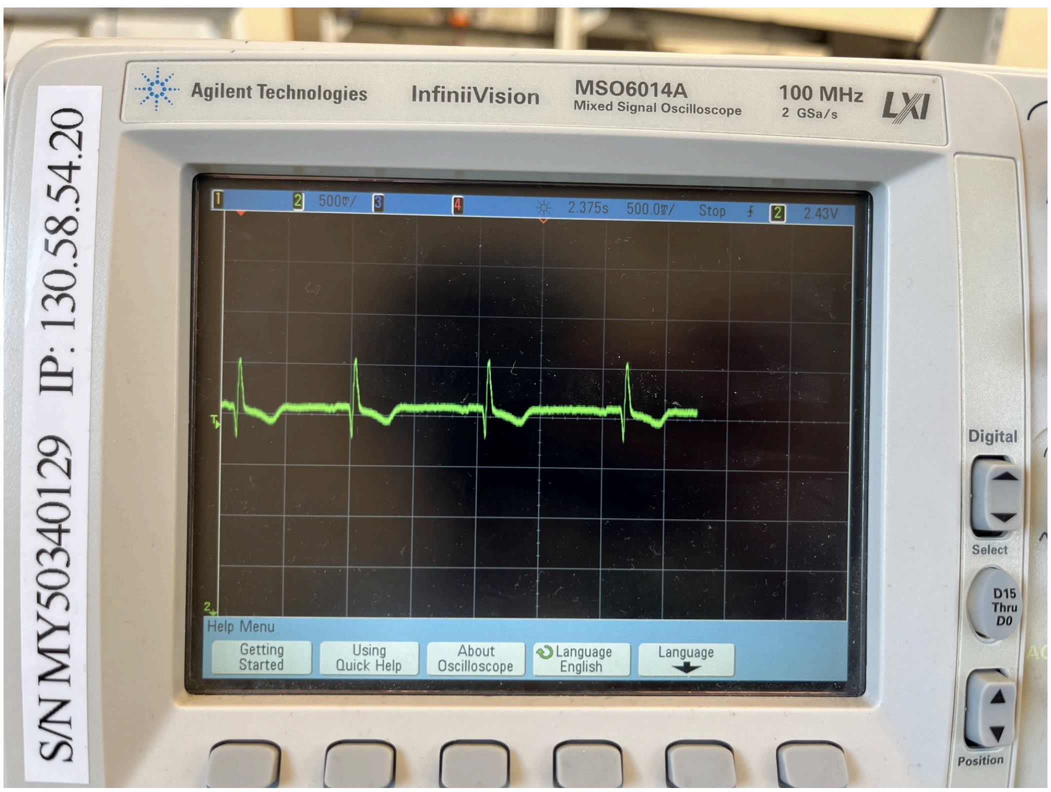
GND

Manual Calculation of IHR

Peak 1 = 16.35
Peak 2 = 15.38

$$\left.\begin{matrix}\text{Peak 1} = 16.35 \\ \text{Peak 2} = 15.38\end{matrix}\right\} \frac{1}{(16.35-15.38)\cdot 100} \approx 61.2 \text{ BPM}$$

Exercise 7: (extra credit) Commit commented final code to Github, include oscilloscope screenshots verifying functionality (you can pause the scope and use cursors to check time between peaks)



Oscilloscope with peaks roughly once per second: around 60 BPM.

Nucleo Serial Output of roughly 60 BPM.