

Lab 6 – taking an electrocardiogram (ECG)

How to work as a group

This lab involves three parts – mostly-reusing your lab equipment from the sEMG labs, taking ECG measurements and writing a report.

You only need to turn in one report per group. However, I would encourage you to each collect your own data and compare the readings with each other. Part of the fun (hopefully!) is building things and hooking up your body to your equipment. If there are substantial discrepancies, feel free to put the graphs for multiple people in the same report (you don't have to tell me whose pictures are whose unless you want to).

ECG terminology: electrodes and leads

Each wire that you connect to your body is called an *electrode*. Basic physics says that voltage is defined as the *difference* between the electric potential at two different points, and so any particular reading that you see on a screen is the voltage difference between two electrodes. Each of these readings is called a *lead*. I don't know why it's called a lead – but that's standard medical terminology, even if it usually sounds a bit strange to engineers at first.

A typical ECG in a doctor's office attaches 10 electrodes to your body and displays 12 leads. With 10 electrodes, it would only take 9 leads to fully represent the data, and so three of the readings are redundant – the redundant readings make it easier for a clinician to quickly diagnose issues.

The particular readings we will perform in this lab are called Lead I, Lead II and Lead III in cardiologist-speak.

Noise in ECGs

One of the big problems in our sEMG measurements was noise. However, we mostly got stuff to work in the end 😊. When we wanted to read the biceps signal, we were able to place two electrodes quite physically close to the biceps muscle, with the closest other muscle (triceps) being further away from the electrodes.

Your heart produces signals of roughly the same voltage (about 60mV) as your muscles do. These signals are quite strong enough to travel from one cardiomyocyte to the next and cause a contraction wave. However, reading an ECG has substantial technical difficulties.

While your biceps are directly under your skin, your heart is much deeper inside your chest. Evolutionarily, this is a good thing – your heart is a valuable organ, and your chest and ribs help to protect it. But they do make the signal more difficult to read.

Furthermore, you will notice that we are *not* placing electrodes on your chest near your heart. A cardiologist would do that, but we are not; partly for personal-privacy reasons and partly just because the simpler arm and leg readings are good enough for our purposes.

By the time it travels through your body to your arms and legs, the ECG signal – originally 60mV – is only a few mV. Furthermore, there are *many* muscles between the heart and the electrodes that are generating their own signals. Thus, ECGs tend to be noisy! While our

AD8232, a commercial circuit designed for ECGs, does reasonably well, you will definitely see artifacts.

You may wonder why, if a lead only involves two electrodes, our experimental setup uses three electrodes rather than two. The third electrode is used to minimize noise. It uses a system called *right-leg drive*, where the AD8232 board tries to dynamically find noise that is common to both electrodes and then drive it back to your body inverted (via your right leg) to cancel it out. We used the same system for our sEMGs, and it is even more critical now.

Hooking up the pads to your body

Our lab setup has three electrodes:

- The red electrode is for right-leg drive (RLD) and should always be attached to your right leg.
- The blue electrode is the positive input.
- The black electrode is the negative input.

The general practice of applying the electrodes is the same as we did for an sEMG, though the locations are different. Please refer to our course website for a nice video.

Hardware and software

The hardware and software for this lab are exactly the same as for lab #3 (sEMG on a scope). You will be using a scope to observe your ECG and then using *adc_capture.py* to digitize and capture it. The only difference now is that, by placing the electrodes in different locations, you will capture your ECG rather than your sEMG.

First reading: lead I

For lead I, connect the positive (blue) electrode to the left arm and the negative (black) electrode to the right arm. There's a video on the course web page showing you just where on your arms/legs to put them. To help keep your arms relaxed, you should rest them on a table or other support. Capture the signal on the scope and take a picture of it with your phone.

Lead-II reading

For lead II, the positive (blue) electrode connects to the left leg and the negative (black) electrode to the right arm. Again, capture the signal on the scope and take a picture of it with your phone.

Lead-III reading

For lead III, the positive (blue) electrode connects to the left leg and the negative (black) electrode to the left arm. Yet again, capture the signal on the scope and take a picture of it with your phone. This time, however, you should also use *adc_sample.py* to digitize and record it. Save the digitized output file – we'll use it next week.

Manipulating the noise level

One large source of noise for both the sEMG and ECG is 60Hz power-line noise. In most buildings (including Halligan) this noise is everywhere and shows up on the electrode wires connecting your body to the AD8232 board. The AD8232 uses a differential amplifier to subtract the signals on its two inputs; when the two wires are physically close and twisted together (like they were in the sEMG labs), the noise on both the electrode wires tends to be identical, and thus mostly cancels out inside the AD8232.

However, when one electrode is on your arm and the other on your ankle, it's not so easy to twist the wires together! But you can still twist the electrode wires together for as much of their length as possible. To minimize the length of wire that is untwisted, you could do a bit of yoga and place your left leg physically as close to your left arm as possible 😊

Recapture your lead III picture this way to see how much of a difference it makes.

Readings with muscular involvement

Our sEMG labs used a very similar experimental setup to the one we're using today. So why does today's lab display our ECG signal and not an EMG? Why didn't our EMG lab display an ECG waveform? Let's run some experiments to find out why.

Use lead I, but this time hold your left arm in the air rather than resting it on a table. Capture the waveform. Next, perform a submaximal static contraction – i.e., clench the muscles of your left arm (specifically, the muscles near the electrode) somewhat hard but not at full force. Again, capture the waveform.

Discussion questions:

1. Look up the shape of a “normal sinus rhythm.” Which of your readings looks most like a normal sinus rhythm? You should be able to look up the expected shape of Lead I and Lead III rhythms; are they mostly as expected?
2. Given your Lead-III image, can you read the numbers for:
 - a. Heart rate
 - b. PR interval (from the start of P to the start of QRS)
 - c. PR segment (from the end of P to the start of QRS)
 - d. Width of the QRS segment

For each number, also write down what it represents (e.g., “how long it takes for the wavefront to traverse the ventricles”).

3. Can you explain the results of any of your noise-manipulation experiments? I.e., your submaximal-arm-muscle experiment and your twisted-leads experiment(s)?

Lab checkout

This lab has a special bonus – you get to play doctor 😊. Joel will come around to each group. Your job is to hook him up to your circuitry, look at his ECG and decide what arrhythmias (if any) you see.

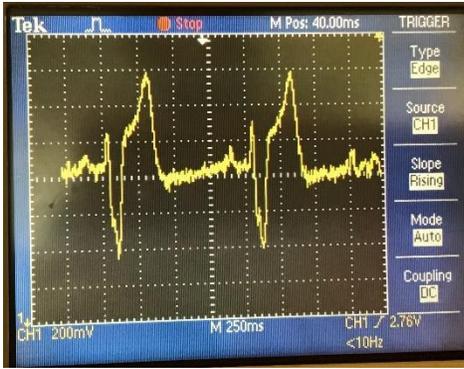
What to turn in

Turn in your pictures for the three regular measurements (Leads I, II and III). Also turn in your pictures for any noise-measurement experiments you did, and your muscle-involvement readings. Finally, turn in your answers to the discussion questions.

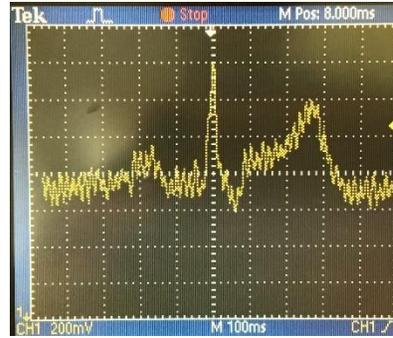
Save the Lead III capture that you did with `adc_capture.py`; you'll use it next week.

Free pictures

You may choose to hand in the pictures below; either because you have not succeeded at capturing your own (though of course please ask for help if that's the case), or because your own ECGs are confidential medical information. The .csv files for these pictures are all in the

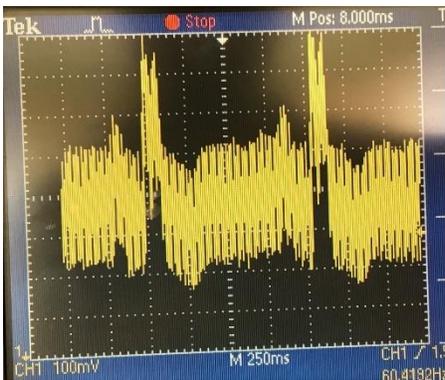


Lead I -- left arm = +,
right arm = -

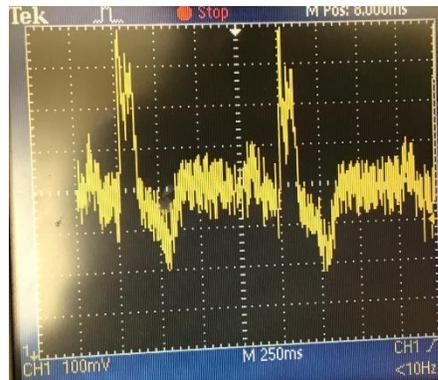


Lead 2. Left leg=+,
right arm = -.

directory Q → en1EIY → 2022f → public_html → labs → lab6. Or you can just grab the pictures from this document and hand those in.

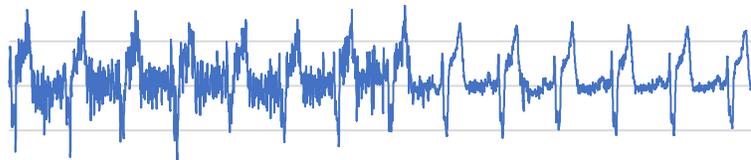


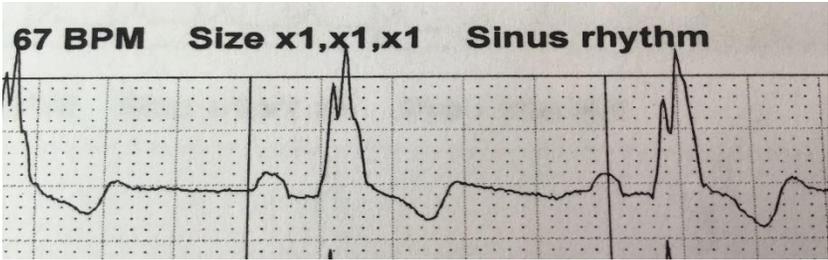
Lead III. Left leg=+,
Left arm=-; noisy



Lead III. Left leg=+,
left arm=-; yoga pose

Lead I ECG (holding an iPad for the left half of the plot)





Professionally-done picture of a sinus rhythm. It's the same person as the rest of the pictures.