

# Laboratory 4 | SpO<sub>2</sub>

## SYSC 4203: Bioinstrumentation | Lab Manual

### Guidelines



#### Instructions

Indicates the step requires a screenshot. Save your screenshots as 'sectionX\_stepX', replacing X with the appropriate section and step number. This takes little time and will make your lab much easier to write up.



Indicates the step requires saving 30 seconds (though it's sometimes 10 or 60 seconds) of data. Save your data files with the name indicated. This will make your postlab quicker to complete.

#### Lab Write-up

Labs should be submitted in the dropbox before 2pm 1 week following the lab session.

All Matlab/Excel figures should have a title, legend (if more than 1 signal per plot), x axis label and y axis label with units indicated.

To load a collected data file in matlab, you can use `a = load('normalairflow.data');` to load the file as a double array.

## Laboratory 24 | SpO<sub>2</sub>

### Learning objectives

- Observe the relationship between breathing,
- heart rate and oxygen saturation
- Determine blood oxygenation using pulse oximetry

### Materials

Wireless BioRadio System

- 3 snap electrodes per student
- Alcohol wipes
- Snap leads

- Finger pulseoximeter
- Respiratory effort belt

## 1.0 – Equipment Preparation

- 1.1 Connect one end of the pulse oximeter to the SpO<sub>2</sub> input of the BioRadio, and place the other end around the subject's index finger. Regarding the SpO<sub>2</sub> connector: Make sure the red dots face each other when retracting because when you retract the outer metal layer, the small 'claws' retract from the end of the cable. This is how you will unplug the cable at the end of the lab.
- 1.2 Place the respiratory belt around the torso of the test subject. Attach the leads from the respiratory effort belt to the + and – inputs of channel 1 of your BioRadio.
- 1.3 Attach the 3 snap electrodes to the test subject; this is called a Lead I ECG. One on the inside of the left wrist, one on the inside of the right wrist, and one on the right ankle similarly to in lab 1. Attach snap wires to the snap electrodes and connect the wires to the BioRadio as shown below.

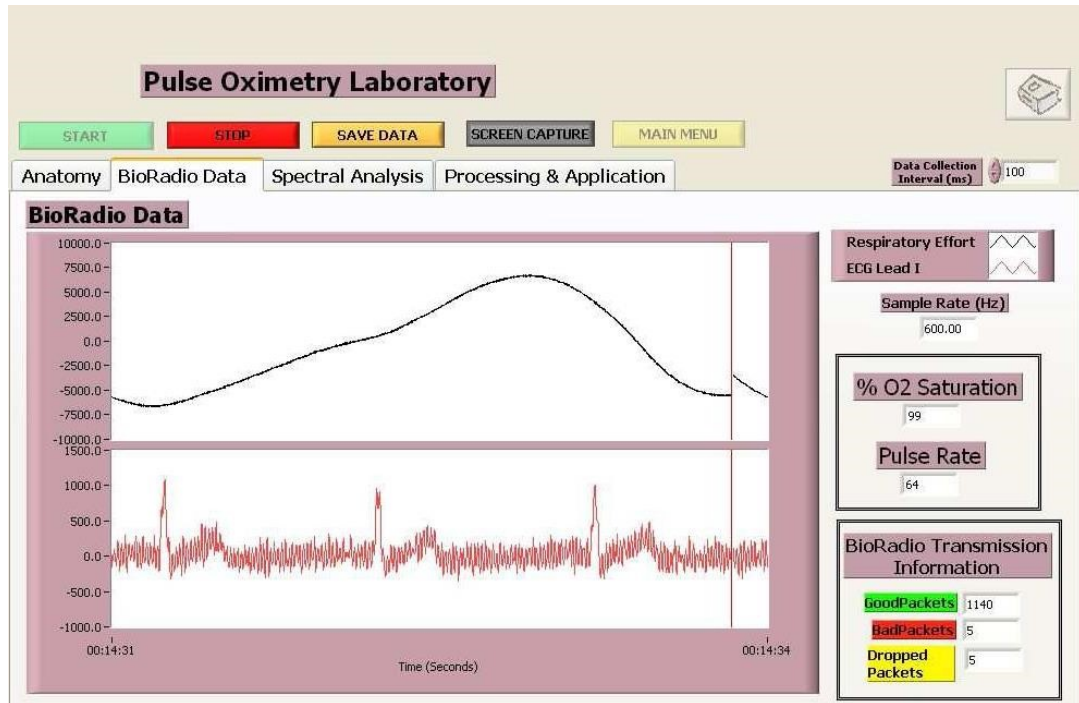


## 2.0 – Data Collection Procedure

Run the *BioRadio\_Lab\_Course* software. Login and select *Pulse Oximetry Lab* from the Advanced Physiology section on the left. Select *Begin Lab*. Turn on your BioRadio and pair it with the software.

Click on the BioRadio data tab and click on the “Start” button. You should see respiratory effort and the ECG signal (one channel only) scrolling on the screen, as well as a value  $\leq 100$  for the SpO<sub>2</sub> as shown below.

- Note: a value 127 for SpO<sub>2</sub> indicates a dropped packet.
- Note: a pulse rate of 511 indicates a dropped packet.



### 3.0 – Data Collection

3.1 Play with the location of the respiratory effort belt to get a signal with the largest amplitude. **Change the data collection interval time if you start to drop packets.**



3.2 Start the data collection and save as **Subject1\_Testing**. Breathe normally for 30s then, test the respiratory effort belt sensor by breathing very quickly for 30s, very slowly for 30s and then with your abdomen instead of your rib cage for 30s.



3.3 Collect a **120s** sample for each situation.

a) **Subject1\_Rest**: at rest, regular breathing.



b) **Subject1\_Hold\_Inhale**: 5 normal breaths, then **inhale** and hold breath (as long as you comfortably can) then breathe normally for the remaining time.



c) **Subject1\_Hold\_Exhale**: 5 normal breaths, then **exhale** and do not inhale (for as long as you comfortably can) then breathe normally for the remaining time.



d) **Subject1\_Running**: while running on the spot.



e) **Subject1\_Recovery**: immediately after running on the spot.

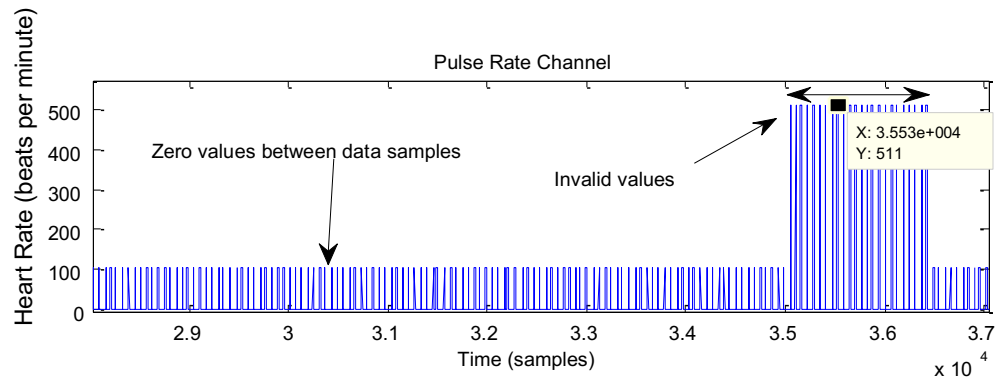


3.4 Repeat the data collection for a second subject and for a third should you have the time (you should). Clean the SpO<sub>2</sub> sensor with an alcohol wipe between subjects.

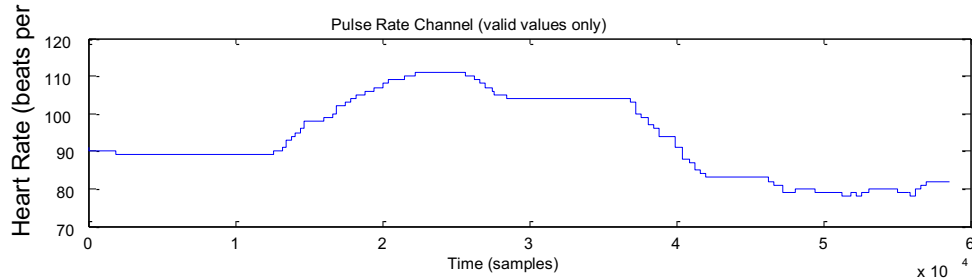
3.5 You have recorded only 1 trial per person, so make sure you have all the (valid) data you need before disconnecting. Ask for help to disconnect the SpO<sub>2</sub> sensor if you need it.

3.6 Turn your BioRadio off and neatly put away all equipment. Do not forget to remove your USB drive.

*Note:* i) the sampling rate indicated in the .header files is for the resp. sensor and ECG data ONLY. The other data (SpO<sub>2</sub> and Pulse rate) is sampled at a lower rate and the CleveMed system compensates for this by adding zeros between the values (this way all 4 data columns have the same length). ii) You may also have invalid values in some files. You MUST process your data to remove invalid values (the 0 values that occur between valid samples for SpO<sub>2</sub> and Pulse rate, as well as values of 127 for SpO<sub>2</sub> and values of 511 for Pulse rate). The invalid values can be replaced by 'NaN', ('not a number') or with known values using a '**sample and hold**' filter. Open Matlab now and think of how you can do this. \* Processed data should have as many samples as unprocessed data, and all values should be valid.



Raw "Pulse Rate data" shown for  $(2.9-3.7) \times 10^4$  range,  $\text{mean}(\text{data}) = 10.1$



Processed "Pulse Rate data" shown for  $(1-6) \times 10^4$  range,  $\text{mean}(\text{data}) = 93$

## Report

- a) Plot your unprocessed and processed Pulse Rate data for one 'testing' file.
  - i What is the mean Pulse Rate for the entire Pulse Rate channel for the unprocessed and processed data? Is the second value realistic? (Hint: should be close to your HR).
  - ii Paste your Matlab code HERE.
- b) One 'Testing' file: For 1 subject, plot your data in the following format (adding appropriate titles & axis labels), and indicate on the breathing plot where the type of breathing changes.

```
ax(1) = subplot(4,1,1);
plot(testing_subject1(:,1)); ax(2) =
subplot(4,1,2);
plot(testing_subject1(:,2)); ax(3) =
subplot(4,1,3);
plot(testing_subject1_processed(:,3))
; ax(4) = subplot(4,1,4);
plot(testing_subject1_processed(:,4))
; linkaxes(ax, 'x');
```

- c) **‘Testing’** files: For each type of breathing (Br.) (regular, fast, slow and abdomen) find: i) the average breathing rate (in breaths per minute), ii) the average breathing amplitude (note the units the amplitude is measured in is somewhat meaningless because it corresponds to the sensor but the relative amplitudes are meaningful), iii) the average

SpO<sub>2</sub>, and iv) average Pulse rate (using the ‘Pulse’ not the ECG data) and fill in the table below. Indicate units.

	Reg. Br. (bpm = __)			Fast Br. (bpm = __)			Slow Br. (bpm = __)			Abdomen Br. (bpm = __)		
	Br. amp.	SpO <sub>2</sub>	Pulse	Br. amp.	SpO <sub>2</sub>	Pulse	Br. amp.	SpO <sub>2</sub>	Pulse	Br. amp.	SpO <sub>2</sub>	Pulse
Subject 1												
Subject 2												
Subject 3												

Comparing the Reg. Br. to the Fast Br., what was the effect of hyperventilation on SpO<sub>2</sub>? Pulse? What was the increase/reduction (in %) of the resp. signal amplitude?

- i) Knowing the sampling rate of the resp. sensor, how fast would you have to breathe to avoid detection? Show your calculations and specify units.
  - ii) Comparing Reg. Br. to Slow Br., what was the effect of hypoventilation on SpO<sub>2</sub>? Pulse? What was the increase/reduction (in %) of the resp. signal amplitude?
  - iii) Comparing Reg. Br. to Abdomen Br., was a breathing signal detected? If so what was the reduction (in %) of the resp. signal when breathing with the abdomen?
  - iv) Discuss the relationship between breathing, SpO<sub>2</sub> and pulse rate (does pulse rate increase/decrease with SpO<sub>2</sub>). Explain why it’s a good thing that the relationships work this way (~200 words).
- d) **‘Hold\_Inhale’** files. Plot the resp. signal and indicate where breath hold starts and ends.

- i What is the pulse rate at beginning and end of the breath hold? How long after resuming breathing did the value return to normal (if this happens during collection time period)?
  - ii What is the SpO<sub>2</sub> at beginning and end of the breath hold? How long after resuming breathing did the value return to normal (if this happens during collection time period)?
  - iii How long (in seconds) did it take for the SpO<sub>2</sub> to decrease by 1%? 2%? 3%? (and so on till lowest value). How long to increase by 1%? 2%? Mark these time intervals on the SpO<sub>2</sub> plot.
- e) **'Hold\_Exhale'** files: Repeat question D (a-c) for **'Hold\_Exhale'** files.
- f) Explain the difference in your results for **'Hold\_Inhale'** and **'Hold\_Exhale'** (comparing subject 1's inhale data to subject 1's exhale data and repeat on subject 2 files...). (~200 words).
- g) Using the information from the 'Hold' analysis:
- i Based on your findings is the pulse or the SpO<sub>2</sub> signal the best respiratory arrest detector? Why does one signal have a quicker response time?
  - ii What causes the changes in Pulse rate?
- h) **'Rest'** files: Compare the heart rate value (in beats per minute) as determined by the pulse oximeter and by the ECG data (using 10 beats for the beginning, middle and end of your file). How similar/different are the values? Why is there (or not) a difference between the two measurement methods?
- i) **'Running'** files: (max 400 words).
- i What changed in the respiratory effort signal? Why would this happen?
  - ii What changed in the SpO<sub>2</sub> signal? Why would this happen?
  - iii What changed in the Pulse rate signal? Why would this happen?
  - iv What changed in the ECG signal? Why would this happen?



- v Does running cause motion artefact in any of the signals? Why? If so, show a plot to support your answer.

j) 'Running' files: (max 100 words)

How long did it take for the pulse rate and breathing rate signal to return to Reg. Br. or 'at rest' values?

- i) Was there any change in the SpO<sub>2</sub> signal?
- ii) How long did it take for the pulse rate and breathing rate signal to return to Reg. Br. or 'at rest' values?
- iii) What happens in your body to account for the changes in the pulse rate and SpO<sub>2</sub> signals? (~ 100 words).