## Experiment HH-8: Heart Sounds and Pulse Wave Analysis

### Background

The sounds created by the opening and closing of the valves between the chambers and vessels leaving the heart were historically used to diagnose cardiac abnormalities. The technique of listening to these sounds is called auscultation, a cornerstone of cardiovascular assessment.

- **S1 (First Heart Sound)** is heard at the start of systole, produced by the closing of the atrioventricular (AV) valves – the mitral and tricuspid valves – just as the ventricles contract. This sound occurs just before the pulse wave rises.
- **S2 (Second Heart Sound)** is heard at the start of diastole, produced by the closing of the semilunar valves – the aortic and pulmonary valves – as the ventricles relax. This sound occurs just after the peak of the pulse wave, when blood pressure begins to fall.

In this lab, students will record heart sounds and the pulse waveform simultaneously, to analyze how mechanical valve events relate to vascular responses.

## Experiment ADS-BIA-5: Heart Sounds

### Equipment Required

PC or Mac Computer

ADS or ADS MAX Board, USB cable, Power Supply Cable

PTN-104 pulse sensor

HSMN-300 heart sounds microphone

SPN-304 spirometry and heart sounds sensor

*Note*: To ease setup, connect the sensor(s) to the A-ADS-IA adapter *before* plugging the adapter into the board. To disconnect, unplug the adapter from the board *first*, then remove the sensor(s).

### Setup (ADS)

1. Locate the PTN-104 pulse sensor, HSMN-300 heart sounds microphone, and the SPN-304 spirometry and heart sounds sensor.
2. Plug the PTN-104 pulse sensor into Channel 1 on the A-ADS-IA.
3. Plug the connector of the heart sounds mic to the white port of the SPN-304.
4. Plug the SPN-304 into the Channel 2 port on the A-ADS-IA.
5. Flip the switch on the SPN-304 into the **right** position, labeled HS.

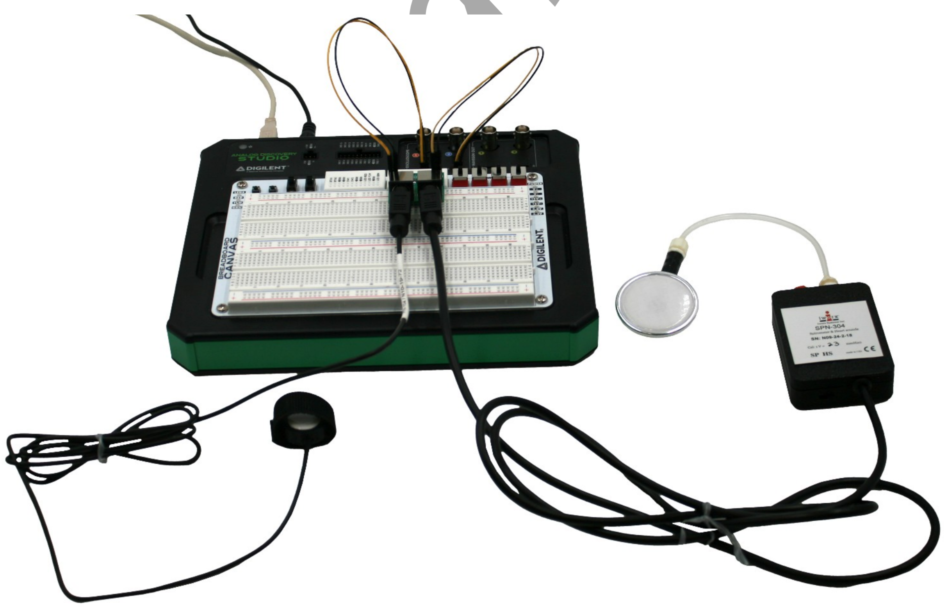


*Figure ADS-BIA-5-S1: The pulse sensor and heart sounds sensor attached to the ADS.*

**Setup (ADS MAX)**

If using the ADS MAX, setup instructions will be the same. Channel connections are labeled on the A-ADS-IA board, as shown below.

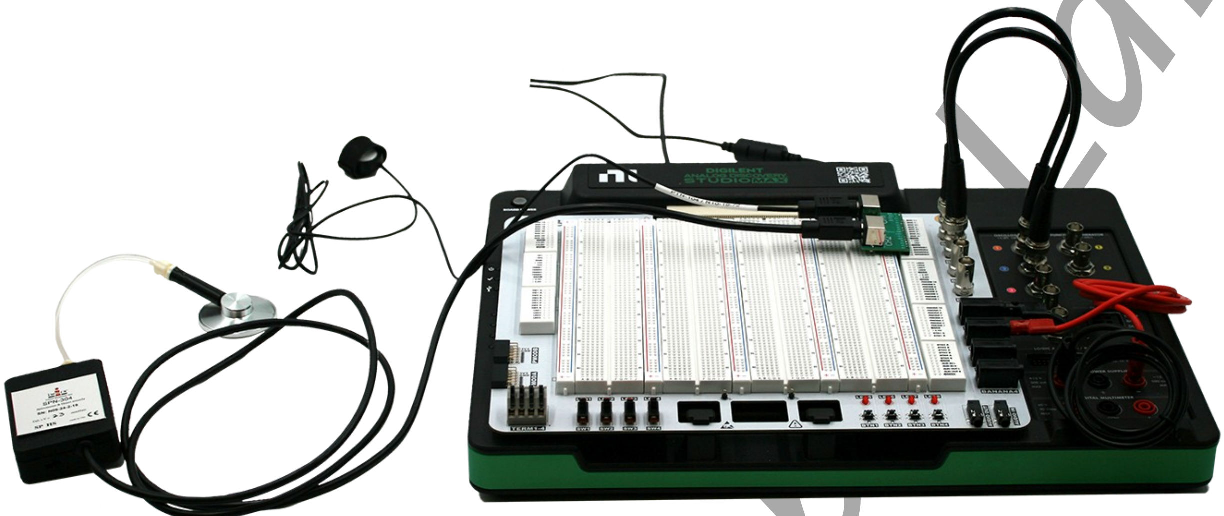


*Figure ADS-BIA-5-S1: The pulse sensor and heart sounds sensor connected to the ADS MAX.*

# Experiment ADS-BIA-5: Heart Sounds and Pulse Wave Analysis

## Exercise 1: Heart Sounds from a Resting Subject

Aim: To record the heart sounds from different points around the chest of a resting subject.

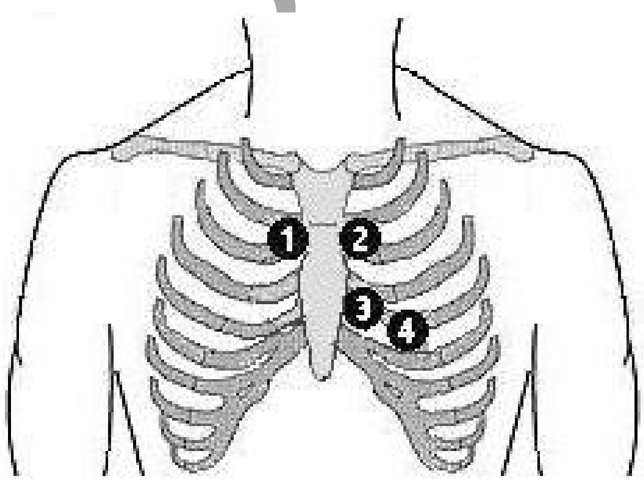
Approximate Time: 15 minutes

The trace will be cleaner if your lab partner or ACE bandage is holding up the heart sounds monitor

***Procedure***

1. Instruct the subject to move away from any electronic equipment and keep still when the pulse and heart sounds are being recorded.
2. Place the pulse sensor on the fleshy part of the left thumb. Tighten the velcro strap so the subject can just feel the pulse in their thumb. It should not be too tight or too loose. Wrap the Velcro strap around the end of the finger to attach the unit firmly in place.
3. Firmly place the heart sounds monitor on one of the four auscultation areas:
    - Aortic, which is located in the second intercostal space at the right sternal margin, #1 on the figure below. At this location, the systolic murmurs of aortic stenosis and Increased aortic valve flow are the loudest.
    - Pulmonic, which is located in the second intercostal space at the left sternal border, #2. At this location, the systolic murmur of pulmonic stenosis and the diastolic murmur of pulmonic regurgitation are the loudest.
    - Tricuspid, which is located at the lower left sternal border, #3. At this location, the diastolic murmur of tricuspid stenosis is the loudest.
    - Mitral, which is usually located in the fifth intercostal space, at the apex beat, #4. At this location, the systolic murmur of mitral regurgitation, and the diastolic murmurs of mitral stenosis and increased valvular flow, are the loudest.

The heart sounds monitor works better under clothes.




The subject will have to move the heart sounds monitor around to find good positioning.
Any sort of movement will create noise on the monitor.

*Figure ADS-BIA-5-L1: Positions of the auscultation areas on the chest: 1-Aortic, 2-Pulmonic, 3-Tricuspid, 4-Mitral.*

3. Click on the Record button. The signal should begin scrolling across the screen.
4. Click on the AutoScale All button.
    - If the signal on the pulse channel is upside down when compared to trace, click on the downward arrow to the left of the channel title and select the Invert function. The trace should now look similar to the one in the figure.
5. ***If the heart sounds recording is noisy***, hold the monitor against the chest more firmly or hold it in place with an elastic bandage (Ace wrap) or belt. Also, have the subject hold their breath during the recording.
6. When you have a suitable trace, type **Resting** in the Mark box. Click the mark button to attach the comment to the data. Record for at least five minutes.
7. Click Stop to halt recording.
8. Select Save As in the File menu, type a name for the file. Click on the Save button to save the data file.
9. Repeat Steps 2 through 7 for the other three auscultation areas.
10. Select Save in the File menu.

### *Data Analysis*

1. Click the 2-Cursor icon so that two vertical lines appear over the recording window.

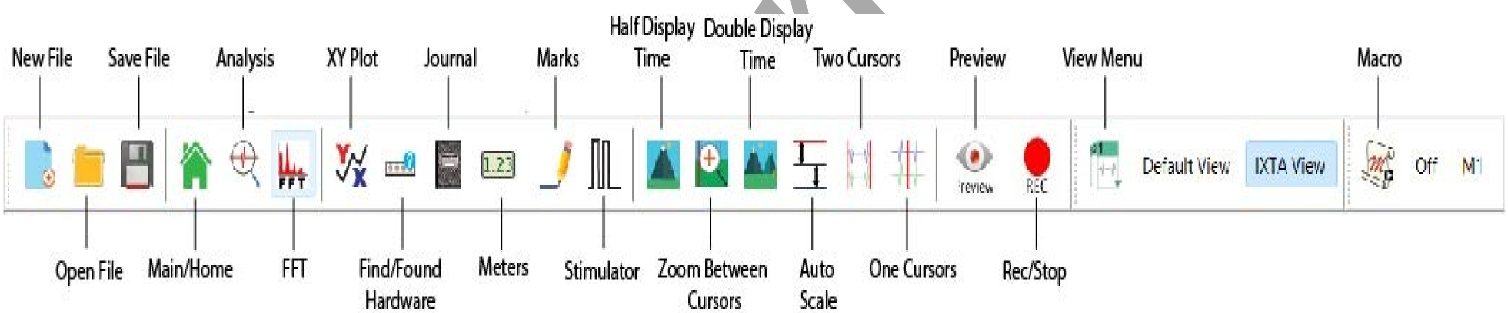



*Figure ADS-BIA-5-L2: The LabScribe toolbar.*

2. Drag the cursors left and right so that five complete pulse waves taken from the first auscultation area, while the subject was resting are located between the two cursors. Click the Zoom Between Cursors button to expand this region.
3. Click the Analysis icon to open the Analysis window.
4. Move the cursors to the first heart sound (S1) in the first of the five selected cardiac cycles. Place one cursor at the beginning of the first S1 sound wave and the second cursor at the end of the same S1 sound wave. The values for the Abs Int and the duration (T2-T1) of the HS Integral of this S1 are displayed in the table in the title area of this window.

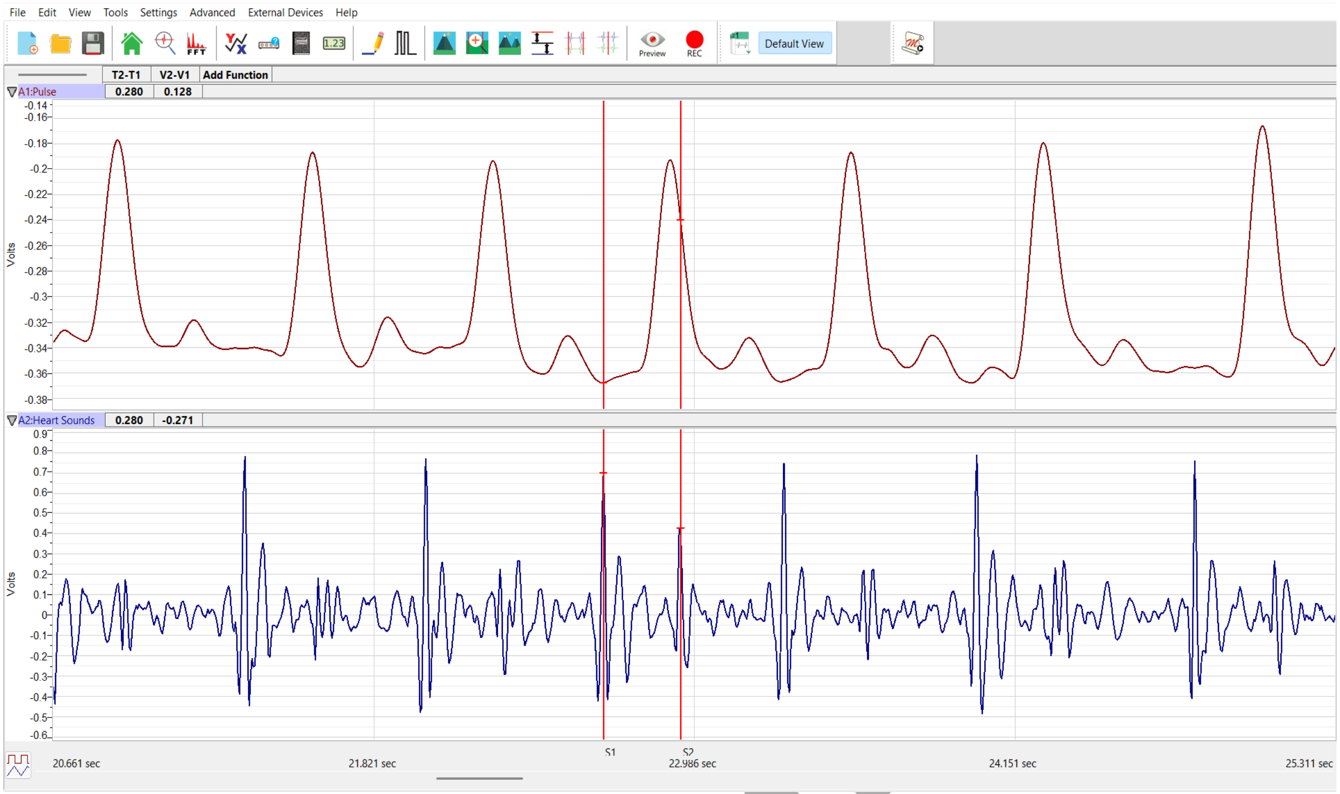



*Figure ADS-BIA-5-L3: The pulse wave and heart sounds channels displayed in the Analysis window. The cursors are placed on the S1 and S2 heart sounds.*

5. Measure the pulse transit time (PTT) by placing the first cursor on S1 and the second cursor just before the initial upstroke of the arterial pulse wave. Take measurements for the four other cycles displayed on the window.
6. These values can be entered into the Journal by either typing the titles and values directly, or by using the right-click menu. When using the functions in the right-click menu of the Analysis window, place the cursors to take measurements, then, select Add Title to Journal or Add Data to Journal to add the values to the Journal.
7. Repeat Steps 4, 5 and 6 for the S1 heart sounds in the four other cardiac cycles displayed on the window.
8. Repeat Steps 4, 5 and 6 for the S2 heart sounds in the five cardiac cycles from the first auscultation area.
9. Repeat Steps 4, 5 and 6 for the S1 and S2 sounds from five cardiac cycles recorded from each of the three other auscultation areas.
10. Find the average Abs Int and average duration of the HS Integrals for the S1 and S2 sounds taken from the four auscultation areas described earlier. Report the averages for these values in the appropriate section in Table 1.
11. Calculate the ratio of the average Abs Int to the average duration of the HS integrals for the S1 and S2 heart sounds from each auscultation area. This ratio (Abs Int/Duration) will yield a value that is the relative amplitude of each heart sound from each auscultation area.

### *Questions*

1. From the data collected while the subject was resting, compare the relative amplitude (Abs Int/Duration) in of the S1 heart sound from the Aortic auscultation area to the relative amplitude of the S2 heart sound from the same auscultation area? Which sound, S1 or S2, is louder at this auscultation area?
2. From the other data collected while the subject was resting, compare the relative amplitude (Abs Int/Duration) of the S1 heart sound to the relative amplitude of the S2 heart sound for each of the other three auscultation areas? Which sound, S1 or S2, is louder at the Pulmonic area? At the Tricuspid area? At the Mitral area?

***Note:*** *Compare the relative amplitude of S1 to the relative amplitude of S2 from the same auscultation area. Do not compare the relative amplitude of S1 from one auscultation area to the relative amplitude of S1 or S2 from another auscultation area. Comparisons between heart sounds from different auscultation areas are invalid because: the force holding the heart sound monitor to the chest probably varies between recordings made from different auscultation areas; and, the thickness and density of the chest wall varies between auscultation areas.*

3. For each auscultation area, which heart sound, S1 or S2, has the higher relative amplitude? Which auscultation area shows the greatest difference between the relative amplitudes of S1 and S2?
4. The S1 heart sound is associated with ventricular contraction and the S2 heart sound is associated with ventricular relaxation. Predict which auscultation areas should have higher relative amplitudes of S1? Of S2? Which auscultation areas actually have higher amplitudes of S1 and S2?

## Exercise 2: Heart Sounds after Exercise

Aim: To record the heart sounds from auscultation areas on the same subject used in Exercise 1 as the subject is recovering from exercise.

Approximate Time: 30 minutes depending on the duration of exercise

### *Procedure*

1. Have the subject exercise by running in place, climbing stairs, or pedaling a bicycle. After 2 minutes of exercise, have the subject sit down. Reattach the pulse sensor and place the heart sounds monitor on the subject's aortic auscultation area as quickly as possible.
2. Click Record, and then click AutoScale All. Observe the pulse and heart sounds signals. If the pulse and heart sounds signals are sizable and relatively noise-free and proceed to Step 6.


*Figure ADS-BIA-5-L4: Recording of pulse and heart sounds displayed in the Main window. The pulse transit time (PTT), measured with the cursors, is 130 ms.*

3. If the pulse waves appear noisy, check the tension on the pulse sensor. If the heart sounds recording is noisy, click the heart sounds monitor against the chest more firmly or hold it in place with an elastic bandage (Ace wrap) or a belt. Also, have the subject hold his or her breath during the recording.
4. When you have a suitable trace, type the name of the auscultation area used for the recording in the comment line to the right of the Mark button. Click the mark button to attach the comment to the data. Record at least 10-15 seconds of noise-free data.
5. Click Stop to halt recording.
6. Repeat Steps 4 through 7 for the other three auscultation areas.
7. Click the Save button to save the file.

***Data Analysis***

1. Click the 2-Cursor icon so that two vertical lines appear over the recording window.
2. Drag the cursors left and right so that five complete cardiac sounds cycles taken from the first auscultation area, during the subject's recovery from exercise, are located between the two cursors. Click the Zoom Between Cursors button to expand this region.
3. Click the Analysis icon to open the Analysis window.
4. Move the cursors to the first heart sound (S1) in the first of the five selected cardiac sound cycles. Place one cursor at the beginning of the first S1 sound wave and the second cursor at the end of the same S1 sound wave. The values for the Abs Int and the duration (T2-T1) of the HS Integral of this S1 are displayed in the table in the title area of this window.
5. Measure the pulse transit time (PTT) by placing the first cursor on S1 and the second cursor just before the initial upstroke of the arterial pulse wave. Take measurements for the four other

cycles displayed on the window.

6. These values can be entered into the Journal by either typing the titles and values directly, or by using the right-click menu. When using the functions in the right-click menu of the Analysis window, place the cursors to take measurements, then, select Add Title to Journal or Add Data to Journal to add the values to the Journal.
7. Repeat Steps 4 and 5 for the S1 heart sounds in the four other cardiac cycles displayed on the window.
8. Repeat Steps 4 and 5 for the S2 heart sounds in the five cardiac cycles taken from the first auscultation area while the subject was recovering from exercise.
9. Repeat Steps 4 and 5 for the S1 and S2 sounds from five cardiac cycles taken from each of the three other auscultation areas while the subject was recovering from exercise.
10. Find the average Abs Int and average duration of the HS Integrals for the S1 and S2 sounds taken from the four auscultation areas while the subject was recovering from exercise. Report the averages for these values from the exercise recovery period in the appropriate section of the table.
11. Calculate the ratio of the average Abs Int to the average duration of the HS integrals for the S1 and S2 heart sounds from each auscultation area while the subject was recovering from exercise. This ratio (Abs Int/Duration) will yield a value that is the relative amplitude of each heart sound from each auscultation area.

***Questions***

1. From the data collected while the subject was recovering from exercise, compare the relative amplitude (Abs Int/Duration) in Table 1 of the S1 heart sound from the Aortic auscultation area to the relative amplitude of the S2 heart sound from the same auscultation area? Which heart sound, S1 or S2, has the higher relative amplitude at the Aortic area?
2. From the other data collected while the subject was recovering from exercise, compare the relative amplitude (Abs Int/Duration in the data table of the S1 heart sound to the relative amplitude of the S2 heart sound for each of the other three auscultation areas? Which sound, S1 or S2, has the higher relative amplitude at the Pulmonic area? At the Tricuspid area? At the Mitral area?

**Reminder:** *Compare the relative amplitude of S1 to the relative amplitude of S2 from the same auscultation area. Do not compare the relative amplitude of S1 from one auscultation area to the relative amplitude of S1 or S2 from another auscultation area.*

3. For each auscultation area, is the heart sound that has the higher relative amplitude while the subject was recovering from exercise the same as the heart sound that had the higher relative amplitude while the subject was resting?
4. Did the measured PTT decrease, increase, or stay the same after exercise for each of the auscultation areas?

**Table ADS-BIA-5-L1:Abs Ints and Durations (Dur) of the S1 and S2 Heart Sounds**

| | Average Values While Resting | | | | | | Average Values After Exercise | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Auscultation Area | S1 | | | S2 | | | S1 | | | S2 | | |
| | Abs Int (V.s) | Dur (s) | Area Dur | Abs Int (V.s) | Dur (s) | Area Dur | Abs Int (V.s) | Dur (s) | Area Dur | Abs Int (V.s) | Dur (s) | Area Dur |
| Aortic | | | | | | | | | | | | |
| Pulmonic | | | | | | | | | | | | |
| Tricuspid | | | | | | | | | | | | |
| Mitral | | | | | | | | | | | | |