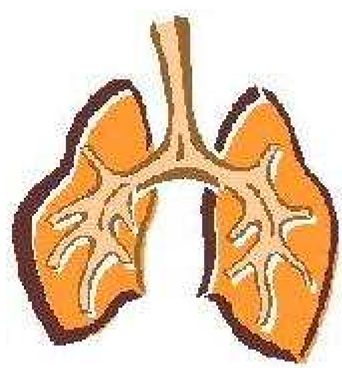
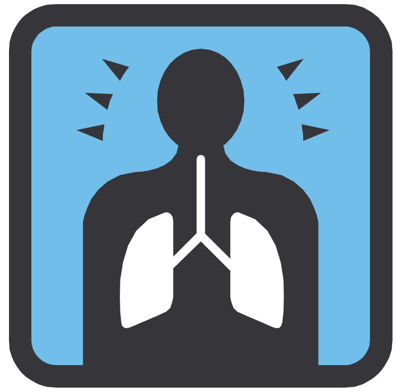
Pressure Based Airflow Laboratory



CleveLabs Laboratory Course System Version 6.0

Introduction



Measuring airflow directly is extremely important for many biomedical engineering applications. For example, airflow measurements can provide important insight into sleep-disordered breathing. By monitoring airflow during sleep, researchers can explore the mechanisms that cause someone to have sleep apnea, or the momentary cessation of breathing during sleep. There are many different methods that can be utilized to measure airflow. Some are direct methods while others are indirect. As you may have already learned in previous laboratory sessions, one common direct method for measuring airflow is to place a thermocouple near the mouth and nostrils. As air flows past the sensor, it changes the temperature of it and hence the output voltage. Another method, although indirect, is a piezo-electric sensor positioned on an elastic belt worn around the waist. A piezo-electric crystal generates an output voltage in response to a change in length. Therefore, as the person breathes, causing their waist expand and contract, the belt length changes and hence the output voltage changes. A new technique that will be learned in this laboratory session is pressure based airflow measurements. Using a pressure sensor to monitor airflow has several advantages compared to other sensors. This laboratory session will discuss the tradeoffs between using different types of sensors to monitor respiration.

Equipment required:

- CleveLabs kit
- CleveLabs Course Software
- Cannula
- Respiratory Effort Belt
- Microsoft® Excel, MATLAB®, or LabVIEW™

Background

Pressure Sensing

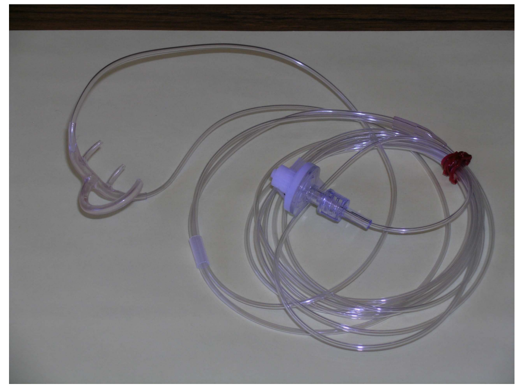


Figure 1. A plastic cannula is used to measure airflow from the mouth and nose.

A typical pressure sensor design includes a diaphragm connected to a strain gauge, or one that has a strain gauge bonded to its surface. A change in pressure around the diaphragm changes its curvature. This in turn causes a tiny change in the resistance of the attached strain gauge. This output is then highly amplified by electronics to capture the voltage change as a function of the resistance change. The BioRadio 150 unit has a small pressure sensor embedded inside the unit. These small semiconductor based pressure sensors are readily available from many commercial manufacturers. The plastic outlet port at the top of the BioRadio is internally connected to the input of the pressure sensor through small flexible tubing. To measure airflow we must tap into the flow of air that a person inhales or exhales during respiration. This is accomplished using a plastic cannula (Fig 1). The plastic cannula should be connected to the plastic input at the top of the BioRadio unit. Breathing in and out of the cannula will then change the flow and hence the pressure on the sensor in the BioRadio unit. This change in pressure is output as a change in voltage recorded by the BioRadio. More specifically, the pressure sensor integrated inside the BioRadio is a differential pressure sensor, which is why there are two input ports located on the unit. The diaphragm in the pressure sensor is deflected in an opposite direction for the different pressure input ports to produce a differential pressure reading. If only one input is connected, the pressure is measured with respect to the atmosphere.

Snoring

It is estimated that 60 million people in the United States snore on a regular basis. On average, the level of noise this creates is around 60 decibels, the sound level of normal conversations or a ringing telephone. However, in some cases, the level can reach up to 90 decibels, rivaling the levels created by heavy truck traffic and lawnmowers. Although this may be an inconvenience to other people in the household, there are other complications also associated with snoring.

The underlying cause for snoring is always blockage in the breathing passage. When your breathing passage is partly blocked, the airflow becomes irregular. This irregular airflow causes your soft palate, the posterior region of the roof of your mouth, to flap. This flapping creates the loud snoring sound. There are many possible reasons why an individual may be snoring and most of them are completely harmless. Aging, stuffy nose due to allergies or the common cold, obesity, and alcohol or sedative use are some of the main causes of snoring, but typically cannot be treated or avoided in any way.

However, snoring may also arise for more complex reasons. Obstructive sleep apnea is one of the most commonly occurring sleep disorders, and snoring is one of the major symptoms. Affecting as many as 12 million people in the United States, up to 10 million of those are undiagnosed. Sleep apnea is a serious condition that is defined as the temporary cessation of respiration during sleep. This stop can occur for over 10 seconds and up to 300 times a night, leading to excessive daytime sleepiness, as well as significant social, behavioral, and emotional problems, including depression. Additionally, physical complications include systemic hypertension, pulmonary hypertension, cardiac problems and accidental death due to falling asleep at inopportune times such as while driving.

There are countless companies that claim to have the cure for snoring. Products on the market today include:

- Injection snoreplasty to stiffen the soft palate
- Posture-correcting pillows
- Herbal supplements
- Aromatherapy
- Throat sprays
- Surgery to enlarge the throat
- Nasal strips
- Hypnosis
- Radio frequency tissue reduction

Although some are more effective than others, the plethora of choices available to the snoring sufferer allows him or her to address the many possible grades and causes of his or her snoring.

Therefore, snoring is an important variable to measure during sleep studies. As described above, there are many transducers that can be used to monitor respiratory signals. One advantage of using a pressure sensor to record respiration is that snoring can also be detected. A pressure sensor is sensitive enough to detect changes in the frequency of airflow when a person is breathing. When a person snores, it yields higher frequencies in the flow and hence the pressure signal than when a person is breathing normally. Other methods for detecting snore are using a microphone near the subject during the study. However, using the cannula based method provides the advantage that you are obtaining two channels of information, airflow and snore, with a single transducer.

Experimental Methods

Experimental set-up

1. For this laboratory, you will need a plastic cannula and the respiratory effort belt.

2. Place the respiratory belt around the torso of the test subject. Securely fasten the respiratory effort belt around the subject just above the stomach and around the rib cage. Attach the leads from the respiratory effort belt to the + and – inputs for channel 1 of your BioRadio (Figure 2).

3. Connect one end of the plastic tubing from the cannula to the pressure input on the BioRadio which is closest to the antenna (Figure 2).

4. The other end of the cannula should be positioned on the subjects face. The two plastic prongs should point up, just into the subject's nostrils while the single prong should point down in front of the subject's mouth. The plastic leads should be routed up and over the subject's ears on each side of their head.

5. Turn the BioRadio on.

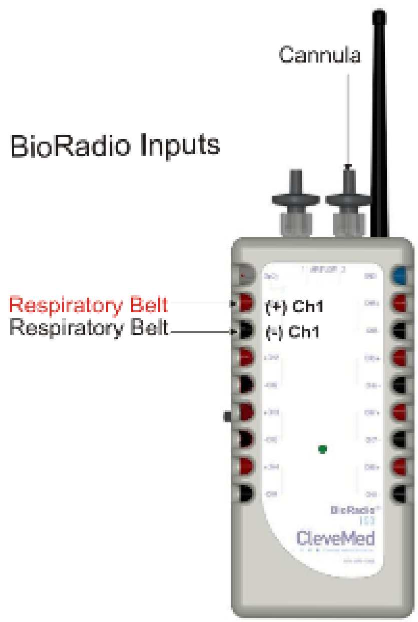


Figure 2. BioRadio set-up for Pressure Based Airflow Laboratory

Procedure

1. Run the CleveLabs Course software. Log in and select the "Pressure Based Airflow" Lab under the Advanced Physiology subheading and click the "Begin Lab" button. The CleveLabs software will automatically program the BioRadio to the "Pressure Based Airflow" configuration.

2. Click on the BioRadio data tab and click on the "Start" button. Respiratory effort and pressure based airflow should be scrolling across the screen.

3. With the subject's signal scrolling across the screen, click on the "Save" button and record approximately 10 seconds of data while the subject breathes normally. Name the data file "normalbreath1".

4. Instruct the subject to inhale deeply and note the direction of the voltage change for the pressure sensor on the display. Instruct the subject to exhale deeply and note the direction of the voltage change for the pressure sensor on the display.

5. Now switch the plastic cannula to the other pressure input port.

6. With the subject's signal scrolling across the screen, click on the "Save" button and record approximately 10 seconds of data while the subject breathes normally. Name the data file "normalbreath2".

7. Instruct the subject to inhale deeply and note the direction of the voltage change for the pressure sensor on the display. Instruct the subject to exhale deeply and note the direction of the voltage change for the pressure sensor on the display.

8. Now click on the Spectral Analysis tab and click on the frequency domain tab. Note the frequency band where most of the power lies during normal respiration by the subject.

9. Instruct the subject to begin snoring. Note what happens in the time domain plot and note any shift in the frequency band where the main power lies during snoring.

10. Save approximately 10 seconds of data while the subject is snoring and name the data file "snore".

Data Analysis

1. Using LabVIEW™, MATLAB®, or the CleveLabs post processing toolbox, open the data file named "normalbreath1".

2. Examine the correlations that exist between the pressure sensor channel and the respiratory effort channel. Do strong correlations exist?

3. Using LabVIEW™, MATLAB®, or the CleveLabs post processing toolbox, open the data file named "normalbreath2".

4. Complete a frequency analysis of each data channel and determine where the peak frequency of the signal is located.
5. Using LabVIEW™, MATLAB®, or the CleveLabs post processing toolbox, open the data file named "snore".

6. Complete a frequency analysis of each data channel and determine where the peak frequency of the signal is located.

Discussion Questions

1. Describe any difference in direction of the respiratory signals based on which port the cannula is connected. Explain why differences do or do not exist.

2. Describe how the power in the spectral content of the pressure based airflow signal changes in response to snore.

3. Is there a difference in spectral content of the respiratory effort belt in response to snoring?

4. Imagine that you can adjust the compliance of the plastic cannula tubing. What impact would you expect a harder or softer plastic to have on the ability to record snore?

5. Describe how you would develop an automated algorithm to detect snoring based on the signal you recorded.

References

1. Guyton and Hall. Textbook of Medical Physiology, 9th Edition, Saunders, Philadelphia, 1996.

2. Normann, Richard A. Principles of Bioinstrumentation, John Wiley and Sons, New York, 1988.

3. Rhoades, R and Pflanzer, R. Human Physiology. *Third Edition.* Saunders College Publishing, Fort Worth 1996.