AIR FLOW AND LUNG VOLUME

OBJECTIVES

Students will learn about the various factors which influence breathing rate and lung volume by working and becoming familiar with Vernier's spirometer. A challenge section at the end of this lab introduces basic LabVIEW programming techniques that allow students to understand how the code acquires and transforms the data into signals that can be analyzed.

MATERIALS

- NI LabVIEW 8.5.1 or later
- NI Biomedical Startup Kit 3.0
- NI ELVIS II Series Benchtop Workstation
- NI ELVIS II Series Prototyping Board
- AC/DC power supply
- NI ELVISmx 4.0 or later CD
- High-speed USB 2.0 cable
- Computer
- Wires to build circuits
- Vernier Analog Proto Board Connector (Order code BTA-ELV)
- Vernier Spirometer (Order code SPR-BTA)

THEORY

The spirometer uses a differential pressure transducer to measure air flow rate. In the center of the flow head is a mesh screen. When a subject blows into the flow head, a slight difference in pressure occurs between the front and the back surface of the screen as air is forced through. A tube in front of the screen and a tube behind the screen pass the pressures to the differential pressure transducer, which allows for direct measurement of airflow rate (L/s). Volume (L) can then be calculated from this data by integrating the flow rate as a function of time.

The spirometer can be used to perform a variety of tests, including tests for forced expiratory volume (FEV), forced vital capacity (FVC), and tidal volume (TV). FEV is the volume of air exhaled after a short period of constant effort. FVC is the volume of air exhaled by a forced maximal exhalation after a full inhalation. TV is the volume of air inhaled and exhaled at rest. In this lab, students will perform each of these tests.

(Summarized from the Spirometer User Guide; http://www.vernier.com)

BUILDING THE EXPERIMENT ON ELVIS II SERIES

The Vernier sensor attaches to NI ELVIS II Series through the Analog Proto Board Connector. The following steps and Figure 1 below illustrate how to connect the Analog Proto Board Connector to the NI ELVIS II Series Prototyping Board.

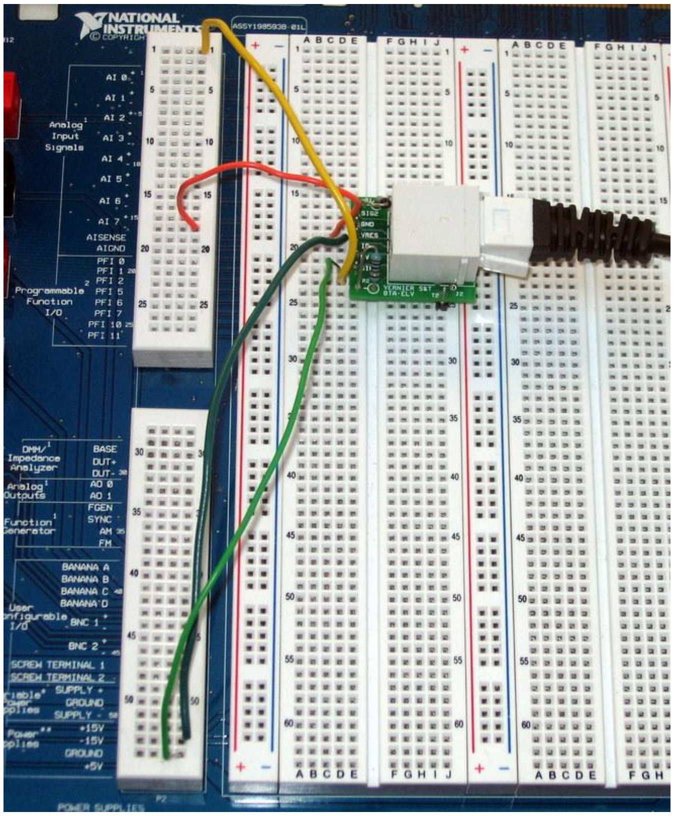


Figure 1: Connecting the Analog Proto Board Connector to NI ELVIS II Series

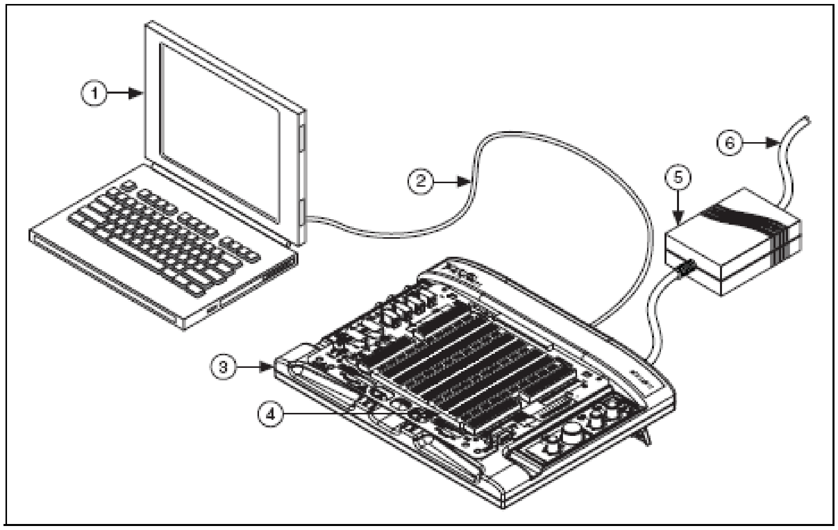
Connect the following pins to wire the connector:

1) $AI0^+$ to SIG1 of the Analog Proto Board Connector
2) +5V DC power supply to 5V of the Analog Proto Board Connector
3) GROUND power supply to GND of the Analog Proto Board Connector
4) AIGND to GND of the Analog Proto Board Connector

RUNNING THE EXPERIMENT

To set up the experiment on NI ELVIS II Series:

1) Connect the USB cable from NI ELVIS II Series to your computer and plug the power supply into a power outlet.
2) Turn the prototyping board power switch located on the rear panel to the on position (see Figure 2).
3) Turn the prototyping power supply switch located on the benchtop workstation to the on position (see Figure 2).
    - A green power LED should now be lit, indicating that the full power supply is turned on.
    - A yellow USB ready LED should also be lit, indicating that the NI ELVIS II Series is properly connected to the USB host.
4) Insert the spirometer into the Analog Proto Board Connector connected to AI 0+.



1	Laptop Computer	4	Prototyping Board
2	USB Cable	5	AC/DC Power Supply (Included with NI ELVIS II)
3	NI ELVIS II Benchtop Workstation	6	To Power Outlet

Figure 2: NI ELVIS II Series Set-Up

To set up the experiment in LabVIEW:

1) Open the LabVIEW program **NI Air Flow and Lung Volume Lab.vi**.
2) If the front panel is not already displayed, go to “Window” and select “Show Front Panel”.
    - The front panel is shown below in Figure 3.
    - The Flow Rate vs. Time graph records the flow rate recorded by the spirometer over time in liters per second.
    - The Volume vs. Time graph displays the volume of air inhaled/exhaled over time based on the integral of the Flow Rate vs. Time graph.
    - The Maximum Exhale Rate and Maximum Inhale Rate indicators supply numerical outputs of the graphed data

- The Physical Channels dropdown menu allows you to choose the device and channel(s) from which to acquire data.
- The default experiment length is 15 seconds.
- The default sampling rate is 1000 samples per second.
- Switching the "Write to file?" Booleans to ON allows you to save the flow rate data and/or volume data as separate .lvm files.
- The "STOP" button will terminate data collection at any point during the experiment.

Figure 3: Air Flow and Lung Volume Front Panel

DATA COLLECTION

The spirometer can be used for both inhalation only and inhalation/exhalation experiments. The following bullets outline some helpful tips to remember when recording data.

- Ensure that the volunteer is breathing only through his or her mouth. A nose clip may be necessary.
- Hold the spirometer vertically and still during measurements.
- For best results, start the data collection on an exhale.
- For experiments in which students will only exhale through the spirometer, use a disposable cardboard mouthpiece. Attach the mouthpiece to the side of the flow head marked “Inlet” (See figure 4).

Figure 4: Spirometer with disposable mouthpiece (www.vernier.com)

- For experiments in which students will inhale and exhale through the spirometer, use a disposable cardboard mouthpiece *and* a disposable bacterial filter. Attach the bacterial filter to the side of the flow head marked “Inlet” and attach the cardboard mouthpiece to the bacterial filter (See figure 5).

Figure 5: Spirometer with disposable mouthpiece and bacterial filter (www.vernier.com)

Part 1: Measuring normal breathing pattern and tidal volume

In the first part of this lab, you will measure your normal breathing pattern and tidal volume at rest with the LabVIEW program **NI Air Flow and Lung Volume Lab.vi**. Figure 6 below illustrates an example of a front panel for this experiment. This experiment requires the students to inhale and exhale through the spirometer. Therefore, the bacterial filter should be used.

1) Choose the correct device and channel in the Physical Channels dropdown menu that corresponds to your NI ELVIS II Series.
2) Verify that the experiment length is set to the default length of 15 seconds and the sample rate is set to 1000 samples per second.
3) Press the run arrow in the upper left-hand corner of your screen to begin collecting data.
4) Place your mouth over the mouthpiece and breathe in and out normally until the measurement process stops.
5) Record the maximum exhale rate, maximum inhale rate, maximum exhale volume, and maximum inhale volume in Table 1.
6) Take a screenshot of the front panel for future reference.
7) Repeat steps 1-6 for each student.

Part 2: Measuring breathing pattern and lung volume with deep breathing

In the second part of this lab, you will measure your air flow rate and lung volume when taking deep breaths. This experiment requires the students to inhale and exhale through the spirometer. Therefore, the bacterial filter should be used.

1) Verify that the correct device and channel is still shown in the Physicals Channels dropdown menu.
2) Ensure that the experiment length is still set to 15 seconds and the sample rate is set to 1000 samples per second.
3) Press the run arrow in the upper left-hand corner of your screen to begin collecting data.
4) Take the deepest breath that you can, place your mouth over the mouthpiece, and exhale all of the air out of your lungs. Continue this deep breathing until the measurement process stops.
5) Record the maximum exhale rate, maximum inhale rate, maximum exhale volume, and maximum inhale volume in Table 2.
6) Take a screenshot of the front panel for future reference.
7) Repeat steps 1-6 for each student.

Part 3: Measuring breathing pattern and tidal volume after physical activity

The third part of this lab demonstrates the effect of physical activity on breathing patterns. This experiment requires the students to inhale and exhale through the spirometer. Therefore, the bacterial filter should be used.

1) Verify that the correct device and channel is still shown in the Physicals Channels dropdown menu.
2) Ensure that the experiment length is still set to 15 seconds and the sample rate is set to 1000 samples per second.
3) Run in place for 3 minutes.
4) Press the run arrow in the upper left-hand corner of your screen to begin collecting data.
5) Place your mouth over the mouthpiece and breathe in and out normally until the measurement process stops.
6) Record the maximum exhale rate, maximum inhale rate, maximum exhale volume, and maximum inhale volume in Table 3.
7) Take a screenshot of the front panel for future reference.
8) Repeat steps 1-7 for each student.

DATA ANALYSIS

Part 1: Measuring normal breathing pattern and tidal volume

Table 1: Air flow rate and tidal volume with normal breathing

Student Name	Maximum Exhale Rate (L/s)	Maximum Inhale Rate (L/s)	Maximum Exhale Volume (L)	Maximum Inhale Volume (L)

Part 2: Measuring breathing pattern and lung volume with deep breathing

Table 2: Air flow rate and volume with deep breathing

Student Name	Maximum Exhale Rate (L/s)	Maximum Inhale Rate (L/s)	Maximum Exhale Volume (L)	Maximum Inhale Volume (L)

Part 3: Measuring breathing pattern and tidal volume after physical activity

Table 2: Air flow rate and volume after physical activity

Student Name	Maximum Exhale Rate (L/s)	Maximum Inhale Rate (L/s)	Maximum Exhale Volume (L)	Maximum Inhale Volume (L)

1) List some factors that could affect your tidal volume and total lung capacity.
2) Compare the data recorded from each student and analyze the screenshots. Do you notice a difference in flow rate or volume based on gender? What about fitness level?
3) Would a trained athlete have a comparatively lower or higher lung capacity? Why?
4) Compare the data in Table 1 with that from Table 3. Did physical activity affect the air flow rate of your breaths? What about the volume of air inhaled/exhaled with each breath? How did the screenshots from Part 1 and Part 3 compare?
5) Were the trends noted in the question above consistent for each member in your group?

CHALLENGE

This section of the lab will introduce some of the basic concepts about the code used to produce this program. This is meant to give you a chance to explore LabVIEW code and to begin to understand how the program is structured.

The front panel of the VI (see Figure 3) is referred to as the user interface and displays the data acquired by the signal. In this lab, the data is displayed on two waveform charts – one showing Flow Rate vs. Time and the other displaying Volume vs. Time. The properties of each chart can easily be altered to change the visual appearance of the plot area (see Figure 7):

1) Select the Flow Rate vs. Time chart.
2) Right click >> Properties.

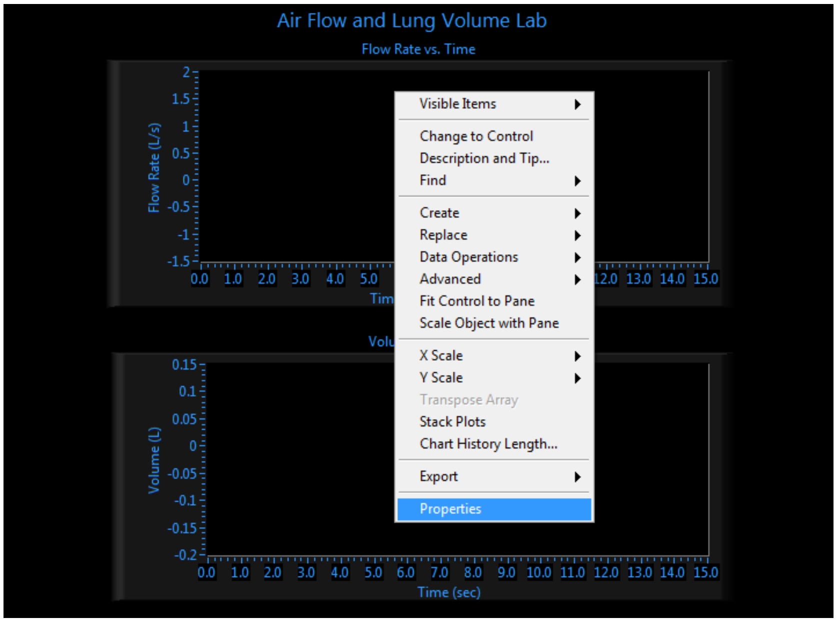


Figure 7: Changing Chart Properties

3) On the properties pop-up menu, look through the tabs to see the different options available. Under the Plots tab, change the color of the plot. Explore the different options to represent the data.
4) Is there a better way to represent the data you have collected? What about for the Volume chart?
5) Select the chart again, right click, and move your mouse to show the Visible Items menu. Select the varying options to explore the different tools you can view that are connected to the chart. Would any of the options be useful in helping you to collect and record more accurate data? How so? Would the same options be appropriate for the Volume chart?
6) Move your mouse over one of the “Write to file?” Booleans. Booleans are used when you want the user to select between two options. Right click to show the different options. Select “Replace” and move your mouse over the Boolean palette to explore the different options for displaying your Boolean (see Figure 8). The palette displays different graphical options for representing your Boolean.

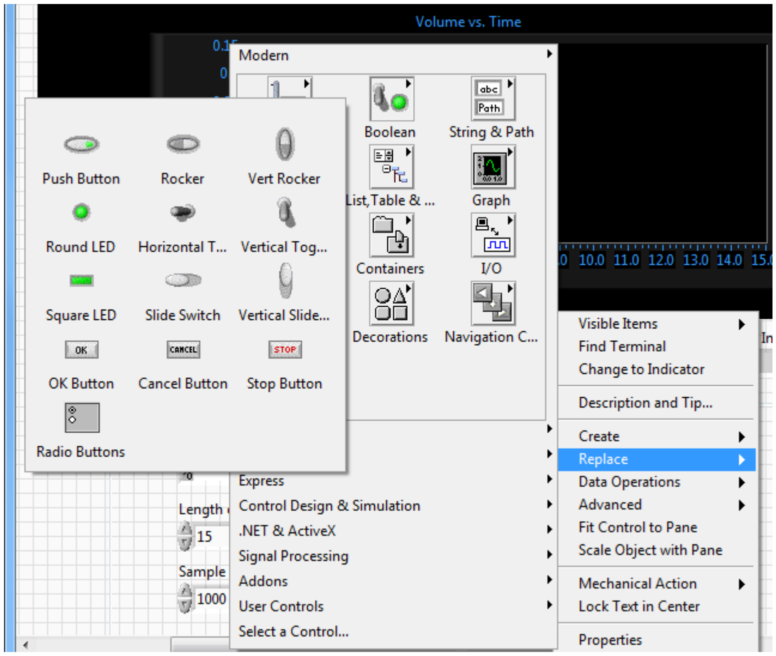


Figure 8: Boolean Options

The above options show just a few ways you can modify the front panel to suit your particular application to make a clean, easy-to-follow user interface. Now, switch to the block diagram to display the code (Window>>Show Block Diagram). This code is responsible for taking the user input, acquiring the signal from ELVIS II Series, manipulating the data to display it in the desired output, and displaying the data.

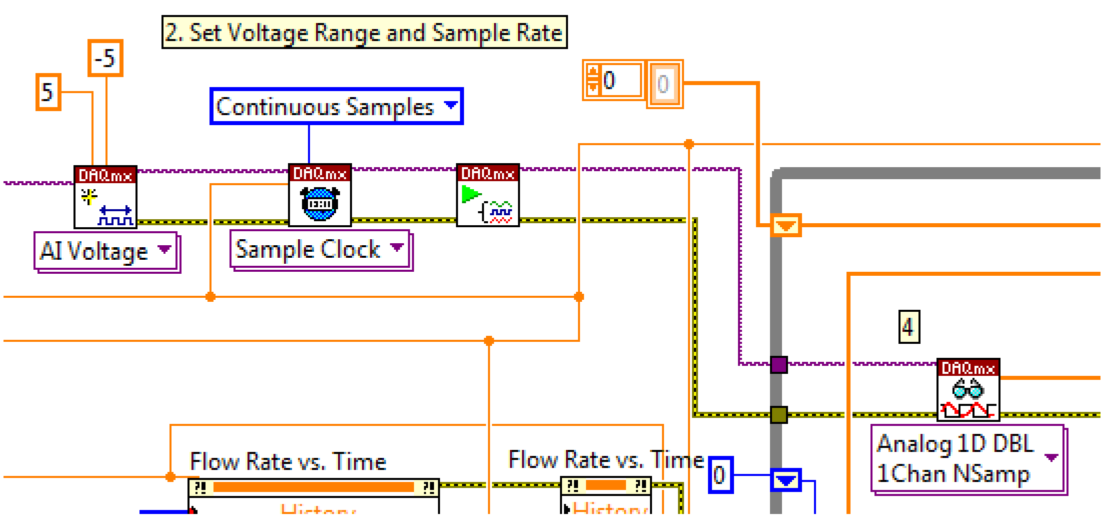


Figure 9: Signal Acquisition, Manipulation, and Display

7) The DAQmx VIs (see Figure 9) automatically acquire the signals read in from spirometer. The DAQmx Read VI (icon with reading glasses) reads in the signal from the sensor and stores it into a channel. This data is output from the DAQmx Read VI in the thick orange wire. Following the data flow through the orange wire, the data is first calibrated and lead

to the Flow Rate vs. Time waveform chart. From there, it is lead to the Convert to Lung Volume subVI and then outputs to the Volume vs. Time chart.
HINT: Press Ctrl+H to show the Context Help pop-up box. As you move your mouse over the screen, information and properties about the different icons will appear in the Context Help box. This should help you determine the functions of the different parts on the block diagram.

8) Using the Context Help tool, explore the properties of a Waveform Chart. What kind of data is accepted for a Waveform Chart? What type of chart results from each type of data?
9) With the Context Help tool still activated, hold your mouse over the wire leading into the Waveform Chart. What type of data is "flowing through" this wire? Was this one of the data types you listed in the previous question? Did the charts from your experiments correspond to the expected resulting chart listed in the Context Help box?

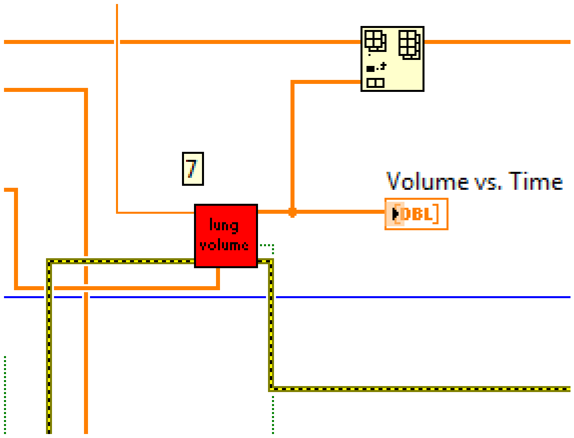


Figure 10: Calculating and Displaying BPM

10) SubVIs are used as functions within LabVIEW to contain a fixed amount of code. They are represented in the block diagram as squares, or icons. Data of one form is passed into the subVI as an input, manipulated within the subVI, and then output. Double-clicking the subVI will open the front panel and block diagram of that VI in two separate windows. Using the Context Help tool, find the subVI used to calculate lung volume (Hint: refer to Figure 10). Using the Context Help window, what types of inputs and outputs are there?

REFERENCES

Spirometer User Guide. Vernier Software & Technology. Rev. 2/17/10. Accessed 7/28/11. www.vernier.com.

NI Educational Laboratory Virtual Instrumentation Suite II Series (NI ELVIS II Series) User Manual. National Instruments. Austin, TX: National Instruments Corporation. 1/09. www.ni.com.