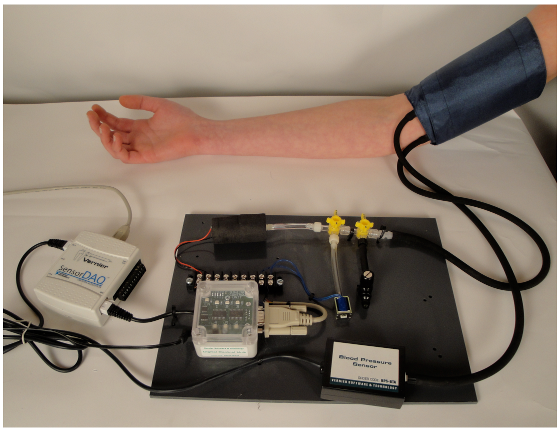
ثانوية التكنولوجيا التطبيقية
Applied Technology High School

Engineering Project-I

Module 3: Blood Pressure Measurement System



PREPARED BY

Academic Services Unit

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Module 3: Blood Pressure Measurement System

Module Objectives

Upon successful completion of this module, students should be able to:

1. Define 'blood pressure'.
2. Differentiate between systolic and diastolic pressure.
3. Describe the oscillometric method of blood pressure measurement.
4. Perform a practical task to measure and display the blood pressure of a test subject.
5. Build a Blood Pressure Measurement system.

Module Contents:

3.1 Introduction to Blood Pressure Measurement

Blood pressure is a measure of the fluid pressure within the circulatory system. This pressure is required to ensure the delivery of oxygen and nutrients to, and the removal of carbon dioxide and waste products from, tissues. Blood pressure varies from a peak pressure produced by the contraction of the left ventricle, to a low pressure produced by ventricular relaxation. The peak pressure is called *systole*, and the pressure that is maintained while the left ventricle is relaxing is called *diastole*. The average pressure is the *mean arterial pressure* or MAP. Blood pressure is traditionally reported with the *systolic* pressure stated first and the *diastolic* pressure stated second. In adults, 120/80 and below is considered normal blood pressure. High blood pressure (also called *hypertension*) is a major risk factor for a number of health problems including strokes and congestive heart failure. In adults, 140/90 and above is considered high blood pressure.

Figure 3.1 shows the photo of an automated blood pressure measurement system, which is the Challenge for this module.

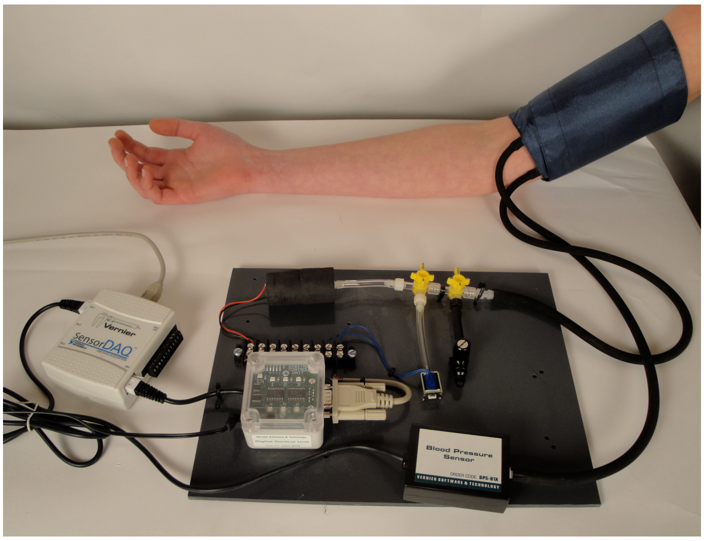

Figure 3.1: Automated blood pressure measurement system

The Blood Pressure Sensor is an analog sensor. It does not measure blood pressure directly, it measures cuff pressure. The cuff pressure waveform can be used to calculate blood pressure using the *oscillometric method*; a non-invasive means of measuring blood pressure without using a stethoscope. This method is based on the principle that when a cuff is pressurized on the upper arm, blood pumped through the arteries causes the arterial walls to flex forming pressure pulses that pass from the arteries, through the arm, and into the pressure cuff itself. The Blood Pressure Sensor records the magnitude of these pressure pulses. When the artery is fully compressed, blood flow stops along with the pulsations; but as the pressure in the cuff is slowly exhausted, the pulses become increasingly significant until they reach maximum amplitude. Further decrease of the cuff pressure minimizes the occlusion of the artery and causes the pulse amplitude to decay.

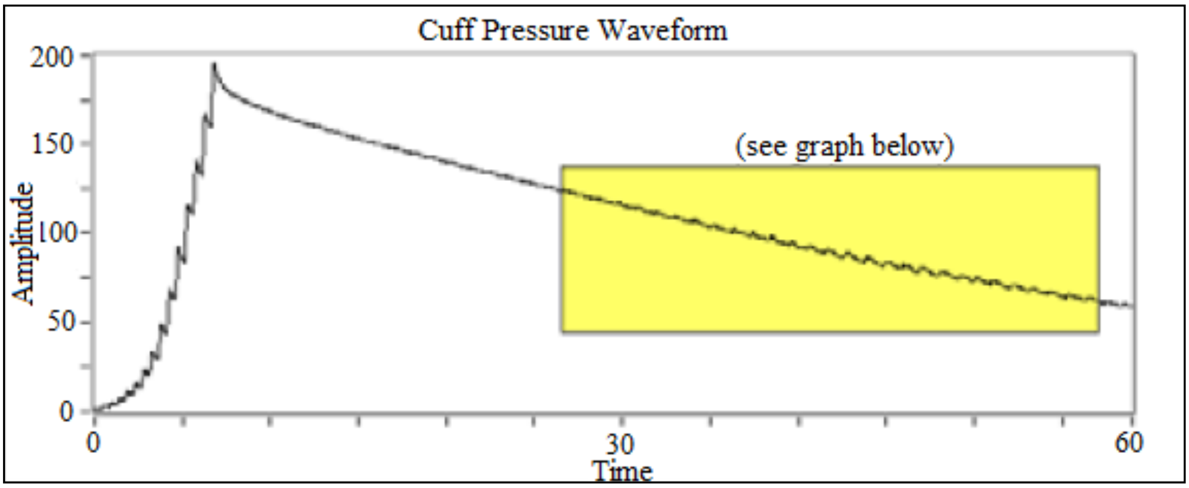

Figure 3.2: Cuff pressure measured by sensor

These pressure pulses, when separated from the decaying mean pressure of the cuff, form an oscillating waveform. In the figure below, the waveform has been "flattened" or reoriented along the horizontal plane causing the peak-to-peak amplitudes to create a bell-shaped "envelope". Within the envelope, the amplitudes of the waveform increase through the systolic blood pressure and continue increasing until the mean arterial pressure (MAP) is reached.

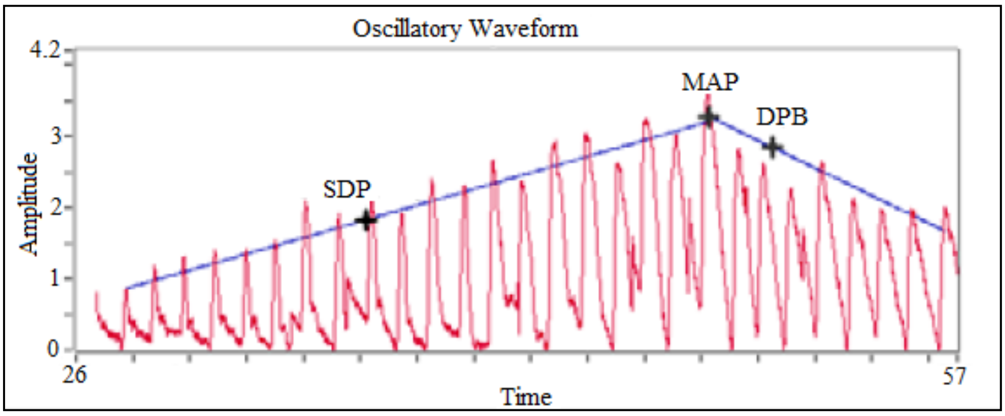

Figure 3.3: Oscillatory waveform used to identify the blood pressure "envelope"

The BP Analysis subVI (found under Data Logging ▸ Physiology Analysis in the Vernier functions palette) will determine the MAP using the method described above, and then display the systolic and diastolic blood pressures. This subVI is designed to work with an array of data collected at a data rate of 100 points per second.

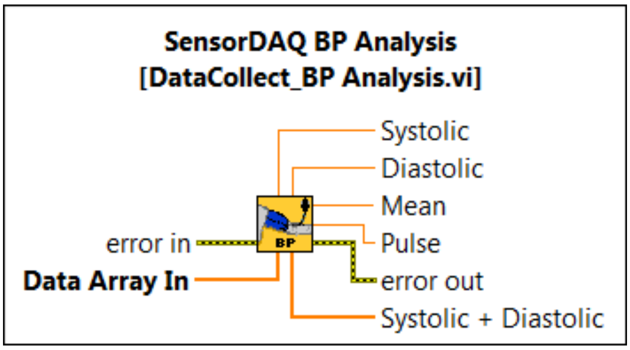

Figure 3.4: BP Analysis subVI

3.2 Displaying Blood Pressure

In this module, you will write a LabVIEW program to display the blood pressure of a test subject. You will use a Vernier Blood Pressure Sensor, a non-invasive unit that includes a handheld pump, pressure release valve, and cuff. The cuff is placed on the upper arm to pressurize the arteries, just like other blood pressure monitoring devices. The sensor connects to the cuff and is used to monitor the pressure in the cuff in units of mm Hg. The cuff is pressurized with the pump. The pressure release valve slowly releases pressure out of the cuff. Your front panel design should include a graphical cuff pressure versus time display with a large, easily readable indicator for live cuff pressure readings. You should have the program provide a visual or audible signal when the cuff pressure has reached 160 mm Hg as a signal to stop inflating the cuff. When data collection ends, the VI should use the recorded cuff pressure to calculate and display the test subject’s systolic and diastolic blood pressures.

3.3 Lab Activity

Objective: To measure and display the blood pressure of a test subject.

Equipment Used:

a) SensorDAQ Interface

b) LabVIEW software

c) PC

d) USB Cable

e) Vernier Blood Pressure Sensor

Procedure:

Connect the sensor to the interface

1. Connect the Vernier Blood Pressure Sensor to Channel 1 on the SensorDAQ interface.
2. Connect the interface to the computer.

Note: Wait until your VI is written before performing the rest of the Setup.

Attach the blood pressure cuff to the subject

1. Connect the rubber hose from the blood pressure cuff to the connector on the Blood Pressure Sensor.
2. Remove any clothing that may cover or constrict the portion of the subject's arm being measured.
3. Wrap the cuff firmly around the subject's upper arm, approximately 2 cm above the elbow. The two rubber hoses from the cuff should be positioned over the bicep muscle (brachial artery) and not under the arm (see Figure 3.5).

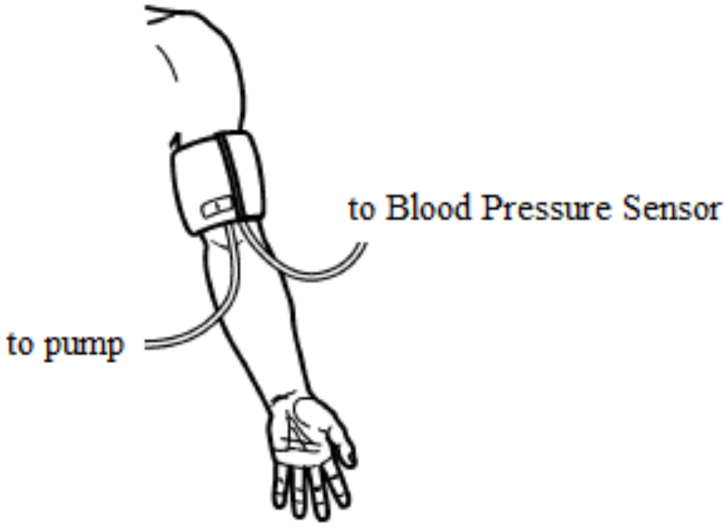

Figure 3.5: Attaching the blood pressure cuff to the subject

Conduct the Blood Pressure Measurement

1. The subject should be seated with his or her arm supported by a nearby table or desktop. Encourage the subject to be relaxed and avoid moving his or her arm during the experiment.
2. Start your VI to begin data collection. Immediately begin to pump until the VI signals that the cuff pressure has reached at least 160 mm Hg. Stop pumping at this point.
3. The pressure will start to drop. The test subject should sit quietly and should not move.
4. When the cuff pressure drops below 50 mm Hg, stop the VI. Release the pressure from the cuff by pressing down on the release valve located next to the pump.
5. If your program (VI) is working correctly, the systolic and diastolic arterial pressures will be calculated and displayed on the front panel of the VI.

Programming using LabVIEW:

Collect and display blood pressure data

Create a simple, concise program to implement this operation. The front panel should contain, a large, easy-to-read digital indicator and graphical display of the live pressure readings of the cuff pressure as well as an alert (either visual or auditory) so the operator will know when to stop inflating the cuff. There should also be indicators for the systolic and diastolic pressures.

Figure 4.8 shows the LabVIEW VI for determining blood pressure. Use the Analog Express VI (found in the Vernier Functions Pallete) to collect and display data from the Blood Pressure Sensor. The design requirements specify that the pressure reading should be displayed both as a digital indicator and as a graphical display. Also, the program should provide the indication that the 160 mm Hg reading has been reached so that the operator will know when to stop inflating the cuff. The indication that the 160mm Hg has reached can be done with a Case Structure. A case structure is used to dynamically select which parts of code should execute.

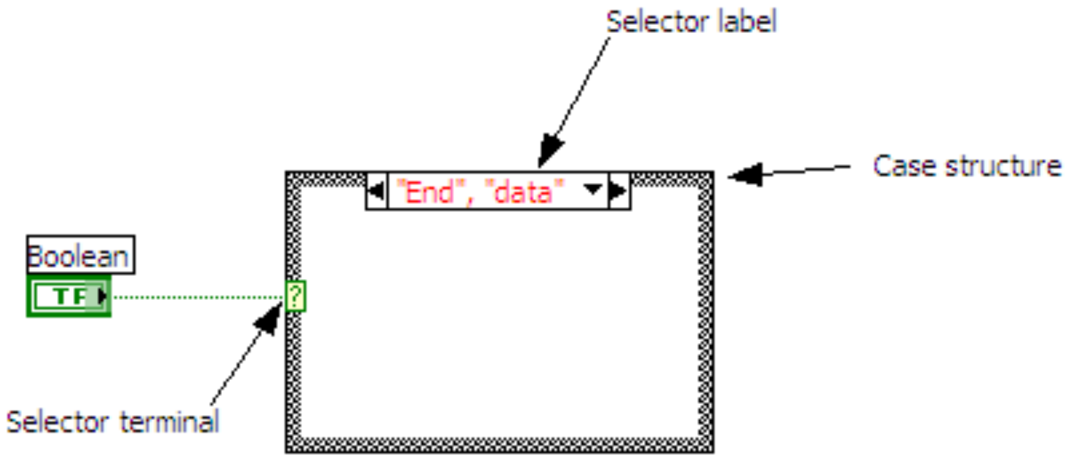

Figure 3.6: Case Structure Illustration

The selection decision of the case structure can be done by several data types such as Boolean, integer, string and so on. However, in this program we shall use the Boolean case structure, which is the default state of the case structure. It has a case for the True and the False state.

Figure 3.7: Boolean Case Structure

For the case that occurs when the pressure exceeds the limit, you can add a sound or code to turn on a Boolean indicator as shown in figure 3.8.

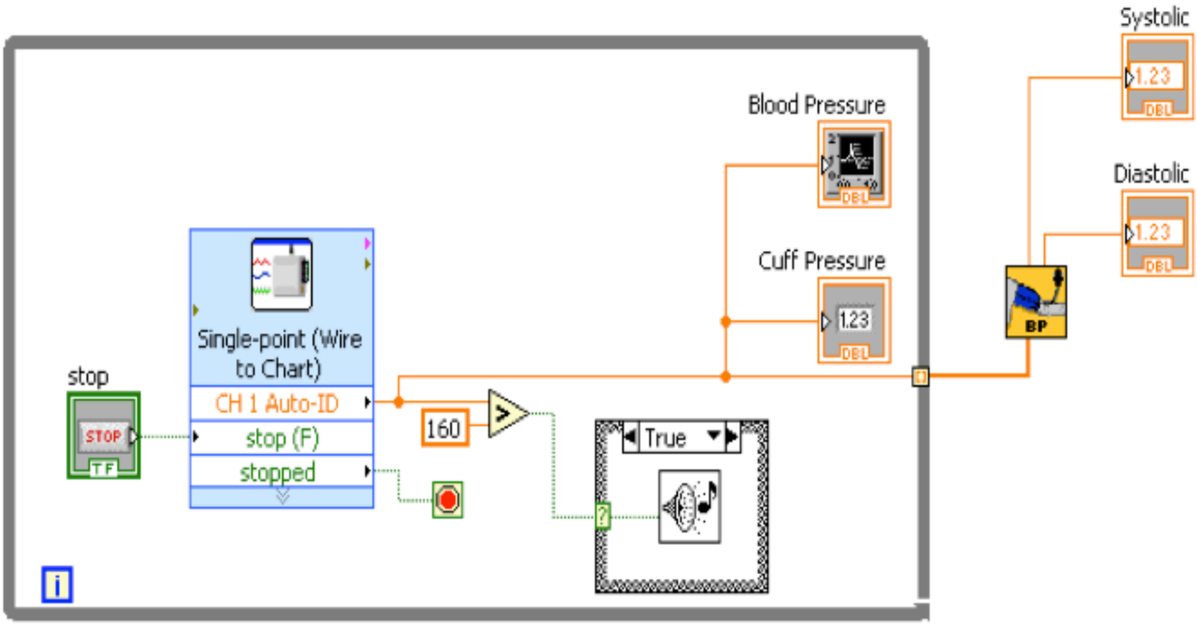

Figure 3.8(a): Sample program for determining blood pressure

The trickiest part of this activity is to collect the entire data set within the While Loop and then send it out as an array so that it can be processed by the BP Analysis subVI found under Data Logging-Physiology Analysis in the Vernier Functions palette).

The BP Analysis subVI assumes that data is collected at 100 points per second. Right clicking on the tunnel at the border of the While Loop and selecting Enable Indexing will cause the data to exit the While Loop as an array. Note that the wire leaving the While Loop is thicker, indicating an array data type.

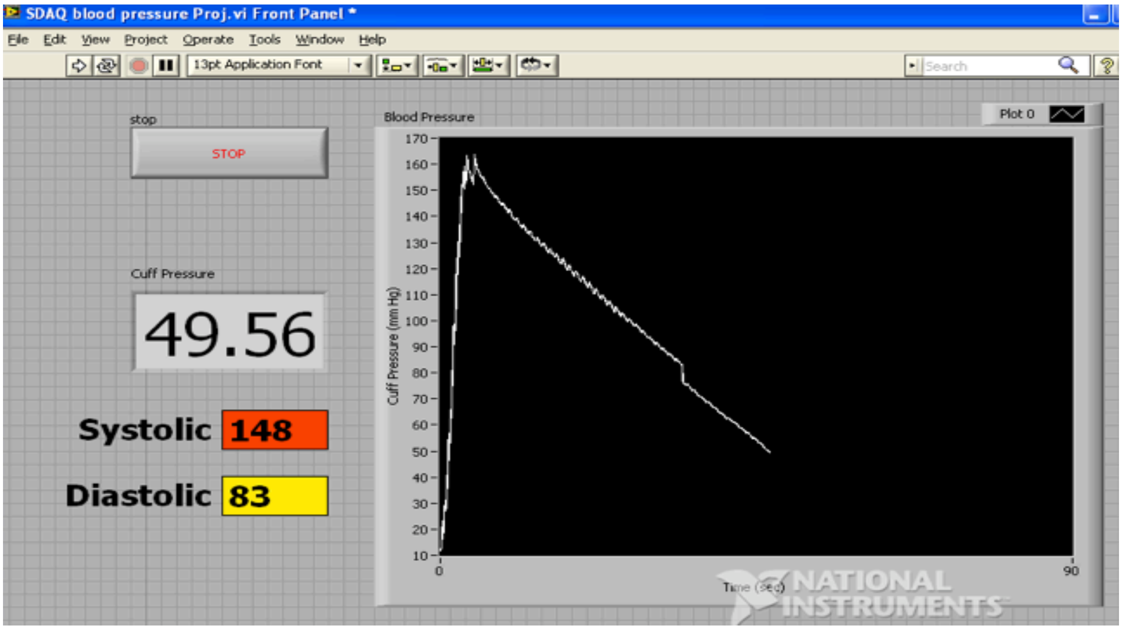

Figure 3.8(a): Sample block diagram for determining blood pressure

Lab Activity Tips:

1. The data collection rate must be 100 samples per second for the BP Analysis subVI to calculate blood pressure accurately.
2. Set the experiment length to 90 seconds to allow ample time for data collection.
3. It is not necessary to inflate the pressure cuff higher than 160 mm Hg. Over inflation of the cuff may cause pain and/or injury.
4. The pressure release valve is used to slowly exhaust the pressure from the cuff. In addition, if you press down on this valve it will immediately exhaust all of the pressure out of the cuff.
5. The subject’s arm and hand must remain still during measurements.
6. Do not touch or move the pressure release valve during measurements.

Troubleshooting:

1. Proper placement of the blood pressure cuff will increase the accuracy of your measurements. The rubber hoses from the cuff should exit over the brachial artery about 2 cm above the crease in the elbow.
2. The larger a subject's arm, the slower the release valve will exhaust. If the pressure release valve is exhausting slower or faster than 2–4 mm Hg/s, use a screwdriver to adjust the exhaust rate of the pressure valve. To increase the rate of exhaust, turn the screwdriver clockwise; to decrease the rate of exhaust, turn the screwdriver counter-clockwise.

If the BP Analysis subVI does not seem to be working correctly, make sure you have set the data-collection rate of the Analog Express VI to 100 points per second and that you are taking data covering cuff pressures from 160 to 50 mm of Hg.

3.4 Mini Project

Design Requirements:

Build a motorized pumping device to automatically inflate the pressure cuff. You can use a Vernier Digital Control Unit to control a pump and also control a quick-release discharge valve. Write a LabVIEW program to activate the pump, inflate the cuff to a pressure of 160 mm Hg, read the pressure in the cuff as the pressure drains to about 50 mm Hg, quickly release the remaining pressure out of the cuff, and then display blood pressure readings. The front panel design should remain the same as in the lab activity, with the addition of a control to quickly release all pressure from the cuff in case of a situation where the cuff pressure is getting too high and causing the subject discomfort.

Additional Materials:

a) Vernier Digital Control Unit (DCU)

b) Pump

c) Solenoid

d) Plastic tubing

e) Two T-valves

Challenge Setup:

1. Build the device as shown in figure 3.9 below. The sensor, cuff, and pressure release valve are provided with the Vernier Blood Pressure Sensor. These parts will be used in the same manner as they were used in the Project. An additional solenoid valve and electric pump will be used. The solenoid valve provides a means to automate the immediate exhaust of all the pressure out of the cuff. This quick release of pressure is desirable in case of discomfort to the user and also when data collection has ended. You will also need to obtain a pump. The electric pump will take the place of the hand pump you used in the Project. The two additional T-valves shown in the figure are optional. Their purpose is to isolate portions of the device to aid in testing during assembly. They may also be useful for immediately stopping cuff inflation in the case of a programming error. These valves should all be turned to the Open position when you are ready to begin blood pressure measurements.

Tip: Mounting the components to some type of backer board will ensure that the connections stay tight.

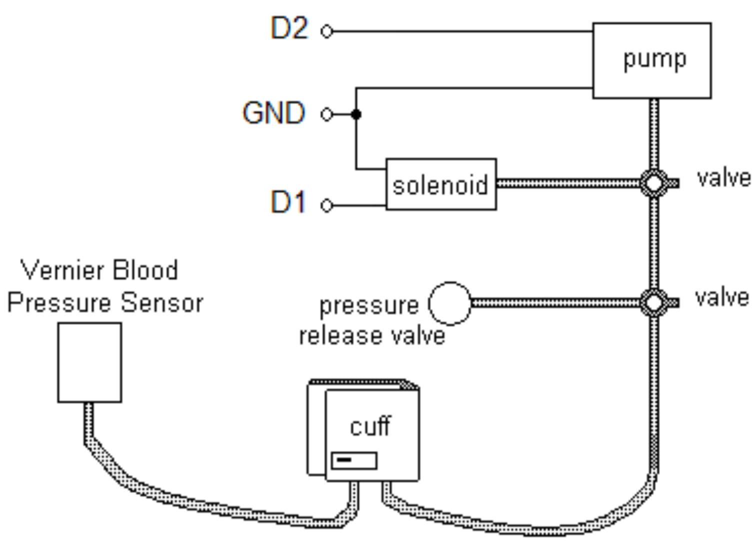

Figure 3.9: Pumping device for blood pressure cuff

2. The pressure release valve should be adjusted to an exhaust rate of 2–4 mm Hg/s.

Tip: The pressure release valve can remain open during cuff inflation, because the discharge rate is insignificant compared to the inflation rate of the pump. The solenoid valve, however, must remain closed during inflation and deflation.

3. Connect the DCU to the DIG port on the interface.

4. Connect a power supply to the DCU.

5. Plug the 9-pin cable into the side of the DCU.

6. Wire the solenoid and pump to the DCU cable as shown in the figure above. You can find the color-coded pin-out for the DCU cable on the label attached to the cord.

Challenge Background Information:

In the Challenge, you will replace the handheld pump with an electric pump to automatically inflate the blood pressure cuff. A solenoid will be used to automate the quick release of pressure from the cuff. A *solenoid* is an electromechanical device, in this case it is used to control a valve for controlling the flow of air. You can use a Vernier Digital Control Unit (DCU) to control these two components of your pumping mechanism. The DCU is an electronic device that allows you to control up to six digital output lines for on/off control of DC electrical components. The DCU plugs into the DIG port on the interface and is powered by a separate DC power supply. A 9-pin, D-sub socket cable is supplied with the DCU. It has bare wires on one end for use in building projects. There are connections for all six digital lines, plus a power connection and two ground connections. The color code of the wires is identified on a label on the cable.

To turn on a component connected to one of the digital lines, your LabVIEW program must send a numeric output pattern to the DCU. Let's assume you have connected the solenoid to line D1 and the pump to line D2. In order to run the solenoid alone, your program would send a pattern of "1" to the DCU. Line D1 (the solenoid) would be turned on and all other lines would be off. To run the pump alone, your program would send a pattern of "2." However, to run both devices simultaneously, your program must send a pattern of "3." You can preview the 16 output patterns available for the DCU within the configuration window of the Digital Express VI. This Express VI is found in the Vernier functions palette.

Challenge Tips:

1. You can obtain the proper solenoid and pump for this Challenge by taking apart an off-the-shelf blood pressure kit found at your local pharmacy. They are fairly inexpensive.
2. Determine if voltage applied to the solenoid opens or closes the valve. Then apply this to your programming logic so that it remains closed until an immediate release of air is required (in case of emergency or at the end of data collection).
3. Make sure your program stops inflating the cuff at 160 mm Hg before testing your device on a human subject. Be prepared to physically detach the cuff from the pump during these trials so as not to overinflate the cuff.
4. Provide some way to physically stop cuff inflation in case of a programming error. One suggestion is to incorporate one or more T-valves into your device to use as an emergency exhaust when conducting initial tests. Another option is to remove power from the DCU.

5. When building your device, keep the power limitations of the DCU and your DCU power supply in mind. You should not exceed 1000 mA total.

Challenge Troubleshooting:

1. Make sure the DCU is receiving power. The green LED in the top of the DCU box will be lit when the DCU is powered on.
2. Double-check the DCU cable connections against the color-coded label attached to the cable.
3. Make sure you are sending the proper output pattern to turn on two digital lines at the same time. Use the red LEDs on the top of the DCU to verify the pattern the DCU is producing.

Sample LabVIEW Program:

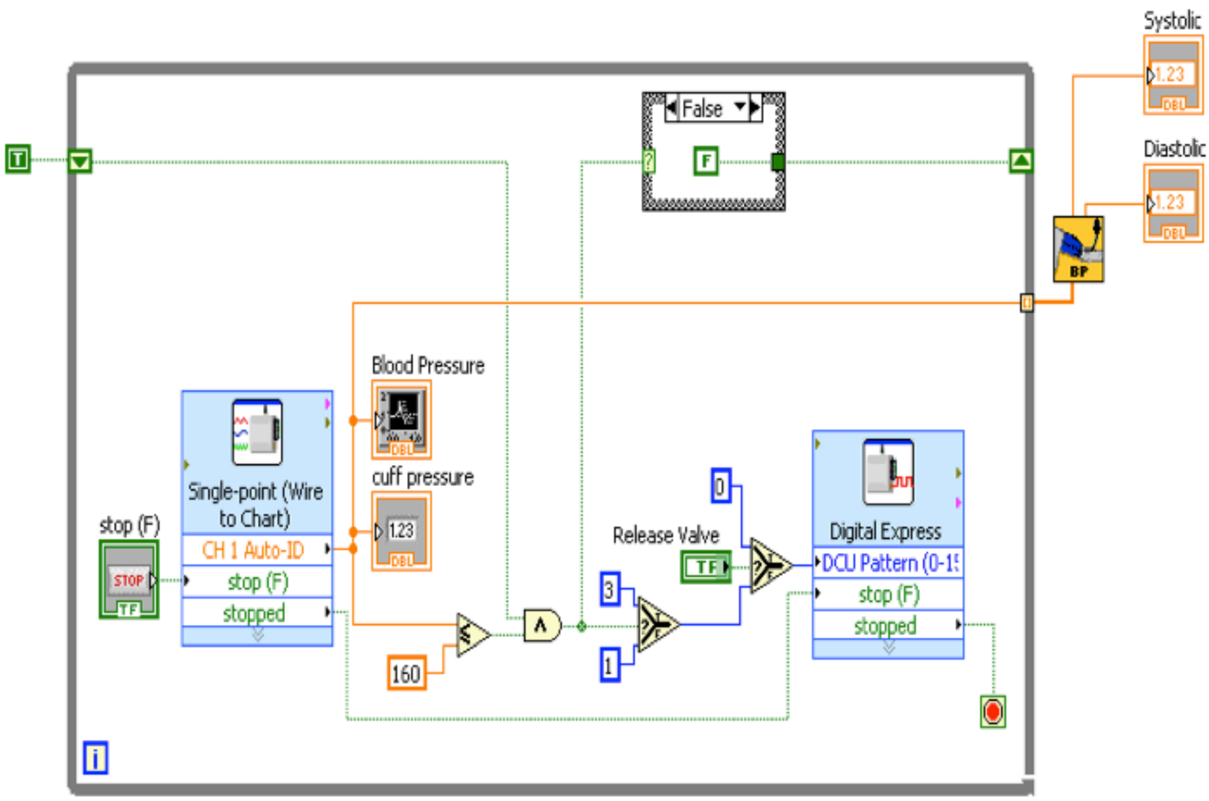

Figure 3.10: Sample program of a blood pressure monitoring system

In the sample program shown in figure 3.10, both the solenoid and the pump are powered on at the beginning of the program by sending a pattern of “3” to the DCU. This causes the blood pressure cuff to inflate. The program monitors the blood pressure sensor until the pressure exceeds 160 mm Hg. At that point, the motor is turned OFF while the solenoid remains ON (a pattern of “1” turns ON DCU line D1 and turns OFF all other lines). With the pump turned OFF, the pressure release valve will slowly release the cuff pressure. Notice that a Boolean shift register has been used as a flag to detect when the pressure reaches the target limit. If some sort of flag is not provided, the DCU will continuously try to re-inflate the cuff every time the pressure starts to drop below 160 mm Hg. Note: The True Case Structure makes no change to the Boolean value, but simply passes it to the shift register. If the user presses the Release Valve front panel Boolean control, a pattern of “0” stops both the pump and opens the release valve to immediately exhaust the cuff pressure. Note that when the Digital Express VI is stopped, a pattern of “0” is automatically sent to the DCU.