5-2018

Pressure Acquisition System for In Vitro Mitral Valve Analysis

Laura Peck
University of Arkansas, Fayetteville

Citation

Pressure Acquisition System for In Vitro Mitral Valve Analysis

An Undergraduate Honors Thesis

In the

Department of Biomedical Engineering

College of Engineering

University of Arkansas

Fayetteville, AR

by

Laura Elizabeth Peck

Table of Contents

1. Abstract

In vitro testing of the mitral valve chordae tendineae is utilized to aid in the understanding of the stresses that occur in vivo and improve upon surgical solutions that exist for mitral valve repair. This project aimed to design the water control system for a left heart simulation chamber, as well as the pressure acquisition inside the chamber. A solenoid valve was utilized to control the water supply to the tank and was powered utilizing National Instruments software. National Instruments hardware and software was also used with the pressure transducer in order to obtain pressure readings from the chamber. The system was able to be fully controlled using LabVIEW and a pressure trend line was acquired. Future work will focus on developing a way to obtain more precise pressure measurements and automating the solenoid valve to shut off the water supply once physiological pressure has been met inside the chamber.

2. Introduction

The mitral valve is located on the left side of the heart between the left atrium and ventricle. The mitral valve contains two leaflets, the anterior and posterior, and numerous chordae tendineae that attach to the leaflets and the papillary muscles in the left ventricle. Of the chordae tendineae, there are three types of chords: primary, secondary, and tertiary as shown in figure 1. As ventricular pressure builds, the chords prevent the leaflets from prolapsing and prevents blood from flowing back into the atrium during ventricular contraction. A common health issue that arises is mitral valve prolapse, which occurs when the mitral valve leaflets bulge into the left atrium. This occurs due to the chordae tendineae becoming stretched out and no longer having the ability to hold the leaflets in place. By analyzing how the chords react in the heart as they are stretched, a better understanding of the mitral valve's function can be obtained.
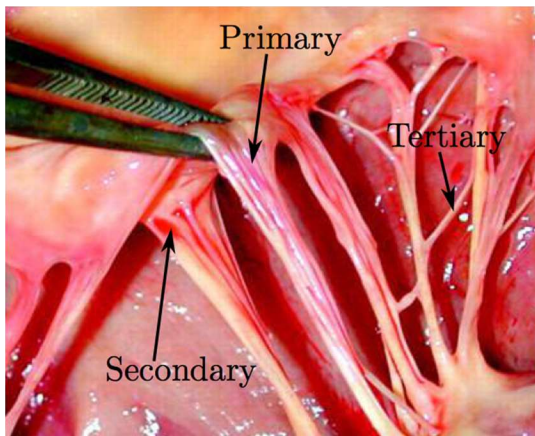

Figure 1: Primary chords are attached to the edge of the mitral valve leaflet and the secondary chords are attached to the belly of the mitral valve leaflet. Tertiary chordae do not extend from the leaflets (1).

A left heart simulator was developed as an acrylic chamber to be filled with water to simulate ventricular contraction. This tank was developed to be an in vitro testing chamber of the mitral valve chordae tendineae. The objective of this experiment was to design a system to control the water supply to the in vitro design holding chamber. Pressure measurements from the chamber as it is being filled with water will also be acquired to eventually be used to control that water supply to the tank.

3. Materials and Methods

3.1 Materials

The tubing chosen to use for the water supply to the chamber was ½" diameter clear vinyl tubing with ½" x ½" barbed barb x MIP adapter fitting, stainless steel adjustable clamps, and ½" nominal PVC couplings to connect to the valve. The solenoid valve chosen for this application was an Adafruit 12V plastic water solenoid valve. National Instruments hardware was important for data acquisition and electrical controls. The NI ELVIS II board, NI 9949 RJ-50 to screw-terminal accessory, a RJ-50 cable, NI 9237 C series strain/bridge input module, and a cDAQ-9171 CompactDAQ Chassis. This hardware was interpreted and controlled with LabVIEW software. To acquire pressure measurements, a MLT0670 disposable blood pressure transducer was used.

3.2 Solenoid Valve Setup

The Adafruit solenoid valve is a closed two-way valve that can be opened when supplied with a 12 volt supply and 320 mA current supply. The valve also requires a minimum 3 psi pressure requirement to operate due to the gasket arrangement inside (2). The solenoid valve served to act as the water control element for the in vitro design holding chamber.

The solenoid valve was connected to the water supply and chamber utilizing ½" vinyl tubing. The couplings were utilized on each side of the valve to connect to the barbed barb adaptor. The vinyl tubing was pushed onto the barbed adaptor and secured with the adjustable clamps to

prevent water leakage as demonstrated in figure 2. The water supply was then connected in the same manner, as well as the connection to the chamber.
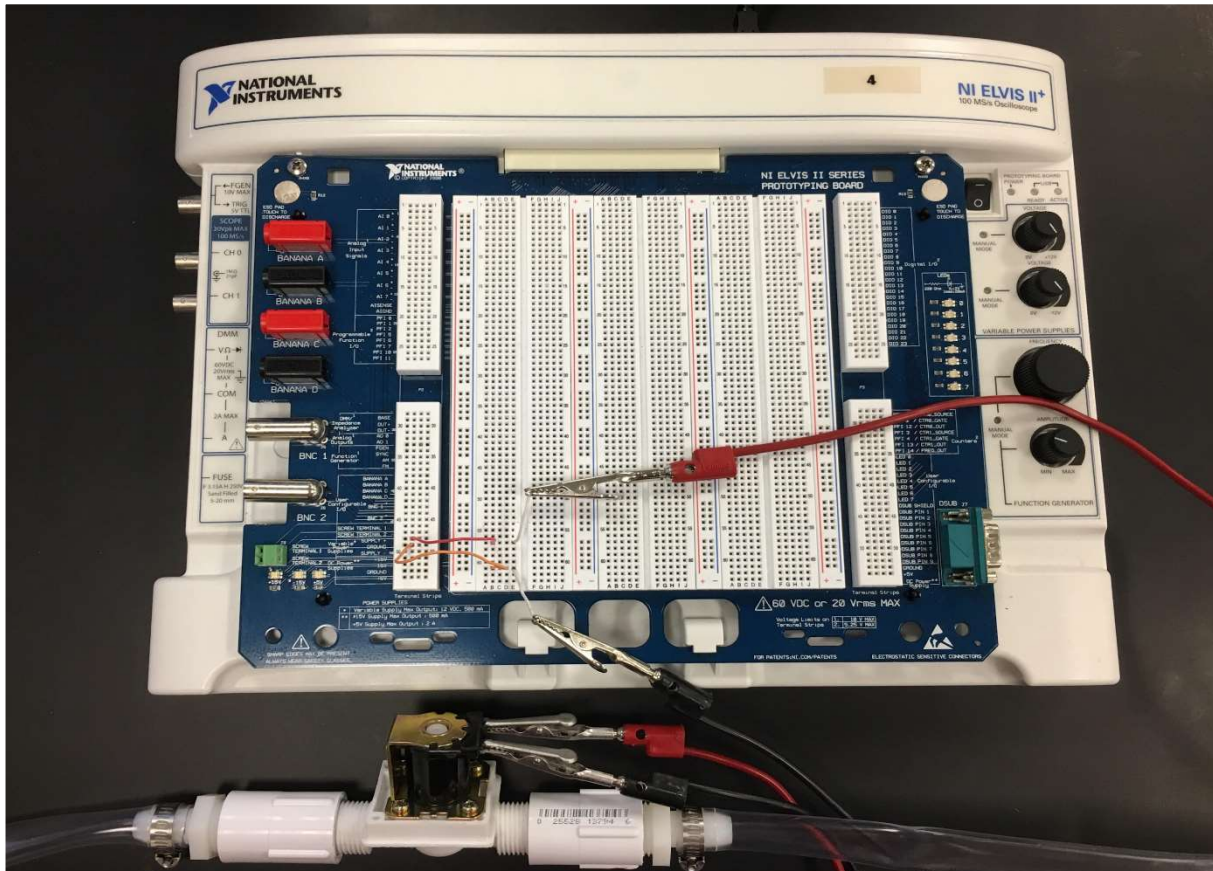

Figure 2. Solenoid valve connected to tubing on either side with power control coming from the NI ELVIS II board.

In order to actuate the valve, it must be supplied with the adequate voltage and current. The NI ELVIS II board has a variable power supply that can be adjusted up to 12 volts and 500 mA. This was controlled utilizing LabVIEW software. The basic function required to supply power to the board was a while loop. The while loop continues to run the function until the indicator is met and then the program is stopped. Inside this while loop, the ELVIS board creates an analog output. Since the variable power supply was utilized, the voltage was programmed to 12 volts which output a current of approximately 500 mA. The solenoid valve was connected with alligator clips to the analog output and the grounded within the variable power supply output of the ELVIS board as shown in figure 2 above. The while loop, once it was actuated, delivered

power to the solenoid valve until the given condition was met. For general testing of the valve

and initial setup, the valve was programmed to shut off once the programmed stop button was

pressed. An LED indicator was also added to the shut off so that it was clear when the valve

was closed and the water supply could be turned off to prevent a buildup of pressure in the

tubing before the valve. The code from the block diagram in LabVIEW is shown below in figure
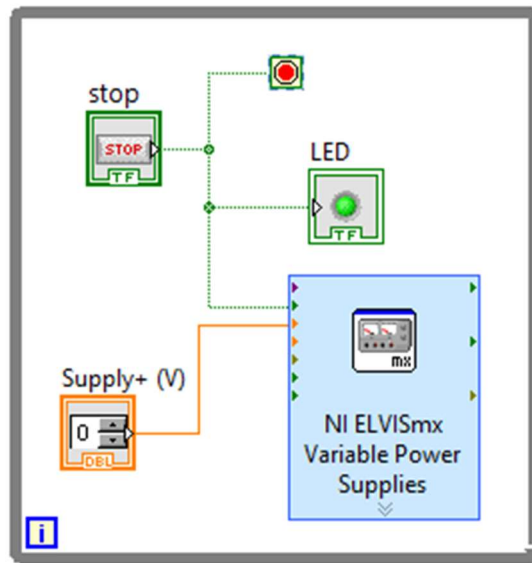
3.

Figure 3. While loop containing the solenoid valve control.

3.3 Pressure Acquisition System

The pressure transducer obtained for this system was originally designed for use with other AD

instruments equipment, so it first had to be adapted to fit this application. The original adapter at

the end of the transducer cord was removed to expose the wires inside. Each individual wire

was then stripped to be inserted into the National Instruments screw terminal accessory. The wires were connected to the NI 9949 as shown in table 1 and figure 4 (3).

Table 1. Wire connections to the NI 9949

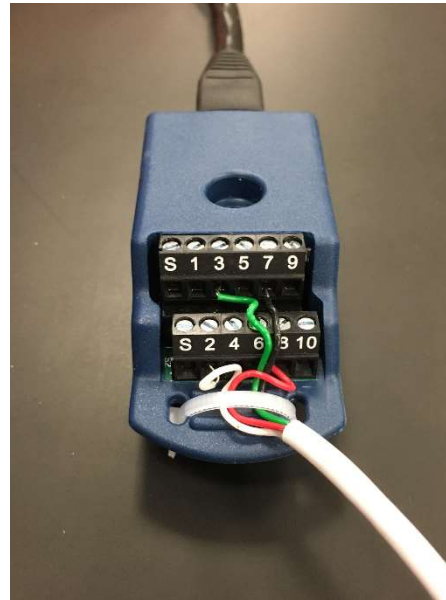| Wire Color	Terminal Name	Pin number
White	Channel Input +	2
Green	Channel Input -	3
Red	Excitation +	6
Black	Excitation -	7

Figure 4. Pressure transducer wires connected to NI 9949

From the NI 9949, the RJ-50 cable was used to connect to the bridge input module. In order to be able to receive the data from the sensor, th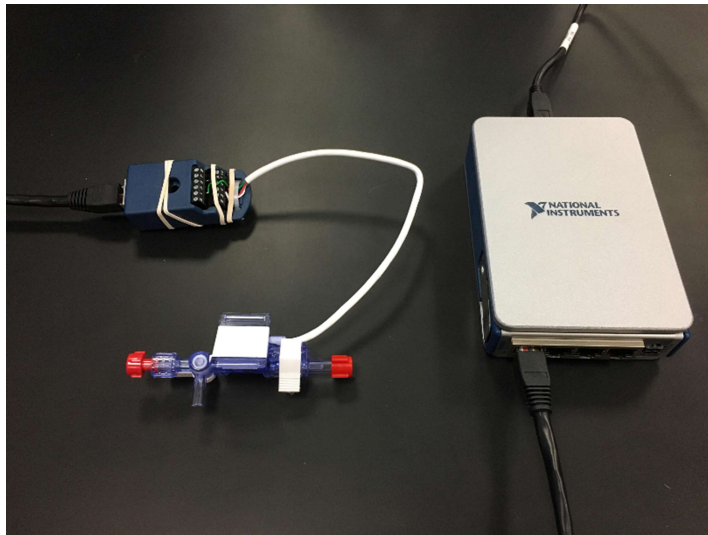e NI 9237 was connected to the compactDAQ chassis which was wired to the computer as shown in figure 5. Through this equipment, data could then be obtained through LabVIEW software.

LabVIEW has a programmed function that that is designed to work with National Instruments equipment. This program that was utilized is DAQ Assistant. Whenever the DAQ assistant is placed into the block diagram, the

Figure 5. Pressure transducer connected with NI 9949, NI 9237 and cDAQ-9171

user was prompted to provide the DAQ the type of measurement device to be used. Under the acquire signals tab, analog input was then selected. The pressure (bridge) selection was then chosen and the software prompted the user to input the channel and device being used. This information was provided, and then the DAQ Assistant was modified to the specific pressure transducer being utilized.

The pressure transducer utilized in this project had an operating range of -50 to +300 mmHg. The voltage range was also 2 to 10 VDC with a sensitivity of 5 µV/V. Most pressure transducers are sent with a calibration report that allows the user to input the given values into a program to convert from electrical values to physical values, but as this device was designed to be automatically calibrated with the AD Instruments equipment, this transducer did not have one provided. To work around this lack of information, the linear scaling equation was determined to be used in this application. The linear scaling equation follows the simple $Y = MX + B$ formula. The Y value of the equation is the output values and the X is the input values. The slope (M) indicates the scaling factor and B is the offset (5). From the given values, the equation for this transducer was:

$$Y = (43.75 mmHg/V)X - 137.5 mmHg$$

The DAQ Assistant only allowed the use of pressure units of either psi, pascals, or bar. To make the data easier to convert from mmHg, pascals was utilized for this application. So, the equation that was used for this application was:

$$Y = (5832.85 Pascals/V)X - 18331.83\ Pascals$$

Once the scaling information was determined, the signal input range was inserted into the configuration settings, as well as the bridge type (full) and internal source. The specific resistance for this sensor is 350 Ω (4) and the excitation voltage was set to 10 V. After inputting

the pressure setup settings, the scaling was configured using the above equation. Once

everything was inserted into the settings, continuous samples was chosen as the acquisition

mode and the setup was complete.

Once created and configured, the DAQ assistant was programmed to output a waveform graph

that is displayed in amplitude (pressure in pascals) and time (in absolute time). Also, to have a

single number output, an indicator that displays the current pressure reading was added to be

utilized in the solenoid valve control setup. Another coding tool that was used to acquire the

data into a different platform was the Write To Measurement File function. This was utilized to

import the data received by the pressure system to be imported into an excel file where it could

be further manipulated. The while loop utilized by the pressure transducer was set to continue to

run until the stop button was pressed. Figure 6 shows the block diagram and front panel of

LabVIEW that was used to acquire the pressure measurements.
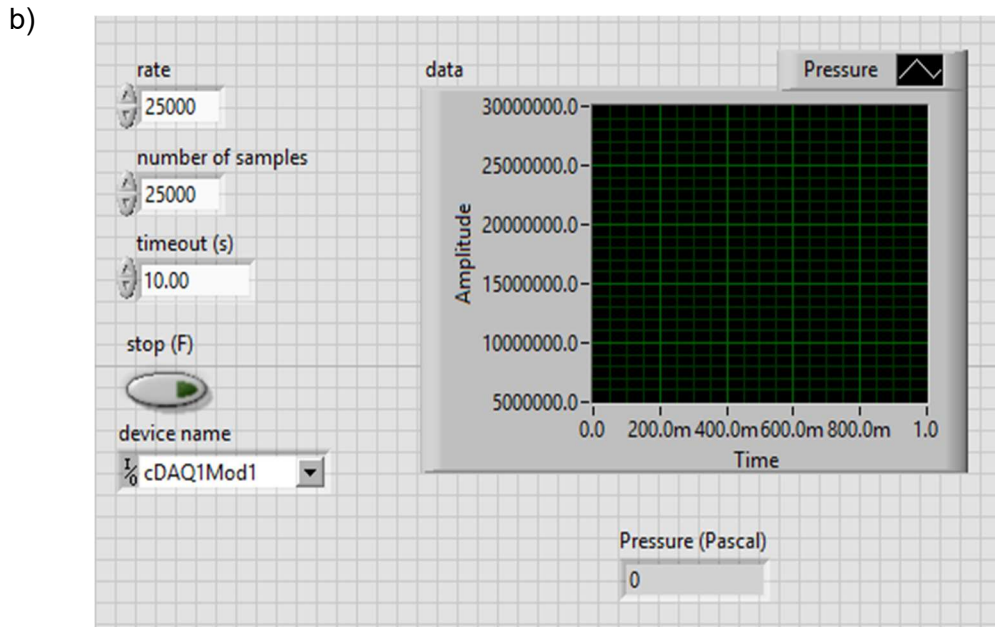
a)

b)
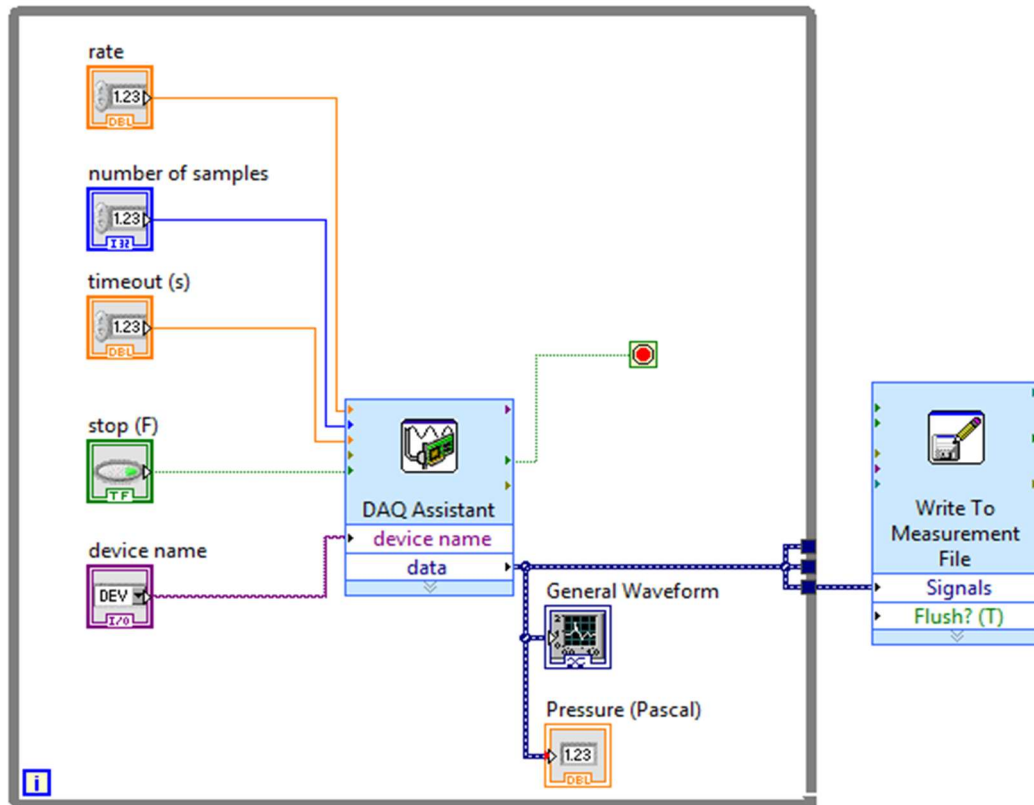
Figure 6. a) LabVIEW block diagram of the pressure transducer code. b) LabVIEW front panel of the same code.

3.4 Pressure Controlled Solenoid Valve
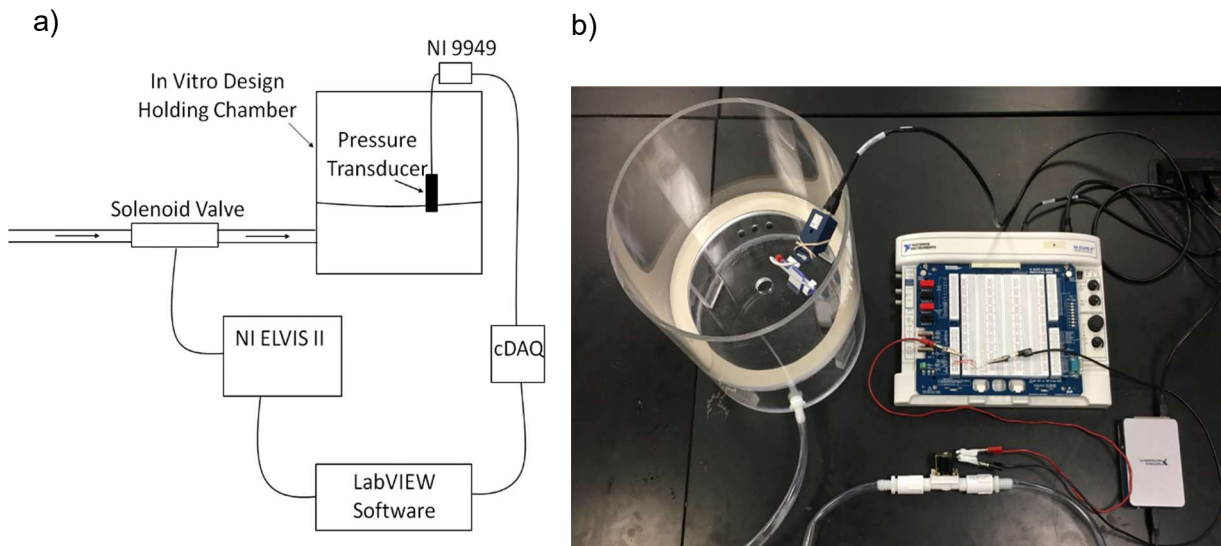
a)   b)

Figure 7. a) Schematic of full setup including chamber. b) Physical setup

The two systems utilized in the aforementioned sections were combined in LabVIEW to create a solenoid valve that could stop the water supply into the tank once physiological pressure had been met in chamber. The full setup of both systems combined, including the in vitro design holding chamber, is shown in figure 7 below. Physiological pressure in Pascals is 18665 and this value was input as a numerical indicator in the solenoid valve while loop. The solenoid valve while loop indicator was then modified to stop the iterations of the loop once the numerical indicator equated the values output by the pressure transducer. Figure 8 illustrates the front panel and the block diagram from LabVIEW that was utilized to combine these two systems.
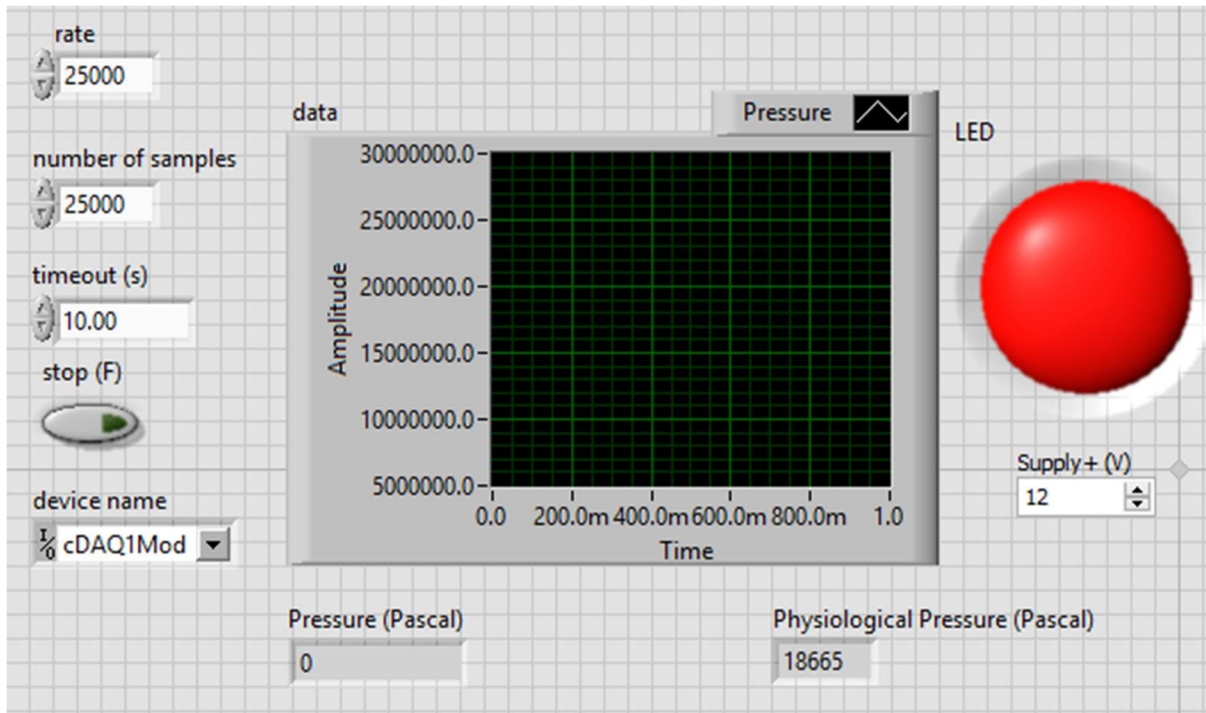
a)
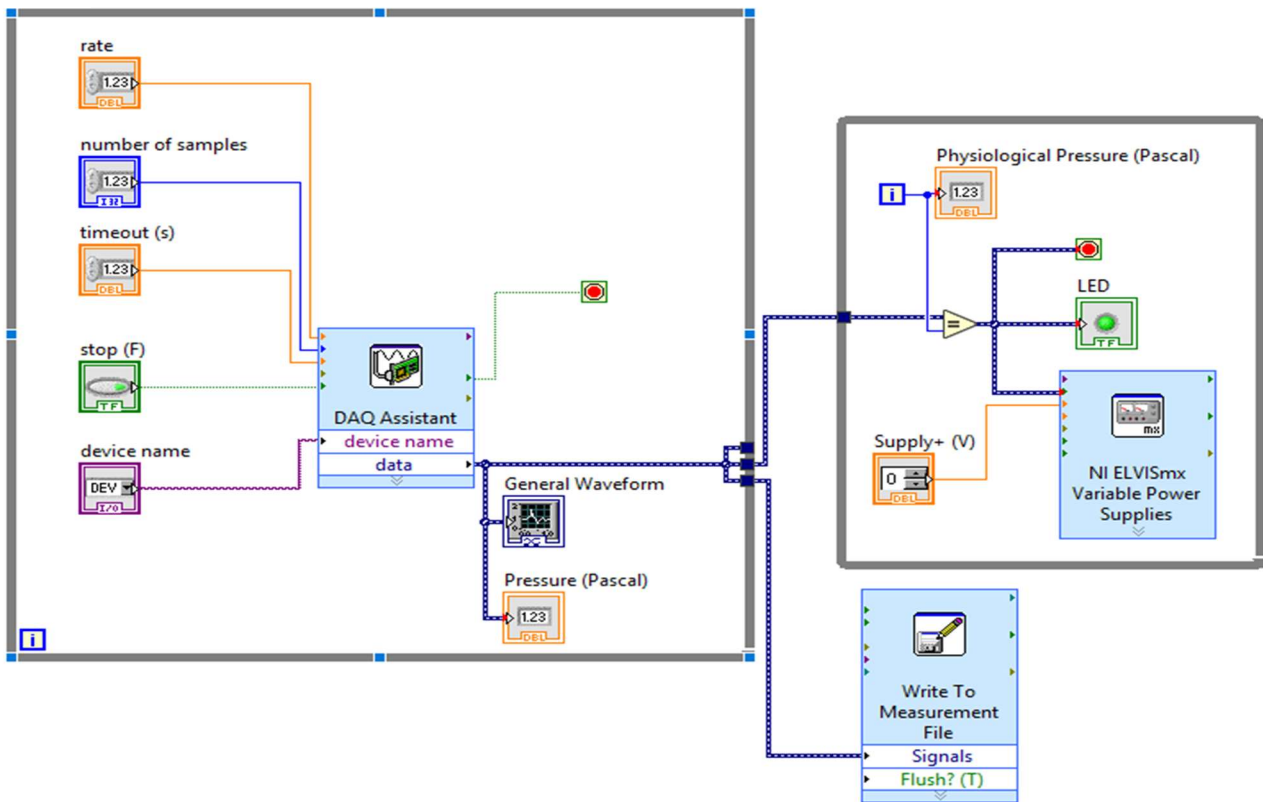
b)

Figure 8. a) LabVIEW block diagram. b) LabVIEW front panel.

4. Results and Discussion

4.1 Solenoid Valve Setup

The solenoid valve successfully supplied the chamber with water without any leaks occurring throughout the system. The valve was also able to be opened and closed with the voltage and current supply from the NI ELVIS II board and with the pressure from the faucet.

4.2 Pressure Acquisition System

The pressure signals received from the chamber contained a lot of noise and was not providing steady measurements. The sensor was able to detect the change in pressure of the tank as it was filled which is reflected in figure 9. This data was first exported to excel in pascals, where it was then converted to mmHg. The original pressure measurements were recorded in the
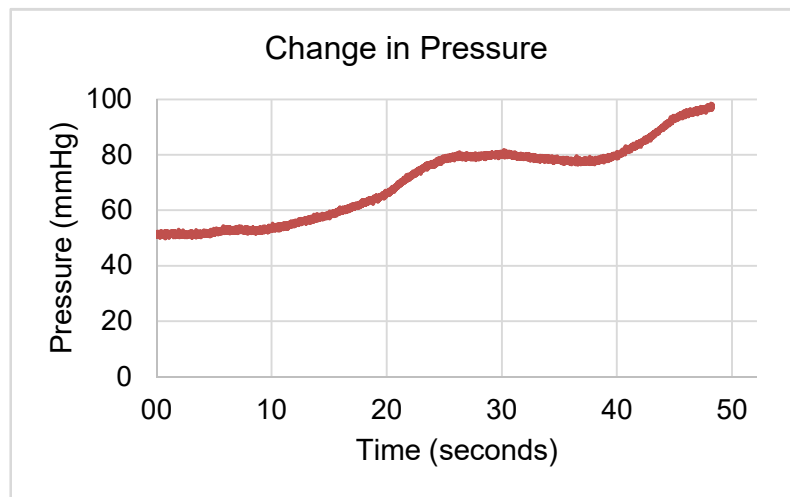

Figure 9. Change in pressure as the water level reached the partition plate.

negative direction and were outside of the pressure transducer's range. Since the transducer was detecting a change in pressure, the decision was made that since the sensor was not developed to be used with alternative equipment that there must have been an error with calibration or scaling. To represent the data, figure 9 shows the values after they have had the absolute value taken and the scale was reduced to be within the capabilities of the transducer. Further testing with this transducer is required to determine why the scaling was incorrect in this application. Another possible reason for error that occurred was that the transducer is exposed to air as the tank is filling and only contacts liquid whenever the water level reaches the partition plate in the chamber. Since this transducer is intended for use to monitor blood pressure, there would be no contact with air in that application, so the sensor may not be designed for this application. Future work may incorporate a small tube into the setup that could be used to

acquire pressure measurements from the bottom of the tank where there would be less interaction with air and improve results.

4.3 Pressure Controlled Solenoid Valve

The code for the pressure controlled shut off valve was developed but could not be utilized in the scope of this project due to the inaccurate readings from the pressure transducer. Once correct measurements can be obtained for this setup, the solenoid valve should be able to have a programmed shut off once the sensor reads out physiological pressures.

5. Acknowledgments

6. References

1. Toma M, Bloodworth C, Pierce E, Einstein D, Cochran R, Yoganathan A et al. Fluid-Structure Interaction Analysis of Ruptured Mitral Chordae Tendineae. Annals of Biomedical Engineering. 2016;45(3):619-631.

2. Plastic Water Solenoid Valve - 12V - 1/2" Nominal - BC Robotics [Internet]. BC Robotics. 2018 [cited 19 April 2018]. Available from: https://www.bc-robotics.com/shop/plastic-water-solenoid-valve-12v-12-nominal/

3. Connecting a Strain Gage in a Quarter-Bridge Configuration to NI 9237 Using NI 9949 - National Instruments [Internet]. Knowledge.ni.com. 2018 [cited 10 March 2018]. Available from: https://knowledge.ni.com/KnowledgeArticleDetails?id=kA00Z000000PA6PSAW

4. MLT0670 Disposable BP Transducer (stopcock) [Internet]. AD Instruments; 2018 [cited 14 March 2018]. Available from: http://m-cdn.adinstruments.com/product-data-cards/MLT0670-DCW-15A.pdf

5. Scaling - Converting Current and Voltage Inputs [Internet]. Omega.com. 2018 [cited 8 March 2018]. Available from: https://www.omega.com/techref/das/scaling.html