Infusion Therapy System

Hanna Engstrom ‘19, Shannon Phillips ‘19

Faculty Advisor: Professor Clayton Byers

The Current State of Infusion Therapy

- The infusion therapy system and the patient must be constantly monitored by a nurse or doctor in a hospital or outpatient setting to ensure constant flow rate, for patient comfort and medication effectiveness
- Many infusion therapy systems have an alarm that will sound if there are kinks in the tubing or if there is something affecting the flow of medicine within the system
- The alarm systems in these pumps are known for being unreliable

Project Goals

The ultimate goal of this project is to be able to simultaneously monitor fluid flow rates and pressures for optimal patient comfort and efficient medication administration.

Necessary Steps

1. Determine flow properties of the nanoribbon to predict how it will react to fluid flow and therefore be able to optimally design the system
2. Order proper materials in order to build an effective measurement system, in addition to calculating and displaying graphically the predicted results from these materials
3. Build the system, take experimental measurements, and compare those measurements to predicted results
4. Have the system output the flow rate and pressure to an LED display for nurses and patients to easily monitor the system

Elastic Filament Velocimetry (EFV) Sensor

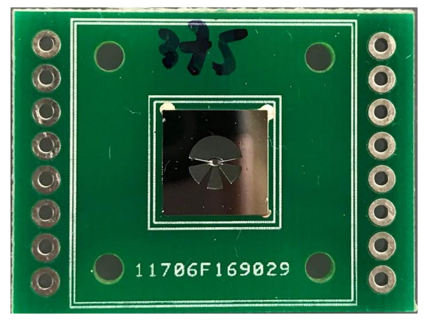


Figure 1: EFV Sensor

The EFV sensor is an all-new method for detecting fluid flow rates. The sensor is an electrically conductive nanoscale ribbon suspended between silicon supports.[1]

When fluid flows across the nanoribbon, the fluid causes a viscous drag, resulting in a strain in the sensor that causes the electrical resistance to increase. The resistance across the nanoribbon can be measured by a wheatstone bridge circuit with wires attached to the proper electrical leads

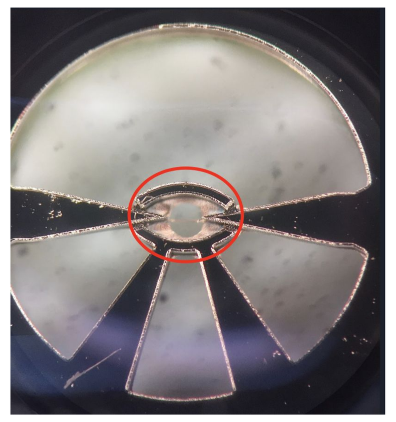


Figure 2: EFV Sensor Zoomed in

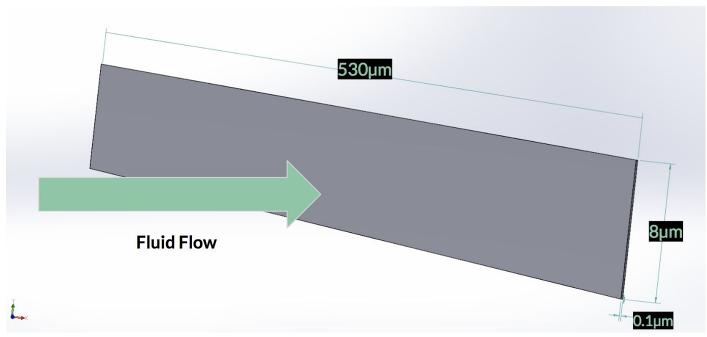


Figure 3: Solidworks Representation of the Nanoribbon

Characterizing the Sensor

Since the EFV sensor is a new technology, it had not yet been fully characterized for how fluid drag will interact with the nanoribbon. Therefore, before building the infusion therapy system, some fluid flow characteristics, such as coefficient of drag, were determined in order to design the optimal device. The nanoribbon is best described as a thin plate/ribbon, however the coefficient of drag for a thin plate/ribbon was not known at the low Reynolds numbers to be encountered in this project.

Reynolds Number of the EFV Sensor

Reynolds number is a dimensionless number that measures the ratio of inertial and viscous forces to determine if an object has laminar or turbulent flow

$$Re = \frac{pVl}{\mu} = \frac{Vl}{\nu}$$

p = The density of the fluid
μ = The dynamic viscosity of the fluid
V = The velocity of the fluid
l = The characteristic length
ν = The kinematic viscosity of the fluid

Verification of Laminar Flow

$$Re = \frac{(998\ kg/m^3)(0.00565 m/s)(8\times10^{-6} m)}{1.0\times10^{-3} kg/m{*}s} = 0.113$$

Utilizing ANSYS

To solve for these low Reynolds values, the computer program ANSYS was utilized to determine what the coefficient of drag of the nanoribbon is at these low Reynolds numbers

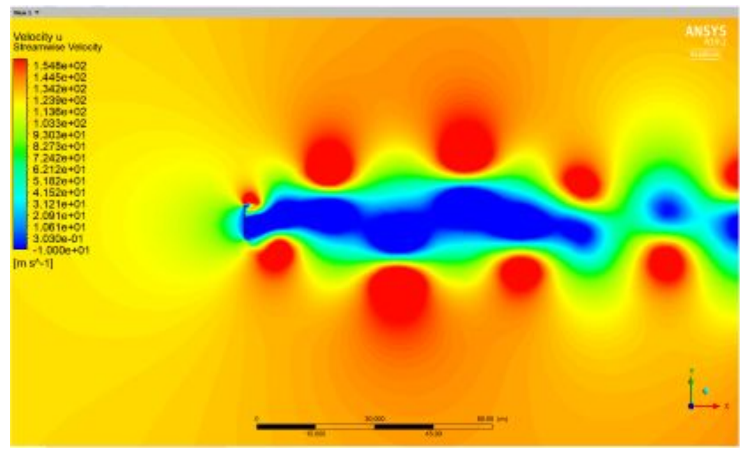


Figure 4: Flow Contour around the Nanoribbon Sensor

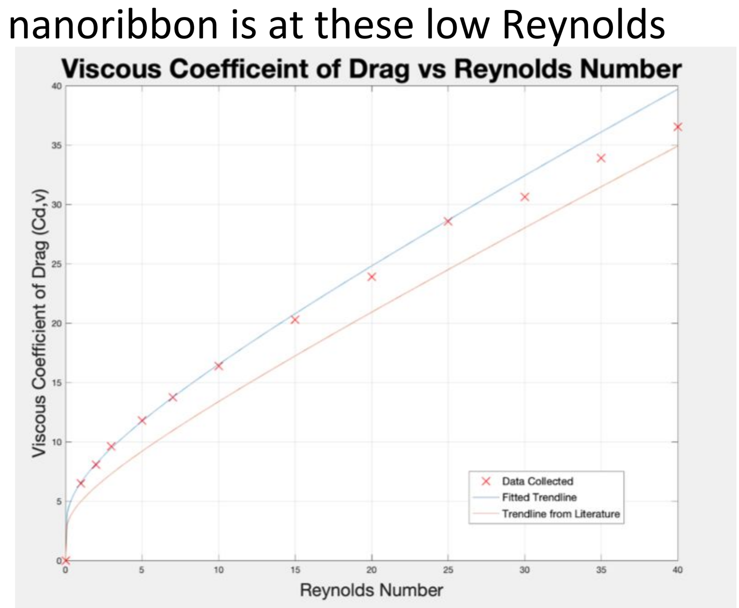
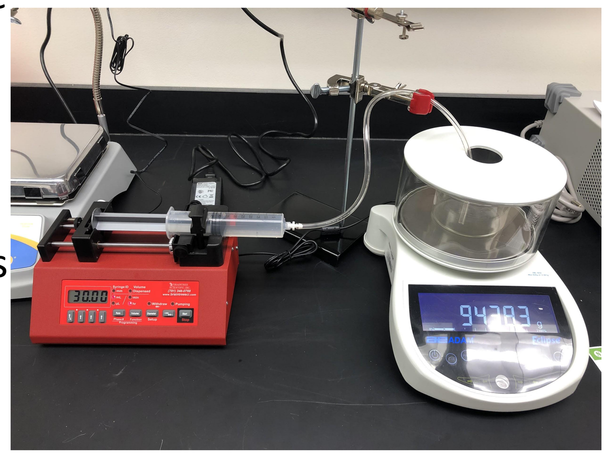


Figure 5: Nonlinreg Fitted to Nanoribbon ANSYS Simulation Results from Cylinder Equation

Building the System

Pump Calibration

First the Braintree Scientific Incorporation Multi-Phaser Programmable Syringe Pump was calibrated to ensure it was pumping at accurate flow rates

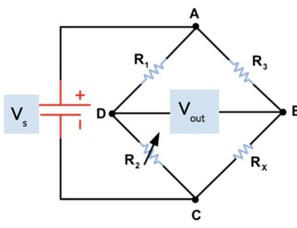


The Wheatstone Bridge

In order to measure the resistance across the sensor, a wheatstone bridge was used. The wheatstone bridge is a commonly used circuit to find an unknown resistance by applying voltage to a circuit with three known resistances along with the resistance in question(R_x). An instrument amplifier was used to amplify the output from the wheatstone bridge followed by a passive-low pass filter to remove noise from the signal.

$$V_{out} = G * V_s\left(\frac{R_2}{R_1+R_2} - \frac{R_x}{R_x+R_3}\right)$$

G= gain factor
Vs= Voltage Source



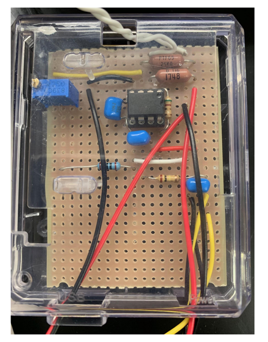
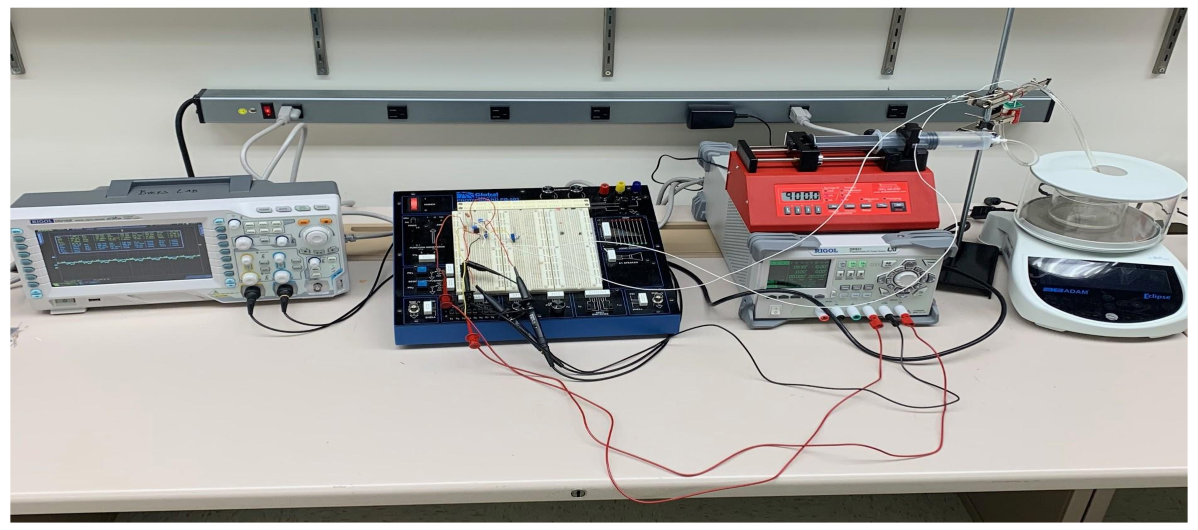


Figure 6: Final Circuit

The Device

The Initial Device

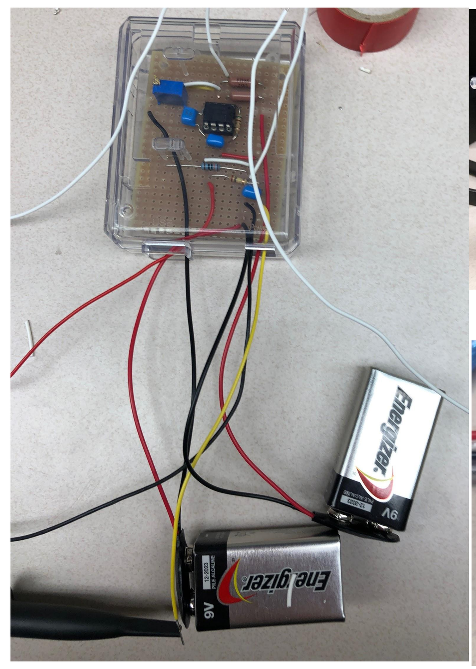


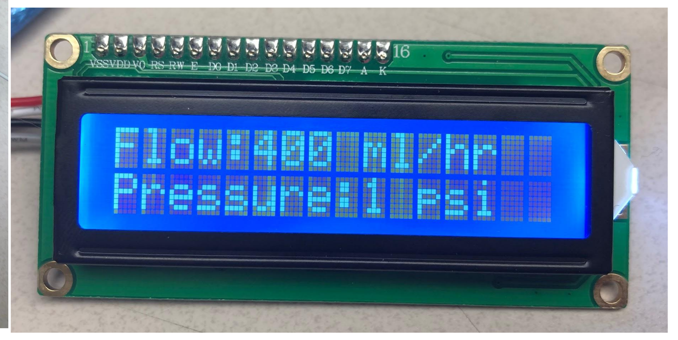
The wheatstone bridge circuit with amplification was combined with the EFV sensor and the pump. A RIGOL DP831 Programmable DC Power Supply was used to generate the input voltage, and a RIGOL DS2102E Digital Oscilloscope was used to measure and record the output voltage.

The average values from the oscilloscope were taken at each flow rate and were found to follow the trends of the predicted curve

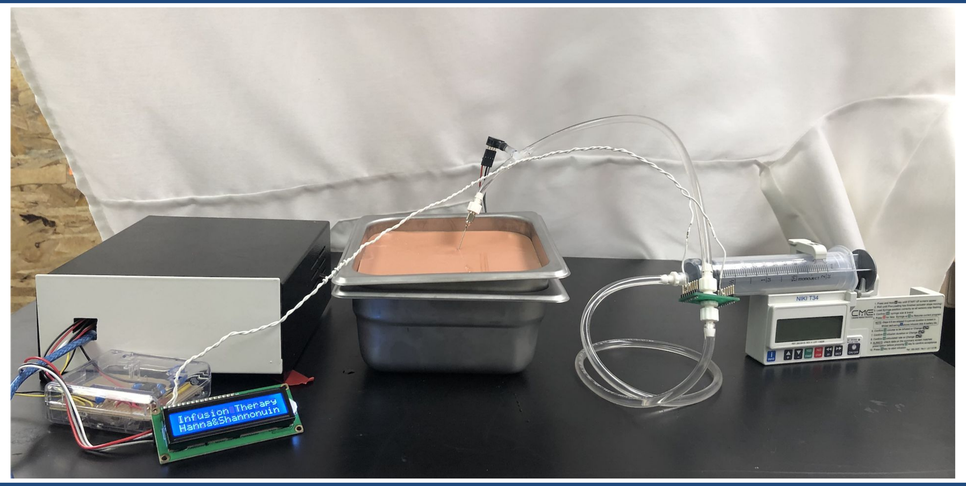
The Portable Device

The electronics were soldered onto a verotec board and two 9V batteries were used to power the system instead of the power supply to avoid 60 Hz DC noise from the outlets that the power supply would have. In addition, the battery powered CME America T34 pump was used. The detected velocity and pressure are displayed on an Arduino LED display.



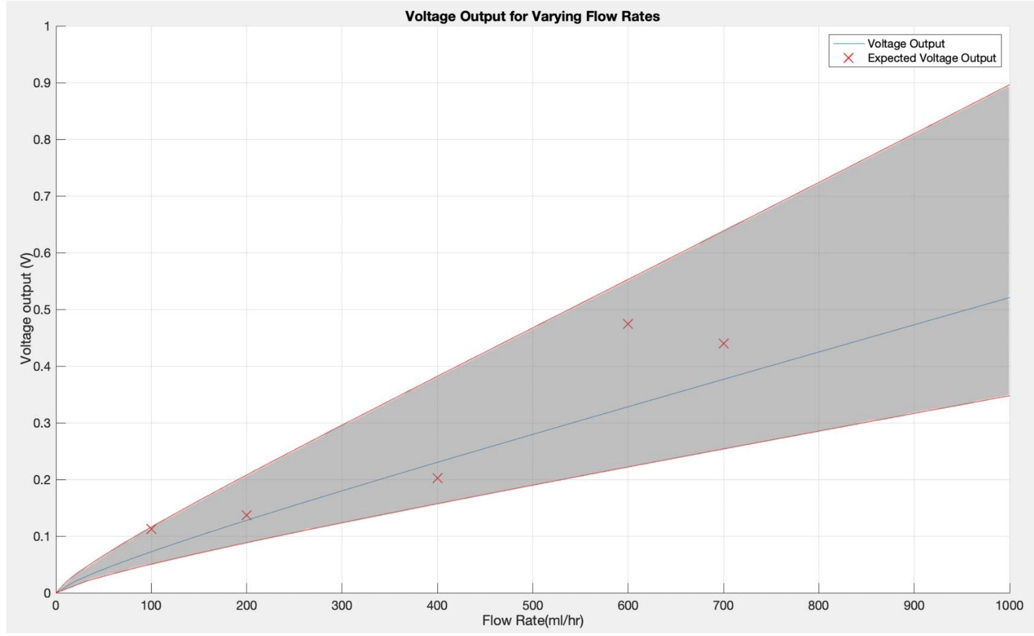


The Final Device



Results and Discussion

Data was then taken from the final system and plotted on the graph with the Expected Voltage outputs. These results followed the expected trends



We were successful in our goal to create a portable infusion therapy system that can monitor fluid flow and pressure rates.

Future Steps

- Use electronics with better tolerances and add more filters to remove as much noise in the signal as possible
- Addition of a feedback system with a pump could be incorporated to ultimately control flow rates and pressures.

Acknowledgements

Thank you to Professor Byers, Professor Mertens, and Professor Blaise for providing guidance and assistance with this project. Thank you to TENDO technologies for providing Elastic Filament Velocimetry sensors for the creation and testing of the system. Thank you to NASA Student Project Grant and to Travelers for providing the funds to purchase materials for this project and to further our education. Thank you to CME America for allowing us to borrow the T34 Pump to demonstrate the infusion therapy system’s portability.

References

[1] Fu, Matthew K., et al. “Elastic filament velocimetry (EFV)”. Measurement Science and Technology. 28.2 (2016): , 28, 2, 025301. Web.

[2] White, F.M., *Fluid Mechanics (8ed),* McGraw-Hill Education, New York, NY, 2016.

[3] Faizan, Ahmad. “Wheatstone Bridge Circuit Theory and Working Principle.” *Electrical Academia*, Electrical Academia, 26 Nov. 2017, electricalacademia.com/instrumentation-and-measurements/wheatstone-bridge-circuit-and-working-principle/.

[4] “LATEST.” *All About Circuits*, www.allaboutcircuits.com/textbook/semiconductors/chpt-8/the-instrumentation-amplifier/.

[5] “Further With Filters.” *Further With Filters |*, 1 July 2004, www.soundonsound.com/techniques/further-filters.

[6] “Cylinder Drag -- from Eric Weisstein's World of Physics.” *Scienceworld.wolfram.com*, scienceworld.wolfram.com/physics/CylinderDrag.html.