Real Time Instrumentation for Micro Particles Detector

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System Overview

A real time particle detector is an instrument for environmental monitoring. By detecting the size and concentration of airborne particles, we would recognize the safety levels in certain environments. The basic set up includes a PDMS three channel separators. Two micro-fans are used to provide sheath air flow in two channels, and one channel is used for particles to travel through. The project will be discussed in two parts: software and hardware. A block diagram (Figure 1) is shown to illustrate the general setup of the system.

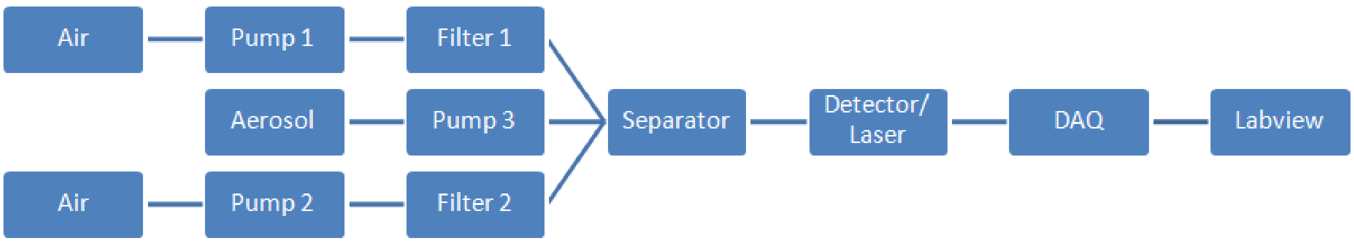

Figure 1: Flow chart of the system.

Hardware:

A fiber coupled diode laser (Blue Sky Research, FTEC2658-60) is used to illuminate the particles. Two power sources are used to run the laser at 3.3V and 5V. (Figure 2) The photodetector (Thorlab, APC 110A) is connected to the laser (Figure 3). A close up snapshot of the photodetector shows that there is a 1mm sensing area (Figure 4) and its objective is to capture the scattered light from a particle and produce a pulse that will enable the user to count the number of particles through LabView software.

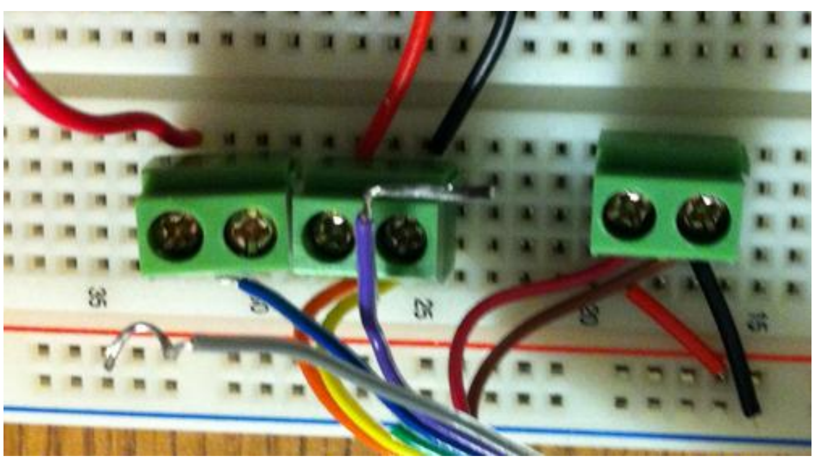

Figure 2: Circuit for laser.

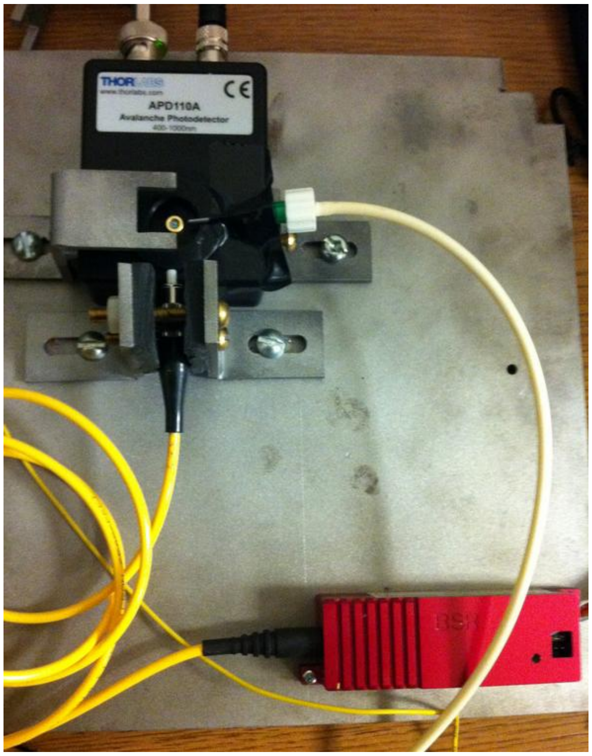

Figure 4: Laser and Photodetector

Figure 3: Close up of sensing area in photodetector

The PDMS (polydimethylsiloxane) separator consists of three inlets and three outputs. Each channel is 100um high, the inlets are 40um high, and 60um wide. The outer channels will provide sheath air, and the middle channel lets particles flow through.

The microfans are used to provide low flow rate. (Figure 5) The microfan that was selected is the UF383-100 (Sunon Fans.) It is powered up to 3VDC and provides an airflow or 0.17 L/min. This microfan is used because a flow rate of 0.00036 L/min is to be achieved. To make this possible, a series of hepa filters is attached to the fan to provide resistance to its flow.To calculate the desired flow rate, calculations in (1) determined our values.

Figure 5: (Note, there are three pins, but only power and ground were used. The third pin is for speed sensing.

Flow (Q) = Velocity * Cross Sectional Area (1)
Velocity (U) = 1m/s
Cross Sectional Area (A) = 100 um * 60 um
Q = U * A = $3.6 * 10^{-7}$ m^3/min * 1000L/min = 0.0036L/min oo

A MOSFET (metal oxide semiconductor field conductor) is used as a pulse width modulator to control the microfans. ((Figure 6) The MOSFET chosen for this circuit is BS107A. Since the Vgs used is 3V, and the current going through the microfan is measure to be 115mA, the BS107A MOSFET's characteristics meet the needs of the circuit. Additionally, a 1N914 diode is connected in reverse diode parallel to the microfan. (Figure 6)To control the microfan with LabView, the connections of the MOSFET are as follows: the drain is connected to Vgs (3V) via the microfan and the diode in parallel. The gate pin is connected to an analog channel of the DAQ. The source pin is connected to ground. (Figure 7)

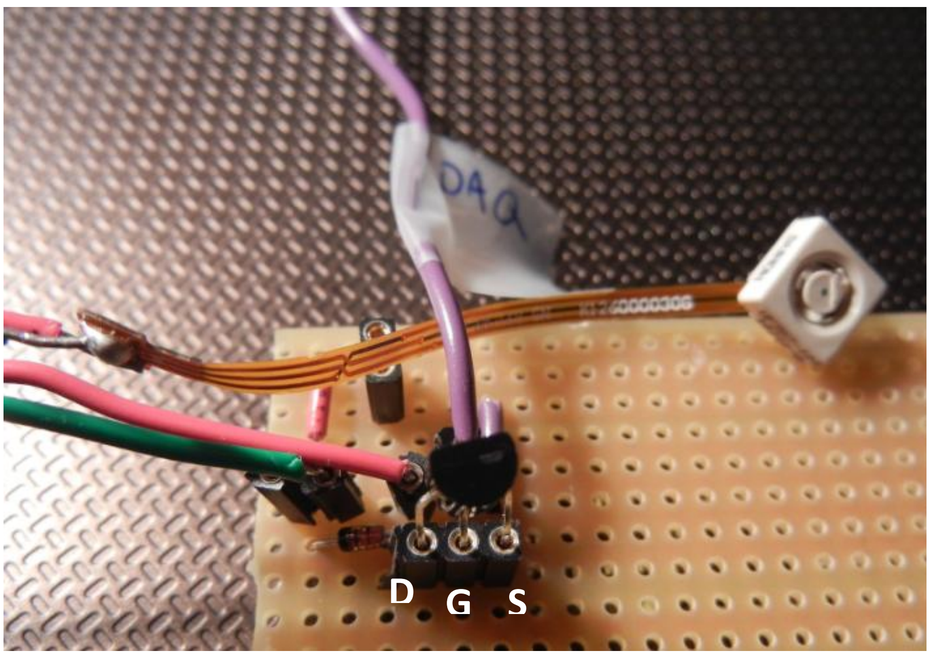

Figure 6: Microfan circuit. The MOSFET is labeled with D (drain), G (gate), and S (source).

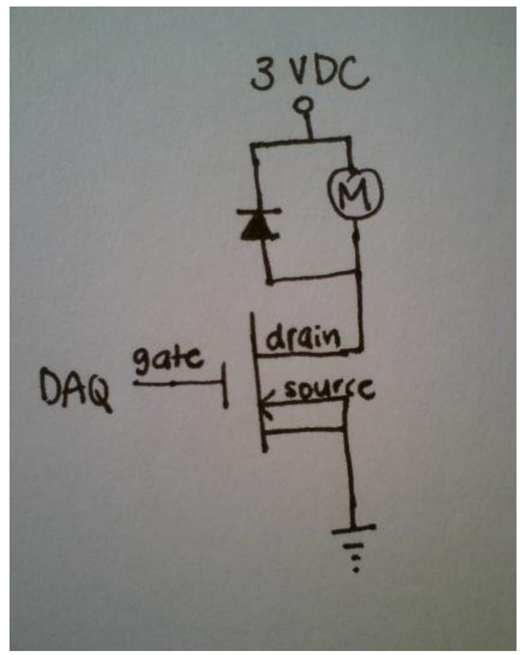

Figure 7: Circuit diagram of microfan.

Software:

DAQ:

A data acquisition system is used to receive an analog signal from the hardware and to provide real time data through National Instruments LabView (Laboratory Virtual Instrumentation Engineering Workbench). The parameters that were focused on were sampling frequency and resolution. Frequency is calculated by (2).

Sensing Area = size of detector = 1 mm
Velocity = 2m/s
Period = 0.001m/2 m/s = 0.0005s
Frequency = 1/period = 2000 Hz (2)

The USB-1208FS DAQ (Measurement Computing) is the data acquisition system that acts as the interface between the signal and the computer. It has a 12 bit resolution, 8 analog inputs, and 16 digital I/O connections. Data can be received at a rate of 50 kilo Samples/second.

Pulse Width Modulation (PWM):

The separation of the particles through micro-channel separator using centrifugal force requires different flow rate for different sizes of the particles. In order to provide variable flow rate with three streams, we have incorporated the PWM method to control each stream. To control the speed of the micro fans, a pulse width modulation was used to change the duty cycle of each fan to vary the flow rate. The user interface allows the user to change the duty cycle from 0-100% by moving the blue meter up and down. (Figure 8) The desired output channel of the DAQ and the frequency is selected as well. To design the circuit in LabView, the basic concept is converting frequency to time, and then multiplying it by duty cycle. (Figure 9) Due to the limited specification of our DAQ, output frequency of 50Hz is used to reduce the amount of error.

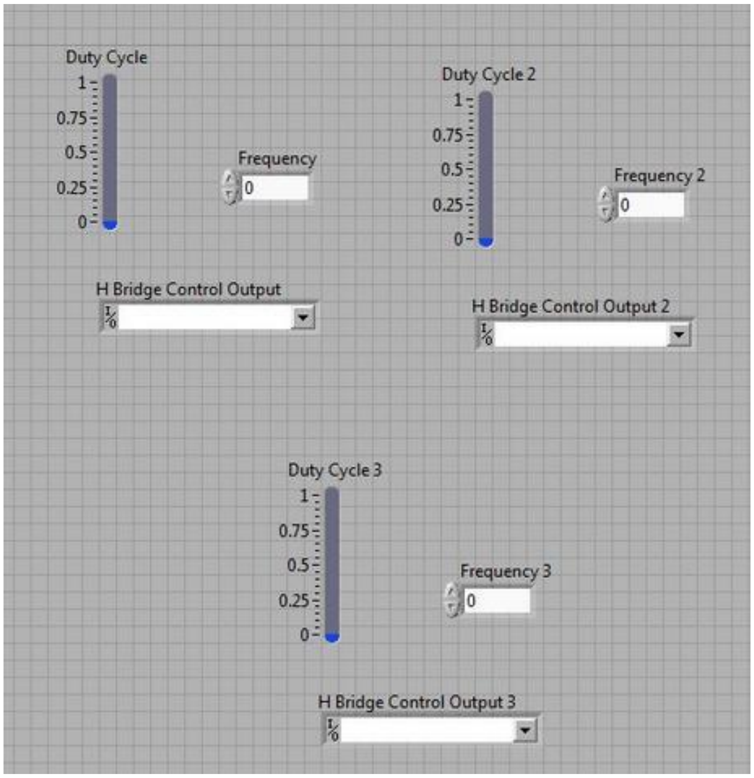

Figure 6: PWM Interface

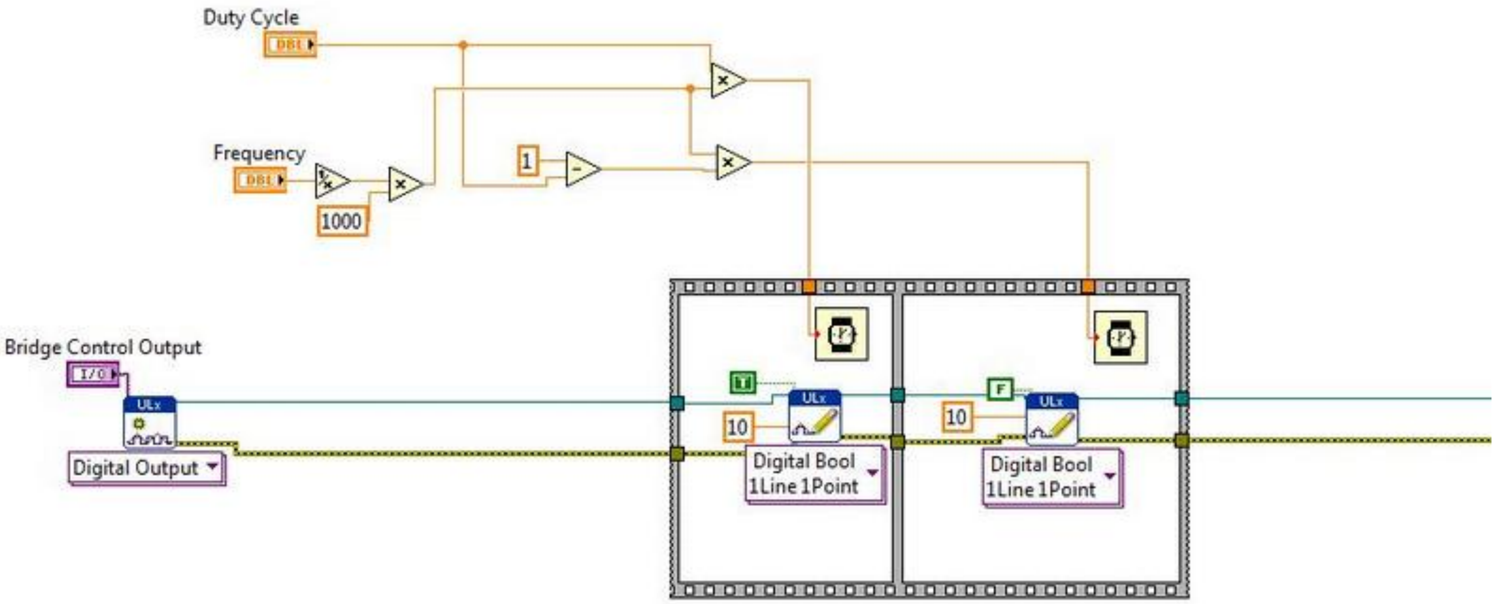

Figure 7: Circuit of PWM implemented in LabView.

Counting Particles:

The user selects the desired input channel of the DAQ which the photo-detector is connected to. With the sampling frequency of 50kS/s, the photo-detector detects the light reflected from the particles. The analog voltage signal from the photo-detector is then acquired by the DAQ. The voltage signal of the particle is distinctively above the noise. (Figure 10) To count the number of particles, the labview not only counts the peak going up but also going down, treating a one cycle of going up and down of the peak as one particle. This prevents the labview from counting the entire noisy signal. We have also included 'deathband' which is an arbitrary boundary value we set up to enhance the accuracy of the counting procedure. The deathband value is usually set up as two to three times higher than the noise. The front panel of the labview allows user to input a desired input channel of the DAQ and deathband value. The number of particles is displayed on the front panel of labview as well. (Figure 11)

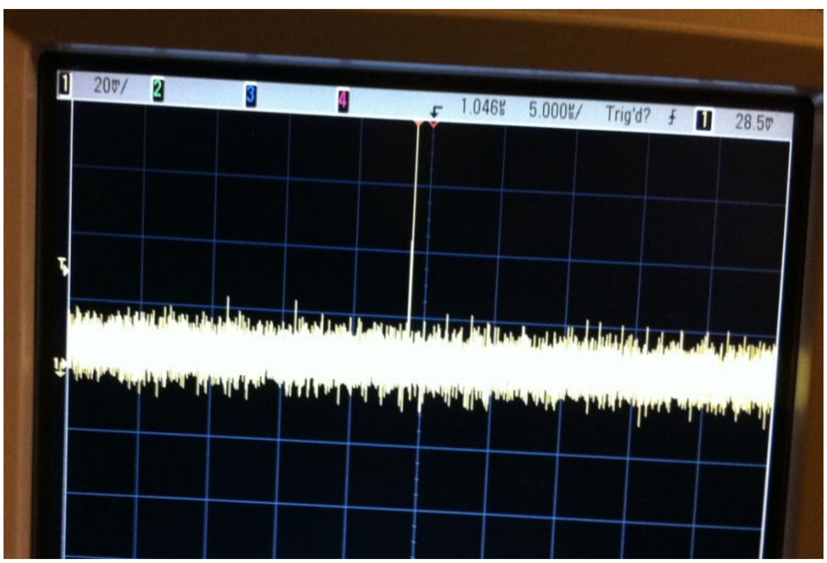

Figure 10: Voltage Signal

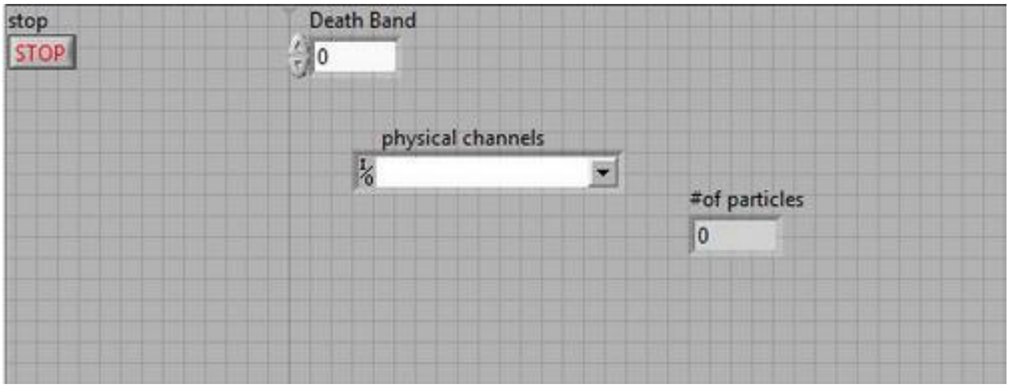

Figure 8: Counting Particles User Interface

The program in LabView receives a signal, from the photodetector, which gets filtered, and a "deathband" is added to ensure only the valid peaks of the particles are counted. The input signal is filtered by the built-in function called "smoothing type" filter (Figure 12). The filter function takes the average of dynamic input voltage signals to reduce the noise and smooth out the curve. (Figure 13) Without the process; it would be more difficult to identify the voltage input that needs to be count as particles. The filtered signal is compared with the original input signal value. If the original signal value is greater than the filtered one, the Boolean function outputs true and will trigger the counter and store the numbers when is becomes false again. This cycle from true to false is treated as one cycle to count the particles as mentioned above.

To see the number of particles counted, the LabVIEW code will save a text file that displays the number of particles counted at the time it was counting, and the duty cycle of each microfan. (Figure 14)

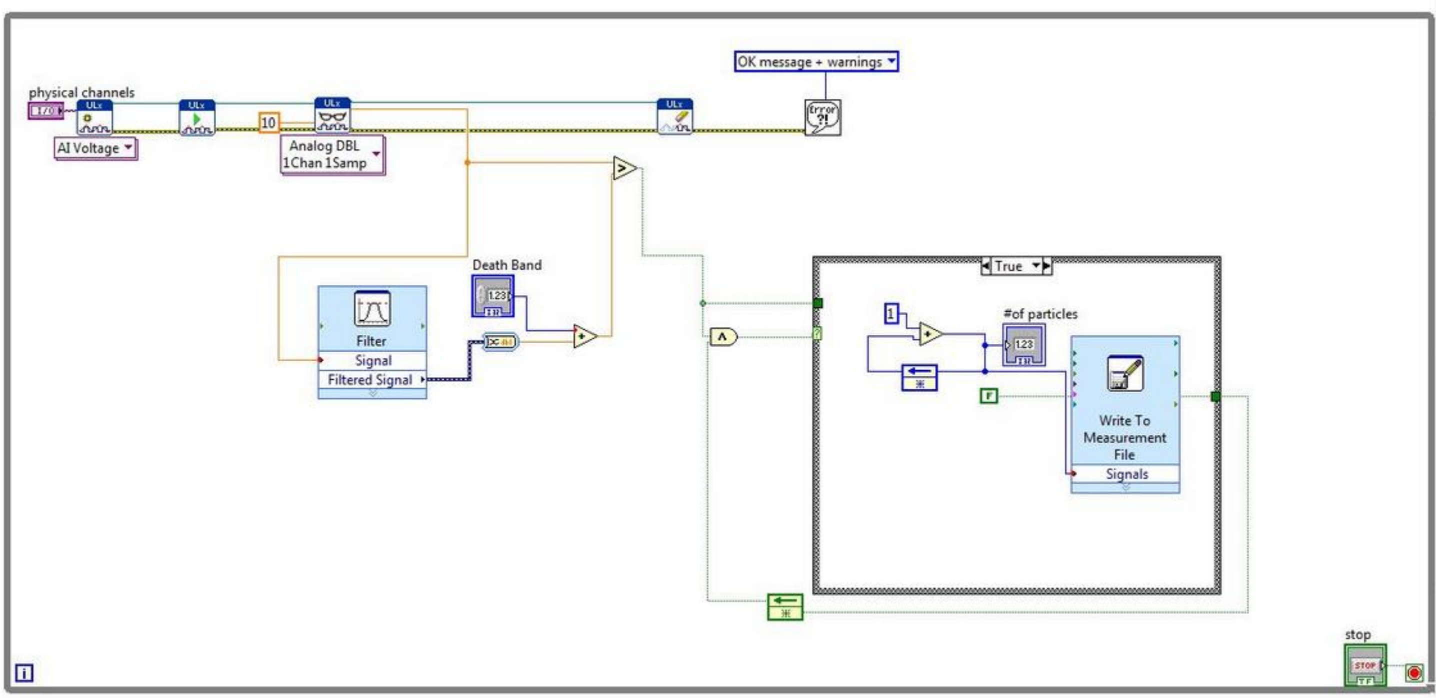

Figure 12: Back view of Labview circuit to count particles

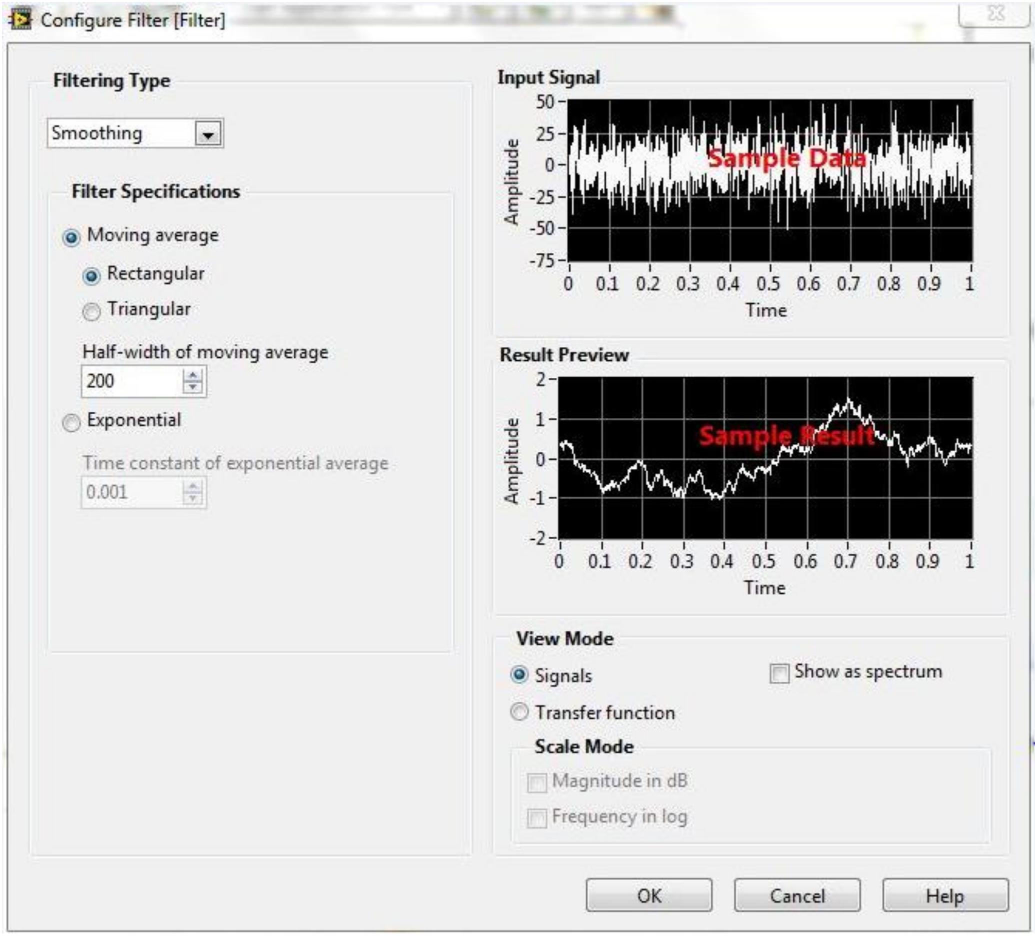

Figure 9: Filtering Properties

0.000000	2.000000	1.000000	1.000000	0.000000
22.066262	3.000000	1.000000	1.000000	0.000000
23.169325	4.000000	1.000000	1.000000	0.000000
23.371336	5.000000	1.000000	1.000000	0.000000
23.484343	6.000000	1.000000	1.000000	0.000000
24.060376	7.000000	1.000000	1.000000	0.000000
24.215385	8.000000	1.000000	1.000000	0.000000
24.539403	9.000000	1.000000	1.000000	0.000000
25.079434	10.000000	1.000000	1.000000	0.000000
26.117494	11.000000	1.000000	1.000000	0.000000
26.368508	12.000000	1.000000	1.000000	0.000000
27.070548	13.000000	1.000000	1.000000	0.000000
27.925597	14.000000	1.000000	1.000000	0.000000
28.007602	15.000000	1.000000	1.000000	0.000000
28.943655	16.000000	1.000000	1.000000	0.000000
29.065662	17.000000	1.000000	1.000000	0.000000
29.384681	18.000000	1.000000	1.000000	0.000000
29.539690	19.000000	1.000000	1.000000	0.000000
29.772703	20.000000	1.000000	1.000000	0.000000
29.933712	21.000000	1.000000	1.000000	0.000000
30.208728	22.000000	1.000000	1.000000	0.000000
31.220786	23.000000	1.000000	1.000000	0.000000
31.510802	24.000000	1.000000	1.000000	0.000000
31.855822	25.000000	1.000000	1.000000	0.000000
32.168840	26.000000	1.000000	1.000000	0.000000

Figure 10: Sample snapshot of a text file showing the number of particles counted at a certain time. The first column is time, second column is the number of particles, and the next three columns are the duty cycle of microfan 1, microfan 2, and microfan 3.

Problems

The initial setup consisted of a micro diaphragm gas sampling pump (KNF NMP 015.1.2 KNDCB) to pump the sheath air. The pump was tested by using a power supply of 6VDC and a flow meter was attached to it to measure the flow rate. To find the relationship between flow and voltage, different flow rates were measured at different voltages. The results indicate the flow increases as voltage increases. (Figure 15) A graph is given to show the plotted points. (Figure 16)

Voltage (V)	Flow(L/min)
6	2.18
5	2.003
4	1.541
3	1.234
2	0.835
1.5	0.595
1	0.005
0	0

Figure 11: Relationship between Voltage and Flow

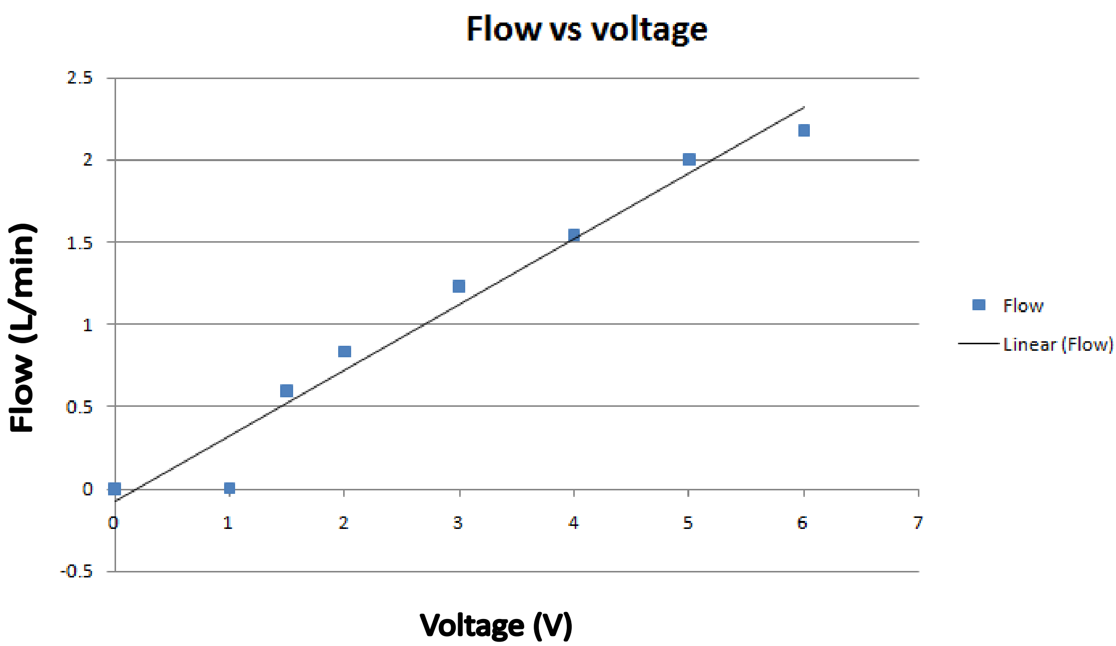

Figure 12: Flow vs Voltage graph of the micro diaphragm pump.

The maximum flow rate of the pump is 2.1 L/min. After adding filters in series and using the PWM to lower the duty cycle, the pump still could not be driven down to produce a flow rate of 0.00036 L/min. Hence, a microfan was used instead.

Results

The instrumentation is proven to be feasibly working. The system is able to produce signals when the photodetector senses particles and communicates with the software via the DAQ. In initial testing, an oscilloscope was used to observe pulses that show particles can be detected when they were being generated through a nebulizer.

To ease the measurement of detecting particles, the DAQ was used instead to detect signals and show the number of particles in LabVIEW. During testing, the program proved to be successful when real time data was collected. The number of particles were displayed on a simple user interface and also saved to a text file. Additionally, a pulse width modulation circuit is integrated successfully within the software. The user can change the flow of the microfan by adjusting its duty cycle. The interface is simple and user friendly. A circuit with an N-Channel MOSFET acts as a switch between the microfan and the program with the use of the DAQ. However, the characteristics of the microfan are not fully investigated. To test if the microfans prove to be feasible, a micro air flow sensor is suggested to be integrated into the system temporarily. Using a micro air flow sensor can detect the microfans' small changes in their flow rate that previously could not be detected. This is a challenge because the parts used are costly and more complicated to implement to have small flow rates. Individual parts of the system have shown successful progress.