The University of Turkish Aeronautical Association

Electrical - Electronics Enginnering

Hot Wire Anemometer

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ABSTRACT

A hot-wire anemometer circuit using a new, low noise and large frequency bandwidth operational amplifier is described. Dynamic tests showed that the circuit response was as fast as a commercial unit. The hot-wire anemometer has been utilized widely for long time as an examination device in liquid mechanics. An exhaustive investigation of this procedure and point by point examination of various system in which this technique can be upgraded has been finished. In hot-wire anemometry a little electrically warmed component presented to a liquid medium to measure a property of that medium is utilized. Typically, the property being measured is the speed. Since these components are touchy to warm exchange between the component and its condition, temperature and creation changes can likewise be detected.

Taking different types of probes and different types of fluid we compare the behavior of sensor so that we can determine the best condition for measurement of property particularly velocity.

ACKNOWLEDGEMENTS

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INTRODUCTION

Hot wire anemometers have been used for a long time, and it remains an important tool for theoretical and experimental analysis of the fluid flow with relative free stream. It is used to describe any wind speed measurement instrument used in meteorology. A hot wire anemometer is a thermal transducer basically. The hot wire anemometer consists of a sensor, a small electrically heated wire exposed to the fluid flow and some other electronic equipments, which performs the transformation of the sensor output into a useful electric signal. An electric current crosses a fine metallic filament which is faced against the movement of a stream. The heat generated by the passage of the electric current in the filament is transferred to the fluid when your thermal balance varies, modifying the electrical resistance. Such variations can be computed and monitored using several electronic circuits, able to correlate to the speed of the fluid, and on my project, after measuring the speed of the wind, we get plots of the values with the help of MATLAB software. The purpose of a graph is to present data that are too numerous or complicated to be described adequately in the text and in less space in a specific time with exact numbers. It also helps to analyze quickly and compare with multiple data on the same time.

In this study, we propose optimizing the two state hot wire anemometer transmission bandwidth by means of two approaches. Our optimization strategy relies on a specialized constant-temperature circuit with variable dynamic parameters and an appropriate measurement cycling strategy. In our solution, the constant temperature circuit can be dynamically regulated. Immediately before switching over to a different heating level, the dynamic parameters of the constant temperature circuit are stored in a way that allows us to calculate minimum time required to reach steady state. This regulation is performed based on flow velocity and heating level.

The measurement cycle strategy is as follows:

▪ switch over to the preset heating level, and then determine flow velocity and temperature of the fluid based on the value of the sensor current recorded during the two previous steady state scenarios,

▪ a sequence of sensor current measurements is performed until the system reaches a steady state consistent with the stated criteria,

▪ given the previously calculated flow velocity and heating level, the optimal dynamic parameters of the constant-temperature circuit are calculated,

▪ the next sensor heating level is targeted and the cycle repeats.

The proposed circuit structure and measurement cycling strategy allow us to achieve a maximum switching frequency between the heating levels. Besides optimizing transmission bandwidth, we also minimize measurement errors. We created a computer simulation to test our proposed solution to optimize two-state hot-wire anemometer transmission bandwidth. We simulated system operation across a wide range of parameters and different operational modes.

HOT WIRE ANEMOMETERS

Hot wire anemometers use a fine wire (on the order of several micrometers) heated up to some temperature above the ambient, the electrical resistance of conductor change with temperature. Air flowing passed the heated wire tends to cool the wire, thereby lowering its resistance. By monitoring the resistance of heated wire and taking the temperature of the surrounding air in to account it is possible to measure the speed of air past the wire. A sensor design for this specific purpose is called hot wire anemometer.

Hot wire anemometer can be used to measure small changes in air movement. Since active surfaces are of the device can be quite small, hot wire anemometer very use full for accurately portraying the flow of air and the turbulence of the wind tunnel models. They can even be used to detect the movement of air created by small insects. For that reason choosing the sensor has huge importance.

Probe selection

Probes are primarily selected depending on:

- Fluid medium
- Number of velocity components to be measured (1-, 2- or 3)
- Expected velocity range

• Quantity to be measured (velocity, wall shear stress etc.)

• High Temperature Coefficient of resistance

• High Specific Resistance.

• High Mechanical Strength.

• Good Oxidation Resistance.

• Low Thermal Conductivity.

• Availability in small diameters.

• Required spatial resolution

• Turbulence intensity and fluctuation frequency in the flow

• Temperature variations

• Contamination risk

• Available space around the measuring point (free flow, boundary layer flows, confined flows).

Quick guide to probe selection

Free and Confined Flows		
Type of flow	**Medium**	**Recommended Probes**
1-Dimensional		
Uni-directional	Gas	Single sensor Wire Single sensor Fiber, thin coat. Wedge-shaped Film, thin coat. Conical Film, thin coat.
	Liquid	Single sensor Fiber, heavy coat. Wedge-shaped Film, heavy coat. Conical Film, heavy coat.
Bi-directional	Gas	Split-fibers, thin coat.
	Liquid	Split-fibers, heavy coat.
2-Dimensional		
One Quadrant	Gas	X-array Wires X-array Fibers, thin coat. V-wedge Film, thin coat.
	Liquids	X-array Fibers, heavy coat. V-wedge Film, heavy coat.
Half Plane	Gas	Split-fibers, thin coat.
	Liquids	Split-fibers, heavy coat.
Full Plane	Gas	Triple-split Fibers, thin coat. X-array Wire, flying hot-wire
	Liquids	Triple-split Fibers, *special*
3-Dimensional		
One Octant (70° Cone)	Gas	Tri-axial Wire Tri-axial Fiber, thin coat.
	Liquids	Tri-axial Fiber, *Special*
90° Cone	Gas	Slanted Wire, rotated probe
	Liquids	Slanted Fiber, heavy coat.
Full Space	Gas	Omnidirectional Film
Wall Flows (Shear Stress)		
Type of flow	**Medium**	**Recommended Probes**
1-Dimensional		
Unidirectional	Gas	Flush-mounting Film, thin coat. Glue-on Film, thin coat.
	Liquids	Flush-mounting Film, heavy coat. Glue-on Film, *special*

Anemometer probes are available with four types of sensors: Miniature wires, Gold-plated wires, Fibre-film or Film-sensors. Wires are normally 5 μm in diameter and 1.2 mm long suspended between two needle-shaped prongs. Gold-plated wires have the same active length but are copper- and gold-plated at the ends to a total length of 3 mm long in order to minimise prong interference. Fibre-sensors are quartz-fibers, normally 70 μm in diameter and with 1.2 mm active length, covered by a nickel thin-film, which again is protected by a quartz coating. Fibre-sensors are mounted on prongs in the same arrays as are wires. Film sensors consist of nickel thin-films deposited on the tip of aerodynamically shaped bodies, wedges or cones. For sensor type selection:

Wire sensors:

Miniature wires:

First choice for applications in air flows with turbulence intensities up to 5-10%. They have the highest frequency response. They can be repaired and are the most affordable sensor type.

Gold-plated wires:

For applications in air flows with turbulence intensities up to 20-25%. Frequency response is inferior to miniature wires. They can be repaired.

Fibre-film sensors:

Thin-quartz coating:

For applications in air. Frequency response is inferior to wires. They are more rugged than wire sensors and can be used in less clean air. They can be repaired.

Heavy-quartz coating:

For applications in water. They can be repaired.

Film-sensors:

Thin-quartz coating:

For applications in air at moderate-to-low fluctuation frequencies. They are the most rugged CTA probe type and can be used in less clean air than fibre-sensors. They normally cannot be repaired.

Heavy-quartz coating:

For applications in water. They are more rugged than fibre-sensors. They cannot normally be repaired.

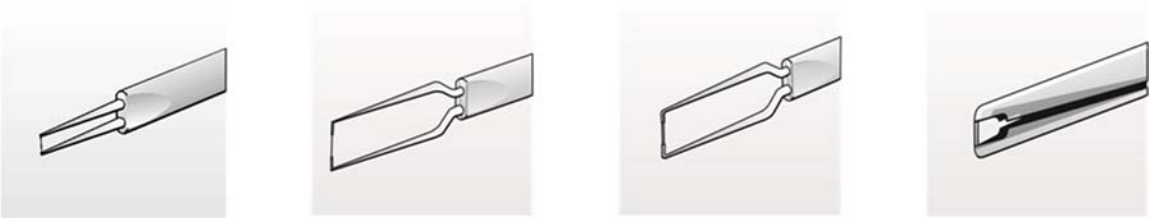

Figure 1 - Sensor types

And probes are available in one-, two- and three-dimensional versions as single-, dual and triplesensor probes referring to the number of sensors. Since the sensors (wires or fibre-films) respond to both magnitude and direction of the velocity vector, information about both can be obtained, only when two or more sensors are placed under different angles to the flow vector.

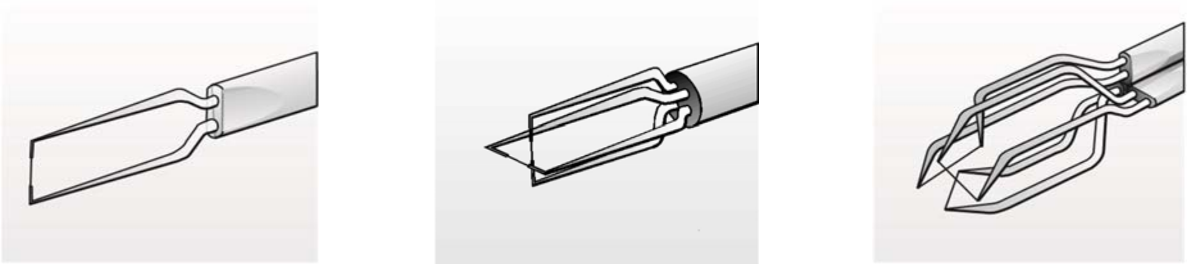

Figure 2 - Sensor arrays

The hot- film sensor is essentially a conducting film on a ceramic substrate. The sensor shown in Figure 3 is a quartz rod with a platinum film on the surface. Gold plating on the ends of the rod isolates the sensitive area and provides a heavy metal contact for fastening the sensor to the supports. The metal film thickness on a typical film sensor is less than 1000 Angstrom units, causing the physical strength and the effective thermal conductivity to be determined almost entirely by the substrate material.

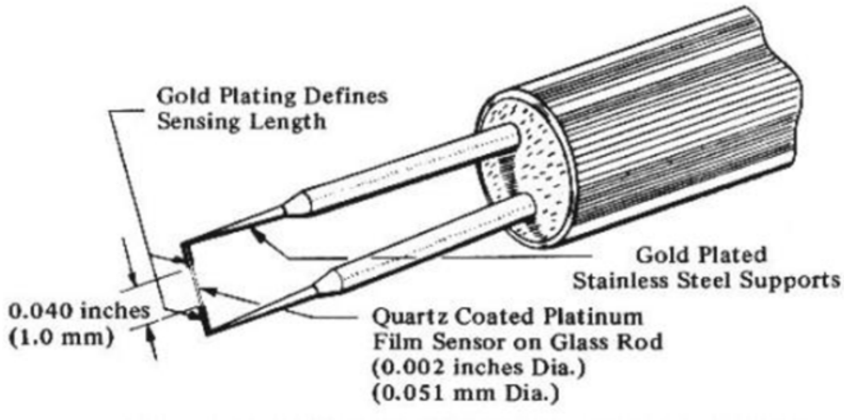

Figure 3 – Hot film sensor

The most common wire materials are tungsten, platinum and a platinum- iridium alloy. Tungsten wires are strong and have a high temperature coefficient of resistance, (0.004/oC). However, they cannot be used at high temperatures in many gases because of poor oxidation resistance. Platinum has good oxidation resistance, has a good temperature coefficient (0.003/ oC), but is very weak, particularly at high temperatures. The platinum- iridium wire is a compromise between tungsten and platinum with good oxidation resistance, and more strength than platinum, but it has a low temperature coefficient of resistance (0.00085/oC). Tungsten is presently the more popular hot wire material. A thin platinum coating is usually applied to improve bond with the plated ends and the support needles.

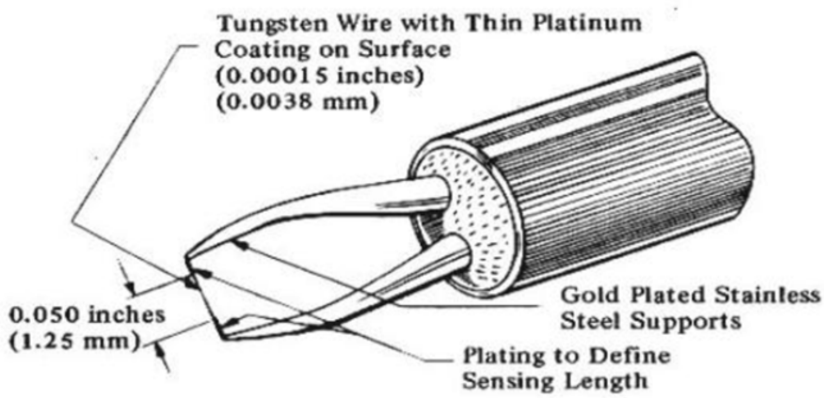

Figure 4 - Hot wire sensor

Advantages of typical Hot wire Anemometer

• Good Frequency response.

• Magnitude can be measured in wide velocity range.

• Temperature measurements.

• Two phase flow measurements in flows containing continuous turbulent

• Phase and distributed bubbles.

• Have low noise levels.

• Measurement of turbulent quantities like vortices, dissipation rate etc.

The voltage output from this anemometers can be taken with two mode of the circuit so that the circuit can be balanced.

1. CCA (Constant-Current Anemometer)

2. CTA (Constant-Temperature Anemometer)

Constant-Current Anemometer

The bridge arrangement along with the anemometer has been shown in below diagram. The anemometer is kept in the flowing gas stream to measure flow rate. A constant current is passed through the sensing wire. That is, the voltage across the bridge circuit is kept constant, that is, not varied. Due to the gas flow, heat transfer takes place from the sensing wire to the flowing gas and hence the temperature of the sensing wire reduces causing a change in the resistance of the sensing wire. (this change in resistance becomes a measure of flow rate). Due to this, the galvanometer which was initially at zero position deflects and this deflection of the galvanometer becomes a measure of flow rate of the gas when calibrated. The wire temperature can be measured in terms of its electrical resistance where the relationship between the resistance and temperature is known.

Although Constant Current Anemometry (CCA) has higher frequency response, there are few disadvantages. This method is difficult to us, because constant temperature anemometry is used the same way as it is calibrated. Calibration is dynamic in this case, while in CCA instruments is calibrated at constant temperature and used in a constant current mode. In constant current mode, wire can be destroyed by burning out due to critical heat flux if the velocity is very small.

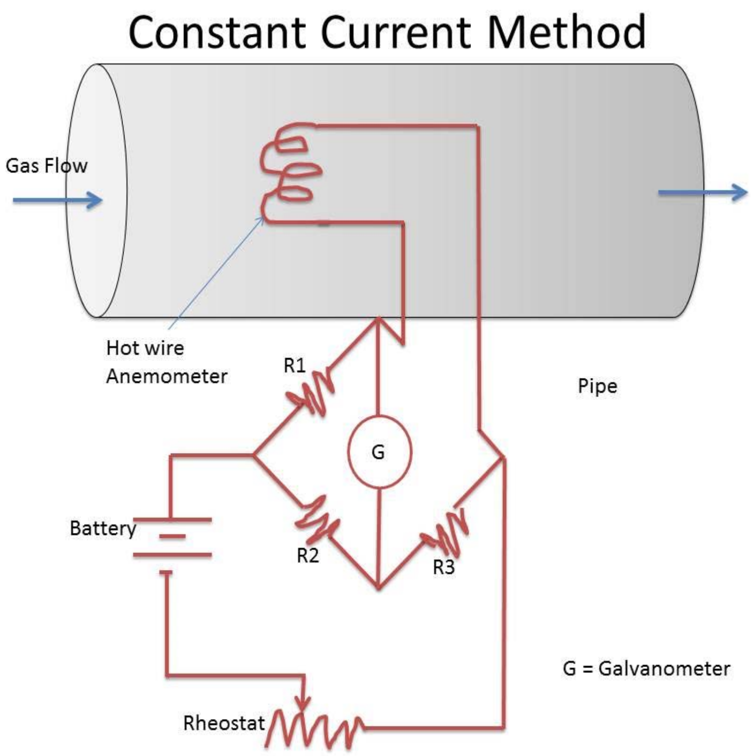

Figure 5 – Constant current method

Constant Temperature Anemometer

The bridge arrangement along with the anemometer has been shown in diagram. The anemometer is kept in the flowing gas stream to measure flow rate. A current is initially passed through the wire. Due to the gas flow, heat transfer takes place from the sensing wire to the flowing gas and this tends to change the temperature and hence the resistance of the wire. The principle in this method is to maintain the temperature and resistance of the sensing wire at a constant level. Therefore, the current through the sensing wire is increased to bring the sensing wire to have its initial resistance and temperature.

The electrical current required in bringing back the resistance and hence the temperature eof the wire to its initial condition becomes a measure of flow rate of the gas when calibrated.

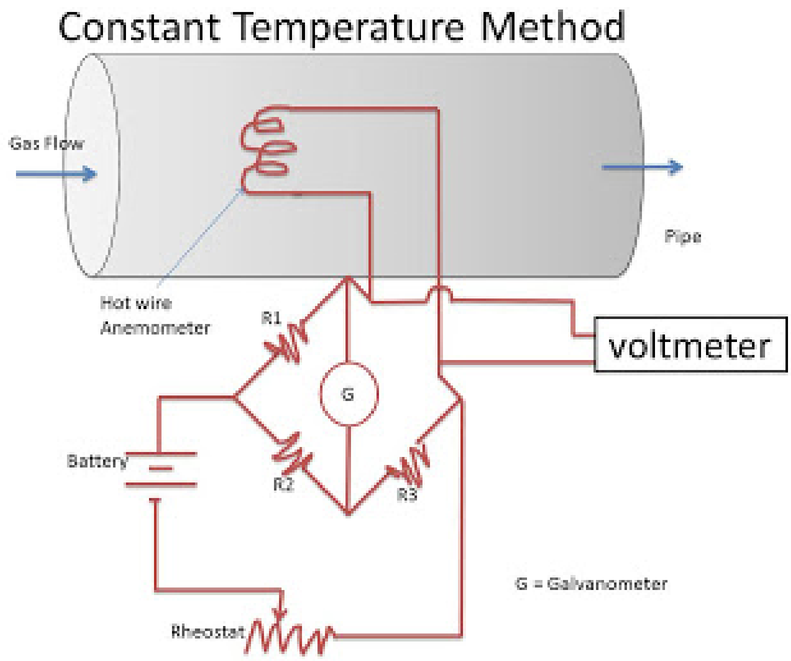

Figure 6 – Constant tempature method

Planning of the Circuit

As mentioned before, the main target of the circuit is to get the voltage reading between 0 to 5V voltage range when the wind hit the bulb filament. For that the filament should be heated above the ambient temperature by providing a constant current and voltage reading value should be taken by because the resistances change of the filament. When working on this, first problem arose was to determining how much current would be sufficient for filament to heat up above the ambient temperature without damaging the bulb filament, because a tungsten filament gets oxidized at higher temperatures.

Whole circuit can be separated as follows.

1. The Sensor

2. The Analog to digital converter

3. Programming

The Probe

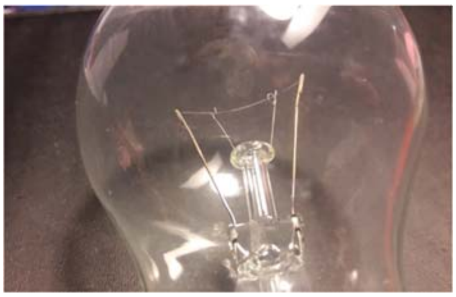

Figure 7 - 5A 6V bulb

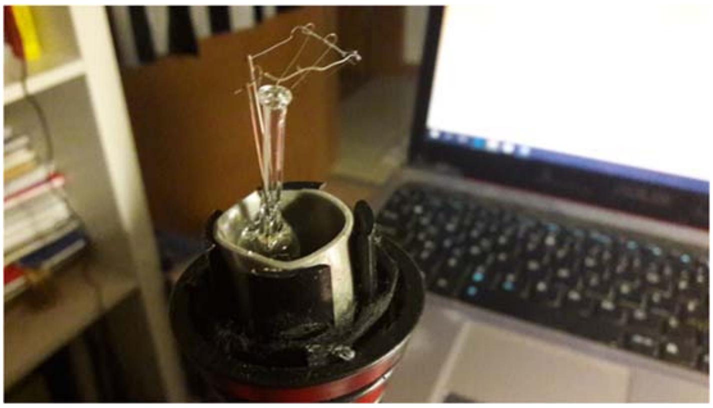

Figure 8 – Removed glass of bulb

Generally, there is a main difference between the typical probe and this probe. Typical probe has tiny platinum mixed tungsten wire, but this probe made by normal torch bulb with removed glass cap. The bulb filament was used as a hot wire. Actually, it is not a wire but like a spring. Different bulbs can be used to do this. It depends on providing voltage. 6 V, 5A, Eveready bulb is most applicable to under this voltage condition 12 V supply voltage.

It must be mentioned that normally a bulb after removing its glass cap, it can be oxidized by air and destroyed when supplying current. Because of that, current must be controlled by some sort of circuit. This can be done by using current source or current sink. Current source can be constructed to provide current One –third of its specification current by manufacture, that means about 100 mA is enough to heat the filament without oxidizing.

Constant current source

Op-amp current source is most suitable and stable than others so that in Project it is choosen.

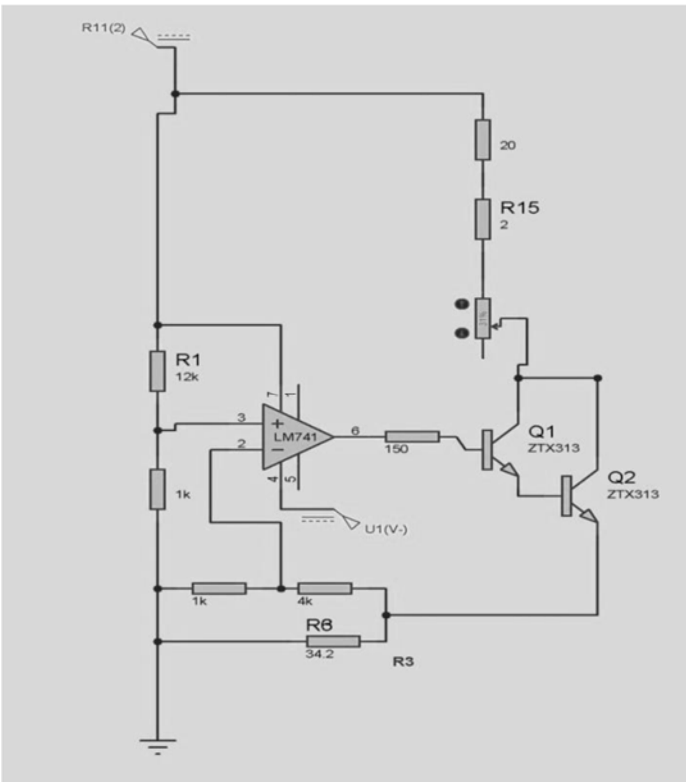

Figure 9 – Circuit of Constant current source

Constant current was obtained from the current source shown in Figure 9. The operational amplifier was set to monitor the resultant voltage drop across R3, current sense resistor. Given a fixed and temperature stable resistance at this point and negligible current flow into the amplifier, a constant combined average current is maintained through the sensing elements in the circuit. The potential across the probe is proportional to the power loss hence power loss proportional to incident airflow velocity. The current was set to 0.06 mA through the filament in this test configuration. Higher power operation of the sensor may provide advantages such as increased measuring ranged, this also increases the possibility of device failure under specific conditions where the system may be capable of thermal runaway. The power to the sensor may be either increased or decreased depending on the required operating conditions and in these prototypes was allocated. Lower temperature operating point more stable and controlled environments such as the laboratory however this results in limited and insufficient sensitivity in the open outdoor environment.

Voltage Regulator

Two terminals of bulb filament voltage difference can be taken using the differential amplifier or voltage regulator. A voltage regulator generates a fixed output voltage of a preset magnitude that remains constant regardless of changes to its input voltage or load conditions. There are two types of voltage regulators: linear and switching. A linear regulator employs an active (BJT or MOSFET) pass device (series or shunt) controlled by a high gain differential amplifier. It compares the output voltage with a precise reference voltage and adjusts the pass device to maintain a constant output voltage. A switching regulator converts the dc input voltage to a switched voltage applied to a power MOSFET or BJT switch. The filtered power switch output voltage is fed back to a circuit that controls the power switch on and off times so that the output voltage remains constant regardless of input voltage or load current changes.

Higher switching frequencies mean the voltage regulator can use smaller inductors and capacitors. It also means higher switching losses and greater noise in the circuit. The linear regulator's power dissipation is directly proportional to its output current for a given input and output voltage, so typical efficiencies can be 50% or even lower. Using the optimum components, a switching regulator can achieve efficiencies in the 90% range. However, the noise output from a linear regulator is much lower than a switching regulator with the same output voltage and current requirements. Typically, the switching regulator can drive higher current loads than a linear regulator. Switching regulators require a means to vary their output voltage in response to input and output voltage changes.

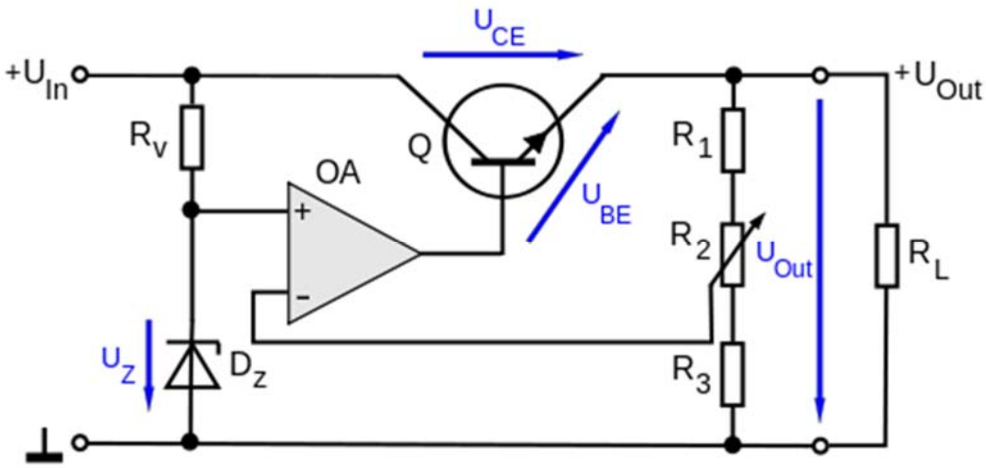

Figure 10 – Circuit of Voltage regulator

The resistor's resistance value which is regulator has it inside like must be a higher value around 1 MΩ and reason for that is to reduce the current flow through the differential amplifier circuit. Otherwise when large amount of current is going through the differential amplifier circuit, it can reduce the amount of current going through the bulb filament and it destroys the stability of constant current.

Analog to digital conversion

During the designing, a problem that occurred was converting an analog signal to a digital signal. There were several methods available. Among them use of microcontroller is a most popular one. The analog to digital converter (ADC), input analog current or a voltage is accepted and converted it to a digital value that can be read by a microcontroller.

Microcontroller

A Microcontroller is a IC chip that executes programs for controlling other devices or machines. It is a micro (small size as its a Integrated Circuit chip) device which is used for control of other devices and machines thats why it is called 'Microcontroller'. It is a Microprocessor having RAM, ROM and I/O ports. A microcontroller is a self-contained system with peripherals, memory and a processor that can be used as an embedded system. Most programmable microcontrollers that are used today are embedded in other consumer products or machinery including phones, peripherals, automobiles and household appliances for computer systems. Due to that, another name for a microcontroller is "embedded controller." Some embedded systems are more sophisticated, while others have minimal requirements for memory and programming length and a low software complexity. Input and output devices include solenoids, LCD displays, relays, switches and sensors for data like humidity, temperature or light level, amongst others.

Arduino Uno Microcontroller

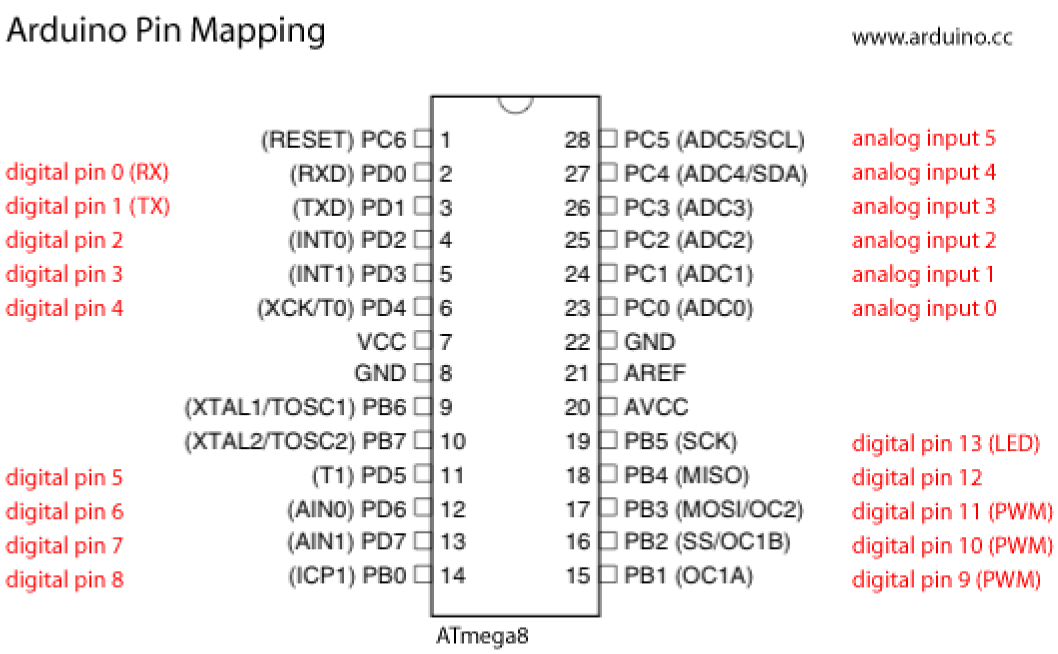

Figure 11- Pinning diagram of Arduino Uno

It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Analog to Digital Converter (ADCs, A/D)

Not every pin on a microcontroller has the ability to do analog to digital conversions. On the Arduino board, these pins have an 'A' in front of their label (A0 through A5) to indicate these pins can read analog voltages. ADCs can vary greatly between microcontroller. The ADC on the Arduino is a 10-bit ADC meaning it has the ability to detect 1,024 (210) discrete analog levels. Some microcontrollers have 8-bit ADCs (28 = 256 discrete levels) and some have 16-bit ADCs (216 = 65,536 discrete levels). The way an ADC works is fairly complex. There are a few different ways to achieve this feat , but one of the most common technique uses the analog voltage to charge up an internal capacitor and then measure the time it takes to discharge across an internal resistor. The microcontroller monitors the number of clock cycles that pass before the capacitor is discharged. This number of cycles is the number that is returned once the ADC is complete.

Specifications of ADCs

Most important specification of ADCs is the resolution because the sensor output voltage varied several millivolt about 6 mV (>4.8 mV). This specifies how accurately the ADC measures the analog input signals. Common ADCs are 8 bit, 10 bit and 12 bit. For example if the reference voltage of ADC is 0 to 5 V then a 8 bit ADC will break it in 256 divisions so it can measure it accurately up to (5/256 V) 19 mV approx. While the 10 bit ADC will break the range in 5/1024 = 4.8 mV approx. So 8 bit ADC can't tell the difference between 1mV and 18 mV.

Input Voltage = (Vref × read value)/1023

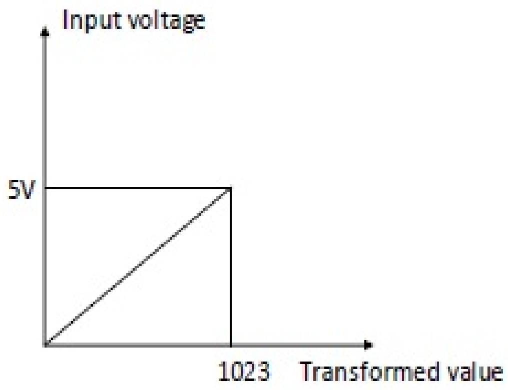

Figure 12 - The graph of input voltage corresponding bit conversion of microcontroller

Coding

```
clc;clear all;close all;
a = arduino()                                   %Constructing the Arduino object

voltage1 = readVoltage(a, 'A0');               %Taking voltage from analog 0 pin of Arduino
pause(1);                                       %Pausing for 1 second
plotTitle = 'Arduino Data Log';                 %Writing graph title
```

```
xLabel = 'Elapsed Time (s)';                      %Writing x label value

yLabel = 'Wind Speed (m/s)';                      %Writing y label value

legend1 = 'Wind Speed'                             %Writing legend value

yMax  = 70                                        % y Maximum Value

yMin  = 0                                         % y minimum Value

plotGrid = 'on';                                  % Opening the grid

min = 0;                                          % Setting  y minimum

max = 70;                                         % Setting y maximum

delay = 10^(-6) ;                                 % Faster than resolution


    % Naming Function Variables

time = 0;                                         % Defining time variable

data = 0;                                         % Defining data variable

count = 0;                                        % Defining count variable

B=0 ;                                             % Setting up plot


plotGraph = plot(time,data,'r' )          % Every value needs to be on its own plot graph

hold on                                   % Optional hold on

title(plotTitle,'FontSize',15);           % Constructing the title
```

```
xlabel(xLabel,'FontSize',15);                    % Constructing x label

ylabel(yLabel,'FontSize',15);                    % Constructing y label

axis([yMin yMax min max]);                       % Constructing axis limits

grid(plotGrid);                                  % Opening the grid

hold on

plotBB=plot(time,B,'-.k')

legend(legend1,'Smoothed Data')                  % Constructing legend

tic                                              % Starting stopwatch timer

while ishandle(plotGraph)                        %Loop when plot is active will run until plot is
closed


    sensorVoltage = abs(readVoltage(a, 'A0')-voltage1)*250;

                        % Data from the Arduino

     %wind=(abs((sensorVoltage- yMin)) * windSpeedMax / (yMax - yMin) * 2.23694);

     count = count + 1;                                    % Increasing count in loop



 time(count) = toc;                              % Reading elapsed time from stopwatch

 data(count) = sensorVoltage(1);                             % Changing variable
```

```
% Using plot slows the sampling time.

    B=smoothdata(data,'movmean',3) ;

    set(plotGraph,'XData',time/2,'YData',data)
    set(plotBB,'XData',time/2,'YData',B);

    axis([0 time(count) min max]);                   % Setting axis

                                                     % Updating the graph
    pause(delay);                                    % Pausing in the loop
end                                                  % Closing the loop

delete(a);                                           % Deleting Arduino object
disp('Plot Closed and arduino object has been deleted');
```

Explanation of the coding

clc clears all input and output from the Command Window display, giving you a “clean screen.”

close all deletes all figures whose handles are not hidden.

clear removes all variables from the current workspace, releasing them from system memory.

a = arduino recreates the last successful connection to the Arduino® hardware. If that connection fails, it creates a connection to the first official Arduino hardware connected to your host computer via USB.

a = arduino(___,Name,Value) creates a connection with additional options specified by one or more Name,Value pair arguments.

analogRead(pin)

Reads the value from the specified analog pin. The Arduino board contains a 6 channel (8 channels on the Mini and Nano, 16 on the Mega), 10-bit analog to digital converter. This means that it will map input voltages between 0 and 5 volts into integer values between 0 and 1023.

pause temporarily stops MATLAB® execution and waits for the user to press any key. The pause function also temporarily stops the execution of Simulink® models, but does not pause their repainting.

pause(n) pauses execution for n seconds before continuing. Pausing must be enabled for this call to take effect.

Xlabel , ylabel

xlabel(txt) labels the *x*-axis of the current axes or chart returned by the gca command. Reissuing the xlabel command replaces the old label with the new label and the same for ylabel.

title(txt) adds the specified title to the axes or chart returned by the gca command. Reissuing the title command causes the new title to replace the old title.

legend creates a legend with descriptive labels for each plotted data series. For the labels, the legend uses the text from the DisplayName properties of the data series. If the DisplayName property is empty, then the legend uses a label of the form 'dataN'. The legend automatically updates when you add or delete data series from the axes. This command creates a legend for the current axes or chart returned by gca. If the current axes are empty, then the legend is empty. If axes do not exist, then this command creates them.

legend(label1,...,labelN) sets the legend labels. Specify the labels as a list of character vectors or strings, such as legend('Jan','Feb','Mar').

tic starts a stopwatch timer to measure performance. The function records the internal time at execution of the tic command. Display the elapsed time with the toc function.

timerVal = tic returns the value of the internal timer at the execution of the tic command, so that you can record time for simultaneous time spans.

toc reads the elapsed time from the stopwatch timer started by the tic function. The function reads the internal time at the execution of the toc command, and displays the elapsed time since the most recent call to the tic function that had no output, in seconds.

toc(timerVal) displays the time elapsed since the tic command corresponding to timerVal.

Consecutive tic commands overwrite the internally recorded starting time.
The clear function does not reset the starting time recorded by a tic command.
The following actions result in unexpected output:
Using tic and toc to time timeit
Using tic and toc within a function timed by timeit

hold on retains plots in the current axes so that new plots added to the axes do not delete existing plots. New plots use the next colors and line styles based on the ColorOrder and LineStyleOrder properties of the axes. MATLAB® adjusts axes limits, tick marks, and tick labels to display the full range of data. If axes do not exist, then the hold command creates them.

hold off sets the hold state to off so that new plots added to the axes clear existing plots and reset all axes properties. The next plot added to the axes uses the first color and line style based on the ColorOrder and LineStyleOrder properties of the axes. This option is the default behavior.

abs

Absolute value and complex magnitude. Y = abs(X) returns the absolute value of each element in array X. If X is complex, abs(X) returns the complex magnitude.

B = smoothdata(A) returns a moving average of the elements of a vector using a fixed window length that is determined heuristically. The window slides down the length of the vector, computing an average over the elements within each window.

If A is a matrix, then smoothdata computes the moving average down each column.

If A is a multidimensional array, then smoothdata operates along the first dimension whose size does not equal 1.

If A is a table or timetable with numeric variables, then smoothdata operates on each variable separately.

B = smoothdata(___,method,window) specifies the length of the window used by the smoothing method. For example, smoothdata(A,'movmedian',5) smooths the data in A by taking the median over a five-element sliding window.

The filter function is one way to implement a moving-average filter, which is a common data smoothing technique. The following difference equation describes a filter that averages time-dependent data with respect to the current hour and the three previous hours of data. We used in our code Moving average filter.

axis(limits) specifies the limits for the current axes. Specify the limits as vector of four, six, or eight elements. In our code , we set x and y axis in array form.

The Calibration

In coming data from instrument in the forms of voltage value to obtain the wind speed instead of voltage value, calibration must be performed with some reference instrument. Calibration establishes a relation between the hot wire anemometer output voltage and the known wind speed. Sensor is basically depending on environment temperature, wind speed and humidity. In the case of filament heated more than the ambient temperature, linear variation could not be expected. The calibration part of the circuit is held on the coding part. data should be analysis to get the relationship between voltage and wind speed. Calibration curve is plotted wind velocity versus Hot Wire Voltage. Typical Calibration curve is nonlinear and sensitivity decreases by increasing the wire temperature.

Theory

Airflow over the hot-wire can be modeled as flow over a cylinder. The convective heat transfer rate Q is given by Newton's law of cooling:

$$Q = hA_s\,(T_s - T) \qquad (1)$$

where

h = heat transfer coefficient [W/m^2 □ K]

A_s = surface area [m^2]

T_s = surface temperature [K]

T = ambient temperature [K]

L.V. King (1914) gave a basic relation between Q and the fluid velocity U:

$$Q = A + BU^{0.5}$$

where A and B are the calibration constants containing A_s and h.

The wire is connected to one arm of a Wheatstone bridge and heated by an electrical current. The heat transfer rate from the wire depends on the flow velocity and must equal I^2R heating in the wire. The bridge voltage E is related to the heat transfer rate and thus, a direct measure of the velocity. The relation between E and U is given first by King as a power function:

$$E^2 = (T_s - T)(A + BU^{0.5}) \tag{3}$$

or as a polynomial:

$$\boxed{U = C_0 + C_1E + C_2E^2 + C_3E^3 + C_4E^4 + C_5E^5} \tag{4}$$

where C_n ($n = 0,\ldots,5$) are constants. This equation is used to determine the air velocity U from a measured voltage E from the hot-wire.

Assuming that the flow is inviscid, steady, incompressible, and irrotational, the ambient pressure P_t is:

$$P_t = P + \frac{1}{2}\rho_{\text{air}} U_x^2 \tag{5}$$

where P is the pressure measured near the Pitot tube and U_x is the free stream velocity. Solving for U_x:

Hot-Wire Anemometry

$$\boxed{U = \sqrt{\frac{2(P_t - P)}{\rho_{\text{air}}}} = \sqrt{\frac{2\rho_{\text{water}} gh}{\rho_{\text{air}}}}} \tag{6}$$

where g is the acceleration due to gravity and h is the height difference of the column in the manometer. This equation is used to find the free stream velocities in the calibration portion of the experiment.

The Reynolds number is defined as:

$$\boxed{Re_D = \frac{UD}{v}} \qquad (7)$$

where D is the diameter and v is the kinematic viscosity of the fluid, which was air in this experiment. The Reynolds number gives an idea of what the flow pattern past a cylinder looks like. At a certain Reynolds number, vortices form downstream past a cylinder. A formula for this phenomenon is:

$$\boxed{\frac{fD}{U} = 0.198 \left(1 - \frac{19.7}{Re_D} \right)}$$

where f is the vortex shedding frequency. If f is around the natural frequency of the body, resonance occurs and something unusual is commonly witnessed, such as excessive vibration.

Results

The first part of the experiment involved calibrating the hot-wire anemometer. The results are presented as follows:

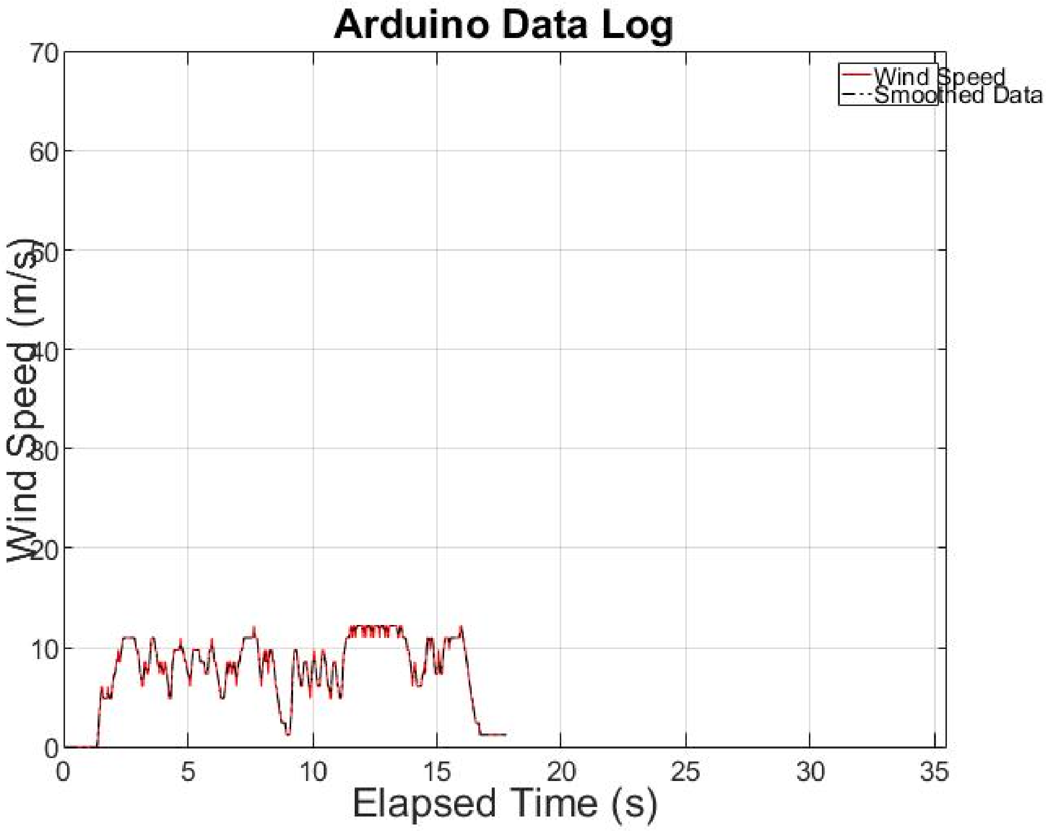

Figure 13– Output Signal after the calibration

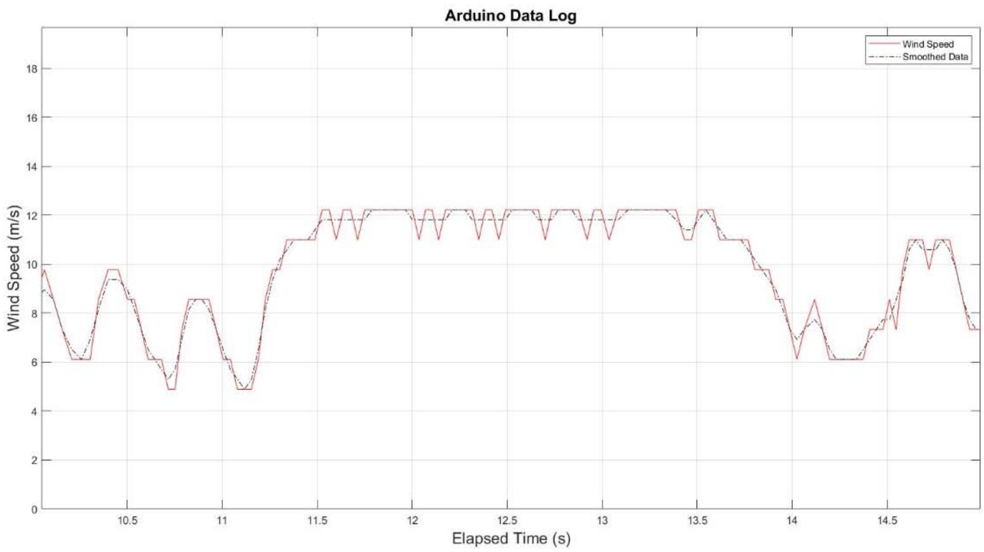

Figure 14– Output Signal after the calibration closer

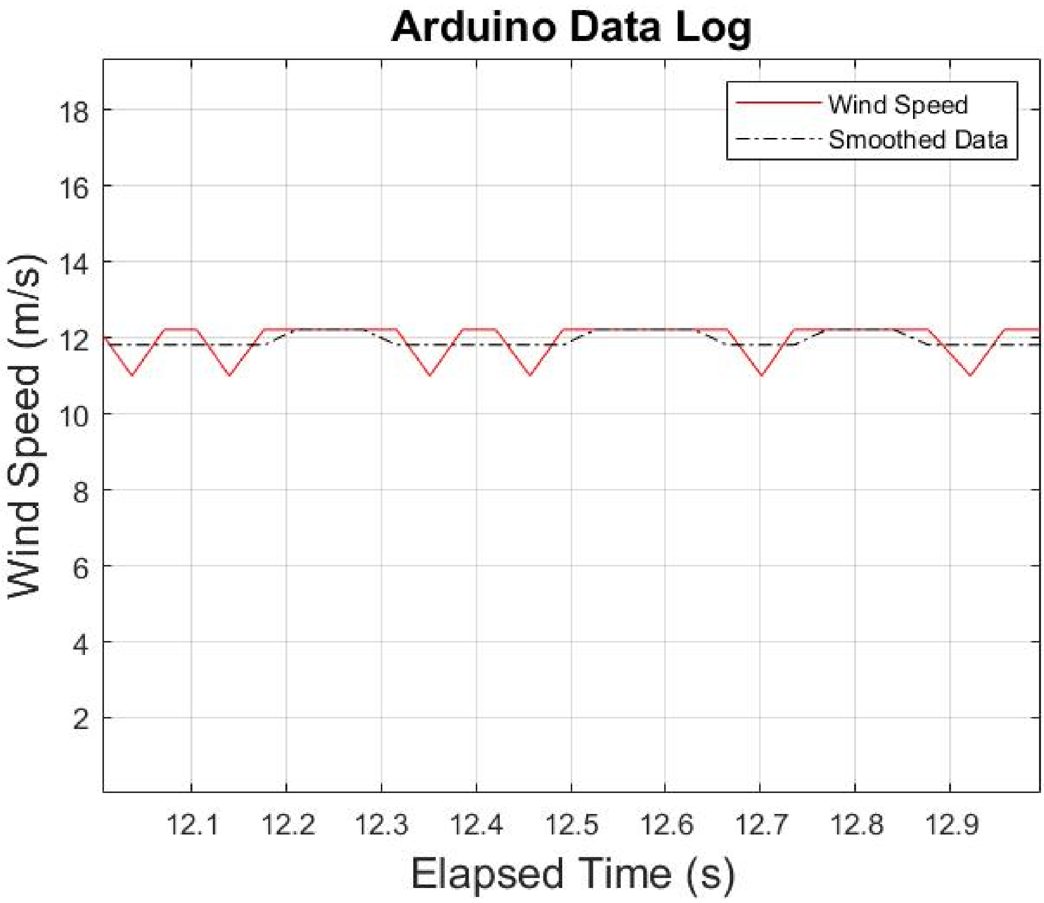

Figure 15– Output Signal after the calibration in 1 sec.

CONCLUSION

This experiment particularly shows how to measure flow velocity of a fluid. The resistance of the sensor changes which is detected by the Wheatstone bridge and a feedback current is supplied to the sensor in order to keep the temperature constant and hence the temperature . This happens in case of constant temperature type anemometer .in the other type i.e. constant current type the current flowing through the sensor is kept constant and the change in resistance is observedThe anemometer design presented in this paper is a relatively inexpensive stable and reliable device. Constant temperature needs a particular type of sensor. It basically uses the wire made up of platinum and tungsten which is very costly in order to get. Temperature above the room temperature is needed to be maintained which is practically not possible in ordinary labs. When the current is supplied to the sensor the temperature of the sensor should increase and hence the resistance which cannot be achieved because the heat would be radiated out and would not contribute totally to the increase in resistance which would cause error. So in order to change the flow we changed the resistance of the sensor (one arm of the Wheatstone bridge). This change caused a change in the output voltage which was amplified using a voltage regulator just to increase the sensitivity. The output obtained by the Wheatstone bridge in order to get the value of flow velocity. And finally, We obtain the velocity of the fluid flow. The data is shown accurately and robustly on MATLAB graph.

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