BE-503

Biosensing and Instrumentation

Mini – Project

SPIROMETER USING STRAIN GAUGE

Team Name : NoName

B.Krishna Sai(B19005)

K.Sam Vivek (B19008)

Amarnath(V21138)

Course Instructor : Srikanth Sugavaram

Introduction

Without adequate lung activity, human life is under threat. The normal respiration rate for an adult at rest is 12 to 20 breaths per minute. A respiration rate under 12 or over 25 breaths per minute while resting is considered abnormal. Oxygen (O_2) enters the blood through lungs, and carbon dioxide (CO_2) is excreted through the alveoli.

Lungs failure is difficult to predict and can become life threatening in a few minutes. Thus a Several non- invasive methods and devices provide information about respiratory rate or depth, or gas exchange. Methods are categorized into: volume and tissue composition detection, air flow sensing, and blood gas concentration. The measuring of lung function is very important because the function of lungs is a predictor of potentially serious clinical events. This project aims to design a spirometer using a strain gauge sensor; by the strain ,the strain gauge resistance of the strain gauge will change. The ΔR component (change in resistance) is translatable into a changing voltage signal this signal will give information about the lungs function.

Project Objectives

The main objective of the project are

1. To design a non-invasive medical device that can be used for medical application.
2. Calibrate lungs function using a strain gauge sensor mounted spirometer.
3. To use a strain gauge sensor to measure the lungs function via analyzing the mechanical movements of the strain gauge by the breathing cycles.

Spirometer.

A spirometer measures the amount of air you can breathe out in one second and the total volume of air you can exhale in one forced breath. These measurements will be compared with a normal result for someone of your age, height and sex, which will help show if your lungs aren't working properly.

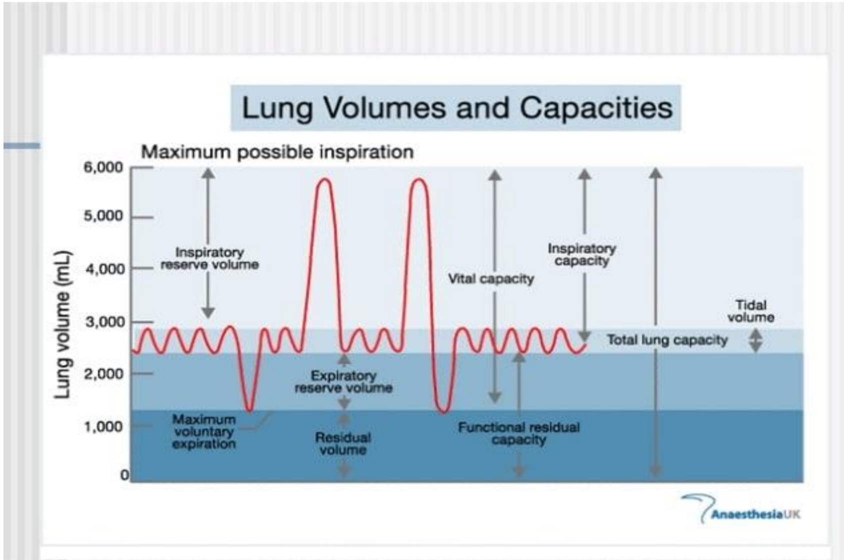
Spirometry is a test of how well your lungs are working, by measuring how fast and how much air you can breathe in and out. Normally as you breathe in, or inhale, air moves freely through your trachea, or windpipe, then through large tubes called bronchi, smaller tubes called the bronchioles and finally into tiny sacs called alveoli. Small blood vessels, called capillaries, surround your alveoli. Oxygen from the air you breathe passes into your capillaries. Then carbon dioxide from your body passes out of your capillaries into an alveolus. You get rid of the carbon dioxide, when you breathe out or exhale. Diseases such as asthma, bronchitis and pulmonary fibrosis narrow your bronchioles, reducing the amount of air going into your lungs and diseases such as lung cancer and emphysema damage your alveoli, reducing the amount of oxygen in our blood. These diseases can make it hard for you to breathe.

A spirometry test typically reports 4 respiratory volumes:

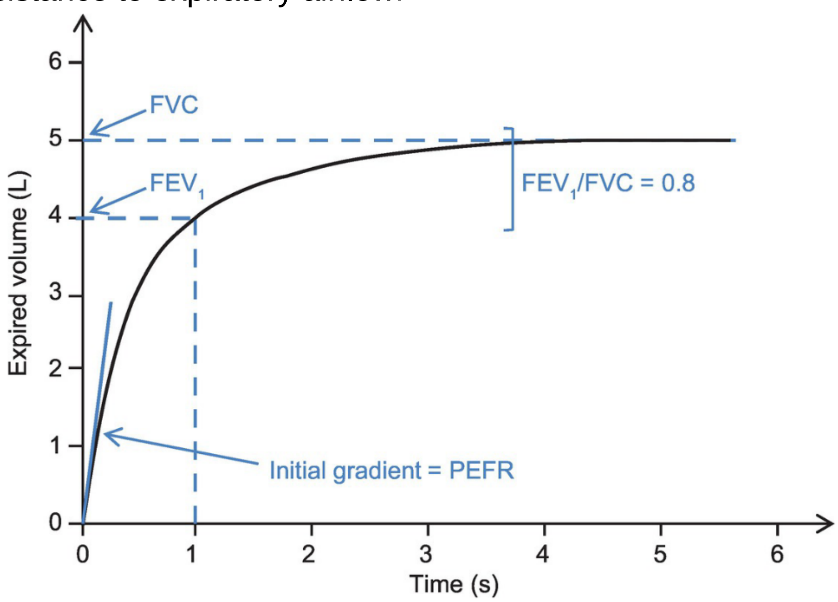
- •**Tidal volume, TV** - the amount of air inhaled or exhaled during normal, quiet breathing, without effort.
- •**Inspiratory reserve volume, IRV** - the amount of air that can be inhaled with maximum effort, after a quiet inhalation.
- •**Expiratory reserve volume, ERV** - the amount of air that can be exhaled with maximum effort, after a quiet exhalation.
- •**Residual volume, RV** – the amount of air remaining in the lungs after a maximum exhalation.

These volumes are used to calculate other parameters, called respiratory capacities:

- •**Inspiratory capacity, IC** – the maximum amount of air that can be inhaled after a quiet exhalation.
- •**Functional residual capacity, FRC**, - the amount of air remaining in the lungs after a quiet exhalation.
- •**Total lung capacity, TLC** - And vital capacity, VC – the amount of air that can be exhaled with maximum effort, after a maximum inhalation.



Vital Capacity is basically the volume of the deepest breath the lungs can possibly handle, and is an important indicator of pulmonary function, as well as strength of respiratory muscles. Vital capacity can be measured as slow vital capacity during slow, relaxed breathing; or as forced vital capacity, FVC, when the patient is asked to breathe out as hard and fast as possible. While there is little or no difference between these two values in healthy individuals, people with difficulty exhaling usually show significantly lower FVC(forced vital capacity). Another important parameter obtained during forced spirometry is the forced expiratory volume(FEV1) - the amount of air that is exhaled during the first second of forceful exhalation, after a full inhalation. FEV1 is used to calculate the percentage of air that is expelled during the first second. his FEV1/FVC ratio inversely reflects the resistance to expiratory airflow.



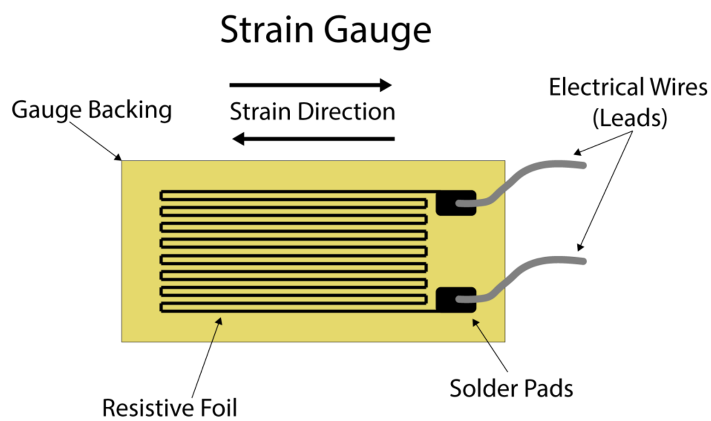
Percentage of predicted FEV1 value	Result
80% or greater	normal
70%–79%	mildly abnormal
60%–69%	moderately abnormal
50%–59%	moderate to severely abnormal
35%–49%	severely abnormal
less than 35%	very severely abnormal

FEV1 is used to calculate the percentage of air that is expelled during the first second. this FEV1/FVC ratio inversely reflects the resistance to expiratory airflow.

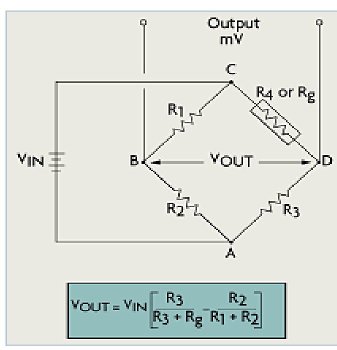
STRAIN GUAGE

Stain gauge is a type of electrical sensor. Its primary use is **to measure force or strain**. The resistance of a strain gauge changes when force is applied and this change will give a different electrical output.

Now we can classify the strain gauge setup as primary and secondary. The primary part is shown below

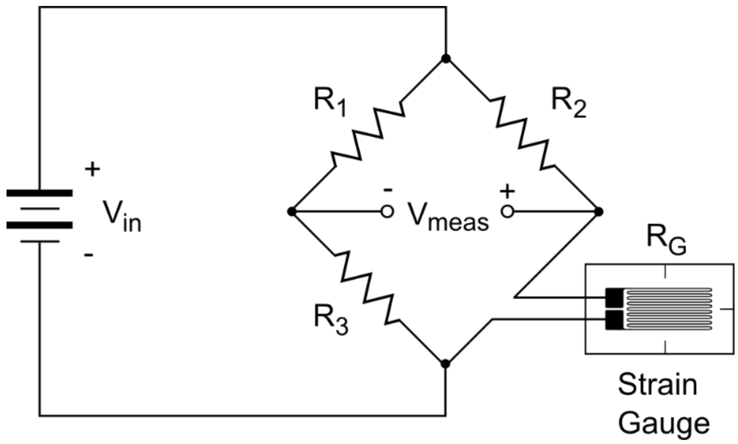


The secondary part of the strain gauge is known as **Wheatstone bridge** shown belowTo measure such small changes in resistance, strain gage configurations are based on the concept of a Wheatstone bridge. The general Wheatstone bridge, illustrated below, V_{IN} that is applied across the bridge. The strain gauge must be connected to an electrical circuit that is capable of accurately responding to the minute changes in resistance associated with strain.



The Wheatstone bridge is the electrical equivalent of two parallel voltage divider circuits. R_1 and R_2 compose one voltage divider circuit, and R_G and R_3 compose the second voltage divider circuit. The output of a Wheatstone bridge, **Vo**, is measured between the middle nodes of the two voltage dividers. From this equation, you can see that when $\mathbf{R_1 / R_2 = R_G / R_3}$, the voltage output $\mathbf{V_O}$ is zero. Under these conditions, the bridge is said to be balanced. Any change in resistance in any arm of the bridge results in a nonzero output voltage. Therefore, if you replace $\mathbf{R_G}$ with an active strain gage, any changes in the strain gage resistance unbalance the bridge and produce a nonzero output voltage that is a function of strain.

The hole setup of strain gauge



STRAIN = Change in dimension (Length, Area, Volume)/ Original dimension
The amount of deformation a material experiences due to an applied force is called strain. Strain is defined as the ratio of the change in dimension of a material to the original dimension.

The electrical resistance of resistive foil changes in proportion to the amount of strain experienced by the Electrical wires(leads).
A fundamental parameter of the strain gage is its sensitivity to strain, expressed quantitatively as the gage factor (GF). GF is the ratio of the fractional change in electrical resistance to the fractional change in length, or strain. strain measurements rarely involve quantities larger than a few millistrain (e x 10^{-3}). **Therefore, to measure the strain, you have to accurately measure very small changes in resistance**

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

delR = Change in Strain Gauge Resistance
R = Unstrained Resistance
del L = Absolute Change in Dimension
L = Original Dimension

Simulink Model of the Spirometer

We calibrate the zero output from the Wheatstone bridge at a given strain of 5 to the strain gauge, so that the bridge is balanced and we get zero Vout. When the input strain increases output Voltage also Increases and when the input strain decreases output voltage also decreases.
Simulink Circuit :

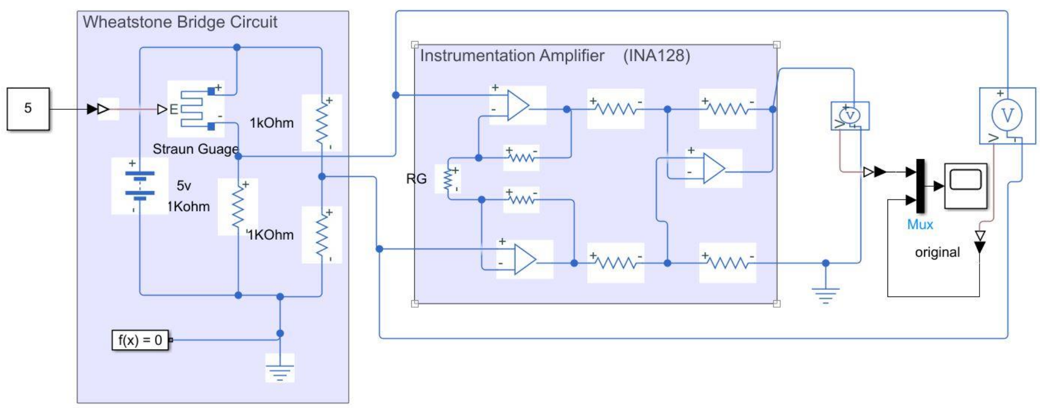


Fig.1

Fig.1 Shows the Simulink Circuit of the Spirometer.it has two parts one is Wheatstone Bridge Circuit and that connects to the instrumentation Amplifier that amplifies the Vout that comes from the Wheatstone bridge.

Circuit Characteristics:

Blocks Used : Sine Wave, PS- Simulink Converter, Battery, Strain Gauge, Resistor, Solver Configuration, Electrical Reference, OP Amp, Voltage Sensor, Mux, Scope.

For INA128 Instrumentation Amplifier:

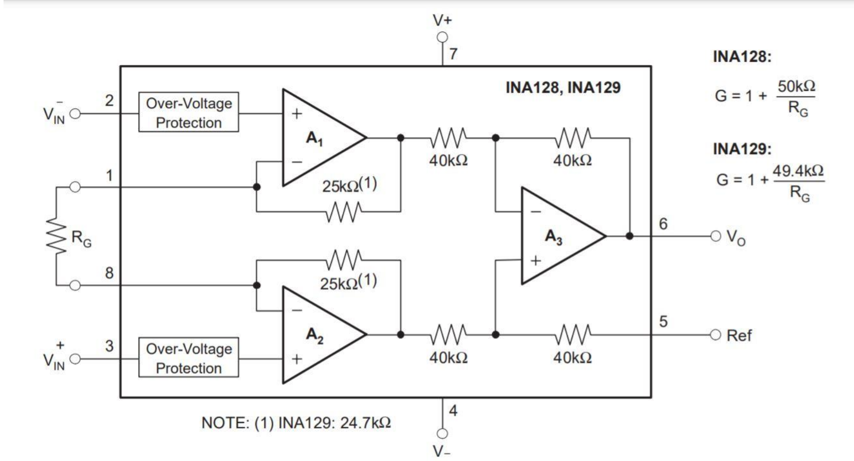


Fig.2

Calculations:

Change in Resistance of the Strain Gauge

$$\frac{\Delta R}{R} = K \cdot \varepsilon$$

Resistance = R(Ω)
Changed resistance = △R(Ω)
Strain = ε
Gage factor = K

When the Strain Gauge is Placed in a Wheatstone bridge due to change in strain, resistance of the strain gauge changes so that the bridge is unbalanced and we get some deviation in the output voltage.

Vout in the Wheatstone bridge is given by the formulae:

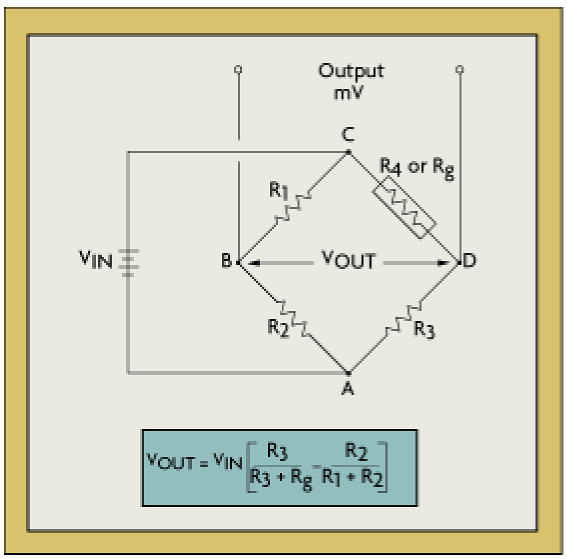


Fig.3

From Our Circuit :
R1 = 1000 ohms
R2 = 1000 Ohms
R3 = 1000 Ohms
Rg = 90.9 Ohms
Gain of the strain Gauge = 2
Vin = 5 Volts

Condition of Balancing Bridge :

When Strain is 5
We get Change is Resistance as

dR/R = K.e

dR = R.K.e
= 1000 x 2 x 5
= 10000
So the resultant Resistance is R+dR = 90.9 + 10000
= 10090.9
Calculating Vout = Vin[(R3/R3+Rg) - (R2/R1+R2)]
= 5[(1000/1000+10090.9) - (0.5)]
= 5[0.50-0.5]
= 0
So Rg is Taken Accordingly to calibrate the zero output voltage at strain 5

Unbalanced Bridge :
Increase in Strain

When Strain is 5.5
We get Change is Resistance as
dR/R = K.e

dR = R.K.e
= 1000 x 2 x 5.5
= 11000
So the resultant Resistance is R+dR = 90.9 + 11000
= 11090.9
Calculating Vout = Vin[(R3/R3+Rg) - (R2/R1+R2)]
= 5[(1000/1000+11090.9) - (0.5)]
= -0.108

Decrease in Strain

When Strain is 4.5
We get Change is Resistance as
dR/R = K.e

dR = R.K.e
= 1000 x 2 x 4.5
= 9000
So the resultant Resistance is R+dR = 90.9 + 9000
= 9090.9

Calculating Vout = Vin[(R3/R3+Rg) - (R2/R1+R2)]
= 5[(1000/1000+9090.9) - (0.5)]
= 0.119

We can See that the Variation in strain gives very less variation in the Output Voltage, So we use Instrumentation amplifier to amplify the out voltage from the wheatstone bridge.

In our Project we used INA128 Instrumentation Amplifier

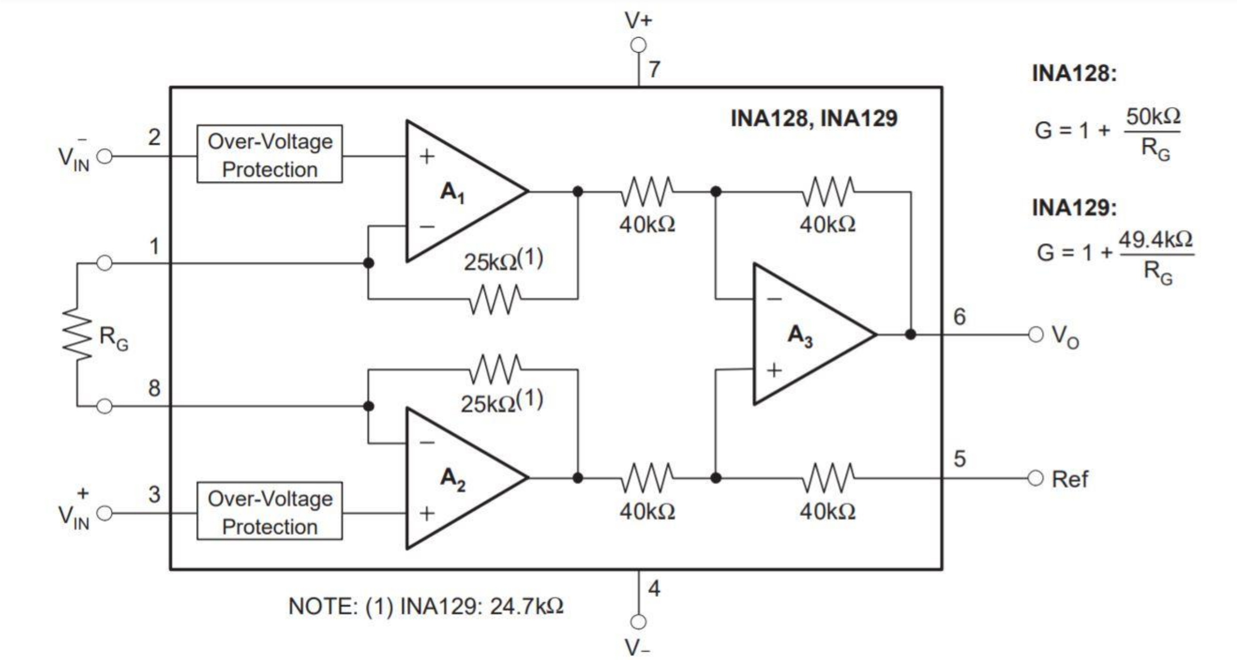


Fig.4

Fig.4 is the circuit of the INA128 instrumentation Amplifier. Gain of the Amplifier dependens on the Rg Resistance value in the amplifier

G= 1 + 50Kohm/2Kohms
(we have used Rg as 2Kohms)
So G = 26

From the Above Result when Strain is 5.5
Amplified Vout will be : 0.108 x 26 = 2.8
When strain is 4.5
Amplified Vout will be : 0.119 x 26 = 3.09

Due to Amplification in the Output Voltage we can clearly see the difference from the applied strain.

Graph of the result of circuit in Fig.1

Fig.5

Fig.5 shows the output graph when the constant strain of 5 is applied to the strain gauge we can see that the wheatstone bridge output voltage and the amplified voltage are zero.

When Sine wave is used in the place of Constant signal as our input signal is continuoes the circuit will be:

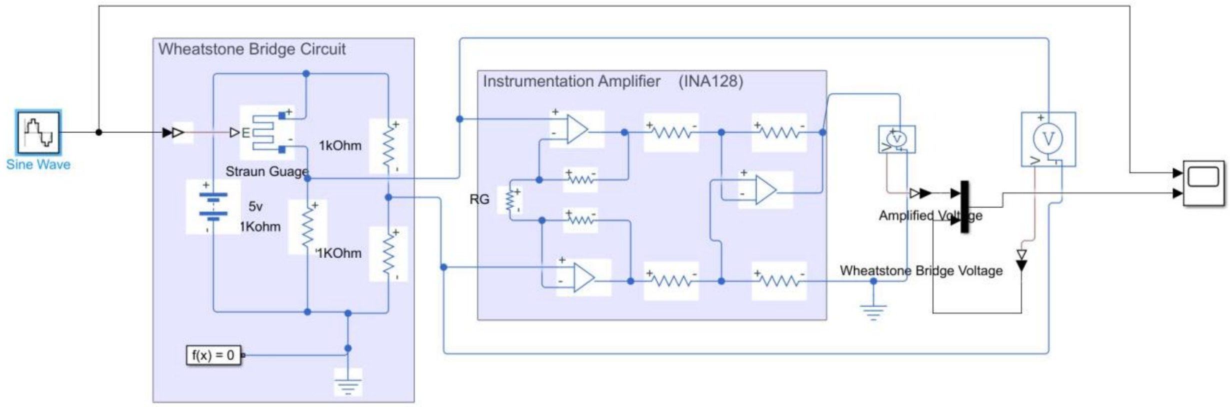


Fig.6

Parametres of the sine wave:
Amplitude :1
Band :5
Frequency :2
Results graph of the circuit in Fig.6 is :

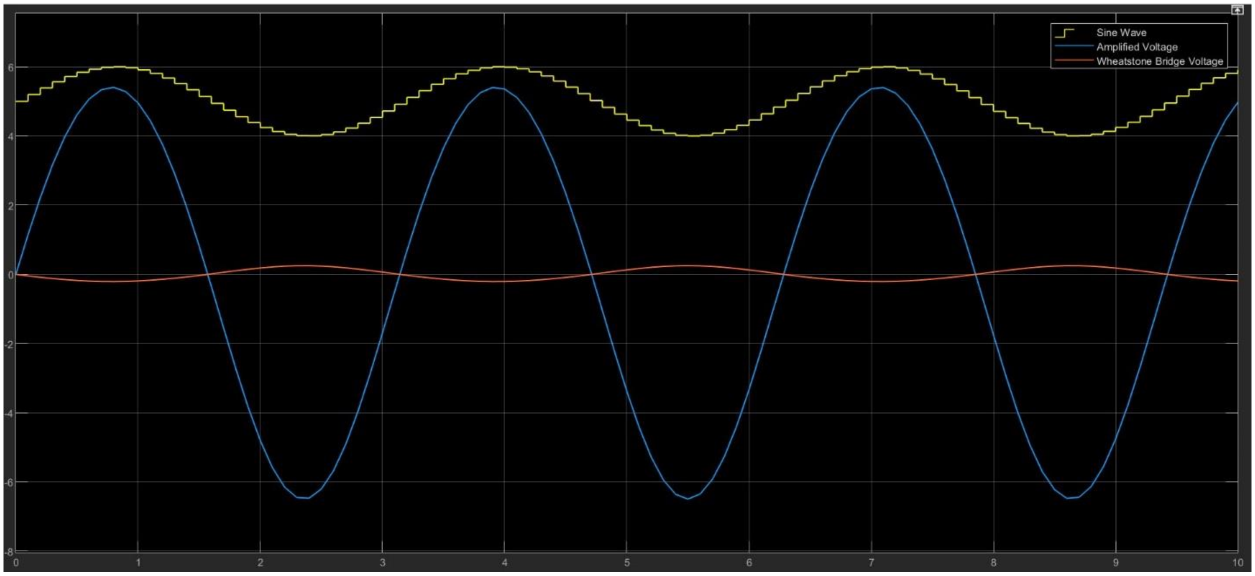


Fig.7

Implementation of Strain guage in Spirometre:

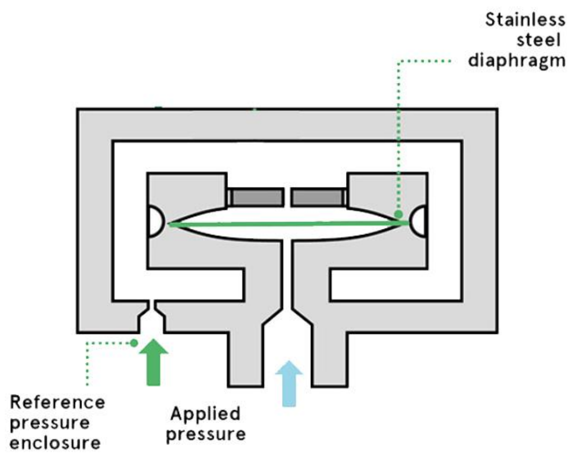


Fig.8

In Fig.8 we can see that at the blue arrow that inlet is connected to the pipe that one can keep in mouth and perform spirometry test. The initial strain of 5 is already given to the siaphram, when the person breathe out diaphram moves that inceses the strain that is connected to the circuit, result in increasign the output voltage and when person breathin strain decreases (i.e less than 5) that decreases the output voltage.

From the Resultant Graph we can Calculate the following :

Tidal volume, TV

Inspiratory reserve volume, IRV

Expiratory reserve volume, ERV

Residual volume, RV

Inspiratory capacity, IC
Functional residual capacity, FRC
Total lung capacity, TLC

Conclusion :

This reports highlights about the Spirometer using strain gauge and how it is useful to diagnose asthma, Chronic Obstructive Pulmonary Disease and other conditions that affect breathing. It is used to capture record air volumes to know the total lung capacity. Increased use of spirometry testing would lead to more accurate diagnoses and may improve physicians' treatment recommendations. A need for spirometry within the developing world certainly exists, as respiratory diseases like COPD are an ever-growing concern due to factors such as smoking and the use of biomass fuels. In the developed world, there is significant potential for an inexpensive spirometer to improve our ability to diagnose respiratory diseases.

References:

https://en.wikipedia.org/wiki/Spirometer
https://www.healthline.com/health/spirometry
https://www.nature.com/articles/s41746-019-0083-3#article-info
https://www.nxp.com/docs/en/application-note/AN4325.pdf
https://www.ijert.org/research/design-development-and-clinical-testing-of-spirometer-IJERTV5IS080386.pdf