Team 15

Design of A Compact Pressure Sensor for Multi-Layer Insulation Inside a Vacuum Environment

Operation Manual

Team Members:

Sebastian Bellini- Sab13j

Jason Carvalho- Jc12v

Stephen Johnson- Ssj12

Michael Kiefer- Mbk13

Faculty Advisor

Dr. Wei Guo

Sponsor

James Jim Martin

12/05/2016

Table of Contents

Table of Figures

Abstract

The capacitor pressure sensor will use a Schering Bridge to determine the capacitance of the sensor. From this capacitance the distance between parallel plates and pressure can be determined. In order to operate the sensor, simply place it in the environment wanting to be measured and turn on the system. The sensor will determine the pressure from known equations programmed into the microcontroller.

I. Functional Analysis

The capacitor sensor will determine pressure as a function of distance between the parallel plates. This distance will vary depending on the pressure being exerted onto the top diaphragm. Due to the vacuum in the system as shown in figure 1, the top diaphragm will deflect as a function of pressure.

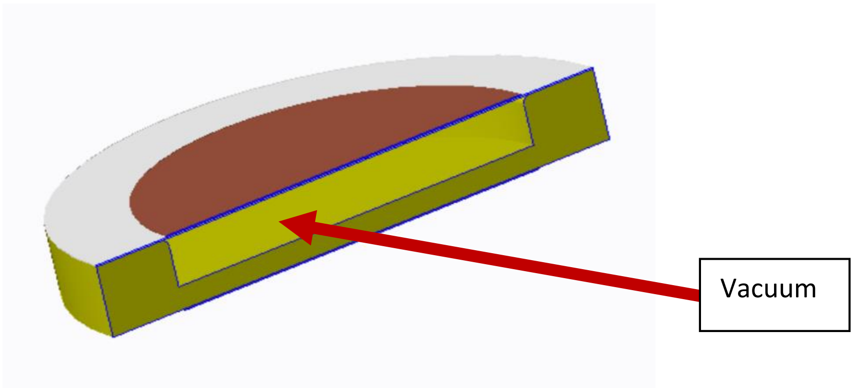

Figure 1 Capacitor pressure sensor with a vacuum chamber

The capacitor is placed in a Schering Bridge circuit as shown in figure 2 below. In the Schering Bridge, R_1, R_2, R_3, C_1 and C_2 are known, while C_3 is the project's capacitor sensor. In between nodes A and B, a voltmeter is attached to measure the voltage.

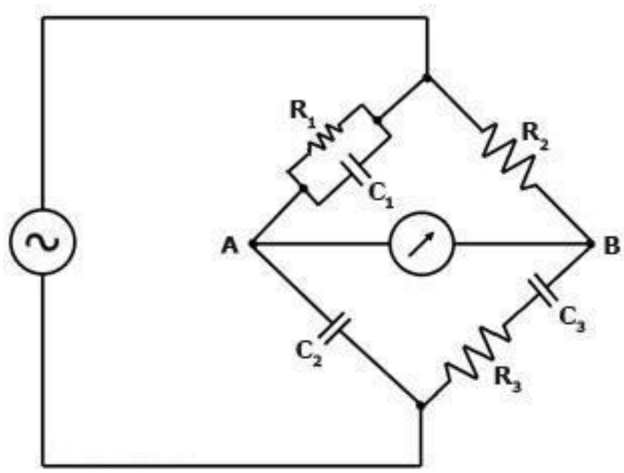

Figure 2 Schering Bridge

The microcontroller will then determine the capacitance of C_3, by adjusting C_1 and R_1 till the voltmeter reads 0 zero. When this occurs, the voltage at node A and node B are equal, thus the bridge is considered balanced. Once the bridge is balanced, the microcontroller will then use equation 1 determine the capacitance.

$$C_1 = \frac{R_1 * C_2}{R_2} \quad (1)$$

The microcontroller will then use equation 2 to determine the distance between the two parallel capacitance plates.

$$d = \frac{\varepsilon A_{S,c}}{C} \qquad (2)$$

Where ε is the permittivity of the dielectric, $A_{s,c}$ is the surface area of the capacitor plate, C is the capacitance. Pressure can then be related to the change in distance using equation 3.

$$d = \frac{-3\Delta P r^4\left[\left(\frac{1}{\nu}\right)^2-1\right]}{16E\left(\frac{1}{\nu}\right)^2 h^3} \qquad (3)$$

Where ΔP is the difference in pressure, r is the radius of the diaphragm, ν Poisson ratio, E young's modulus, and h can be seen in equation 4.

$$h = \sqrt{\frac{3r^2\Delta P}{4\sigma_y}} \qquad (4)$$

where r is the radius of the diaphragm, ΔP is the difference in pressure, and σ_y is the yield stress of the diaphragm.

II. Operation Instruction

Assemble a Schering bridge as show in figure 1. In the Schering Bridge, R_1, R_2, R_3, C_1 and C_2 are known, while C_3 is the project's capacitor sensor. In between nodes A and B, a voltmeter is attached to measure the voltage. Once the Schering Bridge is assembled, place the capacitor sensor in the environment that is being measured. Turn on the microcontroller when ready to measure pressure. The micro controller will calculate the pressure based off the deflection of the diaphragm and display it on the screen.

III. Troubleshooting

There are three issues that are of concern. The first being that the seal keeping the vacuum cavity breaks making the sensor inoperable. Since this seal must be created in a lab with a vacuum chamber, immediate repair cannot be done and must be fixed in a lab. However, a second sensor can be stored so that the entire sensor can be replaced instead of fixing one component. Another problem is if the integrated circuit breaks or malfunctions. This can be fixed if certain individual components of the circuit break. However, if something such as outgassing occurs the circuit must be replaced. Another issue that could occur is if the sputtering faded away with time. If this happens the sputtered surface must be re-doped.

IV. Project Assembly

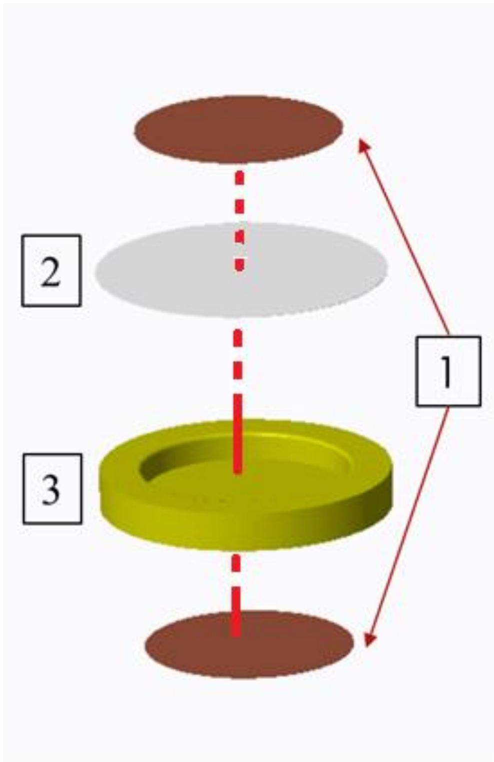

Figure 3 (1) Palladium-Gold sputtered tracts. (2) 0.50 µm thickness Silicone diaphragm. (3) Germanium doped silica base

Figure 3 shows an exploded view of the capacitor pressure sensor. Part 1 in figure 3 is the Palladium- Gold sputtered tracts, part 2 is the silicone diaphragm and part 3 is the silica core or epoxy core for scaled prototype. A Schering bridge as shown in figure 4. In the Schering Bridge, R_1, R_2, R_3, C_1 and C_2 are known, while C_3 is the project's capacitor sensor. In between nodes A and B, a voltmeter is attached to measure the voltage.

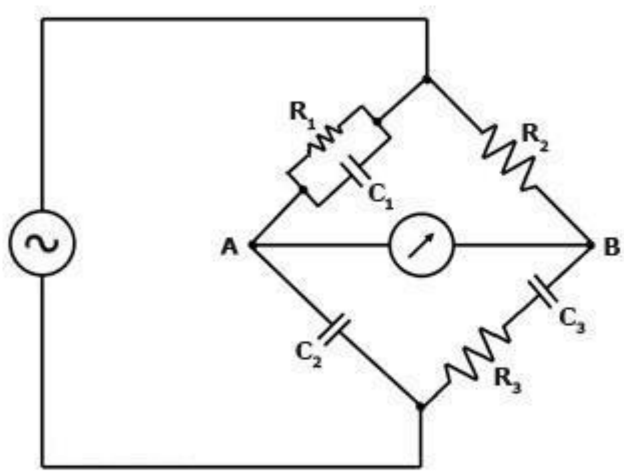

Figure 4 Schering Bridge