CAPACITIVE FORCE SENSOR

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CONTENT

INTRODUCTION

OBJECTIVE

Converting physical applied forces into measurable changes in capacitance.

FUNCTIONALITY OF THE SENSOR

Materials & Components

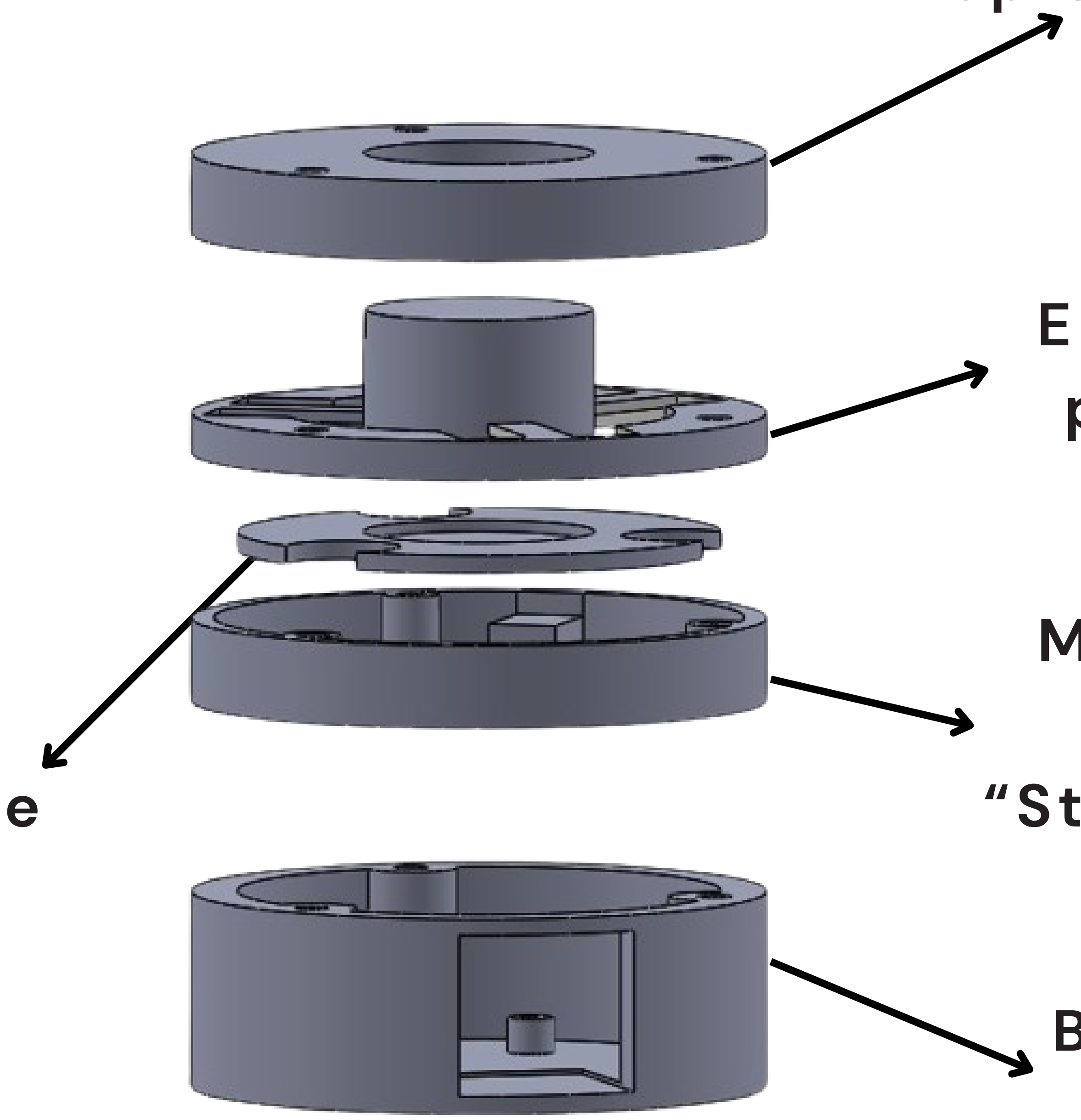
Housing material is
ABS 3D printing
Copper capacitive
plates
Dielectric material: Air

Dimensions

Outer Diameter: 50mm
Inner Diameter: 20mm
Height: 36.75mm
Distance between 2 plates
5.65mm

How it works

Measuring voltage change
after force application to
determine sensor's static and
dynamic characteristics.



METHODOLOGY

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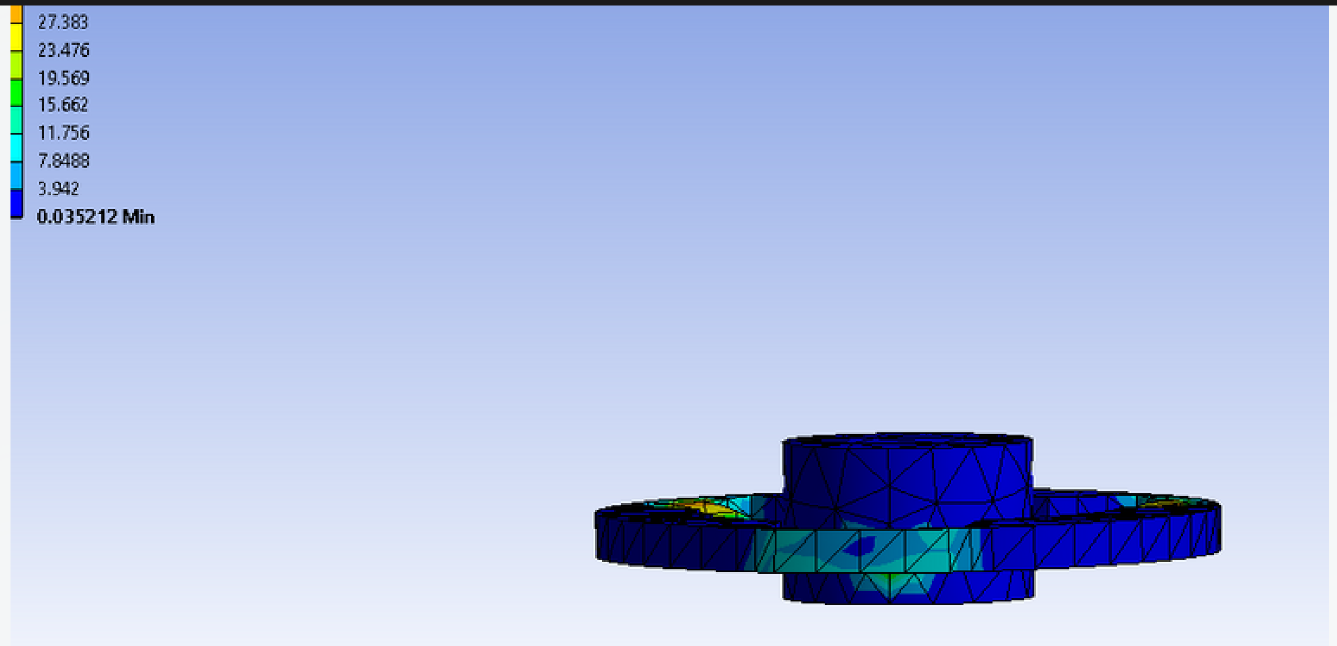
05 LINEARIZATION USING OP-AMP AND POWER AMPLIFICATION CIRCUIT

THEORETICAL ANALYSIS

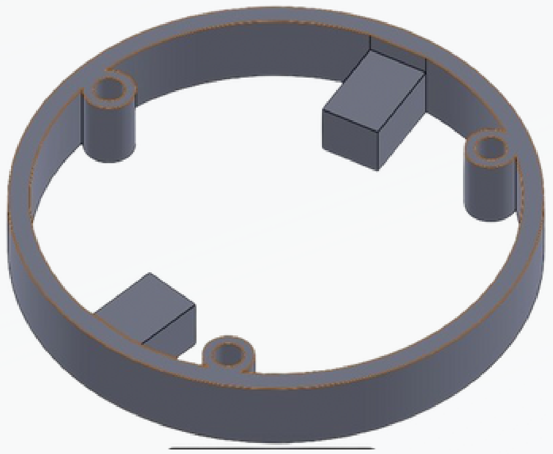
ANSYS Simulations on elastic element



Through Ansys software, we simulated the deflection of the ABS elastic element.

- Safety Factor = 1.1365

- The cantilever beam's maximum deflection was calculated to be 2.02 mm.
- Stoppers were added to prevent further deflection.



Calculations

$$\frac{\delta_{\text{ymax}}}{\sigma_{\max}} = \frac{2L^2}{3EH}$$

EQUATION OF MOTION

Mechanical Model

$$T = \frac{1}{2}m\dot{x}^2$$

$$V = \frac{1}{2}kx^2$$

$$D = \frac{1}{2}b\dot{x}^2$$

$$m\ddot{x} + b\dot{x} + kx = f(t)$$

The Lagrangian method is utilized for determining the equation that governs a mechanical system.

- f(t): Acting Force
- m: 5.5 grams (+load)
- Spring constant k: 1157.4 N/m
- Damping Coefficient b: 0.602

EQUATION OF MOTION

Electrical Model

$$V = \frac{1}{2}\frac{1}{C}q^2 = \frac{1}{2}\left[C1 + Cmeasuresd\right]V_c^2$$

$$D = \frac{1}{2}R\dot{q}^2 = \frac{1}{2}R\left[C1 + Cmeasuresd^2\right]\dot{V_c}^2$$

$$R\left[C1 + Cmeasuresd^2\right]\dot{V_c} + \left[C1 + Cmeasuresd\right]V_c = f(t)$$

The Lagrangian method is utilized for determining the equation that governs an electrical system.

- Since the L is very small, the kinetic energy is neglected of the ease of calculations
- f(t): Acting Force
- C1 = 1 pF
- Resistance R = 35.4 Kohms.

LINEARIZATION USING 555 TIMER

The device possesses two main features: the capacity to read capacitance and the ability to generate a square wave. However, one of its limitations is its insensitivity to small changes in capacitance. It can not detect changes of less than 1 pF with a high degree of fluctuation, which makes it unsuitable for applications that require high levels of precision.

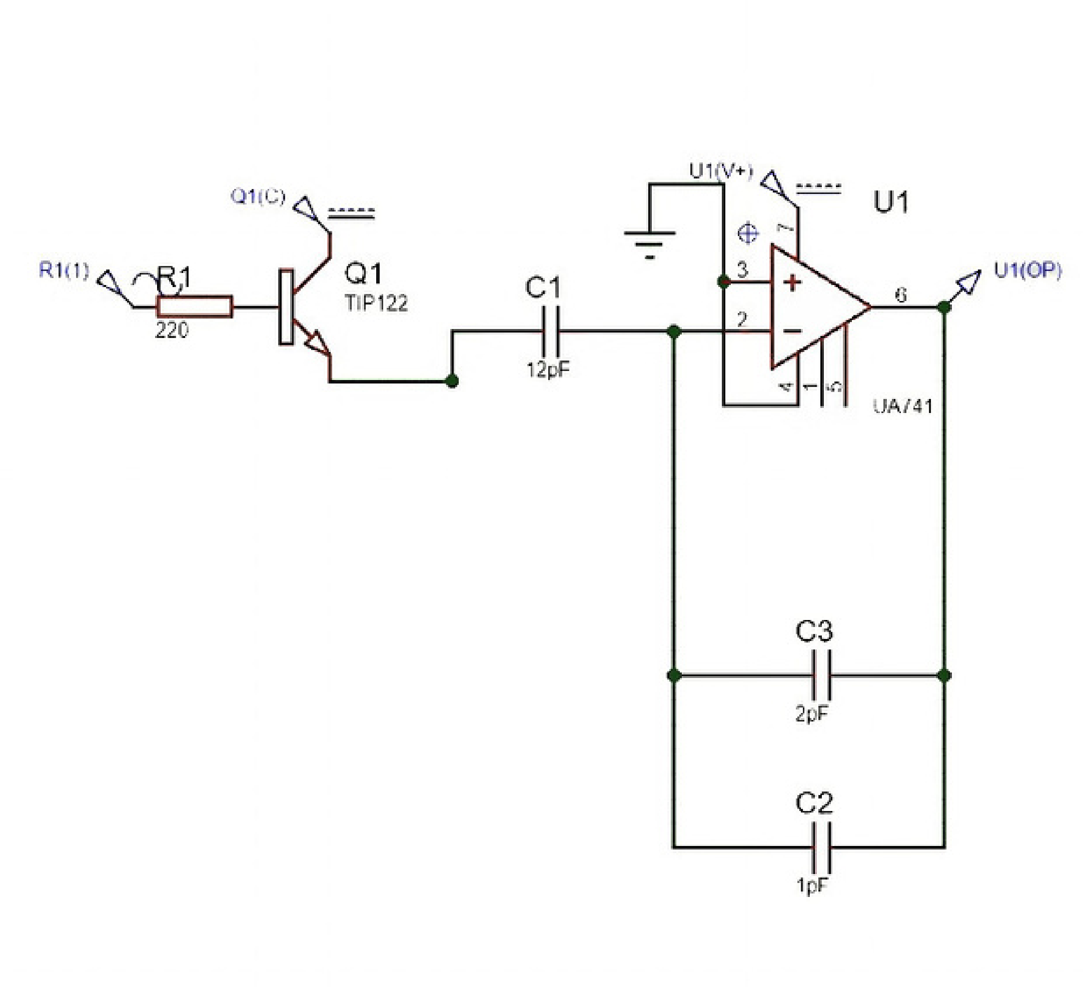
LINEARIZATION USING OP-AMP

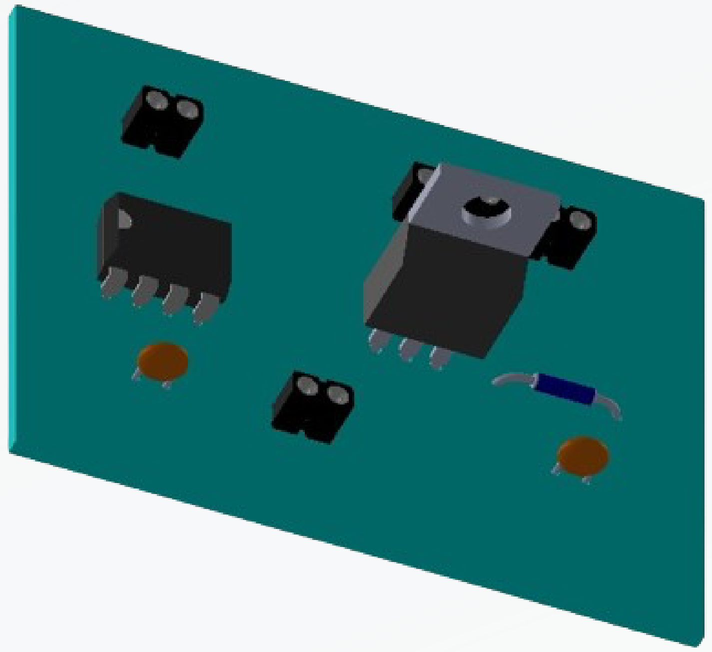
The main problem was that current did not flow in the circuit when capacitance was in the pF range so there was no output.

- No change in capacitance
- No current flow
- No output voltage

LINEARIZATION USING OP-AMP AND POWER AMPLIFICATION CIRCUIT

To achieve system linearization, a power amplification circuit utilizing the *IRF Z44N* was employed. This circuit was instrumental in augmenting the current supplied to the op-amp circuit, thereby facilitating accurate readings.

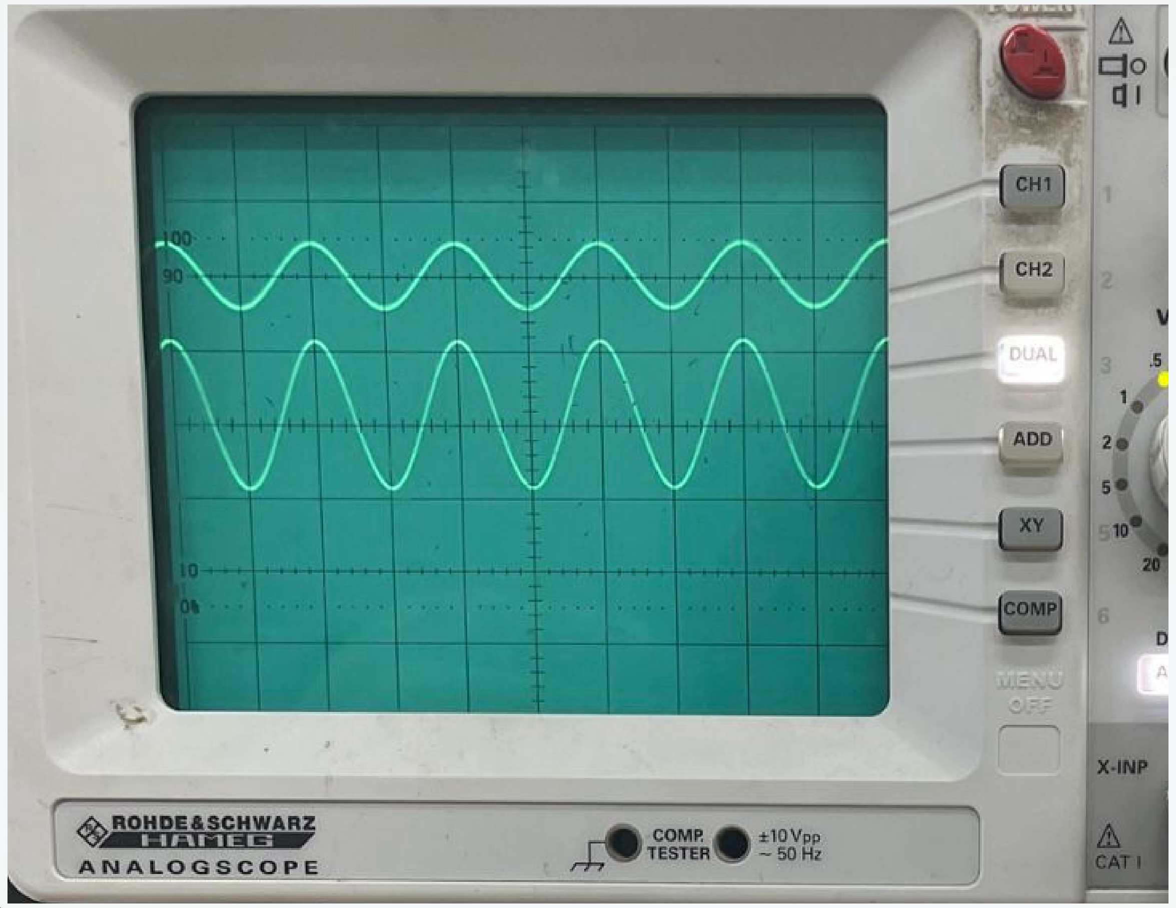


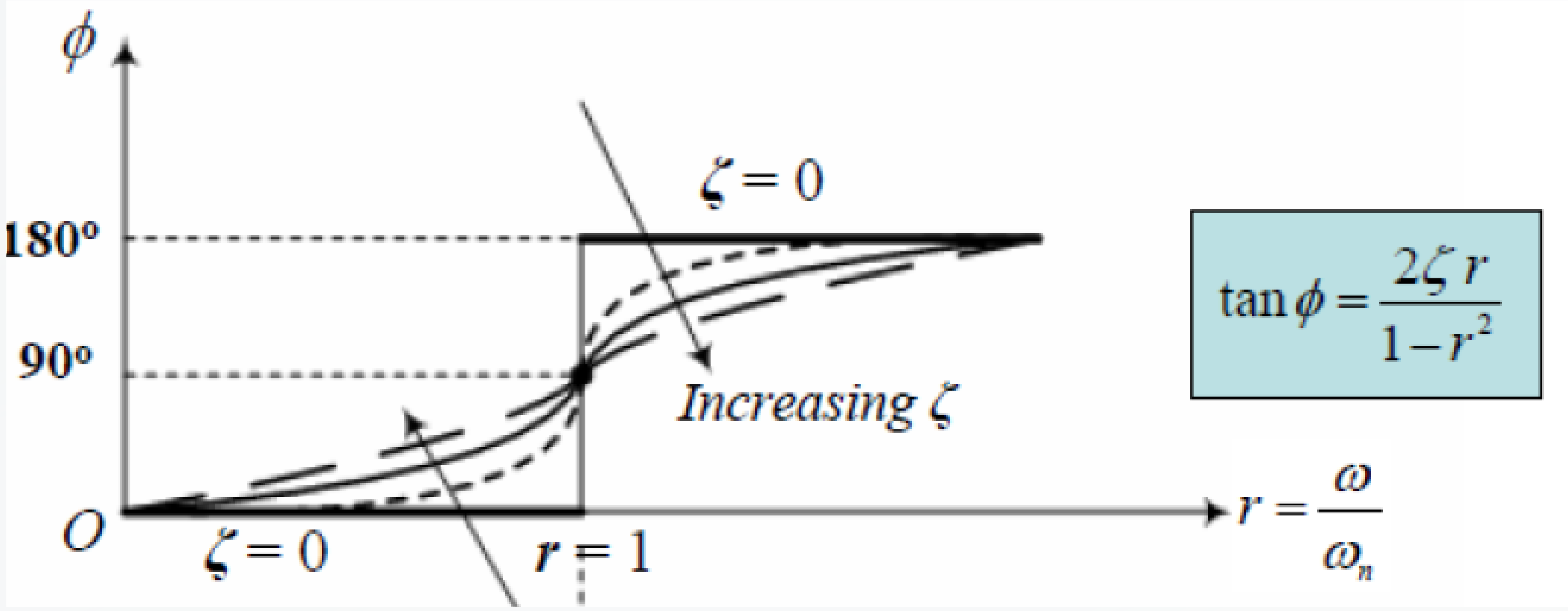


RESULTS

OUTPUT READINGS

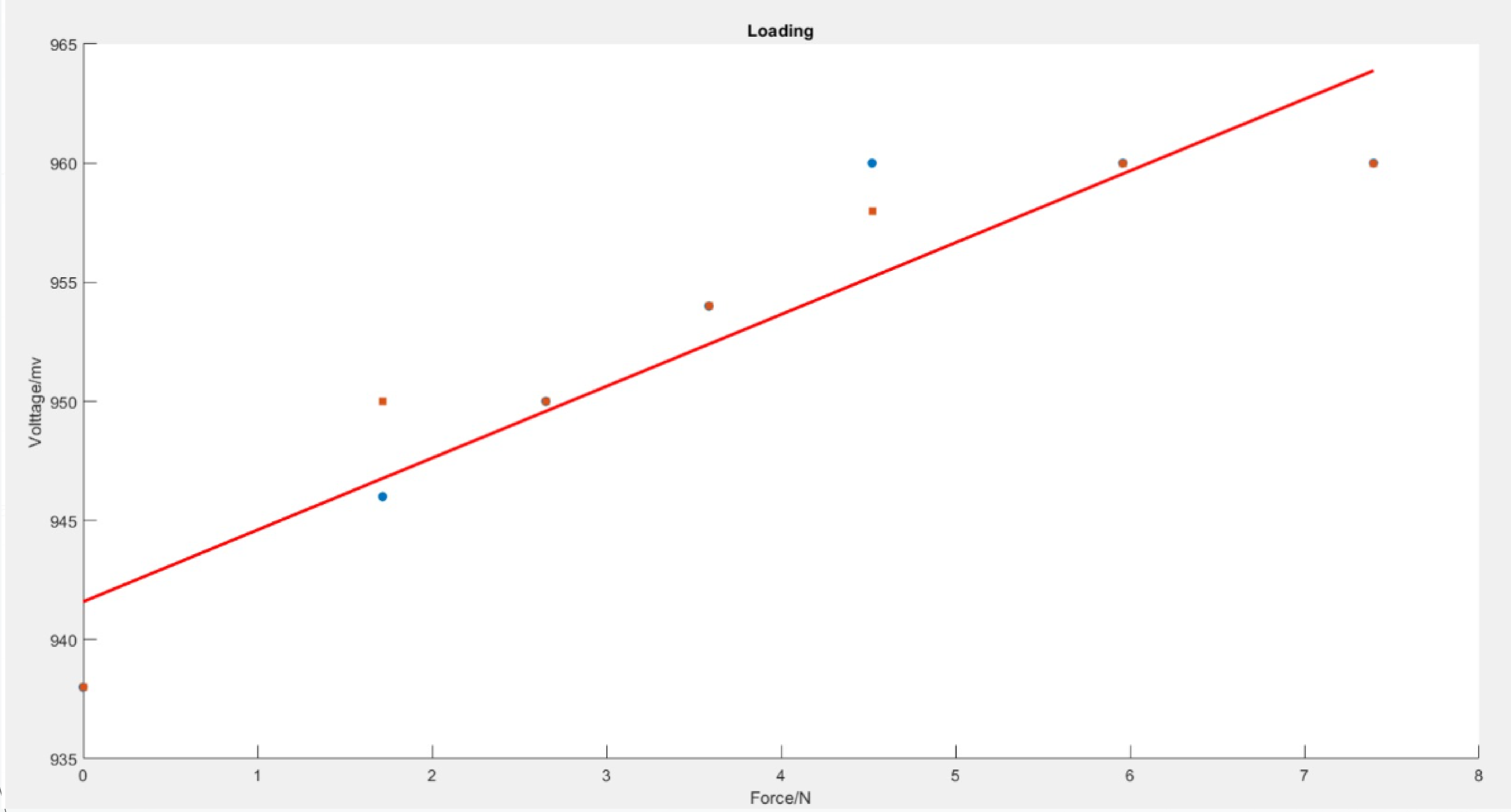
Input Frequency = 120 KHz
Natural frequency = 73 Hz.





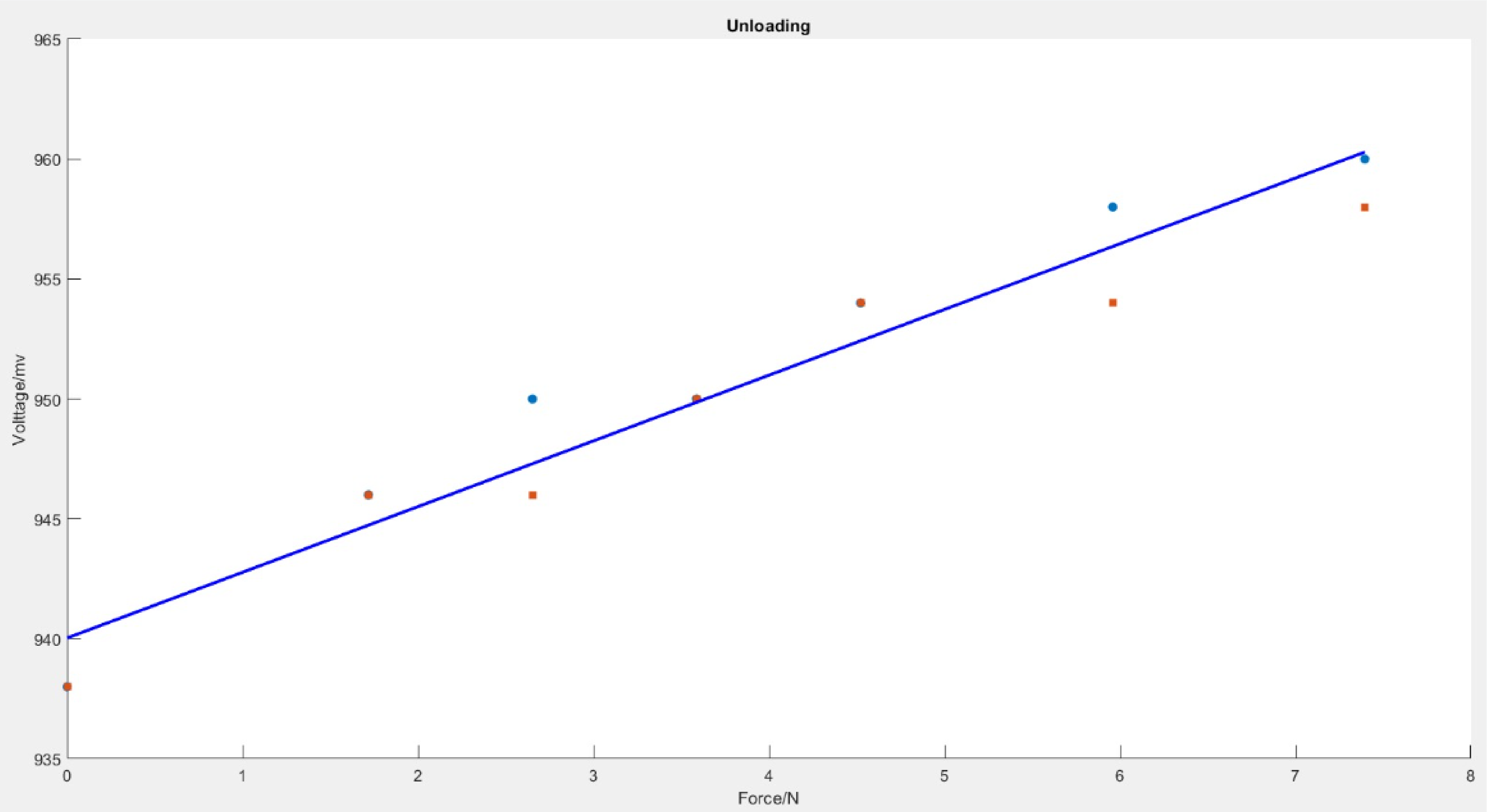
STATIC CHARACTERTSICS

Calibration curve analysis was performed during the loading of weights onto the sensor.



STATIC CHARACTERTSICS

Calibration curve analysis was performed during the <u>unloading</u> of weights onto the sensor.



STATIC CHARACTERTSICS

Sensitivity Assessment

$S = \Delta V/\Delta F$
$S = 3\ mV/N$

Resolution

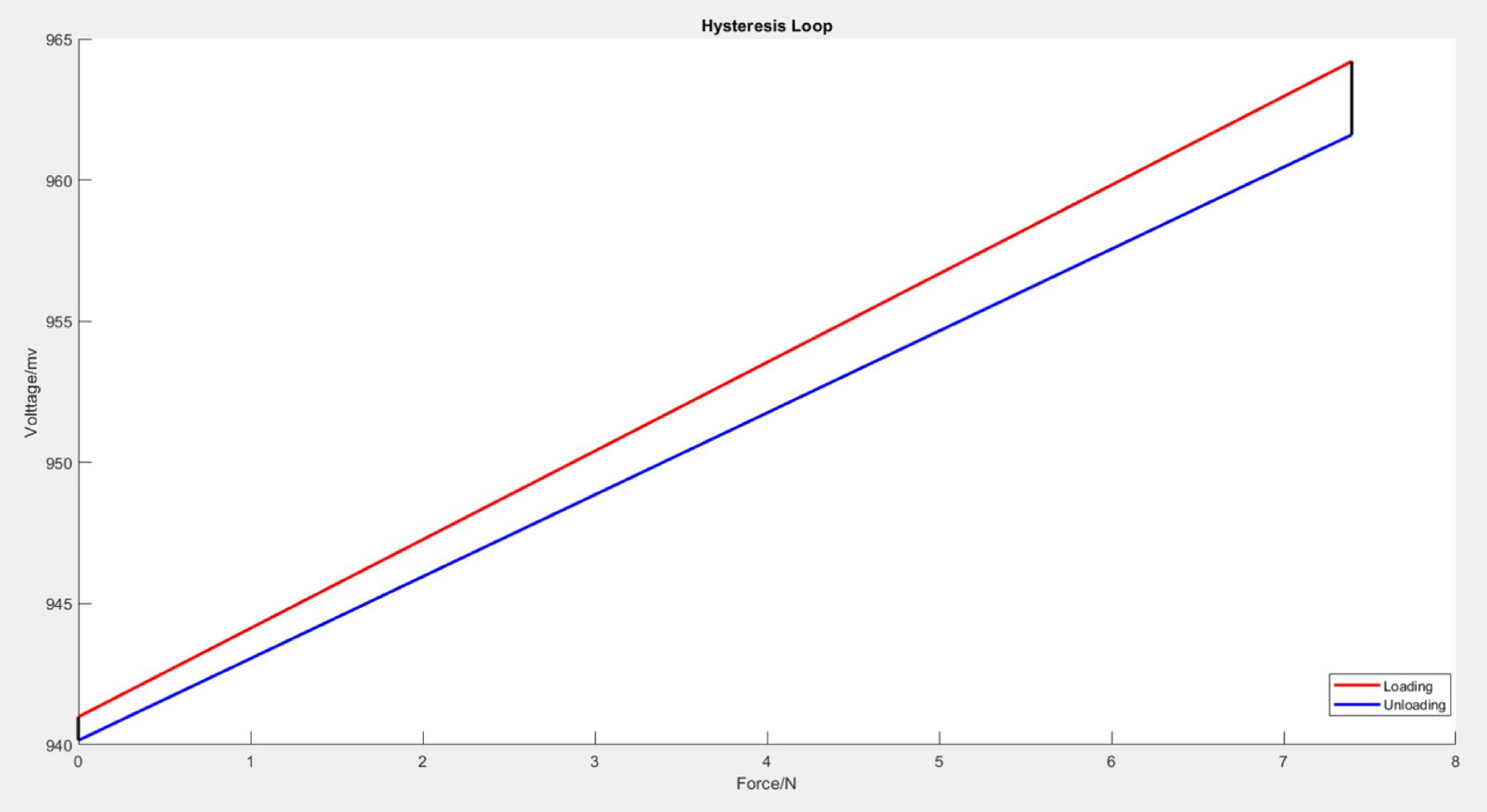
0.93 N

Range

The operational range of the sensor is from 0.93 N to 6.8 N

STATIC CHARACTERTSICS

Hysteresis = 7.73%



DYNAMIC CHARACTERTSICS

Second Order System

Underdamped

Step Input

SECOND ORDER EQUATION

$$\frac{a_2}{a_0}\frac{d^2y(t)}{dt^2}+\frac{a_1}{a_0}\frac{dy(t)}{dt}+y(t)=\frac{b_0}{a_0}x(t)$$

where,

a0= 1157 N/m

a2 = 5,5 g

bo = 3471

a1 = 0.19

FREQUNCY RESPONSE

$\delta = 0.038$

wd = 72.9 Hz

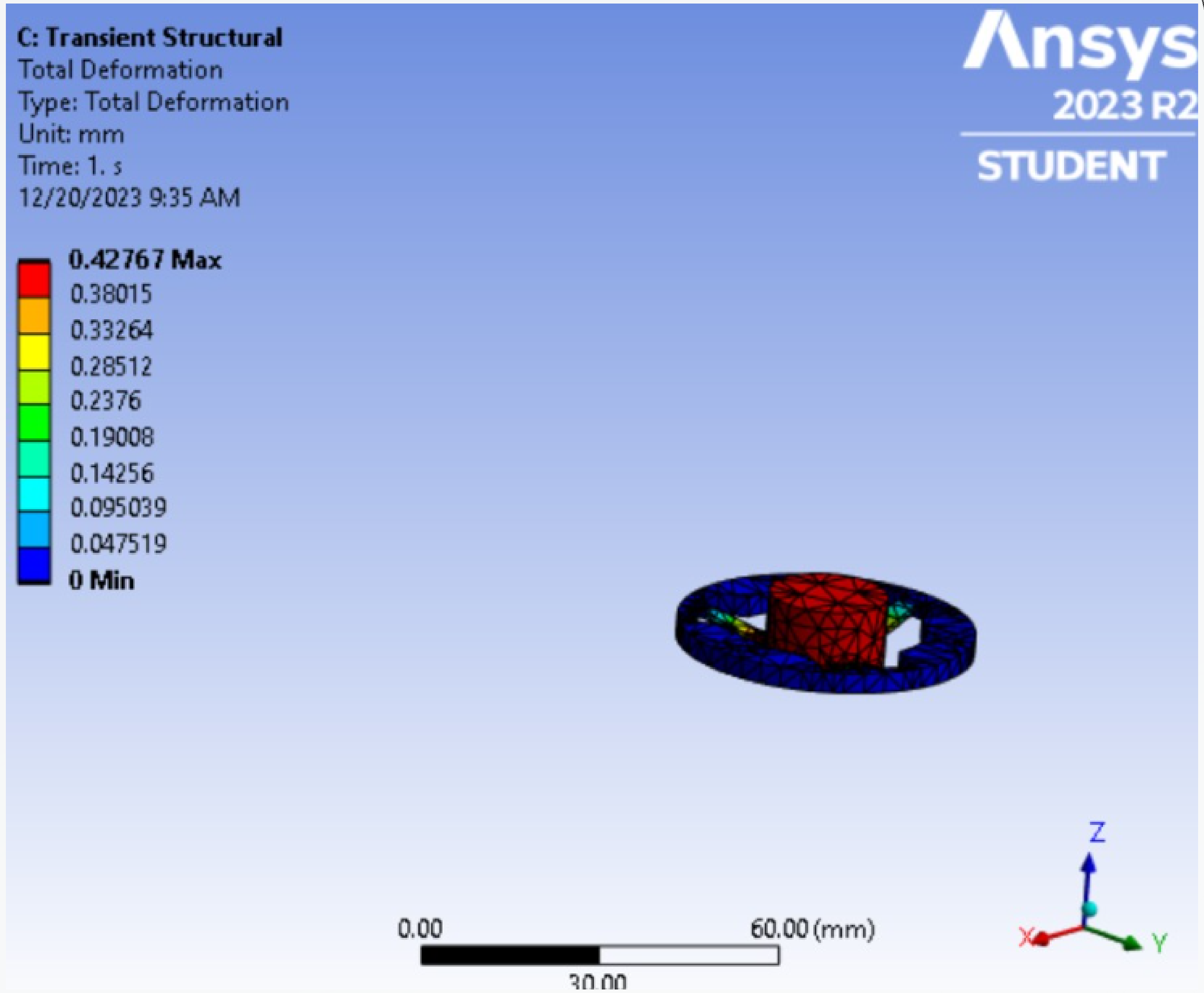
Rise Time = 1.23s

Maximum Overshoot = 0.887

Peak Time = 0.043s

Resonance Frequency = 72.9

Resoance Amplitude = 13.167



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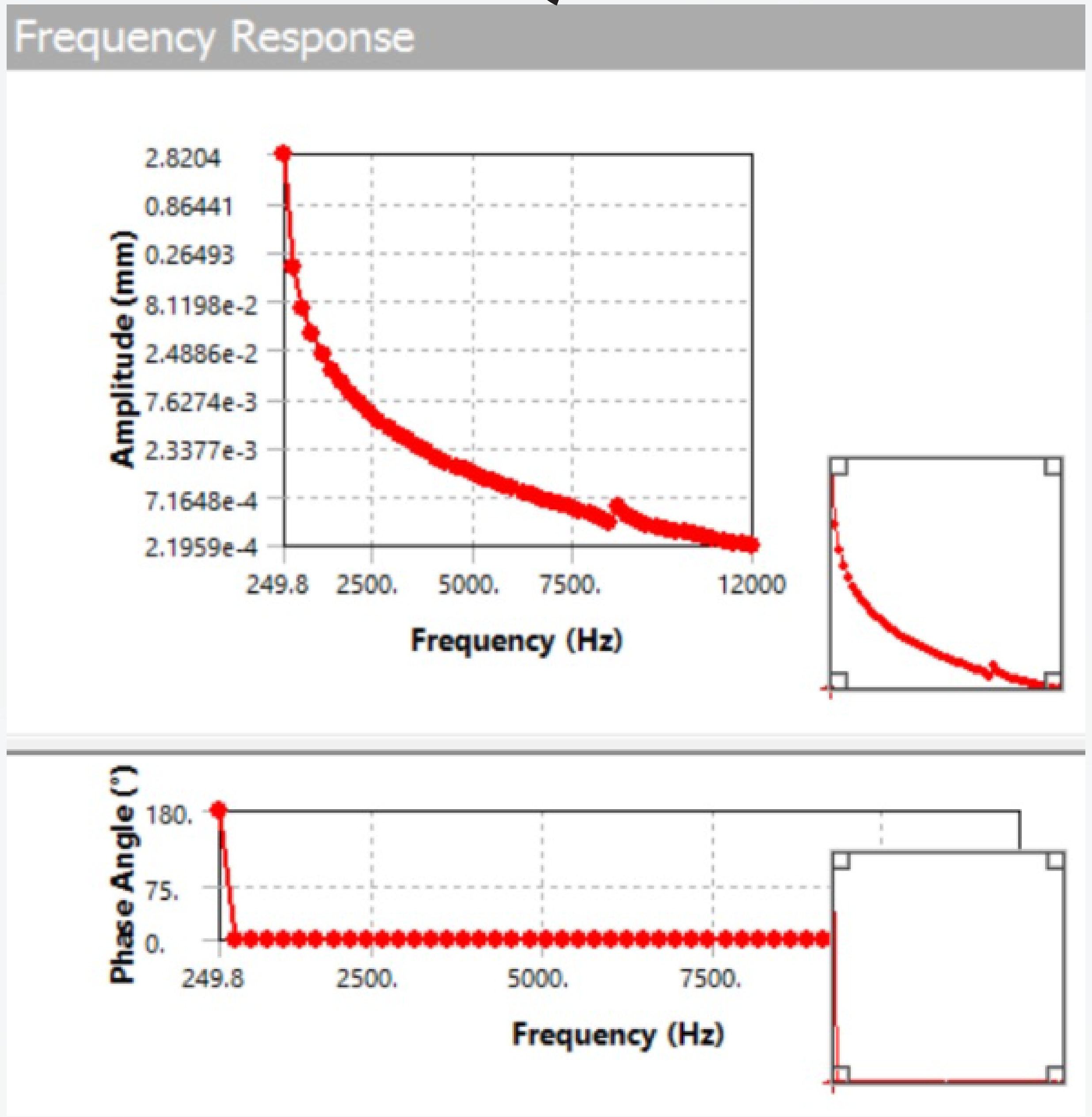

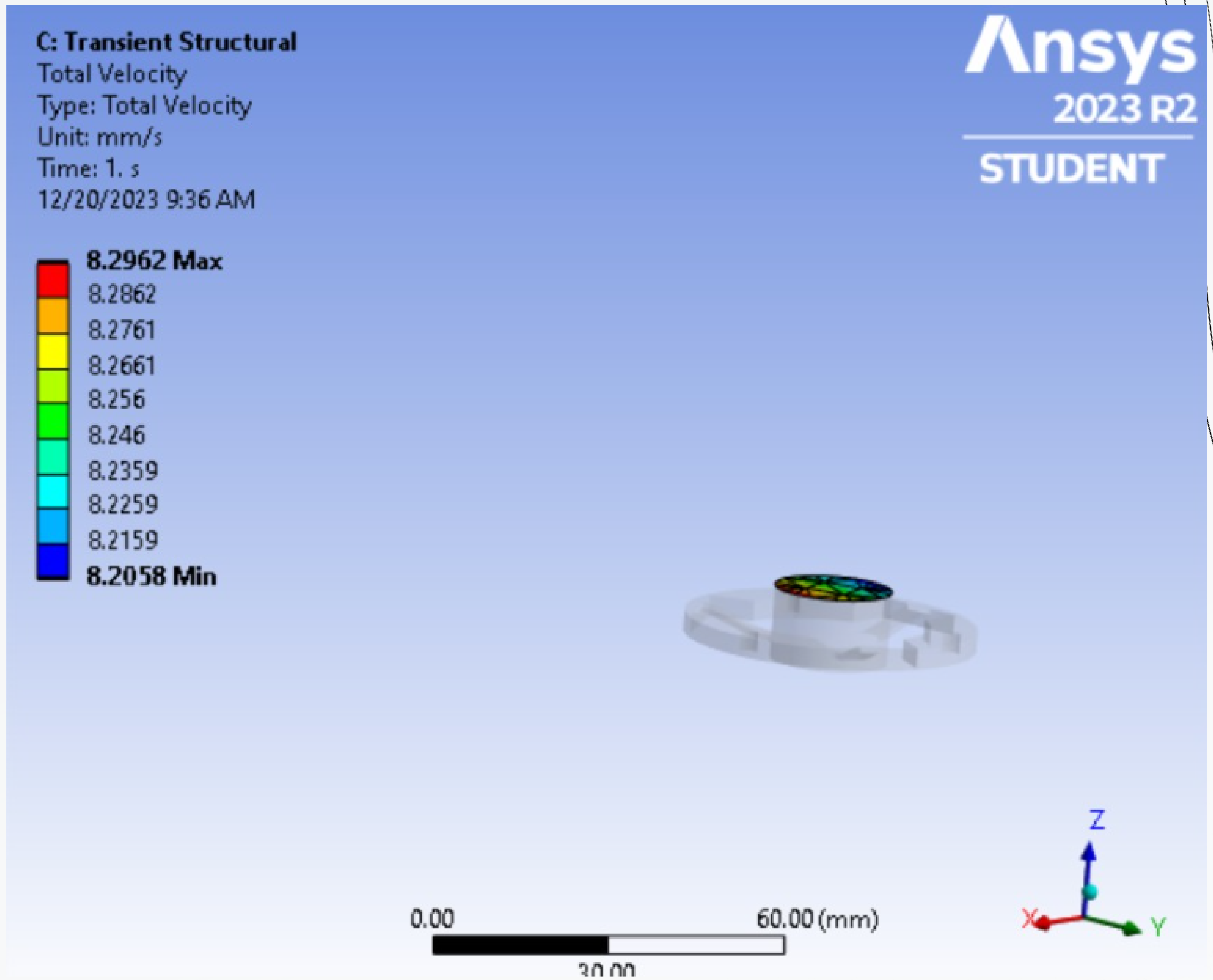

CONCLUSION

FUTURE WORK

Capacitance value should be increased, by increasing the area or decreasing the distance to improve variations.

DESIGN

Dynamic characteristics should be studied more closely.

THEORETICAL ANALYSIS

Try different variations of the circuit components to improve the circuit sensitivity.

AMPLIFICATION CIRCUIT

THANK YOU FOR YOUR ATTENTION