GYROSCOPE ANALYSIS

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https://drive.google.com/drive/folders/16IDY6QKV5cxOew-6zfoORsmpoTyA1H33?usp=drive_link

BACKGROUND

For centuries, gyroscopes have been used as navigational devices. With the development of MEMS, gyroscopes have been a crucial device to miniaturize for uses in consumer electronics, airplanes, ships, and much more. However, miniaturizing sensors are challenging due to design constraints and sensitivity tuning,

1. Non-magnetic Navigation
2. Orientation Sensing
3. Miniaturization

SALFORD & CO.

PROJECT GOALS

1 Minimize design area.

2 Maximize sensitivity.

PROCESS

Step 1

Optimize the design area to ensure that the gyroscope is within the maximum dimensions . The challenge lies in the fact that larger proof masses have better sensitivity, by proxy, so limiting this aspect will require other sensitivity tuning measures.

Step 2

Adjust the number of fingers and the gap between the fingers. Both of these parameters increase the drive force which ultimately increases the Coriolis force, resulting in maximum sensitivity. This takes care of the proof mass limitation.

Step 3

Calculate expected values for drive and sense mode's k, frequency, etc. Then, simulate in COMSOL to validate the design. Plots generated should have a high Q which indicates higher sensitivity. Output voltage per rotation will be calculated from this.

CONSTRAINTS

Fixed Parameters/Constraints

Parameter	Specification
V_{DD}	10 V
Material	Single-crystal silicon
Device Layer Thickness	100 um
Sacrificial layer thickness	0.5 µm
Smallest feature size	1 µm

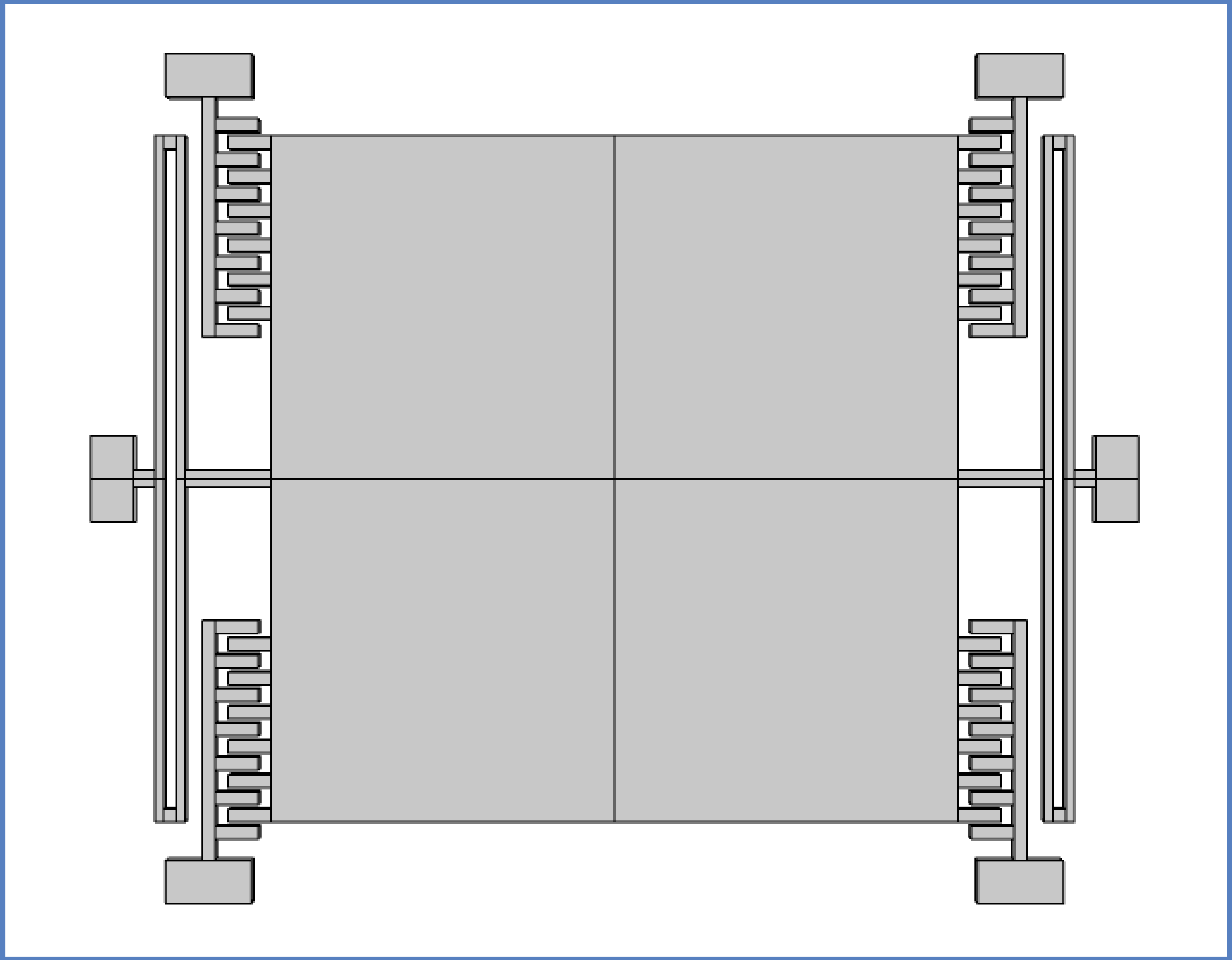
Specifications to Meet

Parameter	Specification
Maximum V_{AC}	1.2 V (CMOS compatible voltage)
Minimum resonant frequency	2 kHz
Maximum transimpedance gain	10 kΩ
Minimum sensitivity (voltage)	150 nV/ (rad/sec)
Design Area	< 2 mm x 2 mm

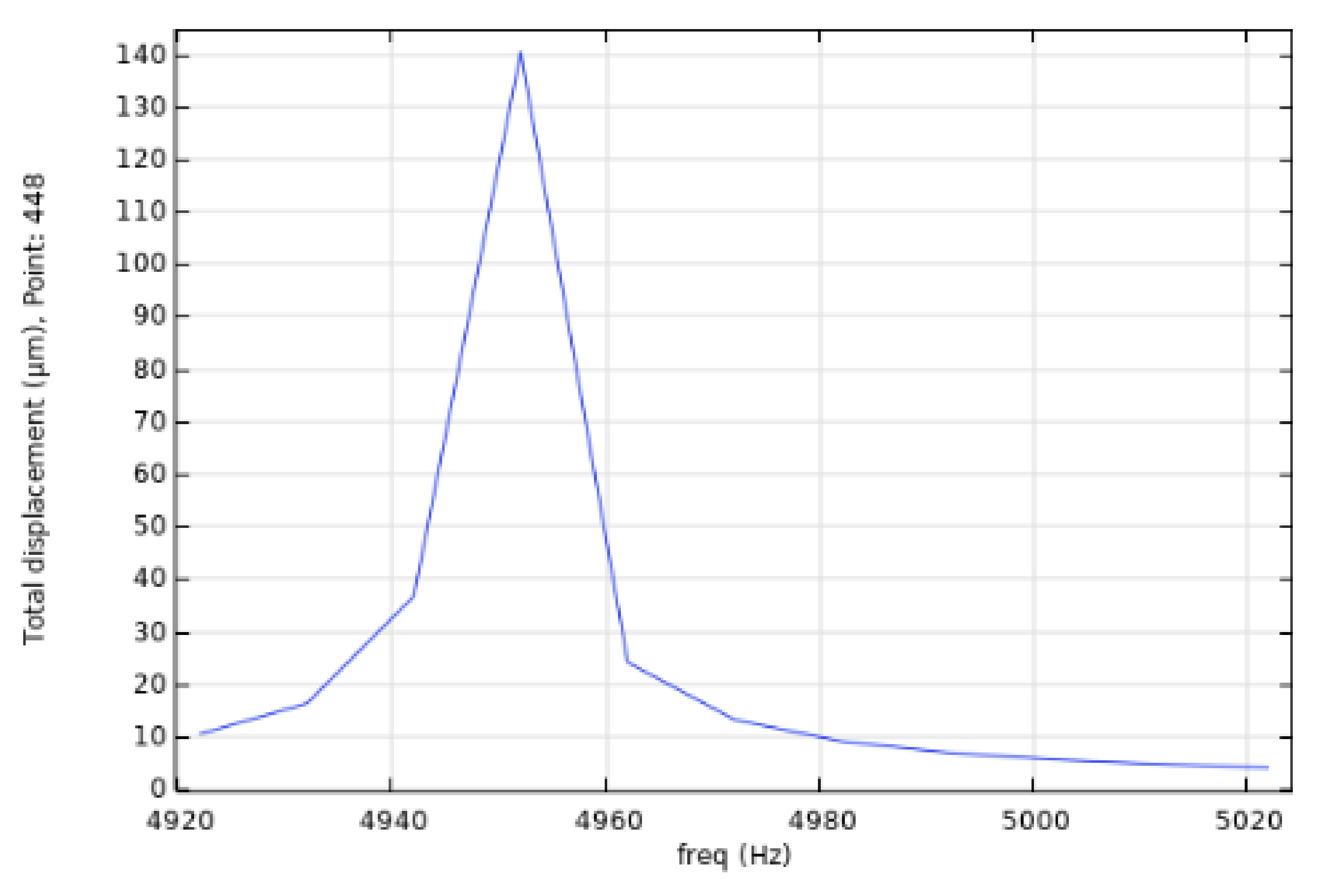
PARAMETERS

w_spring1	20 [um]	2E-5 m	width of spring 1
w_spring_...	30 [um]	3E-5 m	width of spring connector
w_mass	800 [um]	8E-4 m	width of proof mass
w_finger	100 [um]	1E-4 m	finger width
w_drive_fi...	30[um]	3E-5 m	width of drive finger anchor
w_connec...	50 [um]	5E-5 m	width of anchor-spring connector
w_connec...	200 [um]	2E-4 m	width of mass-spring connector
w_anchor2	100 [um]	1E-4 m	width of anchor2
w_anchor	200 [um]	2E-4 m	width of anchor
thickness	100 [um]	1E-4 m	DO NOT CHANGE - device thickness
offset	50 [um]	5E-5 m	offset on anchor
N	6	6	fingers/comb
m	2330[kg/m^3]*(2*w_mass)*(2*h_mass)*(thickness)	5.9648E-7 kg	
l_ov	70 [um]	7E-5 m	equilibrium finger overlap
h_spring1	800 [um]	8E-4 m	height of spring 1
h_spring_...	30 [um]	3E-5 m	height of spring connector
h_mass	800 [um]	8E-4 m	height of proof mass
h_finger	30 [um]	3E-5 m	finger height
h_drive_fi...	2*N*(h_finger+g)+h_finger+offset	4.7E-4 m	height of drive finger anchor
h_connec...	h_connector	2E-5 m	height of anchor-spring connector
h_connec...	20 [um]	2E-5 m	height of mass-spring connector
h_anchor2	100 [um]	1E-4 m	height of anchor2
h_anchor	100 [um]	1E-4 m	height of anchor
g	2.5 [um]	2.5E-6 m	finger gap
finger_spa...	2*(h_finger+g)	6.5E-5 m	adjacent finger space
b	(2*w_mass)*(2*h_mass)*(1.73E-5)/(offset)	8.8576E-7 m	damping coefficient

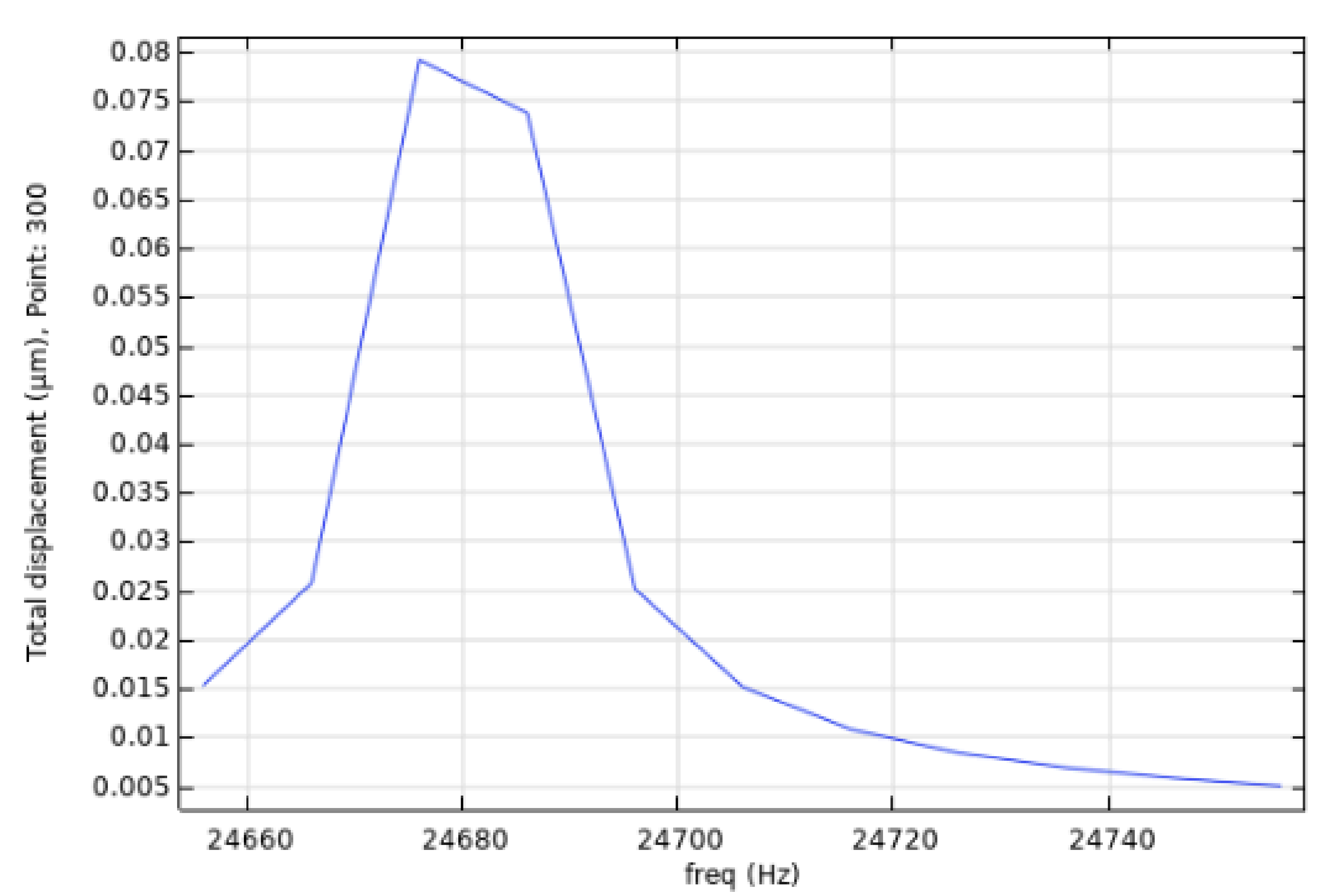
GYROSCOPE



RESULTS

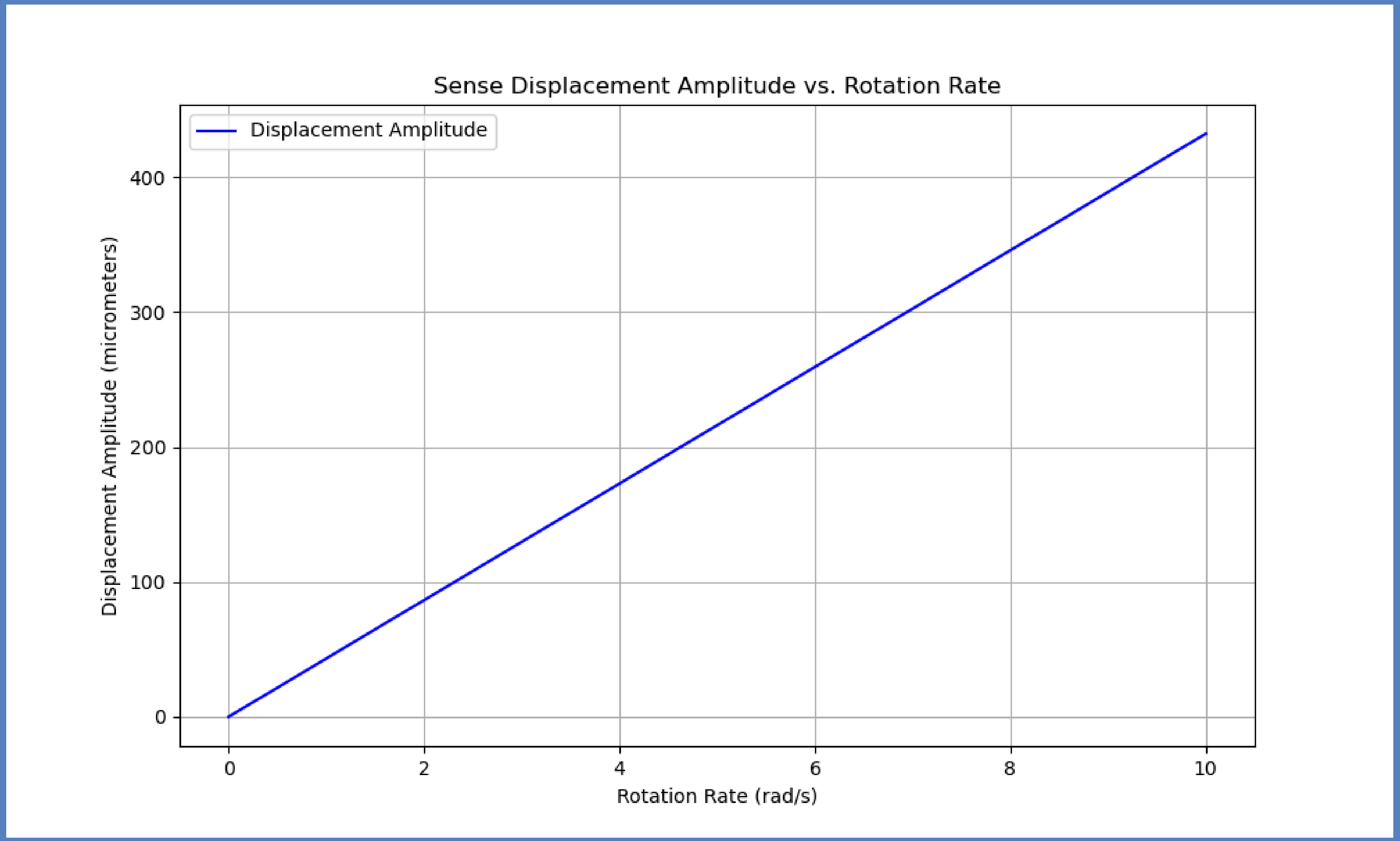


Total displacement (µm), Point: 448
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
4920
4940
4960
4980
5000
5020
freq (Hz)

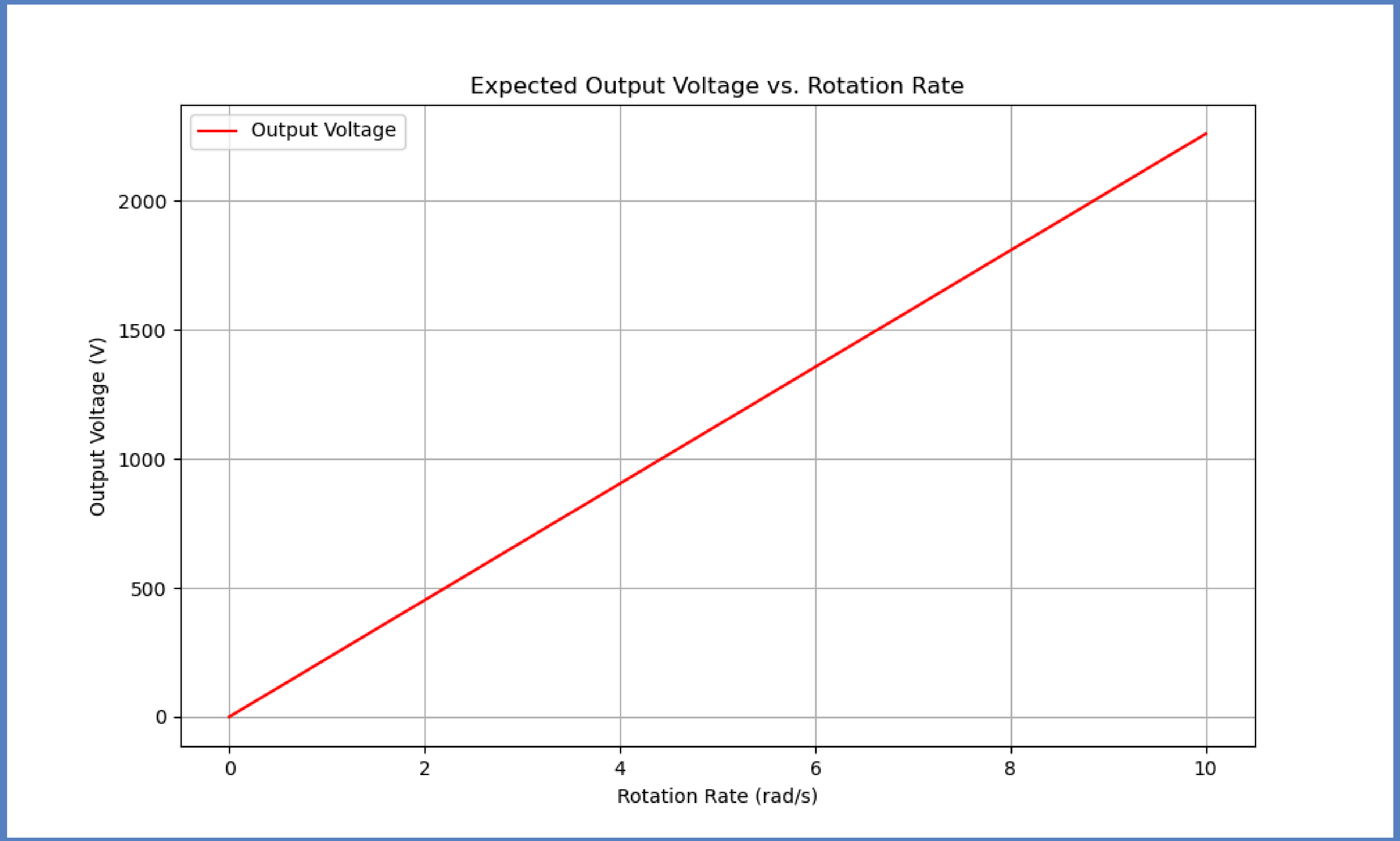


Total displacement (µm), Point: 300
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
0.065
0.07
0.075
0.08
24660
24680
24700
24720
24740
freq (Hz)

RESULTS



Sense Displacement Amplitude vs. Rotation Rate
Displacement Amplitude
Displacement Amplitude (micrometers)
0
100
200
300
400
0
2
4
6
8
10
Rotation Rate (rad/s)



Expected Output Voltage vs. Rotation Rate
Output Voltage
Output Voltage (V)
0
500
1000
1500
2000
0
2
4
6
8
10
Rotation Rate (rad/s)

CONCLUSION

My gyroscope optimization focused on simple changes to tune the design according to the design constraints. Therefore, this project demonstrates the importance of certain key features within gyroscopes, such as sense electrodes, to the design's sensitivity.

SENSITIVITY ACHIEVED **=** 830 nV/rad/sec
NOISE DENSITY = 121.5 fN

THANK YOU