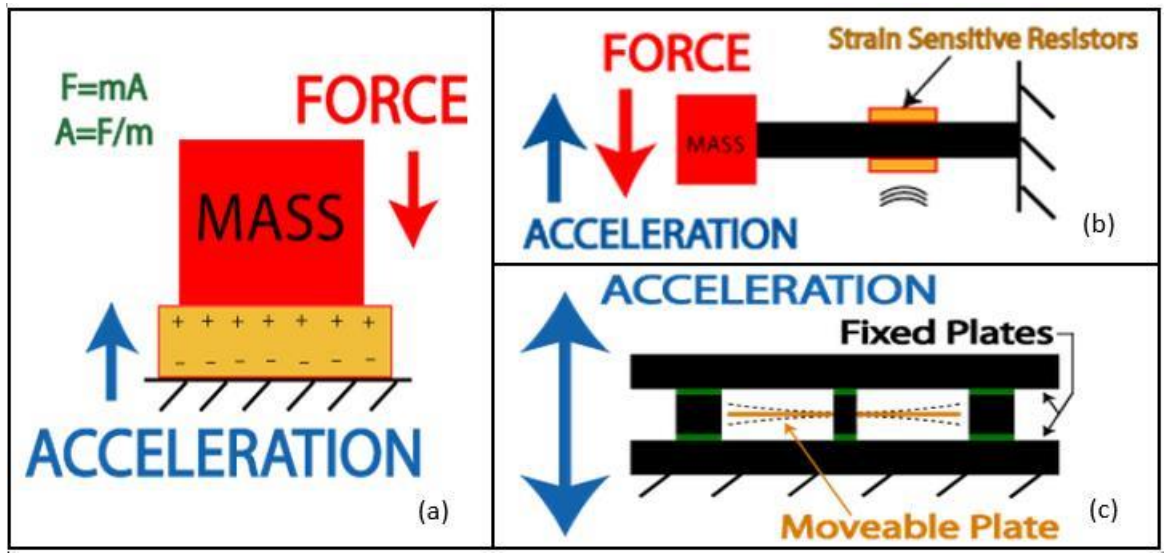
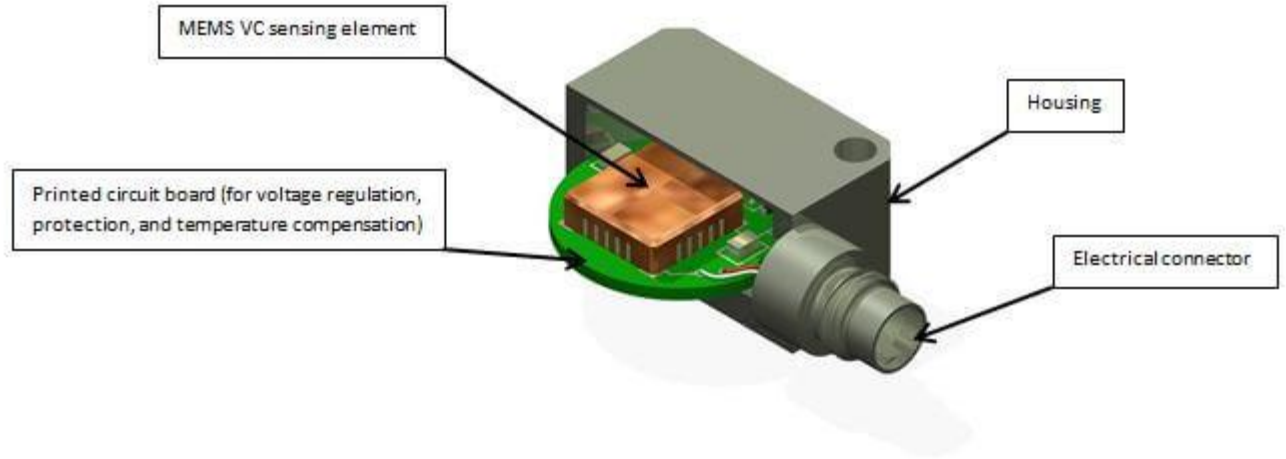
Calibrating MEMS Accelerometers

- Introduction to accelerometers
- MEMS Accelerometers
- Calibration Errors
- Solution
- Future project development.

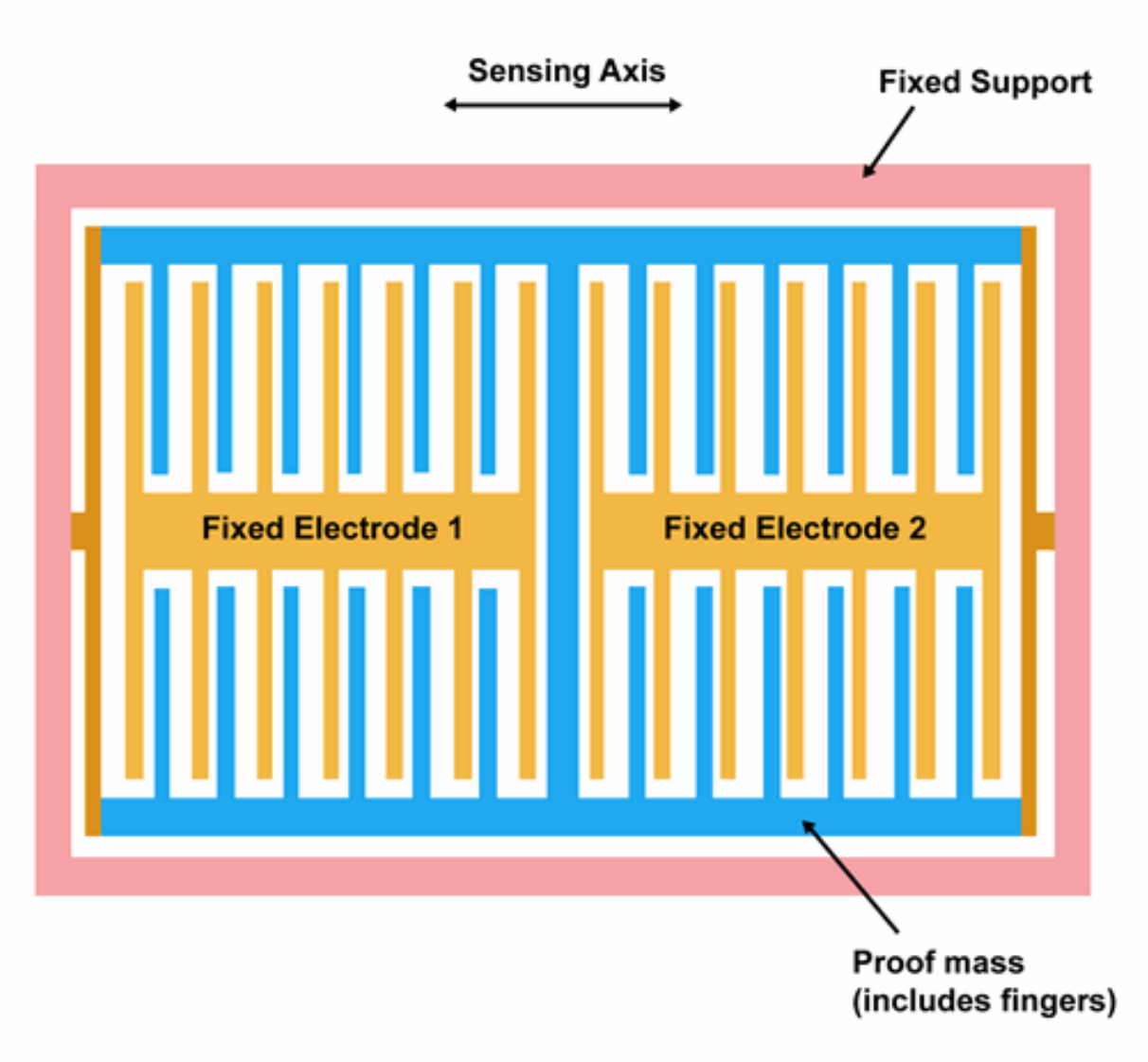
Introduction to accelerometers

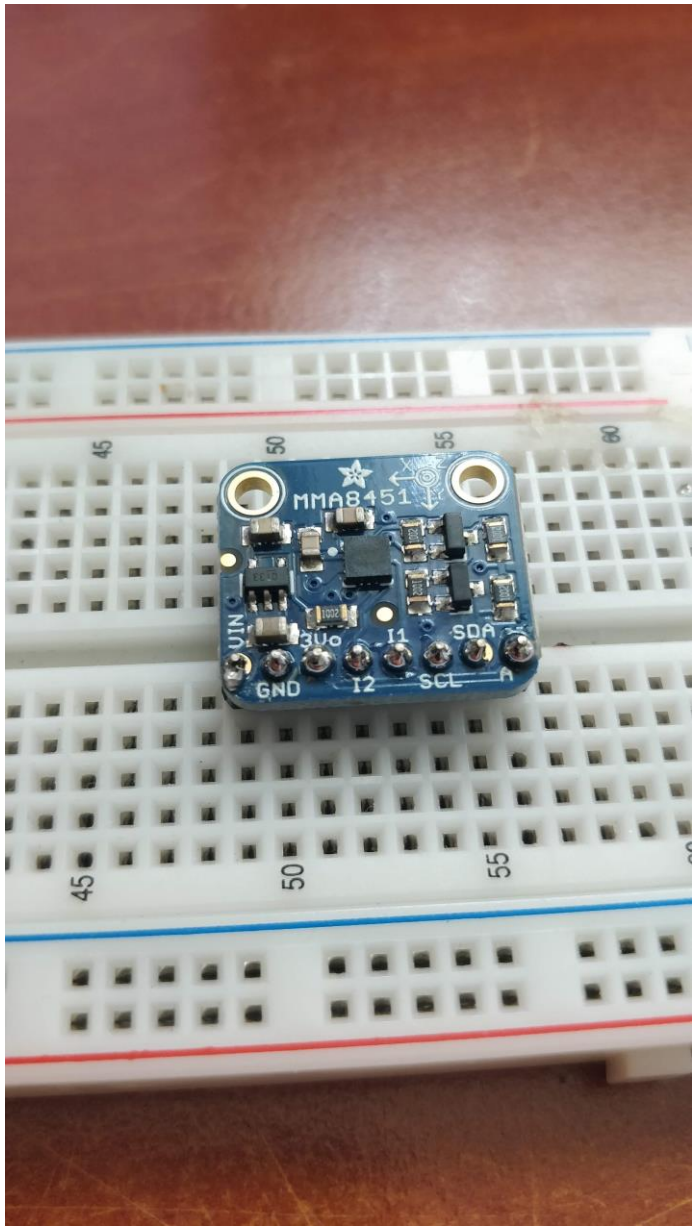
- **MEMS**
- Piezoelectric
- Piezoresistive
- Capacitive





MEMS Accelerometers





Calibration Errors

- Constant Bias
- Scaling Errors
- Errors due to the non- orthogonality of the axes
- Thermo-Mechanical White Noise / Velocity Random Walk
- Flicker Noise / Bias Stability
- Temperature Effects

What do we expect from the sensor?

Uncalibrated		
X	Y	Z
0.686143985	9.693013241	0.146230973
0.307313184	-9.555131822	0.121707371
10.20588166	0.146627372	0.293913142
-9.235730337	0.149835656	-0.153514714

Norms Before Calibration
9.71837
9.56085
10.2112
9.23822
9.72837

Details about data calibration

- $$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} M_{xx} & M_{xy} & M_{xz} \\ M_{yx} & M_{yy} & M_{yz} \\ M_{zx} & M_{zy} & M_{zz} \end{pmatrix} . \begin{pmatrix} \hat{X} \\ \hat{Y} \\ \hat{Z} \end{pmatrix} + \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix}$$

- We can say that the sensor data is calibrated when (the norm of the acceleration vector) – $g^2 \approx 0$.

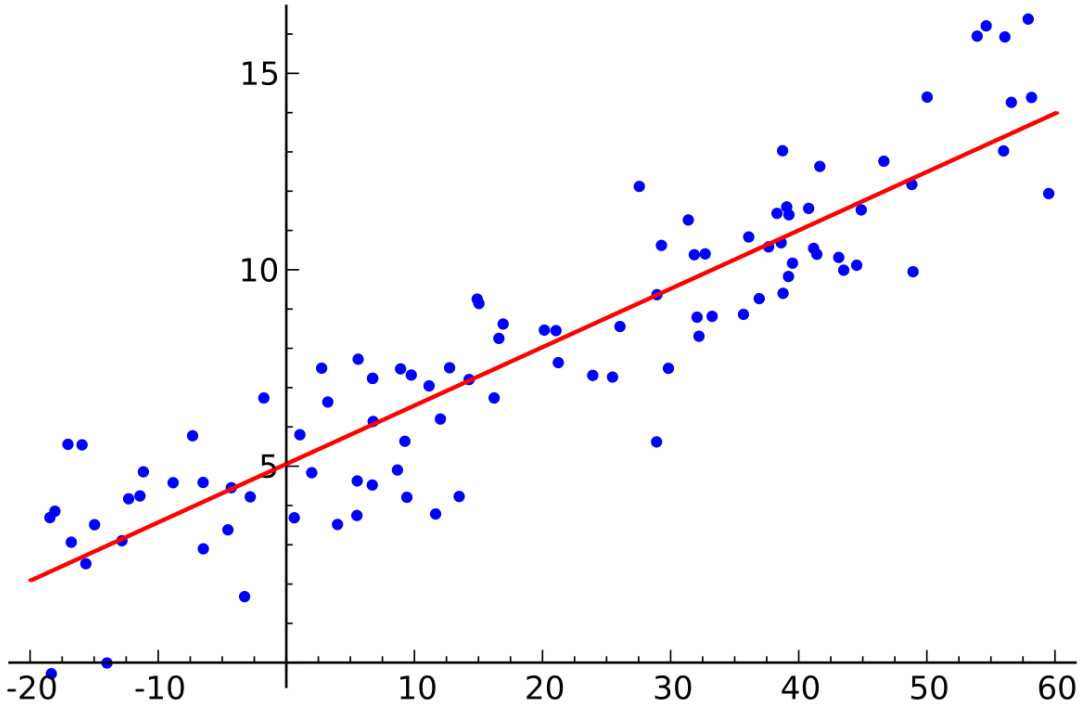
- We need to find for which $\{M_{xx} M_{xx} M_{zz}\}, \{M_{yx}\ M_{yy}\ M_{yz}\}, \{M_{zx}\ M_{zy}\ M_{zz}\}$ and B_x, B_y, B_z we have the smallest error.

$$Err = \left(M_{xx} + M_{xy} + M_{xz}\ + B_x\right)^2 + \left(M_{yx} + M_{yy} + M_{yz}\ + B_y\right)^2 + \left(M_{zx} + M_{zy} + M_{xz}\ + B_z\right)^2 - g^2 = 0$$

Data calibration methods

I use the least squares method in order to find for which $M_{xx} - M_{zz}$ & B_x- B_z I have the smallest error for the given data.

$$M = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}, \qquad B = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

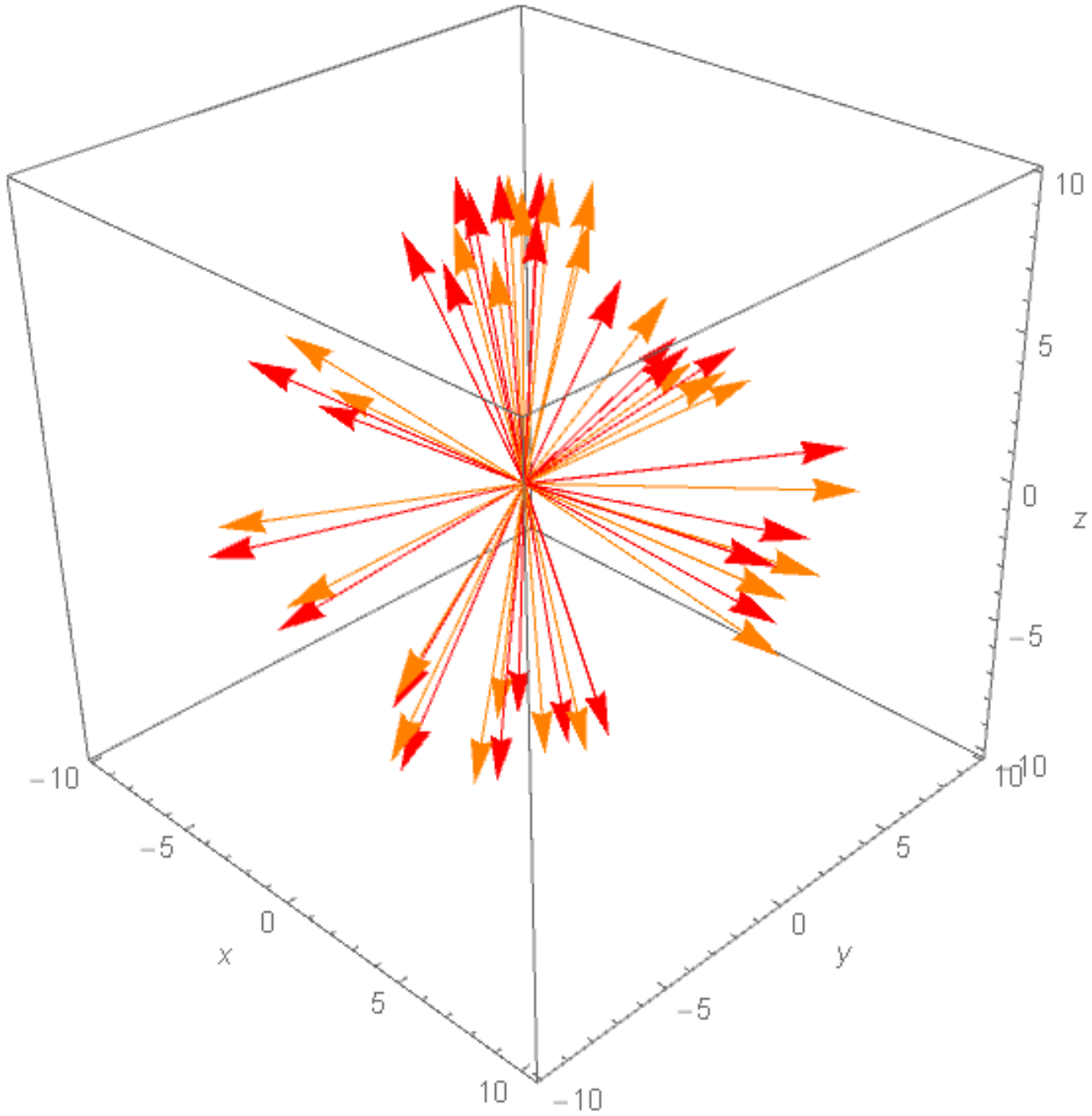


Result Comparison

Uncalibrated				Calibrated		
X	Y	Z		X	Y	Z
0.686143985	9.693013241	0.146230973	>	-0.21872	9.78756	0.393097
0.307313184	-9.555131822	0.121707371		0.23227	-9.79228	-0.00413996
10.20588166	0.146627372	0.293913142		9.7752	0.458216	0.448614
-9.235730337	0.149835656	-0.153514714		-9.79133	-0.299772	-0.18428

Norms Before Calibration		Norms After Calibration
9.71837	>	9.79789
9.56085		9.79504
10.2112		9.79621
9.23822		9.79765
9.72837		9.78336

Uncalibrated Data
Calibrated Data



Future development

- Implementing Newtons Method for 12 variables.
- Extracting and calibrating data from my own sensor.
- Using my sensor on a robot for tracking position and acceleration.

Thank you for the attention!