Sensors And Actuators

Characterization of Angular Rate Sensors

ADXRS300 & BOSCH SMG040

Aadithya Ramamurthy | Matrikel Nr. 3304090
Amod Raut | Matrikel Nr. 3297221
Samir Elsafi | Matrikel Nr. 3101566

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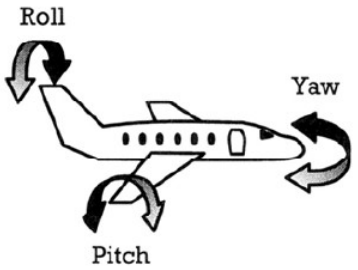
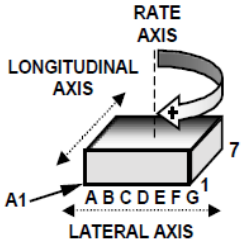
Introduction

Angular Rate Sensor-

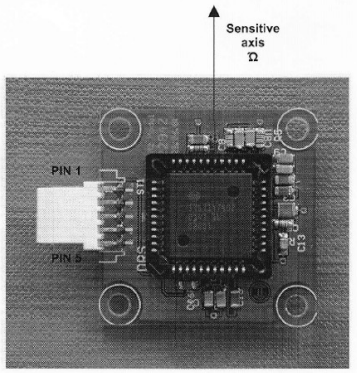


- Angular Rate Sensors measure the rate of rotation of an object with respect to an inertial frame of reference(yaw, pitch, roll)
- They are very important components in active suspension systems and anti-skidding systems, like the ESP system for automobiles.

- The ADXRS 300 is an angular rate sensor (gyroscope) that uses Analog Devices' surface-micro-machining process
- ADXRS300 measures along the axis normal to the top surface.

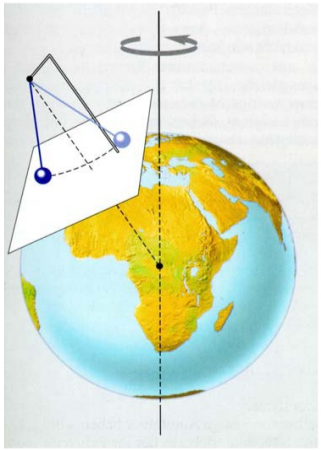


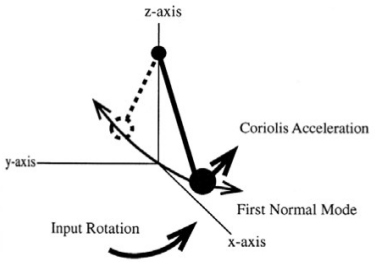
- The Robert Bosch Angular Rate Sensor SMG040 is the second generation of gyroscopes for rollover applications. The SMG040 is a micro-machined gyroscope for the detection of angular rates in car safety applications such as rollover control units.
- SMG040 sense along the axis shown in figure.

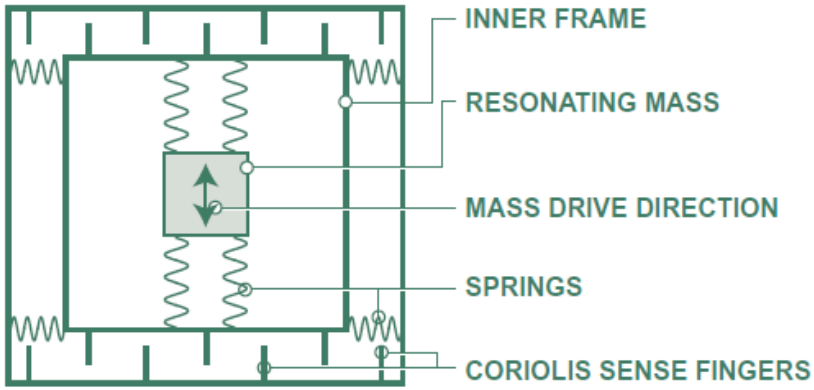


Coriolis Force

- The frame containing the resonating mass is tethered to the substrate by springs at 90
- Coriolis sense fingers are used to sense displacement of the frame in response to the force exerted by the mass, capacitively.
- As the rate of rotation increases, so does the displacement of the Mass, and the Signal derived from the corresponding capacitance change.







Coriolis Force

The Coriolis force is calculated using –

$z = r\varepsilon^{i\theta}$,

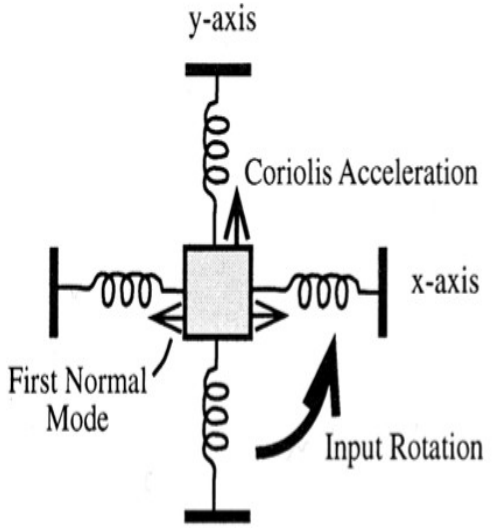
$$\frac{dz}{dt} = \frac{dr}{dt}\varepsilon^{i\theta} + ir\frac{d\theta}{dt}\varepsilon^{i\theta}$$

$$\frac{d^2z}{dt^2} = \left[\frac{d^2r}{dt^2}\varepsilon^{i\theta} + i\frac{dr}{dt}\frac{d\theta}{dt}\varepsilon^{i\theta}\right] + \left[i\frac{dr}{dt}\frac{d\theta}{dt}\varepsilon^{i\theta} + ir\frac{d^2\theta}{dt^2}\varepsilon^{i\theta} - r\left(\frac{d\theta}{dt}\right)^2\varepsilon^{i\theta}\right]$$

$$\frac{d\theta}{dt} = \Omega \text{ and } \frac{dr}{dt} = v$$

then

$$\frac{d^2z}{dt^2} = i2\Omega v\varepsilon^{i\theta} - \Omega^2 r\varepsilon^{i\theta}$$

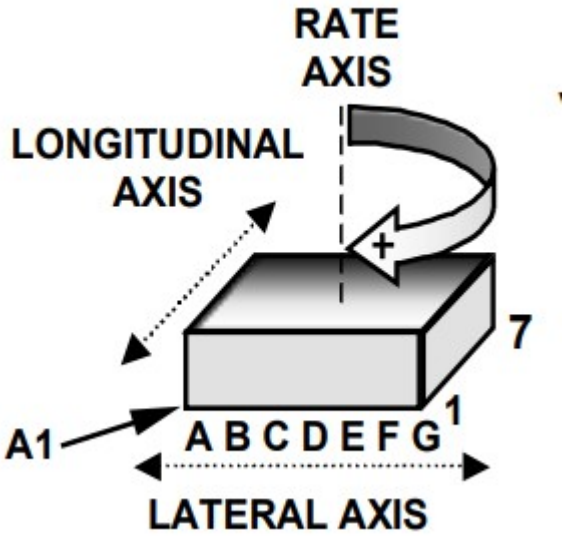


Demonstration of Coriolis effect in response to the resonating silicon mass supported inside a frame. Orange arrow indicates the force applied.

Rate Sensitive Axis

ADXRS300

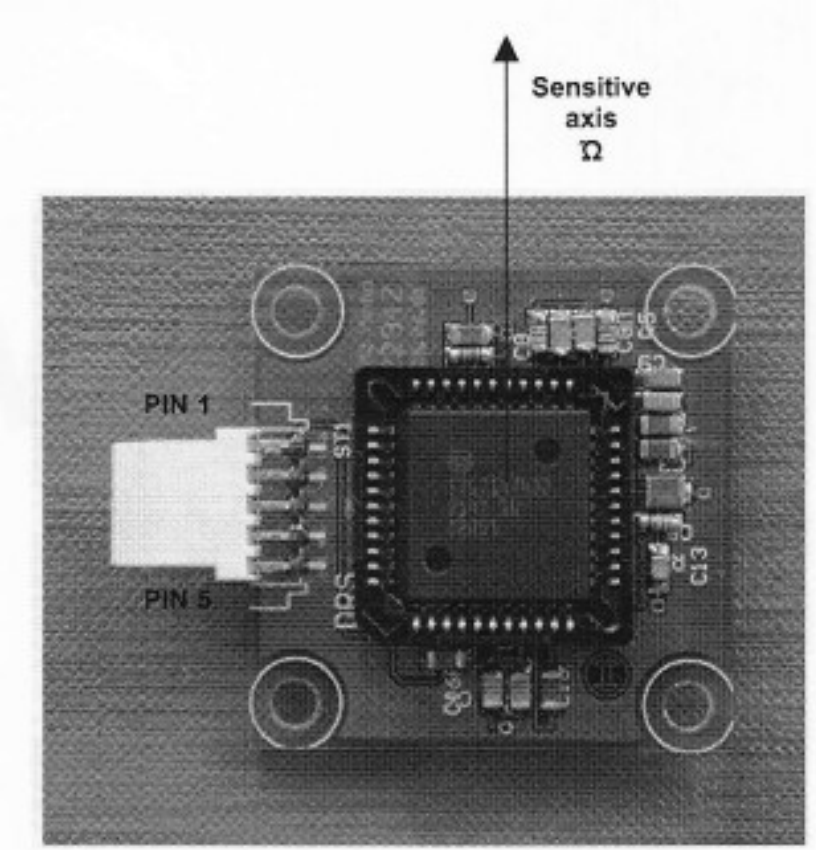
This is a Z-axis rate-sensing device that is also called a yaw-rate sensing device. It produces a positive going output voltage for clockwise rotation about the axis normal to the package top, i.e., clockwise when looking down at the package lid.



Rate Sensitive Axis

Bosch SMG040

Target Application: Roll over sensing (250 °/s)



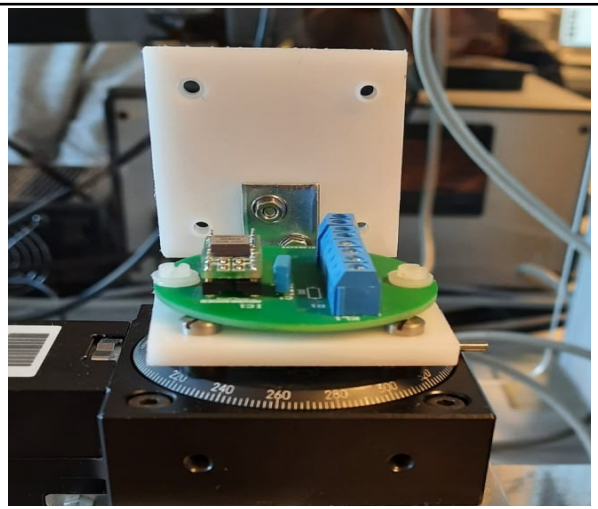
Main characteristic parameters

- Range of operation
- Zero Value voltage
- Sensor sensitivity

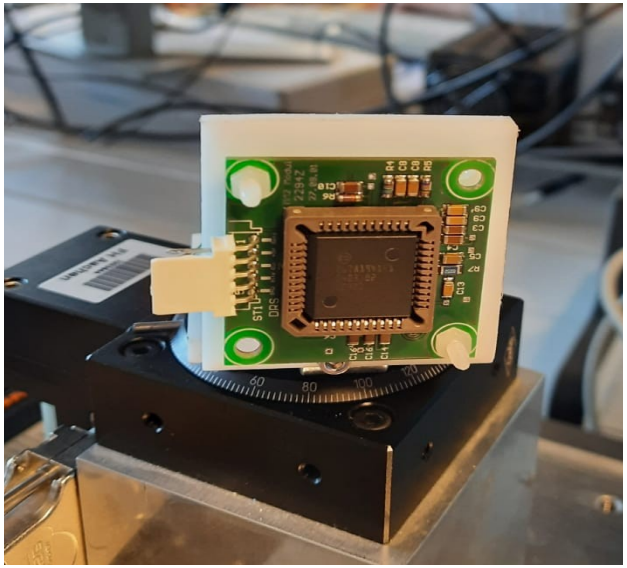
$$Sensitivity = \frac{mean\ value[V] - zero\ Value[V]}{\text{speed of rotation}[\frac{\text{deg}}{\text{sec}}]}$$

Measurement Setup

For ADXRS300, we use the mounting shown in the figure. We have used 5mm spacers for isolating the sensor terminals.



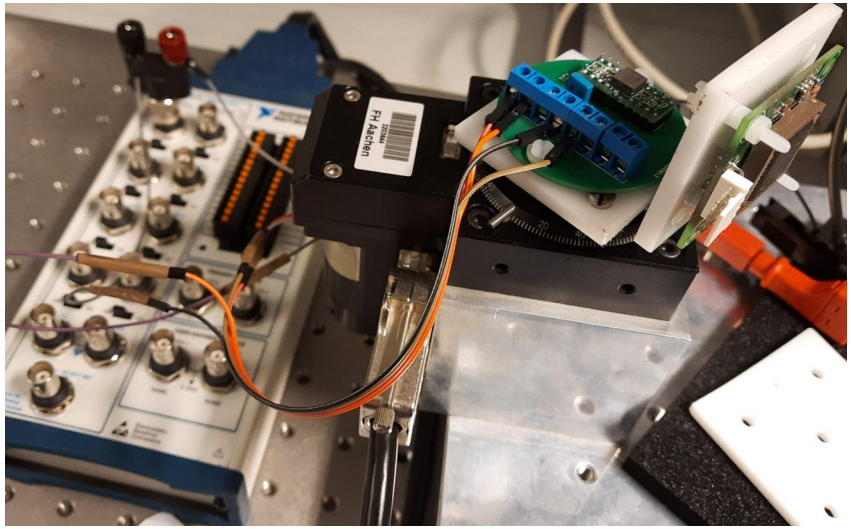
For Bosch SMG040 we mount it vertically as the sensitive axis is horizontal to the chip.



Measurement Setup

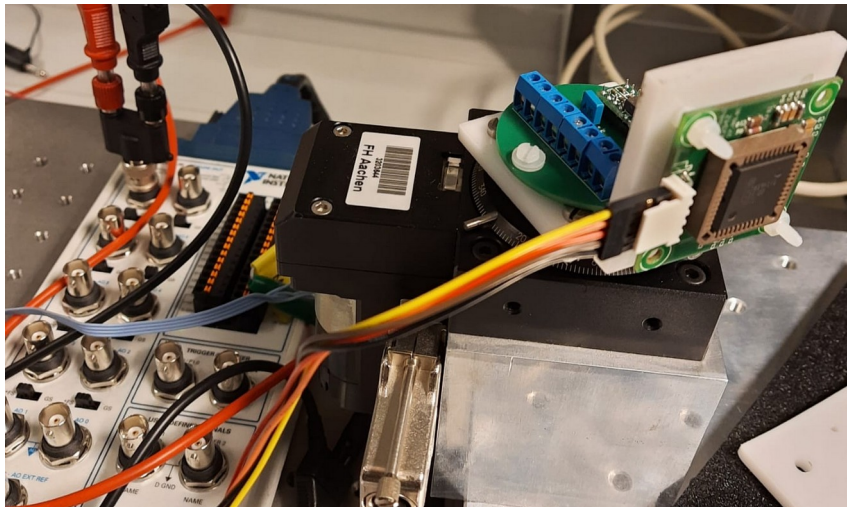
ADXRS 300

PIN1: AVCC - Supply Voltage pin
PIN2: Rate Out (Volts)
PIN4: GND
PIN5: GND



Bosch SMG040

PIN1: nc (V_{ref} = internal reference voltage)
PIN2: Supply voltage 5V
PIN3: Rate Out
PIN4: BITE
PIN5: GND



Measurement Strategy

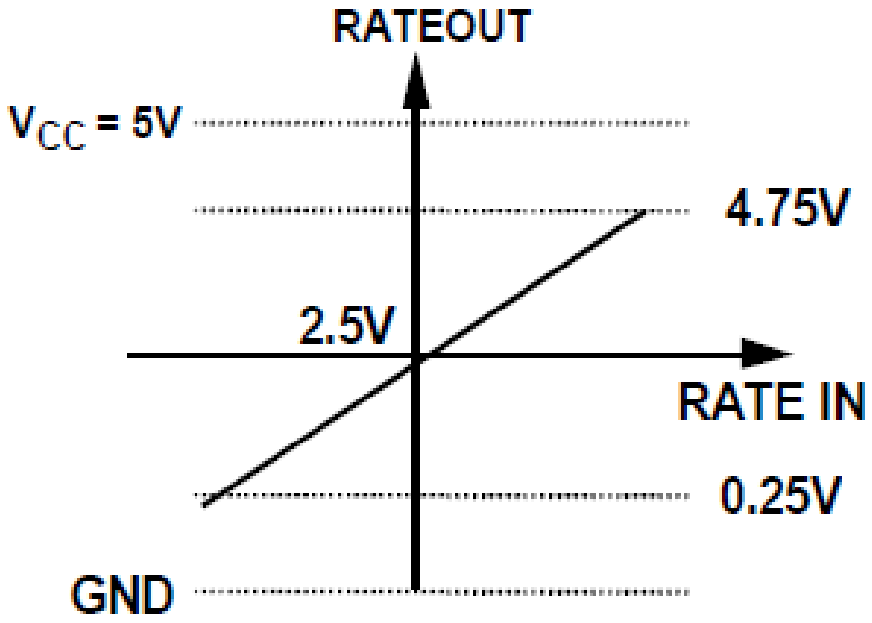
- Rotate the turn table via LabView:
  - Rotate by:
    1. A certain number of turns.
    2. At a certain speed, specified in LabView giving input - dValue

    dValue in ≈ Angular Rate / 7,06

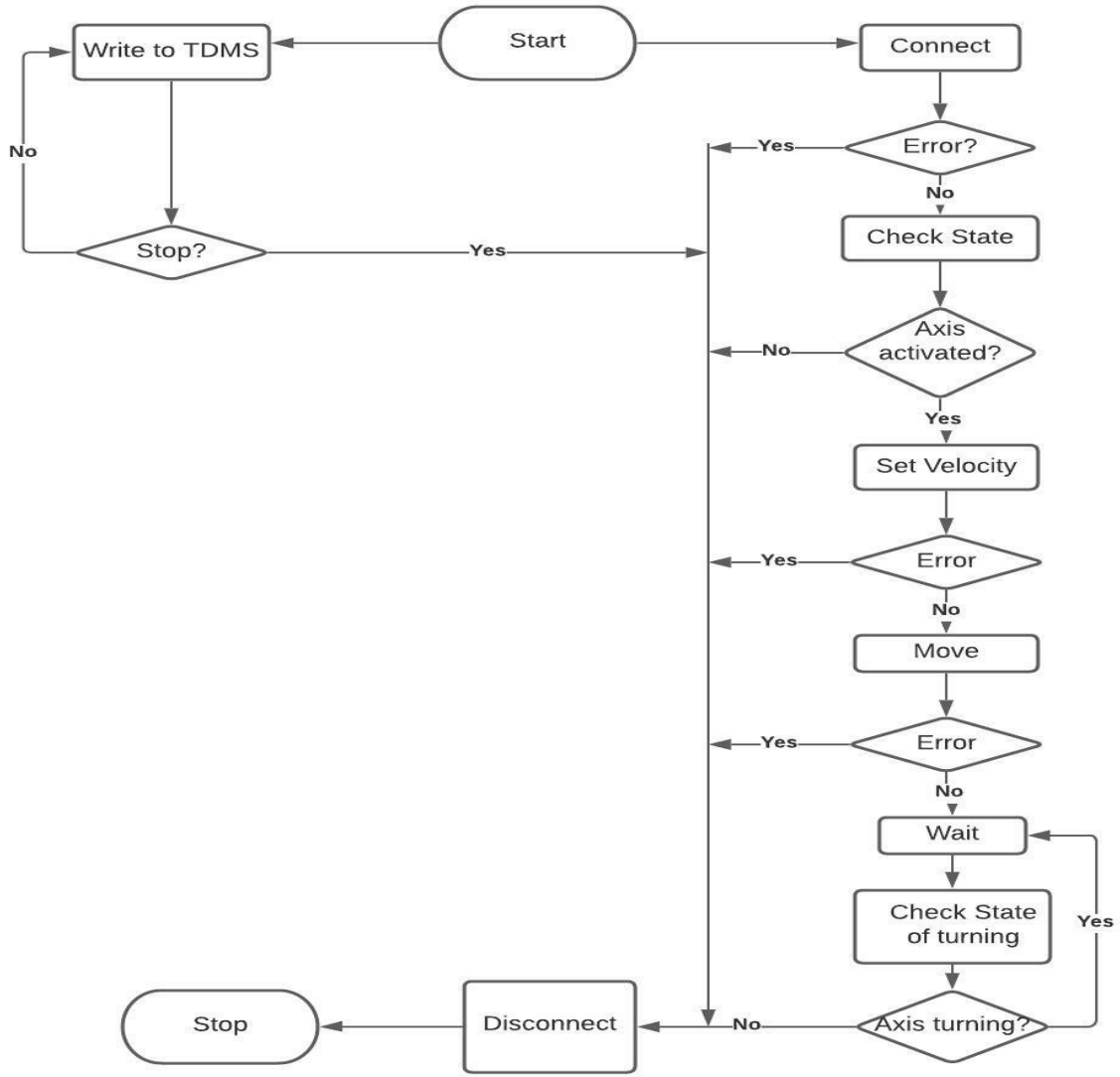
- Read out Voltage of the sensors.
- Calculate Angular Velocity of the Turn table.
- Calculate Sensitivity of the sensor.

Expected Results

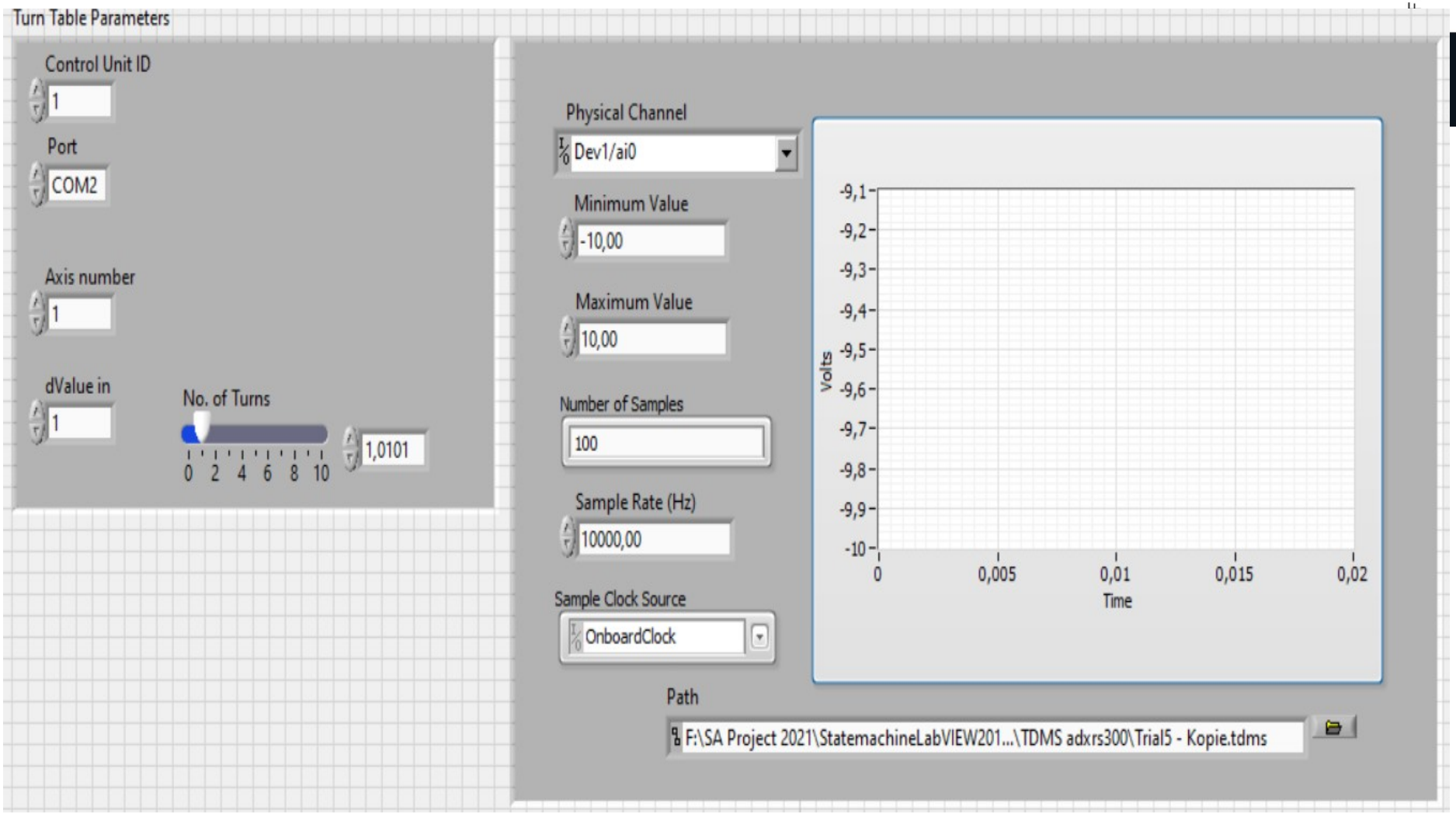
Output voltage vs Angular rate



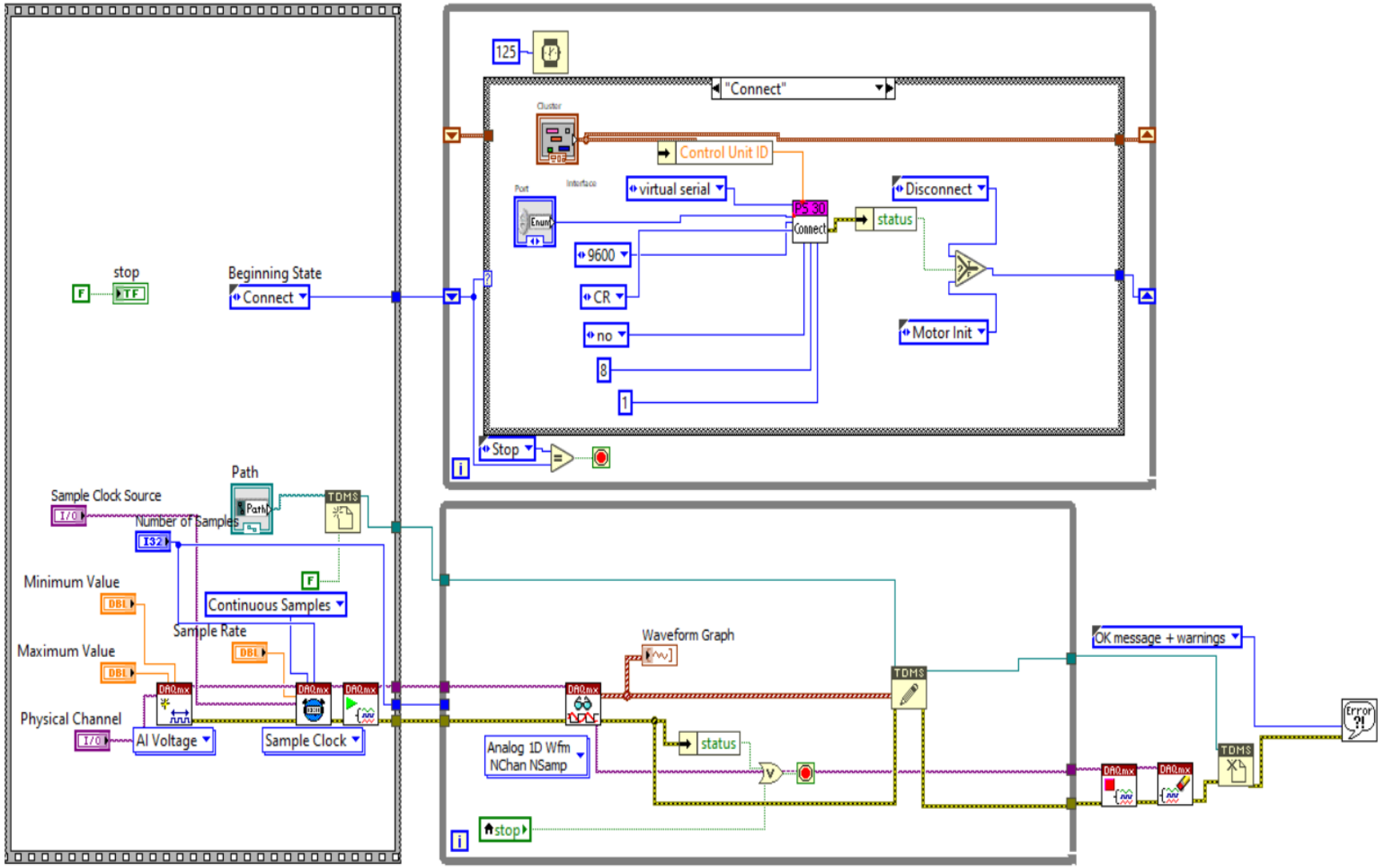
State Flow Diagram



Front panel


Turn Table Parameters
Control Unit ID
1
Port
COM2
Axis number
1
dValue in
1
No. of Turns
0 2 4 6 8 10
1,0101
Physical Channel
Dev1/ai0
Minimum Value
-10,00
Maximum Value
10,00
Number of Samples
100
Sample Rate (Hz)
10000,00
Sample Clock Source
OnboardClock
Volts
-9,1
-9,2
-9,3
-9,4
-9,5
-9,6
-9,7
-9,8
-9,9
-10
0
0,005
0,01
0,015
0,02
Time
Path
F:\SA Project 2021\StatemachineLabVIEW201...\TDMS adxrs300\Trial5 - Kopie.tdms

Block Diagram of VI



ADXRS 300

Sr No	Time	Turns	Angular Rate	Voltage Zero Value	Average Voltage Value	Sensitivity
	(sec)	(deg)	(deg/s)	(V)	(V)	(mV/(deg/sec))
1	5,066	-180	-35,531	2.56	2,375	5,21
2	2,530	-180	-71,146	2.56	2,191	5,19
3	3,403	360	105,789	2.56	3,104	5,14
4	2,599	-360	-138,515	2.56	1,843	5,18
5	1,784	360	201,794	2.56	3,598	5,14
6	1,032	-360	-348,837	2.56	0,762	5,15
7	5,027	180	35,807	2.56	2,743	5,11
8	8,370	-180	-21,505	2.56	2,447	5,25
9	12,538	180	14,356	2.56	2,632	5,02
10	37,400	-270	-7,219	2.56	2,521	5,40
11	3,200	90	28,125	2.56	2,703	5,08

Sensitivity of ADXRS 300

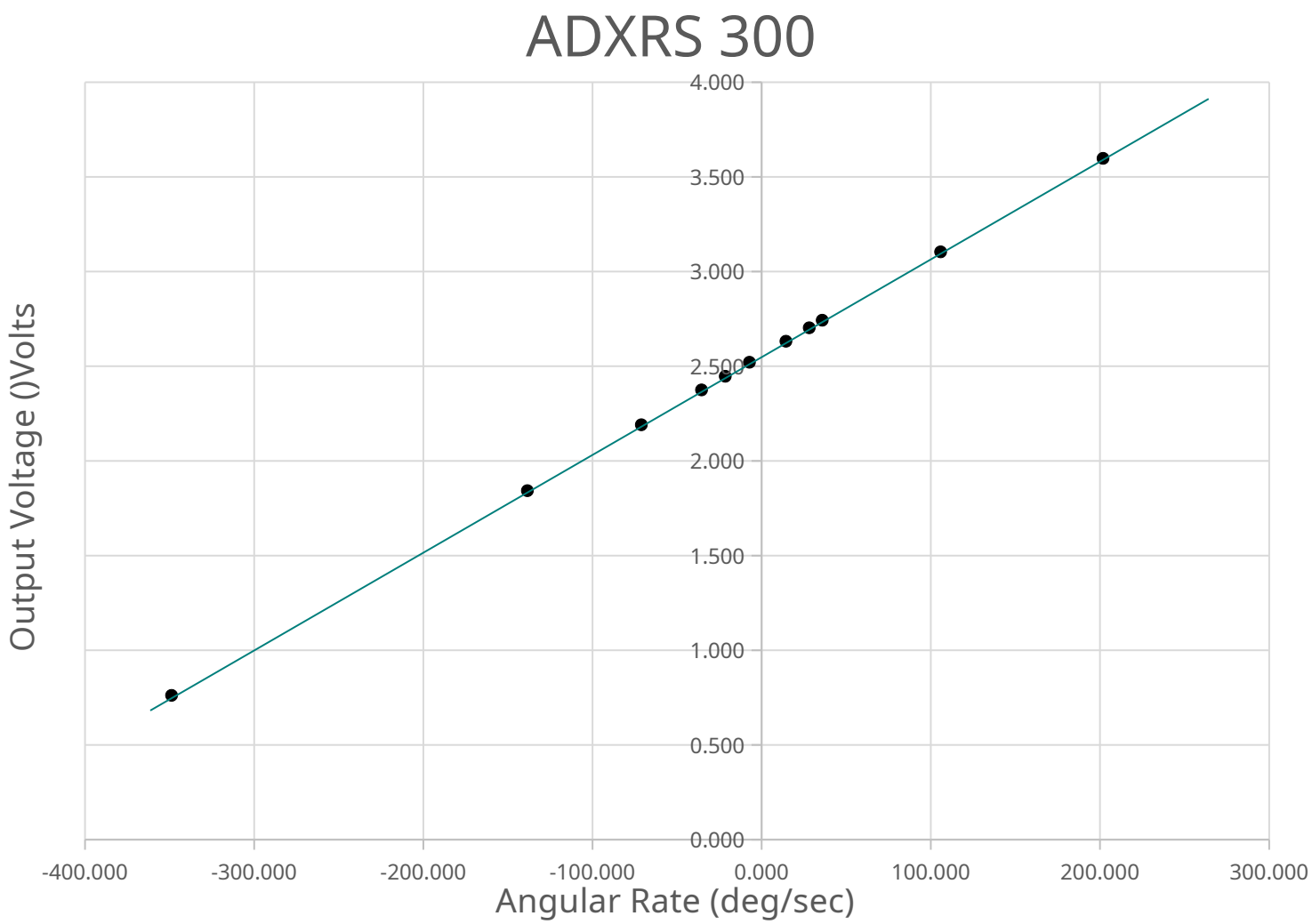
Specified:

Sensitivity
4,6 - 5,4 mV/(deg/sec)

Observed:

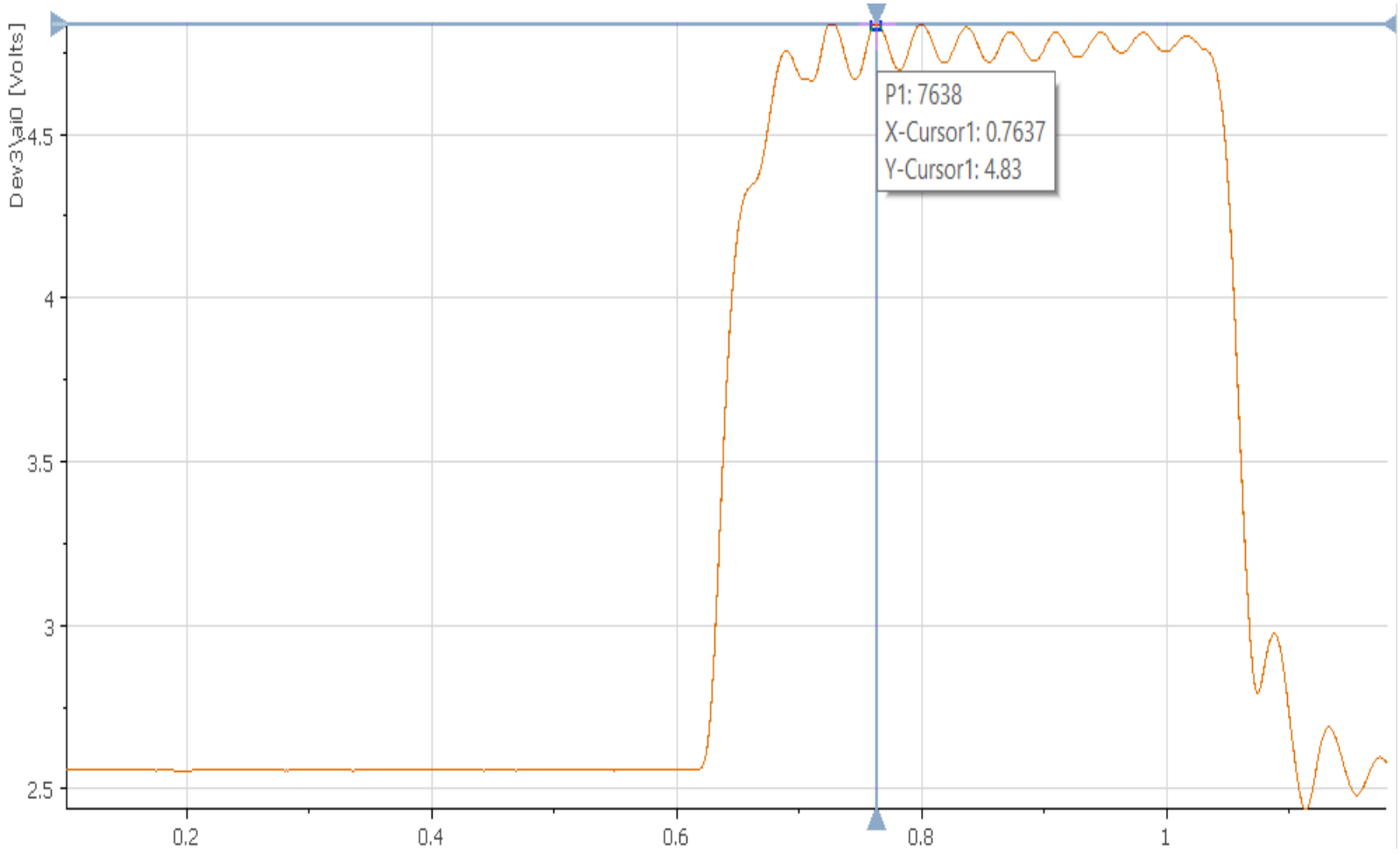
Average Sensitivity
5,17 mV/(deg/sec)

Voltage vs Angular Rate Graph - ADXRS 300



Saturation of ADXRS 300

Angular Rate = 400 deg/sec



Bosch SMG040

Sr no	Time	Turns	Angular Rate	Voltage Zero Value	Average Voltage Value	Sensitivity
	(sec)	(deg)	(deg/s)	(V)	(V)	(mV/(deg/sec))
1	5,009	180	35,935	2,38	2,62	6,68
2	2,925	180	61,538	2,37	2,78	6,66
3	3,339	-360	-107,817	2,34	1,59	6,96
4	2,576	360	139,752	2,34	3,291	6,80
5	1,578	-360	-228,137	2,34	0,86	6,49
6	1,134	360	317,460	2,34	4,41	6,52
7	5,019	-180	-35,864	2,31	2,06	6,97
8	8,338	180	21,588	2,31	2,458	6,86
9	12,495	-180	-14,406	2,33	2,23	6,94
10	37,550	270	7,190	2,32	2,37	6,95
11	3,140	-90	-28,662	2,34	2,147	6,73

Sensitivity of Bosch SMG040

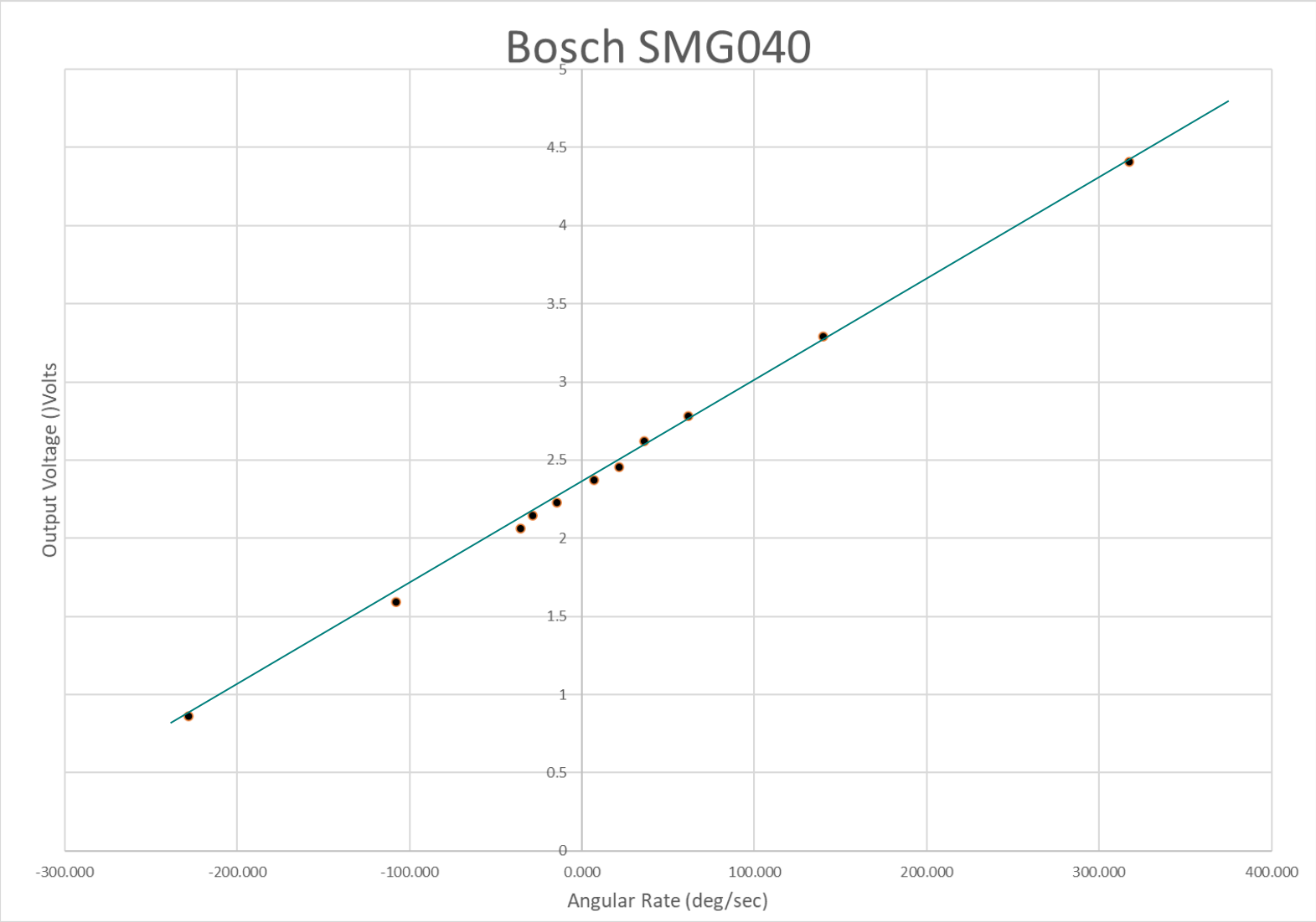
Specified:

Sensitivity
6,50 - 7,50 mV/(deg/sec)

Observed:

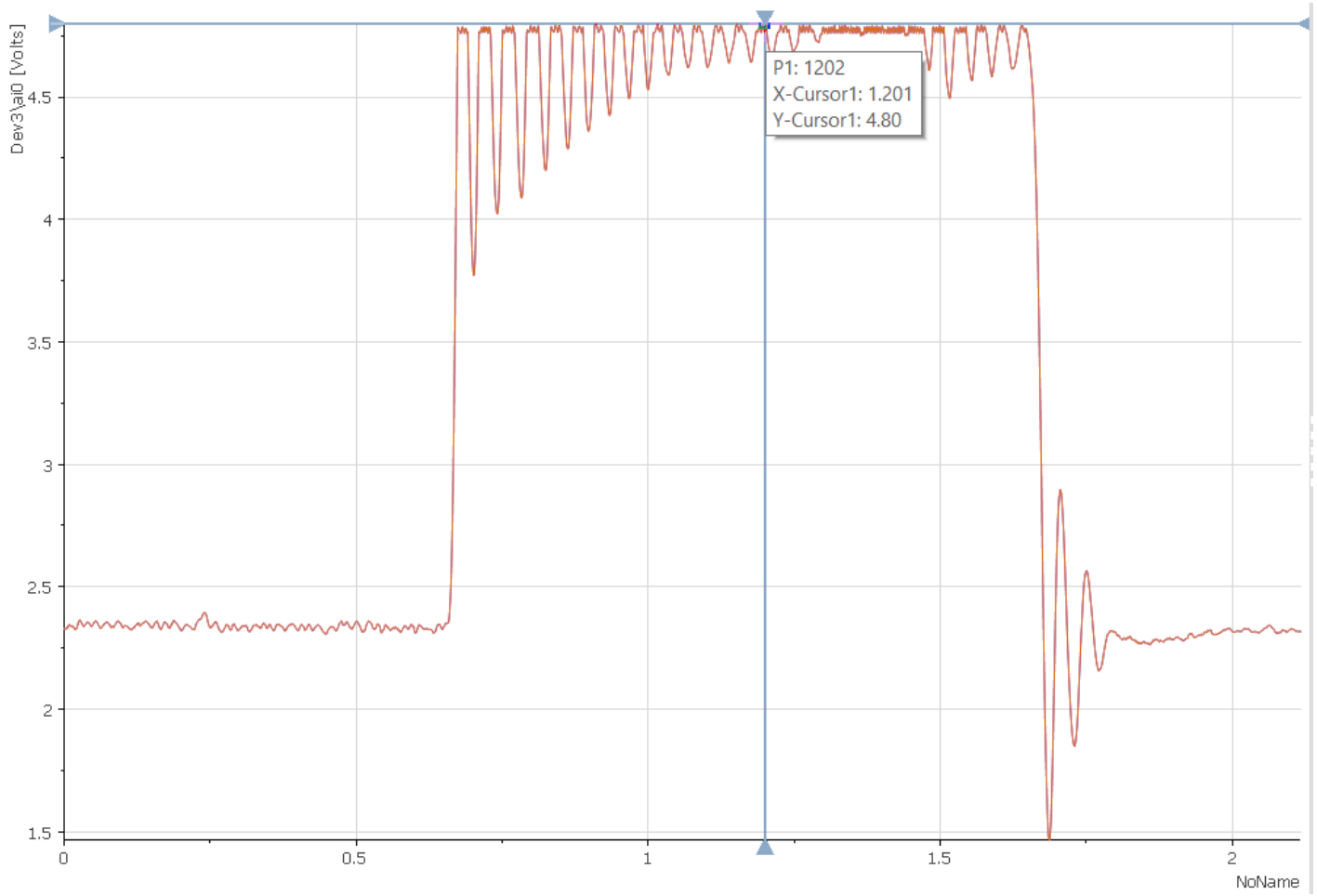
Average Sensitivity
6,78 mV/(deg/sec)

Voltage vs Angular Rate Graph - ADXRS 300



Saturation of Bosch SMG040

Angular Rate = 350 deg/sec



Conclusion

Property	ADXRS 300	SMG040
Maximum Rate (deg/sec)	350	300
Sensitivity (mV sec/deg)	5,17	6,78
Zero Value Voltage (V)	2,56	2,34

Thank you for your attention