Product Specification
AXISENSE-2-200, AXISENSE-2-207
±90 deg Tilt Sensor with CAN J1939 interface

Revision B1

Customer Acceptance

Company: _____

Address: _____

Date: _____

Name: _____

Function: _____

Signature: _____

TE Connectivity Sensors Germany GmbH
Hauert 13, D-44227 Dortmund, Germany

Contents

1 History

Rev.	Date	Purpose / Description of changes	Author
1	2013-06-06	Begin of creation, document not released yet	R. Stonies
2	2013-06-14	Preliminary release	R. Stonies
3	2014-05-13	Minor updates/corrections	R. Stonies
4	2014-07-07	CAN_L and CAN_H pins swapped	R. Stonies
5	2014-07-21	Revision of Tilt Angle Message	M. Kalinowski
6	2014-07-30	Source address changed	M. Kalinowski
7	2014-08-29	Source address changed	M. Kalinowski
A	2014-09-01	Release	M. Kalinowski
A1	2014-12-09	resolution specification corrected to protocol setting	R. Stonies
A2	2015-05-18	version incremented to match updated datasheet	R. Stonies
A3	2016-06-08	Information concerning master source address added	M. Kalinowski
A4	2016-10-19	Filter Level setting added	M. Kalinowski
A5	2017-08-03	ASCII changed to BCD	M. Kalinowski
A6	2017-09-22	Examples in 9.3 Tilt Angle modified	M. Kalinowski
A7	2017-09-28	- Reference to Application note changed - Humidity conditions added	M. Kalinowski
A8	2018-07-03	- CAN ID information added to each CAN message header - 9.6 updated	M. Kalinowski
A9	2019-01-14	Drawing update	F. Schwieger
B	2020-03-26	Transferred to new revisioning format	M. Kalinowski
B1	2020-11-03	- Mounting torque, Ingress Protection Class and CAN transmission rate added - Introduction of AXISENSE brand	M. Kalinowski

2 Applicable Documents

#	Document title	Originator	Description
1	TESS_AN-Serial_Number_AXISENSE	TE	Document on the interpretation and work with protocol serial numbers
2	114-160013	TE	Mounting Recommendations for Sensor Modules of AXISENSE-Series
3			
4			
5			
6			
7			
8			
9			

3 Description of the AXISENSE-2 Tilt Sensor

The tilt sensor is based on a micro machined accelerometer (MEMS). This sensor includes 3 acceleration sensing axes that form a nearly orthogonal 3d coordinate system. A microcontroller reads the sensor information as voltage signal. The amplified signal is digitized with a 12bit ADC using oversampling to increase resolution. Pitch and Roll data is calculated from sensor signals after digital temperature compensation is applied. Misalignment error is minimized by application of a full 3d corrective algorithm.

For this sensor module, a CAN 2.0B interface according to SAE J1939 is used. The protocol is detailed in this document.

TE part number	related drawing	description
AXISENSE-2-200 (TCPN: G-NSDOG2-200) AXISENSE-2-207 (TCPN: 10202069-00)	**220SM200_0001B1_TK**	Tilt Sensor, AXISENSE-Series Standard Assembly, floor mount

4 Mechanics and Connections

4.1 Mechanical Data

parameter	symbol	conditions	min	typ	max	unit
Weight	m			60		g
Width	d_{Width}			70.5		mm
Length	d_{Length}			45		mm
Height	d_{Height}			15		mm

4.2 Dimensions

The dimensions of the tilt sensor are depicted by Figure 4.2.1.

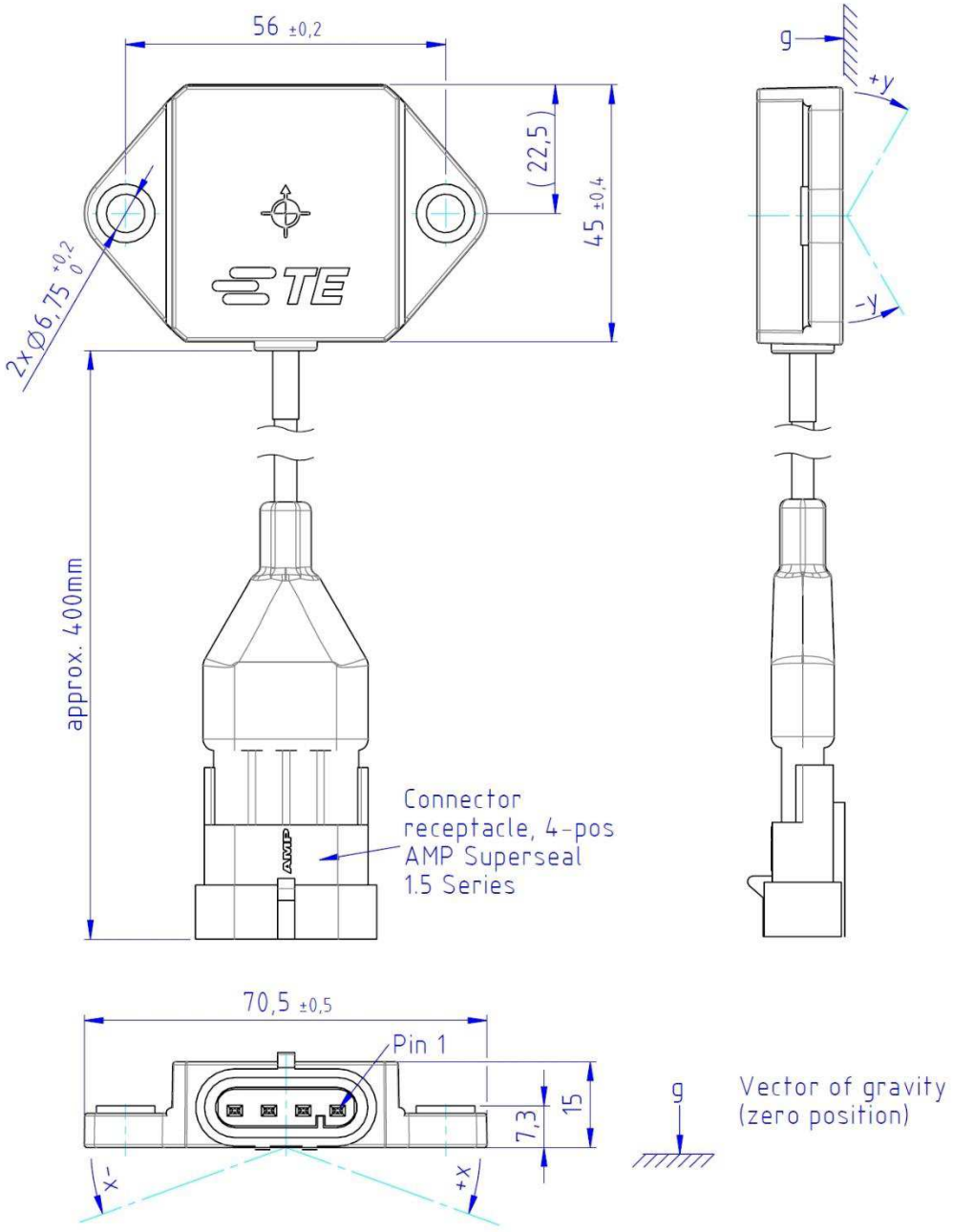

Figure 4.2.1: tilt sensor and connector, g arrow indicates acceleration of gravity in neutral/zero position

4.3 Connector

The tilt sensor has an AMP Superseal 1.5 series connector with 4 terminals. It mates with TE Connectivity part number 282088-1.
The pin assignment is described below.

pin	function	description	direction
1	Supply Voltage	8 – 30 V	in
2	Ground	0 V, ref. voltage	in
3	CAN_H	CAN high line	in/out
4	CAN_L	CAN low line	in/out

5 Absolute Maximum Ratings

CAUTION: Exceeding these values may permanently damage the device!

Parameter	Symbol	Conditions	Min	Type	Max	Unit
Input Voltage	V_{CC}	reference: GND	-33		33	V_{DC}
Operating Temperature	T_{OP}		-40		85	°C
Storage Temperature	T_{STO}		-40		85	°C
Operating Humidity	H_{OP}	>80 less than 40% of time		≤50	90	%RH
Storage Humidity	H_{STO}			≤40	60	%RH
Shock	a_{SHOCK}	non-repetitive 0.5 ms, powered			5000	g
Torque	M_{FIX}	mounting, M6 screws (also depends on strength category of screw)		10	15	Nm

TE is not responsible for identifying all limits of environmental impacts on reliability and sensor performance in application.

5.1 Definition of Absolute Maximum Ratings

Absolute maximum ratings are limiting values of permitted operation and should never be exceeded under the worst possible conditions either initially or consequently. If exceeded by even the smallest amount, instantaneous catastrophic failure can occur. And even if the device continues to operate satisfactorily, its life may be considerably shortened. Operation at an absolute maximum rating is permitted (although not desirable-even a short test is believed by some to cause incipient failure) but operation at two or more limits (i.e., output current and ambient temperature) almost always means that some other limit has been exceeded (in this instance, probably package power dissipation). In certain ICs that include an internal thermal shutdown, fault conditions will generate higher than permitted (steady-state) temperatures and activate device thermal shutdown circuitry. These fault conditions can be tolerated for short periods of time, but they will affect life expectancy and should be avoided.

6 Operating Conditions

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Operating Temperature	T_{OP}		-40		85	°C
Operating Humidity	H_{OP}	>80 less than 40% of time		≤50	90	%RH
Storage Humidity	H_{STO}			≤40	60	%RH
Ingress Protection Class		applies if proper mating connector attached to form sealing	IP67			
Angular Range		both axes	-90		90	deg

7 Electrical Characteristics

If not otherwise noted, 12 VDC supply voltage applied at an ambient temperature of 25 °C.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply voltage	Vcc		8	12 or 24	30	V
Supply current	I_{CC1}			20	30	mA
CAN speed	f_{CAN}			250		kbps
CAN transmission rate [1)]			10	40	255	ms
MTBF		calculated with Telcordia 2 for ground mobile at 50 °C permanent op. temperature		>4 * 10^5		h

[1)] The CAN transmission rate set option is only supported by sensor type AXISENSE-2-207.

8 Characteristics

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
Startup time	t_s	V_{CC} = 0 V to V_{CC} = 12 V transition				1	s
Temperature Offset Drift	T_{off}	$\varphi_x = \varphi_y$ = 0 deg [4)] -40 °C ≤ T ≤ 85 °C		-0.5	-0.4 < T_{off} < 0.4	0.5	deg
Accuracy I, [1)]	$A_{CC,<8°}$	$\lvert\varphi_x\rvert$ < 8 deg [4)] $\lvert\varphi_y\rvert$ < 8 deg		-0.2	-0.1 < $A_{CC,<8°}$ < 0.1	0.2	deg
Accuracy II, [1)]	$A_{CC,>8°}$	$\lvert\varphi_x\rvert$ > 8 deg [4)] $\lvert\varphi_y\rvert$ > 8 deg		-0.5	-0.4 < $A_{CC,>8°}$ < 0.4	0.5	deg
Resolution	Res				0.01		deg
Update Rate	f_u	independent of op. condition			100		Hz
Settling time, [3)]	t_{SET}	to 90 % of final reading		0.1	0.2	1	s
Cross sensitivity, [2)]	CCA					0.25	deg

1) Accuracy is verified by an end of line measurement after calibration without sensor module being removed in between. As the tilt sensor is designed to be fixed with M6 screws, there is some mechanical clearance that may lead to a small misalignment and offset. For some applications, it may be reasonable to implement an in-application offset or/and span correction to attain best overall accuracy.

2) CCA is defined as maximum difference between actual and expected angle on passive axis for whole angular range of active axis and full temperature range.

3) Depends on filter setting; for default configuration response time is 0.2s

4) φ_x = The sensor's x- angle.
φ_y = The sensor's y- angle.

9 Electrical Interface

The tilt sensor has a SAE J1939 CAN-compatible interface described in detail in the following section.
OEM adaption is basically possible.

9.1 Conventions

The tilt sensor complies with SAE J1939 CAN2.0B and uses a baud rate of 250kbps. Proprietary A (0xEF) and B (0xFF) portions of SAE J1939 are used. The 29-bit message identifiers can be formulated using the following scheme.

Bit Position	Description
28:26	Priority (6 is lowest; 0 is highest)
25:24	Always 0:0 for SAE J1939
23:16	Data Content (PF)
15:8	Data Content (PS)
7:0	Source Address of Tx Module

9.2 Source Addresses

The tilt sensor sends a onetime address claim message 500 – 750 ms after startup and upon request by the host. The following is currently defined.

Module	Source Address
Requestor (MA)	Various (except tilt sensor source address)
Tilt sensor (SA)	**AXISENSE-2-200:** 0xC2 **AXISENSE-2-207:** [0x80 - 0xF7]; 0xC0 (uninitialized)

9.3 Tilt Angle

Priority:	4	Source Address:	**SA**
Data Content (PF):	0xFF (Proprietary B)	CAN ID	0x10FF53(**SA**)
Data Content (PS):	0x53	Repetition Rate:	40 ms

Data	Byte	Function
X	0	X-Axis Tilt Reading x100 (Signed Word, LSB)
X	1	X-Axis Tilt Reading x100 (Signed Word, MSB)
X	2	Y-Axis Tilt Reading x100 (Signed Word, LSB)
X	3	Y-Axis Tilt Reading x100 (Signed Word, MSB)
X	4	Internal Temperature (Signed Byte)
X	5	Software Version (Major, Minor upper and lower nibble)
X	6	Data Status and Time Stamp
X	7	Error Codes

Description of Operation:

The tilt sensor broadcasts this message periodically to update the host module.

Data Definition

Data Bytes 0-1 — X-Axis Tilt Reading in hundredths of a degree
E*xample:*
Data Bytes 0, 1 are 0x64, 0x19 for +65.00 deg

Data Bytes 2-3 — Y-Axis Tilt Reading in hundredths of a degree
Example:
Data Bytes 2, 3 are 0xD8, 0xDC for -90.00 deg

Data Byte 4 — Internal Temperature in degrees Centigrade
Example:
Data Byte 4 is 0x55 for +85 °C
Data Byte 4 is 0xD8 for -40 °C

Data Byte 5 — *Software Version (Major bits 4-7; Minor bits 0-3 in hexadecimal; 0x3C for version 3.12 – decimal implied)*

Data Byte 6 — Data Status → lower nibble, bits 0-3
$0x0000_b$ During power up or when data is invalid
$0x0001_b$ Data available and valid
$0x0011_b$ Error (see Byte 7 error code for definitions)
$0xXX10_b$ Undefined Positional data in Bytes 0-5 are set to 0xFF, if status is invalid or undefined, but may be valid in error per Byte 7
Time Stamp → upper nibble, bits 4-7
$0xXXXX_b$ this number is incremented for every transmission to prevent a stagnant transmission, when $0x1111_b$ is reached, value rolls over to $0x0000_b$

Data Byte 7 — Error Codes (bit set = 1 when fault exists; cleared = 0 when no fault present).
For error codes refer to Table below.

9.3.1 Error Codes

Fault Topic	Bit	= 0	=1
EEPROM Error	0	Checksum Ok	Checksum Failure Byte 6 status = 11_b Positional and temperature data transmitted
Sensor Element Error (X-axis)	1	Normal Operation	Fault detected Byte 6 status = 11_b X-axis positional data set = 0xFFFF; remaining positional and temperature data transmitted
Sensor Element Error (Y-axis)	2	Normal Operation	Fault detected Byte 6 status = 11_b Y-axis positional data set = 0xFFFF; remaining positional and temperature data transmitted
Supply Voltage Detection	3	Supply Voltage ≥ 8 V	Supply Voltage < 8 V Byte 6 status = 11_b Positional and temperature data transmitted
Overvoltage Error	4	Supply voltage ≤ 28 V	Supply Voltage > 28 V Byte 6 status = 11_b Positional and temperature data transmitted
Overtemperature Error	5	PCBA temperature ≤ 90 °C	Temperature > 90 °C Byte 6 status = 11_b Positional and temperature data transmitted
Not defined	6	Not defined	Not defined
Not defined	7	Not defined	Not defined

9.4 Tilt Sensor Address Claim

Priority:	6	Source Address:	**SA**
Data Content (PF):	0xEE	CAN ID	0x18EEFF(**SA**)
Data Content (PS):	0xFF	Repetition Rate:	Once after startup

Data	Byte	Function
X	0	Serial Number (LSB)
X	1	Serial Number
X	2	Serial Number (MSB), Manufacture Code (LSB)
X	3	Manufacture Code (MSB)
00	4	ECU Instance, Function Instance
88	5	Function
00	6	Reserved
30	7	Vehicle System Instance, Industry Group, Arbitrary Address Claim

Description of Operation:
The tilt sensor broadcasts this message per J1939-81, 4.2.2.1 with byte definitions as follows:

Data Definition

Data Byte 0	Serial Number, Bits 0 - 7
Data Byte 1	Serial Number, Bits 8 - 15
Data Byte 2, Bits 0-4	Serial Number, Bits 16 - 20
Data Byte 2, Bits 5-7	Manufacturer Code, Bits 0 - 2
Data Byte 3	Manufacturer Code, Bits 3 - 10
Data Byte 4, Bits 0-2	ECU Instance = 0
Data Byte 4, Bits 3-7	Function Instance = 0
Data Byte 5	Function = 136 (Slope Sensor)
Data Byte 6, Bit 0	Reserved = 0
Data Byte 6, Bits 1-7	Vehicle System = 0 (Non-Specific System)
Data Byte 7, Bits 0-3	Vehicle System Instance = 0
Data Byte 7, Bits 4-6	Industry Group = 3 (Construction equipment)
Data Byte 7, Bit 7	Arbitrary Address Claim = 0 (Not Arbitrary)

For details concerning serial number format see **TESS_AN-Serial_Number_AXISENSE**.

9.5 Tilt Sensor Address Claim Request

Priority:	6	Source Address:	**MA**
Data Content (PF):	0xEA	CAN ID	0x18EA(**SA**)(**MA**)
Data Content (PS):	**SA**	Repetition Rate:	As controls dictate

Data	Byte	Function
00	0	PGN (LSB)
EA	1	PGN
C2	2	PGN (MSB)

Description of Operation:
The tilt sensor broadcasts the “Tilt sensor Address Claim” message upon receiving this message per J1939-21, 5.4.2 with byte definitions as follows:

Data Definition

Data Byte 0	PGN – Requestor Source Address
Data Byte 1	PGN (PF) – 0xEA (Address Claim)
Data Byte 2	PGN (PS) – 0xC2 (Chassis Tilt Sensor)

9.6 Master Control Commands – Chassis Tilt Sensor

Attention: Applicability depends on part number!

Priority:	4	Source Address:	**MA**
Data Content (PF):	0xFF (Proprietary B)	CAN ID	0x10FF54(**MA**)
Data Content (PS):	0x54	Repetition Rate:	On Request

Byte	Function
0	Command Byte
1	As defined for Command Byte
2	As defined for Command Byte
3	As defined for Command Byte
4	As defined for Command Byte
5	As defined for Command Byte
6	As defined for Command Byte
7	As defined for Command Byte

Description of Operation:

The Master shall request the S/N of the Tilt Sensor. The intent is to assign different source addresses to the Chassis Tilt Sensor so that multiple sensors can operate on one CAN Bus. The first byte is the Command Byte specifying the meaning for the rest of the message. The rest of the data depends on the Command Byte as detailed below.

Request for Sensor S/N

Data Byte 1	0x00 (commands sensor to respond with Sensor Serial Number message)
Data Bytes 2-8	0xFF; not used

Request for Source Address Change (only applicable for AXISENSE-2-207)

Data Byte 1	0x01 (commands sensor with specified S/N to change SA to given value; this SA is stored in the sensor's non-volatile memory)
Data Bytes 2	New Source Address in hexadecimal
Data Bytes 3-8	Serial Number in BCD

Request for Wait

Data Byte 1	0x02 (commands sensor to send nothing until they get a "GO" message. This includes no response to a subsequent request for serial number commands or address claim)
Data Bytes 2-7	Not used

Request for Repetitive Transmission of Data

Data Byte 1	0x03 ("GO" message – commands the sensor to begin repetitive transmission of data)
Data Bytes 2-7	Not used

Request for Transmission Rate Change

Data Byte 1	0x04 (commands sensor with specified S/N to change the repetitive data transmission rate to given value; this transmission rate is stored in the sensor's non-volatile memory)
Data Bytes 2	New Transmission Period in milliseconds in hexadecimal (e.g., 20 ms = 0x14)
Data Bytes 3-8	Serial Number in BCD

Request for Return to Uninitialized Source Address (only applicable for AXISENSE-2-207)

Data Byte 1	0x09 (commands sensor with specified SA and S/N to change its SA currently stored in the sensor's non-volatile memory to the uninitialized SA = 0xC0)
Data Bytes 2	Current Source Address in hexadecimal of target sensor
Data Bytes 3-8	Serial Number in BCD of target sensor

Request for Filter Level Change (only applicable for AXISENSE-2-207)

Data Byte 1	0x10 (commands sensor with specified S/N to change filter level to given value; value must be between 0x00 and 0x0A; this filter level is stored in the sensor's non-volatile memory)
Data Bytes 2	New Filter Level in hexadecimal
Data Bytes 3-8	Serial Number in BCD

9.6.1 Sensor Serial Number

This message gets transmitted in response to Master Command S/N request.

Priority:	4	Source Address:	**SA**
Data Content (PF):	0xFF (Proprietary B)	CAN ID	0x10FF52(**SA**)
Data Content (PS):	0x52	Repetition Rate:	Response

Data	Byte	Function
X	0	Serial Number in BCD (set = 00); populate extra positions with zero
X	1	Serial Number in BCD (set upper nibble=0; upper digit year of production→lower nibble; year of production; ex. 14 for 2014; AA)
X	2	Serial Number in BCD (set upper nibble=0; upper digit year of production→lower nibble; year of production; ex. 14 for 2014; AA)
X	3	Serial Number in BCD (lower digit of calendar week→upper nibble; reserved X→lower nibble)
X	4	Serial Number in BCD (most significant sequence digits; upper CC)
X	5	Serial Number in BCD (least significant sequence digits; lower CC)
X	6	Software Revision Major Number in BCD
X	7	Software Revision Minor Number in BCD

Sensor Communication Example:

After power-up, the Master requests serial number information:
Message Sent by Master (**MA** = 0xD4):
0x10FF54D40000000000000000+CRC…
Response from Uninitialized Sensor:
0x10FF52C00001435000560105+CRC…
– Sensor is unassigned (not calibrated; assignment occurs during calibration) & is S/N = 143500056, SW Rev = 1.5 decimal is implied)
The ground control assigns sensor (S/N 143500056) the ID of 0xC1
Message Sent:
0x10FF54D401C1000143500056+CRC…
The Master verifies sensor 143500056 has been successfully updated:
Message Sent by Master:
0x10FF54D40000000000000000+CRC…
Response from Sensor:
0x10FF52C10001435000560105+CRC…
The Master sends the “wait for GO” command to the Sensor until conditions are clear to transmit.
Message Sent by Master:
0x10FF54D40200000000000000+CRC…
The Master sends the GO message and the sensor responds with data every 40 ms
Message Sent by Master:
0x10FF54D40300000000000000+CRC…
Sensor responds with: (@ 40 ms intervals) 0x10FF53C1B400F20F00000000+CRC…

A similar exchange shall apply for changing the transmission rate, except command 0x04 rather than 0x01 applies.

10 Qualification and Test

10.1 Vibration

The AXISENSE-2 tilt sensor survives exposure to vibration according to Figure 10.1.1 and Figure 10.1.2. Duration of the test has been 8h each Cartesian axis.

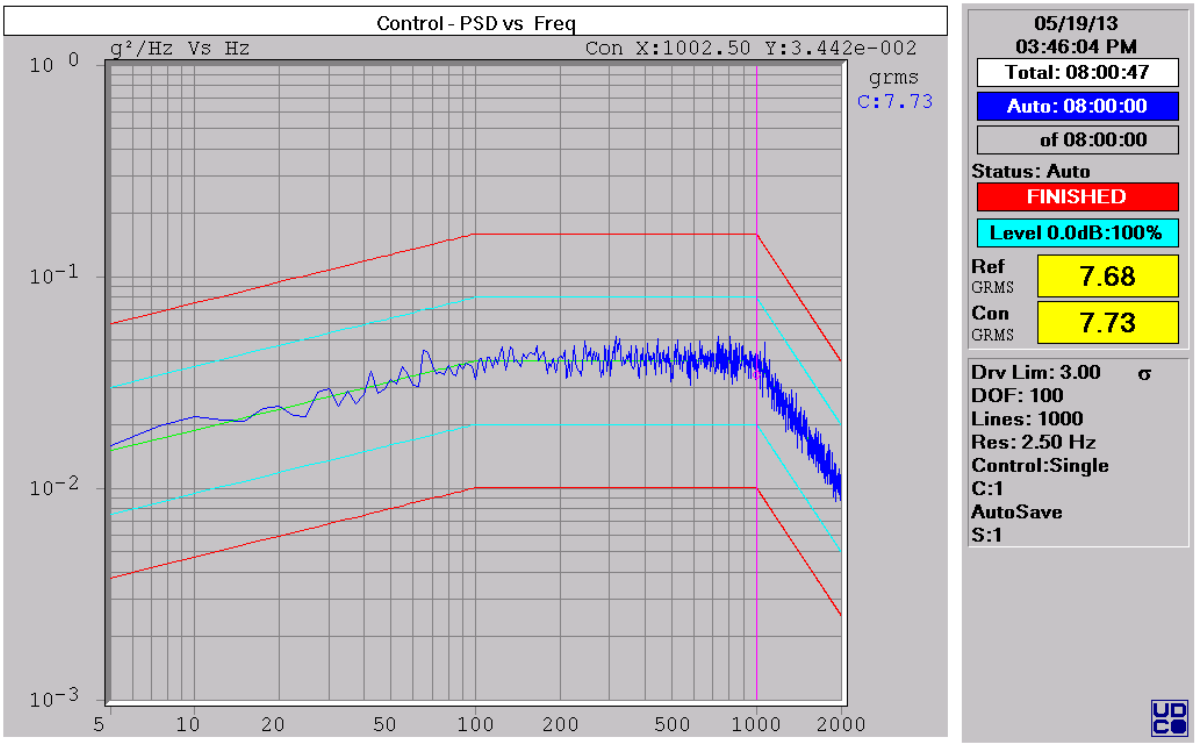

Figure 10.1.1: Random vibration profile used for testing, green trace: ideal excitation, blue trace: actual excitation during test

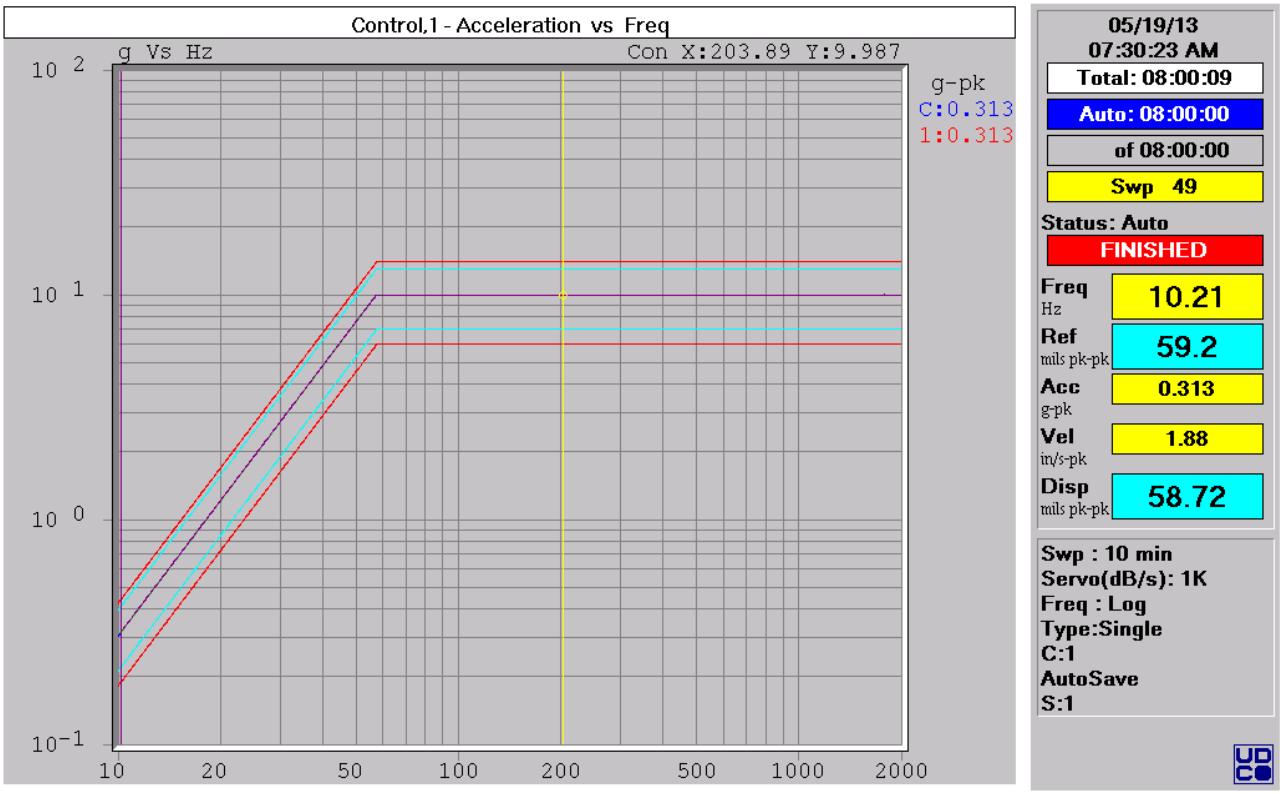

Figure 10.1.2: Sine vibration profile for testing, purple trace: ideal excitation

10.2 Drop

The unit withstands a drop of height 1m onto a concrete surface.

10.3 End of Line Test

Each unit is end of line tested. After calibration, each tilt sensor is tested at different angles at 25 °C (±5 °C).

10.4 Statistical Test

On demand of the customer, a statistical temperature test can be offered.

10.5 Material Testing

All materials used in the process are released by checking the corresponding supplier certificates if available. A regular material analysis from an independent laboratory will not be scheduled.

10.6 Electromagnetic Compatibility

Sensor complies with:

EN 55011 :2009+A1 :2010, Group1, Class B including:

CISPR 11:2009, modified + A1:2010, Group 1, Class B

EN 61326-1:2006 including:

IEC 61000-4-2:2008
IEC 61000-4-3:2006 + A1:2007 + A2:2010
IEC 61000-4-4:2004 + Cor.1:2006 + Cor.2:2007 + A1:2010
IEC 61000-4-5:2005
IEC 61000-4-6:2008
Performance Criteria EN 61326-1:2006, Table 3

11 RoHS and REACH

The tilt sensor complies with RoHS directive 2011/65/EU with addendum 2015/863/EU (“RoHS III”) and REACH 1907/2006 requirements.

12 Additional Information

12.1 Ordering Information

PART NUMBER	SHORT DESCRIPTION
AXISENSE-2-200 (TCPN: G-NSDOG2-200)	Dual axis tilt sensor, range +/-90 deg, Vcc 8 – 30 VDC, J1939 CAN Interface, **Source address 0xC2**
AXISENSE-2-207 (TCPN: 10202069-00)	Dual axis tilt sensor, range +/-90 deg, Vcc 8 – 30 VDC, J1939 CAN Interface, **Source address range [0x80 – 0xF7**]

NORTH AMERICA	EUROPE	ASIA
TE Connectivity Sensors, Inc. 1000 Lucas Way Hampton, VA 23666 United States Phone: +1-800-745-8008 Fax: +1-757-766-4297 Email: customercare.hmpt@te.com Web: www.te.com	TE Connectivity Sensors Germany GmbH Hauert 13 D-44227 Dortmund Germany Phone: +49-(0)231-9740-0 Fax: +49-(0)231-9740-200 Email: customercare.dtmd@te.com Web: www.te.com	TE Connectivity Sensors China Ltd. No. 26, Langshan Road High-tech Park (North) Nanshan District, Shenzhen 518057 China Phone: +86-755-33305088 Fax: +86-755-33305099 Email: customercare.shzn@te.com Web: www.te.com