Specification
AAL-Series
Inclinometer Module

Version 1.7

AAL-Series Inclinometer

Table of Contents

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1 History

Ver.	Date	Purpose	Author
1.0	2005-03-21	First draft	K. Schink
1.1	2005-04-18	Chapter 6: Accuracy defined	K. Schink
1.2	2005-09-28	Chapter 6: different values added	K. Schink
1.3	2005-12-22	Chapter 6: Acc3 and footnote (5): Temperature changed from -25℃ to -40℃	K. Schink
1.4	2008-09-15	Completion new part no.	M. Zürn
1.5	2011-12-13	Update drawing Fig 3.1	M. Zürn
1.6	2012-07-16	Add options, layout	M. Zürn
1.7	2017-03-09	Add options, layout	M. Zürn

2 General Information

The AAL-series are inclinometer modules with a biaxial inclination sensor and integrated temperature sensor on board. The series offers a measurement range of ± 2° up to ± 30°.
It consists of two basic inclination sensor cells, works on a conductance measurement principle and their complete electronic biasing and readout, which is designed for active suppression of scale factor drift. In addition there is a temperature sensor and an EEPROM on board, which is used for storage of following calibration values:

- Sensor type
- Serial No.
- Measured value of reference voltage
- Sensor specific constants for curve linearization

2.1 Functional Block Diagram

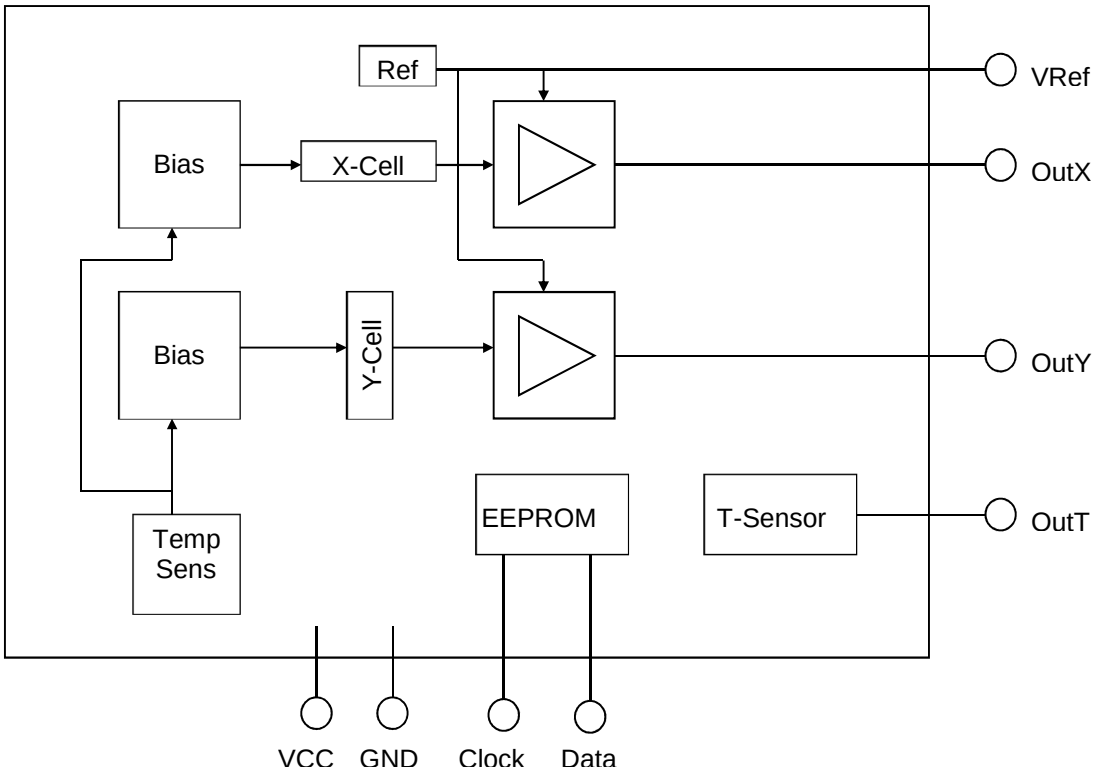

Fig. 2.1.1: Block Diagram of AAL-series

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2.2 Part Number

This products can be ordered by following part numbers:

Type	Measurement angle	Output	Supply voltage	Order number
NS-2/AAL2-UDD	- 2°... + 2°	Voltage,T-signal, e²-prom	+5 VDC	G-NSAAL-006
NS-5/AAL2-UDD	- 5°... + 5°	Voltage,T-signal, e²-prom	+5 VDC	G-NSAAL-017
NS-10/AAL2-UDG	- 10°... +10°	Voltage,T-signal, e²-prom	+5 VDC	G-NSAAL-010
NS-15/AAL2-UDG	- 15°... +15°	Voltage,T-signal, e²-prom	+5 VDC	G-NSAAL-018
NS-30/AAL2-UDN	- 30°... + 30°	Voltage,T-signal, e²-prom	+5 VDC	G-NSAAL-019

3 Mechanics and Connections

3.1 Mounting

This inclinometer is mounted parallel to the x-y-plane, reference is the base plate.
To minimize the mechanical offset, please use `reference edge ´of the board (Fig. 3.4.1)

3.2 Label information

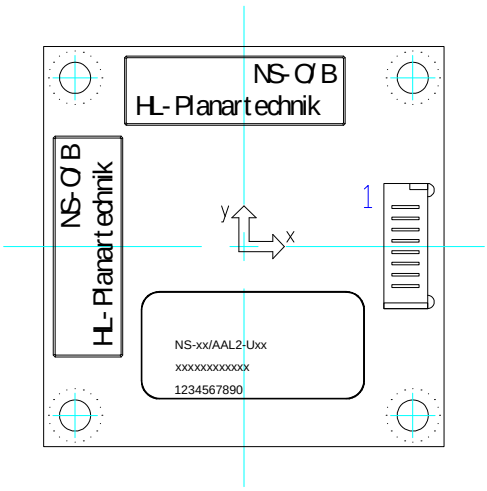

Fig. 3.2.1 top view, position of cells and labels

Parts will be marked with two labels glued on the top of the inclinometer basic cells.
The labels contain following information:

Model:	NS-xx/AAL2-xxx
Meas version:	internal HW version
Serial No.:	YYWWNNNNN

YYWWNNNNN consists of nine digits. YY shows the year of production (2010=10), WW the week of the production and NNNNN the number for identifying.

3.3 Mechanical data

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Weight				20	25	g
Dimensions		W x D x H		45 x 45 x 15 (21)		mm

3.4 Mechanical Dimensions

The mechanical dimensions of the board in [**mm**].

The board is made of FR4-Epoxy with a thickness of 1.5 +/-0.15 mm.

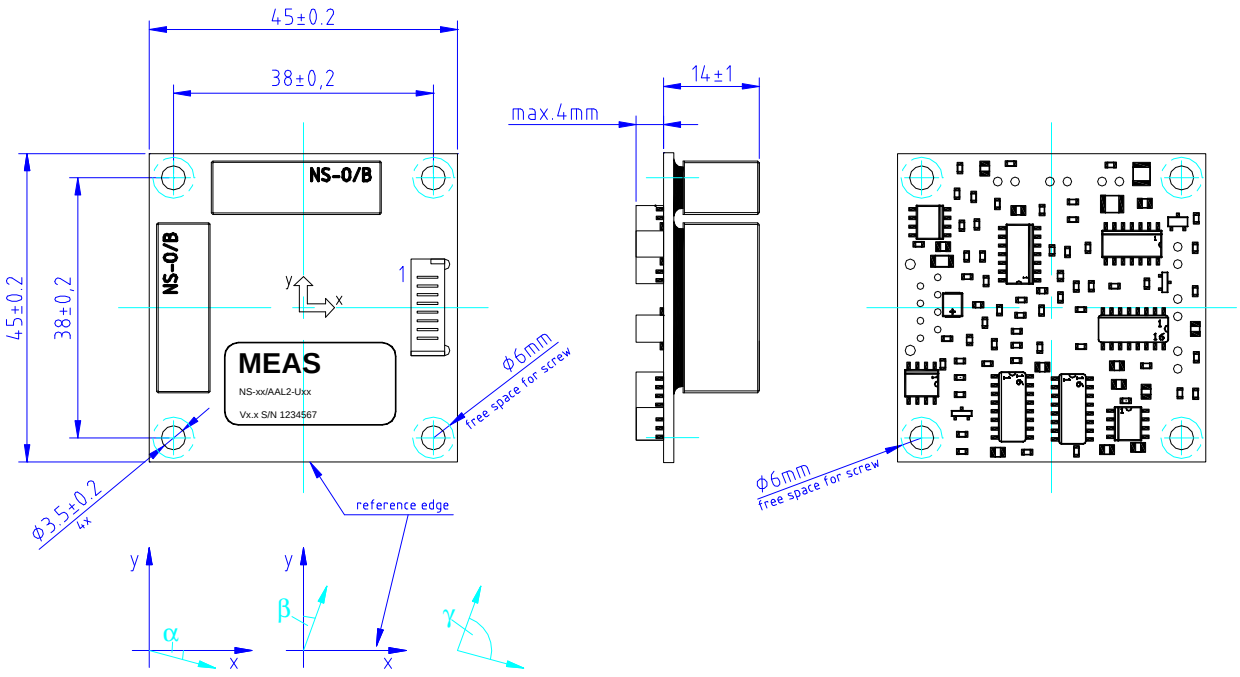

Fig. 3.4.1 Top view, cross sectional and bottom view (from left to right) of the board with dimensions and placement of the connector

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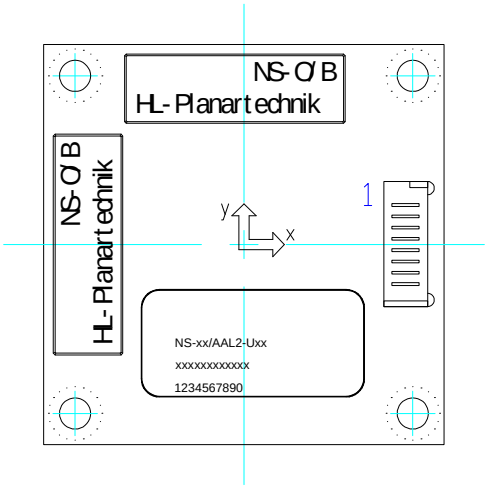
3.5 Terminal Connections



Following Connector has to be used: Company Molex, type Picoflex PF-50 1,27mm (8 contacts).

Pin	Name	Description	Type
1	Vcc	Positive power supply	Supply, Input
2	Vref	Reference potential	Output
3	GND	Ground (negative supply voltage)	Supply, Input
4	Out X	Output signal X axis	Output
5	Out Y	Output signal Y axis	Output
6	Out T	Output Signal Temperature in use	Output
7	Data	IIC like bus for EEPROM	Input/Output
8	Clock	IIC like bus for EEPROM	Input

4 Absolute Maximum Ratings

CAUTION: Exceeding these values may destroy this part!

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
Supply Voltage	Vcc	Measured versus GND		-0.3		+5.5	V
Storage temperature	Tst			-40		+85	℃
Inclination angle in x and y	φmax	Do not exceed maximum angle while under power supply for extended period of time. Irreversible damage may occur.	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN	-10 -10 -25 -25 -60		+10 +10 +25 +25 +60	°

5 Operating Conditions

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
Ambient temperature	Tamb			-40		+85	℃
Supply voltage	Vcc	Measured versus GND		4.75		5.25	V
Operation Range	φop		NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN	-2 -5 -10 -15 -30		+2 +5 +10 +15 +30	°
Resistive Output Load	R load	Applied between OutX (OutY, Ref, OutT) and GND		10k			Ohm
Capacitive Output Load	C load	Applied between Out X (OutY, Ref, OutT) and GND				390	pF
Humidity	Rhop	Operation				80	%

6 Sensor Characteristics

If not otherwise noted, 25℃ ambient temperature, 5V supply voltage were applied. Output Signals are always measured versus GND. Measurement were done using one stepping motor drive for changing the inclination of the module and a rotary drive for selecting the axis.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply current	Icc				15	mA
Output voltage range		Out X(Out Y, Out T) measured vs GND	0.3		Vcc-0.3	V
Reference	Vr		2.45		2.55	V
Temperature Sensor Scale Factor	SensT	-10℃ < Tamb < 50℃ (1) -40℃ < Tamb < -10℃, 50℃ < Tamb < 85℃ (1)	28 26	30 30	32 34	mV/℃
Temperature Sensor Offset	UoffT	Tamb = 0℃ (1)	1.3	1.55	1.8	V

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Temperature Sensor Accuracy	AccT	-10℃ < Tamb < 50℃ (2) -40℃ < Tamb < -10℃, 50℃ < Tamb < 85℃ (2)		-1,5 -3		+1,5 +3	℃
Slope	Slopex, Slopey	Tamb=25℃, (3)	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN	0.60 0.24 0.135 0.090 0.045	0.75 0.30 0.150 0.115 0.055	0.90 0.36 0.165 0.135 0.065	V/°
Offset	Voffx, Voffy	Tamb=25℃, inclination x = 0°, y = 0°	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN	Vr-0.5 Vr-0.2 Vr-0,15 Vr-0,12 Vr-0,08		Vr+0.5 Vr+0.2 Vr+0,15 Vr+0,12 Vr-0,08	V
Temperature drift Offset	TVoffx1, TVoffy1	-10℃<Tamb<50℃, (4)	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN	-0.030 -0,012 -0,010 -0,008 -0,008		0.030 0,012 0,010 0,008 0,008	V
Temperature drift Offset	TVoffx2, TVoffy2	-40℃<Tamb<85℃, (4)	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN	-0.040 -0,015 -0,012 -0,010 -0,010		0.040 0,015 0,012 0,010 0,010	V
Temperature coefficient drift Sensitivity	TcSensx, TcSensy	-40℃<Tamb<85℃, (5)	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG	-250		250	ppm/K
			NS-30/AAL2-UDN	-450		450	
Non linearity	NonLin1	At inclination -1°to +1°, (6) At inclination -2°to +2°, At inclination -5°to +5°,	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG	-0.75 -0.75 -1.5		+0.75 +0.75 +1.5	% FS
Non linearity	NonLin2	At inclination -2°to +2°, (6) At inclination -5°to +5°, At inclination -10°to +10°	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG	-1.5 -1.5 -3		+1.5 +1.5 +3	% FS
Angle between ref.edge –90° and x-cell	Alpha	See Fig. 3.4.1		-1		1	°
Angle between ref.edge and y-cell	Beta	See Fig. 3.4.1		-1		1	°
Orthogonality	Gamma	See Fig. 3.4.1		89		91	°
Accuracy1	Acc1	Tamb=25℃ (7)	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN		0.02 0.03 0.06 0.10 0.20	0.03 0.04 0.10 0,15 0,30	°
Accuracy2	Acc2	-10℃<Tamb<50℃ (7)	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN			0.04 0.06 0.12 0.18 0.50	°

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Accuracy3	Acc3	-40℃<Tamb<85℃ (7)	NS-2/AAL2-UDD NS-5/AAL2-UDD NS-10/AAL2-UDG NS-15/AAL2-UDG NS-30/AAL2-UDN			0.08 0.12 0.25 0.30 1.10	°
Settling Time to 1%	Ts	5 °Step, 25℃	NS-5/AAL2-UDD			1	s

(1) Temperature Sensor Scale Factor and Temperature Sensor Offset are defined by linear Regression of OutputSignalT(Temperature)
with 3 data sets (Temperature= -10℃, 20℃, 50℃ re sp. Temperature= -40℃, 20℃, 85℃)

(2) Temperature Sensor Accuracy is defined by :
AccT = Temperature – (OutputSignalT(Tamb) – UoffT) / SensT

(3) Slope is defined by Difference of signals for angle of φopmax and φopmin in x (y) divided by the difference of φopmax and φopmin
for example slopex at NS-5/AAL2-UDD: (OutX(+5°) – OutX(-5°)) / 10°

(4) Temperature drift Offset is defined by:
TVoff = Voff(Tamb)-Voff(25℃)

(5) Temperature coefficient drift Sensitivity is defined by linear regression of Sensitivity (Temperature) with 6 datasets (temperature = -40℃, -25℃, 0℃, 25℃, 50℃, 85℃)

(6) Non linearity is defined by :
NonLinX = 100 * (OutputSignal(Inclination) – Voff – Inclination * Sens) / OutputRange
NS-2/AAL2-UDD: OutputRange = OutputSignal(2°) –Outp utSignal(-2°)
NS-5/AAL2-UDD: OutputRange = OutputSignal(5°) –Outp utSignal(-5°)
NS-10/AAL2-UDG: OutputRange = OutputSignal(10°) –Ou tputSignal(-10°)

(7) Accuracy is defined by :
Resulting error of the inclination, calculated with the output signals Out X (resp. Out Y). The calculation has to be done as described in NSxxAAL2UDx_AppNote_V1_4.pdf by using the calibration data contained in the EEPROM.

7 Test Requirements

7.1 100% Series Test

100% of delivered pieces were measured at 7 [13] inclinations on X-axis and Y-axis in order to determine corresponding values for Slopex, Slopey, alpha, beta, gamma , Voffx ,Voffy and VoutT at one temperature in the range of 18℃ to 30℃. The corresponding parameter for the angle-computing is written in the EEPROM.
In the second step the sensors were measured at different 7 [13] inclinations on X-axis and Y-axis. With the readout from the EEPROM the angles were computed and the accuracy Acc1 was tested.

	1. measurement	2. measurement
NS-2/AAL2-UDD	-2.4, -1.6, -0.8, 0, 0.8, 1.6, 2.4	-2, -1.2, -0.4, 0, 0.4, 1.2, 2
NS-5/AAL2-UDD	-5.4, -3.6, -1.8, 0, 1.8, 3.6, 5.4	-4.5, -2.7, -0.9, 0, 0.9, 2.7, 4.5
NS-10/AAL2-UDG	-10.8, -7.2, -3.6, 0, 3.6, 7.2, 10.8	-10, -5.4, -1.8, 0, 1.8, 5.4, 10
NS-15/AAL2-UDG	-15, -13.5, -12, -10.5, -7, -3.5, 0, 3.5, 7, 10.5, 12, 13.5, 15	-15.5, -14.25, -12.75, -11.25, -8.75, -1.75, 0, 1.75, 8.75, 11.25, 12.75, 14.25, 15.5
NS-30/AAL2-UDN	-30, -25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25, 30	-31, -27.5, -22.5, -17.5, -12.5, -2.5, 0, 2.5, 12.5, 17.5, 22.5, 27.5, 31

7.2 Statistical Test

Four (two) pieces of each fabrication lot between 51 and 160 (1 and 50) were tested at five temperatures:

-25℃, 0℃, 25℃, 50℃, 85℃
Following values were measured respectively calculated and checked:

Voffx, Voffy, Slopex, Slopey, NonLin1x, Nonlin1y, NonLin2x, NonLin2y, TVoffx, TVoffy, TcSensx and TcSensy, Acc3

8 EMC

Due to the use of these modules for OEM application no CE declaration can be given.

Especially line coupled disturbances like surge, burst, HF etc. cannot be filtered on the module due to the low board area and low price feature. On the board is no protection circuit against reverse polarity or over voltage implemented.

The module will be designed using capacitors for blocking and ground plane areas in order to prevent wireless coupled disturbances as good as possible.

9 Packaging for Delivery

ESD safe package “Cortronic Versandbox”, company “ratioform”, type CVB 2 (250x191x38 mm^3, 20 pieces) or CVB 3 (250x191x64 mm^3, 40 pieces) or 65-TVS (84 pieces) or other type were used for the delivery of the product.

10 Additional Information

10.1 Ordering Information

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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