Instruction Manual
AAL-Series
Inclinometer Module

Version 1.6

AAL-Series Inclinometer

Table of Contents

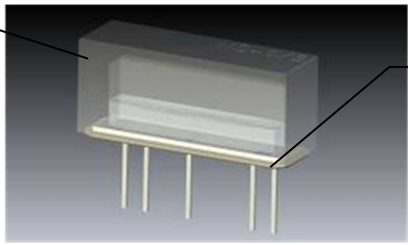
1 History

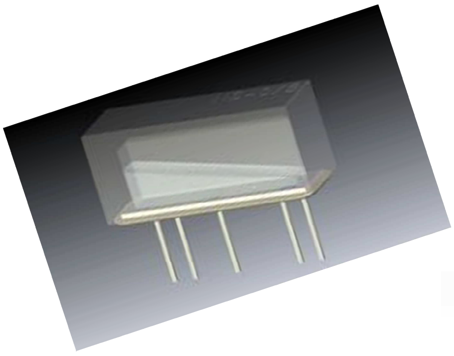
Ver.	Date	Purpose	Author
1.0-1.2		generated in cooperation with the first project details	J.Kube
1.3	2005-03-02	- 2° and 5° Versions added - History and Contents added - Table 2.1: Pin 6, Info “not used” removed Signal Definition for Pin 7 and 8 corrected - Chapter 4 modified - Chapter 5.2: Offset correction for Y revised	K.Schink
1.3_Erw_15-30Grd	2005-09-06	EEPROM table for 15 and 30° added	K.Schi nk
1.4	2010-07-01	Additional	M.Zürn
1.5	2012-07-16	Add options, layout	M.Zürn
1.6	2017-03-09	Add options, layout	M.Zürn

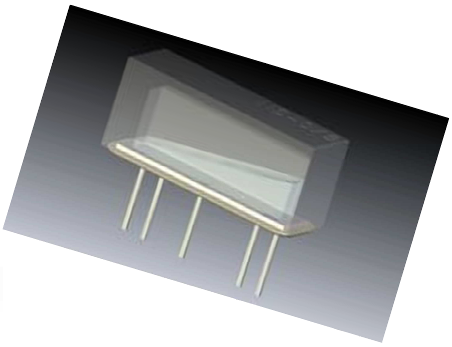
2 General Information

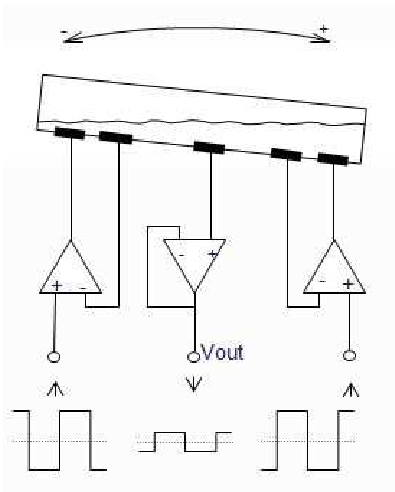
2.1 Description of the liquid/conductive measurement principle

Platinum electrodes are deposited in pairs on the base of the sensor’s cell parallel to the sensitive axis. The chamber is partially filled with an electrolytic liquid. When an alternating voltage is passed between two electrodes, the electric current will create a dispersed field. By tilting the sensor and thereby reducing the level of liquid, it is possible to confine this stray field. Because of the constant, specific conductivity of the electrolytes a variance of resistance is formed in relation to the liquid level. A basic differential principle will yield an angle of inclination from the polarity signs.









2.2 Functional Block Diagram with Interface sample

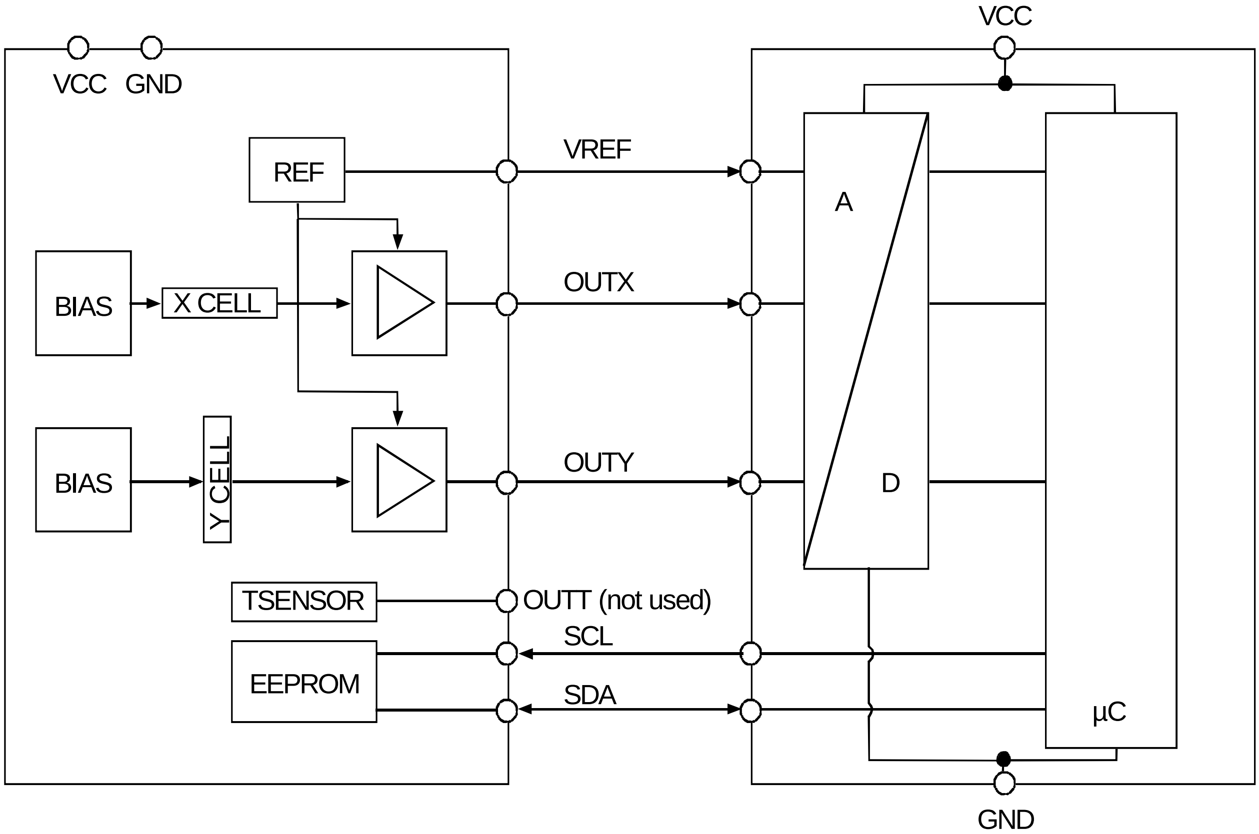


Fig 2.2.1: Practicable Inclination Measurement System

The AAL-series keeps calibration information inside the on-board EEPROM. This information enables the user to linearize the sensor output signal with own software. So the user will be able to fit together the AAL-series with his own microcontroller system to an inclination measurement system with fully linearized and temperature compensated output signal. Fig. 2.3.1 shows one possible realization of an inclination measurement system consisting of NS-10/AAL2-UDG and a µC-system.

Typical applications are:

- Angle Measurement
- Wheel Alignment
- Level Control and Alignment
- Zero Point Detection

2.3 Typical output signal

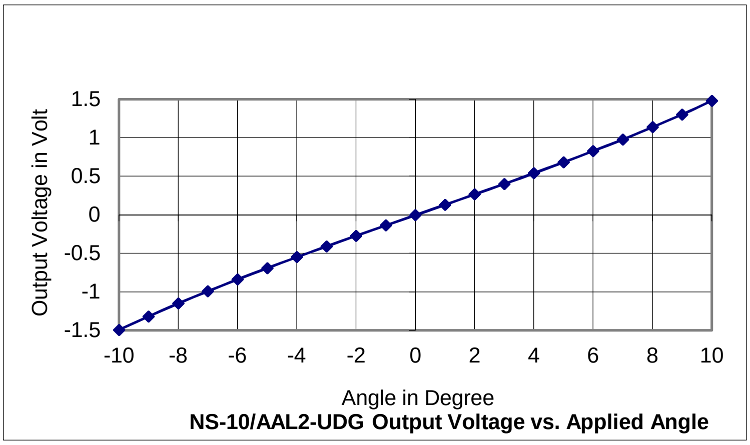


Fig 2.3.1: Output Voltage relating to VREF vs. Angle

2.4 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, e^2-prom	+5 VDC	G-NSAAL-006
NS-5/AAL2-UDD	- 5°… + 5°	Voltage,T-signal, e^2-prom	+5 VDC	G-NSAAL-017
NS-10/AAL2-UDG	- 10°… +10°	Voltage,T-signal, e^2-prom	+5 VDC	G-NSAAL-010
NS-15/AAL2-UDG	- 15°… +15°	Voltage,T-signal, e^2-prom	+5 VDC	G-NSAAL-018
NS-30/AAL2-UDN	- 30°… + 30°	Voltage,T-signal, e^2-prom	+5 VDC	G-NSAAL-019

3 Specification

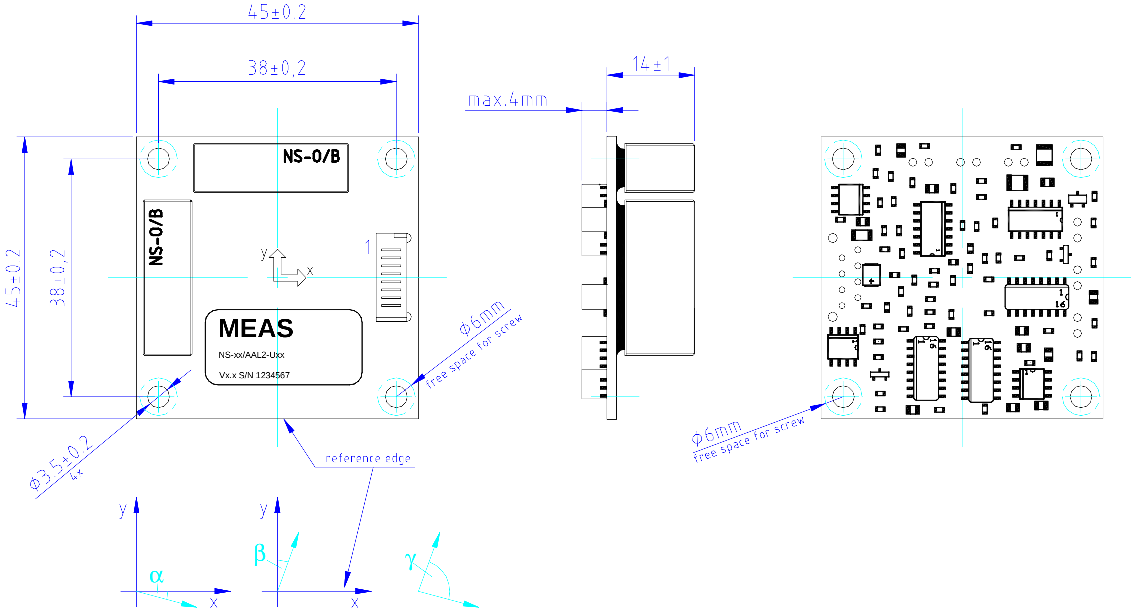


Fig 3.1.1: Dimensions

Connector Type:	Molex, Type Picoflex PF-50, 8-pin connector

Operating Conditions

	Type	Measurement range (each axis)
	NS-2/AAL2-UDD	-2°...+2°
	NS-5/AAL2-UDD	-5°...+5°
	NS-10/AAL2-UDG	-10°...+10°
	NS-15/AAL2-UDG	-15°...+15°
	NS-30/AAL2-UDN	-30°...+30°
Supply Voltage VCC with reference to GND	4.75V < VCC < 5.25V	
Operating temperature range	-40℃ < T_{OP} < +85℃	

Typical System Performance

Typical attainable system resolution	± 0.04°

See chapter 5 for a description of a fully tested system with a 10-bit ADC and a 8-bit µC

3.1 Terminal Connection and Signal Definition

NOTE: OUTX and OUTY signals are temperature compensated. No further temp. comp. is required.

Pin	Description	Symbol	Signal Type	Range	Load Impedance	Remarks
1	Positive Supply Voltage	**VCC**	Supply Input	4.75V < VCC < 5.25V		
2	Reference Voltage	**VREF**	Output	2.4V < VREF < 2.6V	Minimum resistive load 10kOhm, maximum capacitive load 390pF	
3	Negative Supply Voltage	**GND**	Supply Input			
4	Output Voltage X-axis	**OUTX**	Analog Output	0.3V .. VCC-0.3V	Minimum resistive load 10kOhm, maximum capacitive load 390pF	Maximum output bandwidth fmax = 3Hz
5	Output Voltage Y-axis	**OUTY**	Analog Output	0.3V .. VCC-0.3V	Minimum resistive load 10kOhm, maximum capacitive load 390pF	Maximum output bandwidth fmax = 3Hz
6	Output Voltage Sensor Temperature	**OUTT**	Analog Output			
7	Serial Data Line I^2C	**SDA**	Digital Input/Output			See Note 1
8	Clock Line I^2C	**SCL**	Digital Input			See Note 1 $f_{clk,max}$ =400 kHz

Table 3.1: Signal Information

Note 1: EEPROM type is 24LC02B, 2 k Bit (256 byte), f_{max} = 400 kHz, pull-up resistors (10kOhm) are on board

4 EEPROM Contents

As mentioned above it is the part of customer µC-system to linearize the output signal of AAL-series. In order to do this there are some calibration constants needed (see chapter 5 for complete algorithm description). These constants are stored in the EEPROM as well as some general information, like serial number, version and supplier URL. Table 3.1 gives a complete overview of EEPROM contents, including the names, which are referenced in further descriptions. The register map meets PrimSensMem-Standard which is defined in (see chapter 6**Fehler! Verweisquelle konnte nicht gefunden werden.** for additional information). All numbers are stored in “low byte first” manner.

4.1 EEPROM Register Map NS-10AAL2UDG

Block Type	Field Description	Address Offset	Field Length	Contents	Symbol	Field Type	Remarks
Main Block	Length Main Block (without length and checksum)	0	2	137		*Defined in PrimSensMem*	*Note*
Main Block	Length Main Block Identifier	2	1	15		*Defined in PrimSensMem*	
Main Block	Main Block Identifier	3	15	“www.hlplanar.de”	CID	15 Byte ASCII	
Sub Block	Length Sub Block	18	1	120		*Defined in PrimSensMem*	
Sub Block	Length Sub Block Identifier	19	1	14		*Defined in PrimSensMem*	
Sub Block	Sub Block Identifier	20	14	„NS-10/AAL2-UDG“	SID	14 Byte ASCII	
	Serial Number	34	7		SN	7 Byte ASCII	see Note
	System Version	41	4	“04.2”	VER	4 Byte ASCII	
	Description Version	45	2	1	DESVER	2 Byte unsigned int	
	OUTT Output Voltage @ 0°C	47	4	0	OUTT0	4 Byte Float see Note	[V] see Note
	OUTT sensitivity	51	4	0	OUTT_SENSE	4 Byte Float	[K/V] see Note
	Actual Reference Voltage	55	4		VREFCAL	4 Byte Float	[V]
	Temperature Coefficient X-axis	59	4	0	TEMPCOX	4 Byte Float	[ppm/K]
	Temperature Coefficient Y-axis	63	4	0	TEMPCOY	4 Byte Float	[ppm/K]
	Coefficient A3 negative X-axis	67	4		A3XNEG	4 Byte Float	
	Coefficient A2 negative X-axis	71	4		A2XNEG	4 Byte Float	
	Coefficient A1 negative X-axis	75	4		A1XNEG	4 Byte Float	
	Coefficient A0 negative X-axis	79	4		A0XNEG	4 Byte Float	
	Coefficient A3 positive X-axis	83	4		A3XPOS	4 Byte Float	
	Coefficient A2 positive X-axis	87	4		A2XPOS	4 Byte Float	
	Coefficient A1 positive X-axis	91	4		A1XPOS	4 Byte Float	
	Coefficient A0 positive X-axis	95	4		A0XPOS	4 Byte Float	
	Output voltage at 0° X-axis	99	4		V0X	4 Byte Float	[V]
	Coefficient A3 negative Y-axis	103	4		A3YNEG	4 Byte Float	
	Coefficient A2 negative Y-axis	107	4		A2YNEG	4 Byte Float	
	Coefficient A1 negative Y-axis	111	4		A1YNEG	4 Byte Float	
	Coefficient A0 negative Y-axis	115	4		A0YNEG	4 Byte Float	
	Coefficient A3 positive Y-axis	119	4		A3YPOS	4 Byte Float	
	Coefficient A2 positive Y-axis	123	4		A2YPOS	4 Byte Float	
	Coefficient A1 positive Y-axis	127	4		A1YPOS	4 Byte Float	
	Coefficient A0 positive Y-axis	131	4		A0YPOS	4 Byte Float	
	Output voltage at 0° Y-axis	135	4		V0Y	4 Byte Floa t	[V]
Main Block	Data Integrity Information (Checksum from Adress 0 to 138)	139	2			*2 Byte Defined in PrimSensMem*	Note

4.2 EEPROM Register Map NS-2AAL2UDD and NS-5AAL2UDD

Block Type	Field Description	Address Offset	Field Length	Contents	Symbol	Field Type	Remarks
Main Block	Length Main Block (without length and checksum)	0	2	136		*Defined in PrimSensMem*	*Note*
Main Block	Length Main Block Identifier	2	1	15		*Defined in PrimSensMem*	
Main Block	Main Block Identifier	3	15	“www.hlplanar.de”	CID	15 Byte ASCII	
Sub Block	Length Sub Block	18	1	119		*Defined in PrimSensMem*	
Sub Block	Length Sub Block Identifier	19	1	13		*Defined in PrimSensMem*	
Sub Block	Sub Block Identifier	20	13	„NS-2/AAL2-UDD“ resp. „NS-5/AAL2-UDD“	SID	13 Byte ASCII	
	Serial Number	33	7		SN	7 Byte ASCII	see Note
	System Version	40	4	“04.2”	VER	4 Byte ASCII	
	Description Version	44	2	1	DESVER	2 Byte unsigned int	
	OUTT Output Voltage @ 0°C	46	4	0	OUTT0	4 Byte Float see Note	[V] see Note
	OUTT sensitivity	50	4	0	OUTT_SENSE	4 Byte Float	[K/V] see Note
	Actual Reference Voltage	54	4		VREFCAL	4 Byte Float	[V]
	Temperature Coefficient X-axis	58	4	0	TEMPCOX	4 Byte Float	[ppm/K]
	Temperature Coefficient Y-axis	62	4	0	TEMPCOY	4 Byte Float	[ppm/K]
	Coefficient A3 negative X-axis	66	4		A3XNEG	4 Byte Float	
	Coefficient A2 negative X-axis	70	4		A2XNEG	4 Byte Float	
	Coefficient A1 negative X-axis	74	4		A1XNEG	4 Byte Float	
	Coefficient A0 negative X-axis	78	4		A0XNEG	4 Byte Float	
	Coefficient A3 positive X-axis	82	4		A3XPOS	4 Byte Float	
	Coefficient A2 positive X-axis	86	4		A2XPOS	4 Byte Float	
	Coefficient A1 positive X-axis	90	4		A1XPOS	4 Byte Float	
	Coefficient A0 positive X-axis	94	4		A0XPOS	4 Byte Float	
	Output voltage at 0° X-axis	98	4		V0X	4 Byte Float	[V]
	Coefficient A3 negative Y-axis	102	4		A3YNEG	4 Byte Float	
	Coefficient A2 negative Y-axis	106	4		A2YNEG	4 Byte Float	
	Coefficient A1 negative Y-axis	110	4		A1YNEG	4 Byte Float	
	Coefficient A0 negative Y-axis	114	4		A0YNEG	4 Byte Float	
	Coefficient A3 positive Y-axis	118	4		A3YPOS	4 Byte Float	
	Coefficient A2 positive Y-axis	122	4		A2YPOS	4 Byte Float	
	Coefficient A1 positive Y-axis	126	4		A1YPOS	4 Byte Float	
	Coefficient A0 positive Y-axis	130	4		A0YPOS	4 Byte Float	
	Output voltage at 0° Y-axis	134	4		V0Y	4 Byte Floa t	[V]
Main Block	Data Integrity Information (Checksum from Adress 0 to 137)	138	2			*2 Byte Defined in PrimSensMem*	Note

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4.3 EEPROM Register Map NS-15AAL2UDG and NS-30AAL2UDN

Block Type	Field Description	Address Offset	Field Length	Contents	Symbol	Field Type	Remarks
Main Block	Length Main Block (without length and checksum)	0	2	218		*Defined in PrimSensMem*	*Note*
Main Block	Length Main Block Identifier	2	1	15		*Defined in PrimSensMem*	
Main Block	Main Block Identifier	3	15	“www.hlplanar.de”	CID	15 Byte ASCII	
Sub Block	Length Sub Block	18	2	200		*Defined in PrimSensMem*	
Sub Block	Length Sub Block Identifier	20	1	14		*Defined in PrimSensMem*	
Sub Block	Sub Block Identifier	21	14	„NS-15/AAL2-UDG“ resp. „NS-30/AAL2-UDN“	SID	14 Byte ASCII	
	Serial Number	35	7		SN	7 Byte ASCII	see Note
	System Version	42	4	“04.2”	VER	4 Byte ASCII	
	Description Version	46	2	2	DESVER	2 Byte unsigned int	
	OUTT Output Voltage @ 0℃	48	4	0	OUTT0	4 Byte Float see Note	[V] see Note
	OUTT sensitivity	52	4	0	OUTT_SENSE	4 Byte Float	[K/V] see Note
	Actual Reference Voltage	56	4		VREFCAL	4 Byte Float	[V]
	Temperature Coefficient X-axis	60	4	0	TEMPCOX	4 Byte Float	[ppm/K]
	Temperature Coefficient Y-axis	64	4	0	TEMPCOY	4 Byte Float	[ppm/K]
	Coefficient A3 X-axis Range A	68	4		A3X	4 Byte Float	
	Coefficient A2 X-axis Range A	72	4		A2X	4 Byte Float	
	Coefficient A1 X-axis Range A	76	4		A1X	4 Byte Float	
	Coefficient A0 X-axis Range A	80	4		A0X	4 Byte Float	
	Output voltage X at limit between Range A and Range B	84	4		VABX	4 Byte Float	[V]
	Coefficient B3 X-axis Range B	88	4		B3X	4 Byte Float	
	Coefficient B2 X-axis Range B	92	4		B2X	4 Byte Float	
	Coefficient B1 X-axis Range B	96	4		B1X	4 Byte Float	
	Coefficient B0 X-axis Range B	100	4		B0X	4 Byte Float	
	Output voltage X at limit between Range B and Range C	104	4		VBCX	4 Byte Float	[V]
	Coefficient C3 X-axis Range C	108	4		C3X	4 Byte Float	
	Coefficient C2 X-axis Range C	112	4		C2X	4 Byte Float	
	Coefficient C1 X-axis Range C	116	4		C1X	4 Byte Float	
	Coefficient C0 X-axis Range C	120	4		C0X	4 Byte Float	
	Output voltage X at limit between Range C and Range D	124	4		VCDX	4 Byte Float	[V]
	Coefficient D3 X-axis Range D	128	4		D3X	4 Byte Float	
	Coefficient D2 X-axis Range D	132	4		D2X	4 Byte Float	
	Coefficient D1 X-axis Range D	136	4		D1X	4 Byte Float	
	Coefficient D0 X-axis Range D	140	4		D0X	4 Byte Float	
	Coefficient A3 Y-axis Range A	144	4		A3Y	4 Byte Float	
	Coefficient A2 Y-axis Range A	148	4		A2Y	4 Byte Float	
	Coefficient A1 Y-axis Range A	152	4		A1Y	4 Byte Float	
	Coefficient A0 Y-axis Range A	156	4		A0Y	4 Byte Float	
	Output voltage Y at limit between Range A and Range B	160	4		VABY	4 Byte Float	[V]
	Coefficient B3 Y-axis Range B	164	4		B3Y	4 Byte Float	
	Coefficient B2 Y-axis Range B	168	4		B2Y	4 Byte Float	
	Coefficient B1 Y-axis Range B	172	4		B1Y	4 Byte Float	
	Coefficient B0 Y-axis Range B	176	4		B0Y	4 Byte Float	

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	Output voltage Y at limit between Range B and Range C	180	4		VBCY	4 Byte Float	[V]
	Coefficient C3 Y-axis Range C	184	4		C3Y	4 Byte Float	
	Coefficient C2 Y-axis Range C	188	4		C2Y	4 Byte Float	
	Coefficient C1 Y-axis Range C	192	4		C1Y	4 Byte Float	
	Coefficient C0 Y-axis Range C	196	4		C0Y	4 Byte Float	
	Output voltage Y at limit between Range C and Range D	200	4		VCDY	4 Byte Float	[V]
	Coefficient D3 Y-axis Range D	204	4		D3Y	4 Byte Float	
	Coefficient D2 Y-axis Range D	208	4		D2Y	4 Byte Float	
	Coefficient D1 Y-axis Range D	212	4		D1Y	4 Byte Float	
	Coefficient D0 Y-axis Range D	216	4		D0Y	4 Byte Float	
Main Block	Data Integrity Information (Checksum from Adress 0 to 219)	220	2			*2 Byte Defined in PrimSensMem*	see Note

Note 1 Extract from *PrimSensMem:* The length is written in bytes with 7 significant bits per byte. The MSB per Byte indicates, whether there is a higher significant byte for the length information. For the several sensors following length values stored in the EEPROM:

valid for		decimal	binary	with MSB set	EEPROM
NS-2/AAL2-UDD, NS-5/AAL2-UDD	complete value	136	1000 1000		
	lower byte		.000 1000	1000 1000	**88H,**
	higher byte		.000 0001	0000 0001	**01H**
NS-10/AAL2-UDG	complete value	137	1000 1001		
	lower byte		.000 1001	1000 1001	**89H,**
	higher byte		.000 0001	0000 0001	**01H**
NS-15AAL2UDG, NS-30AAL2UDN	complete value	218	1101 1010		
	lower byte		.101 1010	1101 1010	**DAH,**
	higher byte		.000 0001	0000 0001	**01H**

Note 2 Serial Number is: "YYWWNNN" Year – Week of Year – Consecutive Production Number

Note 3 All Floating point values are stored in standard 32-bit IEEE 754- format. (low byte first)

Note 4 Values for Temperature output are not used for NS-10/AAL2-UDG Description Version 1

Note 5 The checksum is the summation of all bytes without the checksum and then stored as 2 hex-bytes, low byte first

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The main task of customer software is the angle calculation by using analog output from e.g. NS-10/AAL2-UDG in association with EEPROM calibration constants.
Fig 4 shows the required workflow as an overview.

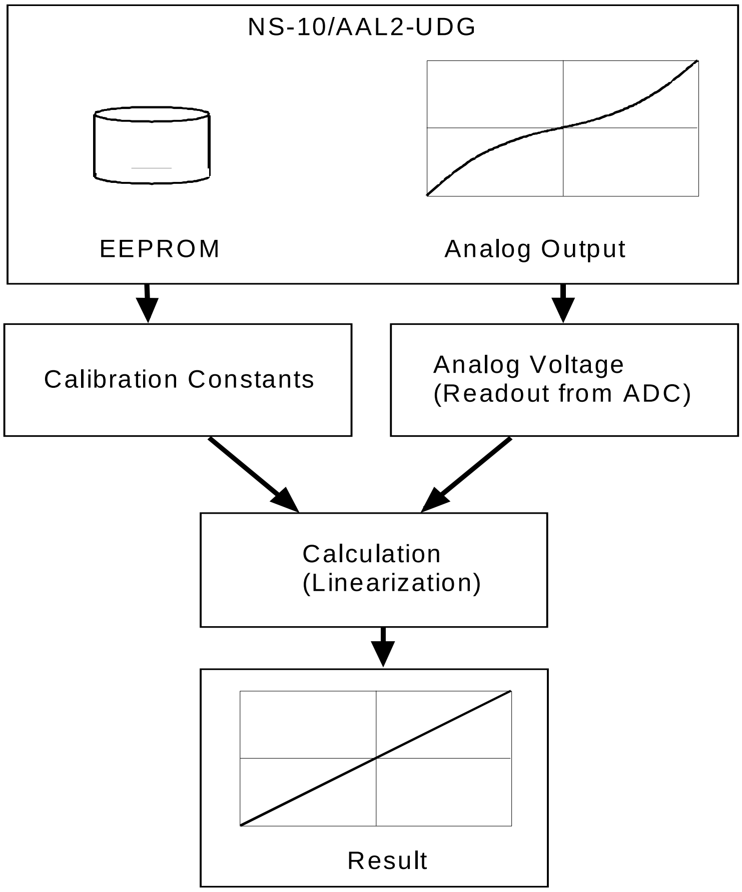

Fig 4: Workflow Overview

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NS-10/AAL2-UDG has a nonlinear output characteristic. Linearization must be done by calculating a 3rd order polynomial. In order to attain high accuracy it is used one polynomial for the positive part of the output curve, and another one for the negative part. As a whole there are 4 polynomials: two for X-axis (positive and negative), and two for Y-axis (positive and negative), see Eq.4.1 to 4.4. Totally 16 coefficients are used, 8 for each axis (see table 3.1 for definition). The constants V0X resp. V0Y are measured during calibration and stored in EEPROM at manufacturer.

$$If\ OUTX \geq V0X : XANGLE_{pos} = A3XPOS \times OUTX^3 + A2XPOS \times OUTX^2 + A1XPOS \times OUTX + A0XPOS$$

(Eq. 4.1)

$$If\ OUTX < V0X : XANGLE_{neg} = A3XNEG \times OUTX^3 + A2XNEG \times OUTX^2 + A1XNEG \times OUTX + A0XNEG$$

(Eq. 4.2)

$$If\ OUTY \geq V0Y : YANGLE_{pos} = A3YPOS \times OUTY^3 + A2YPOS \times OUTY^2 + A1YPOS \times OUTY + A0YPOS$$

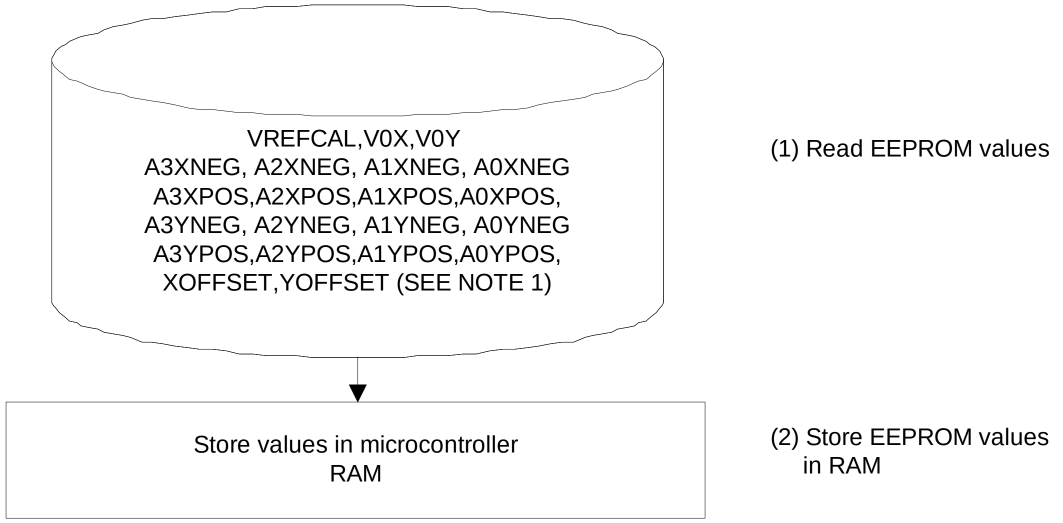
(Eq. 4.3)

$$If\ OUTY < V0Y : YANGLE_{neg} = A3YNEG \times OUTY^3 + A2YNEG \times OUTY^2 + A1YNEG \times OUTY + A0YNEG$$

(Eq. 4.4)

It is supposed that the µC system will make a continuous sampling (see 4.5) and calculating of result values. Before starting this continuous sampling, it's necessary to carry out a short start-up algorithm, which initializes the constants (see 4.4). During NS-10/AAL2-UDG calibration at manufacturer the actual reference voltage is measured and the value is stored inside the EEPROM. It's assumed that the µC- system will be designed as given in Fig.2.2.1, which means especially the use of supply voltage for upper and lower ADC- voltage. In this case the reference voltage of NS-10/AAL2-UDG is used to compensate ADC offset respectively gain error and supply voltage variation and no further reference is needed.

4.4 Start-Up Code



Note 1: XOFFSET and YOFFSET are ***offset values in degree****. The system designer is responsible for handling these values. After mounting the sensor a final calibration step has to be done. In this step the system offset at zero degree position (X=0°, Y=0°) has to be stored in nonvolatile memory. La ter in normal operation mode, these offset values must be subtracted from the internal calculated result. This step is necessary to compensate slight differences of mounting position during calibration and final mounting position.*

Fig. 4.4.1: Steps Required Once Per Program Run: Start-up code

4.5 Continuous Angle Calculating

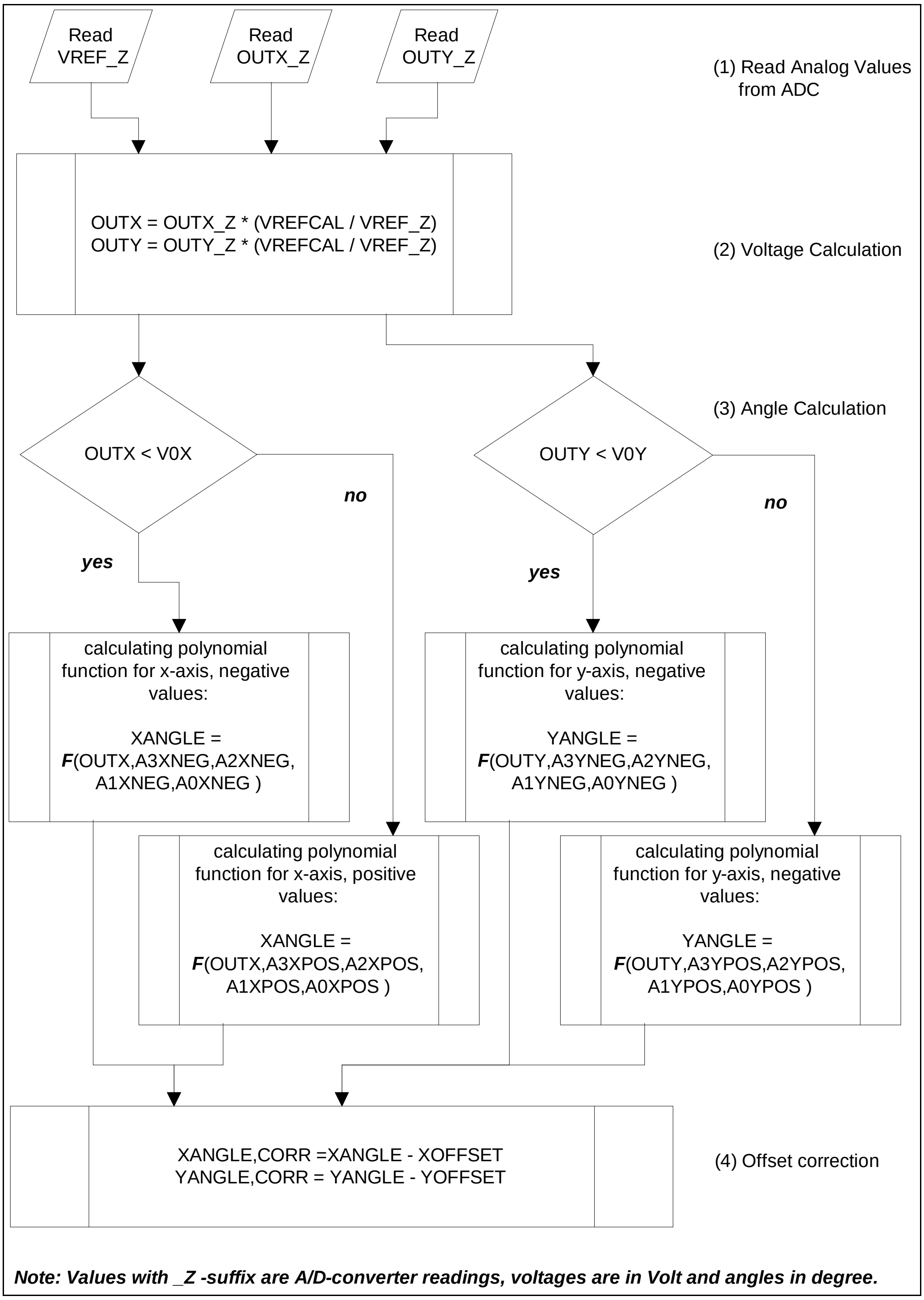


Fig 4.5.1: Angle Calculation Algorithm

In step 2 is calculated the voltage by using the well-known value of the on-board reference voltage. During calibration this value is measured by a Digital Multimeter with an accuracy of ±150µV and stored in the EEPROM. As mentioned above this step is necessary to compensate ADC gain and offset error. If the µC-system at users' side contains a more accurate reference voltage this step isn't necessary at all.

5 Sample Application

5.1 System Hardware

The system hardware has three tasks:

1. Reading calibration constants from sensor EEPROM (at program start)
2. A/D conversion of sensor analog outputs (continuous)
3. Linearization (continuous)

The three tasks can be done by a simple µC-system without need of many external components. That's why for the sample application the PIC18F252 was used.

System Hardware consists of the Microchip Demo Board PICDEM 2 Plus, which is equipped with the PIC18F252 microcontroller. The key features are:

- 10-Bit A/D-converter on board
- 32 k flash memory
- 1536 Byte RAM
- 8x8 hardware multiplier
- I^2C on board

Oscillator frequency is 4 MHz.

5.2 Software

Subsequent is given the main part of the algorithm which is the voltage and angle calculation as described in Fig. 4.4.1 and 4.5.1. Typical properties of the tested sample application based on PIC18F252 are:

- Code length of given sample code, floating point calculation with 24-bit arithmetic — about 2.5 kByte ROM
- Processing time for one axis, only angle calculation (excluding sampling and output time), at oscillator clock frequency of 4 MHz — about 45ms

```
/*-------------------------------------------------------------------
       Modul:                         calc.c
       Function:                      Calculation of Angle
       Modul version:        1.0
       Author:                        Jörg Kube
       Date:                          27.11.2003
-------------------------------------------------------------------*/
#include <calc.h>
#include <main.h>
#include <eeprom.h>
#include <pic18.h>
#include <adu.h>
#include <serial.h>
#include <misc.h>
#include <prot_ns.h>
#include <protocol.h>
#include <stdio.h>
```

```
// *******************************************************************
// Subsequent variables are initialized at start-up with
// EEPROM-Calibration constants

// Reference voltage of NS-10
float gfVREFCAL=0.0;

// Polynomial coefficients (for linearization of NS-10 output
// characteristic)
float gfA3Xneg=0.0,gfA2Xneg=0.0,gfA1Xneg=0.0,gfA0Xneg=0.0;
float gfA3Xpos=0.0,gfA2Xpos=0.0,gfA1Xpos=0.0,gfA0Xpos=0.0;
float gfA3Yneg=0.0,gfA2Yneg=0.0,gfA1Yneg=0.0,gfA0Yneg=0.0;
float gfA3Ypos=0.0,gfA2Ypos=0.0,gfA1Ypos=0.0,gfA0Ypos=0.0;

// Output voltage at 0° of x and y axis
float gfV0X=0.0,gfV0Y=0.0;
// *******************************************************************




/*------------------------------------------------------------------
Author:                              J. Kube
Date:                         27.11.2003
Purpose:                      Angle calculation (solving polynomial function)
Variables:                    nRawAngle:     OUTX or OUTY, ADU-reading (16-bit-normalized)
                  nRawRef:    VREF of NS-10, ADU-reading (16-bit-normalized)
                  nAxis:             axis selction: X_AXIS or Y_AXIS
                  *fAngle:    reference return value, float pointer
                              to the calculated angle in degree
Return:                              TRUE if calculation succeeded
Globals:                      All globals listed above
------------------------------------------------------------------*/
char CalculateAngle(
   unsigned int       nRawAngle,
   unsigned int       nRawRef,
   char                              nAxis,
   float*                     fAngle)
{

   float fVolt;
   char b;

   // calculation of actual voltage
   b = CalculateVoltage( nRawAngle, nRawRef, &fVolt);

   if( !b )
      return FALSE;

   if( nAxis == X_AXIS )
   {
      // decide which of the tw0 polynomials for x-axis has to be used
      if( fVolt < gfV0X )
      {
         // calculate polynomial
         *fAngle =
            gfA3Xneg*fVolt*fVolt*fVolt + gfA2Xneg*fVolt*fVolt +
            gfA1Xneg*fVolt + gfA0Xneg;
      }
      else
      {
         *fAngle =
            gfA3Xpos*fVolt*fVolt*fVolt + gfA2Xpos*fVolt*fVolt +
            gfA1Xpos*fVolt + gfA0Xpos;
      }
      *fAngle -= gfXOFFSET;
   }
   else
   {
      if( fVolt < gfV0Y )
      {
         *fAngle =
            gfA3Yneg*fVolt*fVolt*fVolt + gfA2Yneg*fVolt*fVolt +
            gfA1Yneg*fVolt + gfA0Yneg;
```

```
      }
      else
      {
         *fAngle =
            gfA3Ypos*fVolt*fVolt*fVolt + gfA2Ypos*fVolt*fVolt +
            gfA1Ypos*fVolt + gfA0Ypos;

      }
      *fAngle -= gfYOFFSET;
   }
}

/*---------------------------------------------------------------------
Author:                        J. Kube
Date:                 27.11.2003
Purpose:              Voltage calculation from A/D- reading (OUTX or OUTY):

               Actual value in Volt =
                  actual A/D reading x [ reference voltage in Volt/
                  actual A/D reference reading]
Variables:            nRaw:           ADU-output value (16-bit-normalized)
               nRawRef:       VREF of NS-10, ADU-output value (16-bit-normalized)
               *fVoltage:     Reference return value, float pointer to
                           the calculated voltage in Volt
Return: TRUE if succeeded
Globals: gfVREFCAL (reference voltage of NS-10 in Volt)
-------------------------------------------------------------------*/
char CalculateVoltage(
   unsigned int       nRaw,
   unsigned int       nRawRef,
   float*                     fVoltage)
{

   if( nRawRef==0 )
      return FALSE;

   *fVoltage = (float)nRaw * ( gfVREFCAL / (float)nRawRef );
   return TRUE;
}
```

AAL-Series Inclinometer

5.3 Performance

The most important parameter is the accuracy of angle output reading.

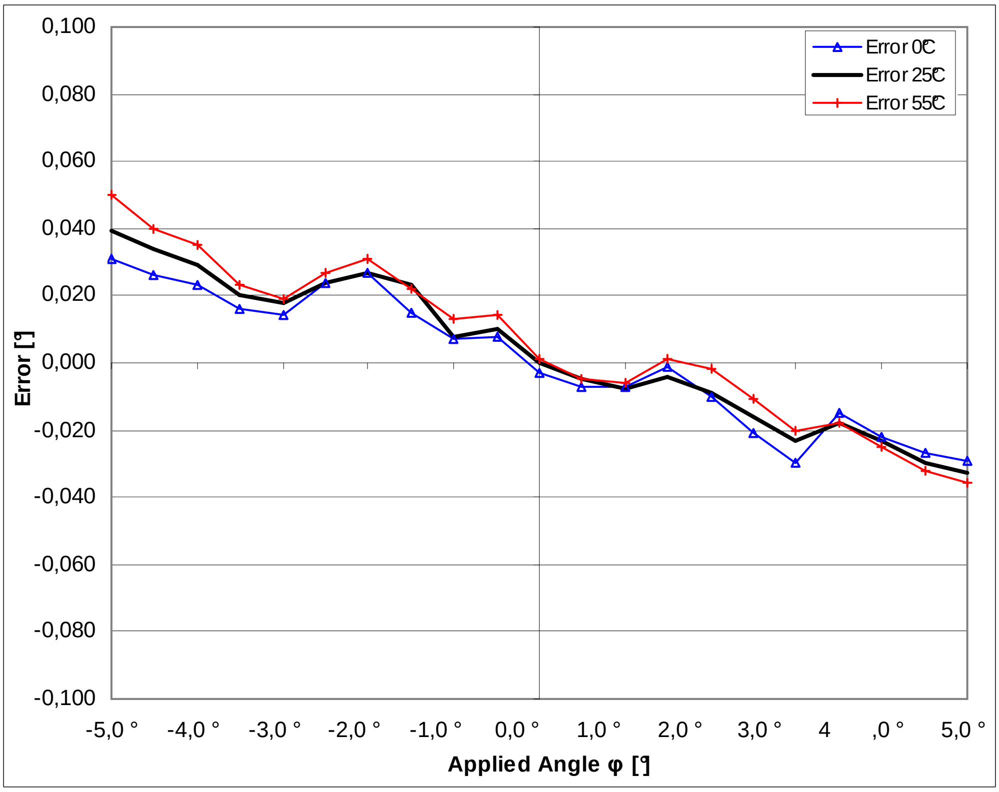


Fig 5.3.1: Angle Deviation, example of NS-5/AAL2-UDD with µC-System including a 12-Bit ADC

6 Additional Information

6.1 Ordering Information

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