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# 1. Internal Memory

## 1.1 Block Diagram

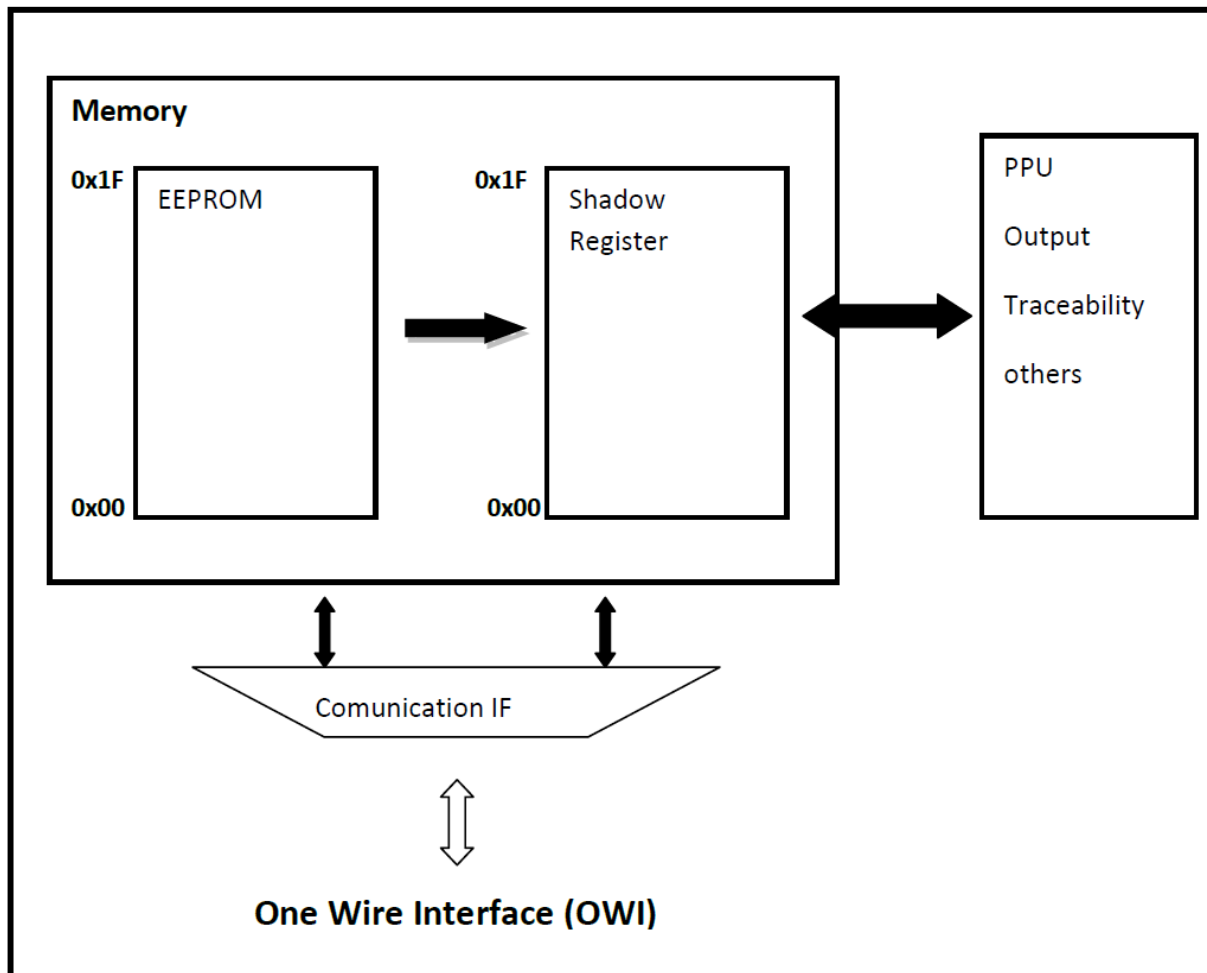


Figure 1. Internal Memory of the ZMID4200

Figure 1 shows the internal memory topology of the ZMID4200 products which is split up into a non-volatile EEPROM (E2P) and a volatile shadow ram (SWR) section. After chip start up the E2P content is copied into the SWR. During IC operation in OWI mode, changes in the SWR will take immediate effect whereas changes in the E2P require an IC power cycle. (Power off/Power on).

Definitions:

0b Binary number prefix.

0x Hexadecimal number prefix.

Table 1. Internal Memory

Address	Name	Type	Location	Function
0x00	Offset	R/W	E2P/SWR	14-bit zero- Zero Angle offset of output signal
0x01	Slope	R/W	E2P/ SWR	13-bit slope value of output signal

Address	Name	Type	Location	Function
0x02	Clamping	R/W	E2P/SWR	Clamp values of output signal
0x03	LinInt0	R/W	E2P/SWR	Linear interpolation of output signal corr1@12.5% (45°) - bit15...8 corr0@0%(0°) - bit7...0
0x04	LinInt1	R/W	E2P/SWR	Linear interpolation of output signal corr3@37.5% (135°) - bit15...8 corr2@25%(90°) - bit7...0
0x05	LinInt2	R/W	E2P/SWR	Linear interpolation of output signal corr5@62.5% (225°) - bit15...8 corr4@50%(180°) - bit7...0
0x06	LinInt3	R/W	E2P/SWR	Linear interpolation of output signal corr7@87.5% (315°) - bit15...8 corr6@75%(270°) - bit7...0
0x07	LinInt4	R/W	E2P/SWR	Linear interpolation of output signal not used - bit15...8 corr8@100%(360°) - bit7...0
0x08	Coil offset	R/W	E2P/SWR	Signal Offset correction of the demodulated input signals - sin and cos (r1,r2 - Ycos,Xsin); Only apply if constant input gain setting is activated.
0x09	CalMode	R/W	E2P/SWR	Calibration mode register contains control bits for output Mode like linear or modulo360 mode sensor; linear correction mode like pre-&post-calibration; Angle offset for linearity correction like 0° or -22.5°; Swap receiver coils polarity ....
0x0A	Output	R/W	E2P/SWR	Output register is used for configuration of the output SENT CRC, SENT Pause, PWM slope current, PWM freq, Analog diagnostic level.
0x0B	Trimming	R/W	E2P/SWR	This register contains control parameters for: PWM slope time, OSR, LC oscillator current, VDDT voltage calibration
0x0C	AGC0	R/W	E2P/SWR	Basic configurations of the analog front-end in terms of timing and gain e.g: Automated gain scheduling in number of samples; Integrator gain stage;
0x0D	AGC1	R/W	E2P/SWR	Configurations of excitation coil frequency limits (alarm setting); CORDIC magnitude limits; Interlink mode (integration time adaption and gain adaption)
0x0E	Mask	R/W	E2P/SWR	Diagnostic mask register is controlling which alarms are generating an output diagnostic flag e.g: Receiver coil1 open/short; Excitation coil break;
0x0F	Trace0	R/W	E2P	factory traceability code 0
0x10	Trace1	R/W	E2P	factory traceability code 1
0x11	Misc	R/W	E2P/SWR	Configuration of voltage regulators and oscillators; e.g. switch off VDDT regulator in case of excitation coil alarm
0x13	Afe_agc	R	SWR	Analog front-end/ Automatic gain regulation. Polarity of R1 & R2 ADC gain. AGC nr. of integration cycles
0x14	Xsine	R	SWR	13-bit Cordic raw input signal
0x15	Ycosine	R	SWR	13-bit Cordic raw input signal
0x16	Angle	R	SWR	15-bit Cordic output angle (0° to 90°)
0x17	Cordic Magnitude	R	SWR	15-bit Cordic output magnitude
0x18	Spa	R	SWR	Spatial angle 16-bit output angle (0° to 360°) before output calibration and linear error correction.
0x19	Pos0	R	SWR	Position0 16-bit output angle (0° to 360°) after output calibration; If linearization done before output calibration this value = Position1; If linearization done after output calibration this value ≠ Position1
0x1A	Pos1	R	SWR	Position1 16-bit output angle (0° to 360°) after output calibration and linearization; This value is always affected by

## 1.2 Offset

Address of register: 0x00.

Default value: 0x0000.

The offset parameter is used for the calibration of the position transfer function. The notation of the offset parameter depends on the output mode (see 1.12). Two output modes can be selected (modulo360 or linear).

Output mode: Modulo360 (set out\_mod = 0b1 (1.10), for selecting the output mode “360Modulo”)

**Table 2. Offset Register Description**

Bits	Symbol	Description	
Off.15 - Off.14	Reserved	Not used, read as 0 (SWR).	
Off.13 - Off.0	Offset	Offset of output transfer function.	
		<b>Offset Value</b>	<b>Value in Degree</b>
		0x0000	0
		0x0800	45
		0x1000	90
		0x1800	135
		0x2000	180
		0x2800	225
		0x3000	270
		0x3800	315
		0x3FFF	360

Note: The reserved bits off.15 & off.14 can be written and read to/from the block E2P. The copy process copies only bits (off.13 down to off.0) to the SWR.

Output mode: Linear (set out\_mod = 0b0 (see section 1.11.1), for selecting Linear Output mode).

**Table 3. Offset Register Description Modulo 360**

Bits	Symbol	Description	
Off.15 - Off.14	Reserved	Not used, read as 0 (SWR).	
Off.13 - Off.0	Offset	Offset of output transfer function.	
		<b>Offset Value</b>	<b>Value in Degree</b>
		0x0000	180
		0x0400	360
		0x0800	540
		0x0C00	720
		0x1000	900
		0x1400	1080
		0x1800	1260
		0x1C00	1440
		0x1FFF	1620
		0x2000	180
		0x2400	0
		0x2800	-180
		0x2C00	-360
		0x3000	-540
		0x3400	-720
		0x3800	-900
		0x3C00	-1080
		0x3FFF	-1260

Note: The reserved bits off.15 & off.14 can be written and read to/from the block E2P. The copy process copies only bits (off.13 down to off.0) to the SWR.

### 1.3 Slope

Address of register: 0x01.

Default value: 0x0400.

#### 1.3.1. Slope of Transfer Function

The slope parameter is used for the calibration of the position transfer function. It is a multiplication factor for the spatial angle. The slope notation is independent from the out\_mode parameter (see section 1.12).

**Table 4. Slope Register Description**

Bits	Symbol	Description																																				
slp.15 - slp.13	Reserved	Not used, read as 0 (SWR)																																				
slp.12 - slp.0	Slope	<table border="1"> <thead> <tr> <th colspan="2">Slope of output transfer function.</th> </tr> <tr> <th>Offset Value</th> <th>Value in Degree</th> </tr> </thead> <tbody> <tr><td>0x0000</td><td>0.0</td></tr> <tr><td>0x0100</td><td>0.25</td></tr> <tr><td>0x0200</td><td>0.5</td></tr> <tr><td>0x0300</td><td>0.75</td></tr> <tr><td>0x0400</td><td>1.0</td></tr> <tr><td>0x0800</td><td>2.0</td></tr> <tr><td>0x0C00</td><td>3.0</td></tr> <tr><td>0x0FFF</td><td>3.999</td></tr> <tr><td>0x1000</td><td>-0.0</td></tr> <tr><td>0x1100</td><td>-0.25</td></tr> <tr><td>0x1200</td><td>0.5</td></tr> <tr><td>0x1300</td><td>0.75</td></tr> <tr><td>0x1400</td><td>-1.0</td></tr> <tr><td>0x1800</td><td>-2.0</td></tr> <tr><td>0x1C00</td><td>-3.0</td></tr> <tr><td>0x1FFF</td><td>-3.999</td></tr> </tbody> </table>	Slope of output transfer function.		Offset Value	Value in Degree	0x0000	0.0	0x0100	0.25	0x0200	0.5	0x0300	0.75	0x0400	1.0	0x0800	2.0	0x0C00	3.0	0x0FFF	3.999	0x1000	-0.0	0x1100	-0.25	0x1200	0.5	0x1300	0.75	0x1400	-1.0	0x1800	-2.0	0x1C00	-3.0	0x1FFF	-3.999
Slope of output transfer function.																																						
Offset Value	Value in Degree																																					
0x0000	0.0																																					
0x0100	0.25																																					
0x0200	0.5																																					
0x0300	0.75																																					
0x0400	1.0																																					
0x0800	2.0																																					
0x0C00	3.0																																					
0x0FFF	3.999																																					
0x1000	-0.0																																					
0x1100	-0.25																																					
0x1200	0.5																																					
0x1300	0.75																																					
0x1400	-1.0																																					
0x1800	-2.0																																					
0x1C00	-3.0																																					
0x1FFF	-3.999																																					

Note: The reserved bits slp.15, slp.14 and slp.13 can be written and read to/from the block E2P.

#### 1.3.2. Slope example

Slope value coded on 13bits with a range between -4 to +4, 1 bit is the sign and defines the sign of (slope).

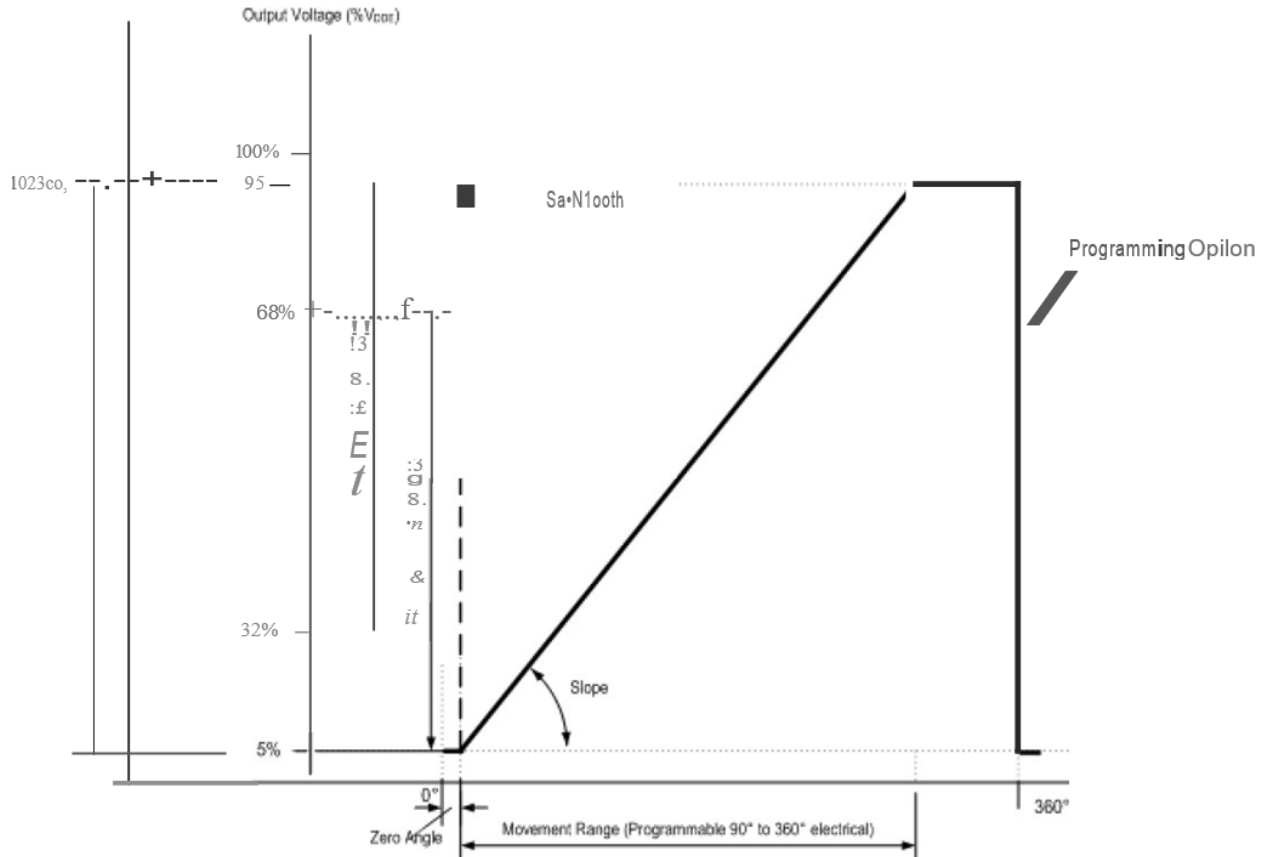


Figure 2. Internal Memory of the ZMID4200

Figure 2 shows the internal memory topology of the ZMID4200 products which is split up into a non-volatile EEPROM (E2P) and a volatile shadow ram (SWR) section. After chip start up the E2P content is copied into the SWR. During IC operation in OWI mode, changes in the SWR will take immediate effect whereas changes in the E2P require an IC power cycle. (Power off/Power on).

### 1.4 Clamping

Address of register: 0x02.

Default value: 0x0000.

The clamping parameters clamp\_low and clamp\_high are located in the clamp memory. These two parameters are used for position calibration if the output protocol mode is for ZMID4200. For the Analog output mode the complete 100% position range is mapped to a voltage range from 250mV to 4750mV. The stepping rate of the clamping parameters is 1%, so that the analog voltage stepping rate is 47.5 mV / 1 %. The diagnostic low level is less or equal 200mV, the high level is higher or equal 4800mV.

For the PWM output mode the position range is mapped to the Pulse Pause Ratio (PPR) of a periodic analog output signal. 100% position range is mapped to the PPR-range from 5% to 95%. So a clamping step of 1% is mapped to a PPR change of 0.9% (e.g. clamp\_low = 10% & pos <= clamp\_low --> PPR = 5% + 9%). The diagnostic low level is mapped to 2.5% PPR, the high level is mapped to 97.5% PPR.



**Table 5. CLAMP Register Description**

Bits	Symbol	Description	
clamp. 15 - clamp. 14	Reserved	Not used, read as 0 (SWR)	
clamp. 13 - clamp. 8	clamp_high	Position output clamp high descend from 4750 mV (Analog) resp. 95% (PWM).	
		<b>clamp_high (CLAMP13 - CLAMP08)</b>	<b>Rate (%)</b>
		0x00	0
		0x01	1
		0x02	2
		....	....
		....	....
		....	....
		....	....
		0x3F	63
clamp. 7 - clamp.6	Reserved	Not used, read as 0 (SWR)	
clamp. 5 - clamp. 0	clamp_low	Position output clamp low rising from 250mV (Analog) resp. 5% (PWM)	
		<b>clamp_low (CLAMP5 - CLAMP00)</b>	<b>Rate (%)</b>
		0x00	0
		0x01	1
		0x02	2
		....	....
		....	....
		....	....
		....	....
		0x3F	63

Note: The reserved bits clamp.15, clamp.14, clamp.7 and clamp.6 can be written and read to/from the block E2P. The copy process copies only bits (clamp.13 down to clamp.8) and (clamp.5 down to clamp.0) to the SWR.

**1.4.1. Clamping Example**

Clamps (applicable for Analog and PWM Output, not for SENT).

Clamp\_low (6 bits): min value is 5%, steps of 1% from minimum value. Max Clamp\_low value is: 68%.

Clamp\_high (6 bits): max value is 95%, steps of -1% from max value. Min Clamp\_high value is: 32%.

In the below example the clamping levels are 5% and 95%.

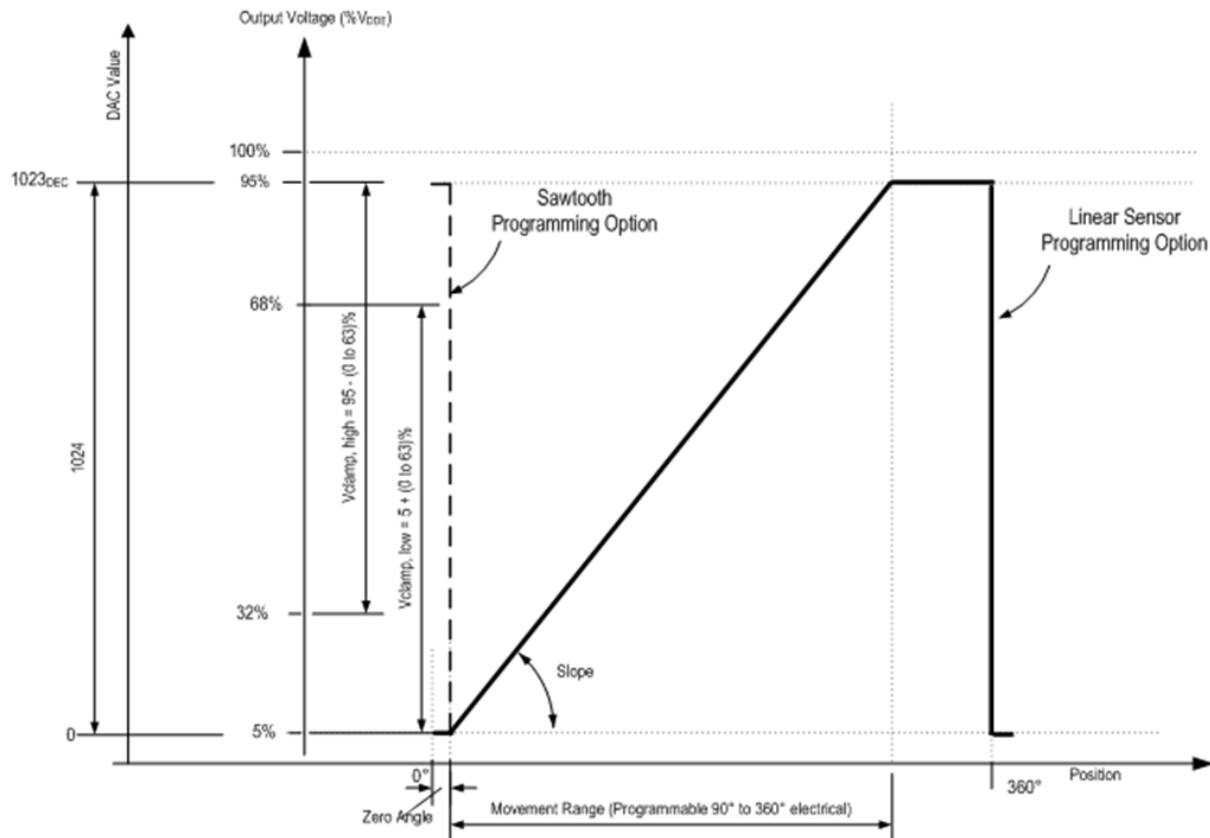


Figure 3. Clamping Example

### 1.5 LinInt0

Address of register: 0x03.

Default value: 0x0000.

The linearity of the position transfer function can be modified by a 9-point correction curve over the whole position range. The correction curve is defined by 9 points: corr0....corr8. The correction factor can be calculated by a linear interpolation over the 9 corresponding points. The correction factor is applied on the 11 most significant position bits.

Table 6. LinInt0 Register Description

Bits	Symbol	Description		
linint0.15 - linint0.8	corr1	Correction factor 1 for position 12.5% (45 deg).		
		<b>Corr0 (linint7 - linint0)</b>		<b>Correction Factor</b>
		0x00	0	
		0x01	1	
		....	....	
		....	....	
		....	....	
		0x7F	127	
		0x10	-0	
		0x11	-1	
		....	....	
....	....			
....	....			
0xFF	-127			

Bits	Symbol	Description	
Linint0.7 -linint0.0	corr0	Correction factor 0 for position 0% ( 0 deg )	
		<b>Corr0 (linint7 - linint0)</b>	<b>Correction Factor</b>
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	-1
		....	....
....	....		
....	....		
0xFF	-127		

Note: The notation of the correction factor is sign & abs. with a range of +127...+0.....-127.

### 1.5.1. Linear Error Correction

The linear error correction function has 9 equidistant fixed correction points (one dimensional). Between each pair of grid points a linear interpolation function evaluates the correction factor.

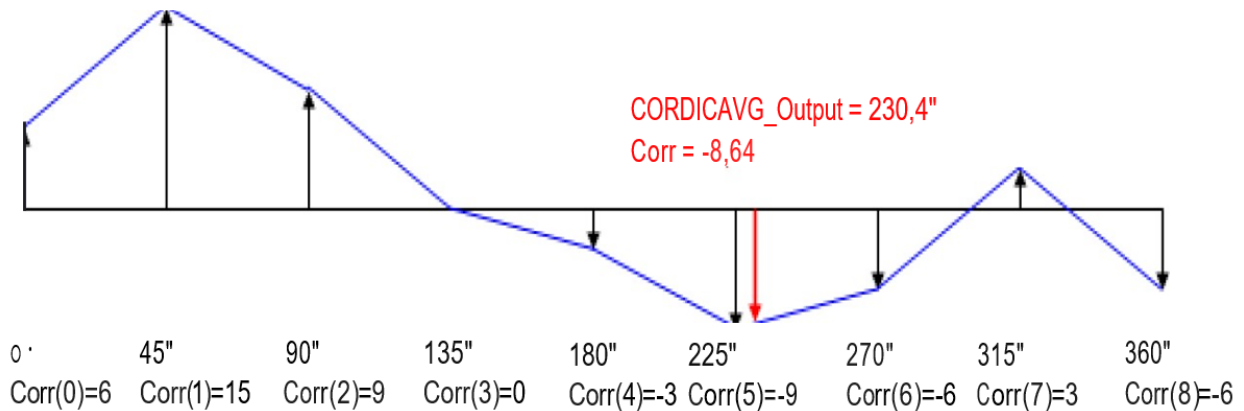


Figure 4. Linear Error Correction Example

### 1.6 LinInt1

Address of register: 0x04.

Default value: 0x0000.

The linearity of the position transfer function can be modified by a correction curve over the whole position range. The correction curve is defined by 9 points: corr0....corr8. The correction factor can be calculated by a linear interpolation over the 9 corresponding points. The correction factor is applied on the 11 most significant position bits.

Table 7. LinInt1 Register Description

Bits	Symbol	Description	
Linint1.15 - linint1.8	Corr3	Correction factor 3 for position 37.5% (135 deg).	
		<b>Corr3 (linint15 - linint8)</b>	<b>Correction Factor</b>
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	-1
		....	....
		....	....
		....	....
		0xFF	-127
Linint1.7 - linint1.0	Corr2	Correction factor 2 for position 25% (90 deg).	
		<b>Corr2 (linint7 - linint0)</b>	<b>Correction Factor</b>
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	-1
		....	....
		....	....
		....	....
		0xFF	-127

Note: The notation of the correction factor is sign & abs. with a range of +127...+ 0.....-127.

### 1.7 LinInt2

Address of register: 0x05.

Default value: 0x0000.

The linearity of the position transfer function can be modified by a correction curve over the whole position range. The correction curve is defined by 9 points: corr0....corr8. The correction factor can be calculated by a linear interpolation over the 9 corresponding points. The correction factor is applied on the 11 most significant position bits.

**Table 8. LinInt2 Register Description**

Bits	Symbol	Description	
Linint2.15 - linint2.8	Corr5	Correction factor 5 for position 62.5% (225 deg).	
		<b>Corr5 (linint15 - linint8)</b>	
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	...
		....	....
		....	....
		....	....
		0xFF	-127
Linint2.7 - linint2.0	Corr4	Correction factor 4 for position 50% (180 deg).	
		<b>Corr4 (linint7 - linint0)</b>	
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	...
		....	....
		....	....
		....	....
		0xFF	-127

Note: The notation of the correction factor is sign & abs. with a range of +127 ... +- 0.....-127.

### 1.8 LinInt3

Address of register: 0x06.

Default value: 0x0000.

The linearity of the position transfer function can be modified by a correction curve over the whole position range. The correction curve is defined by 9 points: corr0....corr8. The correction factor can be calculated by a linear interpolation over the 9 corresponding points. The correction factor is applied on the 11 most significant position bits.

**Table 9. LinInt3 Register Description**

Bits	Symbol	Description	
Linint3.15 - linint3.8	Corr7	Correction factor 7 for position 87.5% (315deg).	
		<b>Corr7 (linint3.15 - linint3.8)</b>	<b>Correction Factor</b>
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	-1
		....	....
		....	....
		....	....
		0xFF	-127
Linint3.7 - linint3.0	Corr6	Correction factor 6 for position 75% (270deg).	
		<b>Corr6 (linint3.7 - linint3.0)</b>	<b>Correction Factor</b>
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	-1
		....	....
		....	....
		....	....
		0xFF	-127

Note: The notation of the correction factor is sign & abs. with a range of +127 ... +- 0..... -127.

### 1.9 LinInt4

Address of register: 0x07.

Default value: 0x0000.

The linearity of the position transfer function can be modified by a correction curve over the whole position range. The correction curve is defined by 9 points: corr0....corr8. The correction factor can be calculated by a linear interpolation over the 9 corresponding points. The correction factor is applied on the 11 most significant position bits.

**Table 10. LinInt4 Register Description**

Bits	Symbol	Description
Linint4.15 - linint4.8	Reserved	Not used, read as 0 (SWR)

Bits	Symbol	Description	
Linint4.7 - linint4.0	Corr8	Correction factor 8 for position 100% (360deg)	
		<b>Corr8 (linint4.15 - linint4.8)</b>	<b>Correction Factor</b>
		0x00	0
		0x01	1
		....	....
		....	....
		....	....
		0x7F	127
		0x10	-0
		0x11	-1
		....	....
		....	....
		....	....
0xFF	-127		

Note: The notation of the correction factor is sign & abs. with a range of +127 ...+0.....-127.

### 1.10 Coil Offset

Address of register: 0x08.

Default value: 0x0000.

The defined register offset values are added/ subtracted to/from the amplitude values (13-bit) of the receiver coil R2 and coil R1 values. When using the signal offset compensation the automated gain control (AGC1) must be switched off. (agc\_mode = 0b00 => Automatic gain OFF, integration time adaption OFF ).

**Table 11. Amplitude Offset Register Description**

Bits	Symbol	Description		
amp.15	mult_r1	Multiplication factor for amplitude offset_r1		
		<b>mult_r1 (amp.15)</b>	<b>Multiplication Factor</b>	
		0b0	2	
		0b1	4	
amp.14 - amp.8	offset_r1	Offset value which is added/subtracted to/from receiver coil R1 amplitude		
		<b>mult_r1</b>	<b>offset_r1</b>	<b>Correction Factor (Decimal)</b>
		0b0	0b0111111	Ycosine + 126
			0b0000000	Ycosine + 0
			0b1000000	Ycosine - 0
			0b1111111	Ycosine - 126
		0b1	0b0111111	Ycosine + 252
			0b0000000	Ycosine + 0
			0b1000000	Ycosine - 0
			0b1111111	Ycosine - 252
amp.7	mult_r2	Multiplication factor for offset_r2		
		<b>mult_r2 (amp.7)</b>	<b>Multiplication Factor</b>	
		0b0	2	
		0b1	4	
amp.6 - amp.0	offset_r2	Offset value which is added/subtracted to/from receiver coil R2 amplitude.		
		<b>mult_r2</b>	<b>offset_r2</b>	<b>Correction Factor (Decimal)</b>
		0b0	0b0111111	Xsine + 126
			0b0000000	Xsine + 0
			0b1000000	Xsine - 0
			0b1111111	Xsine - 126
		0b1	0b0111111	Xsine + 252
			0b0000000	Xsine + 0
			0b1000000	Xsine - 0
			0b1111111	Xsine - 252

Note:  $\text{abs} ( X_{\text{sine}} + \text{offset}_{r2} )$  exceeds max.value of 0x1FFF → amplitude DSP overflow alarm is asserted.

### 1.11 CalMode

Address of register: 0x09.

Default value: 0x0000.

The calibration mode register contains some control bits which configure the calibration mode and evaluation of the correction curve.

**Table 12. CalMode Register Description**

Bits	Symbol	Description	
calmod.15 - calmod.13	Reserved	Not used, read as 0 (SWR)	
calmod.12	out_mod	Output Mode	
		<b>Out_mod</b>	<b>Output Mode</b>
		0b0	Linear
		0b1	Modulo360
calmod.11 – calmod.9	Reserved	Not used, read as 0 (SWR)	
calmod.8	corr_mod	Correction Mode. Defines how the correction curve has to be applied to correct the linearity of the output transfer function.	
		<b>Corr_mod</b>	<b>Correction Mode</b>
		0b0	Linear error correction pre-calibration
		0b1	Linear error correction post-calibration
calmod.7 – calmod.5	Reserved	Not used, read as 0 (SWR)	
calmod.4	angle_offset	Linearization angle offset. If ( angle_offset ) = 1, -22,5° offset is added to the CORDIC calculation only in the case of an Interpolation correction before the Slope calibration ( Corr_MOD ) = 0	
		<b>Angle_offset</b>	<b>Angle Offset in Degree</b>
		0b0	0
		0b1	-22.5
calmod.3	swap_rc_pol	Testing bits for Renesas	
calmod.2	swap_rc_amp	Testing bits for Renesas	
calmod.1	invppr2	Testing bits for Renesas	
calmod.0	invppr1	Testing bits for Renesas	

#### 1.11.1. Output Mode

Linear (Out\_Mod = 0): Linear Output Mode is a non-repeating output mode in which the sensor output signal is clamped at the mechanical end points with a range of -1260° ... + 1620°.

Modulo 360 (Out\_Mod = 1): The Modulo 360 Output (Sawtooth Output) Mode is a repeating output mode in which the sensor output signal is not clamped at the mechanical end points, but is switched back to its origin with a range between 0° to 360°.



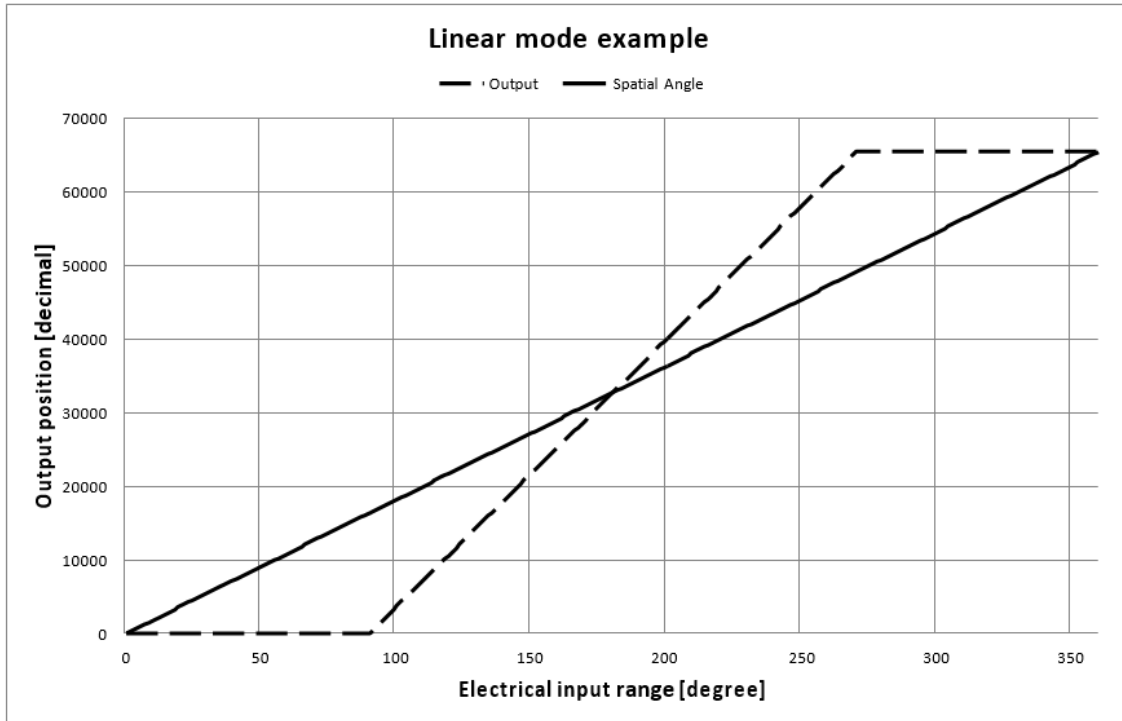


Figure 5. Linear Output Mode Example with Slope = 2, Offset = 90°

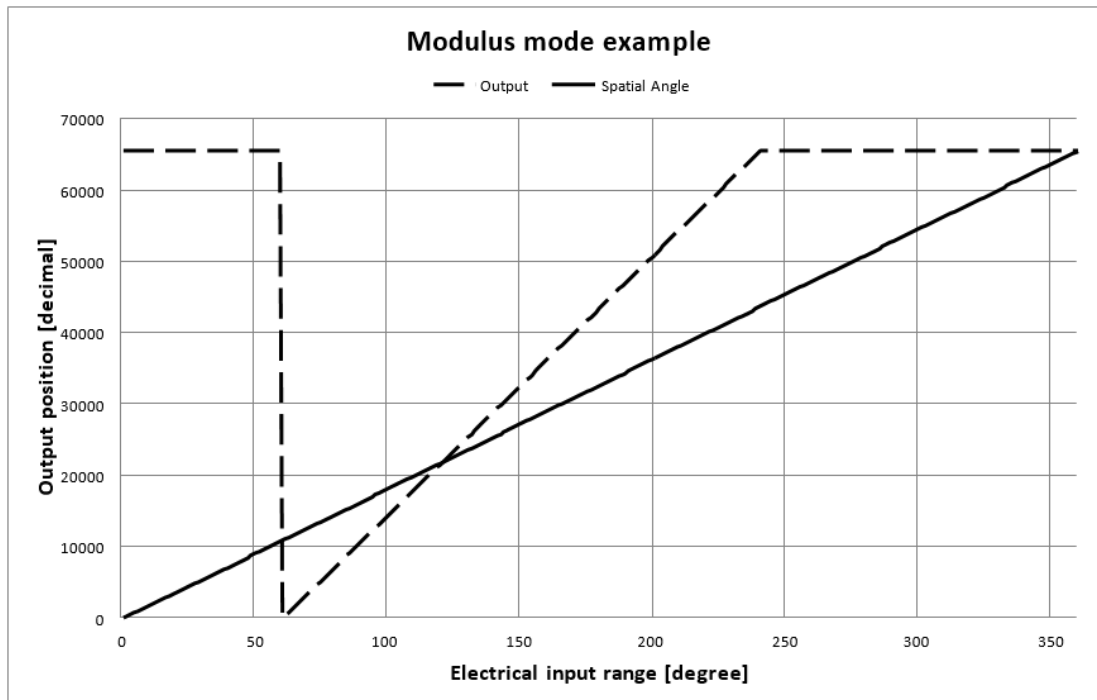
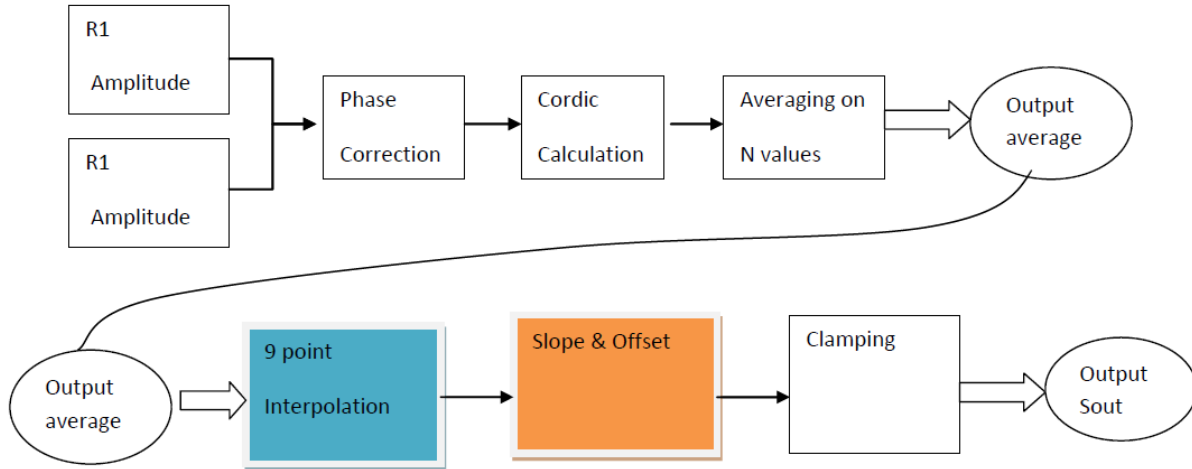


Figure 6. Modulus Output Example with Slope = 2, Offset = 60°

**1.11.2. Correction Mode**

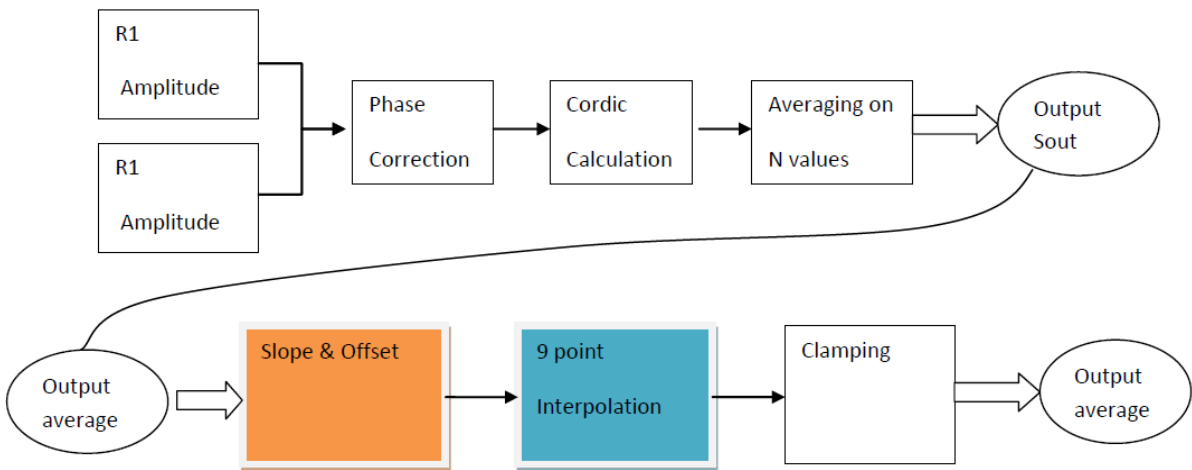
Pre Calibration: if (Corr\_MOD) = 0 then linearity correction is done before "Slope & Offset".

The pre-calibration should be used if the electric input covers a range of a 360°. Using pre-calibration is an advantaged when slope and offset needs to be changed after linearization.



**Figure 7. Pre-Calibration Process**

Post Calibration; if (Corr\_MOD) = 1 then linearity correction is done after " Slope & Offset ". The post-calibration should be the default standard type of calibration.



**Figure 8. Post-Calibration Process**

Note: The reserved bits can be written and read to/from the block E2P. The copy process copies only bits (calmod.12, calmod.8, calmod.4, calout1 and calmod.0) to the SWR.

Note: Individual swapping of receiver polarity & amplitude is only for testing purpose. For application mode both control bits have to be set 0b1 respectively 0b0.



Bits	Symbol	Description										
output.1- output.0	out_pro	Output interface: These bits are used to configure the output interface. The default output is analog.										
		<table border="1"> <thead> <tr> <th>out_pro</th> <th>Outputs</th> </tr> </thead> <tbody> <tr> <td>0b00</td> <td>OWI</td> </tr> <tr> <td>0b01</td> <td>PWM</td> </tr> <tr> <td>0b10</td> <td>Analog output voltage (default)</td> </tr> <tr> <td>0b11</td> <td>SENT</td> </tr> </tbody> </table>	out_pro	Outputs	0b00	OWI	0b01	PWM	0b10	Analog output voltage (default)	0b11	SENT
out_pro	Outputs											
0b00	OWI											
0b01	PWM											
0b10	Analog output voltage (default)											
0b11	SENT											

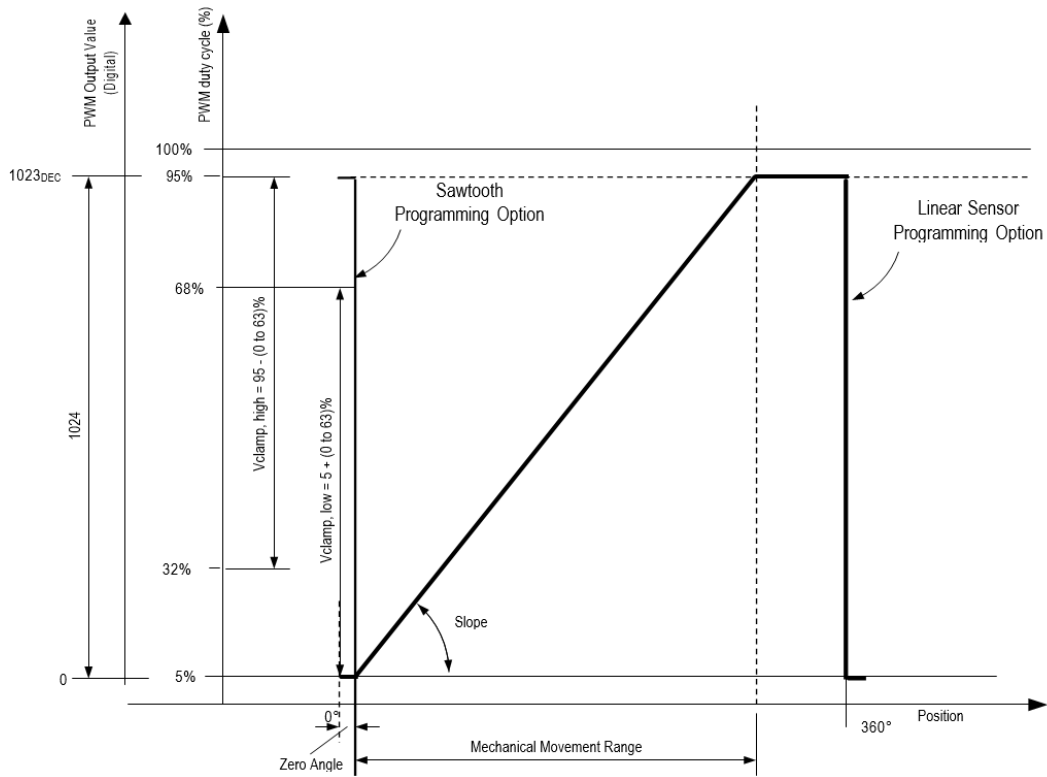


Figure 9. Output PWM Diagnostic Level

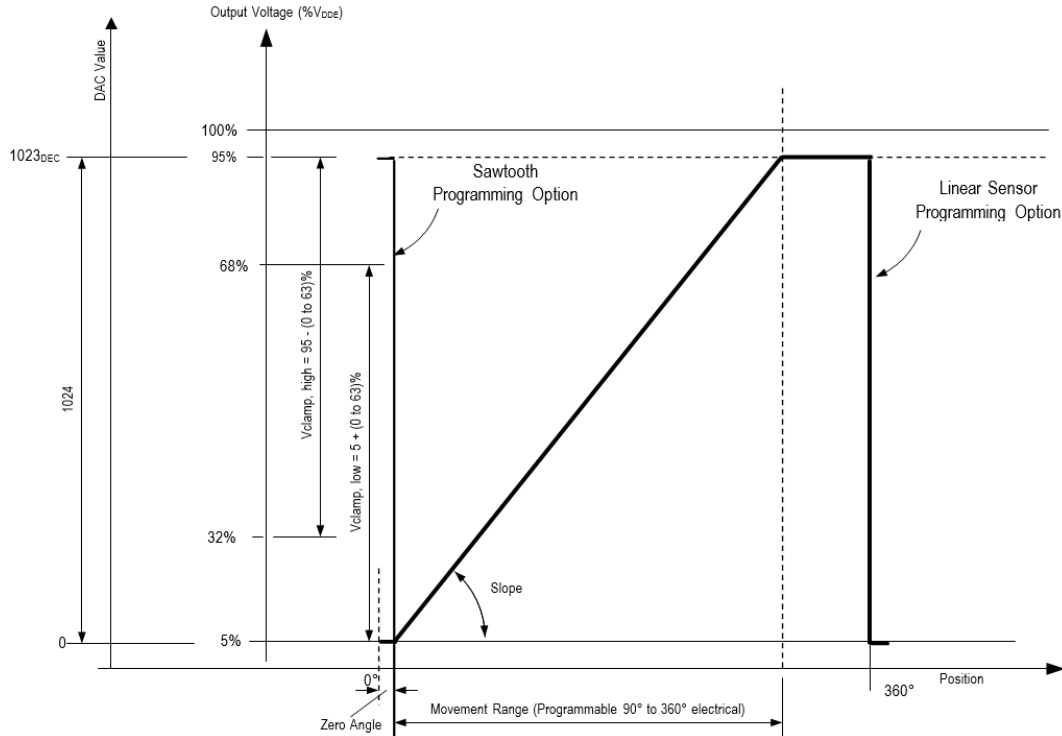


Figure 10. Output Analog Diagnostic Level

Note: The reserved bits can be written and read to/from the block E2P. The copy process copies only defined bits to the SWR.

Note: PWM & SENT timing parameters are based on the ZMID4200 internal oscillator period. To fulfill the electrical specification the oscillator has to be calibrated to 16MHz (see 1.14).

### 1.13 Trimming

Address of register: 0x0B Default value: 0x8107

Trimming and OSR

The Trimming parameters controls the I<sub>c</sub> current and the v<sub>ddt</sub> voltage regulator. The OSR parameter defines the decimation of ADC samples for calculating the position processing update rate.

Table 14. Trim0 Register Description

Bits	Symbol	Description										
trim0.15 - trim0.14	pwm_slope_time	PWM slope time The fall time of the PWM output signal is controlled by current sources. The current sources are switched on in 5 consecutive steps. The time between the steps is defined by the pwm_slope_time parameter. pwm_slope_time= 0b00. 435ns / step pwm_slope_time= 0b01.580ns / step										
trim0.13 - trim0.12	osr	Oversampling Rate The oversampling rate defines the number of samples per receive channel which are accumulated and used for the PPU.										
		<table border="1"> <thead> <tr> <th>OSR</th> <th>Samples/Channel</th> </tr> </thead> <tbody> <tr> <td>0b00</td> <td>4</td> </tr> <tr> <td>0b01</td> <td>8</td> </tr> <tr> <td>0b10</td> <td>16</td> </tr> <tr> <td>0b11</td> <td>32</td> </tr> </tbody> </table>	OSR	Samples/Channel	0b00	4	0b01	8	0b10	16	0b11	32
OSR	Samples/Channel											
0b00	4											
0b01	8											
0b10	16											
0b11	32											
trim0.11 - trim0.9	Reserved	Not used, read as 0 (SWR)										

Bits	Symbol	Description	
trim0.8 - trim0.4	lc_cal	LC Oscillator Calibration (excitation coil)	
		<b>lc_cal</b>	<b>Current (Excitation Coil)</b>
		0b0.0000	Min (0 mA)
		0b1.1111	Max (15 mA)
trim0.3	Reserved	Not used, read as 0 (SWR)	
trim0.2 - trim0.0	vddt_trim	Renesas internal parameter for testing	

### 1.14 AGC0

Address of register: 0x0C Default value: 0x0836

Basic configurations of the analog front end (R1/2 input receive path) gain regulation are controlled by the AGC register. The incoming time division multiplexed signals are amplified by the integrator and the S&H circuit (Figure 6). Both parameters 'ext' and 'gain' will modify the amplification factor of the sampled signals.

The parameter 'smp\_cycle' is a 'timing-factor' in number of sample periods for the adaptive gain regulation to determine the point time for gain / integration time setting. A change of the smp\_cycle parameter should only be done in dependency of the OSR parameter.

Parameter smp\_cycle zero indexed: smp\_cycle = 0 .1st sample. smp\_cycle = 1 .2nd sample.

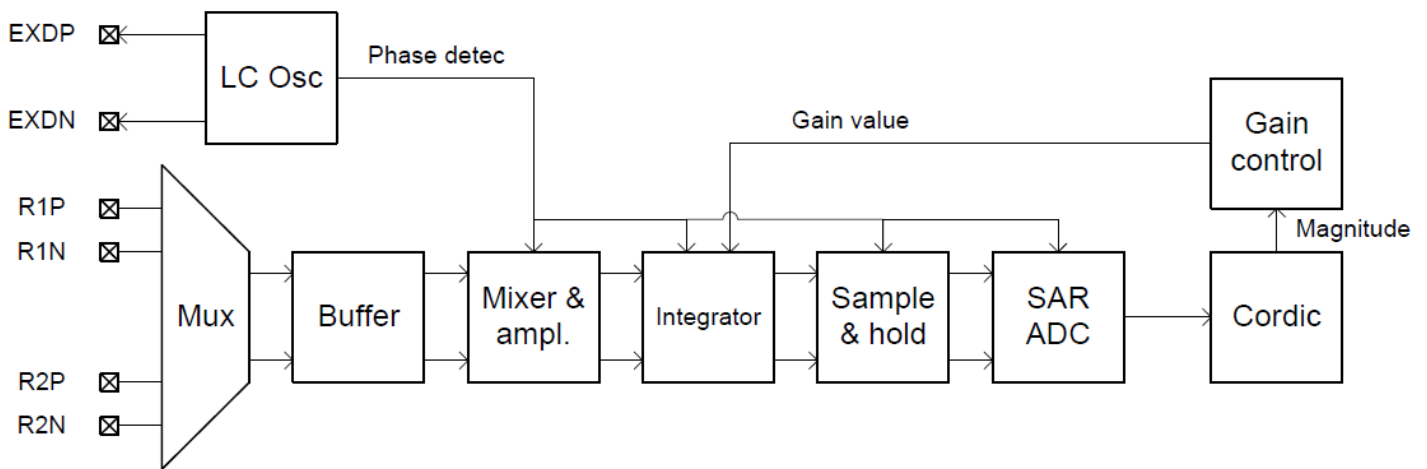


Figure 11. Gain Control

Table 15. AGC0 Register Description

Bits	Symbol	Description			
agc0.15	Reserved	Not used, read as 0 (SWR)			
agc0.14 - agc0.9	smp_cycle	Only when OSR is changed to a non-default value (4) and the AGC control is turned on the sample cycle value needs to be adapted accordingly:			
		<b>OSR</b>	<b>Samples/Channel</b>	<b>2 × Channel</b>	<b>Recommended smp_cycle Setting</b>
		0b00	4	8	0b00.0100
		0b01	8	16	0b00.1100
		0b10	16	32	0b01.1100
		0b11	32	64	0b11.1100
agc0.8 - agc0.4	ext	Renesas internal			

Bits	Symbol	Description	
agc0.3 - agc0.0	gain_stage	Integrator gain stage	
		<b>Gain_stage</b>	<b>Integrator Gain Stage</b>
		0x0	Minimum gain
		...	...
		...	...
		0xC	Maximum gain
		...	Maximum gain
		...	Maximum gain
		0xF	Maximum gain
		<b>AGC Mode (AGC1.13, AGC1.12) in AGC1</b>	<b>Intergrator Gain</b>
Gain regulation OFF (0b00, 0b01)	Fixed gain stage setting.		
Gain regulation ON (0b10)	Maximum gain stage value for gain regulation. This is limiting the gain regulation. It clamps the upper gain stage value. First applicable value for AGC is fixed 0x3.		
	Maximum gain stage value for gain regulation. This is limiting the gain regulation. It clamps the upper gain stage value. After start-up IntegrationTim adaptation is active with gain stage 0x6. Consecutive gainstage adaptation starts with gain stage 0x3.		

### 1.15 AGC1

Address of register: 0x0D Default value: 0x0255.

Automatic Gain Control.

**Table 16. AGC0 Register Description**

Bits	Symbol	Description		
agc1.15	agc_suppress	Renesas internal		
agc1.14	agc_interlink	Renesas internal		
agc1.13 - agc1.12	agc_mode	Extend integration cycle related to excitation clock period effective integration time = (7 + ext ) x Ic_period.		
		<b>Agc_mode</b>	<b>Automatic Gain</b>	<b>Integration Gain Adaptation</b>
		0b00	Off	Off
		0b01	Off	On
		0b10	On	Off
0b11	On	On		
agc1.11 - agc1.10	exc_freq_high	High limit for excitation coil frequency range alarm.		
		<b>Exc_freq_high</b>	<b>Excitation Coil Frequency [MHz]</b>	
		0b00	6.0	
		0b01	6.5	
		0b10	7.0	
0b11	8.0			
An additional variance of about +/- 20% has to be taken into account to frequency variation of ZMID502X internal oscillator over temperature and voltage. The measurement time is ~ 100 us.				
agc1.9 - agc1.8	exc_freq_low	Low limit for excitation coil frequency range alarm.		
		<b>Exc_freq_low</b>	<b>Excitation Coil Frequency [MHz]</b>	
		0b00	1.0	
		0b01	1.5	
		0b10	2.0	
0b11	2.5			
An additional variance of about +/- 20% has to be taken into account to frequency variation of ZMID4200 internal oscillator over temperature and voltage. The measurement time is ~ 100 us.				
agc1.7	Reserved	Not used, read as 0 (SWR).		

Bits	Symbol	Description	
agc1.6 - agc1.4	cordmagul	Cordic magnitude upper level. (100% ....0x34B6.....13494d)	
		<b>Cordmagul</b>	<b>Magnitude Upper Level [%]</b>
		0b111	90
		0b110	85
		0b101	80
		0b100	75
		0b011	70
		0b010	65
		0b001	60
		0b000	55
agc1.3	Reserved	Not used, read as 0 (SWR).	
agc1.2 - agc1.0	cordmagul	Cordic magnitude lower level.	
		<b>Cordmagul</b>	<b>Magnitude Upper Level [%]</b>
		0b111	55
		0b110	50
		0b101	45
		0b100	40
		0b011	35
		0b010	30
		0b001	25
		0b000	20

Notes: The reserved bits can be written and read to/from the block E2P. The copy process copies only defined bits to the SWR. The Cordic magnitude upper level should be higher than the lower level.

### 1.16 Mask

Address of register: 0x0E Default value: 0xBFFF.

The diagnostic mask, in the case that the output is set in the diagnostic state allows to prevent a diagnostic flag. The status of the latched diagnostic flags can be monitored by reading the diagnostic register.

**Table 17. Mask Register Description**

Bits	Symbol	Description	
mask.15	agc_low gain	AGC low gain status	
		<b>Agc_low Gain</b>	<b>AGC Low Gain Alarm</b>
		0b0	Enable
		0b1	Disable
mask.14	ee_ded	EEPROM double error detection	
		<b>Ee_ded</b>	<b>Double Error Alarm</b>
		0b0	Enable
		0b1	Disable
mask.13	r2_coil_fail	Receiver coil2 short/open check status	
		<b>R2_coil_fail</b>	<b>Receiver Coil2 Short/Open Check Status</b>
		0b0	Enable
		0b1	Disable
mask.12	r1_coil_fail	Receiver coil1 short/open check status	
		<b>R1_coil_fail</b>	<b>Receiver Coil1 Short/Open Check Status</b>
		0b0	Enable
		0b1	Disable
mask.11	Open	R1 or R2 receiver coil open	
		<b>Open</b>	<b>R1 or R2 Receiver Coil Open</b>
		0b0	Enable
		0b1	Disable



Bits	Symbol	Description	
mask.10	rc_coil_short	R1 or R2 receiver coil short	
		<b>Rc_coil_short</b>	<b>R1 or R2 Receiver Coil Short</b>
		0b0	Enable
		0b1	Disable
mask.9	rc_gnd_short	R1 or R2 receiver coil short to gnd	
		<b>Rc_gnd_short</b>	<b>R1 or R2 Receiver Coil Short to GND</b>
		0b0	Enable
		0b1	Disable
mask.8	exc_break_p	Not used, read as 0 (SWR).	
		<b>Exc_break_p</b>	<b>Excitation Coil Break P</b>
		0b0	Enable
		0b1	Disable
mask.7	exc_break_n	Cordic magnitude lower level.	
		<b>Exc_break_n</b>	<b>Excitation Coil Break N</b>
		0b0	Enable
		0b1	Disable
mask.6	srb_parity	Shadow Register bank parity	
		<b>Srb_parity</b>	<b>Shadow Register Bank Parity</b>
		0b0	Enable
		0b1	Disable
mask.5	adc_dsp_ovfl	ADC digital signal processing overflow	
		<b>Adc_dsp_ovfl</b>	<b>ADC Digital Signal Processing Overflow (Alarm)</b>
		0b0	Enable
		0b1	Disable
mask.4	amp_dsp_ovfl	Amplitude digital signal processing overflow	
		<b>Amp_dsp_ovfl</b>	<b>Amplitude Digital Signal Processing Overflow</b>
		0b0	Enable
		0b1	Disable
mask.3	lc_osc_fail	LC oscillator range check	
		<b>Lc_osc_fail</b>	<b>LC Oscillator Range Check</b>
		0b0	Enable
		0b1	Disable
mask.2	lc_osc_stuck	LC oscillator stuck check	
		<b>C_osc_stuck</b>	<b>LC Oscillator Stuck Check</b>
		0b0	Enable
		0b1	Disable
mask.1	mag_low	Cordic magnitude is below threshold (lower limit, see section 1.16)	
		<b>C_osc_stuck</b>	<b>Cordic Magnitude is Below Threshold (Lower Limit, 1.14)</b>
		0b0	Enable
		0b1	Disable
mask.0	mag_high	Cordic magnitude is above threshold (upper limit, see section 1.16)	
		<b>mag_high</b>	<b>Cordic Magnitude is Above Threshold (Upper Limit, 1.14)</b>
		0b0	Enable
		0b1	Disable

### 1.17 Traceability0

E2P

Address of register: 0X0F.

Default value: none, read only.

Renesas identification and version number.

**Table 18. Traceability0 Register Description**

Bits	Symbol	Description
trace0.15 - trace0.0	IDT_id	Renesas Identification and version number.

### 1.18 Traceability1

E2P

Address of register: 0x10.

Default value: none, read only.

Renesas identification and version number.

**Table 19. Traceability1 Register Description**

Bits	Symbol	Description
Trace1.15 - Trace1.0	IDT_id	Renesas Identification and version number.

### 1.19 Misc

Address of register: 0x11.

Default value: 0x00C2.

**Table 20. Misc Register Description**

Bits	Symbol	Description	
misc.15 - misc.9	IDT	Renesas internal	
misc.8	agc_offset_sat_mode	AGC offset saturation mode. If this mode is activated an offset saturation detection forces the gain regulation to decrement the gain step to decrease the ADC input signal level.	
		<b>agc_offset_sat_mode</b>	<b>AGC Offset Saturation Mode</b>
		0b0	Extension off
		0b1	Extension on
misc.7	exc_type	Excitation coil alarm type selection (exc_break_p, exc_break_n)	
		<b>exc_type</b>	<b>Coil Alarm Type Selection</b>
		0b0	Event alarm type
		0b1	Latched alarm type
misc.6- misc.0	IDT	Renesas internal	

### 1.20 Afe\_Agc

Address of register: 0x13.

Default value: none, read only.

The integration time regulation adapts the number of integration time cycles that a constant integration time independent of the LC-frequency is achieved. The adjusted cycle number can be monitored by reading the parameter agc\_intgr. The automatic gain regulation process (AGC1) modify the gain by a decision circuit which compares the actual cordic magnitude with the programmed cordic magnitude limits. The adjusted gain value can be monitored by reading the register. The phase information is the polarity of the incoming R1/R2 signal respectively the polarity of the decimated samples R1/2.

**Table 21. Afe\_Agc Register Description**

Bits	Symbol	Description
afe_agc.15 - afe_agc.13	Reserved	Not used, read as 0 (SWR).
afe_agc.12 - afe_agc.8	agc_intgr	AGC adjusted number of integration cycles effective integration time = (7 + agc_intgr) x Tc clock period.
afe_agc.7 - afe_agc.4	agc_gain stage	AGC adjusted gain stage value range 0x0...0xC.

Bits	Symbol	Description	
afe_agc.3	r1_polarity	Polarity of receiver coil R1	
		<b>R1_polarity</b>	<b>Polarity of Receiver Coil R1</b>
		0b0	Negative
		0b1	Positive
afe_agc.2	r2_polarity	Polarity of receiver coil R2	
		<b>R2_polarity</b>	<b>Polarity of Receiver Coil R2</b>
		0b0	Negative
		0b1	Positive
afe_agc.1	y_cos_pol	Phase polarity of Ycosine amplitude parameter. The sensor position is calculated based on the receiver amplitude (see sections 1.21 and 1.22) and related phase polarity.	
afe_agc.0	x_sin_pol	Phase polarity of Xsine amplitude parameter. The sensor position is calculated based on the receiver amplitude (see sections 1.21 and 1.22) and related phase polarity.	

### 1.21 Xsine

Address of register: 0x14.

Default value: none, read only.

The amplitude of the receiver coils after decimation and amplitude offset evaluation (sampler output) can be monitored by reading the register Xsine.

**Table 22. Xsine Register Description**

Bits	Symbol	Description
xsine.15 -xsine.13	Reserved	Not used, read as 0 (SWR).
xsine.12 -xsine.0	x_sin_amp	Amplitude of receiver coil. Absolute amplitude after decimation and amplitude offset evaluation.

### 1.22 Ycosine

Address of register: 0x15.

Default value: none, read only.

The amplitude of the receiver coil after decimation and amplitude offset evaluation (sampler output) can be monitored by reading the register Ycosine.

**Table 23. Ycosine Register Description**

Bits	Symbol	Description
xsine.15 -xsine.13	Reserved	Not used, read as 0 (SWR).
xsine.12 -xsine.0	y_cos_amp	Amplitude of receiver coil absolute amplitude after decimation and amplitude offset evaluation.

### 1.23 Angle

Address of register: 0x16.

Default value: None; read only.

The sensor position is calculated based on the x\_sin\_amp (see section 1.21) and y\_cos\_amp (see section 1.22) parameter. The result of 90 degree angle is calculated by  $\arctan\left(\frac{x\_sin\_amp}{y\_cos\_amp}\right)$ .

The trigonometric function is implemented by an iterative CORDIC (Coordinate Rotation Digital Computer) architecture. The chosen number of iteration steps is 16. CORDIC works by rotating the coordinate system through constant angles until the angle is reduced to zero and the result vector is aligned with the X axis. The result of the vectoring operation is a rotation angle (0deg <= angle <= 90deg) and the scaled magnitude of the original vector. The calculated rotation angle is mapped to a 15-bit vector and can be monitored by the angle register read access.

**Table 24. Angle Register Description**

Bits	Symbol	Description								
angle.15	Reserved	Not used, read as 0 (SWR).								
angle.14 – angle.0	cordic angle	Rotational CORDIC angle from 0 degree to 90 degree.								
		<table border="1"> <thead> <tr> <th>Cordic Angle</th> <th>Angle [Degree]</th> </tr> </thead> <tbody> <tr> <td>0x0000</td> <td>0</td> </tr> <tr> <td>.....</td> <td>.....</td> </tr> <tr> <td>0x7FFF</td> <td>90</td> </tr> </tbody> </table>	Cordic Angle	Angle [Degree]	0x0000	0	.....	.....	0x7FFF	90
Cordic Angle	Angle [Degree]									
0x0000	0									
.....	.....									
0x7FFF	90									

**1.24 Cordic Magnitude**

Address of register: 0x17

Default value: None: read only

The CORDIC algorithm in vectoring mode works by seeking to minimize the Ycosine component of the residual vector at each rotation. The result of the vectoring operation is a rotation angle (see section 1.23) and the scaled magnitude of the original vector  $\sqrt{Xsine^2 + Ycosine^2}$ .

The aggregate constant of all 16 iteration steps resp. the scale factor is  $\frac{1}{0.707}$

It follows for the cordic magnitude:

$$\text{Cordic magnitude} = \frac{\sqrt{Xsine^2 + Ycosine^2}}{0.607}$$

Assumption: Saturation of both receiver channels:

$$Xsine = Ycosine = 0x1FFF$$

$$\text{cordic magnitude(sat)} = 0x4A8B$$

Assumption: Signals of both receive channels at ideal amplification (below saturation).

$$Xsine = 0x1FFF \quad Ycosine = 0x0000$$

$$\text{cordic magnitude(opt)} = 0x34B6$$

Conclusion: The cordic magnitude is a monitor for gain respectively integration time setting. It is important that the magnitude does not exceed the optimum level. Otherwise this will lead to a failure in the position calculation (nonlinearity).

**Table 25. Mag Register Description**

Bits	Symbol	Description								
angle.15	Reserved	Not used, read as 0 (SWR).								
angle.14 – angle.0	cordic angle	Rotational CORDIC magnitude from minimum magnitude saturation.								
		<table border="1"> <thead> <tr> <th>Cordic Mag</th> <th>Magnitude</th> </tr> </thead> <tbody> <tr> <td>0x4A8B</td> <td>Sat</td> </tr> <tr> <td>0x34B6</td> <td>Opt</td> </tr> <tr> <td>0x0000</td> <td>Min</td> </tr> </tbody> </table>	Cordic Mag	Magnitude	0x4A8B	Sat	0x34B6	Opt	0x0000	Min
Cordic Mag	Magnitude									
0x4A8B	Sat									
0x34B6	Opt									
0x0000	Min									

**1.25 SPA**

Address of register: 0x18.

Default value: None: read only.

The CORDIC processor output angle is expanded by the phase polarity information ( y\_cos\_pol & x\_sin\_pol ) to a range from 0 deg to 360 deg. The ZMID4200 internal notation is a 17-bit vector (4 x angle 15-bit). Due to the 16-bit wide data structure of the OWI interface, the spatial angle vector is truncated to 16 bits (17 down to 1) for the read-access.

**Table 26. Spa Register Description**

Bits	Symbol	Description	
spa.15 - spat.0	spatial angle	Spatial angle Expanded cordic angle to 360 degree range. The value is before calibration and linear error correction. The ZMID4200 internal notation is a 17-bit wide vector. From 0 deg to 360 deg.	
		<b>Spatial Angle</b>	<b>Spatial Angle [Degree]</b>
		0x0000	0 min
		0xFFFF	360 max

Note: Due to the truncation of the spatial angle number range to 16-bit (OWI access), the number range of the cordic angle has to be also truncated by one bit (14 down to 1) for direct comparison of this two parameters.

### 1.26 Pos0

Address of register: 0x19.

Default value: None: read only.

The spatial angle is modified by the calibration parameter slope & offset (see sections 1.2 and 1.3) and the linearity error correction. The pos0 value is the calculated value with linearity error correction before calibration (see section 1.11, corr\_mod = 0).

**Table 27. Pos0 Register Description**

Bits	Symbol	Description	
pos0.15 - pos0.0	pos_so_corr0	Position before calibration & linearity error correction (linear error correction pre-calibration, corr_mod= 0), see section 1.11.	
		<b>Spatial Angle</b>	<b>Spatial Angle [Degree]</b>
		0x0000	0
		0xFFFF	360

### 1.27 Pos1

Address of register: 0x1A Default value: None: read only.

The spatial angle is modified by the calibration parameter slope & offset (see sections 1.2 and 1.3) and the linearity error correction. The pos1 value is the calculated value with linearity error correction after calibration (see section 1.11, corr\_mod = 1).

**Table 28. Pos1 Register Description**

Bits	Symbol	Description	
pos0.15 - pos0.0	pos_so_corr1	Position after calibration & linearity error correction (linear error correction post-calibration, corr_mod= 1), see section 1.11.	
		<b>Spatial Angle</b>	<b>Spatial Angle [Degree]</b>
		0x0000	0
		0xFFFF	360

Note: For the different output protocols the calculated position is truncated from MSB down to 1/5/7. For the SENT respectively PWM/Analog the remainder is rounded.

Note: If corr\_mod = 0b0 (1.10, calout.3) pos\_so\_corr1 is equal pos\_so\_corr0 (1.25).

## 2. Glossary

Acronym	Definition
ADC	Analog Digital Converter
ATE	Automatic Test Equipment
ATPG	Automatic Test Pattern Generation
PPU	Position Processing Unit
E2P	Electrically Erasable Programmable Read Only Memory
ECU	Electronic Control Unit
ECC	Error Correction Code
FEC	Forward Error Correction
GND	Ground
IC	Integrated Circuit
LSB	Least Significant Bit
MSB	Most Significant Bit
OWI	One Wire Interface
OSR	Over Sampling Rate
PPR	Pulse Pause Ratio
SWR	Shadow Word Register bank
TDM	Time Division Multiplexer

## 3. Revision History

Revision Date	Description of Change
July 21, 2021	Initial release

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