ams AS5173

Datasheet

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Table of contents

AS5173 High-resolution on-axis magnetic angular position sensor with PSI5 output

1 General description

The AS5173 is a magnetic position sensor with a high resolution 12-bit or 14-bit PSI5 output according to PSI5 specification Version 1.3 and 2.3. Based on hall sensor technology, this device measures the flux density Bz orthogonal to the die surface over a full-turn rotation and compensates for external stray magnetic fields with a robust architecture based on a 14-bit sensor array and analog front-end (AFE). A sub-range smaller than 360 ° can be programmed to achieve the best resolution for the application. To measure the angle, a two-pole magnet rotating over the center of the package is required. The magnet may be placed above or below the device. The absolute angle measurement provides an instant indication of the magnets angular position within a range of up to 360°. The supply pins are protected against reverse polarity. Programmability over the VDD pin reduces the number of pins on the application connector.

The SIP package integrates the sensor die together with the decoupling capacitors necessary to pass system level ESD and EMC requirements. No additional components or PCB is needed. The product is defined as SEooC according to ISO26262. The product is fully system level EMC and ESD tested according to automotive OEM standards.

1.1 Key benefits & features

The benefits and features of AS5173, High-resolution on-axis magnetic angular position sensor with PSI5 output are listed below:

Table 1: Added value of using AS5173

Features	Benefits
Noise filter	Customer adjustable filter for the reduction of angular noise.
PSI5 v1.3 and PSI5 v2.3	PSI5 interface enables voltage supply of the AS5173 and angle communication from the AS5173 to the ECU over just two wires.
UART_over_PSI5	UART_over_PSI5 enables voltage supply and two-way communication between AS5173 and ECU for programming purposes.
Programmable application start point and end point	Allows to program the AS5173 output for angles < 360 °.
Magnetic stray field immunity	Robust and accurate position sensing when stray fields are present exceeding ISO 11452-8 without magnetic shielding needed.
Suitable for safety critical applications	Developed according to ISO26262 compliant development flow. ASIL-B as SEooC. Integrated safety mechanisms
AEC-Q100 grade 1 qualified	Suitable for automotive applications
	• System cost reduction No PCB (Printed Circuit Board) Passive components are integrated into the SIP package • Smaller bill of materials

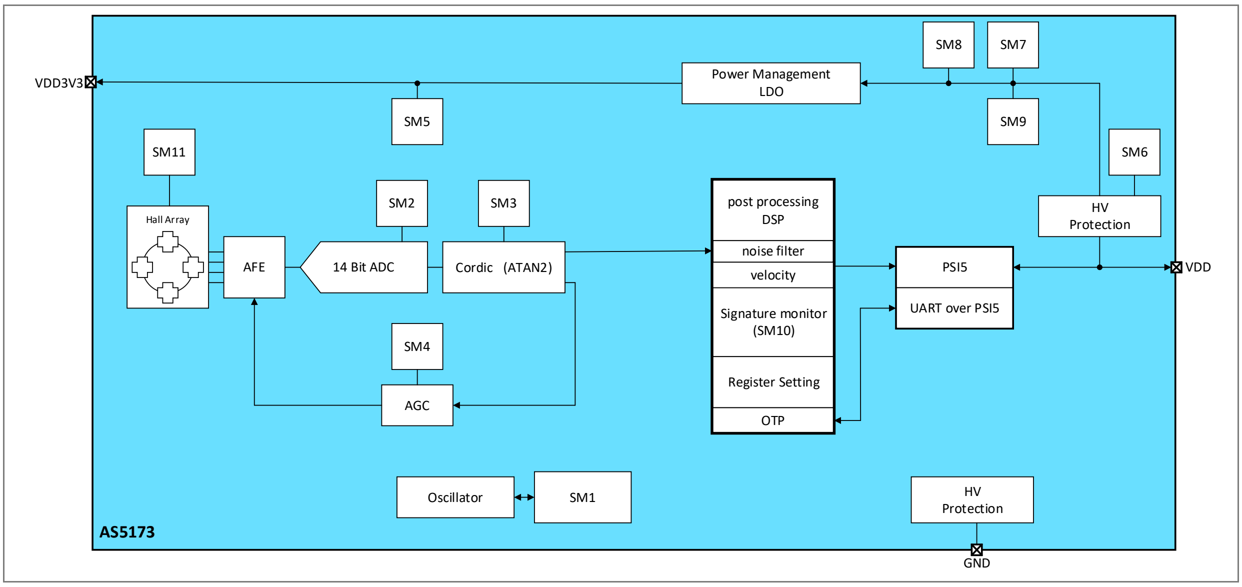
1.2 Applications

- Chassis Position Sensors (CPS)
- Automotive pedals
- Throttle valve
- Tumble flap
- Steering angle sensors
- Fuel level measurement systems

1.3 Block diagram

The functional blocks of the AS5173 device are shown below:

Figure 1: Functional blocks of AS5173



(1) Detailed safety mechanism information can be found in chapter Diagnostic.

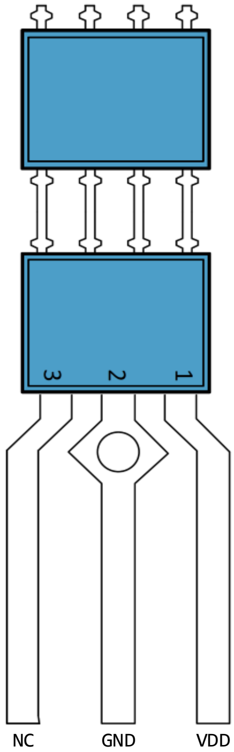
2 Ordering information

Ordering code	Package	Marking	Delivery form	Delivery quantity
Q65113A8926	SIP3	AS5173	13 inch Tape & Reel in dry pack	2000 pcs/reel

3 Pin assignment

3.1 Pin diagram

Figure 2: AS5173 package



3.2 Pin description

Table 2: Pin description of AS5173

Pin number	Pin name	Pin type	Description
1	VDD	Supply	supply and PSI5 and UART_over_PSI5
2	GND	Supply	ground
3	NC	Not connected	leave open in application

4 Absolute maximum ratings

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under "Operating Conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 3: Absolute maximum ratings of AS5173

Symbol	Parameter	Min	Max	Unit	Comments
		Electrical parameters			
VDD	DC supply voltage at VDD pin	-18	20	V	Not operational
VREGOUT	DC voltage at the VDD3V3 pin	-0.3	5	V	
ISCR	Input current (latch-up immunity)	±100		mA	AEC-Q100-004
		Continuous power dissipation (T_{AMB} = 70 °C)			
P_{T_SIP}	Continuous power dissipation		377	mW	
		Electrostatic discharge			
$ESD_{HBM\ on\ all}$	Electrostatic discharge HBM	±2		kV	AEC-Q100-002
$ESD_{HBM\ on\ SIP}$	On VDD and GND	±8		kV	AEC-Q100-002
		Temperature ranges and storage conditions			
T_{AMB}	Operating temperature range	-40	125	°C	AS5173 ambient temperature
T_{aProg}	Programming temperature	5	45	°C	Temperature range within which the programming of the OTP is allowed.
T_{STRG}	Storage temperature range	-55	125	°C	
T_{BODY}	Package body temperature		260	°C	The reflow peak soldering temperature (body temperature) is specified according to IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices." The lead finish for Pb-free leaded packages is "Matte Tin" (100% Sn)
RH_{NC}	Relative humidity (non-condensing)	5	85	%	
MSL	Moisture sensitivity level	3			Represents a maximum floor lifetime of 168 hours

5 System electrical and timing characteristics

All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

Table 4: Operating conditions (Overall Condition: T_{AMB}= -40°C to 125°C)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VDD	Positive supply voltage	Static condition	4		12	V
VDD_Rx	Positive supply voltage	Dynamic condition	4		16.5	V
t_VDD_rise	rise time of VDD for which correct startup is guaranteed				2	V / µs
VDD3	Regulator voltage		3.3	3.45	3.6	V
IDD	Current consumption	Idle current consumption.	7		19	mA
IDDProg	Current consumption	During programming		80		mA
IDDProgUN	Current consumption of unprogrammed device	Unprogrammed device @ T_{AMB} = 25°C ± 10°C			49	mA
IDD max	Current consumption	IDD + IS_Common			49	mA
IS_Common	Sink current (common mode)		22	26	30	mA
IDD_DRate	Current drift rate	Not tested			1	mA/s
TSUP	Start-up time, with ±2mA tolerance in respect to the trimmed ILO value (IL)	Functional mode			5	ms
PSI5_T	Fall/rise time of the current slope	Programmed in production	300	500	700	ns
PSI5_TBITL	Bit time 125kbit/s mode	Not tested - Guaranteed by Design	7.6	8.0	8.4	µs
PSI5_TBITH	Bit time 189kbit/s mode	Not tested - Guaranteed by Design	5.0	5.3	5.6	µs
PSI5_MSR	Mark/space ratio	$(t_{fall,80\%} - t_{rise,20\%})$/PSI5_TBIT or $(t_{fall,20\%} - t_{rise,80\%})$/PSI5_TBIT programmed in production	47	50	53	%

6 Electrical system characteristics

T_{AMB}= -40°C to 125°C for AS5173; VDD = 4V – 12V (sync pulse voltage not included); Magnetic characterization, unless otherwise noted.

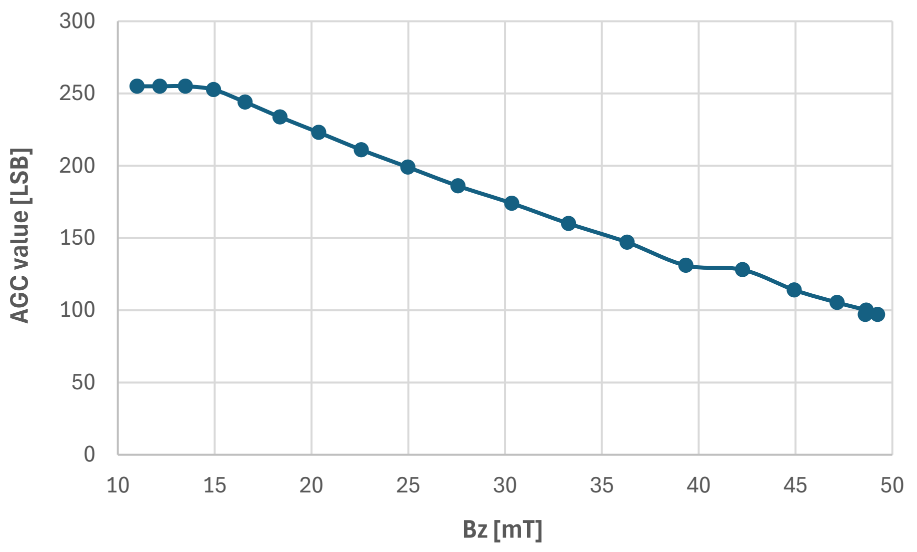
Table 5: Electrical system characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
CRES	Core resolution			14		bit
INLopt	Integral non-linearity (optimum)	Best aligned reference magnet(1) at 25°C over full turn 360°	-0.5		0.5	deg
INLtemp	Integral non-linearity (optimum)	Best aligned reference magnet(1) over temperature -40°C to 125°C over full turn 360°	-0.9		0.9	deg
INL	Integral non-linearity	Reference magnet(1) over temperature -40°C to 125°C over full turn 360º and displacement as specified in Table 7.	-1.4		1.4	deg
ST	Sampling time			128		µs
SPDF	System propagation delay fast	Depending on the PSI5 standard	200		500	µs
CoreClk	Core clock			16		MHz
Coreclk tol	Tolerance of the core clock		-3.5		3.5	%
ON	Output Noise	• No filter activated • RMS noise (1 sigma) • -40 °C to 125 °C ambient temperature. • Extended_range_disable can be set to 0 or 1. AGC needs to be within the range. • Applicable for AGC value: <250 Guaranteed by design. The noise improvement achievable with the filter is shown in Table 22.	0.041	0.043	0.047	deg
ON_high	Output Noise high gap	• No filter activated • RMS noise (1 sigma) • -40 °C to 125 °C ambient temperature. • Extended_range_disable can be set to 0 or 1. AGC needs to be within the range. • Applicable for AGC value: >=250 Guaranteed by design. The noise improvement achievable with the filter is shown in Table 22.	0.1	0.11	0.14	deg

(1) Reference magnet: NdFeB, 8mm diameter, 2.5mm thickness.

The AGC value depends on the magnetic flux density at the hall element. The typical relation between AGC value and flux density Bz is shown in Figure 3. The relation between AGC value and Bz can have a part-to-part variation, but it is guaranteed that the device will work within the limits of Bz and BzE (see Table 7).

Figure 3: Typical relation between Bz [1] and AGC value



(1) Higher Bz allows lower noise applications.

Table 6: Power management – supply monitor - timing

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VDDUVTH	VDD undervoltage upper threshold		3.6	3.8	4.0	V
VDDUVTL	VDD undervoltage lower threshold		3.4	3.6	3.8	V
VDDUH	VDD undervoltage hysteresis	Info parameter	150	200	250	mV
UVDT	VDD undervoltage detection time		10	50	250	µs
UVRT	Undervoltage recovery time		10	50	250	µs
VDDOVTH	VDD overvoltage upper threshold	If sensor in overvoltage condition, ECU gets the Error flag. --> overheating possible in the application	16.7	18	19.1	V
VDDOVTL	VDD overvoltage lower threshold		14.5	15.5	16.5	V
OVDT	VDD overvoltage detection time	From the time VDD exceeding 16.5V		1000	2000	µs
OVRT	VDD overvoltage recovery time	From the time VDD returning from VDD > 16.5V to normal operating voltage (4V< VDD < 17V)		1000	2000	µs
VDD3V3UVTH	VDD3V3 reset upper threshold		2.5	2.8	2.95	V
VDD3V3UVTL	VDD3V3 reset lower threshold		2.4	2.6	2.72	V
VDD3V3UVHYS	VDD3V3 reset hysteresis	Info parameter	105	175	245	mV
TDETWD	Watchdog error detection time				12	ms

7 Magnetic characteristics

T_{AMB}= -40°C to 125°C for AS5173; VDD= 4V – 12V (sync pulse voltage not included); unless otherwise noted.

Two-pole cylindrical diametrically magnetized source:

Table 7: Magnetic characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Bz	Orthogonal magnetic field strength	Required orthogonal component of the magnetic flux density measured at the die surface on the circle on which the hall sensors are located (see HALL RADIUS in Figure 36). If Extended_range_disable (bit 3 in register 0x1D) is set to 1, then it is ensured that SM4 doesn't trigger within the specified Min and Max range.	30		70	mT
BzE	Orthogonal magnetic field strength – extended mode	Required orthogonal component of the magnetic flux density measured at the die surface on the circle on which the hall sensors are located (see HALL RADIUS in Figure 36). If Extended_range_disable (bit 3 in register 0x1D) is set to 0, then it is ensured that SM4 doesn't trigger within the specified Min and Max range.	10		90	mT
Disp[1]	Displacement radius	Offset between defined device center and magnet axis. Depending on the selected magnet.		0.5		mm

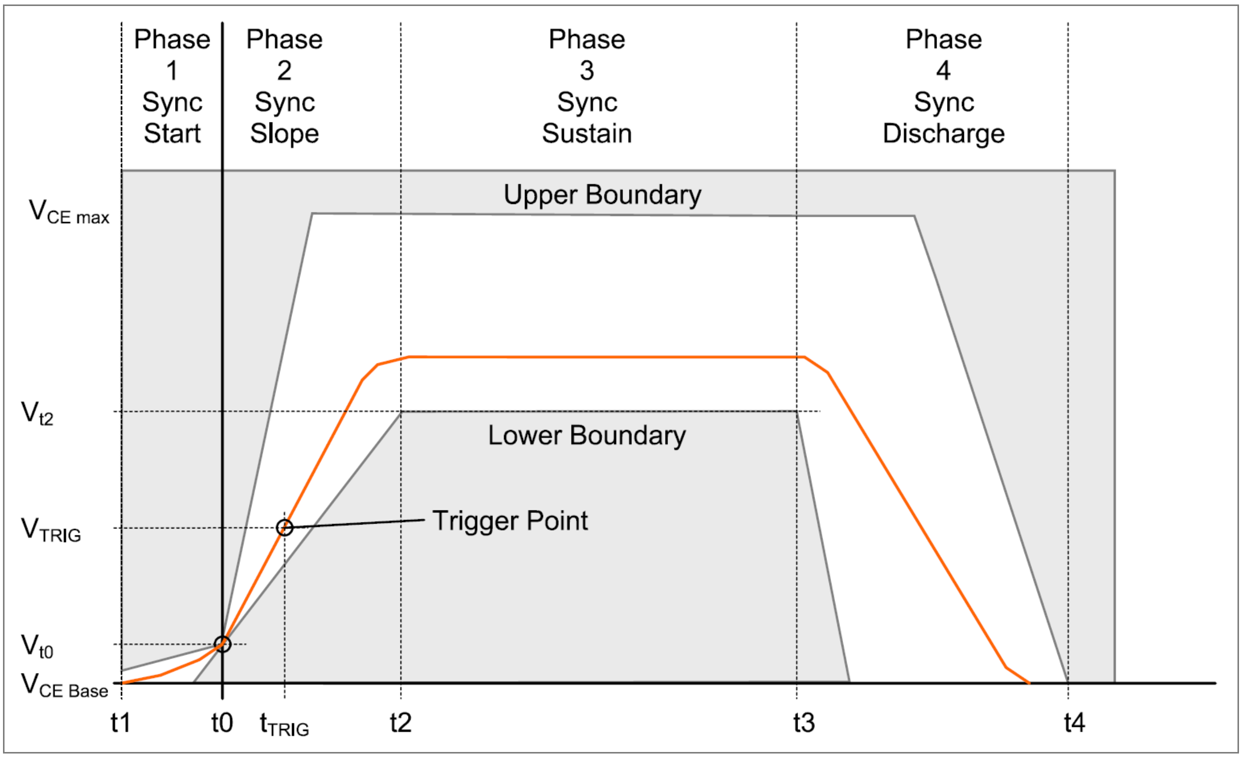
(1) Reference magnet: NdFeB, 8mm diameter, 2.5mm thickness.

8 Electrical and timing characterization of the PSI5 interface

This chapter describes the synchronization signal from the ECU according to the PSI5 specifications V1.3 and V2.3. The parameters in this chapter do not reflect the full specification range of the detection circuit for the synchronization signal.

8.1 Synchronization signal PSI5 V1.3

Figure 4: Synchronization signal



The synchronization signal start time t0 is defined as a crossing of the V_{t0} value. In the "Sync Start" phase before this point, a "rounding in" of the voltage starting from VCE, Base to V_{t0} is allowed for a maximum of t1. During the "Sync Slope" phase, the voltage rises within given slew rates to a value between the minimum sync signal voltage V_{t2} and the maximum interface voltage VCE, max. After maintaining the voltage between these limits until a minimum of t3, the voltage decreases in the "Sync Discharge" phase until having reached the initial VCE, base value until latest t4.

Table 8: Synchronization signal PSI5 V1.3(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VBase	Base supply voltage	Voltage value at ECU	5.7		11	V
Vt0	Sync slope reference voltage	Reference to VBase		0.5		V
Vt2	Sync signal sustain voltage	Reference to VBase	3.5			V
Vce,max	Maximum interface voltage				16.5	V
t0	Reference time	Reference time base; time when the sync signal crosses Vt0		0		µs
t1	Sync signal earliest start	$V=V_{CE}$ Delta current less than 2mA	-3		0	µs
t2	Sync signal sustain start	@ V_{t2}		7		µs
	Sync slope rising slew rate	Lower limit is valid for V_{t0} to V_{t2}	0.43	1.0	1.5	V/µs
	Sync slope falling slew rate		-1.5			V/µs
t3	Sync signal sustain time			16		µs
t4	Discharge time limit			35		µs
Tslot1	Start of time slot 1		44	51	59	µs
Tslot2	Start of time slot 2		181.3	195	210	µs
Tslot3	Start of time slot 3		328.9	350	373	µs

(1) The parameters in this table are just info parameters and therefore not production tested. The production-related parameters are in the PSI5 Block parameters table.

Table 9: Synchronization signal PSI5 V2.3(1)

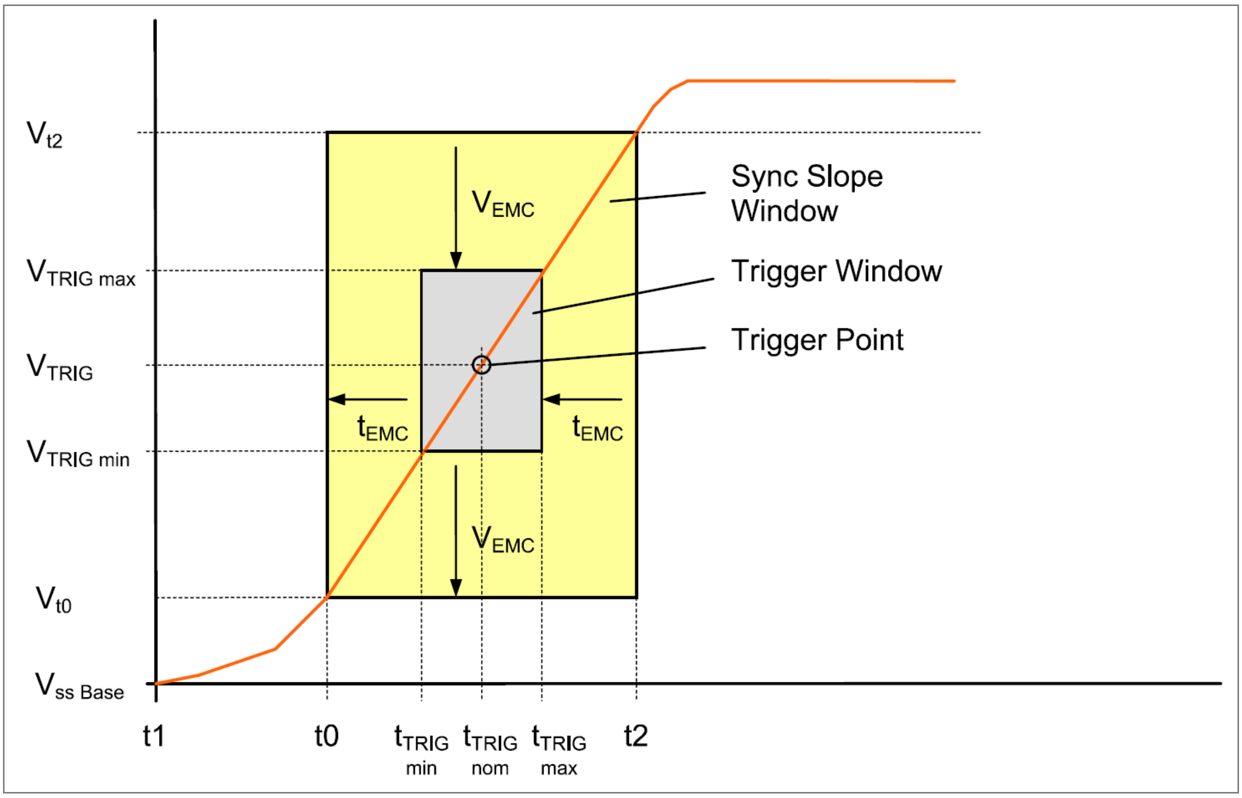
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VBase	Base supply voltage	Voltage value at ECU	5.7		11	V
Vt0	Sync slope reference voltage	Reference to VBase		0.5		V
Vt2	Sync signal sustain voltage	Reference to VBase	3.5			V
Vce,max	Maximum interface voltage				16.5	V
t0	Reference time	Reference time base; time when they sync signal crosses Vt0		0		µs
t1	Sync signal earliest start	V=VCE Delta current less than 2mA	-3		0	µs
t2	Sync signal sustain start	@ Vt2		7		µs
	Sync slope rising slew rate	Lower limit is valid for Vt0 to Vt2	0.43		1.5	V/µs
	Sync slope falling slew rate		-1.5			V/µs
t3	Sync signal sustain time			16		µs
t4	Discharge time limit				35	µs
Tslot1	Start of time slot 1		44			µs

(1) The parameters in this table are just info parameters and therefore not production tested. The production-related parameters are in the PSI5 Block parameters table.

8.2 Synchronization signal detection

The AS5173 detects the trigger within the “trigger window” (see Figure 5) during the rising slope of the synchronization signal at the trigger point with the trigger voltage V_{TRIG} and the trigger time t_{TRIG}.

Figure 5: Trigger window



To account for voltage differences at different points of the interface lines, an additional safety margin for the trigger detection is defined by V_{EMC} and t_{EMC}.

The values are based on the PSI5 specification and show the detection of the synchronization signal from the ECU according to the PSI5 specification.

Table 10: Synchronization detection[1]

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VEMC_C	Margin for voltage variations	Common power mode	-0.9		0.9	V
VTrig_C	Trigger voltage threshold	Common power mode	1.4	2.0	2.6	V
t_{TRIG}	Nominal trigger detection time	@ V_{TRIG}, @ AS5173 Pins; Referenced to a straight sync signal slope with nominal slew rate of 0.43 V/µs	2.1	3.5	4.9	µs
VCE,max	Maximum interface voltage				16.5	V
t_{EMC}	Margin for timing variations of the signal on the interface line	Relative to nominal trigger window time	-2.1		2.1	µs
$t_{tol\ detect}$	Tolerance of internal trigger detection delay				3	µs
T_{TRIG}	Trigger detection time (according PSI5_spec_v2d2_base)	$T_{TRIG} = t_{TRIG} + t_{tol\ detect} + t_{EMC}$; Reference for AS5173 time base	0		10	µs

(1) The parameters in this table are just info parameters and therefore not production tested. The production related parameters are in the PSI5 Block parameters table.

8.3 Synchronization signal with discharge by AS5173

This chapter describes the modifications required if the ECU uses a special transceiver.

The parameters in this chapter do not reflect the full specification range of the detection circuit for the synchronization signal.

Figure 6: Synchronization signal from ECU with discharge by the AS5173

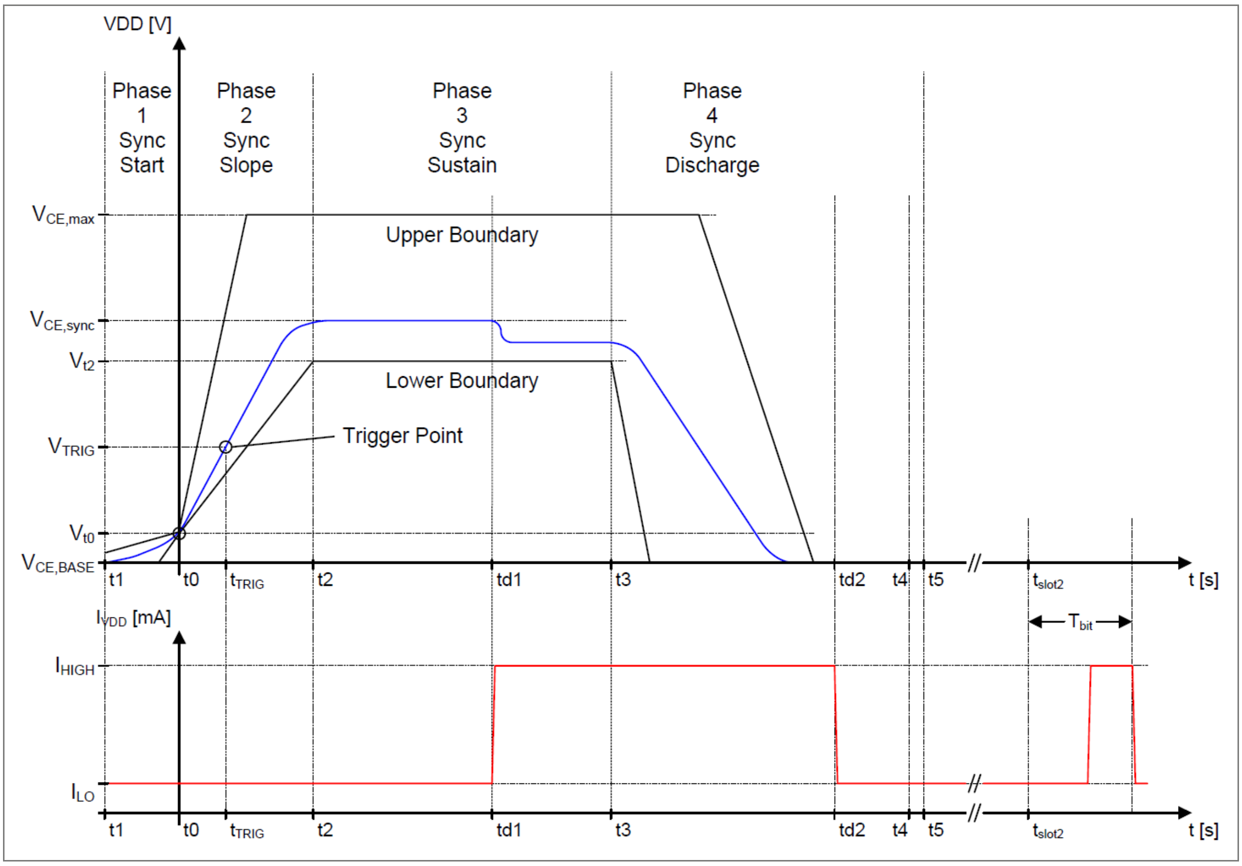


Table 11: Synchronization signal from ECU with discharge parameter

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{CE, BASE}$	Base supply voltage	Mean voltage value at ECU	5.0	6.0	7.0	V
$V_{CE, BASE\_R}$	Base supply voltage including ripple		4.5	6.0	7.0	V
V_{t0}	Sync slope reference voltage	Referenced to $V_{CE, BASE}$		0.5		V
V_{t2}	Sync signal sustain voltage	Referenced to $V_{CE, BASE}$	+3.5	+5.0	+6.0	V
$V_{CE,max}$	Sync signal max. Voltage		10	11	14.5	V
V_{CE,max_R}	Sync signal max. Voltage including ripple		10	14	16.5	V
t0	Reference time	Reference time base; time when the synchronization signal crosses V_{t0}		0		µs
t1	Sync signal earliest start	$V=V_{CE, BASE}$	-3		0	µs
t2	Sync signal sustain start	@ V_{t2}	3	4	5	µs
$S_{sync,r}$	Sync slope rising slew rate	10% to 90% of $V_{CE,max}$	0.7	1.0	1.6	V/µs
$S_{sync,f}$	Sync slope falling slew rate	90% down to 10% of $V_{CE,max}$	-1.6	-1.0	-0.7	V/µs
t3	Sync signal sustain time	$V=V_{CE,sync}$	27.5	31	35.1	µs
td1	AS5173 signals discharge		18.5	22.75	28	µs
td2	Discharge stop time		38	43.25	50	µs
t4	Enable pull down to $V_{CE,BASE}$ by ECU		62.5	65	65.5	µs
t5	Receiver (ECU) enable start time	Receiver (ECU) read for transmission	63	66.2	65.5	µs
V_{TRIG}	Trigger voltage threshold		1.4	2.0	2.6	V
t_{TRIG}	Nominal trigger detection time	@ V_{TRIG}, @ AS5173 Pins; Referenced to a straight sync signal slope with nominal slew rate of 0.7 V/µs	1.25	2.15	3.05	µs
t_{EMC}	Margin for timing variations of the signal on the interface line	Relative to nominal trigger window time	-1.25		1.25	µs
$t_{tol\ detect}$	Tolerance of internal trigger detection delay				3	µs
T_{TRIG}	Trigger detection time (according PSI5_spec_v2d2_base)	$T_{TRIG} = t_{TRIG} + t_{tol\ detect} + t_{EMC}$; Reference for sensor time base	0		7.5	µs
$t_{slot\ 1}$	Start of time slot 1	Time slot 1 cannot be used in this communication mode	44	51	59	µs
t_{slot2}	Start of time slot 2		181.3	195	210	µs
t_{slot3}	Start of time slot 3		328.9	350	373	µs

(1) The parameters in this table are just info parameters and therefore not production tested. The production related parameters are in the PSI5 Block parameters table.

8.4 PSI5 block parameters

Table 12: PSI5 Block parameters

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{CE,BASE\ ECU}$	Base ECU supply voltage	Voltage at ECU	4.4		11	V
$V_{CE,BASE}$	Base supply voltage	Voltage at the Sensor	4.0		11	V
V_{SUPPLY}	Low supply voltage	Supply voltage for comparator	3.3	3.45	3.6	V
V_{t0}	Sync slope reference	Referred to $V_{CE,BASE}$		0.5		V
V_{t2}	Minimum sync signal sustain voltage (common mode)	Referred to $V_{CE,BASE}$	3.5			V
$V_{CE\ MAX}$	Maximum interface voltage				16.5	V
t_2	Sync signal sustain start	Voltage @ V_{t2}			7	µs
SL_{RISE}	Rising slope		0.43		1.6	V/µs
SL_{FALL}	Falling slope	Depends on voltage and discharge limit, external load has to meet these values	-1.75			V/µs
t_3	Sync signal sustain time	Info parameter: Recommended ECU timing	16		35.1	µs
t_4	Discharge time limit	Info parameter: Allowed variation of synch pulse width for synch pulse detection circuit	17.67		62	µs
T_{SYNC}	Synchronization period	Info parameter: To prevent shifts of detection threshold	250	500		µs
V_{TRIG}	Trigger voltage threshold (common mode)		1.4	2.0	2.6	V
$V_{TRIG\ EMC}$	Trigger voltage threshold under EMC (common mode)	At SL_{RISE} = 0.43 V/µs; For EMC $\leq 1V_{PEAK}$ $\geq$ 100kHz Not tested - Guaranteed by Design	0.5	2.0	3.5	V
$t_{tol\ detect}$	Tolerance of internal trigger detection delay				3	µs
t_{BLANK}	Output signal blanking time	Blanking of trigger signal in digital part after first rising edge to avoid multiple trigger signals during EMC events. Not tested - Guaranteed by Design	121		135	µs

9 Detailed description

The AS5173 is a Hall-based rotary magnetic position sensor using CMOS technology. The lateral Hall sensor array converts the magnetic field component perpendicular to the surface of the chip into a voltage.

The signals coming from the Hall sensors are first amplified and filtered before being converted by the analog-to-digital converter (ADC). The output of the ADC is processed by the CORDIC block (Coordinate-Rotation Digital Computer) to compute the angle and magnitude of the magnetic field vector. The sensor and analog front-end (AFE) section work in a closed loop alongside an AGC to compensate for temperature and magnetic field variations. The calculated magnetic field strength (MAG), the automatic gain control (AGC) and the angle can be read through the UART-over-PSI5 protocol during programming.

The magnetic field coordinates provided by the CORDIC block are fed into a linearization block (DSP) which generates the transfer function.

The output of the AS5173 can be programmed to define a starting position (zero angle) and a stop position (maximum angle).

The AS5173 can be programmed through the VDD Pin with a special UART-over-PSI5 protocol which allows writing an on-chip non-volatile memory (One Time Programmable memory) where the specific settings are stored.

The AS5173 is equipped with a PSI5 Interface current driver and a PSI5 Interface receiver. The current driver drives the additional sink current to reach the I_high level on the VDD. The receiver compares the voltage level at the VDD Pin with the internal voltage thresholds.

The Sensor to ECU communication is described in the chapters below and is based upon the PSI5 standard.

The AS5173 supports the synchronous mode or asynchronous mode according to PSI5 standard.

In PSI5 V1.3 (10-bit mode), the asynchronous modes can only use one time slot per period. For a transmission of one 12/16-bit data word, two periods are necessary.

AS5173 supports the bus modes PSI5-U and PSI5-P. The daisy chain mode is not supported.

10 Register description

10.1 OTP (non-volatile memory) register description

Table 13: OTP (non-volatile memory) register description

Address	Bit nr.	Symbol	Description
0x01	0	velocity_compatibility_range	Changes max velocity range to 4608 deg/s (see Table 21)
	1	PSI516bitmode_noE	PSI5 setting for 16-bit data frame without error bit
	2	Direction	Changes direction in 14-bit mode
	3	PSI5_14bit_angle	Enables 14-bit angle output
	4	PSI5_quad_info	Enables quadrant information
	5	PSI5_16bit_frame	Enables the PSI5 16-bit frame
	6	Velocity_extended_range	(see Table 21) 0 = 1250 deg/s 1 = 5000 deg/s
	7	Extended_init_phase	0 = 22 datablocks during Init phase 1 = 32 datablocks during Init phase
0x02	0	Factory settings	ams OSRAM factory settings
	7:1	ams OSRAM ID	ams OSRAM production ID (F9)
0x03	7:0	ams OSRAM ID	ams OSRAM production ID (F9)
0x04	5:0	ams OSRAM ID	ams OSRAM production ID (F9)
	7:6	Factory settings	ams OSRAM factory settings
0x05	7:0	Factory settings	ams OSRAM factory settings
0x06	7:0		
0x07	7:0		
0x08	7:0		
0x09	7:0		
0x0A	7:0		
0x0B	7:0		
0x0C	0	Month[3]	Sensor Production Date (F8)
	1	Year[0]	
	2	Year[1]	
	3	Year[2]	
	4	Year[3]	

Address	Bit nr.	Symbol	Description
	5	Year[4]	
	6	Year[5]	
	7	Year[6]	
0x0D	0	Day[0]	Sensor Production Date (F8)
	1	Day[1]	
	2	Day[2]	
	3	Day[3]	
	4	Day[4]	
	5	Month[0]	
	6	Month[1]	
	7	Month[2]	
0x0E	0	Type[0]	Sensor Type (F4)
	1	Type[1]	
	2	Type[2]	
	3	Type[3]	
	4	Parameter[4]	Sensor Parameter (F5)
	5	Parameter[5]	
	6	Parameter[6]	
	7	Parameter[7]	
0x0F	0	Parameter[0]	Sensor Parameter (F5)
	1	Parameter[1]	
	2	Parameter[2]	
	3	Parameter[3]	
	4	Sensor_Code_Man[4]	Sensor Code Manufacturer (F6)
	5	Sensor_Code_Man[5]	
	6	Sensor_Code_Man[6]	
	7	Sensor_Code_Man[7]	
0x10	0	Sensor_Code_Man[0]	Sensor Code Manufacturer (F6)
	1	Sensor_Code_Man[1]	
	2	Sensor_Code_Man[2]	
	3	Sensor_Code_Man[3]	
	4	Sensor_Code_Veh[0]	Sensor Code Vehicle (F7)
	5	Sensor_Code_Veh[1]	
	6	Sensor_Code_Veh[2]	
	7	Sensor_Code_Veh[3]	
0x11	7:0	PSI5Mode	PSI5 mode selection

Address	Bit nr.	Symbol	Description
0x12	0	Sync_discharge	Enables sync pulse discharging
	1	Init_phase_repetition[0]	PSI5 initialization phase repetition factor (k-times)
	2	Init_phase_repetition[1]	
	3	PSI5_timeslot[0]	PSI5 timeslot for bus mode
	4	PSI5_timeslot[1]	
	5	Init_phase_disable	Disables the PSI5 initialization phase
	6	Velocity_info	Enables PSI5 velocity output
	7	Psi5_4_timeslot	Enables PSI5 with 4 timeslots (16-bit mode only)
0x13	0	Psi5_16_bit_new_init	Use different initialization frame for PSI5 16-bit mode
	1	discont_avoid_en	Must be set to “1” if FLTRCFG[0] and FLTRCFG[1] is not “0” (see Table 22).
	2	-	Not used
	3	Quadrant[0]	Quadrant selection
	4	Quadrant[1]	
	5	Velocity_filter[0]	Filter configuration for velocity measurement
	6	Velocity_filter[1]	
	7	Velocity_filter[2]	
0x14	7:0	CLH[7:0]	Clamping level high
0x15	0	CLH[8]	Clamping level high
	1	CLH[9]	
	2	CLH[10]	
	3	CLH[11]	
	4	CLL[0]	Clamping level low
	5	CLL[1]	
	6	CLL[2]	
	7	CLL[3]	
0x16	7:0	CLL[11:4]	Clamping level low
0x17	7:0	Offset[7:0]	Offset
0x18	7:0	Offset[15:8]	Offset
0x19	0	Offset[16]	Offset
	1	Offset[17]	
	2	Offset[18]	
	3	Offset[19]	
	4	Gain[0]	Gain
	5	Gain[1]	
	6	Gain[2]	

Address	Bit nr.	Symbol	Description
	7	Gain[3]	
0x1A	7:0	Gain[11:4]	Gain
0x1B	0	Gain[12]	Gain
	1	Gain[13]	
	2	Gain[14]	
	3	Gain[15]	
	4	Gain[16]	
	5	BP[0]	Breakpoint / 14-Bit Mode zero offset
	6	BP[1]	
	7	BP[2]	
0x1C	7:0	BP[10:3]	Breakpoint / 14-Bit Mode zero offset
0x1D	0	BP[11]	Breakpoint / 14-Bit Mode zero point offset
	1	BP[12]	
	2	BP[13]	
	3	Extended_range_disable	Disables the extended range for magnetic input field. Effects tresholds for SM4 trigger as explained in Table 7.
	4	Reduced_angle_range	Enables the reduced angle range for segments smaller 23 degree
	5	FLTRCFG[0]	Bits for the configuration of the filter (see Table 22).
	6	FLTRCFG[1]	
	7	Customer_lock	Customer lock
0x1E	7:0	VendorID[7:0]	Vendor ID (F3)
0x1F	7:0	Signature[7:0]	Signature calculated across the full OTP

(1) The registers 0x01, 0x0C:0x1F have default values = 0.

10.2 Volatile memory register description

Table 14: Volatile memory register description

Address	Bit nr.	Symbol	R/W	Description
0x23	4:0	-		Not used
	5	DSP_reset	R/W	Reset of the DSP (Digital Signal Processing)
	6	GLoad	R/W	Enables GLoad
	7	-		Not used
0x32	7:0	Angle_CORDIC[7:0]	R	14-bit angle information (raw value without zero offset)
0x33	5:0	Angle_CORDIC[13:8]	R	
	7:6	-		Not used
0x34	7:0	Magnitude	R	Magnitude at the CORDIC output
0x35	7:0	AGC	R	AGC (Automatic Gain Control)
0x36	7:0	DSPOUT[7:0]	R	14-bit angle information as calculated by the post processing DSP
0x37	5:0	DSPOUT[13:8]	R	
	7:6	-		Not used
0x38	7:0	Velocity[7:0]	R	Velocity output
0x39	3:0	Velocity[11:8]	R	
	7:4	-		Not used

10.3 SFR description

Table 15: SFR description

Address	Bit nr.	Symbol	Description
0x60	7:0	Pass2Function	Pass-to-function, see programming chapter
0x61	7:0		
0x62	7:0	BurnOTP	BurnOTP, see programming chapter
0x63	7:0		

11 Programming

11.1 UART-over-PSI5

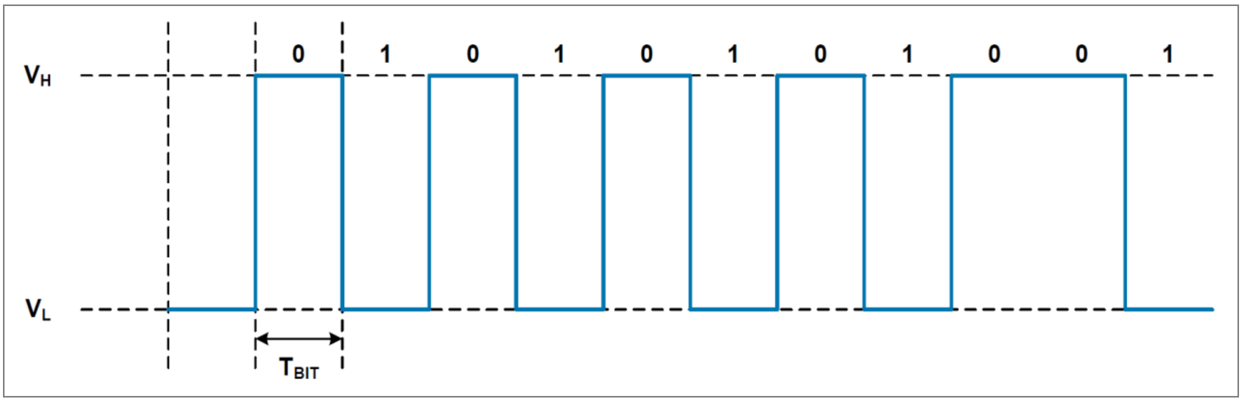
The AS5173 is equipped with a one wire UART-over-PSI5 interface based on a “Tooth Gap” similar method according PSI5 specification, which allows reading and writing the registers as well as permanent programming of the non-volatile OTP memory (One Time Programmable).

By default, the AS5173 is in the so-called Communication Mode. In this mode, it is possible to configure the register settings.

A voltage modulation on the supply lines (VDD and GND) is used to realize a Programmer-to-Sensor communication. The Sensor-to-Programmer communication is done with current modulation.

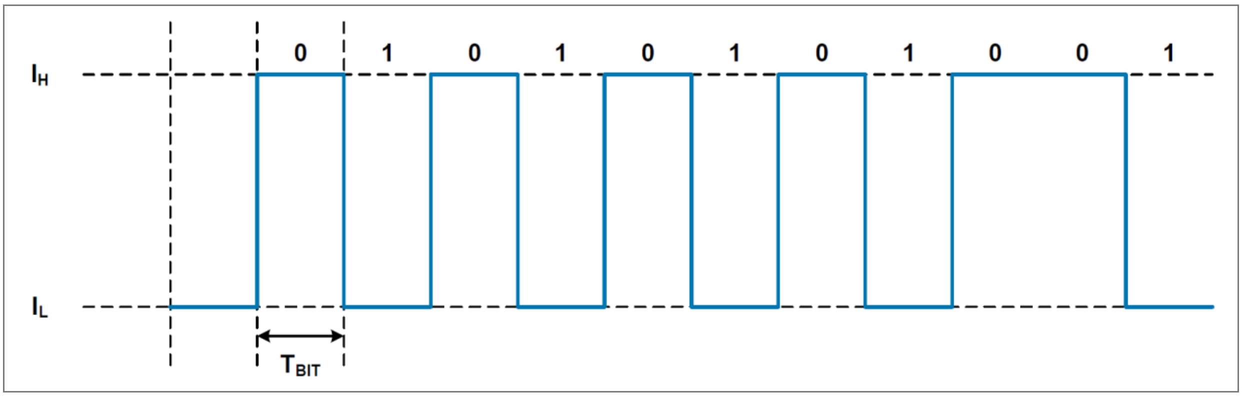
The physical layer of the two communication modes is shown in Figure 7 and Figure 8 below.

Figure 7: Bit encoding of programmer-to-sensor communication



A logical “0” is represented by a sync pulse (V_H) on the VDD line for a duration of t_{BIT}. A logical “1” by the absence of the sync pulse (V_L) for a duration of t_{BIT}.

Figure 8: Bit encoding of sensor-to-programmer communication



A logical “0” is represented by an increased sink current (I_H) on the VDD line for a duration of t_{BIT}. A logical “1” by normal sink current (I_H) for a duration of t_{BIT}.

Table 16: UART-over-PSI5 protocol

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_H	High level voltage		11		12	V
V_L	Low level voltage		5.5		6	V
I_H	High level sink current	Typical value		49		mA
I_L	Low level sink current	Typical value		19		mA
t_{BIT}			25.6	26	26.5	µs
Baudrate			37800	38400	39000	Baud

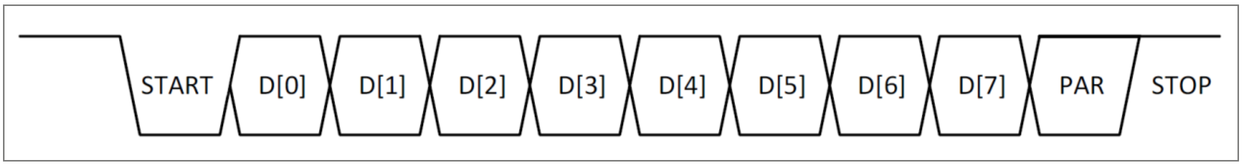
For further information please refer to application note AN_AS5173_Programming_Procedure_V1-00

ams OSRAM also provides a programmer which supports the above-mentioned protocol. Please get in contact with the application engineering team.

11.2 UART protocol

The UART interface allows reading and writing two consecutive addresses. The UART sequence consists of four frames. Each frame begins with a start bit (START), which is followed by 8 data bits (D[0:7]), one parity bit (PAR), and a stop bit (STOP), as shown in Figure 9.

Figure 9: UART protocol frame



The PAR bit is even parity calculated over the data bits (D[7:0]). Each frame is transferred from LSB to MSB.

The first frame is the synchronization frame and consists D[7:0] = 0x55. This frame synchronizes the baud rate between the AS5173 and the programmer.

The second frame contains the register address (D[6:0] = ADDRESS) and the write/read command (WRITE: D[7]=0; READ: D[7]=1).

The third and fourth frame will be written/read to/from the location specified by ADDRESS and ADDRESS+1, respectively.

Figure 10 and Figure 11 show examples of a WRITE and READ sequence.

Figure 10: Example of WRITE (Reg[0x23] = 0x20 and Reg [0x24] = 0x00)

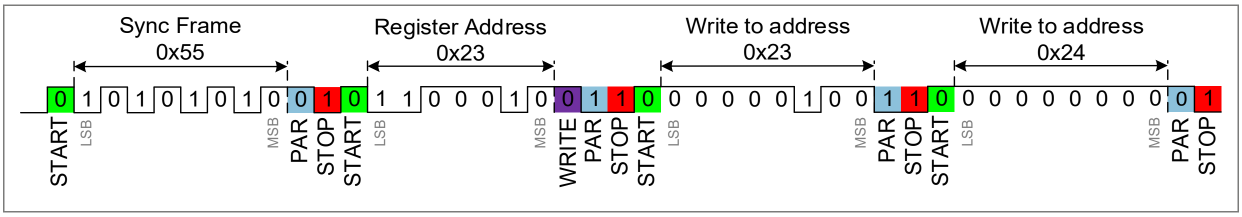
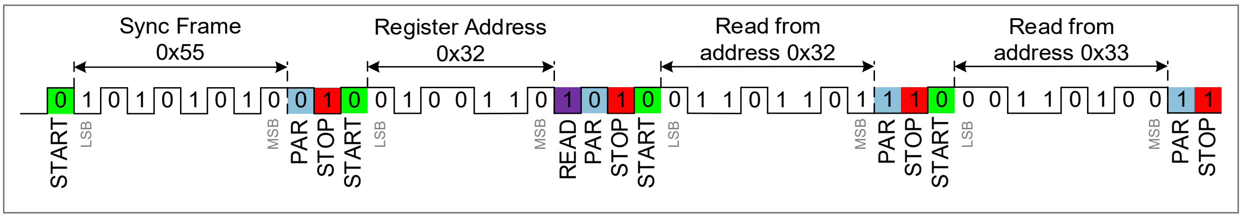


Figure 11: Example of READ (Reg[0x32] = 0xB6 and Reg [0x33] = 0x2C)



11.2.1 Reading of the 14-bit angle information

To read the current position of the magnet (Angle) the following procedure is necessary:

1. Set the DSP_reset bit in Reg(0x23) to 1 (WRITE Reg(0x23) = 0x20)
2. Read Angle_CORDIC register (READ Reg(0x32) and Reg(0x33))
3. Set the DSP_reset bit in Reg(0x23) to 0 (WRITE Reg(0x23) = 0x00)

The DSP_reset bit resets the internal DSP. After a reset, the Angle_CORDIC register is updated.

Information:

The linearity error can be slightly higher if the angular information is read with UART-over-PSI5 interface. The INL specifications in Table 5 are only valid if the PSI5 interface is used.

11.2.2 Reading the magnitude and AGC

To read the current Magnitude and AGC value the following procedure is necessary:

1. Set the DSP_reset bit in Reg(0x23) to 1 (WRITE Reg(0x23) = 0x20)
2. Read Magnitude and AGC register (READ Reg(0x34) and Reg(0x35))
3. Set the DSP_reset bit in Reg(0x23) to 0 (WRITE Reg(0x23) = 0x00)

The DSP_reset bit resets the internal DSP. After a reset, the Magnitude and AGC registers are updated.

11.2.3 Exiting the communication mode

To exit the Communication Mode and enter Functional Mode a Pass-to-function command is necessary. Therefore, a specific value must be written into registers 0x60 and 0x61.

Pass2Function: WRITE Reg(0x60) = 0x70 and Reg(0x61) = 0x51

The device is temporarily set to operational mode until a sensor reset happens.

11.2.4 Burn the OTP registers

To permanently program the device a BurnOTP command is necessary. Therefore, a specific value has to be written into registers 0x62 and 0x63.

BurnOTP: WRITE Reg(0x62) = 0x70 and Reg(0x63) = 0x51

This commands permanently burns the OTP memory based on poly silicon fuses. After fusing a verification of the burn quality is mandatory to avoid bit-flips over temperature and lifetime. This can be done with the GLoad operation. For further information please refer to the application note AN_AS5173_Programming_Procedure_V1-00.

11.3 AS5173 transfer function

After programming the Customer_lock in the OTP or by using the Pass-to-function command the AS5173 is working in the selected PSI5 mode over the VDD pin.

The DSP block generates a linear transfer function proportional to the angle of the rotating magnet which is fed into the PSI5 interface. The PSI5 interface works with 10-bit resolution in PSI5 V1.3 and 12 or 14 bit resolution in PSI5 V2.3. Figure 12 shows the transfer function in detail.

Figure 12: Transfer function

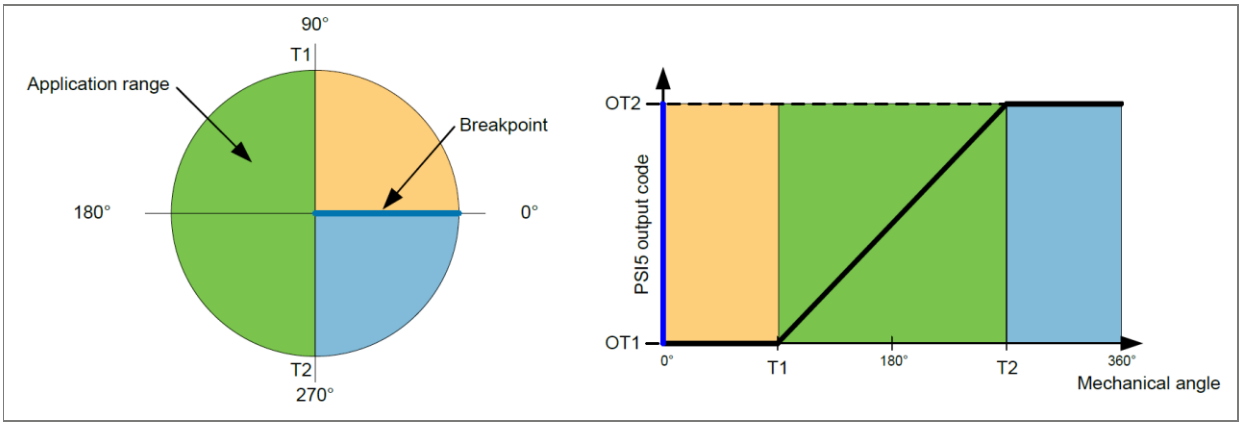


Table 17: PSI5 protocol output resolution

Symbol	Parameter	Conditions	Value	Unit
OTR_V1.3	Output resolution PSI5 V1.3	PSI5 V1.3	10	Bit
OT1			-480	LSB
OT2			+480	LSB
OTR_V2.3	Output resolution PSI5 V2.3	PSI5 V2.3	12	Bit
OT1			-2048	LSB
OT2			+2048	LSB

The PSI5 output characteristic is programmable in the OTP memory. The parameters T1, T2 and BP define the linear transfer function. Figure 12 shows a simple example of a typical output function.

The mechanical starting point T1 and the mechanical end point T2 define the mechanical range. BP (Breakpoint) defines the transition point between OT1 and OT2.

These parameters are input parameters. Using software provided by ams OSRAM, these parameters are converted into the final OTP parameters: CLH, CLL, Offset, Gain and BP.

11.4 Multiple quadrants

The multiple quadrant option allows repeating the same output slope up to four times over a full 360° rotation as shown in Figure 13, Figure 14, Figure 15 and Figure 16. The Quadrant bits in register 0x13 set the number of quadrants as shown in Table 18. Additionally, a built-in quadrant detection can indicate the currently active quadrant in a special PSI5 data frame. For more information, please refer to chapter PSI5 modes.

Table 18: Quadrant selection

Quadrant	Number of quadrants	Max. mechanical range
00	Single	360°
01	Dual	180°
10	Triple	120°
11	Quadruple	90°

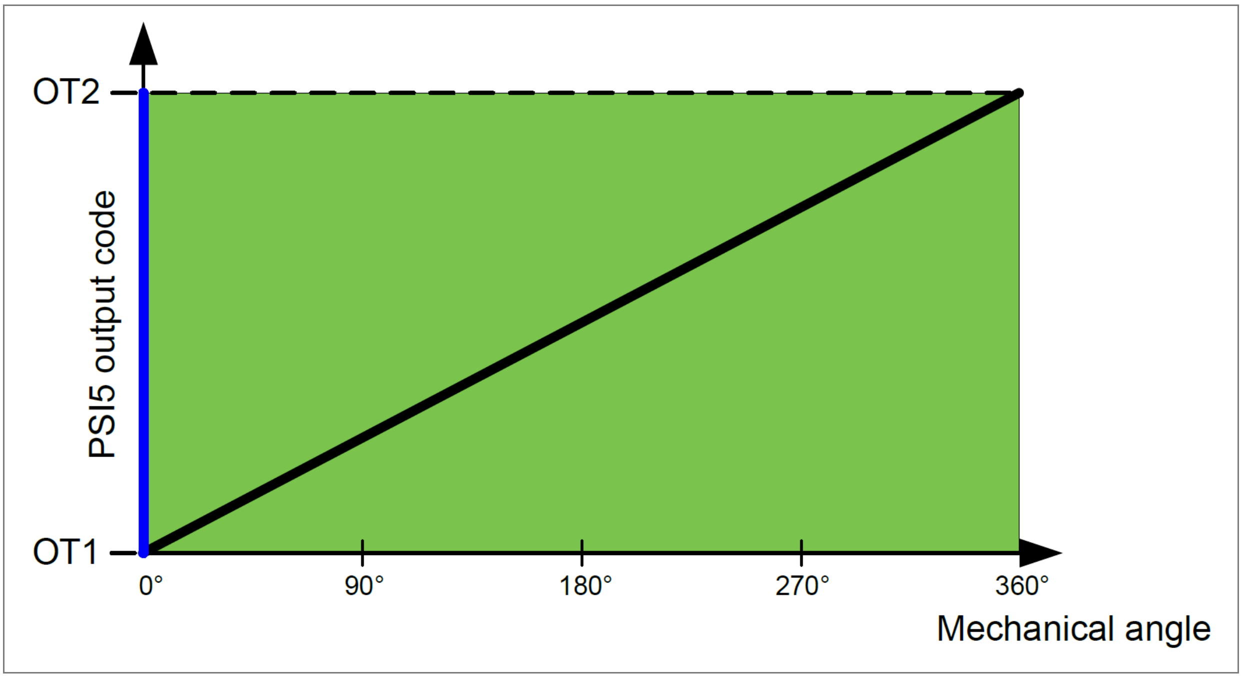


Figure 13: Single quadrant

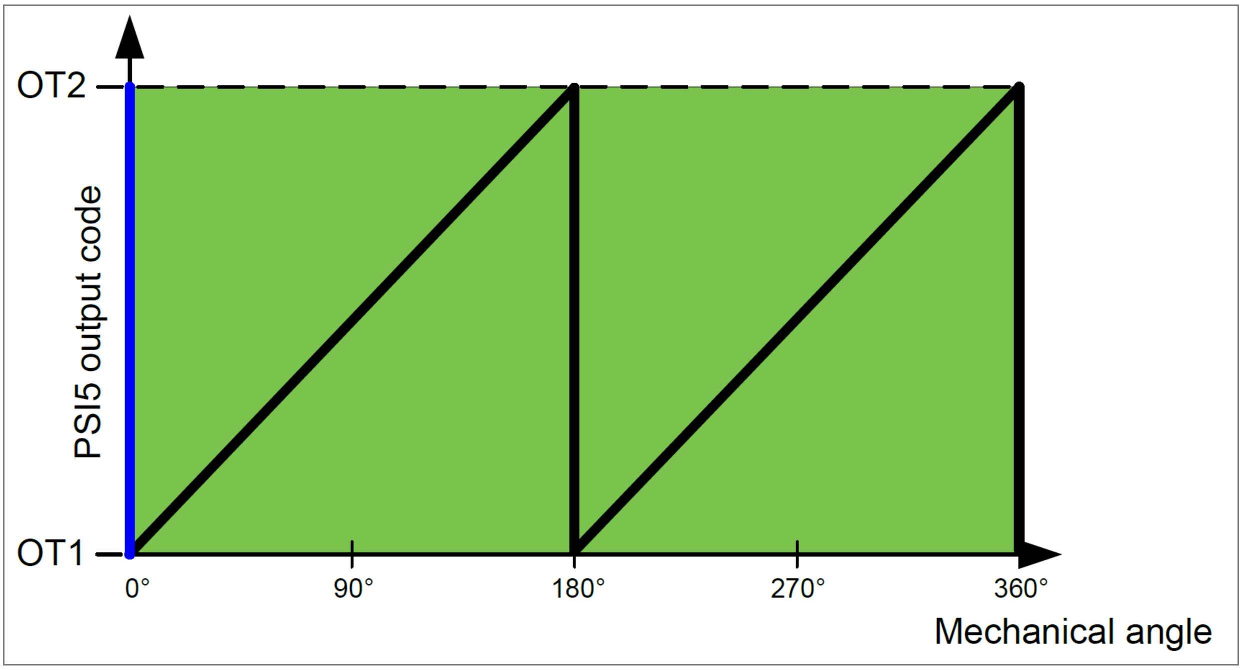


Figure 14: Dual quadrant

Figure 15: Triple quadrant

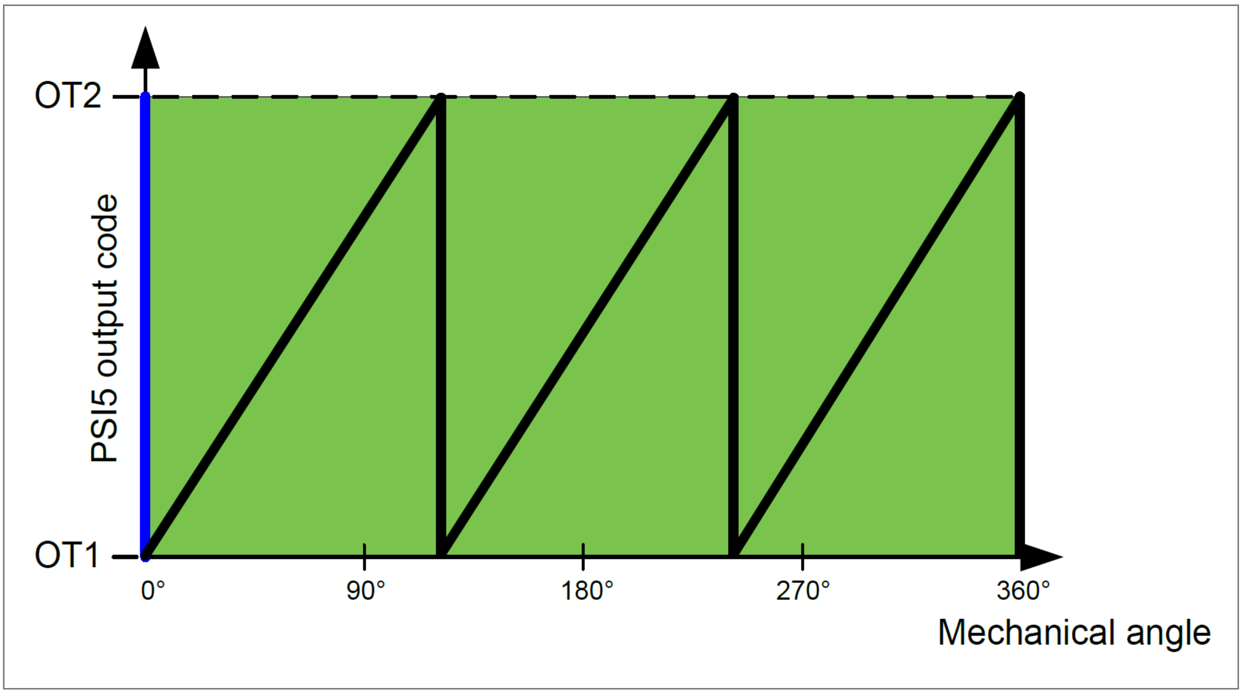
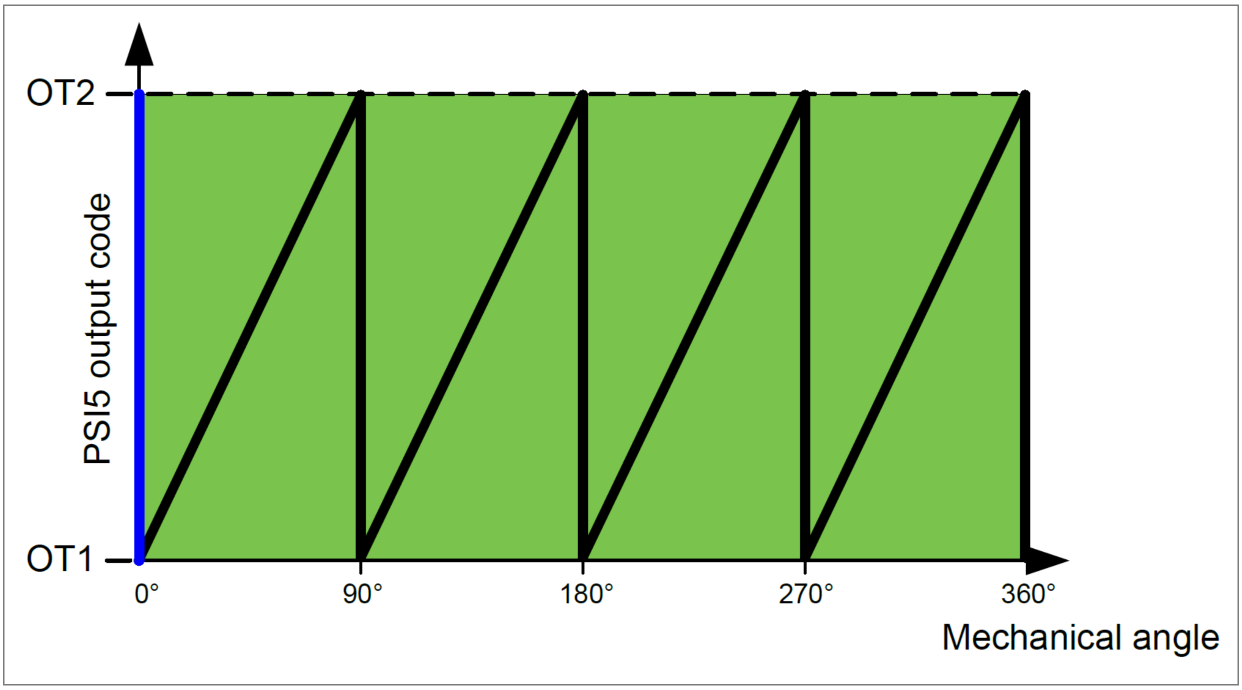


Figure 16: Quadruple quadrant



11.4.1 Extended magnetic input range

By default, the AS5173 operates in Extended Mode. This mode extends the magnetic input field range and allows increasing of the air gap between sensor and magnet. The extended range can be disabled with Extended_range_disable bit.

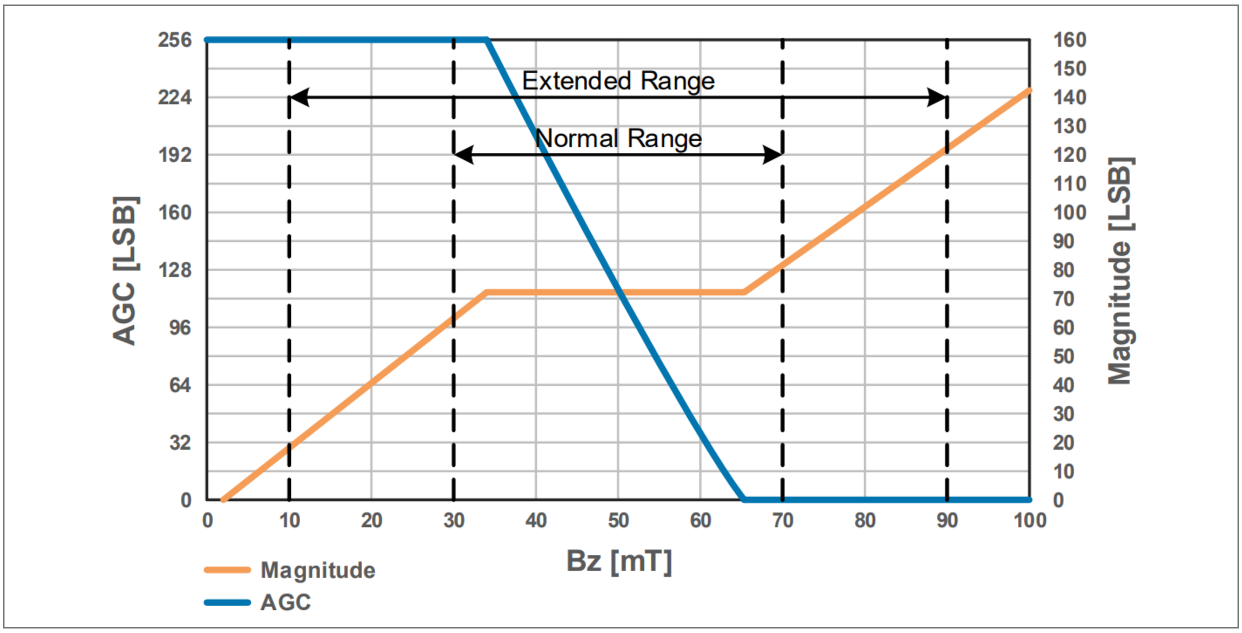
The frontend of the AS5173 sensor has an AGC (Automatic Gain Control) circuit integrated. The AGC is used to regulate the Magnitude (see Table 14) to a target value of 72 LSB. If the AGC hits the maximum (255LSB) or minimum value (0LSB) the regulation loop cannot regulate the Magnitude anymore. The magnitude will fall below or increase above its target value.

The trigger for the SM4 safety mechanism (Magnetic field out of range) is linked to the value of the Magnitude.

- If the Extended_range_disable bit is set to 0 then SM4 triggers if the Magnitude is >127 LSB or <18 LSB.
- If the Extended_range_disable bit is set to 1 then SM4 triggers if the Magnitude is >80 LSB or <63 LSB.

Figure 17 shows the typical relationship between AGC, Magnitude and flux density.

Figure 17: Typical relationship between AGC, magnitude and flux density



11.4.2 Rolling counter

The frame control bits in the PSI5 frame can be used as a rolling counter. This setting can be enabled in the OTP. If this setting is enabled the rolling counter starts incrementing from value 0x0 once the initialization is finished. When reaching a value of 0x7 the counter is reset at starts with 0x0 again.

In PSI5 16-bit frame mode, the rolling count enables a toggle bit in A14 of the frame.

11.4.3 Angular velocity measurement

The AS5173 features an average angular velocity calculation algorithm with 12-bit resolution. This angular velocity information can be used without further averaging in the ECU. The sensor calculates the velocity for each CORDIC cycle (typ. 128µs). Due to the PSI5 interface limitation the information can only be send every 500µs.

To optimize the signal-to-noise performance the cut off frequency is programmable via Velocity_filter[2:0] bits in register 0x13. The velocity information is available in all P20CRC-500 and P16CRC-500 modes. Additionally, the range of the velocity can be programmed by Velocity_extended_range bit in register 0x01.

Table 19: Angular velocity measurement parameter

Symbol	Parameter	Min	Typ	Max	Unit	Comments
VRes	Velocity signal resolution		12		Bit	
VRange	Measurement range (default)		1250	1374	°/s	Only typical value is guaranteed
VRangeE	Measurement range (extended)		5000	5496	°/s	Only typical value is guaranteed
Vα	Measurement range (compatibility)		4608		°/s	Only typical value is guaranteed, valid only when velocity compatibility range is programmed in OTP
VSens	Velocity sensitivity (default)		0.671		°/s/Bit	12-bit resolution
VSensE	Velocity sensitivity (extended)		2.684		°/s/Bit	12-bit resolution, only in Extended Mode
VSensα	Sensitivity for Vα (compatibility range)		2.4		°/s/Bit	12-bit resolution, valid only when velocity compatibility range is programmed in OTP
FCutOff	Cut off frequency	19	77	260	Hz	Programmable with Velocity_filter[2:0]
VNoise	Velocity noise	4.9		70.5	°/s	RMS noise depending on Velocity_filter[2:0]
VError	Velocity total error			±3.5	%	Clock frequency accuracy

Table 20: Angular velocity measurement filter parameters

Velocity_filter[2:0]	FCutOff [Hz]	VNoise [°/s]	VDelay [ms]	VStepResponse [ms]
000	260	70.5	0.61	0.9
001	152	37.3	1.05	1.8
010	77	19.2	2.07	3.7
011	39	9.7	4.08	6.7
100	19	4.9	8.38	13.9

Table 21: Velocity ranges

velocity_compatibility_range	Velocity_extended_range	Selected velocity range
0	0	1250 °/s
0	1	5000 °/s
1	0	4608 °/s
1	1	This combination must not be used.

11.5 Special functions

The AS5173 features special functions which can be activated in the OTP. These settings are not according to the PSI5 V2.3 standard.

11.5.1 Quadrant detection

The PSI5 protocol includes information of the used quadrant. Detection necessary for safety relevant application to detect a movement from one quadrant to the next. See detailed Protocol Information.

11.5.2 Extended PSI5 initialization phase

Extending to 32 datablock during Init phase. D1 to D22 according to Table 45. D23 to D32 = 0000. Extension necessary for systems with 32 datablocks during Init Phase.

11.5.3 Filter for reduction of angular noise

The AS5173 has an integrated filter to reduce the angle noise. It can be activated as described in Table 22.

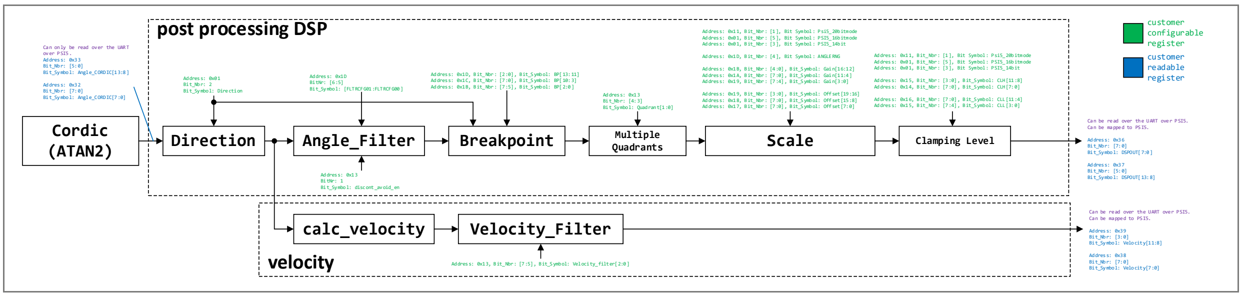
Table 22: Noise filter configurations

FLTRCFG[1]	FLTRCFG[0]	discont_avoid_en	Noise improvement factor	Description
0	0	x	1	Filter disabled.
0	1	1	0.92	Does calculate the average of the last 2 angles calculated. discont_avoid_en must be set to 1 to ensure the correct function of the filter
1	0	1	0.75	Does calculate the average of the last 4 angles calculated. discont_avoid_en must be set to 1 to ensure the correct function of the filter
1	1	1	0.568	Does calculate the average of the last 8 angles calculated. discont_avoid_en must be set to 1 to ensure the correct function of the filter

11.5.4 Post processing DSP

The post processing DSP can be used to configure a full scale 12-bit or 14-bit output even if the magnet only moves within a mechanical range smaller than 360°.

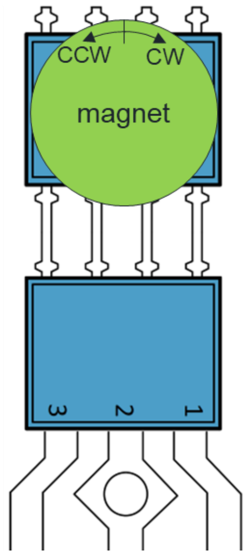
Figure 18: Post processing DSP



On request ams OSRAM will provide a detailed description of the blocks in Figure 18.

The output of the Cordic block shown in Figure 18 provides the raw angle data Angle_CORDIC within a 360° angular range. Angle_CORDIC is only readable over the UART_over_PSI5 interface. With default configuration, rotating the magnet into the clockwise direction (CW) decreases the Angle_CORDIC. Rotating the magnet into the counterclockwise direction (CCW) increases the Angle_CORDIC. Figure 19 shows how CW and CCW are defined.

Figure 19: Definition of clockwise (CW) and counterclockwise (CCW) rotation direction

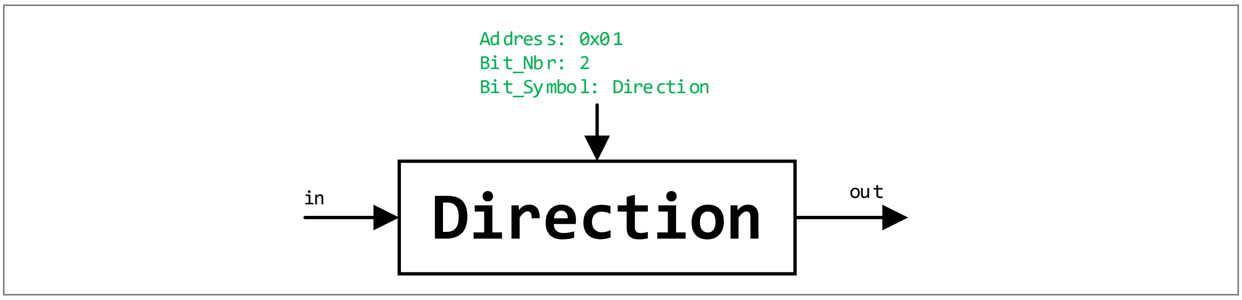


In applications like pedals or chassis position sensors the angle only needs to be measured within a segment smaller than 360° resulting in Angle_CORDIC range smaller than 360°. The N to S pole orientation of the magnet within the application is often random. This means that jumps between the minimum possible and maximum possible Angle_CORDIC can happen.

The purpose of the post processing DSP is to scale Angle_CORDIC to the AS5173 users' needs and to avoid jumps between minimum and maximum possible value of Angle_CORDIC.

11.5.4.1 Behavior of the direction block:

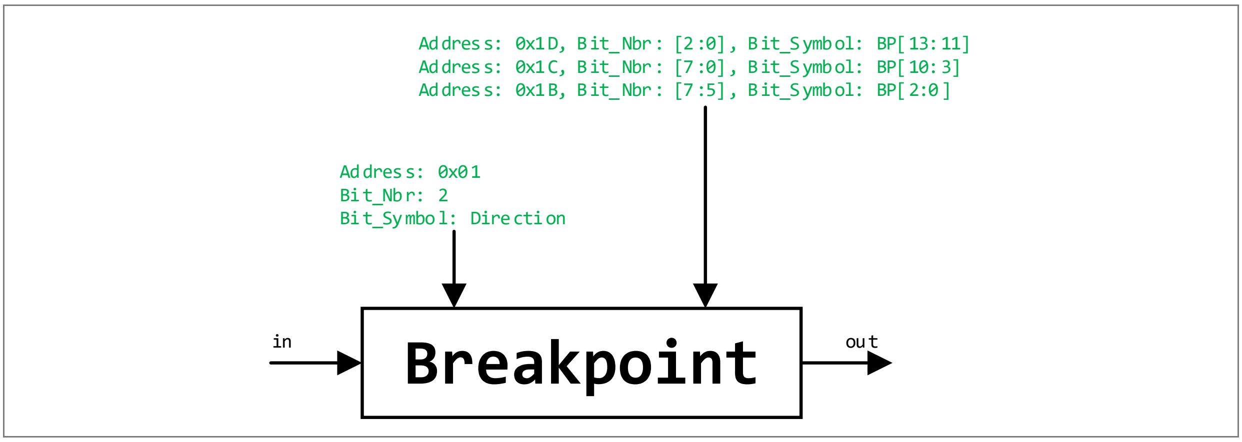
Figure 20: Direction block




```
if Direction == 1:
      out = -in
else:
      out = in
```

11.5.4.2 Behavior of the breakpoint block:

Figure 21: Breakpoint block

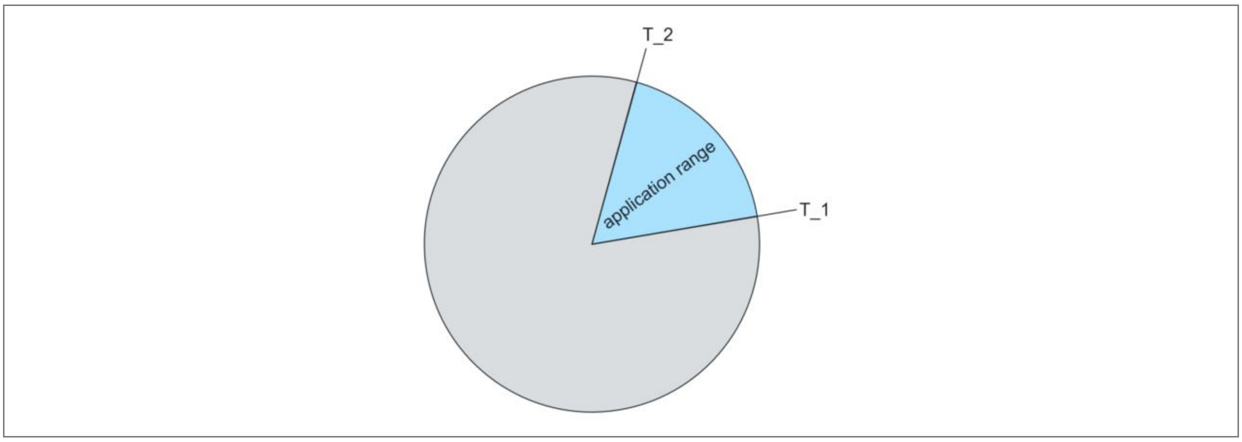



```
if Direction == 1:
      out = (in + BP) % (2**14)
else:
      out = (in – BP) % (2**14)
```

11.5.5 Procedure for programming a segment smaller than 360° to the post processing DSP with 12-bit output resolution

Figure 22 visualizes the application range of an application which utilizes a segment smaller than 360°. T_1 stands for the start position of the magnet and T_2 stands for the stop position of the magnet.

Figure 22: Visualization of the application range



Mandatory steps for calculating the register content within the post processing DSP:

1. Set the Gain[16:0] to 8192. Gain[16:0] is a signed integer.
2. Write 0x28 into register 0x01 to enable 14-bit angle output and 16-bit frame.
3. Write 0x01 into register 0x11 to select the PSI5 mode “P16CRC-500/3H Angle:Timeslot1”.
4. Calculate the signature see chapter Signature calculation 12.1”.
5. Write the calculated signature into register 0x1F.
6. Perform the pass2function command as explained in chapter 11.2.3.
7. Move the magnet to the desired zero position T_1.
8. Read the angle over PSI5 interface while the magnet is standing at T_1 and store T_1 (it is needed to calculate Gain, Offset, BP and Quadrant).
9. Move the magnet to the desired end position T_2.
10. Read the angle over PSI5 while the magnet is standing at T_2 and store T_2 (it is needed to calculate Gain, Offset, BP and Quadrant). Note T_1 to T_2 shall be a rising ramp.
11. Decide if the output ramp after programming shall be falling or rising when the magnet moves from T_1 to T_2. If a falling ramp is desired, then ramp_dir = falling. If a rising ramp is desired, then ramp_dir = rising.

12. Decide how many Quadrants shall be programmed (see chapter 11.4).
13. Quadrant, Offset, BP and Gain need to be calculated and written into the memory of the AS5173 device.
14. Test if the chip output behaves as expected.
15. Formulas for calculating Quadrant, Offset, BP and Gain are shown in the Python code below (the code is designed to calculate the configuration for a 12-bit PSI5 output):

```
T_1 = 13699          # 14 bit value read from DSPOUT at position T_1
T_2 = 15487          # 14 bit value read from DSPOUT at position T_2
N_Quadrants = 2      # desired number of quadrants.
ramp = 'rising'      # if the ramp shall be rising or falling is up to the users
choice
CLH = 0              # shall be 0 if no clamping is desired
CLL = 0              # shall be 0 if no clamping is desired

Quadrant = N_Quadrants – 1

Gain_raw = (2048 * (16383 / ((T_2 - T_1) % 16384)) * ((4095 - (CLL + CLH)) / 4095))

Offset_raw = int(round(-(((4096 * (Gain_raw / (N_Quadrants * 2048))) - 4096) / 2) +
CLL))

BP_raw = ((T_1 - (((((4096 * (Gain_raw / (N_Quadrants * 2048))) - 4096) / 2) /
(4096 * (Gain_raw / (N_Quadrants * 2048)))) * (16384 / N_Quadrants))) % 16384)

if ramp == 'rising':
    Gain = int(round(Gain_raw)) # the round() function rounds to the nearest int
    Offset = Offset_raw
    BP = int(round(BP_raw))     # the int() function coverts to an int datatype
else:
    Gain = -int(round(Gain_raw))
    Offset = 4096 - Offset_raw
    BP = int(round(BP_raw))

print('Gain: {0}'.format(Gain))
print('Offset: {0}'.format(Offset))
print('BP: {0}'.format(BP))
```

```
print('Quadrant: {0}'.format(Quadrant))
```

11.5.6 Procedure for programming a 12-bit and 360° output to the post processing DSP

1. Set the bit PSI5_14bit_angle to 0 to enable 12-bit angle output.
2. Write the following values into the respective registers:

   Gain=2048

   Offset=0

   Quadrant=0

   CLH=0

   CLL=0
3. Set the desired BP in the respective register to adjust at what mechanical position the jump from min to max output value happens (see Figure 20 and Figure 21). Note that BP is a 14-bit value.

11.5.7 Procedure for programming a 14-bit and 360° output to the post processing DSP

1. Set PSI5_14bit_angle to 1 to enable 14-bit angle output.
2. Write the following values into the respective registers:

   Gain=8192

   Offset=0

   Quadrant=0

   CLH=0

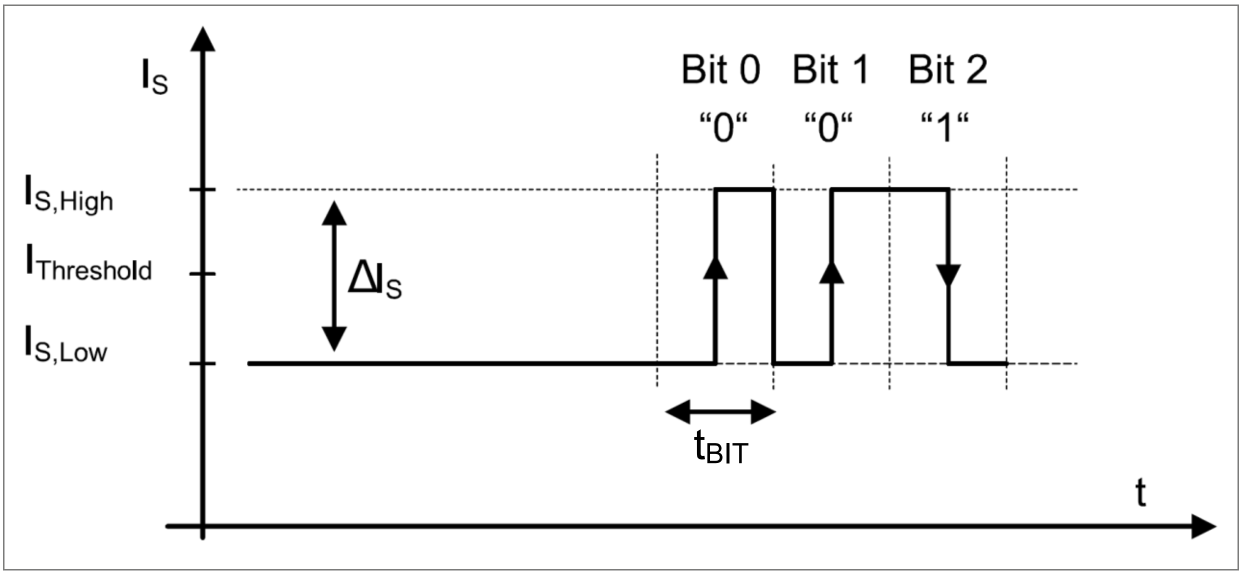
   CLL=0
3. Set the desired BP in the respective register to adjust at what mechanical position the jump from min to max output value happens (see Figure 20 and Figure 21).

11.6 PSI5 interface

11.6.1 Bit encoding - AS5173 to ECU communication

A "low" level ($I_{S,Low}$) is represented by the normal (quiescent) current consumption of the Sensor(s). A "high" level ($I_{S,High}$) is generated by an increased current sink of the Sensor ($I_{S,Low + \Delta IS}$). The current modulation is detected within the receiver Sensor.

Figure 23: Bit encoding using supply current modulation



Manchester coding is used for data transmission. A logic "0" is represented by a rising slope and a logic "1" by a falling slope of the current in the middle of t_{Bit}.

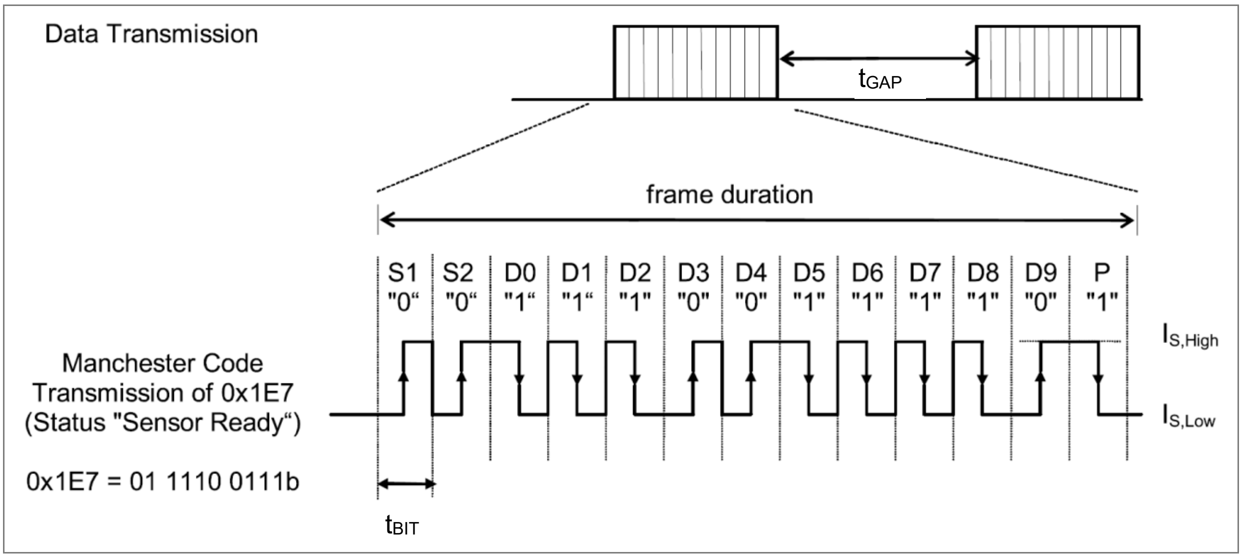
Table 23: Bit encoding timing

Symbol	Parameter	Min	Typ	Max	Unit	Comments
t_{Bit_L}	Bit time (125 kbit/s mode)		8		µs	16 CLK cycles of the internal 2 MHz clock
t_{Bit_H}	Bit time (189 kbit/s mode)		5.3		µs	14 CLK cycles of the internal 2.67 MHz clock

11.6.2 Data frames - AS5173 to ECU communication

Each PSI5 data frame consists of N bits containing two start bits and one parity bit with even parity (or 3 CRC bits) and N-3 (N-5) data bits. Data bits are transmitted LSB first. The data frames are sent periodically from the sensor to the ECU. A minimum gap time t_{Gap} larger than one maximum bit duration t_{Bit} is required between two data frames.

Figure 24: Example of a 10-bit data frame



11.6.3 Data ranges

The AS5173 supports the data range according PSI5 standard V1.3 and V2.3.

PSI5 data messages are divided into three separate ranges: A data range for the sensor output signal, a range for status and error messages and a range for initialization data.

11.6.3.1 Data range according PSI5 V1.3

If AS5173 is used in the 10-bit mode, the decimal values –480 to +480 are used for the sensor output signal. The range –512 to –481 is reserved block and data IDs which are used for transmitting initialization data during startup of the AS5173. The range from +481 to +511 is used for status and error messages.

The 10-bit data range is used only in the LowRes mode of the sensor. The 12-bit output value from the DSP has to be mapped to the data range of -480 to +480 (10-bit, signed) by taking only the 10 higher order bits, subtracting the mid-code, and apply clamping to the data range of -480 to +480.

Table 24: Data range for 10-bit mode

Dec	Hex	Signification	Range
+511	0x1FF	Reserved (ECU internal use) *1	Status and Error Messages 2
:	:	Reserved (ECU internal use) *1	
+504	0x1F8	Reserved (ECU internal use) *1	
+503	0x1F7	Reserved (Sensor use) *2	
+502	0x1F6	Reserved (Sensor use) *2	
+501	0x1F5	Reserved (Sensor use) *2	
+500	0x1F4	“Sensor Defect”	
+499	0x1F3	Reserved (ECU internal use) *1	
:	:	Reserved (ECU internal use) *1	
+496	0x1F0	Reserved (ECU internal use) *1	
+495	0x1EF	Reserved (Sensor use) *2	
:	:	Reserved (Sensor use) *2	
+489	0x1E9	“Sensor in Diagnostic Mode”	
+488	0x1E8	“Sensor Busy”	
+487	0x1E7	“Sensor Ready”	
+486	0x1E6	“Sensor Ready but Unlocked”	
+485	0x1E5	Reserved (Sensor use) *2	
+484	0x1E4	Reserved (Sensor use) *2	

Dec	Hex	Signification	Range	
+483	0x1E3	Reserved (Sensor use) *2		
+482	0x1E2	Bidirectional Communication: RC “Error”		
+481	0x1E1	Bidirectional Communication: RC “OK”		
+480	0x1E0	Highest Positive Sensor Signal	Sensor Output Signal	1
:	:	:		
0	0x000	Signal Amplitude “0”		
:	:	:		
-480	0x220	Highest Negative Sensor Signal		
-481	0x21F	Status Data 1111	Block IDs and Data for Initialization	3
:	:	:		
-496	0x210	Status Data 0000		
-497	0x20F	Block ID 16		
:	:	:		
-512	0x200	Block ID 1		

When using the AS5173 in 10-bit mode the data frame consists of 2 start bits (S1, S2), 10 data bits (D0-D9) which represent the angle and an even parity bit (P).

Table 25: Data frame for 10-bit mode

Start bits		10-bit sensor data (LSB first)										Parity
S1	S2	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	P
0	0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	P

The AS5173 has also the possibility to provide the 12-bit angle value in the PSI5 V1.3 specification.

The substandard vehicle describes this method to map a 12-bit word into a 16-bit data frame and splitting of this into two 10-bit frames.

11.6.4 Data range according PSI5 V2.3

If AS5173 is used in the 20-bit mode, the decimal values –30720 to +30720 are used for the sensor output signal. The range –32768 to –30784 is reserved block and data IDs which are used for transmitting initialization data during startup of the AS5173. The range from +31168 to +32767 is used for status and error messages.

Table 26: Data range for 20-bit mode

Dec	Hex	Signification	Range	
32767	0x7FFF	Reserved (ECU internal use)	Status and Error Messages	2
+31168	0x79C0	“Sensor Ready”		
:	:			
+30720	0x7800	Highest Positive Sensor Signal	Sensor Output Signal	1
:	:	:		
0	0x0000	Signal Amplitude “0”		
:	:	:		
-30720	0x8800	Highest Negative Sensor Signal		
-30784	0x87C0	Status Data 1111	Block IDs and Data for Initialization	3
:	:	:		
-31744	0x8400	Status Data 0000		
-31808	0x83C0	Block ID 16		
:	:	:		
-32768	0x8000	Block ID 1		

11.6.5 PSI5 data frame 20-bit mode with 12-bit sensor data

In 20-bit mode the PSI5 frame consists of 2 start bits (S1, S2), 3 frame control bits (F0, F1, F2), an error status bit (E0), 16 data bits (A0 to A15), and 3 CRC bits (C2, C1, C0).

As described in chapter Rolling counter the 3 frame control bits can be used as rolling counter. The error status bit is used to indicate a failure of the sensor to ECU (E0 = 1). If no failure is present this bit is always set to 0. The 12-bit angle information is transmitted on A0 – A11. The upper fields A12 – A15 are set to 0.

Table 27: PSI5 data frame 20-bit mode with 12-bit sensor data

Start bits		Frame control			Error status	12-bit sensor data (LSB first)																CRC		
S1	S2	F0	F1	F2	E0	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	C2	C1	C0
0	0	C0	C1	C2	E0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	0	0	0	0	C2	C1	C0

11.6.6 PSI5 data frame 20-bit mode with 12-bit sensor data and quadrant detection

For safety relevant applications, where multiple quadrant mode is used, additionally to the 12-bit angle information a quadrant information can be transmitted in A12 and A13. For more information refer to chapter Multiple quadrants.

Table 28: PSI5 data frame 20-bit mode with 12-bit sensor data and quadrant detection

Start bits		Frame control			Error status	12-bit sensor data (LSB first)												Quadrant info				CRC		
S1	S2	F0	F1	F2	E0	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	C2	C1	C0
0	0	C0	C1	C2	E0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	Q0	Q1	0	0	C2	C1	C0

Table 29: Quadrant information

Quadrant	Quadrant mode	Quadrant info on PSI5
00	Single	Q1 = 00 Q2 = 01
01	Dual	Q1 = 00 Q2 = 01
10	Triple	Q1 = 00 Q2 = 01 Q3 = 10
11	Quadruple	Q1 = 00 Q2 = 01 Q3 = 10 Q4 = 11

11.6.7 PSI5 data frame 20-bit mode with 14-bit sensor data

For special applications where the full sensor resolution is necessary over a 360° rotation the AS5173 features a 14-bit mode. In this mode the 14-bit angle information is transmitted from A0 – A13. A14 and A15 are filled with 0.

Table 30: PSI5 data frame 20-bit mode with 14-bit sensor data

Start bits		Frame control			Error status	14-bit sensor data (LSB first)																CRC		
S1	S2	F0	F1	F2	E0	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	C2	C1	C0
0	0	C0	C1	C2	E0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	0	0	C2	C1	C0

11.6.8 PSI5 data frame 16-bit mode

In 16-bit mode the PSI5 frame consists of 2 start bits (S1, S2), an error status bit (E0), 15 data bits (A0 to A14), and 3 CRC bits (C2, C1, C0).

The error status bit is used to indicate a failure of the sensor to ECU (E0 = 1). If no failure is present this bit is always set to 0. The 16-bit frame can transmit the 12-bit angle information (A0 – A11) but also the 14-bit angle by activating the 14-bit mode in the OTP. (A0 – A13). The field A14 is by default set to 0 but can also be used as a toggle bit by activating the Rolling Counter.

Table 31: PSI5 data frame 16-bit mode with 14-bit sensor data

Start bits		Error status	14-bit sensor data (LSB first)															CRC		
S1	S2	E0	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	C2	C1	C0
0	0	E0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	0	C2	C1	C0

Table 32: PSI5 data frame 16-bit mode with 14-bit sensor data without error bit

PSI5 frame for 16-bit mode																				
S1	S2	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	C2	C1	C0
0	0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	0	0	C2	C1	C0

The 16-bit mode has also a second data format, without error bit. It is possible to activate this in the same way of the other 16-bit mode, plus the bit to select the modality without error bit.

Table 33: Velocity information

PSI5 frame for 16-bit mode																				
S1	S2	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	C2	C1	C0
0	0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	0	0	C2	C1	C0

The velocity information is transmitted from A4 to A15, with the bit A0 to A3 filled with 0s.

11.7 PSI5 modes

The AS5173 can be configured in several PSI5 modes according standard V1.3 and V2.3. These modes can be selected via registers 0x01, 0x11 and 0x12. The tables in Table 27 and Table 28 show the different modes.

Independent from the specific mode also other options can be activated in these registers:

- Initialization Phase Repetition Factor
- Extended Initialization Phase (32 blocks)
- Rolling Counter (set bit[7] in register 0x11)
- 14-Bit Mode
- Velocity Extended Range

Table 34: PSI5 modes V1.3

PSI5 mode	Timeslot	Discharge	High resolution	Register	
				0x11	0x12
P10P-500/3L	Timeslot 1	-	-	0x00	0x00
P10P-500/3L	Timeslot 2	-	-	0x00	0x08
P10P-500/3L	Timeslot 3	-	-	0x00	0x10
P10P-500/3L	Timeslot 2	X	-	0x00	0x09
P10P-500/3L	Timeslot 3	X	-	0x00	0x11
P10P-500/3L	Timeslot 1 and 2	-	X	0x40	0x00
P10P-500/3L	Timeslot 2 and 3	-	X	0x40	0x08
P10P-500/3L	Timeslot 2 and 3	X	X	0x40	0x09
A10P-500/1L	-	-	-	0x10	0x00
A10P-250/1L	-	-	-	0x30	0x00
A10P-500/1L	-	-	X	0x50	0x00
A10P-250/1L	-	-	X	0x70	0x00

Table 35: PSI5 modes V2.3

PSI5 mode	Timeslot angle	Timeslot velocity	Register			PSI5 4 timeslot bit
			0x01	0x11	0x12	
P20CRC-500/1L	Timeslot 1	-	0x00	0x02	0x00	0
P20CRC-500/2L	Timeslot 2	-	0x00	0x02	0x08	0
P20CRC-500/2L	Timeslot 1	Timeslot 2	0x00	0x02	0x40	0
P20CRC-500/2H	Timeslot 1	-	0x00	0x03	0x00	0
P20CRC-500/2H	Timeslot 2	-	0x00	0x03	0x08	0
P20CRC-500/2H	Timeslot 1	Timeslot 2	0x00	0x30	0x48	0
P20CRC-500/3H	Timeslot 1	-	0x00	0x0B	0x00	0
P20CRC-500/3H	Timeslot 2	-	0x00	0x0B	0x08	0
P20CRC-500/3H	Timeslot 3	-	0x00	0x0B	0x10	0
P20CRC-500/3H	Timeslot 1	Timeslot 2	0x00	0x0B	0x48	0
P20CRC-500/3H	Timeslot 2	Timeslot 3	0x00	0x0B	0x50	0
P20CRC-500/3H	Timeslot 1	Timeslot 3	0x00	0x0B	0x58	0
P16CRC-500/3H	Timeslot 1	-	0x20	0x01	0x00	0
P16CRC-500/3H	Timeslot 2	-	0x20	0x01	0x08	0
P16CRC-500/3H	Timeslot 3	-	0x20	0x01	0x10	0
P16CRC-500/3H	Timeslot 1	Timeslot 2	0x20	0x01	0x48	0
P16CRC-500/3H	Timeslot 2	Timeslot 3	0x20	0x01	0x50	0
P16CRC-500/3H	Timeslot 1	Timeslot 3	0x20	0x01	0x58	0
P16CRC-1000/4H	Timeslot 1	Timeslot 2	0x20	0x01	0x48	1
P16CRC-1000/4H	Timeslot 3	Timeslot 4	0x20	0x01	0x10	1
A20CRC-200/1H	-	-	0x00	0x33	0x00	0
A20CRC-500/1H	-	-	0x00	0x13	0x00	0
A20CRC-200/2H	-	-	0x00	0x1B	0x00	0
A20CRC-300/1L	-	-	0x00	0x12	0x00	0

11.7.1 PSI5 timing

The following chapter describes the timings for the different PSI5 modes.

The timing is according to the internal clock rate of 2 MHz or 2.67 MHz respectively. This clock rates are derived from the main clock of 16 MHz with a ±3.5% variation.

11.7.1.1 Timing synchronous mode P10P-500/3L

Figure 25: Synchronous mode P10P-500/3L

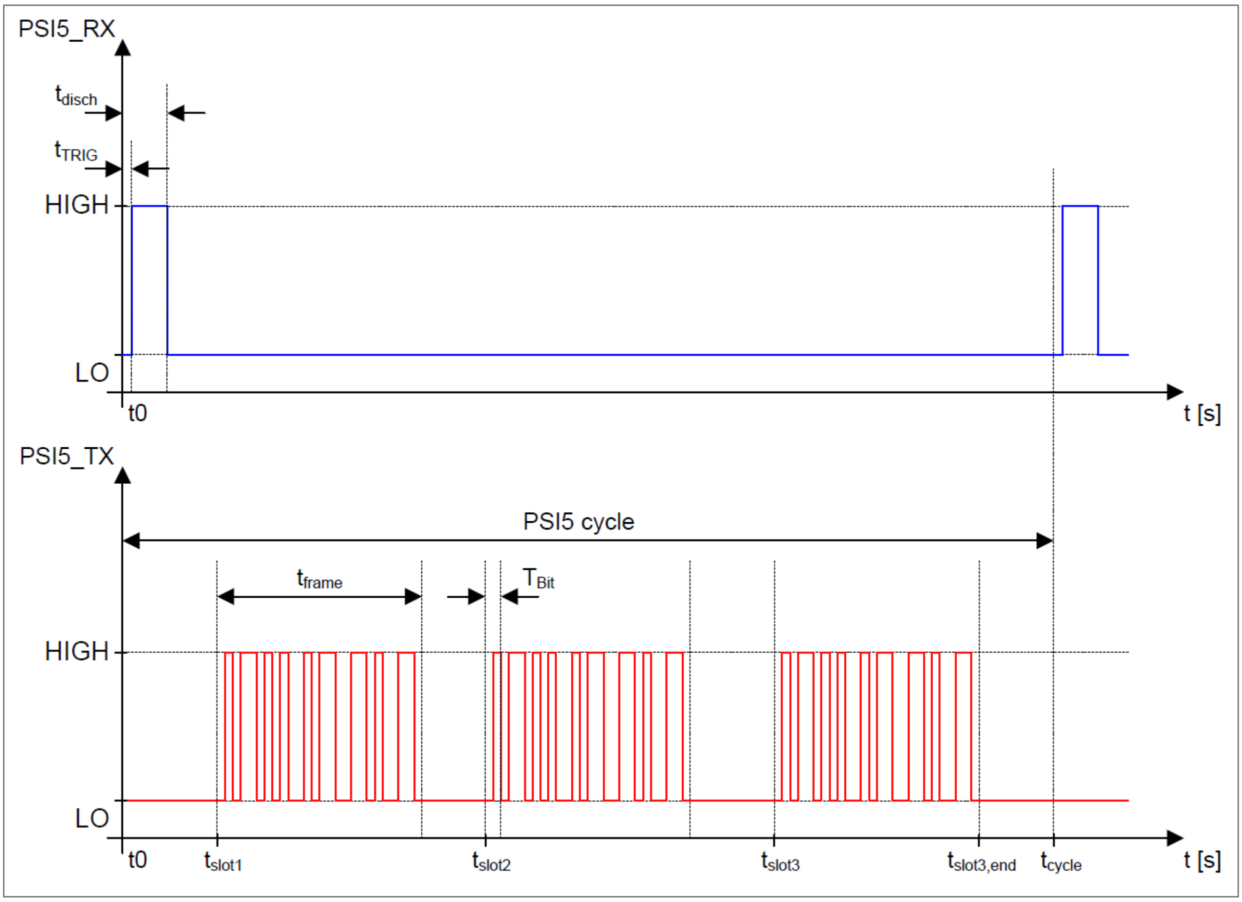


Table 36: Timings parameters of P10P-500/3L

Symbol	Parameter	Min	Typ	Max	Unit	Comments
t_{Bit_L}	Bit time	7.7	8	8.3	µs	
t_{frame_10L}	Frame duration	100.4	104	107.6	µs	
t_{TRIG}	Trigger detection time	0	4.5	10	µs	From start of synch. pulse
t_{slot1}	Start of time slot 1	44	51	59	µs	
t_{slot2}	Start of time slot 2	181.3	195	210	µs	
t_{slot3}	Start of time slot 3	328.9	350	372.8	µs	
$t_{slot3,end}$	End of time slot 3	427.7	454	482	µs	
$t_{cycle,P500}$	Cycle time p10p-500/3l	250	500	-	µs	

11.7.1.2 Timing synchronous mode P10P-500/3L with discharge pulse

Figure 26: Synchronous mode P10P-500/3L with discharge pulse

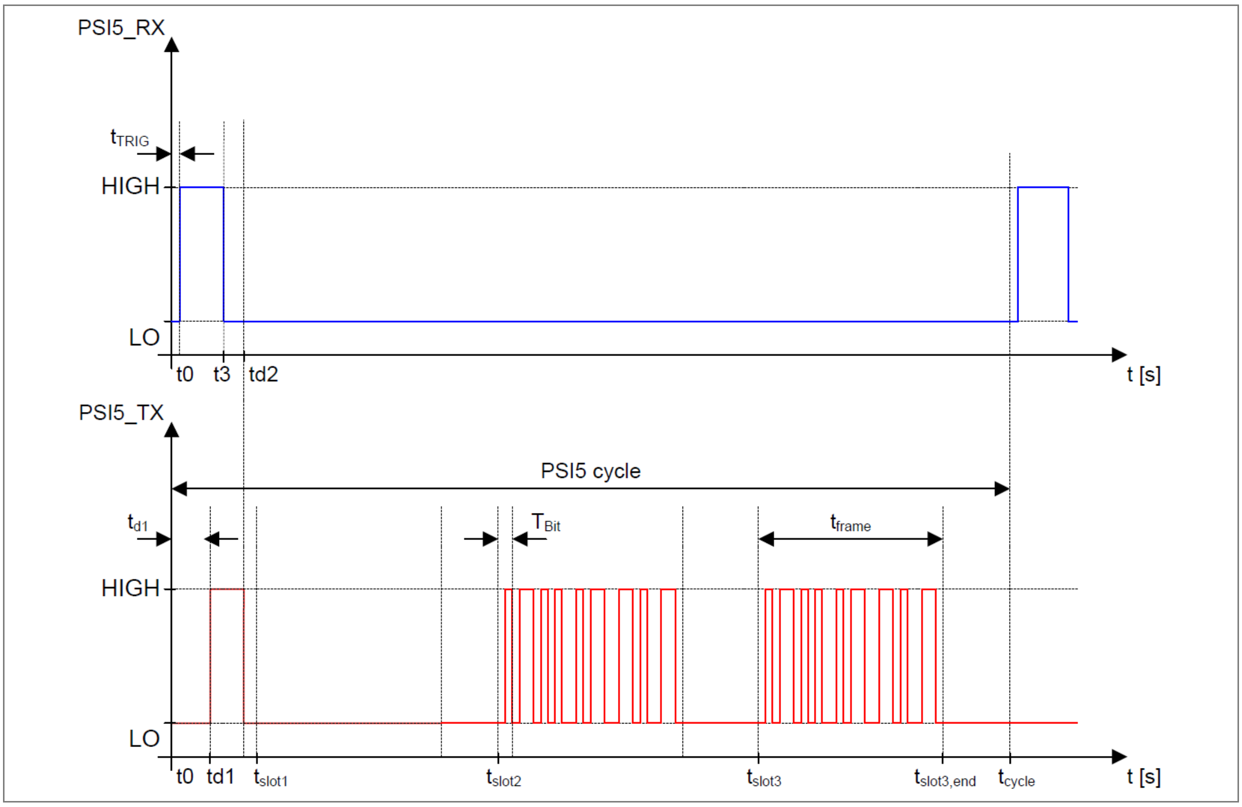


Table 37: Timings parameters of P10P-500/3L with discharge pulse

Symbol	Parameter	Min	Typ	Max	Unit	Comments
t_{Bit_L}	Bit time	7.7	8	8.3	µs	
t_{frame_10L}	Frame duration	100.4	104	107.6	µs	
t_{TRIG}	Trigger detection time	0	3.25	7.5	µs	
td1	Signal discharge	18.5	22.75	28	µs	
td2	Discharge stop time	38	43.25	50	µs	
t_{slot1}	Start of time slot 1	44	51	59	µs	
t_{slot2}	Start of time slot 2	181.3	195	210	µs	
t_{slot3}	Start of time slot 3	328.9	350	372.8	µs	
$t_{slot3,end}$	End of time slot 3	427.7	454	482	µs	
$t_{cycle,P500}$	Cycle time P10P-500/3L	250	500	-	µs	

11.7.1.3 Timing asynchronous modes A10P-250/1L and A10P-500/1L

Figure 27: Asynchronous modes A10P- 50/1L and A10P-500/1L

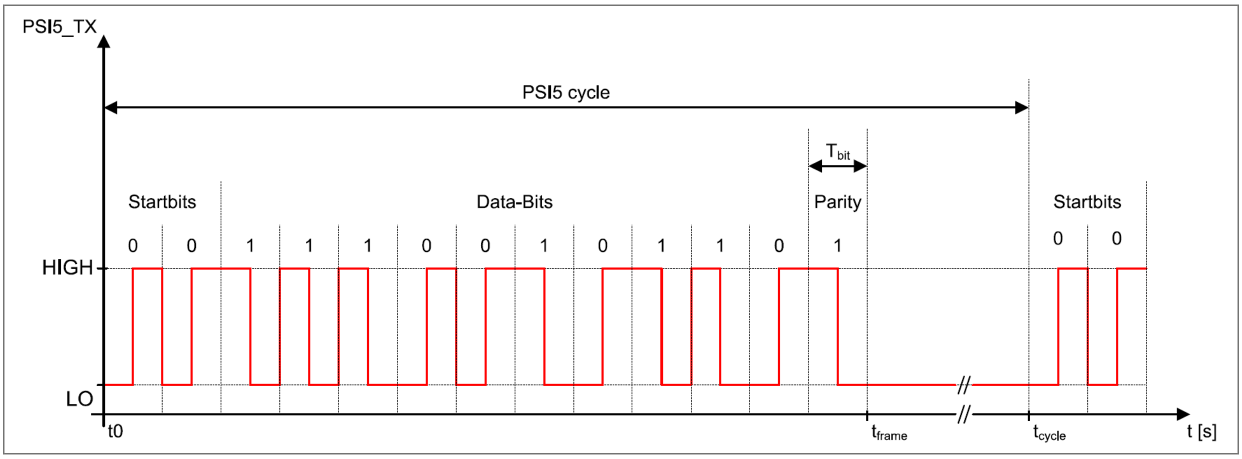


Table 38: Timings parameters of A10P- 50/1L and A10P-500/1L

Symbol	Parameter	Min	Typ	Max	Unit	Comments
t_{Bit_L}	Bit time	7.7	8	8.3	µs	
t_{frame_10L}	Frame duration	100.4	104	107.6	µs	
$t_{cycle,250L}$	Cycle time A10P-250/1L	241.2	250	258.8	µs	
$t_{cycle,500L}$	Cycle time A10P-500/1L	482.5	500	517.5	µs	

11.7.1.4 Timing synchronous modes P20CRC-500/1L, P20CRC-500/2L, P20CRC-500/2H, P20CRC-500/3H, P16CRC-500/3H

The supported protocol modes for synchronous transmission with 20-bit format are P20CRC-500/1L, P20CRC-500/2L, P20CRC-500/2H and P20CRC-500/3H. For all these modalities except P20CRC-500/1L it is possible to select also the velocity output. In this case two consecutive timeslots will be used.

The protocol P20CRC-500/3H is specifically studied for sensors that must transmit more data on two consecutive timeslots (e.g. angle and velocity). Usually there should be on the bus one sensor transmitting data on timeslot 1 & 2 and another sensor transmitting on timeslot 3, or a sensor transmitting on timeslot 1 and another transmitting on timeslot 2 & 3. Because of the relative tolerances due to the different clocks on the different sensors, the timing of the second timeslot is different when the sensor is transmitting only on one timeslot (not legacy situation for timeslot 2 only but allowed) and when is transmitting also the velocity using 2 consecutive timeslots, differentiating from the case of timeslot 1 & 2 or timeslot 2 & 3.

When there is a new synchronization pulse from the ECU before the current transmission of the AS5173 is finished the current transmission must be stopped and a new transmission has to be started in the programmed time slots.

Table 39: Timing parameters of synchronous modes P20CRC-500/1L, P20CRC-500/2L, P20CRC-500/2H, P20CRC-500/3H

Symbol	Parameter	Min	Typ	Max	Unit	Comments
t_{Bit_L}	Bit time P20CRC-500/1L/2L	7.7	8	8.3	µs	
t_{frame_20L}	Frame duration P20CRC-500/1L/2L	193	200	207	µs	
T_{Bit_H}	Bit time P20CRC-500/2H/3H	5.06	5.25	5.44	µs	
t_{frame_20H}	Frame duration P20CRC-500/2H/3H	126.66	131.25	135.84	µs	
t_{TRIG}	Trigger detection time	0	4.5	10	µs	
t_{slot1_20L}	Start of time slot 1 P20CRC-500/1L/2L	44	46	57.5	µs	
$t_{slot1\_20L,end}$	End of time slot 1 P20CRC-500/1L/2L	234	246	265	µs	
t_{slot1_20H}	Start of time slot 1 P20CRC-500/2H	44	51	59	µs	
$t_{slot1\_20H,end}$	End of time slot 1 P20CRC-500/2H	169	182.25	198	µs	
t_{slot1_20H}	Start of time slot 1 P20CRC-500/3H	44	45	56	µs	
$t_{slot1\_20H,end}$	End of time slot 1 P20CRC-500/3H	175.4	177.5	190.5	µs	
t_{slot2_20L}	Start of time slot 2 P20CRC-500/2L	267.5	273	288	µs	
$t_{slot2\_20L,end}$	End of time slot 2 P20CRC-500/2L	464	473	492	µs	
t_{slot2_20H}	Start of time slot 2 P20CRC-500/2H	203.5	218.25	235.5	µs	
$t_{slot2\_20H,end}$	End of time slot 2 P20CRC-500/2H	328.5	349.5	374.5	µs	
t_{slot2_20H}	Start of time slot 2 P20CRC-500/3H	183	186.5	199.5	µs	
$t_{slot2\_20H,end}$	End of time slot 2 P20CRC-500/3H	313.5	319	334	µs	
t_{slot2_20H}	Start of time slot 2 P20CRC-500/3H with velocity on time slot 1 & 2	180	183.5	196.5	µs	
$t_{slot2\_20H,end}$	End of time slot 2 P20CRC-500/3H with velocity on time slot 1 & 2	310.5	316	331	µs	
t_{slot2_20H}	Start of time slot 2 P20CRC-500/3H with velocity on time slot 2 & 3	195.5	199	212	µs	
$t_{slot2\_20H,end}$	End of time slot 2 P20CRC-500/3H with velocity on time slot 2 & 3	326	331.5	346.5	µs	
t_{slot3_20H}	Start of time slot 3 P20CRC-500/3H	336	341.5	357	µs	

Symbol	Parameter	Min	Typ	Max	Unit	Comments
$t_{slot3\_20H,end}$	End of time slot 3 P20CRC-500/3H	466.5	474	491.5	µs	
$t_{cycle,P500}$	Cycle time P20CRC-500/1L/2L	270	500	-	µs	
$t_{cycle,P500}$	Cycle time P20CRC-500/2H/3H	250	500	-	µs	

Table 40: Distinct timing parameters of P16CRC-500/3H and P16CRC-1000/4H

Symbol	Parameter	Min	Typ	Max	Unit	Comments
$t_{Bit\_L\_P16CRC-500/3H}$	Bit time P16CRC-500/3H	7.7	8	8.3	µs	
t_{frame_16H}	Frame duration P16CRC-500/3H	106.4	110.25	114.1	µs	
$t_{slot1\_16H,start}$	Start of time slot 1 P16CRC-500/3H	44	45	56	µs	
$t_{slot1\_16H,end}$	End of time slot 1 P16CRC-500/3H	153.5	156.5	169.5	µs	
$t_{slot2\_16H,start}$	Start of time slot 2 P16CRC-500/3H	183	186.5	199.5	µs	
$t_{slot2\_16H,end}$	End of time slot 2 P16CRC-500/3H	292.5	298	313	µs	
$t_{slot3\_16H,start}$	Start of time slot 3 P16CRC-500/3H	336	341.5	357	µs	
$t_{slot3\_16H,end}$	End of time slot 3 P16CRC-500/3H	445.5	453	470.5	µs	
$t_{slot1\_P16CRC-1000/4H\_start}$	Start of time slot 1 P16CRC-1000/4H	44		56	µs	
$t_{slot1\_P16CRC-1000/4H\_end}$	End of time slot 1 P16CRC-1000/4H			169.5	µs	
$t_{slot2\_P16CRC-1000/4H\_start}$	Start of time slot 2 P16CRC-1000/4H	183			µs	
$t_{slot2\_P16CRC-1000/4H\_end}$	End of time slot 2 P16CRC-1000/4H			313	µs	
$t_{slot3\_P16CRC-1000/4H\_start}$	Start of time slot 3 P16CRC-1000/4H	336			µs	
$t_{slot3\_P16CRC-1000/4H\_end}$	End of time slot 3 P16CRC-1000/4H			470.5	µs	
$t_{slot4\_P16CRC-1000/4H\_start}$	Start of time slot 4 P16CRC-1000/4H	476.5	493.5	521.5	µs	
$t_{slot4\_P16CRC-1000/4H\_end}$	End of time slot 4 P16CRC-1000/4H	584.0	605	636.5	µs	

11.7.1.5 Timing asynchronous modes A20CRC-200/1H and A20CRC-300/1L

Figure 28: Asynchronous modes A20CRC-200/1H and A20CRC-300/1L

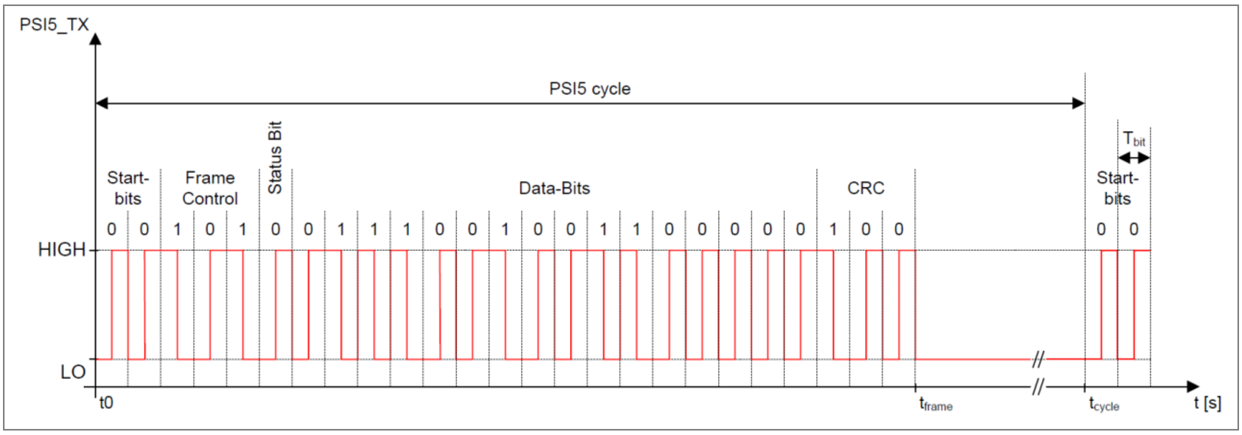


Table 41: Timing parameters of A20CRC-200/1H and A20CRC-300/1L

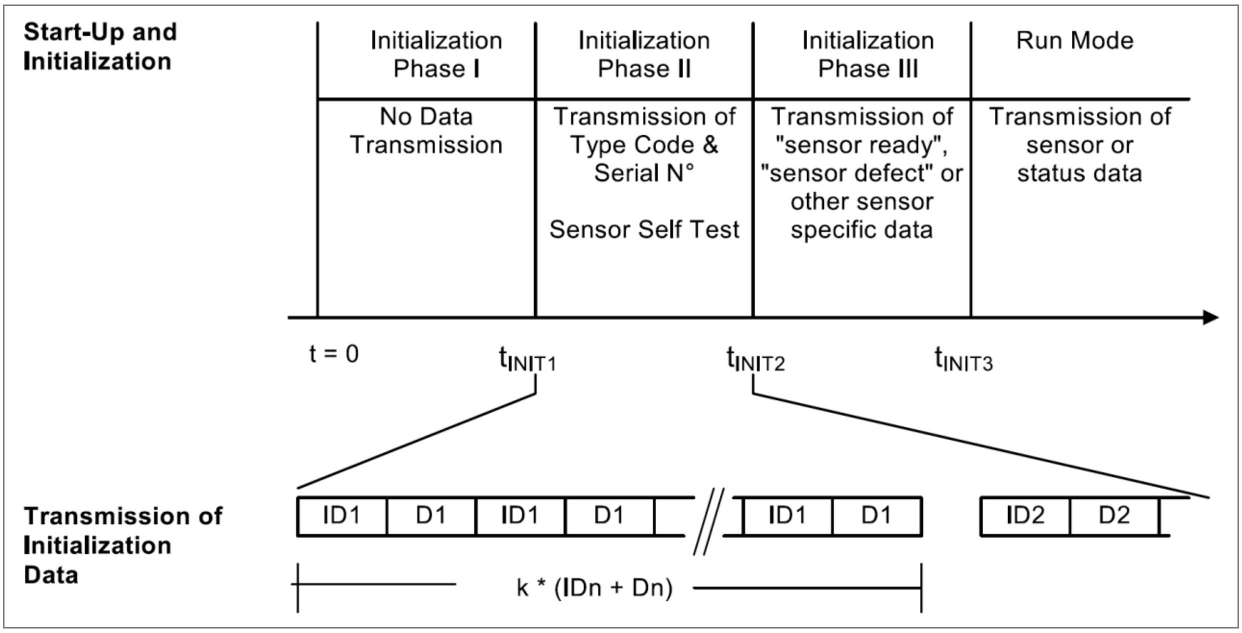
Symbol	Parameter	Min	Typ	Max	Unit	Comments
t_{Bit_L}	Bit time A20CRC-300/1L	7.7	8	8.3	µs	
t_{frame_20L}	Frame duration A20CRC-300/1L	193	200	207	µs	
$t_{cycle,300L}$	Cycle time A20CRC-300/1L	298.5	300	310.5	µs	
t_{Bit_H}	Bit time A20CRC-200/1H	5.06	5.25	5.44	µs	
t_{frame_20H}	Frame duration A20CRC-200/1H	126.66	131.25	135.84	µs	
$t_{cycle,200H}$	Cycle time A20CRC-200/1H	193	200	207	µs	

11.7.2 PSI5 initialization

The Startup and Initialization is working according the PSI5 standard.

After each power on or undervoltage reset, the AS5173 performs an internal initialization which is divided into three phases:

Figure 29: Start-up and initialization



11.7.2.1 Initialization phase I

During the first initialization phase, no data is transmitted, and the ECU can perform a connectivity test. Duration 50 – 150ms; typical 100ms. If using synchronous transmission mode, the ECU can terminate the initialization phase I by sending the sync pulse at least TSUP after AS5173 power on.

11.7.2.2 Initialization phase II

During the second initialization phase, the AS5173 transmits sensor and application specific information to the ECU.

In High Resolution mode the AS5173 transmits the same PSI5 frame on both programmed time slots. The same is valid if the velocity output is activated.

For the 20-bit mode the 10-bit values are extended to 20 bits. This is done by shifting the data bits [9:0] to bits A15 to A6. The remaining 6 LSBs are filled with “0”. The frame control bits (F0 to F2) and the status bit (E0) are at “0”.

Table 42: Initialization phase in 20-bit mode

Start bits		Frame control			Error status	16-bit sensor data (LSB first)																CRC		
S1	S2	F0	F1	F2	E0	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	C2	C1	C0
0	0	0	0	0	0	0	0	0	0	0	0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	C2	C1	C0

Table 43: Initialization phase in 16-bit mode

Start bits		Error status	16-bit sensor data (LSB first)															CRC		
S1	S2	E0	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	C2	C1	C0
0	0	0	0	0	0	0	0	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	C2	C1	C0

11.7.3 Initialization phase III

During the third initialization phase, the sensor transmits “Sensor Ready”, “Sensor Defect” or other status data. If the sensor is defective, it will continue to send the “Sensor Defect” messages and other optional status data until it is powered off.

- “Sensor Ready” Code 0x1E7 at A15 to A6 – if the sensor is OK
- “Sensor Defect” Code 0x1F4 at A15 to A6 – if there is a diagnostic error

In High Resolution mode the AS5173 transmits the same PSI5 frame on both programmed time slots. The same is valid if the velocity output is activated.

In overvoltage, undervoltage case and AGC High, Low the AS5173 does not report these errors in initialization phase III, but it will send the error code in the run mode.

Table 44: P16CRC protocol init phase

	Start bits		16-bit sensor data (LSB first)																CRC		
	S1	S2	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	C2	C1	C0
Sensor	0	0	-	-	-	-	-	-	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	C2	C1	C0
defect 0x1F4	-	-	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	-	-	-
ready 0x1E7	-	-	1	1	1	1	1	1	1		1	0	0	1	1	1	1	0	-	-	-
			LSBs filled with LSB of reserved code						10-bit status Code												

This 16-bit mode has the error codes transmitted from A6 to A15, with the A0 to A5 error flags. The initialization message is also represented on A6 to A15 bits, while A0 to A5 are filled with 1s in case of sensor ready, with 0s in case of sensor defect.

11.7.3.1 Initialization phase data format

ID blocks and data blocks are sent in an alternating sequence, “k” times each. The block identifiers are used for a numbering of the following data nibbles. After any power-on or undervoltage reset, the internal logic starts up with an initialization program. The factor “k” can vary between 1 and 4 and can be configured with “Init_phase_repetition” in register 0x12.

Figure 30: Block ID and data nibbles

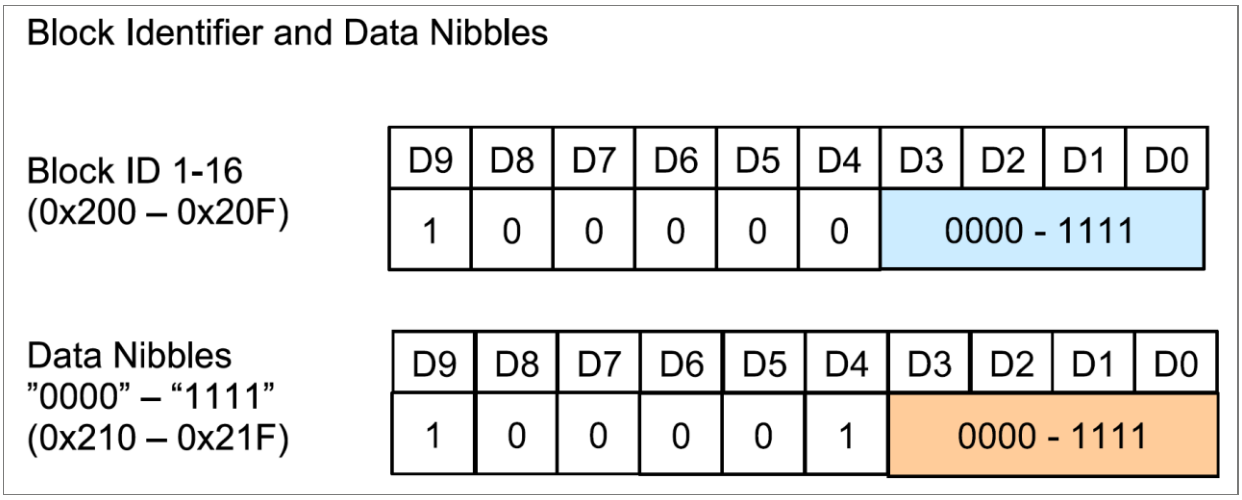
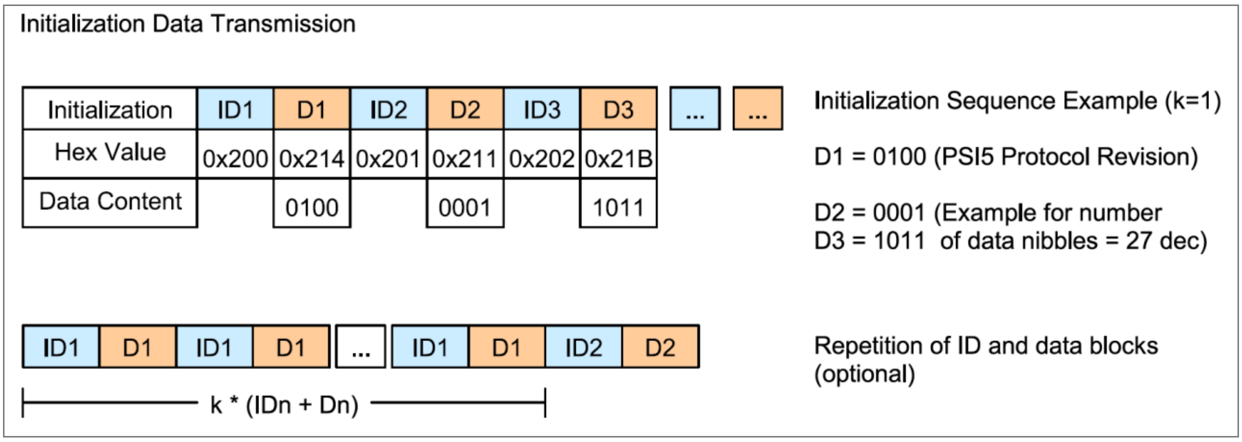


Figure 31: Startup sequence



11.7.3.2 Initialization data content

During the second initialization phase, the AS5173 transmits sensor and application specific information to the ECU. That information is described into Table 45.

Table 45: Initialization content

Field ID#	Nibble ID#	Name	Description	Register address	Value
F1	D1	Protocol revision	PSI5 V1.3	Hard-coded	0100
			PSI5 V2.3	Hard-coded	0110
F2	D2, D3	Number of data blocks	Number of data blocks = 22	Hard-coded	0001 0110
			Number of data blocks = 32	Hard-coded	0010 0000
F3	D4, D5	Manufacturer code	Vendor ID	0x1E	Customer
F4	D6, D7	Sensor type	Sensor type	0x0E	Customer
F5	D8, D9	Sensor parameter	Sensor parameter	0x0E, 0x0F	Customer
F6	D10, D11	Sensor code (sensor)	Sensor code (sensor)	0x0F, 0x10	Customer
F7	D12	Sensor code (vehicle)	Sensor code (vehicle)	0x10	Customer
F8	D13 – D16	Production date	Production date	0x0C, 0x0D	Customer
F9	D17 – D22	Lot and serial number	ams OSRAM ID	0x02, 0x03, 0x04	Factory

11.7.3.3 Run mode

After finishing Initialization Phase III the AS5173 enters Run Mode. If the sensor is configured in asynchronous mode, it will start transmitting data continuously according PSI5 standard. Using the synchronous mode, the transmission is triggered by a sync pulse of the ECU.

If the AS5173 is configured in asynchronous mode, it will transmit the data continuously according the PSI5 Specification.

In case of an application or sensor error, AS5173 is performing in run mode according to the description in chapter Diagnostic.

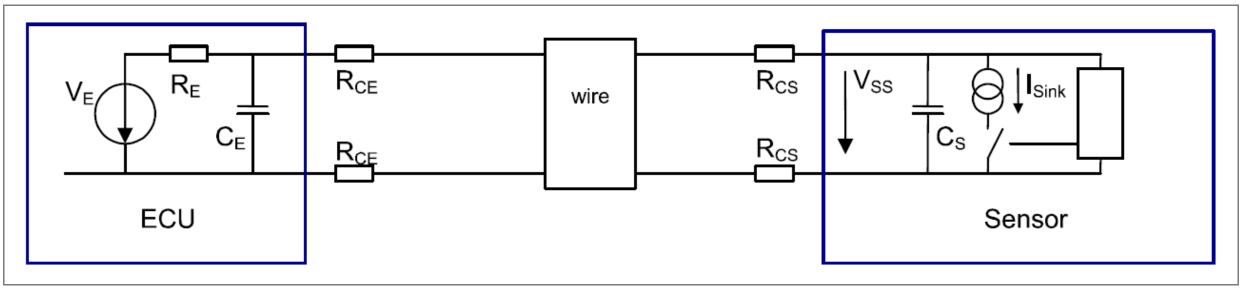
11.7.4 Communication modes

11.7.4.1 Asynchronous mode (PSI5-A)

PSI5-A describes a point-to-point connection for unidirectional, asynchronous data transmission.

Each sensor is connected to the ECU by two wires. After switching on the power supply, the sensor starts transmitting data to the ECU periodically. Timing and repetition rate of the data transmission are controlled by the sensor.

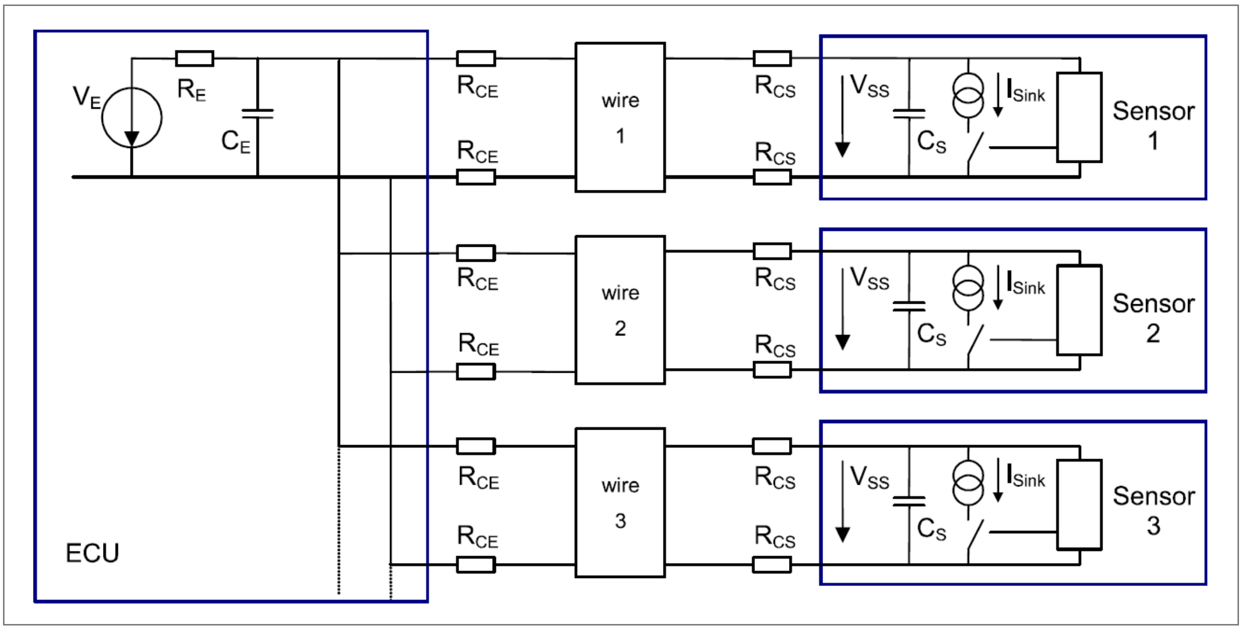
Figure 32: Asynchronous single sensor configuration



11.7.4.2 Synchronous parallel bus mode (PSI5-P)

PSI5-P describes a bus configuration for synchronous data transmission of one or more sensors. Each sensor is connected to the ECU by a separate pair of wires (star topology). Each data transmission period is initiated by a voltage synchronization signal from the ECU to the sensors. Having received the synchronization signal, each sensor starts transmitting its data with the corresponding time shift in the assigned time slot.

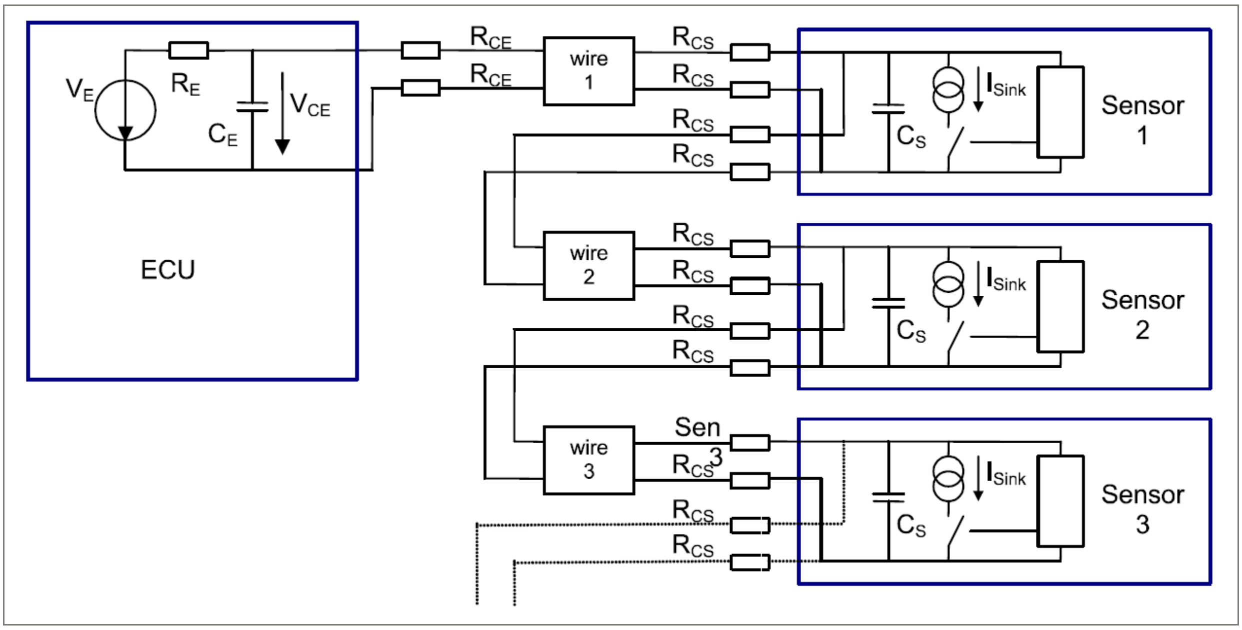
Figure 33: Synchronous parallel bus mode (PSI5-P)



11.7.4.3 Synchronous universal bus mode (PSI5-U)

PSI5-U describes a bus configuration for synchronous data transmission of one or more sensors. The sensors are connected to the ECU in different wiring topologies including splices or pass-through configurations. Each data transmission period is initiated by a voltage synchronization signal from the ECU to the sensors. Having received the synchronization signal, each sensor starts transmitting its data with the corresponding time shift in the assigned time slot.

Figure 34: Synchronous parallel bus mode (PSI5-P)



11.8 Diagnostic

The AS5173 allows a high ASIL-B(C) level in the application through a robust embedded self-diagnostic.

AS5173 sensor is developed as SEooC according the ISO26262. For more information refer to the AS5173 Safety Manual which is available on request to the application engineering team.

Table 46: Diagnostic table

SM	Failure mode	Recoverable	10-bit mode error info	16-bit mode error info	20-bit mode error info
SM1	Watchdog fail	-	Permanent low level	Permanent low level	Permanent low level
SM2	Offset compensation	X	0x1ED	0x1ED at A9 to A0 E0 = 1	0x1ED at A15 to A6 E0 = 1
SM3	CORDIC overflow	-	0x1F4	0x1F4 at A9 to A0 E0 = 1	0x1F4 at A15 to A6 E0 = 1 A0 = 1
SM4	Magnetic field out of range	X	0x1EB	0x1EB at A9 to A0 E0 = 1	0x1EB at A15 to A6 E0 = 1
SM5	VDD3V3 undervoltage	X	Permanent low level	Permanent low level	Permanent low level
SM6	Reverse polarity	X	Permanent low level	Permanent low level	Permanent low level
SM7	VDD overvoltage	X	0x1EA	0x1EA at A9 to A0 E0 = 1	0x1EA at A15 to A6 E0 = 1
SM8	VDD undervoltage under POR level	-	Permanent low level	Permanent low level	Permanent low level
SM9	VDD undervoltage	X	0x1EC	0x1EC at A9 to A0 E0 = 1	0x1EC at A15 to A6 E0 = 1
SM10	OTP checksum error	-	0x1F4	0x1F4 at A9 to A0 E0 = 1	0x1F4 at A15 to A6 E0 = 1 A2 = 1
SM11	Broken hall element	-	0x1F4	0x1F4 at A9 to A0 E0 = 1	0x1F4 at A15 to A6 E0 = 1 A3 = 1

(1) Recoverable: Sensor is working if the error condition is solved.

11.8.1 Diagnostic procedure in PSI5

If an OTP checksum error (SM10) occurs after the first OTP download the PSI5 interface shows a “Sensor Defect” Code - 0x1F4 in initialization phase III. This error code will be sent until the device is powered off.

If any other diagnostic error condition occurs during initialization phase I or II the error will be masked. It will then be reported in initialization phase III by transmitting “Sensor Defect” Code - 0x1F4.

When a diagnostic error condition appears during PSI5 run mode the specific error code will be transmitted on the PSI5 interface.

During run mode:

When a diagnostic error condition appears during the PSI5 run mode the error code “Sensor Defect” (0x1F4) has to be transmitted on the PSI5 interface until the AS5173 is reset by the ECU.

The internal diagnostic error conditions are:

- CORDIC Overflow
- OTP Check Fail
- Broken Hall Element
- Broken Channel
- Watchdog

When a watchdog error is present the PSI5_out signal from the digital part is forced to “0”. Therefore, the PSI5 interface shows a permanent low-level current as long as the watchdog error is present.

When an VDD3 undervoltage is present the PSI5_out signal from the digital part is forced to “0”. Therefore, the PSI5 interface shows a permanent low-level current as long as the VDD3 undervoltage is present.

In magnet field strength out of spec, the AS5173 is transmitting the error code 0x1EB during the PSI5 run mode and keeps transmitting this error code until the flag goes to low or the AS5173 is powered off by ECU.

In overvoltage, the AS5173 is transmitting the error code 0x1EA during the PSI5 run mode and keeps transmitting this error code until the flag from the analog part goes to low or AS5173 is powered off by ECU.

In undervoltage (between threshold and min VDD), the AS5173 is transmitting the error code 0x1EC during the PSI5 run mode and keeps transmitting this error code until the flag from the analog part goes to low or AS5173 is powered off by ECU.

When an undervoltage below the POR threshold is present the PSI5_out signal from the digital part is forced to “0”. Therefore, the PSI5 interface shows a permanent low-level current as long as the undervoltage is present.

When using the 20-bit or 16-bit mode the status message “Sensor Defect” (code 0x1F4) is transmitted at the bits A15 to A6 and also the bit E0 is set to “1” when there is a diagnostic error condition. The frame control bits (F2 to F0) keep the functionality of the frame counter. On the bits A5 to A0 a detailed failure code is transmitted with the following bit assignment.

11.9 System level EMC/ESD

AS5173 in the (SIP Package) is built to fulfill system level EMC and ESD standards.

A full certified test report is available upon request. Please get in contact with the application engineering team.

12 Application information

12.1 Signature calculation

The OTP of AS5173 uses a BIST technique with Multiple Input Signature Register circuits. To activate this BIST a calculation of the Signature Byte is necessary which has to be stored in the OTP during programming. For calculating the signature byte the content of the whole memory (0x01 to 0x1F) has to be read out. Out of this information the following calculation has to be done.

Byte: 0x01 = data1

Byte: 0x02 = data2

…

Byte: 0x1F = data31

```
unsigned int misr, misr_shift, misr_xor, misr_msb;
            misr = 0;
            for (int i = 0; i<30; i++) {
                        misr_shift = (misr << 1);
                        misr_xor = (misr_shift ^ content[i]) % 256;
                        misr_msb = misr / (128);
                        if (misr_msb == 0)
                              misr = misr_xor;
                        else
                              misr = (misr_xor ^ 29) % 256;
}
content= { data1,data2,data3,data4,data5,data6,
data7,data8,data9,data10,data11,
data12,data13,data14,data15,data16,
data17,data18,data19,data20,data21,data22,
```

```
data23,data24,data25,data26,data27,data28,
data29,data30,data31};
```

12.2 Programming procedure

For further information about the programming please refer to application note AN_AS5173_Programming_Procedure_V1-00. Please get in contact with the application engineering team.

12.3 Built-in capacitors

Figure 35: AS5173 components

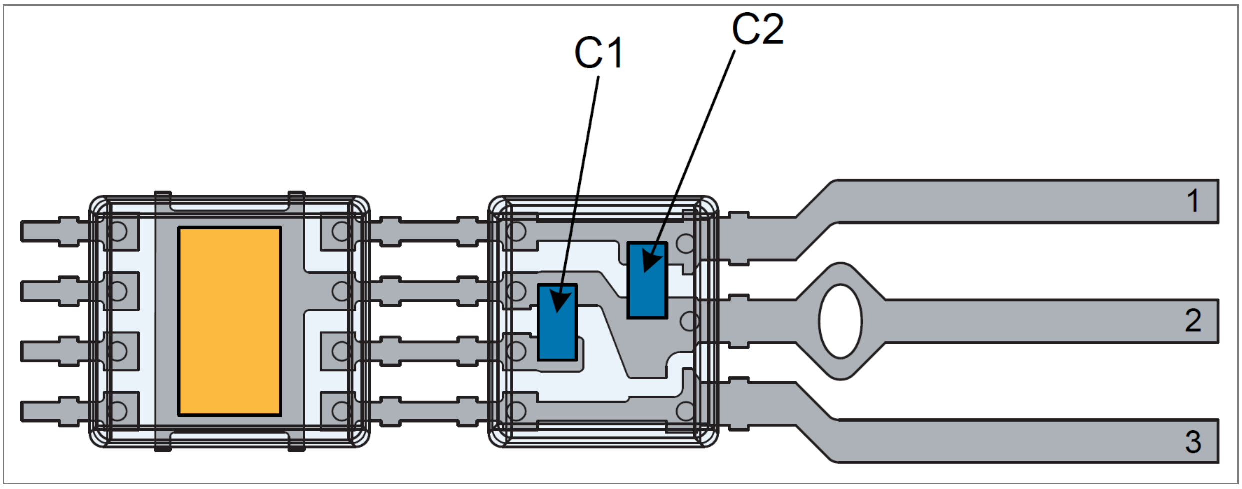
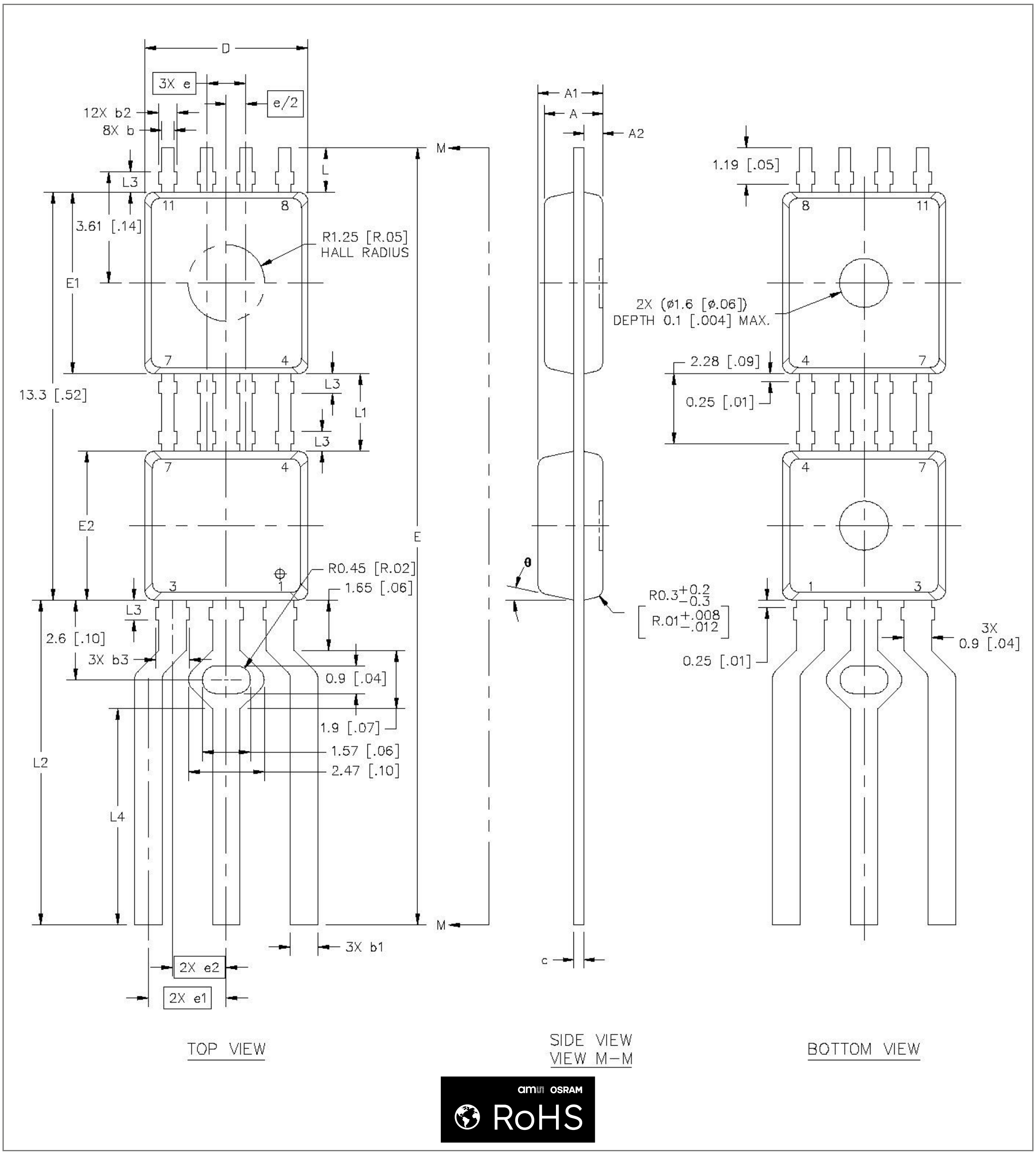


Table 47: AS5173 component specification

Symbol	AS5173 components	Min	Typ	Max	Unit	Notes
C1	VDD buffer capacitor	13.5	15	16.5	nF	
C2	VDD3V3 regulator capacitor		470		nF	

13 Package drawings & markings

Figure 36: SIP package outline drawing



(1) All linear dimensions are in millimeters, inches are indicated in brackets [in].
(2) Angles are in degrees.

(3) Dimension D does not include mold flash, protrusions or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.3mm (0.012in) per side.
(4) Dimension b and b1 does not include dam bar protrusion and matte tin plating. Allowable dam bar protrusion shall be 0.3mm (0.012in) total in excess of the b, b1, b2 and b3 dimension at maximum material condition.
(5) Dimension E1 and E2 does not include interlead flash or protrusion. Interlead flash or protrusion shall not exceed 0.3mm (0.012in) per side.
(6) Dimension tolerance: ±0.15mm unless otherwise specified.

Table 48: SIP package dimensions

		Symbol	Min	Nom	Max	Min	Nom	Max
`Total thickness		A	1.75	1.9	2.05	.069	.075	.081
		A1	1.95	2.1	2.25	.077	.083	.089
Mold thickness		A2	0.5	0.6	0.7	.020	.024	.028
Lead width		b	0.35	0.4	0.45	.014	.016	.018
		b1	0.8	0.9	1	.031	.035	.039
		b2	0.45	---	0.65	.018	---	.026
		b3	0.9	---	1.2	.035	---	.047
L/F thickness		c	0.3	0.35	0.45	.012	.014	.018
Body size	X	D	5.16	5.31	5.46	.203	.209	.215
	Y	E1	5.77	5.92	6.07	.227	.233	.239
	Y	E2	4.7	4.85	5	.185	191	.197
		E	25.19	25.34	25.49	.992	.998	1.004
Lead pitch		E		1.27 BSC			.050 BSC	
		e1		2.54 BSC			.100 BSC	
		e2		1.75 BSC			.069 BSC	
Footprint		L	1.29	1.44	1.64	.051	.057	.065
		L1	2.43	2.53	2.63	.096	.100	.104
		L2	10.4	10.6	10.85	.409	.417	.427
		L3	0.5	0.65	0.85	.020	.026	.033
		L4	6.85	7.05	7.3	.270	.278	.287
		Θ	10°	12°	14°	10°	12°	14°

Figure 37: SIP marking drawing AS5173

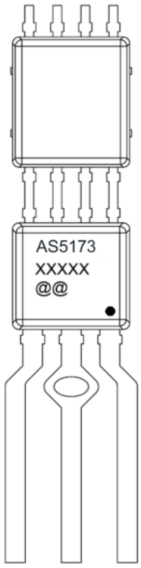
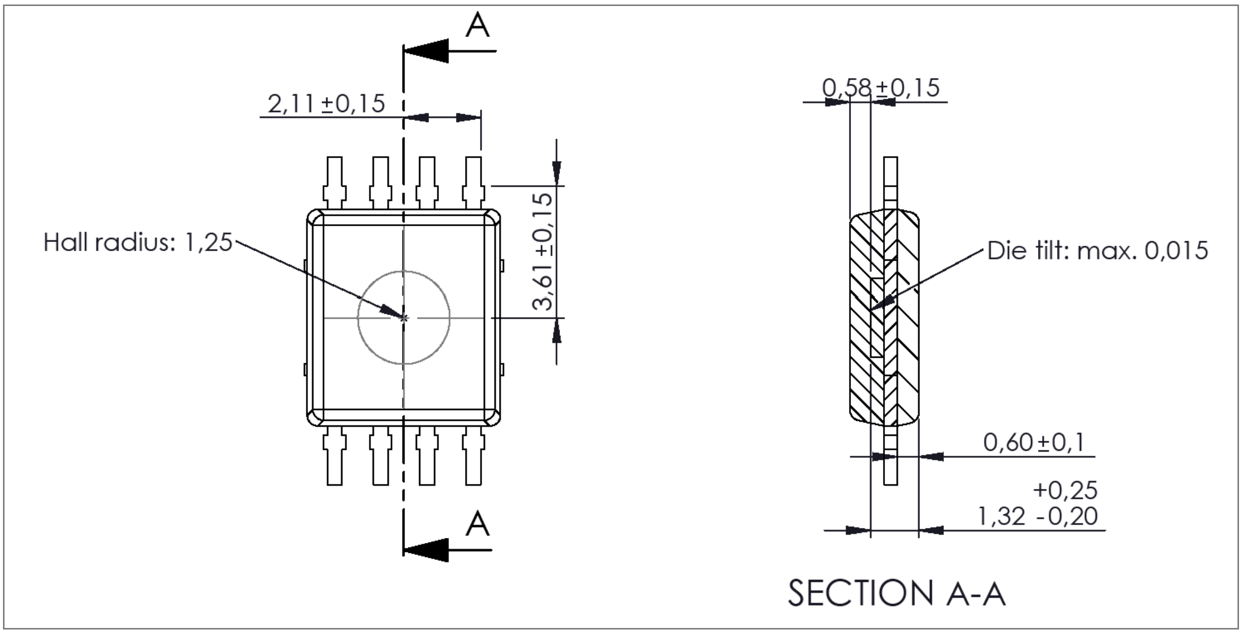


Table 49: SIP package code

XXXXX	@@
Tracecode	Sublot identifier

14 Mechanical data

Figure 38: SIP die placement and hall array position



(1) All dimensions in mm.
(2) Tolerances shown represent expected values and are to be verified. Tolerances will be guaranteed prior to product release.

14.1 Mechanical information

For information in terms of manufacturability with different processes, please refer to the following document, which is available upon request: AN_ams OSRAM_SIP Handling_V1.01.pdf.

15 Revision information

Document status	Product status	Definition
Product Preview	Pre-development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice
Preliminary Datasheet	Pre-production	Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice
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Changes from previous version to current revision v1-01	Page
Changes to v1-00	
Initial production version	
Changes from v1-00 to v1-01	
Updated Table 1	5
Updated Table 4	11
Updated Table 10	20
Updated Table 12	23
Updated description under section 11.7	61

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.

16 Legal information

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