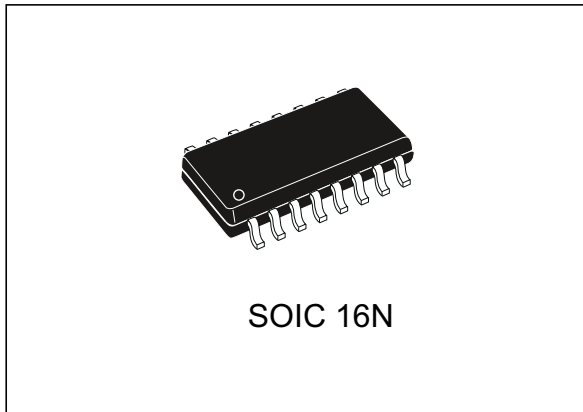


## MEMS acceleration sensor: single-axis with PSI5 point-to-point interface

Datasheet - production data



### Features

- 5 V to 16 V single supply operation
- 10-bit data output
- Embedded voltage regulator
- Embedded self-test
- Asynchronous 2 wire connectivity
- PSI5-A10P v1.3 compliant
- Error detection: single bit even parity
- Automotive AEC-Q100 qualified
- ECOPACK® compliant
- Extended temperature range: -40 °C to +125 °C

### Applications

- Airbag systems
- Vibration, impact monitoring

### Description

The AIS1200PS is a peripheral acceleration sensor with a single-axis sensing element and an IC interface able to provide acceleration information to a master control unit through a Manchester-coded protocol (125 kbps).

The sensing element, capable of detecting the acceleration, is manufactured using a dedicated process developed by ST to produce inertial sensors and actuators in silicon.

The IC interface is manufactured using a BCD process that allows a high level of integration. The device is factory trimmed to better tune the sensing element characteristics with the acceleration information to be supplied.

The AIS1200PS has a full scale of  $\pm 200\text{ g}$ . The acquisition chain is made up of a C/V converter, a full-differential charge amplifier, a 2<sup>nd</sup> order LPF with a cutoff frequency of 175 Hz, and a second charge amplifier to adapt the dynamic range to an SAR A/D converter.

The differential capacitance of the sensor is proportional to the proof mass displacement; thus, by sensing the differential capacitance, the position of the sensor is determined. Then, since the mass position is known and the position is related to the input acceleration, the input acceleration can be easily deduced.

The device is available in a plastic SOIC package with 150 mils reverse frame forming for EMC enhancement and is specified over a temperature range extending from -40 °C to +125 °C.

Table 1. Device summary

Order code	<i>g</i> -range	Operating temperature range [°C]	Package	Packing
AIS1200PSTR	200 <i>g</i>	-40 to +125	SOIC 16N	Tape and reel

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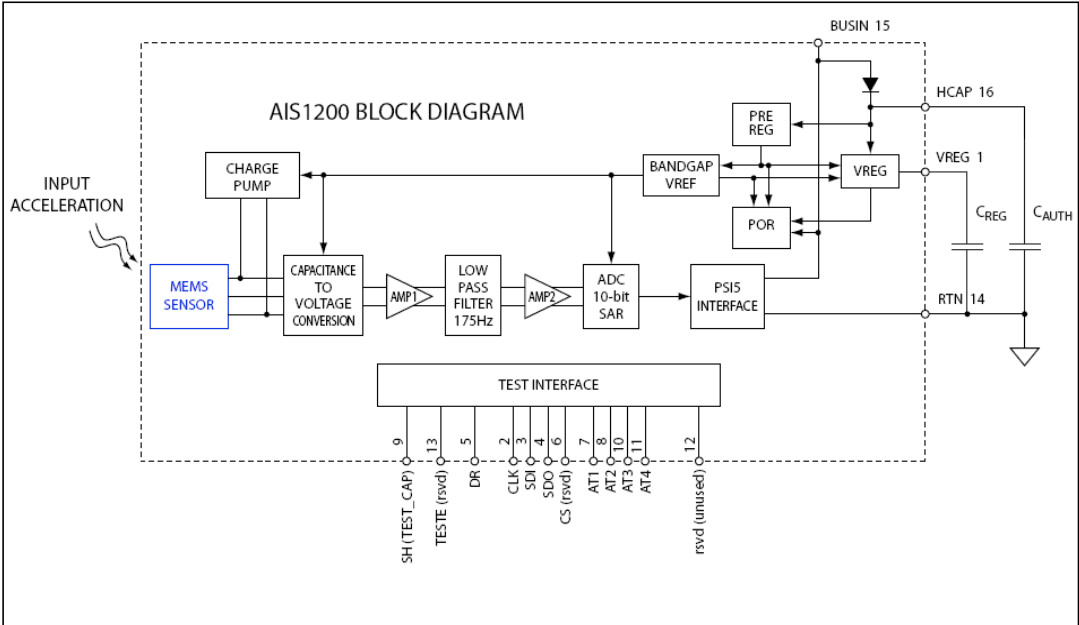
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# 1 Block diagram and pin description

## 1.1 Block diagram

Figure 1. AIS1200PS block diagram



## 1.2 SOIC 16N pin description

Figure 2. Detectable accelerations and pinout

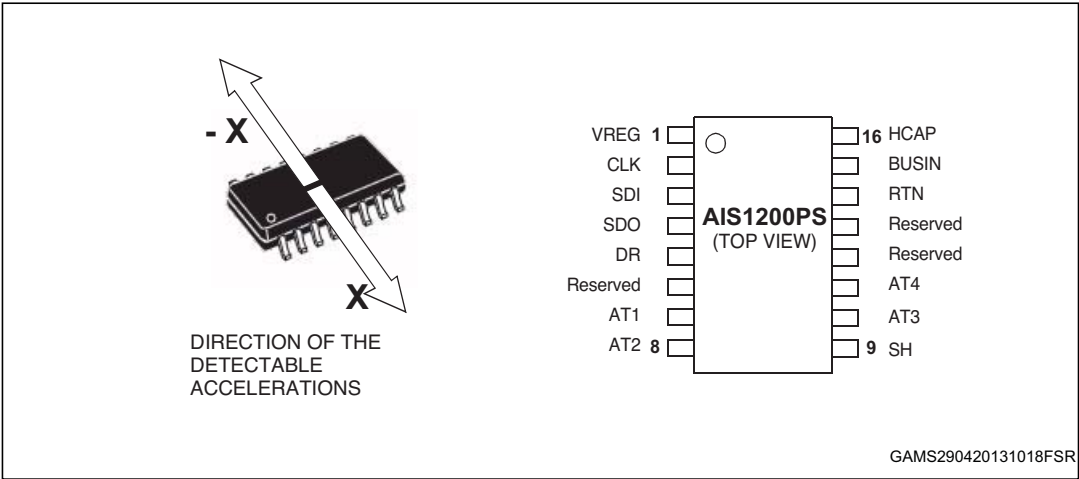


Table 2. Pin description

Pin#	Name	Function
1 - LV <sup>(1)</sup>	VREG	Voltage regulator output. A ceramic capacitor of $1.0\mu\text{F} \pm 40\%$ must be connected to this pin, which should not be used to power up other devices.
2 - LV	CLK	SPI interface - connect to GND.
3 - LV	SDI	SPI interface - connect to GND.
4 - LV	SDO	SPI interface - driven to "0" by the device.
5 - LV	DR	Data Ready - driven to "0" by the device.
6 - LV	CS	SPI chip select, connect to GND.
7 - LV	AT1	Analog port 1 - driven to "0" by the device.
8 - LV	AT2	Analog port 2 - driven to "0" by the device.
9 - LV	SH	Connect to GND.
10 - LV	AT3	Analog port 3 - driven to "0" by the device.
11 - LV	AT4	Analog port 4 - driven to "0" by the device.
12 - LV	Reserved	Leave unconnected.
13 - LV	Reserved	Connect to GND.
14 - HV <sup>(2)</sup>	RTN	Bus low side.
15 - HV	BUSIN	Bus high side.
16 - HV	HCAP	An autarky ceramic capacitor of $0.047\mu\text{F} \pm 50\%$ must be connected to this pin.

1. LV (low voltage) pin: 4.5 V max absolute rating.

2. HV (high voltage) pin: 20 V max absolute rating.

## 2 Mechanical and electrical specifications

### 2.1 Mechanical characteristics

$V_{DD} \geq 5 \text{ V}$  to  $V_{DD} \leq 16 \text{ V}$ ,  $T_L \geq -40 \text{ }^\circ\text{C}$  to  $T_H \leq 125 \text{ }^\circ\text{C}$ , unless otherwise noted.

**Table 3. Mechanical characteristics**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
FS	Full-scale range <sup>(2)</sup>			±200		g
$S_0$	Sensitivity		1.8	2	2.2	LSb/g
$TCS_0$	Sensitivity change vs. temperature	$T_A = 25^\circ\text{C}$	-5		5	%
		$T_L \leq T_A \leq T_H$	-10		10	
Off	Zero-g level offset <sup>(1)</sup>	$T_A = 25^\circ\text{C}$	-26	0	26	LSb
		$T_L \leq T_A \leq T_H$	-54	0	54	
NL	Non-linearity <sup>(2)</sup>	Best-fit straight line	-2		+2	% FS
Asym	Asymmetry <sup>(2)</sup>		-1.2		+1.2	%
CrAx	Cross axis <sup>(2)</sup>		-5		+5	%
$F_0$	MEMS resonant frequency <sup>(2)</sup>		16.6	19.6	22.5	kHz
$T_{op}$	Operating temperature range		-40		+125	$^\circ\text{C}$

1. Zero-g level offset (10-bit representation) including aging and soldering effects.
2. Verified by characterization, not tested in production.

### 2.2 Electrical characteristics

$T_A \geq -40^\circ\text{C}$  to  $T_H \leq 125 \text{ }^\circ\text{C}$ , unless otherwise noted<sup>(a)</sup>

**Table 4. Electrical characteristics**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{bus}$	Supply voltage at BUSIN		5		16	V
$I_Q$	Quiescent current <sup>(1)</sup>		2	4	7	mA
$I_d$	Drift of quiescent current (time gradient) <sup>(3)</sup>	$\left  \frac{\Delta I}{\Delta t} \right  \leq 0.5 \left[ \frac{^\circ\text{C}}{\text{s}} \right]$			±1	mA/min
RNG	Output range	±200 g	-400		400	LSb
$RNG_{max}$	Output range before clamp		-480		480	LSb
$Out_{FF}$	Output frequency flatness	5 g @ freq 20, 30, 40 Hz <sup>(2)</sup>	-10		+10	%
$I_S$	Data sink current		$I_Q$		$I_Q + \Delta I_S$	mA

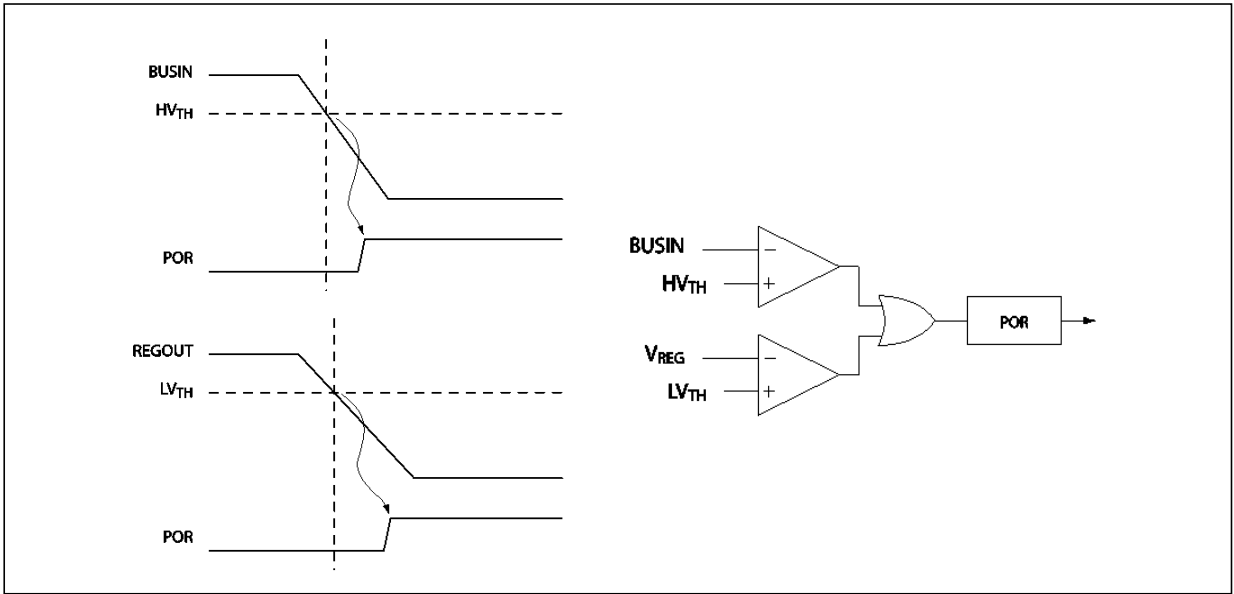
a. All voltage levels are referred to RTN

Table 4. Electrical characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$\Delta I_S$	Delta sink current		22	26	30	mA
$t_r, t_f$	Current rise and fall times	20%...80% of $\Delta I_S$	0.33		1	$\mu s$
$V_{regout}$	$V_{REG}$ output voltage	$C_{reg} = 1.0 \mu F$ , ceramic	3.1	3.3	3.5	V
$HV_{TH}$	BUSIN reset threshold <sup>(3)</sup>	Rise	4.30	4.60	4.96	V
		Fall	4.30	4.60	4.90	V
$LV_{TH}$	REGOUT reset threshold <sup>(4)</sup>	Rise	2.65	2.85	3.05	V
		Fall	2.62	2.85	3.05	V
$DELTA_{def}$	Deflection (self-test - offset)	$T = 25^\circ C^{(4)}$	52	61	72	LSb
		$T_L \leq T_A \leq T_H$	52	61	154	LSb
N	Noise	Max deviation from mean	-4		+4	LSb
$T_{op}$	Operating temperature range		-40		+125	$^\circ C$

1. Over life and temperature.
2. Verified by characterization, not tested in production.
3. See [Figure 3](#).
4. Without aging or stressing.

Figure 3. Power-on-Reset (POR) operation<sup>(b)</sup>



b. Whenever BUSIN falls below  $HV_{TH}$  or VREG falls below  $LV_{TH}$ , the device will go into reset.



## 2.3 Control timing

Table 5. Control timing

Symbol	Parameter	Conditions <sup>(1)</sup>	Min	Typ	Max	Unit
$f_c$	Bessel filter cutoff frequency	-3 dB	157	175	193	Hz
Att	Signal attenuation	1 kHz		-26	-20	dB
		2 kHz		-38	-35	
$f_{osc}$	Internal oscillator frequency		11.63	12.25	12.9	MHz
$t_{ref}$	Refresh period		212	224	236	$\mu s$
$T_{bit}$	Bit duration	125 kbps	7.6	8	8.4	$\mu s$
DC	Duty cycle	$(t_{fall,80} - t_{rise,20})/T_{bit}$ $(t_{fall,20} - t_{rise,80})/T_{bit}$	47	50	53	%
$T_{delay}$	Signal processing time <sup>(2)(3)</sup>			1.31		ms
$T_{set}$	Settling time for quiescent current	$I = I_Q \pm 2 \text{ mA}$			5	ms
$T_{reset}$	Recovery time after high-g shock <sup>(3)</sup>				10	ms
$T_{TH}$	Undervoltage reset delay	Ramping BUSIN from 16 V to 0 V over 2 $\mu s$			200	$\mu s$
$T_{RJ}$	Microcut rejection time <sup>(3)</sup>	Ramping BUSIN from 16 V to 0 V over 2 $\mu s$	10			$\mu s$

1.  $C_{reg} = 1.0 \mu F \pm 40\%$ , ceramic,  $C_{auth} = 0.047 \mu F \pm 50\%$ , ceramic.

2. Bessel filter = 1.24 ms, [SAR A/D + C/V + Gain] = 0.07 ms.

3. Verified by characterization, not tested in production.

## 2.4 Sensor communication interface

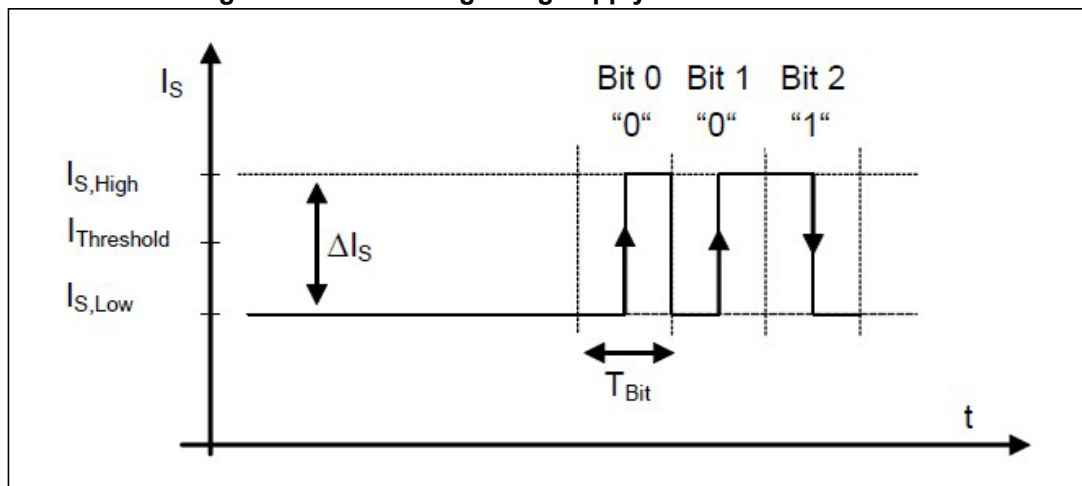
The AIS1200PS is a single-axis accelerometer with a PSI5 v.1.3 asynchronous communication interface (PSI5-A). PSI5-A describes a point-to-point connection for unidirectional, asynchronous data transmission. The sensor is connected to the ECU by two wires. After switching on the power supply, the sensor starts transmitting data to the ECU periodically. Timing and repetition rate of the data transmission are controlled by the sensor.

### 2.4.1 Physical layer

PSI5 uses two wires for both power supplies to the sensors and data transmission. The ECU provides a preregulated voltage to the sensor. Data transmission from the sensor to the ECU is done by current modulation on the power supply lines. Current oscillations are damped by the ECU.

Bit encoding is done by a "low" level ( $I_{S,Low}$ ) which is represented by the normal (quiescent) current consumption of the sensor(s); a "high" level ( $I_{S,High}$ ) which is generated by an increased current sink of the sensor ( $I_{S,Low} + \Delta I_S$ ). The current modulation is detected within the receiver ASIC.

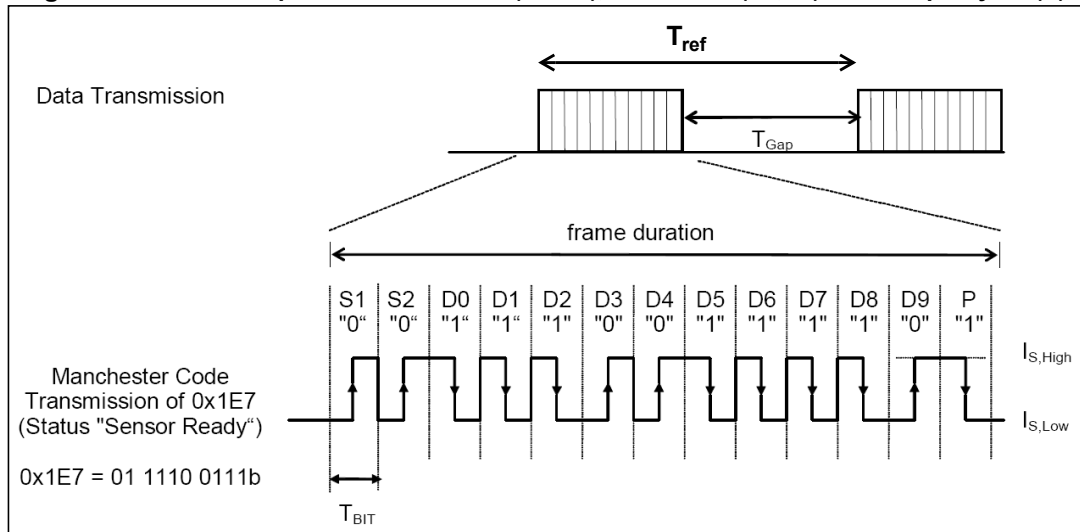
Figure 4. Bit encoding using supply current modulation



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  $T_{Bit}$  (125 kbps  $\geq 8 \mu s \pm 5\%$ ).

### 2.4.2 Data link layer

Each AIS1200 PSI5 data frame consists of 13 bits containing two start bits and one parity bit with even parity and 10 data bits. Data bits are transmitted LSB first. The data frames are sent periodically from the sensor to the ECU at intervals  $T_{ref}$  of 224  $\mu s$  (typ).

**Figure 5. Frame example with 10 data bits (D0-D9), 2 start bits (S1,S2) and one parity bit (P).**

Error detection by single bit even parity.

\* Frame duration = 104  $\mu$ s  $\pm$  5%

### 2.4.3 Data range

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.

The decimal values  $-480$  to  $+480$  are used for the sensor output signal. The range  $-512$  to  $-481$  is reserved for the block and data ID's which are used for transmitting initialization data during startup of the sensor (see [Section 2.5](#)). The range from  $+481$  to  $+511$  is used for status and error messages.

Table 6. Data mapping

Dec	Hex	Description	Range	
+511	0x1FF	Reserved for ECU internal use <sup>(1)</sup>	Status & errors messages	2
:	:	Reserved for ECU internal use <sup>(1)</sup>		
+504	0x1F8	"Memory Fail"		
+503	0x1F7	Reserved <sup>(2)</sup>		
+502	0x1F6	Reserved <sup>(2)</sup>		
+501	0x1F5	Reserved <sup>(2)</sup>		
+500	0x1F4	"Sensor defect"		
+499	0x1F3	Reserved for ECU internal use <sup>(1)</sup>		
:	:	Reserved for ECU internal use <sup>(1)</sup>		
+496	0x1F0	Reserved for ECU internal use <sup>(1)</sup>		
+495	0x1EF	Reserved <sup>(2)</sup>		
:	:	Reserved <sup>(2)</sup>		
+489	0x1E9	Reserved <sup>(2)</sup>		
+488	0x1E8	"Sensor busy"		
+487	0x1E7	"Sensor ready"		
+486	0x1E6	Reserved <sup>(2)</sup>		
+485	0x1E5	Reserved <sup>(2)</sup>		
+484	0x1E4	Reserved <sup>(2)</sup>		
+483	0x1E3	Reserved <sup>(2)</sup>		
+482	0x1E2	Reserved <sup>(2)</sup>		
+481	0x1E1	Reserved <sup>(2)</sup>		
+480	0x1E0	Maximum positive sensor signal	Sensor output signal	1
:	:	Intermediate positive sensor signal values		
0	0x000	Signal amplitude "0"		
:	:	Intermediate negative sensor signal values		
-480	0x220	Maximum 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		

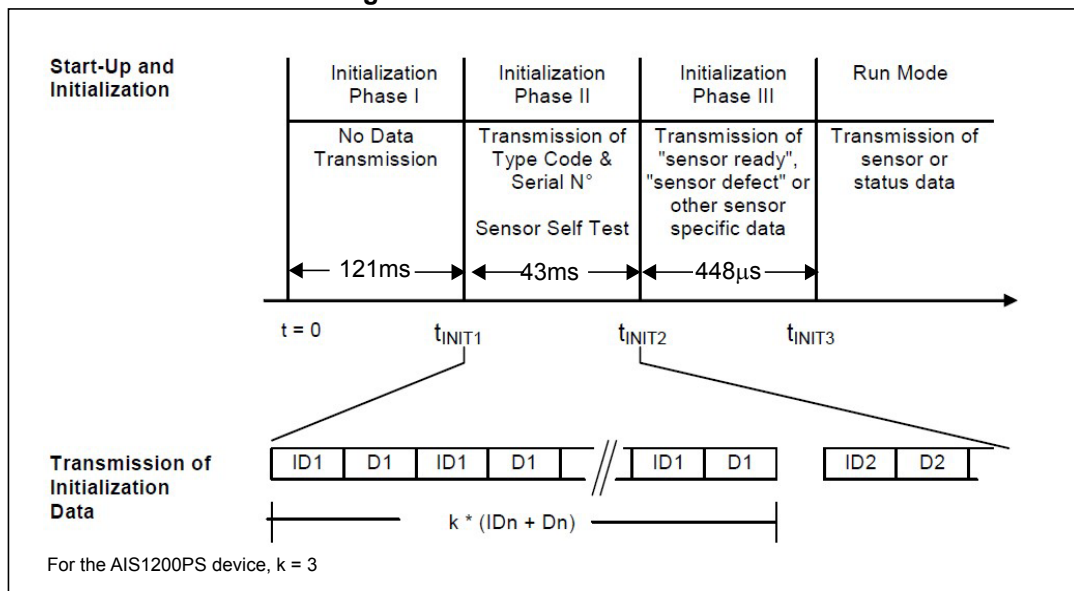
1. Usage for ECU internal purposes is possible (e.g. "No Data", "Manchester Error" etc.)

2. Not to be used.

## 2.4.4 Initialization

After each power-on or undervoltage reset, the sensor performs an internal initialization which is divided into three phases.

**Figure 6. Initialization of the sensor**



ID blocks and data blocks are sent in an alternating sequence, 3 times each. The block identifiers are used for numbering of the following data nibbles. After any power-on or undervoltage reset, the internal logic starts up with an initialization program.

During the first initialization phase, no data is transmitted and the ECU can perform a connectivity test.

During the second initialization phase, the sensor transmits sensor and application-specific information to the ECU. During the third initialization phase, the sensor transmits "Sensor Ready", "Sensor Defect" or other optional 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. The sensor status information must consist of data words out of data range 2 and 3. Usage of sensor output signal data words out of data range 1 is not allowed during initialization phases II and III.

If the initialization is finished successfully, the sensor goes into run mode and starts transmitting sensor signal data or optional status data until it is switched off or an internal error is detected.

In the AIS1200PS, phase 1 has a typical duration of 121 ms, and phase 2 of 43 ms. Phase 3 duration may vary, depending on the number of iterations needed to pass the self-test routine.

If the self-test fails, the self-test routine is repeated until it passes, up to 5 times. If the self-test does not pass after 5 attempts, it will transmit a message of sensor failure.

After phase 3 is passed successfully, the sensor goes into run mode and starts transmitting sensor signal data.

The actual duration of all phases depends on the oscillator period, which has a tolerance of  $\pm 5\%$  (see [Table 5](#)).

The following is the sequence of steps during the initialization phases, along with the approximate durations (all numbers are intended as typical values):

- **Step 1.** After POR, the Flash download begins and ends typically in 23 ms.
- **Step 2.** There is a waiting period of 16 ms after the Flash is downloaded.
- **Step 3.** The self-test starts at 39 ms and ends at 117 ms, provided it passes the first iteration.
- **Step 4.** If the self-test fails the first iteration, then second self-test will begin.
- **Step 5.** Each additional self-test operation requires 75 ms.
- **Step 6.** If the 5<sup>th</sup> iteration of self-test fails, then the PSI5 protocol will transmit a “**sensor defect**” code during phase 3.

The PSI5 transmission sequence is accordingly the following:

- **P1.** Phase 1 ends at 121 ms (it varies with the oscillator frequency tolerance, as indicated previously).
- **P2.** Phase 2 starts after phase 1 and ends at 164 ms.
- **P3.** Phase 3 starts after phase 2 and transmits the “**sensor ready**” code twice (i.e. 448  $\mu$ s), then the ADC transmission begins. The start of the ADC transmission, however, is gated by step 4 above. If the self-test goes to the 2<sup>nd</sup> iteration and beyond, then the PSI5 will transmit the “**sensor busy**” code during phase 3 until either the self-test passes, at which point the “sensor ready” code will be transmitted once followed by the ADC data, or the self-test fails, in which case phase 3 will transmit the “**sensor defect**” code.

The memory test is done during the Flash download phase (0 ms-23 ms). If the memory CRC error/parity error occurs during this phase, then a “**memory fail**” code will be transmitted during phase 3.

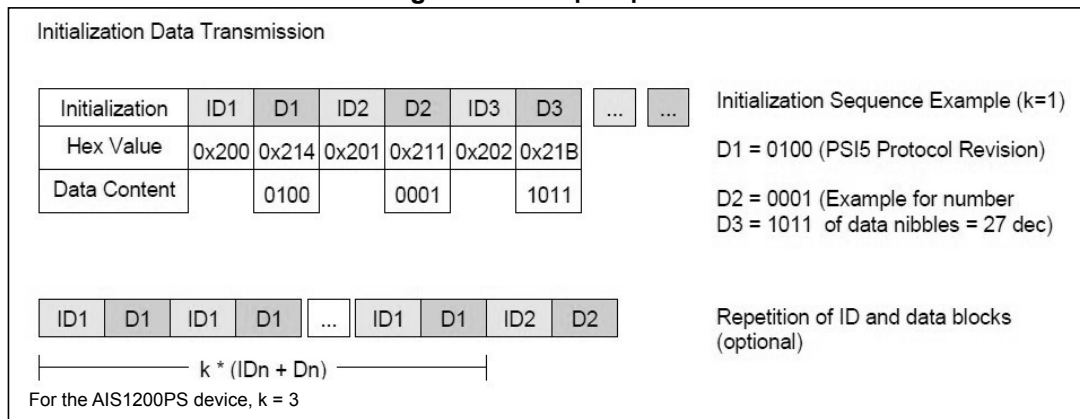
The PSI5 codes transmitted during these phases are:

- Sensor ready: 0x1E7
- Sensor busy: 0x1E8
- Sensor defect: 0x1F4
- Memory fail: 0x1F8

**Figure 7. Block ID and data nibbles**

Block Identifier and Data Nibbles									
Block ID 1-16 (0x200 – 0x20F)	D9	D8	D7	D6	D5	D4	D3	D2	D1 D0
	1	0	0	0	0	0	0000 - 1111		
Data Nibbles "0000" – "1111" (0x210 – 0x21F)	D9	D8	D7	D6	D5	D4	D3	D2	D1 D0
	1	0	0	0	0	1	0000 - 1111		

Figure 8. Startup sequence



A special data format and a reserved data range are used during initialization in order to avoid a possible mix-up with sensor signal data. "Data Range 3" contains 16 block identifiers and 4-bit data nibbles (see [Section 2.4.3](#)).

If the initialization data exceeds  $4 \times 16 = 64$  bits (more than 36-bits of sensor specific information), data can be paged. The ID codes are reused for every 64-bit page of data to be transmitted. Data pages are not numbered. Mapping of the information contained in different data pages has to be derived from the chronology of the startup sequence. It is not mandatory to transmit complete data pages.

The initialization data is based on a 10-bit data word length (see [Section 2.4.3](#)).

The initialization data contains the following information:

- PSI protocol revision
- Total number of data blocks (nibbles) transmitted during initialization
- Manufacturer code
- Sensor type
- Sensor and application specific information

Table 7. Data content in initialization phase II

Field	Name	Parameter	Value
F1 (D1)	Protocol description	PSI5 v1.3	0100
F2 (D2, D3)	Number of data blocks	32 nibbles	0010 0000
F3 (D4, D5)	Sensor manufacturer code	STMicroelectronics	1001 0011
F4 (D6, D7)	Sensor type	High-g accelerometer	0000 0001
F5 (D8, D9)	Sensor parameter	Sensitivity: 2 LSb/g	0000 1001
F6 (D10-D11)	Sensor code (sensor)		Customer defined
F7 (D12-D14)	Sensor code (vehicle)		Customer defined
F8 (D15-D18)	Production date		(1)
F9 (D19-D32)	Serial information		(2)

1. This field contains the back-end assembly date. It contains 16 bits of data and is encoded as Year-Month-Day. The year code is a two-digit code. In terms of bits, the sequence is YYYY YYMM MMMD DDDD.
2. This field contains a specific product serial number. It originates from both the back-end lot number and the ASIC wafer number and die location on the wafer. Each part contains a unique number.

In normal operation mode, the sensor transmits sensor output data in data range 1. A special “diagnostic mode” is foreseen for testing and failure analysis. In the diagnostic mode, the sensor may send other than the specified sensor output data in data range 1. The condition for entering the diagnostic mode is the recognition of a valid “XLong” data frame during initialization phase II. The sensor indicates the diagnostic mode by sending the “Sensor in diagnostic mode” identifier during initialization phase III, see [Section 2.4.3](#).

## 2.5 Absolute maximum ratings

Stresses above those listed as absolute maximum ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device under these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

**Table 8. Absolute maximum ratings**

Symbol	Parameter	Value	Unit
$V_{BUS}$	Supply voltage <sup>(1)</sup>	-0.3 to 16	V
$I_{MAX}$	BUSIN input current	1.7	A
$A_{MAX}$	Max acceleration before mechanical stops	±3500 to ±4000	g
$A_{UNP}$	Mechanical shock with device unpowered	2000	g
$h_{DROP}$	Drop shock survivability	1.2	m
ESD	ESD protection HBM (low-voltage pins)	2	kV
	ESD protection HBM (high-voltage pins)	4	kV
	CDM (corner pins)	750	V
	CDM (inside pins)	500	V
	MM	100	V
$T_{STG}$	Storage temperature range	-40 to 125	°C
$T_j$	Junction temperature range	-40 to 150	°C

1. Voltage referred to RTN.



This device is sensitive to mechanical shock, improper handling can cause permanent damage to the part



This device is sensitive to electrostatic discharge (ESD), improper handling can cause permanent damage to the part

## 2.6 Factory calibration

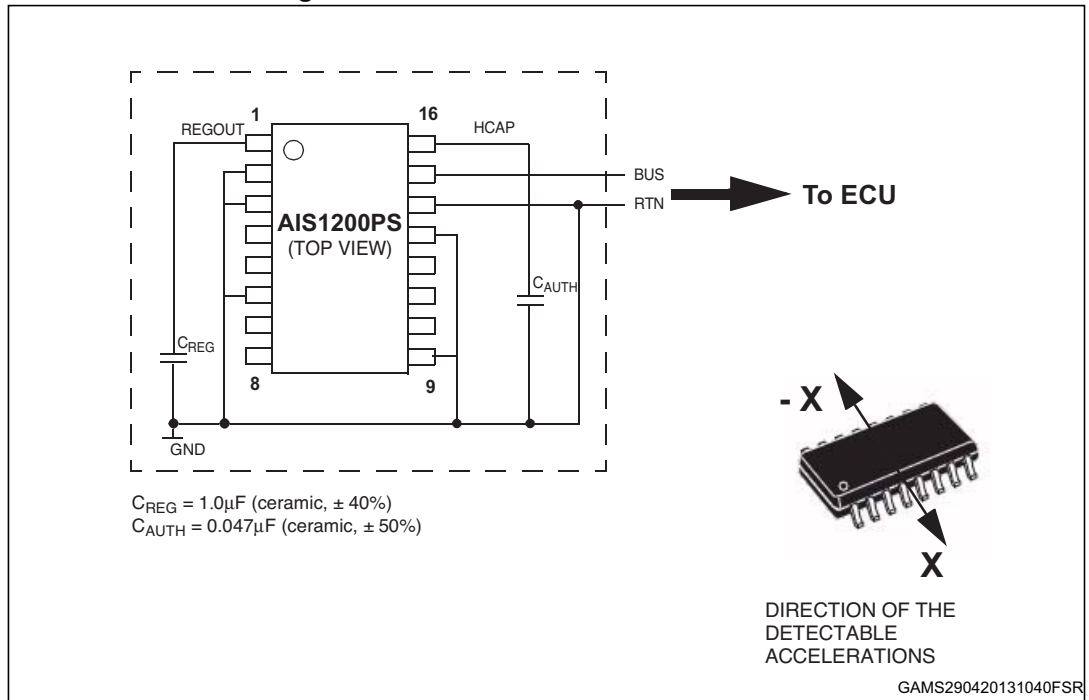
The IC interface is factory calibrated for sensitivity ( $S_o$ ) and Zero-g level (Off).

The trimming values are stored inside the device in a non-volatile structure. Any time the device is turned on, the trimming parameters are downloaded into the registers to be employed during normal operation. This allows the user to employ the device without further calibration.



### 3 Application hints

Figure 9. AIS1200PS electrical connections



Note: Both  $C_{REG}$  and  $C_{AUTH}$  are mandatory for correct usage of the device.

## 4 Package information

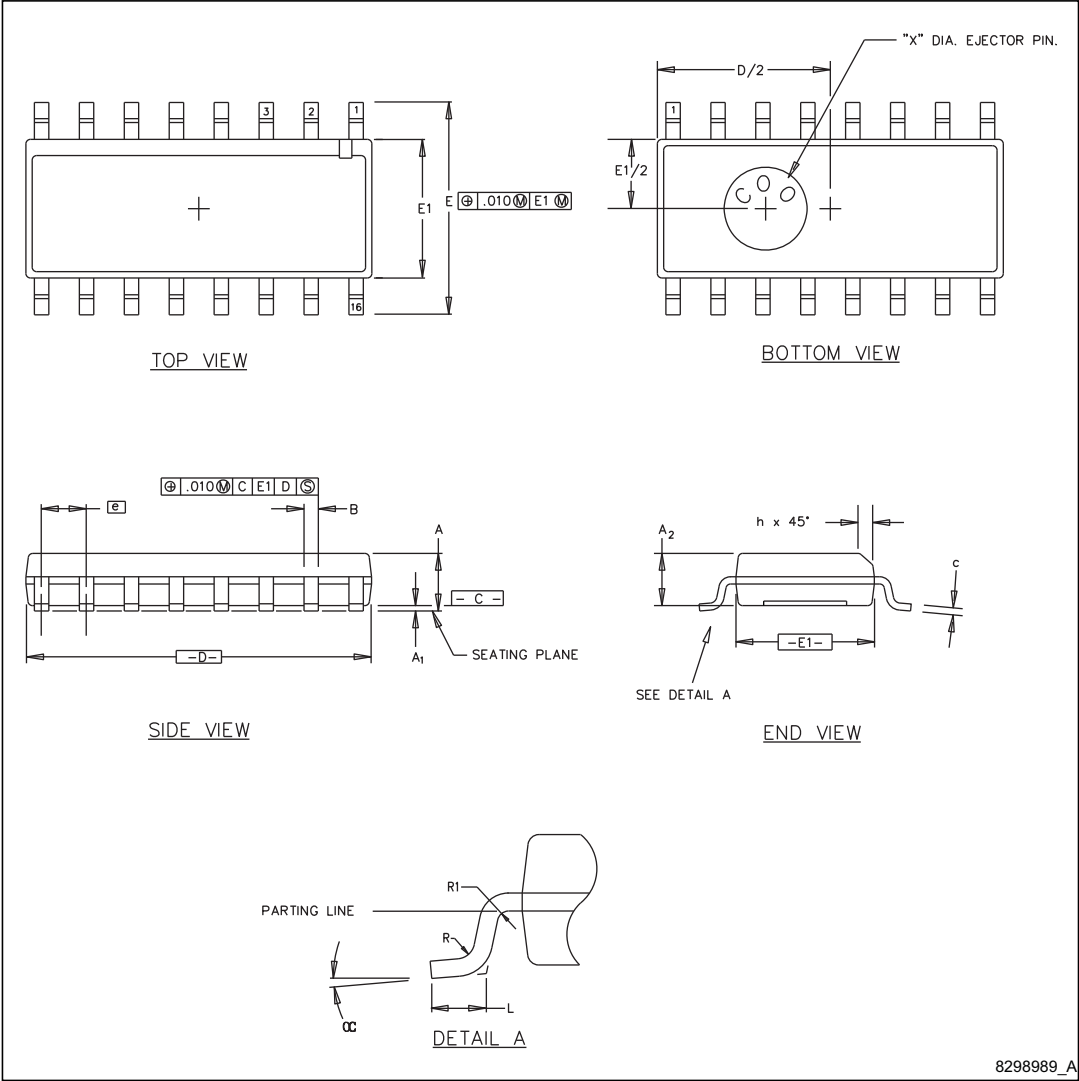
In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK is an ST trademark.

### 4.1 SOIC 16N package information

Table 9. SOIC 16N package mechanical data

Dim.	mm.		
	Min.	Typ.	Max.
A	1.55	1.63	1.73
A1	0.127	0.15	0.25
A2	1.40	1.47	1.55
B	0.35	0.41	0.49
c	0.19	0.20	0.25
D	9.80	9.93	9.98
E1	3.81	3.94	3.99
e	1.27 bsc		
E	5.84	5.99	6.20
h	0.25	0.33	0.41
L	0.41	0.64	0.89
α	0°	5°	8°
X	2.16	2.36	2.54

Figure 10. SOIC 16N package outline



8298989\_A

## 5 Revision history

**Table 10. Document revision history**

Date	Revision	Changes
16-May-2013	1	First issue.
22-May-2013	2	Document status promoted from preliminary to production data.
04-Mar-2014	3	Updated <a href="#">Table 1: Device summary</a> ; minor textual updates.
14-Dec-2015	4	Updated $T_j$ in <a href="#">Table 8: Absolute maximum ratings</a> .

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