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AXO315 Datasheet

Features

- ±14 g range in-plane linear single axis accelerometer
- Hermetic SMD ceramic package for reliable assembly on FR4
- Fully hard-coded electronic, no embedded software
- Built-in temperature compensation and self-test
- Complementarity with GYPRO® high performance gyros which share the same digital interface
- Best in-class 1 year composite bias repeatability of 1mg under -55°C to 105°C and > 4g$_{rms}$ environment
- Unmatched vibration rejection of 20µg/g²
- Excellent 1 year composite scale factor repeatability of 600ppm over temperature
- Very low noise of 15µg/√Hz, non-linearity of 100ppm
- Non classified under dual-use export control

General Description

AXO®315 **high performance**, closed-loop, MEMS accelerometer offers a precision-equivalent alternative to incumbent analog force-rebalance quartz and mechanical accelerometers at a fraction of their size weight and cost. Its hermetic full SMD package combined with its digital 24 bits SPI interface eases its integration and reduces the e-BOM.

With a **1 year composite bias repeatability** of **1mg** under demanding temperature and vibrations conditions, the AXO®315 overpasses all commercially available MEMS accelerometers. AXO®315 is **free from dual-use export control**, according to Annex 1 of Council Regulation (EC) No 428/2009, as well as **REACH** and **RoHS compliant.**

AXO® is ideally complemented by GYPRO® high performance digital gyrometers.

AXO®315 is a very low noise sensor which provides an excellent linearity and 600 ppm 1 year composite scale factor repeatability over -55°C to +105°C extended temperature range.

Our AXO® & GYPRO® products families are well suited to precision attitude, guidance and motion control and GNSS-aided positioning applications in demanding industrial, land, railway and naval environments.

All AXO® & GYPRO® products sensors are factory calibrated and compensated for temperature effects to provide high-accuracy digital output over a broad temperature range. Raw data output can be also chosen to enable customer-made compensations.

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Disclaimer

Block diagram

Overall dimensions

Internal ref. : MCD018-F

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1. Specifications

Parameter	Unit	Typ.	Max[2]	Notes
Measurement Ranges				
Full Scale range	g		±14	Electronic clamping is applied and sensors will saturate before ±15g
Temperature range	°C	-55 to +105		
Bias				
1 Year Composite bias repeatability	mg	1		Total bias drift per year, quadratic sum of all bias errors
Bias instability	µg	4	15	Lowest point of Allan variance curve at room temperature
Bias in-run (short term) stability	µg	15	45	Standard deviation of the 1 second filtered output over 1 hour at room temperature, after 30 min of stabilization
Residual bias temperature error, calibrated [1][3][5]	mg	±0.5	±1.5	Maximum variation of the bias over the specified temperature range
Bias repeatability	µg	±220		See note [4]
Bias long term stability	mg	0.4		Drift per year, based on Allan variance extrapolation
Warm-up bias drift	µg	50		Bias drift during initial sensor self-heating after power on at 0g
Vibration rectification error	µg/g²	20		Bias rectification under operating vibrations; root mean square of all axis
Scale Factor				
Scale factor [1]	LSB/g		500 000	Nominal scale factor
1 Year Composite scale factor repeatability	ppm	600		Total scale factor drift per year, quadratic sum of all scale factor errors
Residual scale factor temperature error, calibrated [1][3]	ppm	±400	±1000	Maximum variation of the scale factor over the specified temperature range
Scale factor repeatability	ppm	±280		See note [4]
Scale factor long term stability	ppm	350		Drift per year, based on Allan variance extrapolation
Linearity, Noise				
Non linearity [1]	ppm	100	350	Maximum deviation of the output from the expected value using a best fit straight line over the [0g ; 8g] range, at room temperature
Noise density [1]	µg/√Hz	15	20	Over the [0 - 300] Hz frequency range, at room temperature
Velocity Random Walk	m/s/√h	0.006		-1/2 slope tangent, based on Allan Variance at 1s
Frequency response				
Bandwidth	Hz	>300		Defined as the frequency for which attenuation is equal to -3dB
Data Rate	Hz	2500		Refresh rate of the output data at room temperature
Latency	ms	1		Time delay between the physical acceleration (input) and the output signal
Start-up Time	ms	400		Time interval between the application of power and the presence of a usable output, i.e. at least 90% of the input, at room temperature

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Parameter	Unit	Typ.	Max[2]	Notes
Axis alignment				
Axis misalignment	mrad		20	By design
Environmental				
Storage temperature range	°C	-55 to +125		
Component shelf life	Years	5		
Humidity at 45°C	%	<98		
Moisture Sensitivity Level (MSL)	--	1		Unlimited (hermetic package)
Shock (operating)	g | ms	50 | 6		Half sine
Shock (survival)	g | ms	2000 | 0.3		
Vibrations (operating)	g_{rms}	4.12		DO-160G standard , curve C
Vibrations (survival)	g_{rms}	20		Random acceleration, applied on any axis within 20Hz to 2kHz during 10min
Electrical				
Power Supply Voltage	V	4.75 to 5.25		
Current consumption (normal mode) [1]	mA		<30	Tested at room temperature
Current consumption (power down mode)	µA		<5	Power down mode is activated by switching EN pin to GND, at room temperature
Power supply rejection ratio	µg/V	130		
Temperature sensor				
Scale Factor (raw data)	LSB/°C	85		Temperature sensor is not factory-calibrated
25°C typical output (raw data)	LSB	8 000		Temperature sensor is not factory-calibrated
Refresh rate	Hz	6		
Reliability				
MTBF	h	>1 000 000		Predictive elapsed time between inherent failures of the sensor during normal system operation at 50°C

Table 1: Specifications

[1] 100% tested in production.

[2] Unless otherwise specified, max values are ±3 sigma variation limits from validation test population.

[3] Temperature range of -53°C to +105°C.

[4] Bias and scale factor repeatabilities include the following parameters:
- Turn On to Turn Off repeatability at constant temperature and constant accelerations,
- Repeatability over temperature, at constant acceleration,
- Repeatability over acceleration, at constant temperature,
- Day to day repeatability, over ten days.

[5] Due to the sigma delta architecture, there is a dead band of 200µg around zero input level.

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2. Maximum Ratings

Stresses at or exceeding the maximum ratings listed below may cause permanent damage to the device, or affect its reliability. Exposure to maximum ratings conditions for extended periods may also affect device reliability.

Functional operation is not guaranteed once stresses exceeding the maximum ratings have been applied.

Parameter	Unit	Min	Max
Supply Voltage	V	-0.5	+7
Electrostatic Discharge (ESD) protection, any pin, Human Body Model	kV	--	±2
Storage temperature range	°C	-55	+125
Shock survival, half sine	g	--	2000
Vibrations survival, 20-2000Hz	g_{rms}	--	20
Ultrasonic cleaning	Not allowed		

Table 2: Maximum ratings

Caution!

The product may be damaged by ESD, which can cause performance degradation or device failure! We recommend handling the device only on a static safe work station. Precaution for the storage should also be taken.

The sensor MUST be powered-on *before* any SPI operation, as shown in Figure 1 below. Having the SPI pads, VDDIO or EN at a high level while VDD is at a low level could damage the sensor, due to ESD protection diodes and buffers.
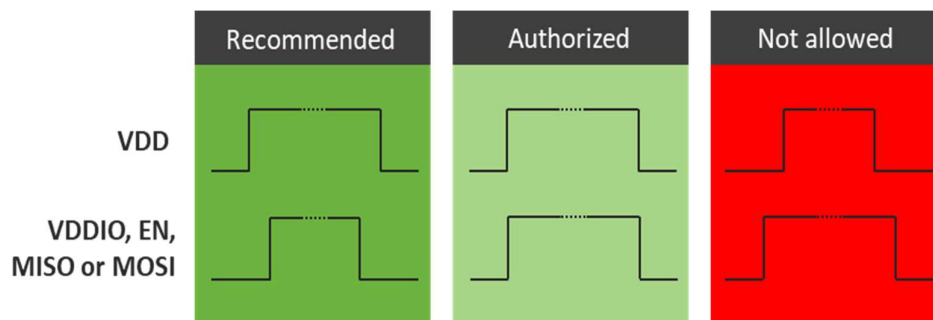

Figure 1: Recommended voltage sequence.
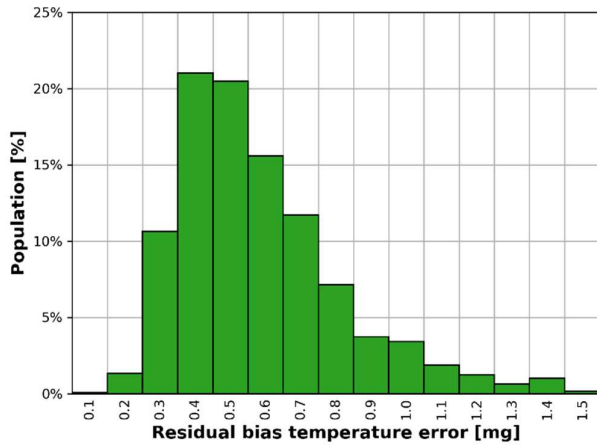
3. Typical performances

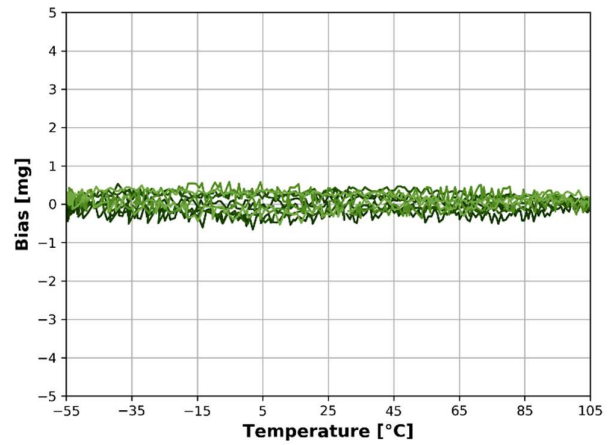Figure 2: Residual bias temperature error distribution, absolute value

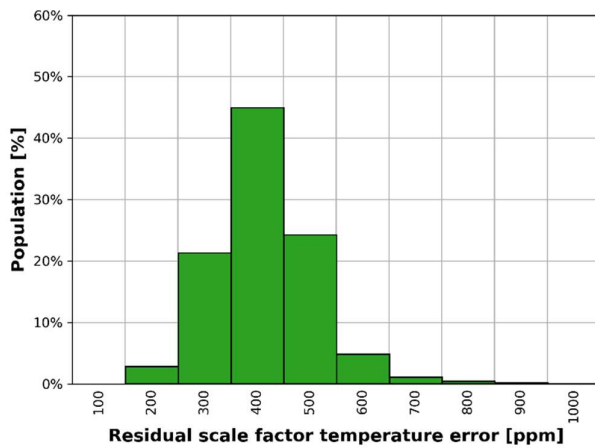Figure 5: Residual bias temperature error (5 samples)

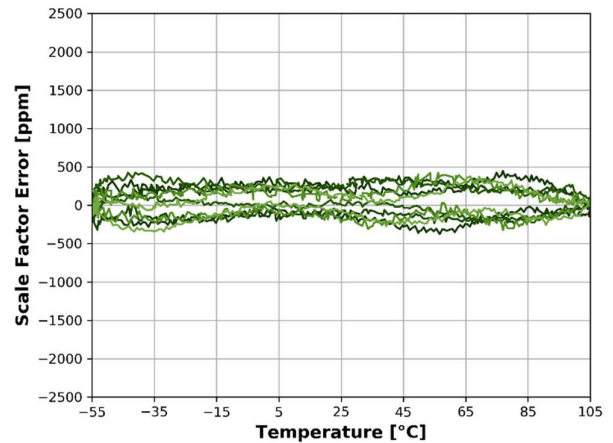Figure 3: Residual scale factor temperature error distribution, absolute value

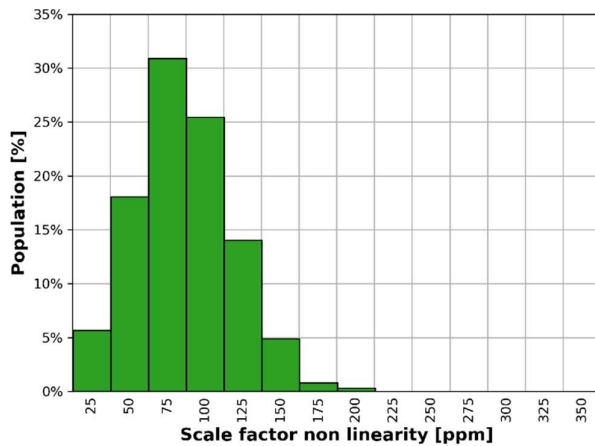Figure 6: Residual scale factor temperature error (5 samples)

Figure 4: Scale Factor non linearity distribution (room temperature)
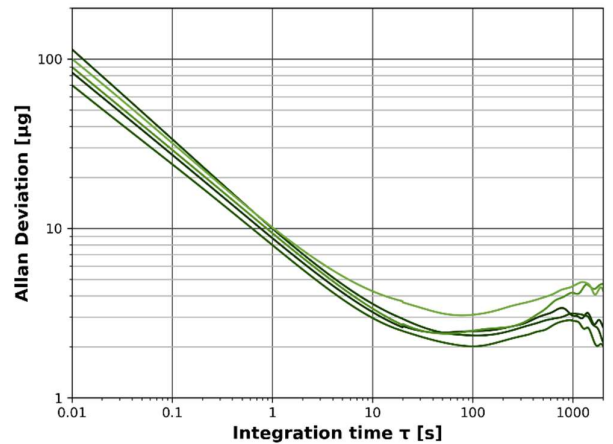
Figure 7: Allan variance (5 samples at 35°C)

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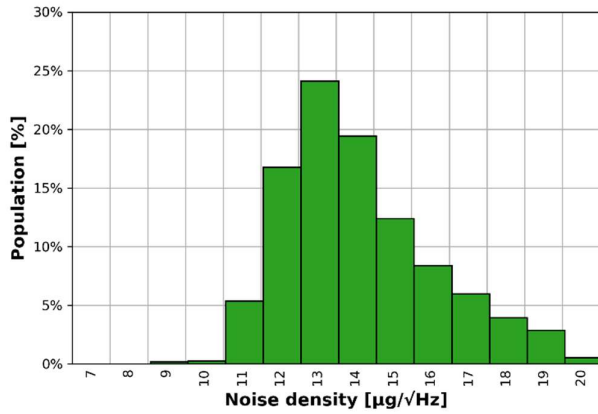
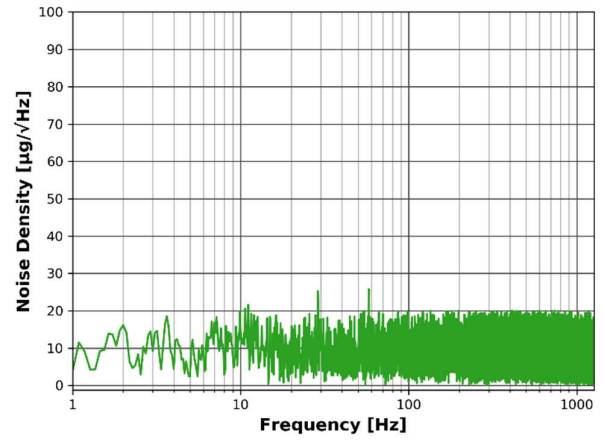**Figure 8: Noise density distribution (room temperature)**

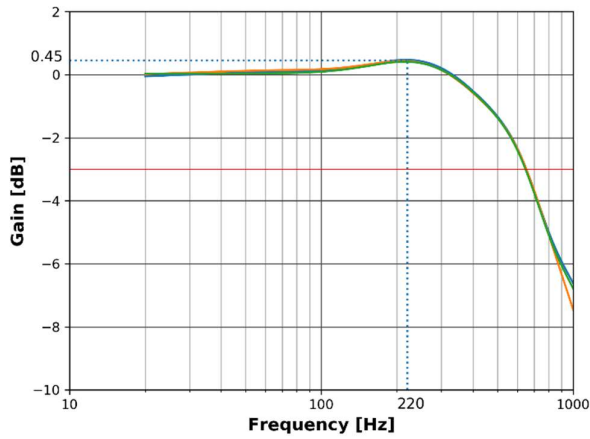**Figure 11: Noise density (room temperature)**

Figure 9: Frequency response (3 samples at room temperature)
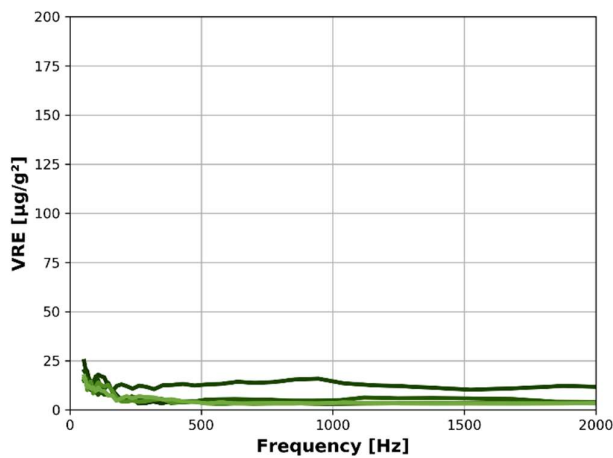
Figure 10: Vibration rectification error (5 samples, frequency sweep [50-2000Hz], root mean square of all axis)

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4. Interface

4.1. Pinout, Sensitive Axis identification
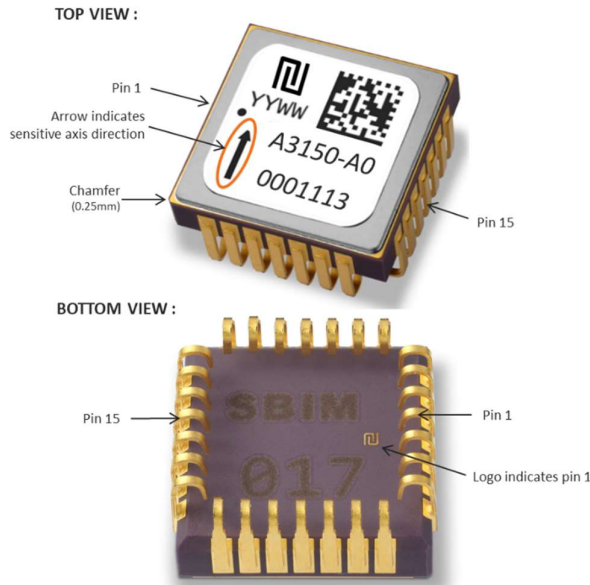
Figure 12: How to locate Pin 1 and Sensitive Axis
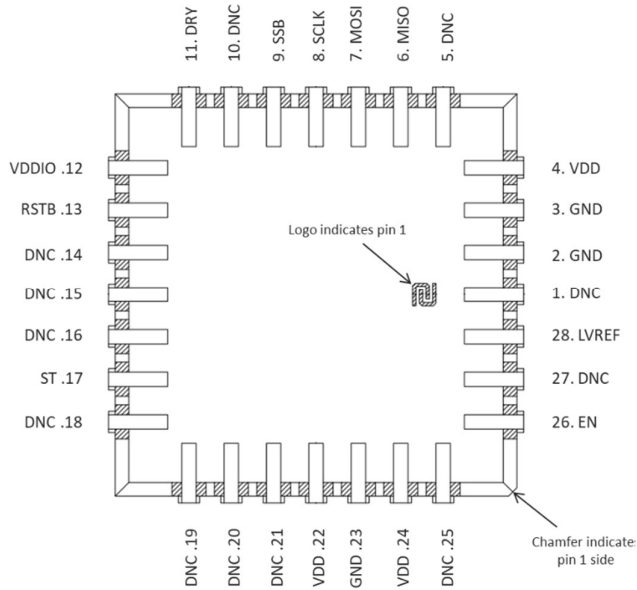
Figure 13: AXO315 Sensors Pinout (BOTTOM VIEW)

4.2. Application circuit
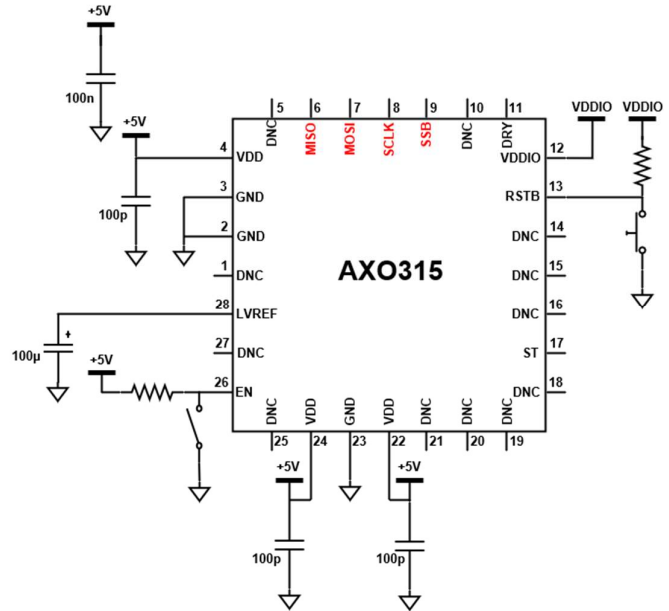
Figure 14: Recommended Application Schematic

Notes:

- All capacitances of Figure 14 should be placed as close as possible to their corresponding pins, except the 100nF capacitance between VDD and GND, which should be as close as possible to the board's supply input.

- The 100µF filtering capacitance between LVREF and GND should have low Equivalent Series Resistance (ESR < 1Ω) and low leakage current (< 6µA).

Figure 15: Recommended Pad Layout (dimensions in mm)

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4.3. Input/Output Pin Definitions

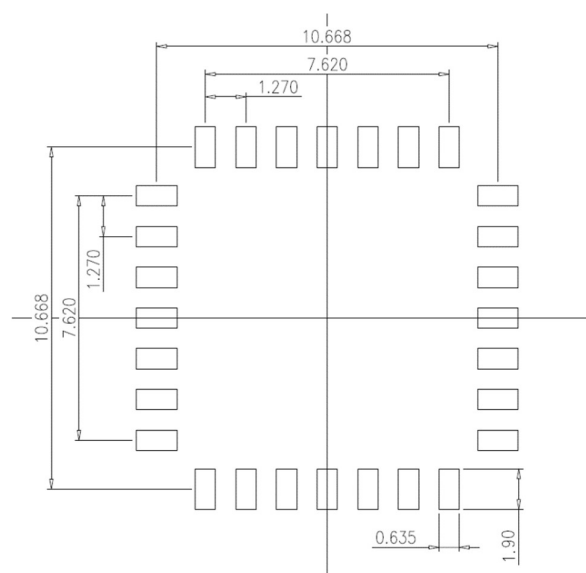| Pin name	Pin number	Pin type	Pin direction	Pin levels	Function
GND	2, 3, 23	Supply	n/a	0V	Power Ground.
VDD	4, 22, 24	Supply	n/a	+5V	Power Supply.
MISO	6	Digital	Output	VDDIO	Master Input Slave Output signal.
MOSI	7	Digital	Input	VDDIO	Master Output Slave Input signal.
SCLK	8	Digital	Input	VDDIO	SPI clock signal.
SSB	9	Digital	Input	VDDIO	Slave Selection signal. Active low.
DRY	11	Digital	Output	VDDIO	Data Ready flag. Generates a pulse when a new acceleration data is available.
VDDIO	12	Supply	n/a	+1.8V to +5V	Reference voltage for the SPI signals and DRY, RSTB wires.
RSTB	13	Digital	Input	VDDIO with pull-up of 100kΩ	Reset. Reloads the internal calibration data.
ST	17	Digital	Output	+5V	Self-test status high when the sensor is properly operating. See 6.3.3 for details.
EN	26	Digital	Input	+5V	Enable command. Active high.
LVREF	28	Analog	n/a	4.4V	External decoupling pad. MUST be connected to the board's VSS through a 100µF external capacitor, in order to ensure low noise.
DNC	1, 5, 10, 14, 15, 16, 18, 19, 20, 21, 25 & 27	--	--	--	Do Not electrically Connect. These pins provide additional mechanical fixing to the Host System and should be soldered to an unconnected pad.

Table 3: Pin Functions

Note: The digital pads maximum ratings are GND-0.3V and VDD+0.3V.

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5. Soldering Recommendations

Please note that the reflow profile to be used does not depend only on the sensor. The whole populated board characteristics shall be taken into account.

IMPORTANT NOTES: The package leads are gold-plated. To obtain a reliable soldering, it is recommended to eliminate the excess gold by performing a pre-tinning step.

If you are using flux cleaner after soldering, please avoid spreading the sticker, so that it stays readable.
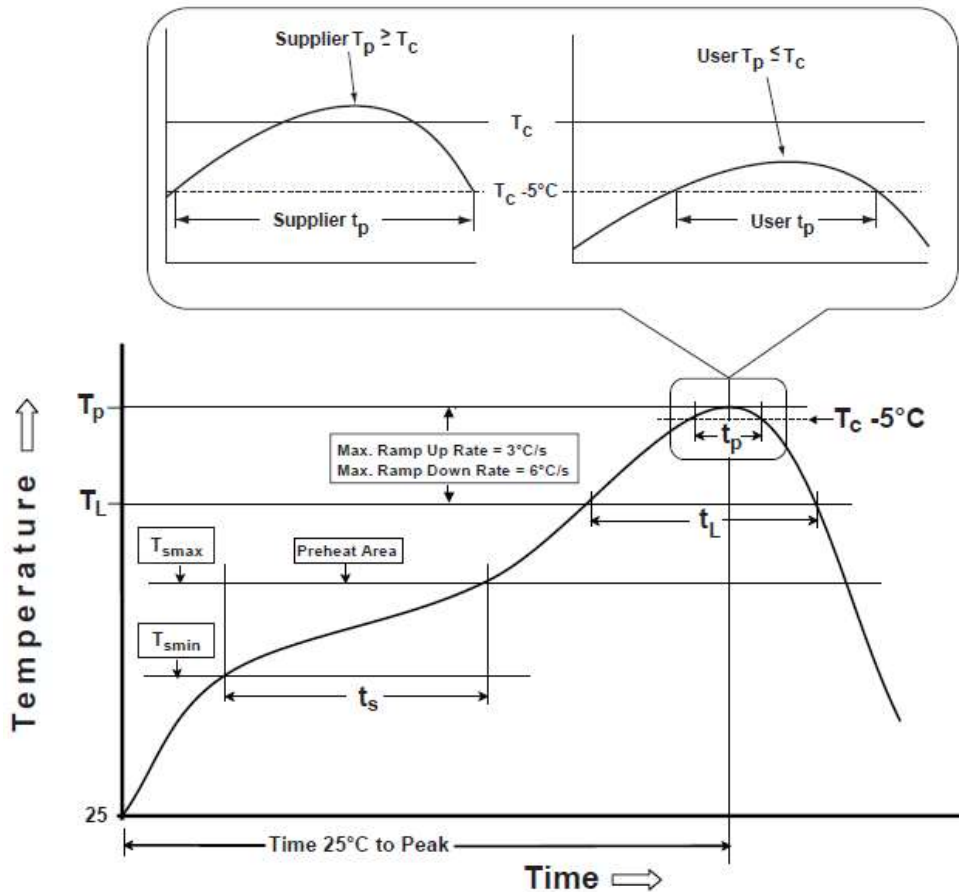
Figure 16: Reflow Profile, according to IPC/JEDEC J-STD-020D.1

Profile Feature	Sn-Pb Eutectic Assembly
Time maintained above	
Temperature (T_L)	183°C
Time (t_L)	60-150 sec
Peak Temperature (T_p)	240°C (+/-5°C)
Time within 5°C of Actual Peak Temperature (t_p)	10-30 sec

Table 4: Reflow Profile Details, according to IPC/JEDEC J-STD-020D.1

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6. Digital SPI interface

6.1. Electrical and Timing Characteristics

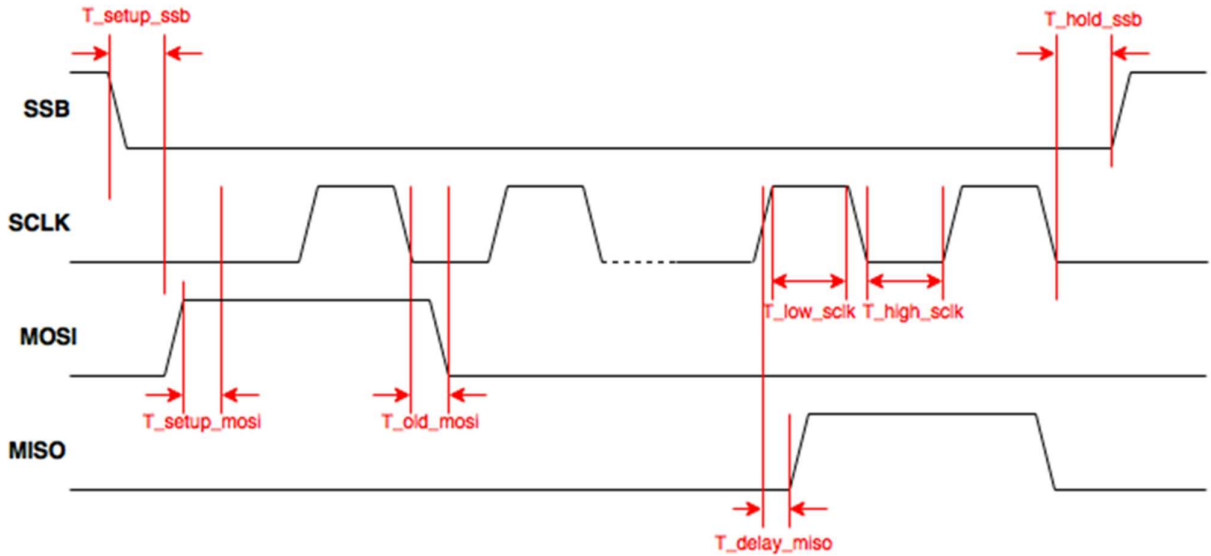The device acts as a slave supporting only SPI "mode 0" (clock polarity CPOL=0, clock phase CPHA=0).

Figure 17: SPI timing diagram

Symbol	Parameter	Condition	Unit	Min	Typ	Max
Electrical characteristics						
VIL	Low level input voltage		VDDIO	0		0.1
VIH	High level input voltage		VDDIO	0.8		1
VOL	Low level output voltage	ioL=0mA (Capacitive Load)	V		GND	
VOH	High level output voltage	ioH=0mA (Capacitive Load)	V		VDDIO	
Rpull_up	Pull-up resistor	Internal pull-up resistance to VDD	kΩ		100	
Rpull_down	Pull-down resistor	Internal pull-down resistance to GND	kΩ		-	
Timing parameters						
Fspi	SPI clock input frequency	Maximal load 25pF on MOSI or MISO	MHz		0.2	8
T_low_sclk	SCLK low pulse		ns	62.5		
T_high_sclk	SCLK high pulse		ns	62.5		
T_setup_mosi	MOSI setup time		ns	10		
T_hold_mosi	MOSI hold time		ns	5		
T_delay_miso	MISO output delay	Load 25pF	ns			40
T_setup_ssb	SSB setup time		Tsclk	1		
T_hold_ssb	SSB hold time		Tsclk	1		

Table 5: SPI timing parameters

The MISO pin is kept in high impedance when the SSB level is high, which allows sharing the SPI bus with other components.

IMPORTANT NOTE: It is forbidden to keep SPI pads at a high level while VDD is at 0V due to ESD protection diodes and buffers.

6.2. SPI frames description

The SPI frames used for the communication through the SPI Register are composed of an instruction followed by arguments. The SPI instruction is composed of 1 byte, and the arguments are composed of 2, 4 or 8 bytes, depending on the cases, as can be seen in Table 6 below.
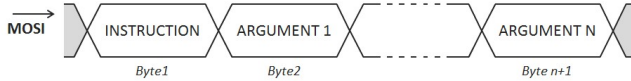

Figure 18: SPI Message Structure

Instruction	Argument	Meaning
0x50	0x00000000 (n=4)	Read Acceleration
0x54	0x0000 (n=2)	Read Temperature
0x58	0x00000000 (n=4)	Advanced commands. See Section 6.5 for more details.
0x78	0xXXXXXXXX (n=8)	
0x7C	0xXXXX (n=2)	

Table 6: Authorized SPI commands

6.3. Acceleration readings

From the 32-bits (4 bytes) frame obtained after the "Read acceleration" command, the 24-bits word of acceleration data (ACC) must be extracted as shown below in Figure 19.

DRY and ST are respectively the "data ready" and "self-test" bits, also directly available on Pins 11 and 17 of the sensor.
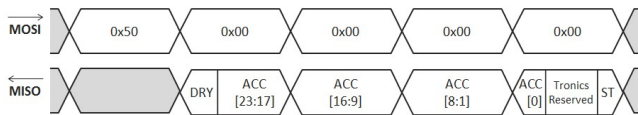

Figure 19: Acceleration reading frames and data organization

6.3.1. Acceleration (ACC) output

The 24-bit accelerometer output is coded in two's complement (Table 7).

- If the temperature compensation is not enabled (A_COMP_ON=0), then the user should perform scale factor measurements.
- If the temperature compensation of the acceleration output is enabled (default case), dividing the 24-bit value by a factor **500 000** results in the acceleration in g, as shown in Table 7.

-14.0000	g	⇔	1001 0101 0011 0000 0011 1111
			..
-0.000004	g	⇔	1111 1111 1111 1111 1111 1110
-0.000002	g	⇔	1111 1111 1111 1111 1111 1111
0.000000	g	⇔	0000 0000 0000 0000 0000 0000
+0.000002	g	⇔	0000 0000 0000 0000 0000 0001
+0.000004	g	⇔	0000 0000 0000 0000 0000 0010
			..
+14.0000	g	⇔	0110 1010 1100 1111 1100 0000

Table 7: Conversion table for calibrated acceleration output

6.3.2. Data Ready (DRY) bit

The Data Ready bit is a flag which is raised when a new acceleration data is available. The flag stays raised until the data is read.

Similarly to the Data Ready pin, the Data Ready bit signal can be used as an interrupt signal to optimize the delays between newly available data and their readings.

6.3.3. Self-Test (ST) bit

AXO®315 provides an initial self-test done during the sensor start-up to check the ASIC digital blocks integrity.

The ST bit contains the same information as the ST pin. It is updated at the sensor data rate. The ST pin can be connected to an interrupt input.

An additional continuous self-test feature is available under request.

6.4. Temperature readings

The temperature data is an unsigned integer, 14-bits word (TEMP). It must be extracted from the 2 bytes of read data, as shown below in Figure 20.
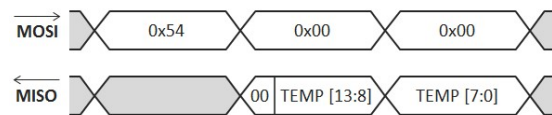

Figure 20: Temperature reading frames and data organization

By default the temperature sensor is *not* factory-calibrated (TOUT_SEL=0).

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6.5. Advanced use of SPI registers

SPI registers can also be used to access the System register or the MTP (Multi-Time-Programmable memory).

6.5.1. R/W access to the System Registers

IMPORTANT NOTE: Modifications to the system registers are **reversible**. Modified registers will *not* be restored after a RESET. There is no limitation to the number of times the system registers can be modified.
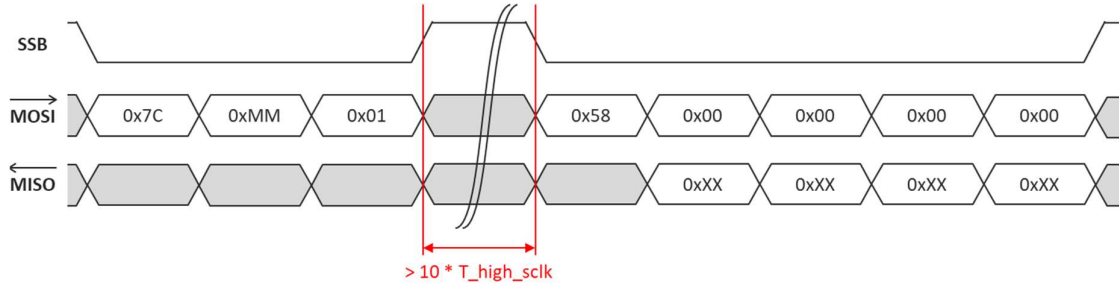

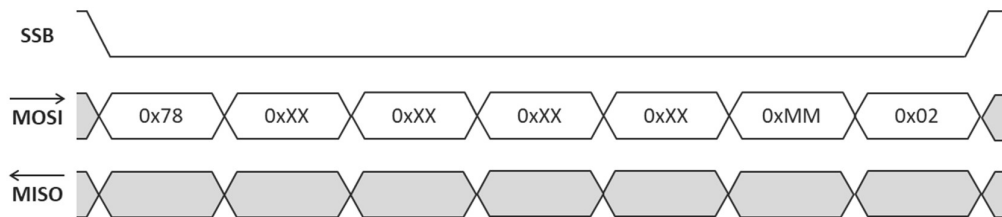**Figure 21: Sequence of instructions to READ address MM of the system registers**

Figure 22: Sequence of instructions to WRITE '0xXXXXXXXX' to address '0xMM' of the system registers

6.5.2. R/W access to the MTP

IMPORTANT NOTE: Modifications to the MTP are **non-reversible**. Modified parameters will be restored, even after a RESET, and previous values of the MTP cannot be accessed anymore. The maximum number of times the MTP can be written depends on the address:
- 5 times for the acceleration calibration coefficients (not described in this document; please contact Tronics if you need more information about this topic)
- Only 1 time for all the other coefficients, including the temperature sensor calibration coefficients.
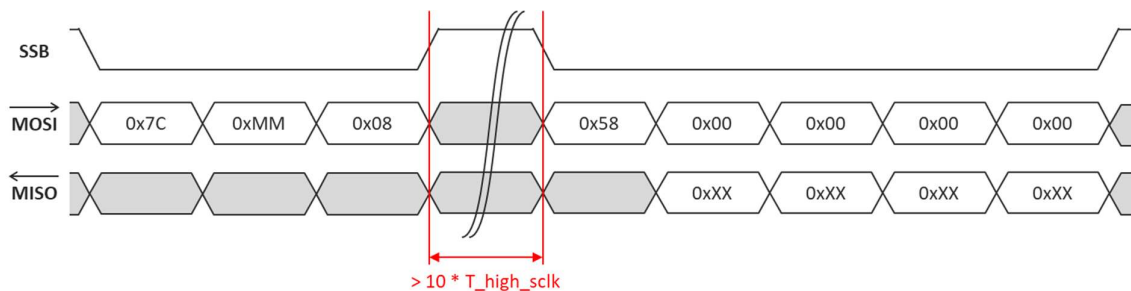

Figure 23 : Sequence of instructions to READ address 0xMM of the MTP

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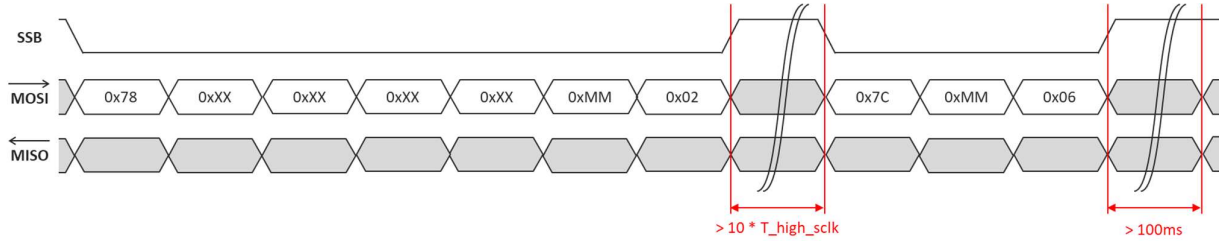**www.tronicsgroup.com**

Figure 24: Sequence of instructions to WRITE data '0xXXXXXXXX' to address '0xMM' of the MTP

6.5.3. Useful Sensor Parameters

The instructions given in Sections 6.5.1 and 6.5.2 can be used to read and/or to modify the sensor's useful parameters given in Table 8 below.

Parameter	Address M (System Register & MTP)	Bits	Encoding	Meaning
Sensor Identification				
UID	0x03	[31:1]	Decimal	Sensor 'Unique Identification' number
Temperature output compensation				
TOUT_SEL	0x04	3	0** 1	Disable the calibrated temperature output Enable the calibrated temperature output
O	0x04	[31:18] *	0x0000 ** See § 7	Offset calibration of temperature sensor
G	0x04	[17:4] *	0x0800 ** See § 7	Gain calibration of temperature sensor
Acceleration output compensation				
GOUT_SEL	0x3D	31*	0 1**	Disable the calibrated acceleration output Enable the calibrated acceleration output
MTPSLOTNB	0x3D	[12:8]*	0b00000 0b00001 0b00011 0b00111 0b01111 0b11111	Unprogrammed part Programmed once, 4 slots remaining Programmed twice, 3 slots remaining Programmed 3 times, 2 slots remaining Programmed 4 times, 1 slot remaining Programmed 5 times, no slot remaining
SF4	0x48	[18:0] *	See Table 9	Scale Factor 4th order coefficient (calibrated acceleration)
SF3	0x46	[19:0] *	See Table 9	Scale Factor 3rd order coefficient (calibrated acceleration)
SF2	0x44	[20:0] *	See Table 9	Scale Factor 2nd order coefficient (calibrated acceleration)
SF1	0x42	[29:0] *	See Table 9	Scale Factor 1st order coefficient (calibrated acceleration)
SF0	0x3F	[30:0] *	See Table 9	Bias 4th order coefficient (calibrated acceleration)
B4	0x47	[18:0] *	See Table 9	Bias 3rd order coefficient (calibrated acceleration)
B3	0x45	[19:0] *	See Table 9	Bias 2nd order coefficient (calibrated acceleration)
B2	0x43	[19:0] *	See Table 9	Bias 1st order coefficient (calibrated acceleration)
B1	0x41	[29:0] *	See Table 9	Bias constant coefficient (calibrated acceleration)
B0	0x3E	[23:0] *	See Table 9	Bias 4th order coefficient (calibrated acceleration)
TMID	0x40	[19:0] *	See Table 9	Mid-temperature calibration point

Table 8: Useful parameters information

Notes:

* The other bits at those addresses shall remain unchanged. Please make sure that you write them without any modification!
** Default Value

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7. Acceleration calibration procedure

7.1. Algorithm overview

After filtering, the raw acceleration sensor output is temperature compensated based on the on-chip temperature sensor output and the stored temperature compensation parameters.

7.1.1.   Acceleration output calibration model

The formula below models the link between raw and compensated acceleration outputs:

$$ACC[g] = \frac{ACC_{COMP}[LSB]}{SF_{setting}[LSB/g]} = \frac{ACC_{RAW}[LSB] - \mathbf{BIAS}[LSB]}{\mathbf{SF}[LSB/g]}$$

where:

- ACC is the acceleration output converted in g;
- ACC_{COMP} is the calibrated acceleration output;
- $SF_{setting}$ is the constant conversion factor from LSB to g for the calibrated acceleration output. Default value for this parameter is $SF_{setting}$ = 500 000;
- ACC_{RAW} is the raw data acceleration output;
- **BIAS** is a polynomial (4th degree) temperature-varying coefficient to model the sensor's bias temperature variations;
- **SF** is a polynomial (4th degree) temperature-varying coefficient to model the sensor's Scale Factor temperature variations.
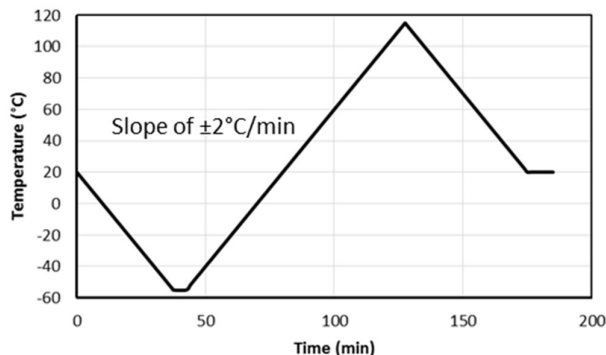

Figure 25: Recommended Temperature profile for calibration

_____

[1] Temperature profile can be adapted to be in line with customer applications.

[2] Rate applied can be adapted to be in line with customer applications.

7.1.2.   Recommended procedure

1. Set GOUT_SEL to 0 in the System Registers (disable the calibration)

2. Place the sensor on a rate table in a thermal chamber and implement temperature profile according to Figure 25[1]

3. Perform continuous acquisition of the acceleration output with the following pattern:
   - Rest position (0g input) to evaluate the BIAS parameter
   - + 1g input then -1g input to evaluate the SF parameter[2]

4. Calculate the coefficients of BIAS and SF polynomials:

$$BIAS = \sum_{i=0}^{4} b_i (T_{RAW} - T_{MID})^i$$

$$SF = \sum_{i=0}^{4} sf_i (T_{RAW} - T_{MID})^i$$

where

- T_{RAW} is the raw output of the temperature sensor **multiplied by 64**;
- T_{MID} is the mid-value of T_{RAW};
- b_0 to b_4 are the 5 coefficients of BIAS polynomial;
- sf_0 to sf_4 are the 5 coefficients of SF polynomial.

5. Convert T_{MID}, b_i and sf_i parameters to their binary values according to Table 9 below:

Parameter	Value (decimal)	Format
SF4	$sf_4 . 2^{92} / SF_{setting}$	signed 2's comp
SF3	$s3_2 . 2^{72} / SF_{setting}$	signed 2's comp
SF2	$sf_2 . 2^{55} / SF_{setting}$	signed 2's comp
SF1	$sf_1 . 2^{46} / SF_{setting}$	signed 2's comp
SF0	$sf_0 . 2^{27} / SF_{setting}$	signed 2's comp
B4	$b_4 . 2^{73}$	signed 2's comp
B3	$b_3 . 2^{53}$	signed 2's comp
B2	$b_2 . 2^{32}$	signed 2's comp
B1	$b_1 . 2^{20}$	signed 2's comp
B0	b_0	signed 2's comp
TMID	T_{MID}	unsigned

Table 9: Acceleration calibration parameters

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7.2. Programming of the new coefficients

IMPORTANT NOTE: The following steps are **non-reversible**. The previous values of the coefficients will not be accessible anymore. The temperature compensation coefficients can be re-programmed up to 4 additional times.

The programming procedure consists in three major steps:

- Checking the available MTP slot status
- Programming the coefficients
- Updating the available MTP slot status

An overview of the procedure is given in Figure 26.

7.2.1.   Checking the MTP slot status

The first step is to check the number of remaining MTP slots (MTPSLOTNB), in other words, checking how many times the chip has been programmed before.

The detailed information of MTPSLOTNB register content is given in Table 8. The sequence of instructions to read the register is given in section 6.5.

The MTP slot number (MTPSLOTNB) re-programming iteration is given in the following table:

Iteration	Correspondence	MTP number	
		Value	Binary
0	Unprogrammed part	0	00000
1	Programmed once	1*	00001
2	Programmed twice	3	00011
3	…	7	00111
4		15	01111
5	Cannot be further programmed	31	11111

Table 10: MTPSLOTNB iterations

* Default value

7.2.2.   Programming the coefficients

This step describes the procedure for programming the calculated coefficients (temperature compensation of acceleration output). The programming procedure is:

1. Write SF4 in the system register
2. Program SF4 in the MTP
3. Write SF3 in the system register
4. Program SF3 in the MTP
5. Write SF2 in the system register
6. Program SF2 in the MTP
7. Write SF1 in the system register
8. Program SF1 in the MTP
9. Write SF0 in the system register

10. Program SF0 in the MTP
11. Write B4 in the system register
12. Program B4 in the MTP
13. Write B3 in the system register
14. Program B3 in the MTP
15. Write B2 in the system register
16. Program B2 in the MTP
17. Write B1 in the system register
18. Program B1 in the MTP
19. Write B0 in the system register
20. Program B0 in the MTP
21. Write TMID in the system register
22. Program TMID

The detailed SPI commands are given in section 6.5. The detailed information about each coefficient is given in Table 8.
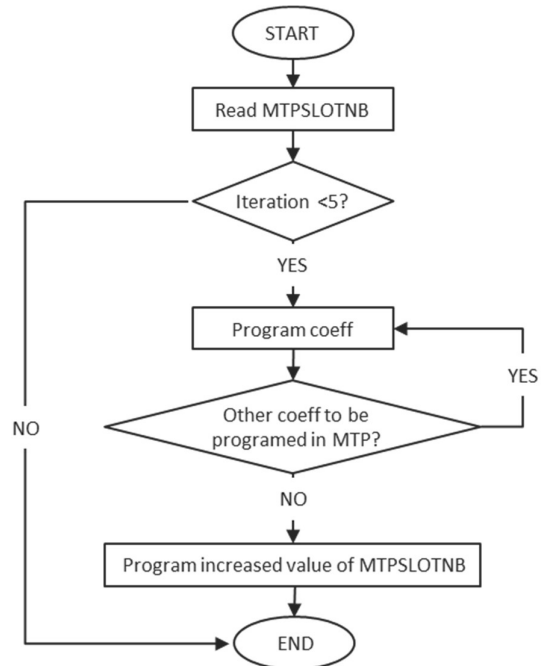

Figure 26: Procedure to program new calibration parameters

7.2.3.   Updating MTP slot status

This section describes the procedure for programming the updated status of the MTP slots.

If this step is not performed properly, the new compensation coefficients will not be effective.

1. Read the MTPSLOTNB as described in section 6.5.2
2. Increment MTPSLOTNB according Table 10.
3. Write the updated MTPSLOTNB in the system register.
4. Program the updated MTPSLOTNB in the MTP.
5. After a reset, the new coefficients will be available.

7.3. Switch to uncompensated data output

To optimize the thermal compensation of the acceleration output, it is possible to disable the on-chip compensation and use the uncompensated (raw) output to perform an external thermal compensation.

IMPORTANT NOTE: This step is **non-reversible**. The previous values of the coefficients will not be accessible anymore.

To switch the acceleration output to uncompensated data, the procedure is exactly the same as describe in section 7.2, but the coefficients given in Table 9 must be replaced by the coefficients given below in Table 11.

Parameter	Value (hexadecimal)
SF4	0x0
SF3	0x0
SF2	0x0
SF1	0x0
SF0	0x0800 0000
B4	0x0
B3	0x0
B2	0x0
B1	0x0
B0	0x0
TMID	0x0

Table 11: Acceleration compensation coefficients to obtain raw data

8. Temperature Sensor Calibration Procedure

The temperature output of AXO315 sensors is *not* factory-calibrated, since only the raw temperature information is needed by the acceleration calibration blocks. However, it is possible to perform a first-order polynomial calibration of the temperature sensor, in order to output the absolute temperature information.

This section shows how to get and store temperature calibration parameters for the temperature output.

8.1. Temperature sensor calibration model

The formula below models the link between raw and calibrated acceleration outputs:

$$T[°C] = \frac{T_{COMP\_OUT}[LSB]}{GAIN_{setting}[LSB/°C]} = \frac{GAIN.T_{RAW}[LSB] - \textbf{OFFSET}[LSB]}{GAIN setting[LSB/°C]}$$

where:

- T is the output temperature converted in °C;
- T_{COMP_OUT} is the calibrated temperature output;
- $GAIN_{setting}$ is the constant conversion factor from LSB to °C for the calibrated temperature output. This gain is set to 20LSB/°C to provide an output resolution of 0,1°C;
- T_{RAW} is the raw data temperature output;
- **OFFSET** is a constant coefficient to tune the offset;
- **GAIN** is a constant coefficient to tune gain.

The **OFFSET** and **GAIN** parameters will be obtained and written in the IC through the following calibration procedure.

8.2. Recommended Procedure

1. Check that TOUT_SEL = 0. If not, set it to 0 in the System Registers.

2. Measure the temperature output with at least 2 temperature points T_1 and T_2.

3. Calculate the GAIN and OFFSET coefficients according to formula above

$$GAIN = GAIN_{setting} \cdot \frac{T1_{ABS}[°C] - T2_{ABS}[°C]}{T1_{RAW}[LSB] - T2_{RAW}[LSB]}$$

$$OFFSET = GAIN_{setting}.T1_{ABS}[°C] - GAIN.T1_{RAW}[LSB]$$

where:
- $T1_{ABS}$ is the absolute temperature of T_1 in °C;
- $T2_{ABS}$ is the absolute temperature of T_2 in °C;
- $T1_{RAW}$ is the raw output temperature of T_1 in LSB;
- $T2_{RAW}$ is the raw output temperature of T_2 in LSB;

4. Convert GAIN and OFFSET to their binary values according to Table 12 below:

Parameter	Value (decimal)	Format
G	GAIN . 2^{11}	Unsigned
O	OFFSET	Unsigned

Table 12: Temperature calibration parameters

5. [Optional step: Write GAIN and OFFSET in the System Registers and repeat step 2. to check for the new calibration accuracy.]

6. Write GAIN and OFFSET in the MTP according to instructions of Section 6.5.2. Meanwhile, set TOUT_SEL to 1 during this step, so that the new calibration parameters are effective after a RESET.

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9. Device Identification

9.1. Device information

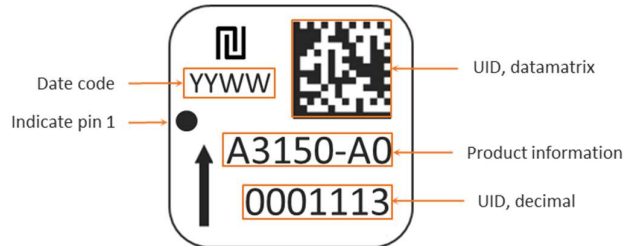AXO315 tracking information is accessible on the label, as shown in the next figure.

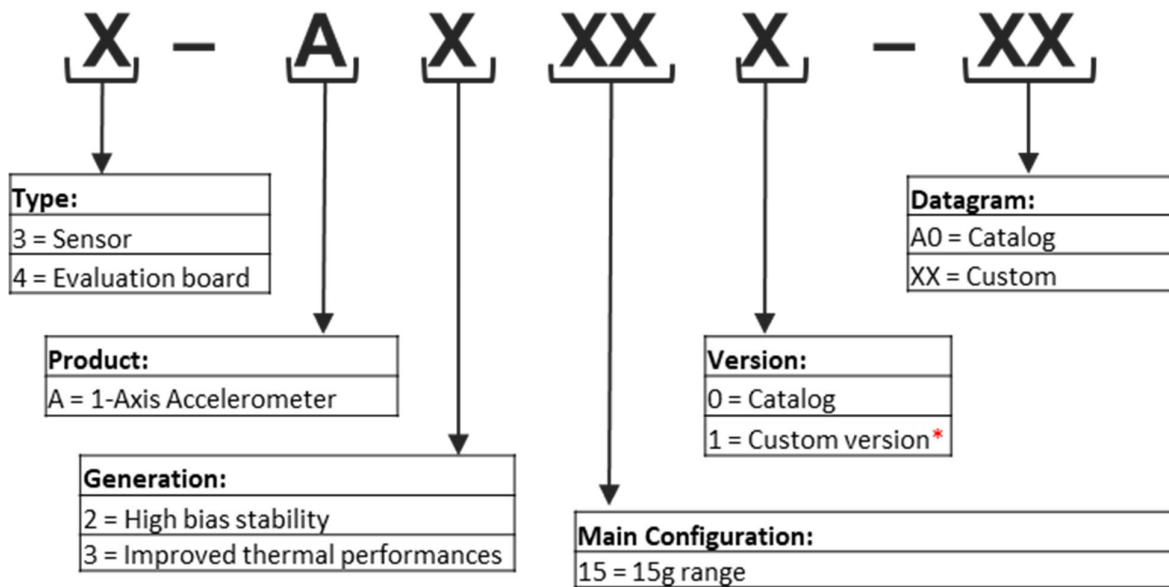**Figure 27: AXO315 label.**

9.2. Ordering information

Figure 28: Ordering information

* Custom version or specific requirement can be addressed upon request.

Product	Ordering code
AXO315	3-A3150-A0
AXO315-EVB3	4-A3150-A0

10.   Internal construction and Theory of Operation

AXO315 sensor is using the dominant architecture for high performance MEMS accelerometers, namely the "In-plane Force-rebalance" design. A symmetric silicon proof mass is suspended by pairs of opposing spring flexures on either side of the proof mass. An applied acceleration acts on the proof mass. This in-plane motion is counterbalanced by applying voltages that generate electrostatic forces to rebalance the proof mass (closed-loop operation). The applied voltage is directly proportional to the input acceleration.

In details, each sensor consists in a MEMS transducer and an integrated circuit (IC) packaged in a 28-pins J-leaded Ceramic Package.

The MEMS transducer is manufactured using Tronics' hermetic wafer-level packaging technology where the microstructure is micro-machined thick single crystal silicon for its mechanical reliability.

The MEMS die is located on the left part of the block diagram. Differential detection and actuation are used for efficient common mode rejection. The sensor is factory calibrated and compensated for temperature effects to provide high-accuracy digital output over a broad temperature range.

Raw data output can be also chosen to enable customer-made compensations.

The IC is located on the right part of the block diagram. The IC is designed to interface the MEMS sensing element. It is fully hard-coded and includes no firmware or software. Its 24-bit digital SPI output suppresses the need for costly high resolution A/D converter at the systems level.

It includes ultra-low noise capacitive to voltage converters (C2V) followed by high resolution voltage digitization (ADC). Excitation voltage required for capacitance sensing circuits is generated on the common electrode node. 1-bit force feedbacks (DAC) are used for electrostatic actuation.

The digital part implements digital control loop and processes the acceleration output based on the on-chip temperature sensor output. The system controller manages the interface between the SPI registers, the system register and the non-volatile memory (OTP). The non-volatile memory provides the accelerometer settings, in particular the coefficients for acceleration temperature compensation. On power up, the settings are transferred from the OTP to the system registers and output data are available in the SPI registers. The acceleration output and the temperature sensor output are available in the SPI registers. The SPI registers are available through the SPI interface (SSB, SCK, MOSI, MISO). The self-test and the data ready are available respectively on the external pin ST and DRY.

The "References" block generates the required biasing currents and voltages for all blocks as well as the low-noise reference voltage for critical blocks.

The "Power Management" block manages the power supply of the sensor from a single 5V supply between the VDD and GND pins. It includes a power on reset as well as an external reset pin (RSTB) to start or restart operation using default configuration. An enable pin (EN) with power-down capability is also available.

The sensor is powered with a single 5V DC power supply through pins VDD and GND. Although the sensor contains three separate VDD pins, the sensor is supplied by a single 5V voltage source. It is recommended to supply the three VDD pins in a star connection with appropriate decoupling capacitors. Regarding the sensor grounds, all the GND pins are internally shorted. The GND pins redundancy is used for multiple bonds in order to reduce the total ground inductance. It is therefore recommended to connect all the GND pins to the ground.

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11.   Available Tools and Resources

The following tools and resources are available on the AXO® product page of our **website**.

Item	Description
Documentation & technical notes	
	AXO315 – Datasheet
	GYPRO2300 series – Datasheet
	GYPRO3300 series – Datasheet
Mechanical tool	
	AXO315 - 3D model
	GYPRO2300/GYPRO3300 - 3D model
Evaluation kit	
	Tronics EVB3 – Evaluation board *Evaluation board for AXO315, compatible with Arduino Leonardo and Arduino Yùn*
	Tronics EVB2 – Evaluation board *Evaluation board for GYPRO2300 series and GYPRO3300 series, compatible with Arduino Leonardo and Arduino Yùn*
	Tronics Evaluation Tool – Software
	Tronics EVB3 – User manual
	Tronics EVB2 – User manual
	Tronics Evaluation Kit – Quick Start Guide
	Tronics Evaluation Tool – Software User Manual
	Tronics Evaluation Tool – Arduino Firmware