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## AIS328DQ: high-performance, ultra-low-power, 3-axis digital output accelerometer for automotive non-safety applications

### Introduction

This document provides application information for the low-voltage 3-axis digital output linear MEMS accelerometer provided in a QFN package.

The **AIS328DQ** is a high-performance ultra-low-power 3-axis linear accelerometer, which belongs to the automotive non-safety family of MEMS accelerometers, with digital I<sup>2</sup>C/SPI serial interface standard output.

The device features ultra-low-power operational modes that allow advanced power saving and smart sleep-to-wakeup functions and may be used in a variety of automotive non-safety applications such as telematics boxes, e-call systems and crash recording.

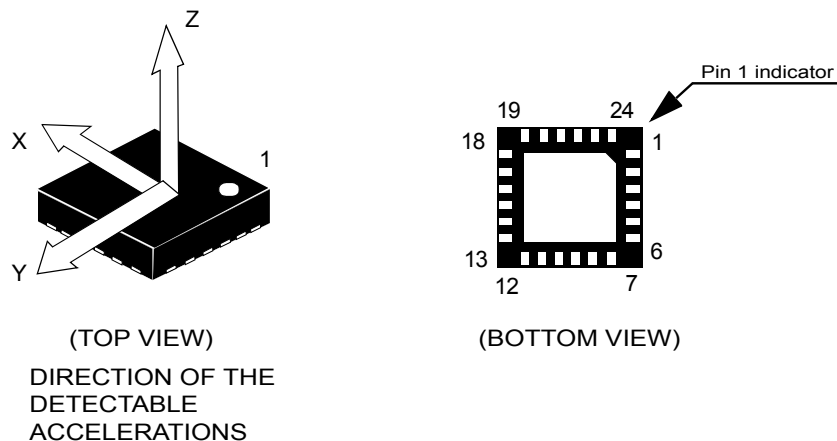
The AIS328DQ has dynamically user-selectable full scales of  $\pm 2 g$  /  $\pm 4 g$  /  $\pm 8 g$  and is capable of measuring acceleration with output data rates from 0.5 Hz to 1 kHz.

The self-test capability allows the user to check the functioning of the sensor in the final application.

The device can be configured to generate interrupt signals in response to inertial wake-up/free-fall events or based on the position of the device itself.

The thresholds and timing of interrupt generators are programmable by the end user while fully operational. The AIS328DQ is available in a small, quad flat no-lead package (QFN) with a reduced 4x4 mm footprint and is guaranteed to operate over a wide temperature range of -40 °C to +105 °C.

# 1 Pin description

**Figure 1. Pin connections**

**Table 1. Pin description**

Pin #	Name	Function	Pin status
1	NC	Not connected	
2	NC	Not connected	
3	INT_2	Interrupt pin 2	Output forced to GND
4	Reserved	Connect to GND	
5	VDD	Power supply	
6	GND	0 V supply	
7	INT_1	Interrupt pin 1	Output forced to GND
8	GND	0 V supply	
9	GND	0 V supply	
10	GND	0 V supply	
11	SPC SCL	SPI serial port clock (SPC) I <sup>2</sup> C serial clock (SCL)	Input with pull-up
12	CS	SPI enable I <sup>2</sup> C/SPI mode selection: (0: SPI enabled; I <sup>2</sup> C disabled 1: SPI idle mode / I <sup>2</sup> C communication enabled)	Input with pull-up
13	Reserved	Connect to Vdd	
14	VDD_IO	Power supply for I/O pins	
15	SDO SA0	SPI serial data output (SDO) I <sup>2</sup> C less significant bit of the device address (SA0)	Input with pull-up
16	SDI SDO SDA	SPI serial data input (SDI) 3-wire interface serial data output (SDO) I <sup>2</sup> C serial data (SDA)	Input with pull-up
17-24	NC	Not internally connected	

## 2 Registers

**Table 2. Register table**

Register name	Address	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
WHO_AM_I	0Fh	0	0	1	1	0	0	1	0
CTRL_REG1	20h	PM2	PM1	PM0	DR1	DR0	Zen	Yen	Xen
CTRL_REG2	21h	BOOT	HPM1	HPM0	FDS	HPen2	HPen1	HPCF1	HPCF0
CTRL_REG3	22h	IHL	PP_OD	LIR2	I2_CFG1	I2_CFG0	LIR1	I1_CFG1	I1_CFG0
CTRL_REG4	23h	BDU	BLE	FS1	FS0	STsign	0	ST	SIM
CTRL_REG5	24h	-	-	-	-	-	-	TurnOn1	TurnOn0
HP_FILTER_RESET	25h	-	-	-	-	-	-	-	-
REFERENCE	26h	REF7	REF6	REF5	REF4	REF3	REF2	REF1	REF0
STATUS_REG	27h	ZYXOR	ZOR	YOR	XOR	ZYXDA	ZDA	YDA	XDA
OUTX_L	28h	XD7	XD6	XD5	XD4	XD3	XD2	XD1	XD0
OUTX_H	29h	XD15	XD14	XD13	XD12	XD11	XD10	XD9	XD8
OUTY_L	2Ah	YD7	YD6	YD5	YD4	YD3	YD2	YD1	YD0
OUTY_H	2Bh	YD15	YD14	YD13	YD12	YD11	YD10	YD9	YD8
OUTZ_L	2Ch	ZD7	ZD6	ZD5	ZD4	ZD3	ZD2	ZD1	ZD0
OUTZ_H	2Dh	ZD15	ZD14	ZD13	ZD12	ZD11	ZD10	ZD9	ZD8
INT1_CFG	30h	AOI	6D	ZHIE	ZLIE	YHIE	YLIE	XHIE	XLIE
INT1_SRC	31h	-	IA	ZH	ZL	YH	YL	XH	XL
INT1_THS	32h	0	THS6	THS5	THS4	THS3	THS2	THS1	THS0
INT1_DURATION	33h	0	D6	D5	D4	D3	D2	D1	D0
INT2_CFG	34h	AOI	6D	ZHIE	ZLIE	YHIE	YLIE	XHIE	XLIE
INT2_SRC	35h	-	IA	ZH	ZL	YH	YL	XH	XL
INT2_THS	36h	0	THS6	THS5	THS4	THS3	THS2	THS1	THS0
INT2_DURATION	37h	0	D6	D5	D4	D3	D2	D1	D0

### 3 Start-up sequence

Once the device is powered up, it automatically downloads the calibration coefficients from the embedded Flash memory to the internal registers. When the boot procedure is complete (i.e. after about 5 milliseconds), the device automatically enters power-down mode.

To turn on the device and gather acceleration data, it is necessary to select one of the operating modes through the CTRL\_REG1 register, and to enable at least one of the axes. The following general-purpose sequence can be used to configure the device:

1. Write CTRL\_REG1
2. Write CTRL\_REG2
3. Write CTRL\_REG3
4. Write CTRL\_REG4
5. Write Reference
6. Write INT1\_THS
7. Write INT1\_DUR
8. Write INT2\_THS
9. Write INT2\_DUR
10. Read HP\_FILTER\_RESET (if filter is enabled)
11. Write INT1\_CFG
12. Write INT2\_CFG
13. Write CTRL\_REG5

Register values can be changed at any time and with the device in any operating mode. Modifications take effect immediately.

Note that in case of changes in full scale, ODR or enabling/disabling of self-test, the output of the device will require  $1 \text{ ms} + 1/\text{ODR}$  to settle (see [Table 12](#)). If the HP filter cutoff frequency is changed, the filter can be reset by reading the HP\_FILTER\_RESET register.

## 3.1 Reading acceleration data

### 3.1.1 Using the status register

The device features a STATUS\_REG register which should be polled to check when a new set of data is available. The reading procedure is the following:

1. Read STATUS\_REG
2. If STATUS\_REG(3) = 0, then go to 1
3. If STATUS\_REG(7) = 1, then some data have been overwritten
4. Read OUTX\_L
5. Read OUTX\_H
6. Read OUTY\_L
7. Read OUTY\_H
8. Read OUTZ\_L
9. Read OUTZ\_H
10. Data processing
11. Go to 1

The check performed at step 3 determines whether the reading rate is adequate compared to the data production rate. In cases where one or more acceleration samples have been overwritten by new data due to an excessively slow reading rate, the ZYXOR bit of the STATUS\_REG register is set to 1.

The overrun bits are automatically cleared when all the data present inside the device have been read and new data have not been produced in the meantime.

### 3.1.2 Using the data-ready signal

The device may be configured to have one HW signal to determine when a new set of measurement data is available to be read. This signal is represented by the XYZDA bit of the STATUS\_REG register. The signal can be driven to the INT1 or INT2 pins and its polarity set to active-low or active-high through the CTRL\_REG3 register. The interrupt is reset when the higher part of the data of all the enabled channels has been read.

### 3.1.3 Using the block data update feature

If reading the acceleration data is particularly slow and cannot be (or does not need to be) synchronized with either the XYZDA bit within the STATUS\_REG or with the RDY signal, it is strongly recommended to set the BDU (block data update) bit in CTRL\_REG4 to 1.

This feature prevents the need to read the values (most significant and least significant parts of the acceleration data) related to different samples. In particular, when the BDU is activated, the data registers related to each channel always contain the most recent acceleration data produced by the device. But if the reading of a given pair (i.e. OUTX\_H and OUTX\_L, OUTY\_H and OUTY\_L, OUTZ\_H and OUTZ\_L) is initiated, the refresh for that pair is blocked until both the MSB and LSB parts of the data are read.

*Note: BDU only guarantees that OUTX(Y, Z)\_L and OUTX(X,Z)\_H have been sampled at the same moment. If the reading speed is too slow, it is possible, for example, to read X and Y sampled at T1 and Z sampled at T2.*

### 3.2 Output data rate selection and read timing

The output data rate is user-selectable through the DRx bits of the CTRL\_REG1 (20h) register. At power-on-reset, the DRx bits are reset to 0, thus providing a default output data rate of 50 Hz.

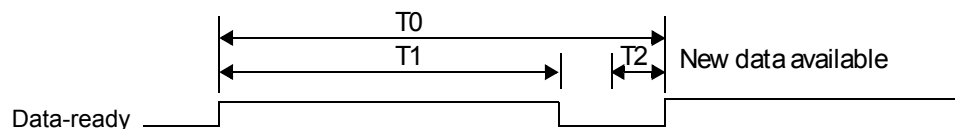
The analog signal coming from the mechanical sensor is filtered by a low-pass filter before being converted by the internal ADC. The frequency at -3 dB of the low-pass filter determines the effective system resolution. The cutoff frequency depends on the DR[1:0] bits in the CTRL\_REG1 (20h) register, refer to the following table.

**Table 3. Output data rate**

DR1, DR0	Output data rate	Analog filter cutoff frequency (-3 dB)
00	50 Hz	37 Hz
01	100 Hz	74 Hz
10	400 Hz	292 Hz
11	1000 Hz	780 Hz

*Note:* The output data rate precision is related to the internal oscillator; an error of  $\pm 10\%$  should be taken into account. A typical reading period is defined which is 616  $\mu\text{s}$  shorter than the output data rate period, in order to prevent the loss of any data produced. During this time period the reading of the data must be performed and the data-ready signal can be used as a trigger to begin the reading sequence. At the end of the complete sequence, the data-ready signal goes down and the rising edge that follows signals that new data are available. If this minimum reading frequency is not observed, some data loss is possible and the data-ready signal is no longer considered a trigger signal. The status register can be used to infer the occurrence of an overrun.

**Figure 2. Read timing**



**Table 4. Timing value to prevent data loss**

Time	Description	Typ
T0	Data rate	1/ODR
T1	Reading period	T0-T2
T2	New data generation	616 $\mu\text{s}$

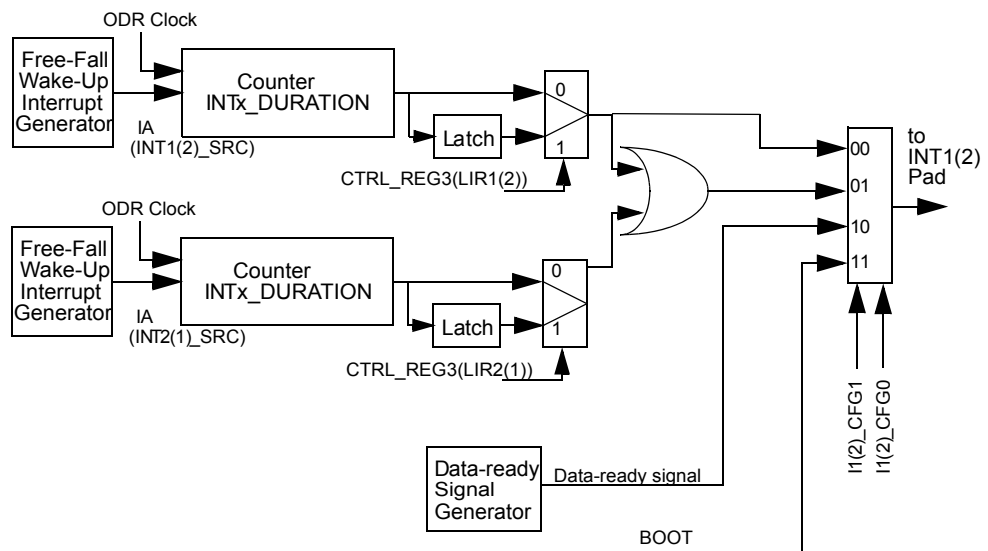
### 3.3 Data ready vs. interrupt signal

The device has two pins which can be activated to generate either the data-ready signal or the interrupt signal. The functionality of the pins is selected acting on bit I1(2)\_CFGx bits of the CTRL\_REG3 register, according to Table 5 and the block diagram shown in Figure 3.

**Table 5. Data signal on INT 1 and INT 2 pads**

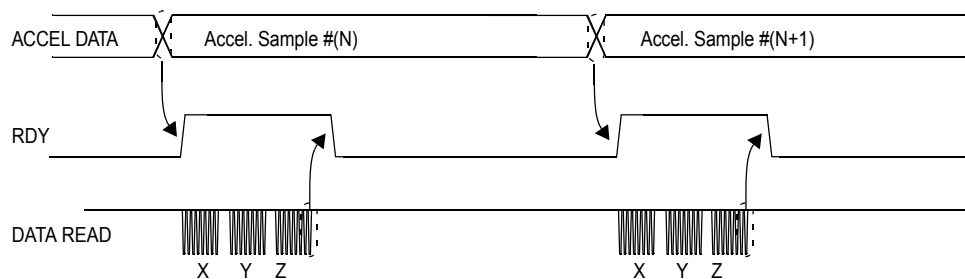
I1(2)_CFG1	I1(2)_CFG0	INT 1(2) Pin
0	0	Interrupt 1 (2) source
0	1	Interrupt 1 source OR Interrupt 2 source
1	0	Data ready
1	1	Boot running

**Figure 3. Interrupt and data-ready signal generation block diagram**



In particular, the data-ready (DR) signal rises to 1 when a new set of acceleration data has been generated and is available to be read. The signal is reset after all the enabled channels are read through the serial interface.

**Figure 4. Data-ready signal**



### 3.4 Understanding acceleration data

The measured acceleration data are sent to the OUTX\_H, OUTX\_L, OUTY\_H, OUTY\_L, OUTZ\_H and OUTZ\_L registers. These registers contain, respectively, the most significant part and the least significant part of the acceleration signals acting on the X, Y and Z axes.

The complete acceleration data for the X (Y, Z) channel is given by the concatenation OUTX\_H & OUTX\_L (OUTY\_H & OUTY\_L, OUTZ\_H & OUTZ\_L) and is expressed as a 2's complement number.

Acceleration data are represented as 12-bit numbers (left justified).

#### 3.4.1 Big-little endian selection

The AIS328DQ allows the swapping of the content of the lower and the upper part of the acceleration registers (i.e. OUTX\_H with OUTX\_L), to be compliant with both little-endian and big-endian data representations.

“Little endian” means that the low-order byte of the number is stored in memory at the lowest address, and the high-order byte at the highest address (the little end comes first). This mode corresponds to bit BLE in the CTRL\_REG4 set to 0 (default configuration).

Conversely, “big endian” means that the high-order byte of the number is stored in memory at the lowest address, and the low-order byte at the highest address.

#### 3.4.2 Example of acceleration data

The following table provides a few basic examples of the data that will be read in the data registers when the device is subject to a given acceleration. The values listed in the table are based on the assumption that the device is perfectly calibrated (i.e., no offset, no gain error, etc.) and show the effect of the BLE bit.

**Table 6. Output data register content vs. acceleration (FS = ±2 g)**

Acceleration values	BLE = 0		BLE = 1	
	Register address			
	28h	29h	28h	29h
0 g	00h	00h	00h	00h
343 mg	E0h	15h	15h	E0h
1004 mg	00h	40h	40h	00h
-343 mg	20h	EAh	EAh	20h
-1004 mg	00h	C0H	C0H	00h



## 4 Operating modes

The AIS328DQ can operate in the following four modes, which are selected through the configuration of CTRL\_REG1 and CTRL\_REG5:

- Power-down
- Normal mode
- Low-power
- Sleep-to-wake

With reference to the datasheet of the device, the PowerMode (PM) and DataRate (DR) bits of CTRL\_REG1 register are used to select the basic operating modes (power-down, normal mode and low-power). The TurnOn bits of the CTRL\_REG5 register are used to enable sleep-to-wake, which is an advanced mode involving the interrupt configuration also.

*Note:* The PMx bits are disabled if the TurnOnx bits of CTRL\_REG5 are not configured as zeros.

**Table 7. Power mode and low-power output data rate configurations**

PM2	PM1	PM0	Power mode selection	Output data rate [Hz] ODR <sub>LP</sub>
0	0	0	Power-down	--
0	0	1	Normal mode	ODR
0	1	0	Low-power	0.5
0	1	1	Low-power	1
1	0	0	Low-power	2
1	0	1	Low-power	5
1	1	0	Low-power	10

**Table 8. CTRL\_REG1 - data rate**

DR1	DR0	Data rate generation [Hz] ODR
0	0	50
0	1	100
1	0	400
1	1	1000

**Table 9. CTRL\_REG5 - sleep-to-wake configuration**

TurnOn1	TurnOn0	Sleep-to-wake status
0	0	Sleep-to-wake function disabled
0	1	An interrupt event has occurred and the system is generating data at ODR
1	0	Not allowed
1	1	Sleep-to-wake function enabled

Table 10 and Table 11 show the typical power consumption values (@ Vdd = 3.3 V) for the different operating modes.

Note: Higher data rates correspond to lower device resolution.

**Table 10. Power consumption - normal mode (µA)**

ODR	50 Hz	100 Hz	400 Hz	1000 Hz
<b>Power consumption</b>	290	300	330	400

**Table 11. Power consumption - low-power mode (µA)**

ODR <sub>LP</sub>	0.5 Hz	1 Hz	2 Hz	5 Hz	10 Hz
DR[1:0] = 00	11	18	32	70	125
DR[1:0] = 01	9	13	22	45	90
DR[1:0] = 10	9	13	22	45	90
DR[1:0] = 11	7	9	14	30	60

## 4.1 Power-down mode

When the device is in power-down mode, almost all internal blocks of the device are switched off to minimize power consumption. Digital interfaces (I<sup>2</sup>C and SPI) are still active to allow communication with the device. The content of the configuration register is preserved and output data registers are not updated, thus keeping in memory the last data sampled before going to power-down mode.

**Table 12. Turn-on time in normal mode**

Data rate generation (Hz)	Turn-on time - typ. (ms)
50	21
100	11
400	3.5
1000	2

## 4.2 Normal mode

In Normal mode, data are generated at the data rate (ODR) selected through the DR bits and for the axis enabled through the Zen, Yen and Xen bits of the CTRL\_REG1 register. Data generated for a disabled axis is 00h.

Data interrupt generation is active and configured through the INT1\_CFG and INT2\_CFG registers.

Typical turn-on time in normal mode is 1 ms + 1/ODR, as indicated in Table 12.

## 4.3 Low-power mode

When the device is in low-power mode, data are produced at the ODR<sub>LP</sub> selected by the PM bits of CTRL\_REG1.

Data interrupt generation is active and configured through the INT1\_CFG and INT2\_CFG registers.

Typical turn-on time in low-power mode is 1 ms + 1/ODR.

## 4.4 Sleep-to-wake

The sleep-to-wake function, in conjunction with low-power mode, allows further reduction of system power consumption and the development of new smart applications. The AIS328DQ can be set in a low-power operating mode, characterized by lower data rate refreshes. In this way the device, even if “sleeping”, continues sensing acceleration and generating interrupt requests.

When the sleep-to-wake function is activated, the AIS328DQ is able to automatically wake up as soon as the interrupt event has been detected, increasing the output data rate and bandwidth. With this feature the system can be efficiently switched from low-power mode to full performance, depending on user-selectable positioning and acceleration events, thus ensuring power saving and flexibility.

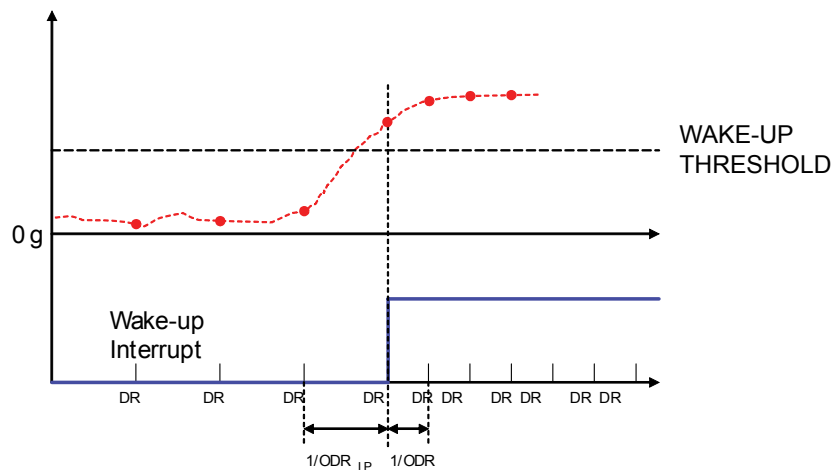
The sleep-to-wake function is activated through the TurnOnx bits of CTRL\_REG5 (Table 9).

When the device is in sleep-to-wake mode, it automatically samples the acceleration data at  $ODR_{LP}$  to verify if interrupt conditions have been reached. When an interrupt event occurs, the device goes back to generate data at ODR (Figure 5). If interrupt conditions have not been reached, the device remains in low-power mode at  $ODR_{LP}$ .

The device is ready to immediately generate valid samples as soon as it exits from sleep-to-wake mode.

*Note:* When an interrupt event occurs, the content of CTRL\_REG5 changes to 0x01 while the content of CTRL\_REG1 is left untouched. The PMx bits are ignored. To return to normal mode or low-power mode, the TurnOnx bits of CTRL\_REG5 must be set to zero.

**Figure 5. Sleep-to-wake mode**



### 4.4.1 Entering sleep-to-wake mode

Perform the following procedure to set up the sleep-to-wake function:

1. Configure the desired interrupt event (free-fall, wake-up, 6D position or 6D movement).
2. Select the desired low power mode ( $ODR_{LP}$ ) and data rate (ODR) in CTRL\_REG1.
3. Enable the sleep-to-wake mode through CTRL\_REG5 (TurnOn1 = TurnOn0 = 1).

Once an interrupt event occurs, the TurnOn bits change to TurnOn1 = 0 and TurnOn0 = 1 and the system generates data at ODR. The user can re-activate the sleep-to-wake function by executing step 3 again.

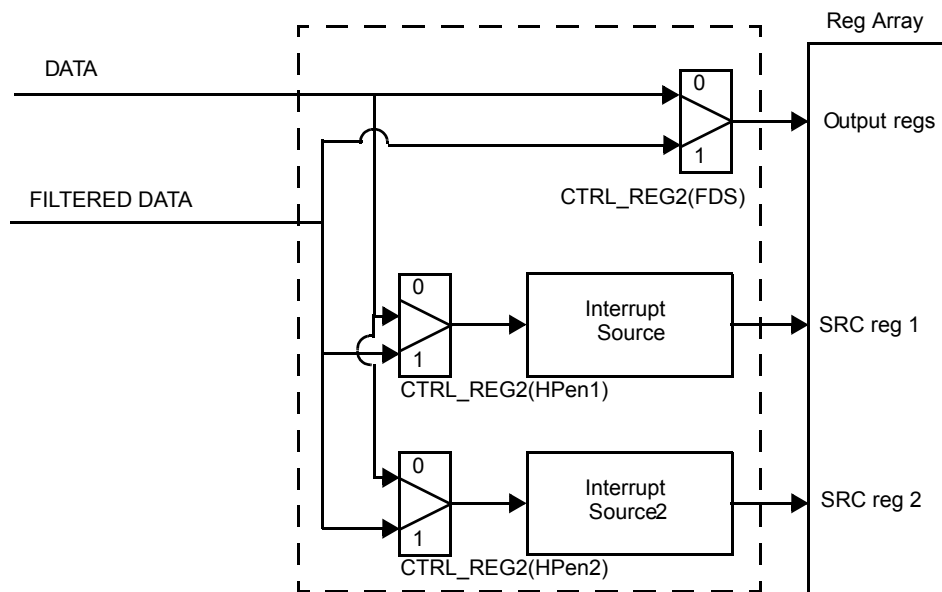
### 4.4.2 Exiting sleep-to-wake mode

To return to normal mode or to low-power mode, the user must disable the sleep-to-wake function by setting TurnOn1 = TurnOn0 = 0.

## 5 High-pass filter

The AIS328DQ provides embedded high-pass filtering capability to easily remove the DC component of the measured acceleration. As shown in the following figure, it is possible to independently apply the filter on the output data and/or on the interrupt data through the FDS, HPen1 and HPen2 bits of the CTRL\_REG2 register configuration. This means that it is possible, for example, to obtain filtered data while interrupt generation works on unfiltered data.

**Figure 6. High-pass filter connections block diagram**



### 5.1 Filter configuration

As shown in the following table, two operating modes are possible for the high-pass filter.

**Table 13. High-pass filter mode configuration**

HPM1	HPM0	
0	0	Normal mode (reset by reading HP_RESET_FILTER)
0	1	Reference mode
1	0	Same as configuration 00h
1	1	Not allowed

The bandwidth of the high-pass filter depends on the selected ODR and on the settings of the HPCFx bits of CTRL\_REG2. The high-pass filter cutoff frequencies ( $f_t$ ) are shown in the following table.

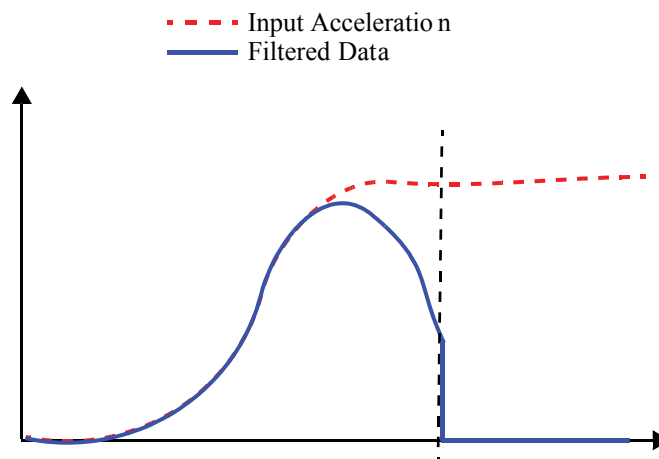
**Table 14. High-pass filter cutoff frequency configuration**

HPcoeff2,1	$f_t$ [Hz]			
	Data rate = 50 Hz	Data rate = 100 Hz	Data rate = 400 Hz	Data rate = 1000 Hz
00	1	2	8	20
01	0.5	1	4	10
10	0.25	0.5	2	5
11	0.125	0.25	1	2.5

### 5.1.1 Normal mode

In this configuration the high-pass filter can be reset by reading the HP\_FILTER\_RESET register, instantly matching the output data to the input acceleration.

**Figure 7. Reading HP\_FILTER\_RESET**



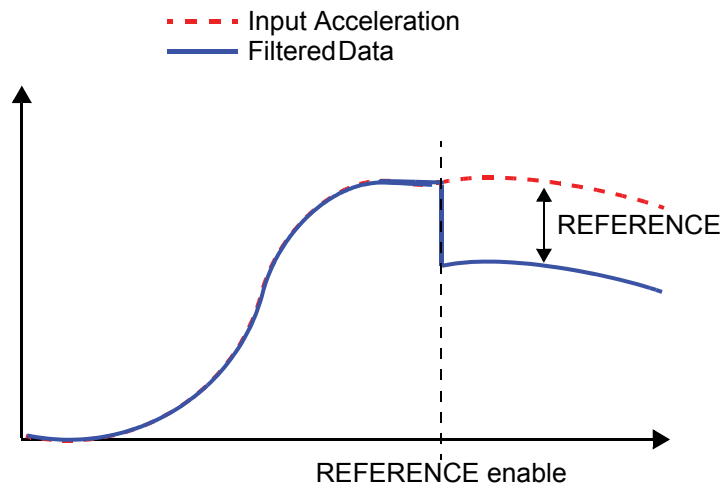
### 5.1.2 Reference mode

In reference mode configuration the output data is calculated as the difference between the input acceleration and the content of the REFERENCE register. This register is in 2's complement representation and the value of 1LSB of these 7-bit registers depends on the selected full scale (refer to the following table).

**Table 15. Reference mode LSB value**

Full scale	Reference mode LSB value (mg)
$\pm 2 g$	~16
$\pm 4 g$	~31
$\pm 8 g$	~63

**Figure 8. Reference mode**



## 6 Interrupt generation

The AIS328DQ can provide two interrupt signals and offers several possibilities for personalizing these signals. The registers involved in the interrupt generation behavior are CTRL\_REG3, INT1\_CFG, INT2\_CFG, INT1\_THS, INT2\_THS, INT1\_DURATION, and INT2\_DURATION.

The AIS328DQ interrupt signal can behave as free-fall, wake-up or 6D orientation detection.

**Table 16. Interrupt mode configuration**

AOI	6D	Interrupt mode
0	0	OR combination of interrupt events
0	1	6-direction movement recognition
1	0	AND combination of interrupt events
1	1	6-direction position recognition

Whenever an interrupt condition is verified, the interrupt signal is generated and by reading the INT1\_SRC and INT2\_SRC registers, it is possible to detect which condition has occurred.

### 6.1 Duration

The content of the duration registers set the minimum duration of the interrupt event to be recognized. Duration steps and maximum values depend on the ODR chosen.

When in normal mode, duration time is measured in  $N/ODR$ , where N is the content of the duration register and ODR is 50, 100, 400, 1000 Hz.

**Table 17. Duration LSB value in normal mode**

ODR (Hz)	Duration LSB value (ms)
50	20
100	10
400	2.5
1000	1

When in low-power mode, duration time is measured in  $N/ODR_{LP}$ , where N is the content of the duration register and  $ODR_{LP}$  is 0.5, 1, 2, 5, 10 Hz.

**Table 18. Duration LSB value in low-power mode**

ODR (Hz)	Duration LSB value (s)
0.5	2
1	1
2	0.5
5	0.2
10	0.1

## 6.2 Threshold

Threshold registers define the reference accelerations used by the interrupt generation circuitry. The value of 1LSB of these 7-bit registers depends on the selected full scale (refer to the following table).

**Table 19. Threshold LSB value**

Full scale	Threshold LSB value (mg)
$\pm 2 g$	~16
$\pm 4 g$	~31
$\pm 8 g$	~63

## 6.3 Free-fall and wake-up interrupts

The AIS328DQ interrupt signals can behave as free-fall, wake-up or 6D orientation detection. When an interrupt condition is verified, the interrupt signal is generated and by reading the INT1\_SRC and INT2\_SRC registers it is possible to determine which condition has occurred.

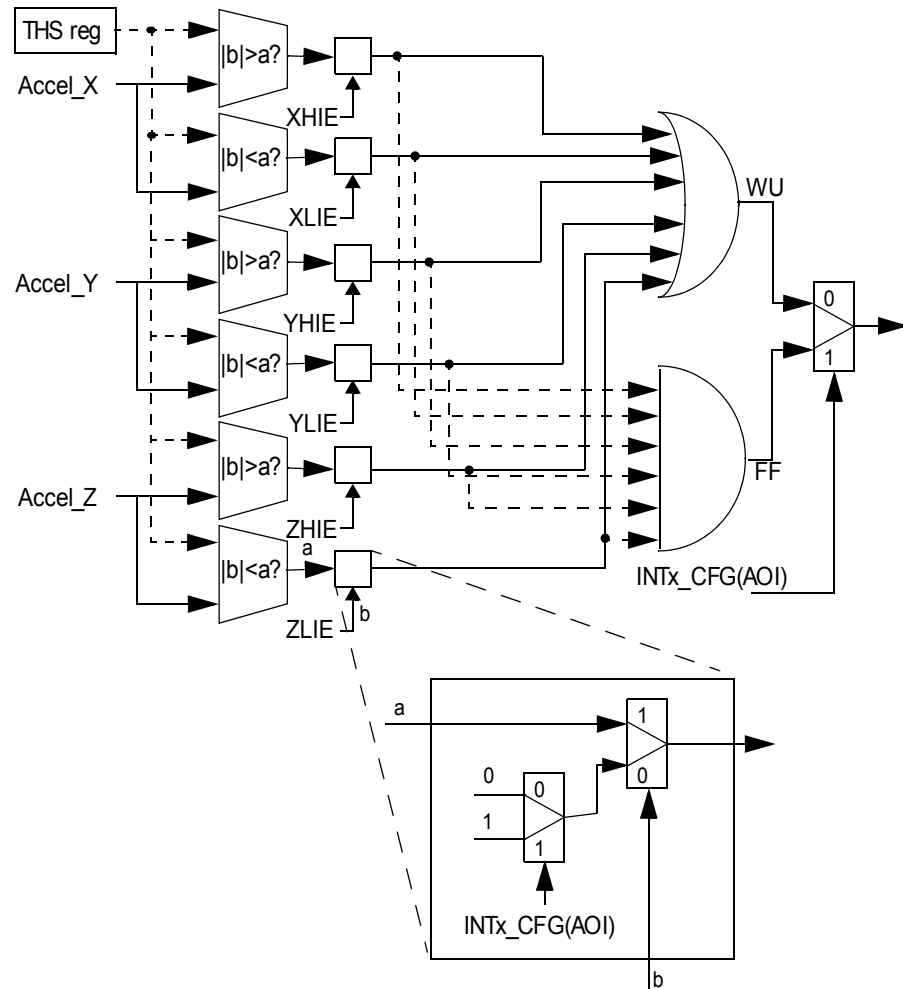
The free-fall signal (FF) and wake-up signal (WU) interrupt generation block is represented in [Figure 9. Free-fall, wake-up interrupt generator](#).

FF or WU interrupt generation is selected through the AOI bit in the INTx\_CFG register. If the AOI bit is '0', signals coming from comparators are put in logical "OR". Depending on the values written in the INT1\_CFG register, every time the value of at least one of the enabled axes exceeds the threshold written in the module in the INTx\_THS registers, a WU interrupt is generated. Otherwise, if the AOI bit is '1', signals coming from the comparators go into an "AND" port. In this case, an interrupt signal is generated only if all the enabled axes exceed the threshold written in the INTx\_THS register.

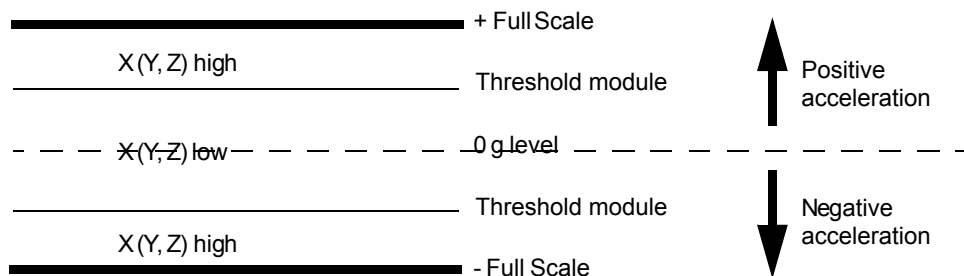
The LIRx bits of the CTRL\_REG3 can be used to determine whether or not the interrupt request must be latched. If the LIRx bit is '0' (default value), the interrupt signal goes high when the interrupt condition is satisfied and immediately returns low if the interrupt condition is no longer verified. Otherwise, if the LIRx bit is '1', when an interrupt condition is applied, the interrupt signal remains high even if the condition returns to a non-interrupt status, until a read operation of the INTx\_SRC register is performed.

The ZHIE, ZLIE, YHIE, YLIE, XHIE and HLIE bits of the INTx\_CFG register select on which axis the interrupt decision must be performed, and in which direction the threshold must be exceeded to generate the interrupt request.



**Figure 9. Free-fall, wake-up interrupt generator**


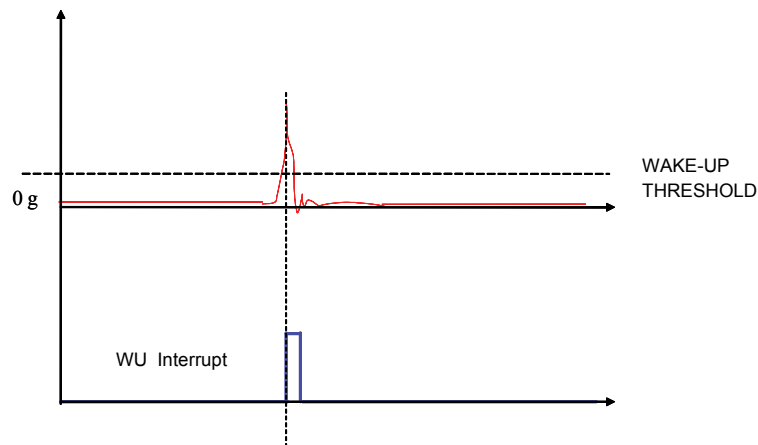
The threshold module which is used by the system to detect free-fall or inertial wake-up events is defined by the INTx\_THS registers. The threshold value is expressed over 7 bits as an unsigned number and is symmetrical around the zero-g level. XH (YH, ZH) is true when the unsigned acceleration value of the X (Y, Z) channel is higher than INTx\_THS. Similarly, XL, (YL, ZL) low is true when the unsigned acceleration value of the X (Y, Z) channel is lower than INTx\_THS. Refer to the following figure for additional details.

**Figure 10. FF\_WU\_CFG high and low**


## 6.4 Inertial wake-up

The wake-up interrupt refers to a specific configuration of the INTx\_CTRL registers that allows the interrupt generation when the acceleration on the configured axis exceeds a defined threshold (refer to the following figure).

**Figure 11. Inertial wake-up interrupt**



### 6.4.1 HP filter bypassed

This paragraph provides a basic algorithm which shows the practical use of the inertial wake-up feature. In particular, with the code below, the device is configured to recognize when the absolute acceleration along either the X or Y-axis exceeds a preset threshold (250 mg used in the example). The event which triggers the interrupt is latched inside the device and its occurrence is signaled through the use of the INT1 pin.

- |  |   |
|--|---|
| <ol style="list-style-type: none"> <li>1. Write 2Fh in CTRL_REG1</li> <li>2. Write 00h in CTRL_REG2</li> <li>3. Write 00h in CTRL_REG3</li> <li>4. Write 00h in CTRL_REG4</li> <li>5. Write 00h in CTRL_REG5</li> <li>6. Write 10h in INT1_THS</li> <li>7. Write 00h in INT1_DURATION</li> <li>8. Write 0Ah in INT1_CFG</li> <li>9. Poll INT1 pad; if INT1=0 then go to 8</li> <li>10. Read INT1_SRC</li> <li>11. (Wake-up event has occurred; insert code here)</li> <li>12. Go to 8</li> </ol> | <pre> // Turn on the sensor and enable X, Y and Z // ODR = 100 Hz // High-pass filter disabled // Latched interrupt active high on INT1 pad // FS = ±2 g // Sleep-to-wake disabled // Threshold = 250 mg // Duration = 0 // Enable XH and YH interrupt generation // Poll RDY/INT pin waiting for the // wake-up event // Return the event that has triggered the // interrupt // Event handling </pre> |
|--|---|

## 6.4.2 Using the HP filter

The code which follows provides a basic routine showing the practical use of the inertial wake-up feature performed on high-pass filtered data. In particular, the device is configured to recognize when the high-frequency component of the acceleration applied along either the X, Y or Z-axis exceeds a preset threshold (250 mg is used in the example). The event which triggers the interrupt is latched inside the device and its occurrence is signaled through the INT1 pin.

```
1. Write 2Fh in CTRL_REG1 // Turn on the sensor, enable X, Y and Z
// ODR = 100 Hz
2. Write 15h in CTRL_REG2 // High-pass filter enabled on data and interrupt1
3. Write 00h in CTRL_REG3 // Latched interrupt active high on INT1 pad
4. Write 00h in CTRL_REG4 // FS = ±2 g
5. Write 00h in CTRL_REG5 // Sleep-to-wake disabled
6. Write 10h in INT1_THS // Threshold = 250 mg
7. Write 00h in INT1_DURATION // Duration = 0
// Dummy read to force the HP filter to
8. Read HP_FILTER_RESET // actual acceleration value
// (i.e. set reference acceleration/tilt value)
9. Write 2Ah in INT1_CFG // Configure desired wake-up event
// Poll INT1 pin waiting for the
10. Poll INT1 pad; if INT1 = 0 then go to 9 // wake-up event
11. (Wake-up event has occurred; insert your code here) // Event handling
// Return the event that has triggered the
12. Read INT1_SRC // interrupt and clear interrupt
13. (Insert code here) // Event handling
14. Go to 9
```

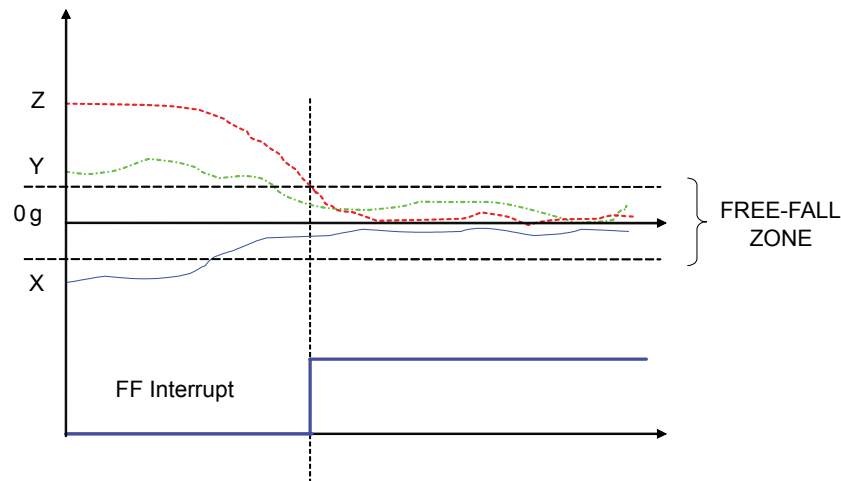
At step 8, a dummy read of the HP\_FILTER\_RESET register is performed to set the current/reference acceleration/tilt state against which the device performed the threshold comparison.

This read may be performed any time it is required to set the orientation/tilt of the device as a reference state without waiting for the filter to settle.

## 6.5 Free-fall detection

Free-fall detection refers to a specific configuration of the INTx\_CTRL registers that allows the recognition of device free-fall: the acceleration measurements along all the axes go to zero. In real cases, a “free-fall zone” is defined around the zero-g level, where all accelerations are small enough to generate the interrupt (refer to the following figure).

Figure 12. Free-fall interrupt



This paragraph provides the fundamentals for using the free-fall detection feature. In particular, the software routine which configures the device to detect and signal free-fall events is as follows:

- |     |   |  |
|-----|---|--|
| 1.  | Write 2Fh in CTRL_REG1                                | // Turn on the sensor, enable X, Y and Z         |
|     |   | // ODR = 100 Hz                                  |
| 2.  | Write 00h in CTRL_REG2                                | // High-pass filter disabled                     |
| 3.  | Write 04h in CTRL_REG3                                | // Latched interrupt on INT1                     |
| 4.  | Write 16h in INT1_THS                                 | // Set free-fall threshold = 350 mg              |
| 5.  | Write 03h in INT1_DURATION                            | // Set minimum event duration                    |
| 6.  | Write 95h in INT1_CFG                                 | // Configure free-fall recognition               |
| 7.  | Poll INT1 pad; if INT1 = 0 then go to 8               | // Poll INT1 pin waiting for the free-fall event |
| 8.  | (Free-fall event has occurred; insert your code here) | // Event handling                                |
| 9.  | Read INT1_SRC register                                | // Clear interrupt request                       |
| 10. | Go to 7   |  |

The code sample exploits a threshold set at 350 mg for free-fall recognition and the event is notified by the hardware signal INT1. At step 5, the INT1\_DURATION register is configured to ignore events that are shorter than  $3/DR = 3/100 \approx 30$  ms in order to avoid false detections.

Once the free-fall event has occurred, a read of the INT1\_SRC register clears the request and the device is ready to recognize other events.

## 6.6 6D direction

The AIS328DQ features an advanced capability to detect the orientation of the device in space. The 6D direction function can be enabled through the AOI and 6D bits of the INT1\_CFG register (Table 16). When configured for the 6D function, the ZH, ZL, YH, YL, XH, XL bits of INTx\_SRC send information about the value of the acceleration generating the interrupt when it exceeds the threshold, and whether the acceleration value is positive or negative. More specifically:

- ZH (YH, XH) is 1 when the sensed acceleration is greater than the threshold in the positive direction.
- ZL (YL, XL) is 1 when the sensed acceleration is greater than the threshold in the negative direction.

Figure 13. ZH, ZL, YH, YL, XH, XL behavior



There are two possible configurations for the 6D direction function:

- **6D movement recognition:** In this configuration the interrupt is generated when the device moves from one direction (known or unknown) to a different, known direction. The interrupt is active only for 1/ODR.
- **6D position recognition:** In this configuration the interrupt is generated when the device is stable in a known direction. The interrupt is active as long as the position is maintained, as shown in Figure 14, (a) and (b).

In Figure 14, the 6D Movement line shows the behavior of the interrupt when the device is configured for 6D Movement recognition on the X and Y axes (INT1\_CFG = 0x4Ah), while the 6D Position line shows the behavior of the interrupt when the device is configured for 6D Position recognition on the X and Y axes (INT1\_CFG = 0xCAh). INT1\_THS is set to 0x21.

With reference to Figure 15, the device has been configured for the 6D Position function on the X, Y and Z axes. Table 20 shows the content of the INT1\_SRC register for each position.

Figure 14. 6D movement vs. 6D position

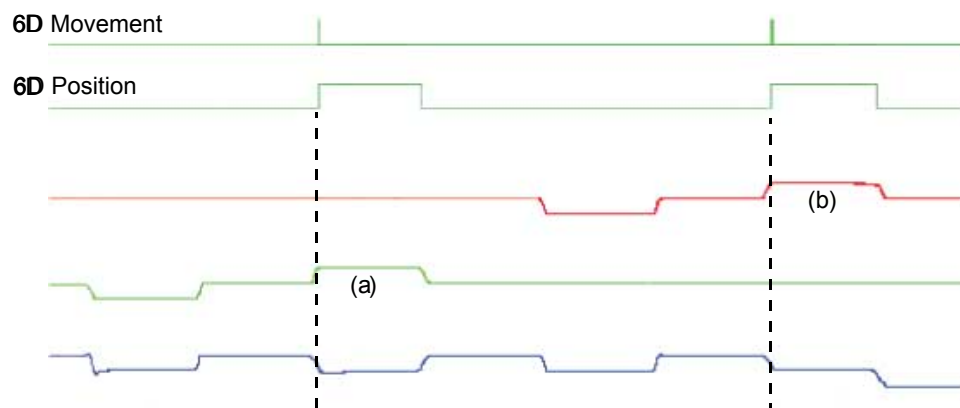


Figure 15. 6D recognized positions

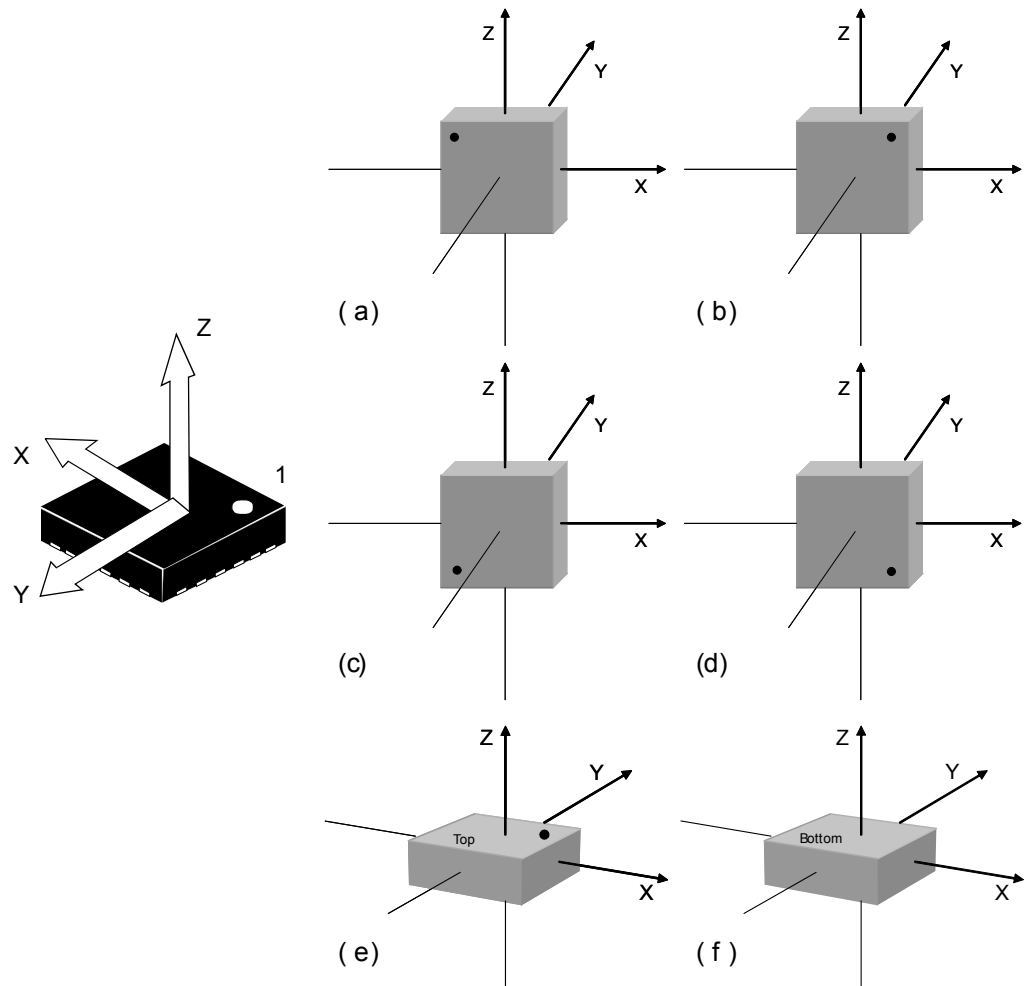


Table 20. INTx\_SRC register in 6D position

Case	IA	ZH	ZL	YH	YL	XH	XL
(a)	1	0	0	0	0	0	1
(b)	1	0	0	0	1	0	0
(c)	1	0	0	1	0	0	0
(d)	1	0	0	0	0	1	0
(e)	1	1	0	0	0	0	0
(f)	1	0	1	0	0	0	0

## 7 Self-test

The embedded self-test functions allow checking device functionality without moving it.

When the self-test is enabled, an actuation force is applied to the sensor, leading to a deflection of the moveable part of the sensor. In this case the sensor outputs exhibit a change in their DC levels which are related to the selected full scale through the sensitivity value.

The self-test function is off when the ST bit of the CTRL\_REG4 register is programmed to 0; it is enabled when the ST bit is set to 1. The STsign bit of the CTRL\_REG4 register can be used to configure the self-test sign: 0 for positive sign self-test, 1 for negative sign self-test.

When the self-test is activated, the sensor output level is given by the algebraic sum of the data produced by the electrostatic test-force.

The procedure consists of:

1. enabling the accelerometer
2. averaging five samples before enabling the self-test
3. averaging five samples after enabling the self-test
4. computing the difference in absolute value for each axis and verifying that it falls within a given range. The reference range is given in the following table:

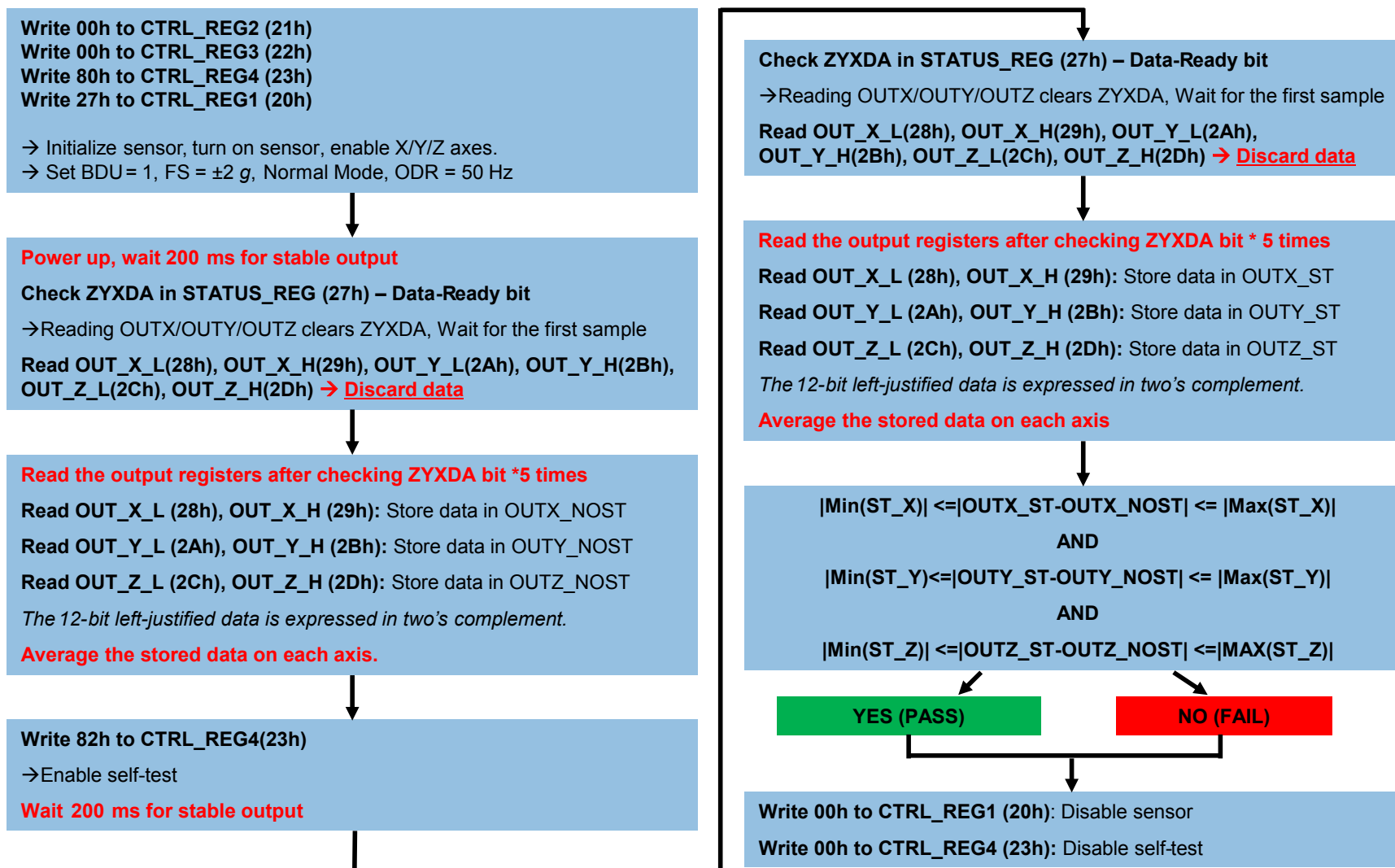
**Table 21. Reference range**

Min (@ Vmin)	X = -183 lsb	Y = 183 lsb	Z = 102 lsb
Max (@ Vmax)	X = -1510 lsb	Y = 1510 lsb	Z = 1326 lsb

The complete accelerometer self-test procedure is indicated in [Figure 16. Self-test procedure](#).

*Note:* *Keep the device still during the self-test procedure.*

Figure 16. Self-test procedure





## Revision history

**Table 22. Document revision history**

Date	Revision	Changes
02-Feb-2018	1	Initial release
08-Oct-2018	2	Updated <a href="#">Introduction</a> Updated <a href="#">Section 3.4 Understanding acceleration data</a> Updated acceleration values in <a href="#">Table 6. Output data register content vs. acceleration (FS = ±2 g)</a> Updated <a href="#">Section 6.3 Free-fall and wake-up interrupts</a>

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