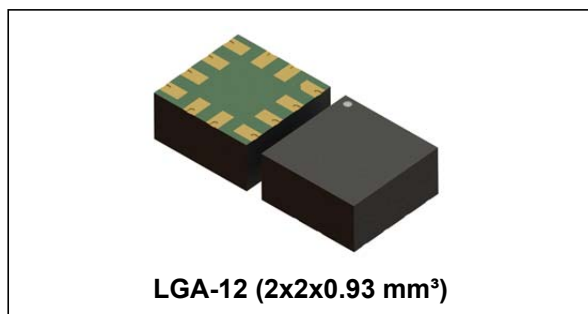


## MEMS digital output motion sensor: ultra-low-power 3-axis accelerometer for automotive applications

Datasheet - production data



### Features



- AEC-Q100 qualified
- Supply voltage, 1.62 V to 3.6 V
- Independent IO supply and supply voltage compatible
- Ultra-low-power mode consumption down to 380 nA @1.6 Hz
- $\pm 2g/\pm 4g$  dynamically selectable full scales
- High-speed I<sup>2</sup>C/SPI digital output interface
- 2 independent programmable interrupts
- Single data conversion on demand
- 16-bit data output
- Embedded temperature sensor
- Self-test
- 32-level embedded FIFO
- 10000 g high shock survivability
- ECOPACK, RoHS and “Green” compliant

### Applications

- Car key applications
- Inclination / orientation detection
- Motion-activated functions
- Gesture recognition
- Free-fall detection
- Smart power saving

### Description

The AIS2DW12 is an ultra-low-power three-axis linear accelerometer which leverages on the robust and mature manufacturing processes already used for the production of micromachined accelerometers and designed to address non-safety automotive applications.

The AIS2DW12 has four different ultra-low-power modes, two user-selectable full scales ( $\pm 2g/\pm 4g$ ) and is capable of measuring accelerations with output data rates from 1.6 Hz to 100 Hz.

The AIS2DW12 has an integrated 32-level first-in, first-out (FIFO) buffer allowing the user to store data in order to limit intervention by the host processor.

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

The AIS2DW12 has a dedicated internal engine to process motion and acceleration detection including free-fall, motion and no-motion, wakeup, activity/inactivity and 6D/4D orientation.

The AIS2DW12 is available in a small thin plastic land grid array package (LGA) and it is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

Table 1. Device summary

| Order codes | Temp. range [°C] | Package | Packaging     |
|-------------|------------------|---------|---------------|
| AIS2DW12    | -40 to +85       | LGA-12  | Tray          |
| AIS2DW12TR  | -40 to +85       | LGA-12  | Tape and reel |

# Contents

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Block diagram and pin description</b>                   | <b>8</b>  |
| 1.1      | Block diagram  | 8         |
| 1.2      | Pin description  | 9         |
| <b>2</b> | <b>Mechanical and electrical specifications</b>            | <b>11</b> |
| 2.1      | Mechanical characteristics                                 | 11        |
| 2.2      | Electrical characteristics                                 | 12        |
| 2.3      | Temperature sensor characteristics                         | 13        |
| 2.4      | Communication interface characteristics                    | 14        |
| 2.4.1    | SPI - serial peripheral interface                          | 14        |
| 2.4.2    | I <sup>2</sup> C - inter-IC control interface              | 15        |
| 2.5      | Absolute maximum ratings                                   | 17        |
| <b>3</b> | <b>Terminology and functionality</b>                       | <b>18</b> |
| 3.1      | Terminology  | 18        |
| 3.1.1    | Sensitivity  | 18        |
| 3.1.2    | Zero-g level offset  | 18        |
| 3.2      | Functionality  | 19        |
| 3.2.1    | Operating modes  | 19        |
| 3.2.2    | Single data conversion on-demand mode                      | 19        |
| 3.2.3    | Self-test  | 20        |
| 3.2.4    | Activity/Inactivity, stationary/motion detection functions | 20        |
| 3.2.5    | Offset management  | 21        |
| 3.3      | Sensing element  | 21        |
| 3.4      | IC interface   | 22        |
| 3.5      | Factory calibration  | 22        |
| 3.6      | Temperature sensor   | 22        |
| <b>4</b> | <b>Application hints</b>                                   | <b>23</b> |
| <b>5</b> | <b>Digital main blocks</b>                                 | <b>25</b> |
| 5.1      | Block diagram of filters                                   | 25        |
| 5.2      | FIFO   | 26        |

|          |                                   |           |
|----------|-----------------------------------|-----------|
| 5.2.1    | Bypass mode                       | 27        |
| 5.2.2    | FIFO mode                         | 27        |
| 5.2.3    | Continuous mode                   | 27        |
| 5.2.4    | Continuous-to-FIFO mode           | 28        |
| 5.2.5    | Bypass-to-Continuous mode         | 29        |
| <b>6</b> | <b>Digital interfaces</b>         | <b>30</b> |
| 6.1      | I <sup>2</sup> C serial interface | 30        |
| 6.1.1    | I <sup>2</sup> C operation        | 31        |
| 6.2      | SPI bus interface                 | 33        |
| 6.2.1    | SPI read                          | 34        |
| 6.2.2    | SPI write                         | 35        |
| 6.2.3    | SPI read in 3-wire mode           | 36        |
| <b>7</b> | <b>Register mapping</b>           | <b>37</b> |
| <b>8</b> | <b>Register description</b>       | <b>39</b> |
| 8.1      | OUT_T_L (0Dh)                     | 39        |
| 8.2      | OUT_T_H (0Eh)                     | 39        |
| 8.3      | WHO_AM_I (0Fh)                    | 39        |
| 8.4      | CTRL1 (20h)                       | 40        |
| 8.5      | CTRL2 (21h)                       | 41        |
| 8.6      | CTRL3 (22h)                       | 42        |
| 8.7      | CTRL4_INT1 (23h)                  | 43        |
| 8.8      | CTRL5_INT2 (24h)                  | 44        |
| 8.9      | CTRL6 (25h)                       | 45        |
| 8.10     | OUT_T (26h)                       | 46        |
| 8.11     | STATUS (27h)                      | 46        |
| 8.12     | OUT_X_L (28h)                     | 47        |
| 8.13     | OUT_X_H (29h)                     | 47        |
| 8.14     | OUT_Y_L (2Ah)                     | 47        |
| 8.15     | OUT_Y_H (2Bh)                     | 47        |
| 8.16     | OUT_Z_L (2Ch)                     | 48        |
| 8.17     | OUT_Z_H (2Dh)                     | 48        |
| 8.18     | FIFO_CTRL (2Eh)                   | 48        |

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|           |                                  |           |
|-----------|----------------------------------|-----------|
| 8.19      | FIFO_SAMPLES (2Fh) .....         | 49        |
| 8.20      | SIXD_THS (30h) .....             | 49        |
| 8.21      | WAKE_UP_THS (34h) .....          | 50        |
| 8.22      | WAKE_UP_DUR (35h) .....          | 50        |
| 8.23      | FREE_FALL (36h) .....            | 51        |
| 8.24      | STATUS_DUP (37h) .....           | 52        |
| 8.25      | WAKE_UP_SRC (38h) .....          | 53        |
| 8.26      | SIXD_SRC (3Ah) .....             | 53        |
| 8.27      | ALL_INT_SRC (3Bh) .....          | 54        |
| 8.28      | X_OFS_USR (3Ch) .....            | 54        |
| 8.29      | Y_OFS_USR (3Dh) .....            | 54        |
| 8.30      | Z_OFS_USR (3Eh) .....            | 55        |
| 8.31      | CTRL7 (3Fh) .....                | 55        |
| <b>9</b>  | <b>Package information .....</b> | <b>56</b> |
| 9.1       | Soldering information .....      | 56        |
| 9.2       | LGA-12 package information ..... | 56        |
| 9.3       | LGA-12 packing information ..... | 57        |
| <b>10</b> | <b>Revision history .....</b>    | <b>59</b> |

## List of tables

|           |   |    |
|-----------|---|----|
| Table 1.  | Device summary . . . . .  | 1  |
| Table 2.  | Pin description . . . . .   | 9  |
| Table 3.  | Internal pull-up values (typ.) for SDO/SA0 and CS pins . . . . .                              | 10 |
| Table 4.  | Mechanical characteristics @ Vdd = 3.0 V, T = -40°C to +85°C unless otherwise noted . . . . . | 11 |
| Table 5.  | Electrical characteristics @ Vdd = 3.0 V, T = -40°C to +85°C unless otherwise noted . . . . . | 12 |
| Table 6.  | Temperature sensor characteristics . . . . .  | 13 |
| Table 7.  | SPI slave timing values . . . . .   | 14 |
| Table 8.  | I <sup>2</sup> C slave timing values . . . . .  | 15 |
| Table 9.  | I <sup>2</sup> C high-speed mode specifications at 1 MHz and 3.4 MHz . . . . .                | 16 |
| Table 10. | Absolute maximum ratings . . . . .  | 17 |
| Table 11. | Operating modes . . . . .   | 19 |
| Table 12. | Internal pin status . . . . .   | 24 |
| Table 13. | Serial interface pin description . . . . .  | 30 |
| Table 14. | I <sup>2</sup> C terminology . . . . .  | 30 |
| Table 15. | SAD+Read/Write patterns . . . . .   | 31 |
| Table 16. | Transfer when master is writing one byte to slave . . . . .                                   | 32 |
| Table 17. | Transfer when master is writing multiple bytes to slave . . . . .                             | 32 |
| Table 18. | Transfer when master is receiving (reading) one byte of data from slave . . . . .             | 32 |
| Table 19. | Transfer when master is receiving (reading) multiple bytes of data from slave . . . . .       | 32 |
| Table 20. | Register map . . . . .  | 37 |
| Table 21. | OUT_T_L register . . . . .  | 39 |
| Table 22. | OUT_T_L register description . . . . .  | 39 |
| Table 23. | OUT_T_H register . . . . .  | 39 |
| Table 24. | OUT_T_H register description . . . . .  | 39 |
| Table 25. | WHO_AM_I register default values . . . . .  | 39 |
| Table 26. | Control register 1 . . . . .  | 40 |
| Table 27. | Control register 1 description . . . . .  | 40 |
| Table 28. | Data rate configuration . . . . .   | 40 |
| Table 29. | Operating mode selection . . . . .  | 40 |
| Table 30. | Power mode selection . . . . .  | 40 |
| Table 31. | Control register 2 . . . . .  | 41 |
| Table 32. | Control register 2 description . . . . .  | 41 |
| Table 33. | Control register 3 . . . . .  | 42 |
| Table 34. | Control register 3 description . . . . .  | 42 |
| Table 35. | Self-test mode selection . . . . .  | 42 |
| Table 36. | Control register 4 . . . . .  | 43 |
| Table 37. | Control register 4 description . . . . .  | 43 |
| Table 38. | Control register 5 . . . . .  | 44 |
| Table 39. | Control register 5 description . . . . .  | 44 |
| Table 40. | Control register 6 . . . . .  | 45 |
| Table 41. | Control register 6 description . . . . .  | 45 |
| Table 42. | Digital filtering cutoff selection (FDS bit set to '0') . . . . .                             | 45 |
| Table 43. | LPF1 cutoff (FDS bit set to '0') . . . . .  | 45 |
| Table 44. | Digital high-pass filter cutoff selection (FDS bit set to '1') . . . . .                      | 45 |
| Table 45. | Full-scale selection . . . . .  | 45 |
| Table 46. | OUT_T register . . . . .  | 46 |
| Table 47. | OUT_T register description . . . . .  | 46 |
| Table 48. | STATUS register . . . . .   | 46 |

|           |  |    |
|-----------|--|----|
| Table 49. | STATUS register description . . . . .                        | 46 |
| Table 50. | OUT_X_L register . . . . .                                   | 47 |
| Table 51. | OUT_X_H register . . . . .                                   | 47 |
| Table 52. | OUT_Y_L register . . . . .                                   | 47 |
| Table 53. | OUT_Y_H register . . . . .                                   | 47 |
| Table 54. | OUT_Z_L register . . . . .                                   | 48 |
| Table 55. | OUT_Z_H register . . . . .                                   | 48 |
| Table 56. | FIFO_CTRL register . . . . .                                 | 48 |
| Table 57. | FIFO_CTRL register description . . . . .                     | 48 |
| Table 58. | FIFO mode selection . . . . .                                | 48 |
| Table 59. | FIFO_SAMPLES register . . . . .                              | 49 |
| Table 60. | FIFO_SAMPLES register description . . . . .                  | 49 |
| Table 61. | SIXD_THS register . . . . .                                  | 49 |
| Table 62. | SIXD_THS register description . . . . .                      | 49 |
| Table 63. | 4D/6D threshold setting FS @ $\pm 2$ g . . . . .             | 49 |
| Table 64. | WAKE_UP_THS register . . . . .                               | 50 |
| Table 65. | WAKE_UP_THS register description . . . . .                   | 50 |
| Table 66. | WAKE_UP_DUR register . . . . .                               | 50 |
| Table 67. | WAKE_UP_DUR register description . . . . .                   | 50 |
| Table 68. | FREE_FALL register . . . . .                                 | 51 |
| Table 69. | FREE_FALL register description . . . . .                     | 51 |
| Table 70. | FREE_FALL threshold decoding @ $\pm 2$ g FS . . . . .        | 51 |
| Table 71. | STATUS_DUP register . . . . .                                | 52 |
| Table 72. | STATUS_DUP register description . . . . .                    | 52 |
| Table 73. | WAKE_UP_SRC register . . . . .                               | 53 |
| Table 74. | WAKE_UP_SRC register description . . . . .                   | 53 |
| Table 75. | SIXD_SRC register . . . . .                                  | 53 |
| Table 76. | SIXD_SRC register description . . . . .                      | 53 |
| Table 77. | ALL_INT_SRC register . . . . .                               | 54 |
| Table 78. | ALL_INT_SRC register description . . . . .                   | 54 |
| Table 79. | X_OFS_USR register . . . . .                                 | 54 |
| Table 80. | X_OFS_USR register description . . . . .                     | 54 |
| Table 81. | Y_OFS_USR register . . . . .                                 | 54 |
| Table 82. | Y_OFS_USR register description . . . . .                     | 54 |
| Table 83. | Z_OFS_USR register . . . . .                                 | 55 |
| Table 84. | Z_OFS_USR register description . . . . .                     | 55 |
| Table 85. | CTRL7 register . . . . .                                     | 55 |
| Table 86. | CTRL7 register description . . . . .                         | 55 |
| Table 87. | Reel dimensions for carrier tape of LGA-12 package . . . . . | 58 |
| Table 88. | Document revision history . . . . .                          | 59 |

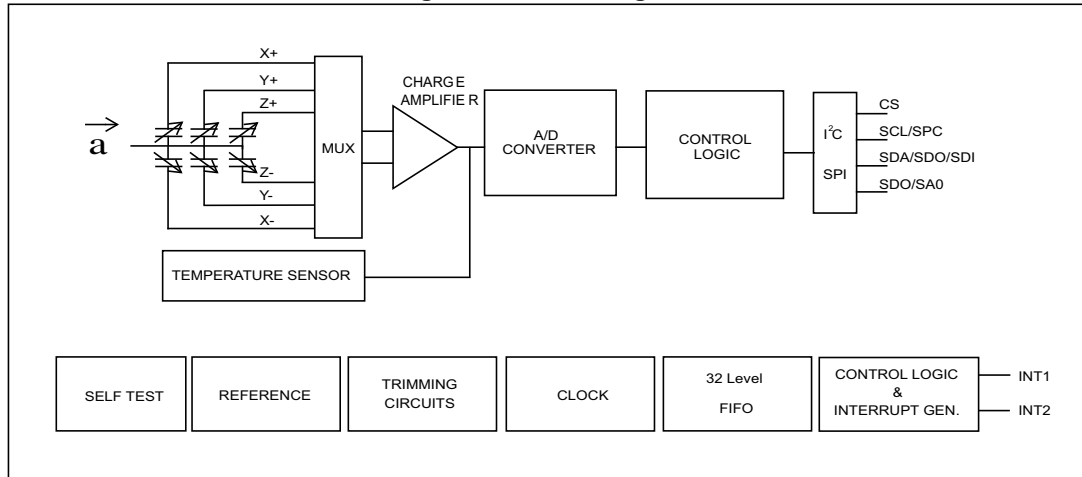
## List of figures

|            |   |    |
|------------|---|----|
| Figure 1.  | Block diagram . . . . .   | 8  |
| Figure 2.  | Pin connections . . . . .   | 9  |
| Figure 3.  | SPI slave timing diagram . . . . .                                      | 14 |
| Figure 4.  | I <sup>2</sup> C slave timing diagram . . . . .                         | 15 |
| Figure 5.  | Single data conversion on demand functionality. . . . .                 | 20 |
| Figure 6.  | AIS2DW12 electrical connections (top view) . . . . .                    | 23 |
| Figure 7.  | Accelerometer chain . . . . .   | 25 |
| Figure 8.  | Continuous-to-FIFO mode . . . . .                                       | 28 |
| Figure 9.  | Trigger event to FIFO for Continuous-to-FIFO mode . . . . .             | 28 |
| Figure 10. | Bypass-to-Continuous mode. . . . .                                      | 29 |
| Figure 11. | Trigger event to FIFO for Bypass-to-Continuous mode . . . . .           | 29 |
| Figure 12. | Read and write protocol . . . . .                                       | 33 |
| Figure 13. | SPI read protocol . . . . .   | 34 |
| Figure 14. | Multiple byte SPI read protocol (2-byte example). . . . .               | 34 |
| Figure 15. | SPI write protocol . . . . .  | 35 |
| Figure 16. | Multiple byte SPI write protocol (2-byte example). . . . .              | 35 |
| Figure 17. | SPI read protocol in 3-wire mode . . . . .                              | 36 |
| Figure 18. | LGA-12 2.0 x 2.0 x 0.93 mm package outline and mechanical data. . . . . | 56 |
| Figure 19. | Carrier tape information for LGA-12 package. . . . .                    | 57 |
| Figure 20. | LGA-12 package orientation in carrier tape . . . . .                    | 57 |
| Figure 21. | Reel information for carrier tape of LGA-12 package . . . . .           | 58 |

# 1 Block diagram and pin description

## 1.1 Block diagram

Figure 1. Block diagram





## 1.2 Pin description

Figure 2. Pin connections

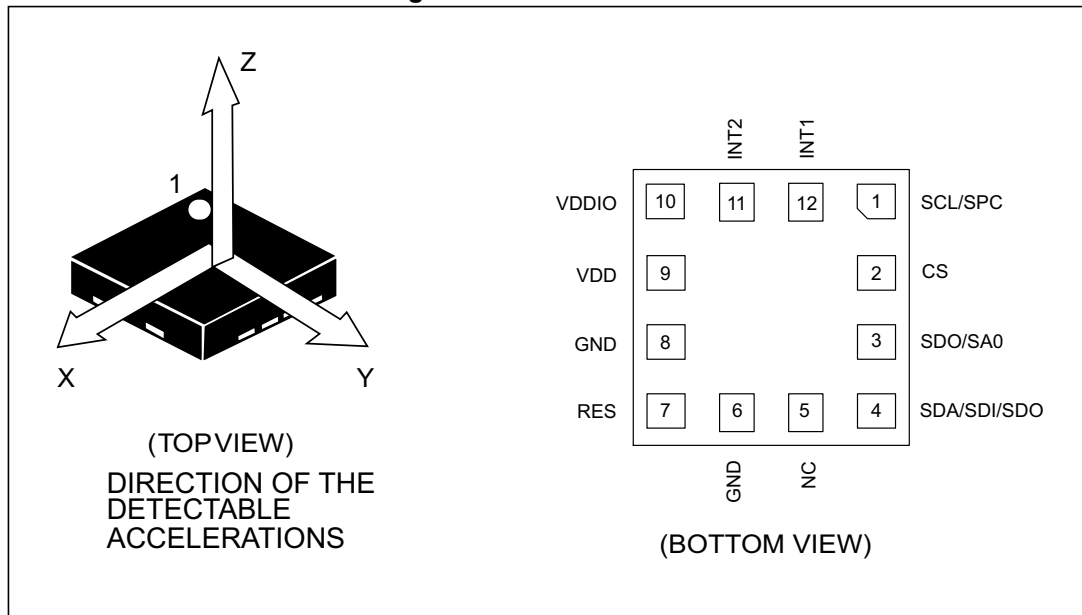


Table 2. Pin description

| Pin#             | Name              | Function   |
|------------------|-------------------|--|
| 1                | SCL<br>SPC        | I <sup>2</sup> C serial clock (SCL)<br>SPI serial port clock (SPC)   |
| 2 <sup>(1)</sup> | CS                | SPI enable<br>I <sup>2</sup> C/SPI mode selection (1: SPI idle mode / I <sup>2</sup> C communication enabled; 0: SPI communication mode / I <sup>2</sup> C disabled) |
| 3 <sup>(1)</sup> | SDO<br>SA0        | SPI serial data output (SDO)<br>I <sup>2</sup> C less significant bit of the device address (SA0)  |
| 4                | SDA<br>SDI<br>SDO | I <sup>2</sup> C serial data (SDA)<br>SPI serial data input (SDI)<br>3-wire interface serial data output (SDO)   |
| 5                | NC                | Internally not connected. Can be tied to VDD, VDDIO, or GND.   |
| 6                | GND               | 0 V supply   |
| 7                | RES               | Connect to GND   |
| 8                | GND               | 0 V supply   |
| 9                | VDD               | Power supply   |
| 10               | VDD_IO            | Power supply for I/O pins  |
| 11               | INT2              | Interrupt pin 2. Clock input when selected in single data conversion on demand.  |
| 12               | INT1              | Interrupt pin 1  |

1. SDO/SA0 and CS pins are internally pulled up. Refer to [Table 3](#) for the internal pull-up values (typ).

Table 3. Internal pull-up values (typ.) for SDO/SA0 and CS pins

| Vdd_IO | Resistor value for SDO/SA0 and CS pins |
|--------|--|
|        | Typ. (k $\Omega$ )                     |
| 1.7 V  | 54.4                                   |
| 1.8 V  | 49.2                                   |
| 2.5 V  | 30.4                                   |
| 3.6 V  | 20.4                                   |

## 2 Mechanical and electrical specifications

### 2.1 Mechanical characteristics

Table 4. Mechanical characteristics @ Vdd = 3.0 V, T = -40°C to +85°C unless otherwise noted <sup>(1)</sup>

| Symbol | Parameter  | Test conditions                                   | Min.  | Typ. <sup>(2)</sup> | Max.  | Unit     |
|--------|--|---|-------|---------------------|-------|----------|
| FS     | Measurement range                                      |   |       | ±2                  |       | g        |
|        |  |   |       | ±4                  |       |          |
| So     | Sensitivity (long term) <sup>(3)</sup>                 | @ FS ±2 g<br>For all power modes<br>except Mode 1 | 0.207 | 0.244               | 0.281 | mg/digit |
|        |  | @ FS ±4 g<br>For all power modes<br>except Mode 1 | 0.415 | 0.488               | 0.561 |          |
|        |  | @ FS ±2 g<br>in Power Mode 1                      | 0.829 | 0.976               | 1.122 |          |
|        |  | @ FS ±4 g<br>in Power Mode 1                      | 1.659 | 1.952               | 2.245 |          |
| RMS    | RMS noise <sup>(4)</sup><br>@ FS ±2 g                  | Power Mode 4                                      |       | 1.6                 | 2.9   | mg(RMS)  |
|        |  | Power Mode 3                                      |       | 2.1                 | 3.8   |          |
|        |  | Power Mode 2                                      |       | 3.0                 | 5.7   |          |
|        |  | Power Mode 1                                      |       | 5.5                 | 11.0  |          |
| TyOff  | Zero-g level offset accuracy <sup>(5)</sup>            |   |       | ±20                 |       | mg       |
|        | Zero-g level offset accuracy, long term <sup>(3)</sup> |   | -700  |                     | 700   |          |
| TCO    | Zero-g offset change vs. temperature                   |   |       | ±0.2                |       | mg/°C    |
| TCS    | Sensitivity change vs. temperature                     |   |       | 0.01                |       | %/°C     |
| ST     | Self-test positive difference                          | @ 25°C  | 70    |                     | 1500  | mg       |

1. The product is factory calibrated at 3.0 V. The operational power supply range is from 1.62 V to 3.6 V.
2. Typical specifications are not guaranteed.
3. Long term includes the following contributions: post solder, drift in temperature in the range [-40 deg; +85 deg] and over life.
4. RMS noise is the same for all ODRs, max values from design and characterization at ambient temperature
5. Values after factory calibration test and trimming.

## 2.2 Electrical characteristics

**Table 5. Electrical characteristics @ Vdd = 3.0 V, T = -40°C to +85°C unless otherwise noted <sup>(1)</sup>**

| Symbol          | Parameter                              | Test conditions                             | Min.           | Typ. <sup>(2)</sup> | Max.       | Unit |
|-----------------|--|---|----------------|---------------------|------------|------|
| Vdd             | Supply voltage                         |   | 1.62           |                     | 3.6        | V    |
| Vdd_IO          | I/O pins supply voltage <sup>(3)</sup> |   | 1.62           |                     | Vdd+0.1    | V    |
| IddLP           | Current consumption in Power Mode 1    | ODR 100 Hz<br>@ Vdd = 1.8 V <sup>(4)</sup>  |                | 5                   |            | μA   |
|                 |  | ODR 50 Hz<br>@ Vdd = 1.8 V <sup>(4)</sup>   |                | 3                   |            |      |
|                 |  | ODR 12.5 Hz<br>@ Vdd = 1.8 V <sup>(4)</sup> |                | 1                   |            |      |
|                 |  | ODR 1.6 Hz<br>@Vdd = 1.8 V <sup>(4)</sup>   |                | 0.38                |            |      |
|                 |  | ODR 100 Hz<br>@ Vdd = 3 V                   |                | 6.5                 | 12.0       |      |
|                 |  | ODR 50 Hz<br>@ Vdd = 3 V <sup>(4)</sup>     |                | 3.7                 | 6.4        |      |
|                 |  | ODR 12.5 Hz<br>@ Vdd = 3 V <sup>(4)</sup>   |                | 1.3                 | 2.9        |      |
|                 |  | ODR 1.6 Hz<br>@ Vdd = 3 V <sup>(4)</sup>    |                | 0.67                | 1.9        |      |
| Idd_PD          | Current consumption in power-down      | @ Vdd = 1.8 V <sup>(4)</sup>                |                | 50                  |            | nA   |
|                 |  | @ Vdd = 3 V                                 |                | 100                 | 950        |      |
| V <sub>IH</sub> | Digital high-level input voltage       |   | 0.8*Vdd_IO     |                     |            | V    |
| V <sub>IL</sub> | Digital low-level input voltage        |   |                |                     | 0.2*Vdd_IO | V    |
| V <sub>OH</sub> | Digital high-level output voltage      | I <sub>OH</sub> = 4 mA <sup>(5)</sup>       | VDD_IO - 0.2 V |                     |            |      |
| V <sub>OL</sub> | Digital low-level output voltage       | I <sub>OL</sub> = 4 mA <sup>(5)</sup>       |                |                     | 0.2 V      |      |

1. The product is factory calibrated at 3.0 V. The operational power supply range is from 1.62 V to 3.6 V.
2. Typical specifications are not guaranteed.
3. It is possible to remove Vdd maintaining Vdd\_IO without blocking the communication busses. In this condition the measurement chain is powered off.
4. Verified at characterization level in Power Mode 1 configuration.
5. 4 mA is the maximum driving capability, ie. the maximum DC current that can be sourced/sunk by the digital pad in order to guarantee the correct digital output voltage levels V<sub>OH</sub> and V<sub>OL</sub>.

## 2.3 Temperature sensor characteristics

@ V<sub>dd</sub> = 1.8 V, T = 25 °C unless otherwise noted

**Table 6. Temperature sensor characteristics**

| Symbol | Parameter  | Min. | Typ. <sup>(1)</sup> | Max. | Unit   |
|--------|--|------|---------------------|------|--------|
| Top    | Operating temperature range                                | -40  |                     | +85  | °C     |
| Toff   | Temperature offset <sup>(2)</sup>                          | -15  |                     | +15  | °C     |
| TSDr   | Temperature sensor output change vs. temperature           |      | 1 <sup>(3)</sup>    |      | LSB/°C |
|        |  |      | 16 <sup>(4)</sup>   |      |        |
| TODR   | Temperature refresh rate for ODRs equal to 100Hz and 50 Hz |      | 50                  |      | Hz     |
|        | Temperature refresh rate for ODR equal to 25 Hz            |      | 25                  |      |        |
|        | Temperature refresh rate for ODR equal to 12.5 Hz          |      | 12.5                |      |        |
|        | Temperature refresh rate for ODR equal to 1.6 Hz           |      | 1.6                 |      |        |

1. Typical specifications are not guaranteed.
2. The output of the temperature sensor is 0 LSB (typ.) at 25 °C.
3. 8-bit resolution.
4. 12-bit resolution.

## 2.4 Communication interface characteristics

### 2.4.1 SPI - serial peripheral interface

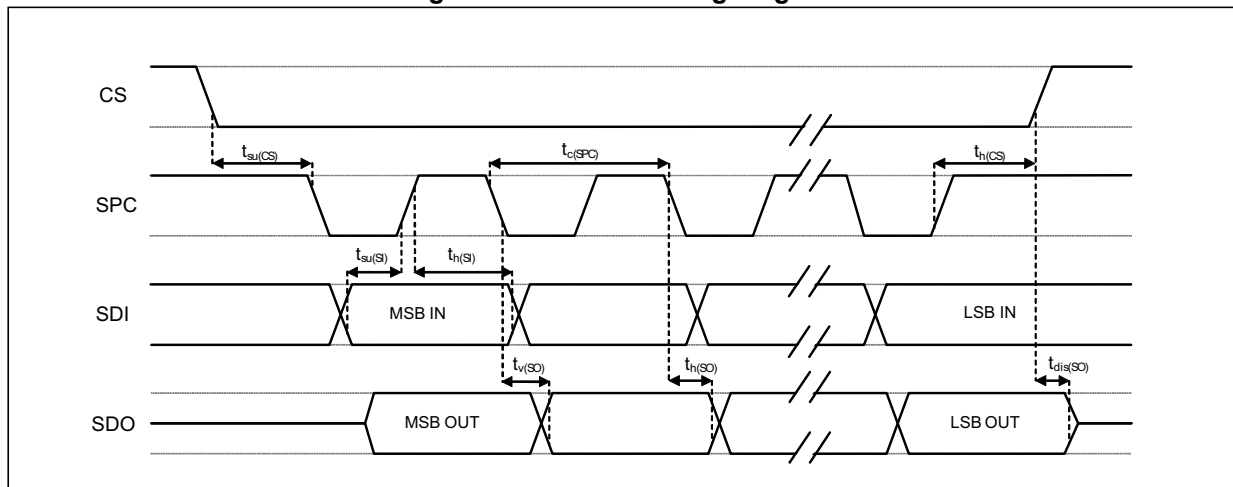
Subject to general operating conditions for Vdd and Top.

Table 7. SPI slave timing values

| Symbol        | Parameter               | Value <sup>(1)</sup> |     | Unit |
|---------------|-------------------------|----------------------|-----|------|
|               |                         | Min                  | Max |      |
| $t_{c(SPC)}$  | SPI clock cycle         | 100                  |     | ns   |
| $f_{c(SPC)}$  | SPI clock frequency     |                      | 10  | MHz  |
| $t_{su(CS)}$  | CS setup time           | 6                    |     | ns   |
| $t_{h(CS)}$   | CS hold time            | 8                    |     |      |
| $t_{su(SI)}$  | SDI input setup time    | 12                   |     |      |
| $t_{h(SI)}$   | SDI input hold time     | 15                   |     |      |
| $t_{v(SO)}$   | SDO valid output time   |                      | 50  |      |
| $t_{h(SO)}$   | SDO output hold time    | 9                    |     |      |
| $t_{dis(SO)}$ | SDO output disable time |                      | 50  |      |

1. 10 MHz clock frequency for SPI with both 4 and 3 wires, based on characterization results, not tested in production.

Figure 3. SPI slave timing diagram



Note: Measurement points are done at  $0.2 \cdot V_{dd\_IO}$  and  $0.8 \cdot V_{dd\_IO}$ , for both input and output ports.

### 2.4.2 I<sup>2</sup>C - inter-IC control interface

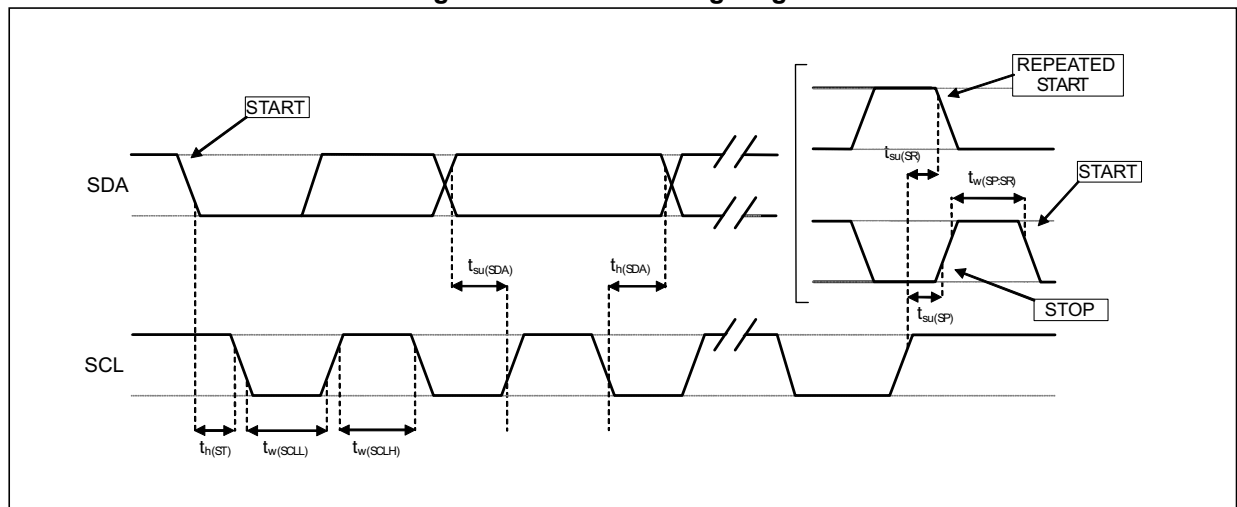
Subject to general operating conditions for Vdd and Top.

**Table 8. I<sup>2</sup>C slave timing values**

| Symbol                | Parameter                                      | I <sup>2</sup> C standard mode <sup>(1)</sup> |      | I <sup>2</sup> C fast mode <sup>(1)</sup> |     | Unit |
|-----------------------|--|---|------|---|-----|------|
|                       |  | Min   | Max  | Min                                       | Max |      |
| f <sub>(SCL)</sub>    | SCL clock frequency                            | 0   | 100  | 0   | 400 | kHz  |
| t <sub>w(SCLL)</sub>  | SCL clock low time                             | 4.7   |      | 1.3                                       |     | μs   |
| t <sub>w(SCLH)</sub>  | SCL clock high time                            | 4.0   |      | 0.6                                       |     |      |
| t <sub>su(SDA)</sub>  | SDA setup time                                 | 250   |      | 100                                       |     | ns   |
| t <sub>h(SDA)</sub>   | SDA data hold time                             | 0.01  | 3.45 | 0.01                                      | 0.9 | μs   |
| t <sub>h(ST)</sub>    | START condition hold time                      | 4   |      | 0.6                                       |     | μs   |
| t <sub>su(SR)</sub>   | Repeated START condition setup time            | 4.7   |      | 0.6                                       |     |      |
| t <sub>su(SP)</sub>   | STOP condition setup time                      | 4   |      | 0.6                                       |     |      |
| t <sub>w(SP:SR)</sub> | Bus free time between STOP and START condition | 4.7   |      | 1.3                                       |     |      |

1. Data based on standard I<sup>2</sup>C protocol requirement, not tested in production

**Figure 4. I<sup>2</sup>C slave timing diagram**



Note: Measurement points are done at 0.2·Vdd<sub>IO</sub> and 0.8·Vdd<sub>IO</sub>, for both ports.

**Table 9. I<sup>2</sup>C high-speed mode specifications at 1 MHz and 3.4 MHz**

|                                | Symbol  | Parameter  | Min        | Max | Unit |    |
|--------------------------------|---|--|------------|-----|------|----|
| Fast mode plus <sup>(1)</sup>  | f <sub>SCL</sub>  | SCL clock frequency  | 0          | 1   | MHz  |    |
|                                | t <sub>HD;STA</sub>   | Hold time (repeated) START condition   | 260        | -   | ns   |    |
|                                | t <sub>LOW</sub>  | Low period of the SCL clock  | 500        | -   |      |    |
|                                | t <sub>HIGH</sub>   | High period of the SCL clock   | 260        | -   |      |    |
|                                | t <sub>SU;STA</sub>   | Setup time for a repeated START condition  | 260        | -   |      |    |
|                                | t <sub>HD;DAT</sub>   | Data hold time   | 0          | -   |      |    |
|                                | t <sub>SU;DAT</sub>   | Data setup time  | 50         | -   |      |    |
|                                | t <sub>rDA</sub>  | Rise time of SDA signal  | -          | 120 |      |    |
|                                | t <sub>fDA</sub>  | Fall time of SDA signal  | -          | 120 |      |    |
|                                | t <sub>rCL</sub>  | Rise time of SCL signal  | 20*Vdd/5.5 | 120 |      |    |
|                                | t <sub>fCL</sub>  | Fall time of SCL signal  | 20*Vdd/5.5 | 120 |      |    |
|                                | t <sub>SU;STO</sub>   | Setup time for STOP condition  | 260        | -   |      |    |
|                                | C <sub>b</sub>  | Capacitive load for each bus line  | -          | 550 |      | pF |
|                                | t <sub>VD;DAT</sub>   | Data valid time  | -          | 450 |      | ns |
|                                | t <sub>VD;ACK</sub>   | Data valid acknowledge time  | -          | 450 |      |    |
|                                | V <sub>nL</sub>   | Noise margin at low level  | 0.1Vdd     | -   | V    |    |
|                                | V <sub>nH</sub>   | Noise margin at high level   | 0.2Vdd     | -   |      |    |
| t <sub>SP</sub>                | Pulse width of spikes that must be suppressed by the input filter | 0  | 50         | ns  |      |    |
| High-speed mode <sup>(1)</sup> | f <sub>SCLH</sub>   | SCLH clock frequency   | 0          | 3.4 | MHz  |    |
|                                | t <sub>SU;STA</sub>   | Setup time for a repeated START condition  | 160        | -   | ns   |    |
|                                | t <sub>HD;STA</sub>   | Hold time (repeated) START condition   | 160        | -   |      |    |
|                                | t <sub>LOW</sub>  | Low period of the SCLH clock   | 160        | -   |      |    |
|                                | t <sub>HIGH</sub>   | High period of the SCLH clock  | 60         | -   |      |    |
|                                | t <sub>SU;DAT</sub>   | Data setup time  | 10         | -   |      |    |
|                                | t <sub>HD;DAT</sub>   | Data hold time   | 0          | 70  |      |    |
|                                | t <sub>rCL</sub>  | Rise time of SCLH signal   | 10         | 40  |      |    |
|                                | t <sub>rCL1</sub>   | Rise time of SCLH signal after a repeated START condition and after an acknowledge bit | 10         | 80  |      |    |
|                                | t <sub>fCL</sub>  | Fall time of SCLH signal   | 10         | 40  |      |    |
|                                | t <sub>rDA</sub>  | Rise time of SDAH signal   | 10         | 80  |      |    |
|                                | t <sub>fDA</sub>  | Fall time of SDAH signal   | 10         | 80  |      |    |
|                                | t <sub>SU;STO</sub>   | Setup time for STOP condition  | 160        | -   |      |    |
|                                | C <sub>b</sub>  | Capacitive load for each bus line  | -          | 100 |      | pF |
|                                | V <sub>nH</sub>   | Noise margin at high level   | 0.2Vdd     | -   | V    |    |
| t <sub>SP</sub>                | Pulse width of spikes that must be suppressed by the input filter | 0  | 10         | ns  |      |    |

1. Data based on characterization, not tested in production





## 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 10. Absolute maximum ratings**

| Symbol             | Ratings  | Maximum value                           | Unit |
|--------------------|--|---|------|
| V <sub>dd</sub>    | Supply voltage   | -0.3 to 4.8                             | V    |
| V <sub>dd_IO</sub> | I/O pins supply voltage  | -0.3 to 4.8                             | V    |
| V <sub>in</sub>    | Input voltage on any control pin (CS, SCL/SPC, SDA/SDI/SDO, SDO/SA0) | -0.3 to V <sub>dd_IO</sub> +0.3         | V    |
| A <sub>POW</sub>   | Acceleration (any axis, powered, V <sub>dd</sub> = 1.8 V)            | 3000 g for 0.5 ms                       | g    |
|                    |  | 10000 g for 0.2 ms                      | g    |
| A <sub>UNP</sub>   | Acceleration (any axis, unpowered)                                   | 3000 g for 0.5 ms                       | g    |
|                    |  | 10000 g for 0.2 ms                      | g    |
| T <sub>OP</sub>    | Operating temperature range  | -40 to +85                              | °C   |
| T <sub>STG</sub>   | Storage temperature range  | -40 to +125                             | °C   |
| ESD                | Electrostatic discharge protection                                   | 2 kV (HBM)<br>200 V (MM)<br>500 V (CDM) |      |

*Note:* Supply voltage on any pin should never exceed 4.8 V.

-  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.

## 3 Terminology and functionality

### 3.1 Terminology

#### 3.1.1 Sensitivity

Sensitivity describes the gain of the sensor and can be determined by applying 1 *g* acceleration to it. As the sensor can measure DC accelerations this can be done easily by pointing the axis of interest towards the center of the Earth, noting the output value, rotating the sensor by 180 degrees (pointing to the sky) and noting the output value again. By doing so,  $\pm 1$  *g* acceleration is applied to the sensor. Subtracting the larger output value from the smaller one, and dividing the result by 2, leads to the actual sensitivity of the sensor. This value changes very little over temperature and time. The sensitivity tolerance describes the range of sensitivities of a large population of sensors.

#### 3.1.2 Zero-*g* level offset

Zero-*g* level offset describes the deviation of an actual output signal from the ideal output signal if no acceleration is present. A sensor in a steady state on a horizontal surface will measure 0 *g* on the X-axis and 0 *g* on the Y-axis whereas the Z-axis will measure 1 *g*. The output is ideally in the middle of the dynamic range of the sensor (content of OUT registers 00h, data expressed as two's complement number). A deviation from ideal value in this case is called Zero-*g* level offset. Offset is to some extent a result of stress to the MEMS sensor and therefore the offset can slightly change after mounting the sensor onto a printed circuit board or exposing it to extensive mechanical stress. Offset changes little over temperature, see "Zero-*g* level offset change vs. temperature".

## 3.2 Functionality

### 3.2.1 Operating modes

The AIS2DW12 offers 2 operating modes: continuous mode and single-shot mode, selectable through OP\_MODE[1:0] in [CTRL1 \(20h\)](#). Each operating mode supports four different power modes, selectable through PW\_MODE[1:0] in [CTRL1 \(20h\)](#).

**Table 11. Operating modes**

| Parameter   |             | Power Mode 4                    | Power Mode 3                    | Power Mode 2                    | Power Mode 1                     |
|---|-------------|---------------------------------|---------------------------------|---------------------------------|----------------------------------|
| Resolution [bit]  |             | 14-bit                          | 14-bit                          | 14-bit                          | 12-bit                           |
| ODR [Hz]  |             | 1.6 - 100                       | 1.6 - 100                       | 1.6 - 100                       | 1.6 - 100                        |
| BW [Hz]   |             | 180<br>ODR/4, ODR/10,<br>ODR/20 | 360<br>ODR/4, ODR/10,<br>ODR/20 | 720<br>ODR/4, ODR/10,<br>ODR/20 | 3200<br>ODR/4, ODR/10,<br>ODR/20 |
| Typ. RMS noise [mg(RMS)]  |             | 1.6                             | 2.1                             | 3.0                             | 5.5                              |
| Typ. current consumption [ $\mu$ A]<br>@ Vdd=1.8 V <sup>(1)</sup> | ODR=1.6 Hz  | 0.65                            | 0.55                            | 0.45                            | 0.38                             |
|   | ODR=12.5 Hz | 4                               | 2.5                             | 1.6                             | 1                                |
|   | ODR=25 Hz   | 8.5                             | 4.5                             | 3                               | 1.5                              |
|   | ODR=50 Hz   | 16                              | 9                               | 5.5                             | 3                                |
|   | ODR=100 Hz  | 32                              | 17.5                            | 10.5                            | 5                                |
| Typ. current consumption [ $\mu$ A]<br>@ Vdd=3 V <sup>(1)</sup>   | ODR=1.6 Hz  | 1.3                             | 0.95                            | 0.75                            | 0.67                             |
|   | ODR=12.5 Hz | 5.3                             | 3                               | 2                               | 1.3                              |
|   | ODR=25 Hz   | 10.5                            | 6                               | 3.8                             | 2.1                              |
|   | ODR=50 Hz   | 20.5                            | 11.5                            | 7                               | 3.7                              |
|   | ODR=100 Hz  | 40                              | 22                              | 13.5                            | 6.5                              |

1. Verified at characterization level.

### 3.2.2 Single data conversion on-demand mode

The device features a single data conversion on-demand mode in the 4 power modes. This mode is enabled by writing the OP\_MODE[1:0] bits to '10' in [CTRL1 \(20h\)](#). Power modes are selected by writing the PW\_MODE[1:0] bits in [CTRL1 \(20h\)](#).

The trigger for output data generation can be managed through the I<sup>2</sup>C/SPI or by applying a clock signal on the INT2 pin acting here as an input by writing the SLP\_MODE\_SEL bit in [CTRL3 \(22h\)](#):

- When SLP\_MODE\_SEL = '0', output data generation is triggered by the clock signal on the INT2 pin (see [Figure 5](#)).
- When SLP\_MODE\_SEL = '1', output data generation starts when the SLP\_MODE\_1 bit is set to '1' logic through the I<sup>2</sup>C/SPI. When XL data are available in the registers, this bit is automatically set to '0' and the device is ready for another triggered session.

Output data are generated according to the selected power mode.

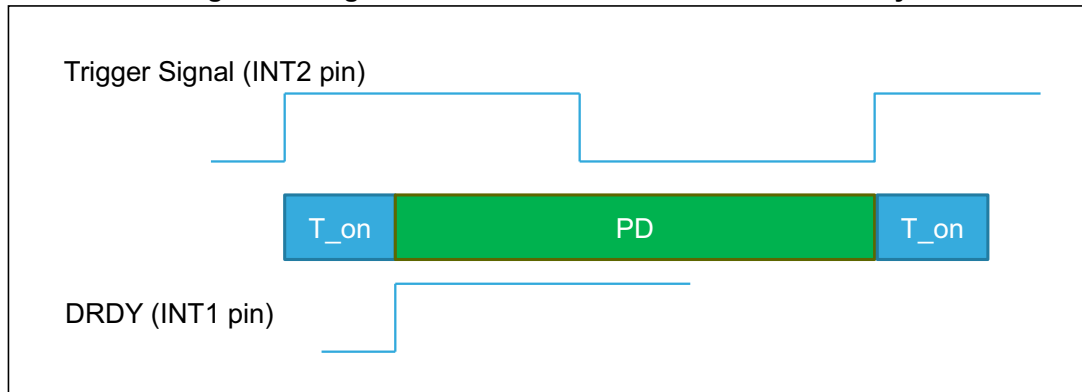
When output data is saved in an output register or FIFO, the device goes to power-down mode and waits for a new trigger.

All ODRs in the range from 0 to up to 100 Hz are supported due to the INT2 clock input.

A DRDY signal or FIFO flags are available on the INT1 pin.

Power consumption is the same as that of standard power modes for the same ODR.

**Figure 5. Single data conversion on demand functionality**



At the end of turn-on time  $T_{on}$ , the DRDY interrupt is activated, output data are available to be read and the device goes into power-down.  $T_{on}$  values depend on the power mode as follows:

$T_{on}$  (typ.) =

- 1.20 ms for Power Mode 1
- 1.70 ms for Power Mode 2
- 2.30 ms for Power Mode 3
- 3.55 ms for Power Mode 4

### 3.2.3 Self-test

The self-test allows checking the sensor functionality without moving it. The self-test function is off when the self-test bits (ST) are programmed to '00'. When the self-test bits are changed, an actuation force is applied to the sensor, simulating a definite input acceleration. In this case the sensor outputs will exhibit a change in their DC levels which are related to the selected full scale through the device sensitivity. When the self-test is activated, the device output level is given by the algebraic sum of the signals produced by the acceleration acting on the sensor and by the electrostatic test-force. If the output signals change within the amplitude specified in [Table 4](#), then the sensor is working properly and the parameters of the interface chip are within the defined specifications.

### 3.2.4 Activity/Inactivity, stationary/motion detection functions

The activity/inactivity function recognizes the device's sleep state and allows reducing system power consumption.

When the activity/inactivity function is activated by setting the SLEEP\_ON bit in [WAKE\\_UP\\_THS \(34h\)](#), the AIS2DW12 automatically goes to 12.5 Hz ODR in the mode previously selected by the PW\_MODE[1:0] bits in [CTRL1 \(20h\)](#) if the sleep state condition is detected and wakes up as soon as the interrupt event has been detected, increasing the output data rate and bandwidth.

With this feature the system may be efficiently switched from 12.5 Hz to full performance depending on user-selectable positioning and acceleration events, thus ensuring power saving and flexibility.

The stationary/motion detection function only recognizes the device's sleep state.

When the stationary/motion detection function is activated by setting the STATIONARY bit in [WAKE\\_UP\\_DUR \(35h\)](#), the AIS2DW12 detects acceleration below a fixed threshold but does not change either ODR or operating mode after sleep state detection.

The Activity/Inactivity recognition and stationary/motion detection functions are activated by writing the desired threshold in the [WAKE\\_UP\\_THS \(34h\)](#) register. The high-pass filter is automatically enabled.

If the device is in sleep (inactivity/stationary) mode, when at least one of the axes exceeds the threshold in [WAKE\\_UP\\_THS \(34h\)](#), the device goes into a sleep-to-wake state (as wake-up).

For the activity/inactivity function, the device, in a wake-up state, will return to the operating mode and ODR before sleep state detection.

Activity/Inactivity, stationary/motion detection threshold and duration can be configured in the following control registers:

[WAKE\\_UP\\_THS \(34h\)](#)

[WAKE\\_UP\\_DUR \(35h\)](#)

### 3.2.5 Offset management

The user can manage offset in the output or for wakeup detection using dedicated embedded hardware (see [Section 5.1: Block diagram of filters](#)).

## 3.3 Sensing element

A proprietary process is used to create a surface micromachined accelerometer. The technology allows processing suspended silicon structures which are attached to the substrate in a few points called anchors and are free to move in the direction of the sensed acceleration. In order to be compatible with the traditional packaging techniques, a cap is placed on top of the sensing element to avoid blocking the moving parts during the molding phase of the plastic encapsulation. When an acceleration is applied to the sensor the proof mass displaces from its nominal position, causing an imbalance in the capacitive half-bridge. This imbalance is measured using charge integration in response to a voltage pulse applied to the capacitor.

At steady-state the nominal value of the capacitors are a few pF and when an acceleration is applied, the maximum variation of the capacitive load is in the fF range.

### 3.4 IC interface

The complete measurement chain is composed of a low-noise capacitive amplifier which converts the capacitive unbalancing of the MEMS sensor into an analog voltage using an analog-to-digital converter.

The acceleration data may be accessed through an I<sup>2</sup>C/SPI interface thus making the device particularly suitable for direct interfacing with a microcontroller.

The AIS2DW12 features a data-ready signal which indicates when a new set of measured acceleration data is available, thus simplifying data synchronization in the digital system that uses the device.

### 3.5 Factory calibration

The IC interface is factory-calibrated for sensitivity (So) and Zero-g level offset.

The trim values are stored inside the device in nonvolatile memory. Any time the device is turned on, the trimming parameters are downloaded into the registers to be used during active operation. This allows using the device without further calibration. If an accidental write occurs in the registers where trimming parameters are stored, the BOOT bit in [CTRL2 \(21h\)](#) can help to retrieve the correct trimming parameters from nonvolatile memory without the need to switch on/off the device. This bit is automatically reset at the end of the download operation. Setting this bit has no impact on the control registers.

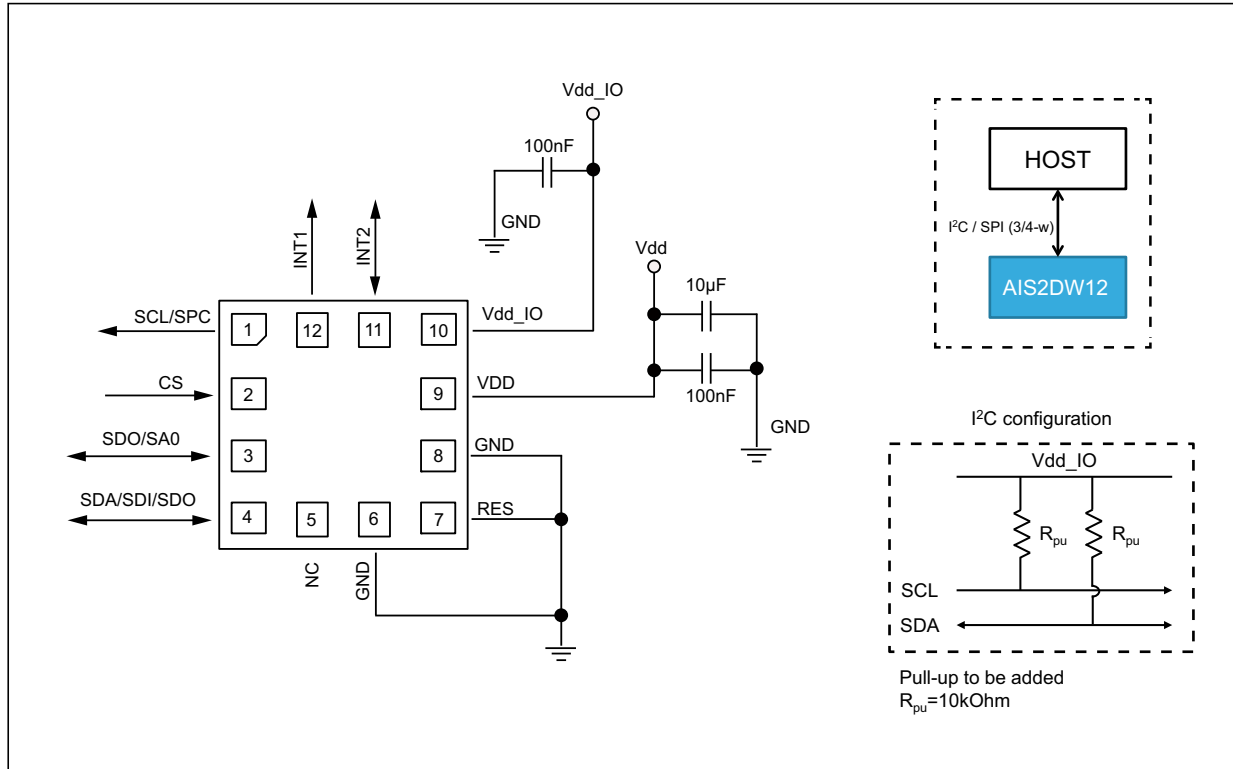
### 3.6 Temperature sensor

The temperature is available in [OUT\\_T\\_L \(0Dh\)](#), [OUT\\_T\\_H \(0Eh\)](#) stored as two's complement data, left-justified in 12-bit mode and in [OUT\\_T \(26h\)](#) stored as two's complement data, left-justified in 8-bit mode.

Refer to [Table 6: Temperature sensor characteristics](#) for the conversion factor.

## 4 Application hints

Figure 6. AIS2DW12 electrical connections (top view)



The device core is supplied through the Vdd line while the I/O pads are supplied through the Vdd\_IO line. Power supply decoupling capacitors (100 nF ceramic, 10 µF aluminum) should be placed as near as possible to pin 9 of the device (common design practice).

All the voltage and ground supplies must be present at the same time to have proper behavior of the IC (refer to [Figure 6](#)). It is possible to remove Vdd while maintaining Vdd\_IO without blocking the communication bus, in this condition the measurement chain is powered off.

The functionality of the device and the measured acceleration data are selectable and accessible through the I<sup>2</sup>C or SPI interfaces. When using the I<sup>2</sup>C, CS must be tied high (i.e. connected to Vdd\_IO).

The functions, the threshold and the timing of the two interrupt pins (INT1 and INT2) can be completely programmed by the user through the I<sup>2</sup>C/SPI interface.

Table 12. Internal pin status

| Pin # | Name              | Function  | Pin status  |
|-------|-------------------|---|---|
| 1     | SCL<br>SPC        | I <sup>2</sup> C serial clock (SCL)<br>SPI serial port clock (SPC)  | Default: open drain                                 |
| 2     | CS                | SPI enable<br>I <sup>2</sup> C/SPI mode selection<br>1: SPI idle mode / I <sup>2</sup> C communication enabled<br>0: SPI communication mode / I <sup>2</sup> C disabled | Default: input with internal pull-up <sup>(1)</sup> |
| 3     | SDO<br>SA0        | Serial data output (SDO)<br>I <sup>2</sup> C less significant bit of the device address (SA0)   | Default: input with internal pull-up                |
| 4     | SDA<br>SDI<br>SDO | I <sup>2</sup> C serial data (SDA)<br>SPI serial data input (SDI)<br>3-wire interface serial data output (SDO)  | Default: (SDA) input open drain                     |
| 5     | NC                | Internally not connected. Can be tied to VDD, VDDIO, or GND.  |   |
| 6     | GND               | 0 V supply  |   |
| 7     | RES               | Connect to GND  |   |
| 8     | GND               | 0 V supply  |   |
| 9     | VDD               | Power supply  |   |
| 10    | VDD_IO            | Power supply for I/O pins   |   |
| 11    | INT2              | Interrupt pin 2. Clock input when selected in single data conversion on demand.   | Default: push-pull output forced to Gnd             |
| 12    | INT1              | Interrupt pin 1   | Default: push-pull output forced to Gnd             |

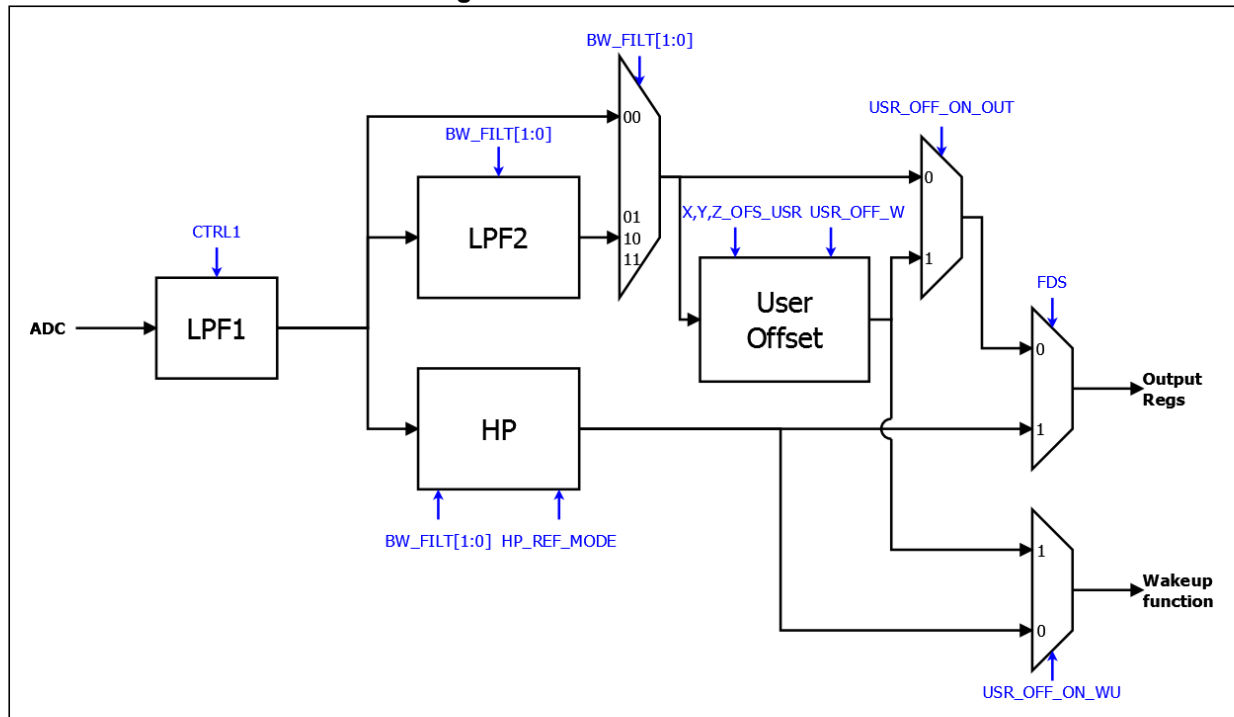
1. Pull-up on the CS pin can be removed by performing an I<sup>2</sup>C/SPI write procedure



## 5 Digital main blocks

### 5.1 Block diagram of filters

Figure 7. Accelerometer chain



Referring to *Figure 7*, the first block is the Low-Pass Filter 1 (LPF1) whose behavior is a function of the actual ODR and mode selected in *CTRL1 (20h)*. The signal is then downsampled and can be either directly sent to the output registers or to the Low-Pass Filter 2 (LPF2) or High-Pass-Filter (HP) using the *BW\_FILT[1:0]* bits and *FDS* bit in *CTRL6 (25h)*.

In the low-pass path, it is possible to apply a user offset determined by the *X\_OFS\_USR (3Ch)*, *Y\_OFS\_USR (3Dh)*, *Z\_OFS\_USR (3Eh)* register values and the *USR\_OFF\_W* bit in *CTRL7 (3Fh)* and send the result to the output using the *USR\_OFF\_ON\_OUT* bit in *CTRL7 (3Fh)*.

In the high-pass path, it is possible to use the high-pass filter reference mode (HP) using the *HP\_REF\_MODE* bit in *CTRL7 (3Fh)*.

## 5.2 FIFO

The AIS2DW12 embeds 32 slots of 14-bit data FIFO for each of the three output channels, X, Y and Z of the acceleration data. This allows consistent power saving for the system, since the host processor does not need to continuously poll data from the sensor, but it can wake up only when needed and burst the significant data out from the FIFO.

The internal FIFO allows collecting 32 samples (14-bit size data) for each axis.

When the FIFO mode is other than Bypass, reading the output registers (28h to 2Dh) returns the oldest FIFO sample set. In order to minimize communication between the master and slave, the address read may be automatically incremented by the device by setting the IF\_ADD\_INC bit of *CTRL2 (21h)* to '1'; the device rolls back to 0x28 when register 0x2D is reached.

This buffer can work according to the following 5 different modes:

- Bypass mode
- FIFO mode
- Continuous-to-FIFO
- Bypass-to-Continuous
- Continuous

Each mode is selected by the FMode[2:0] bits in the *FIFO\_CTRL (2Eh)* register.

Programmable FIFO threshold is selected in *FIFO\_CTRL (2Eh)*. Status and FIFO overrun events are available in the *FIFO\_SAMPLES (2Fh)* register and can be used to generate dedicated interrupts on the INT1 and INT2 pins using the *CTRL4\_INT1 (23h)* and *CTRL5\_INT2 (24h)* registers.

*FIFO\_SAMPLES (2Fh)* (FIFO\_FTH) goes to '1' when the number of unread samples *FIFO\_SAMPLES (2Fh)* (Diff[5:0]) is greater than or equal to FTH[4:0] in *FIFO\_CTRL (2Eh)*.

If FTH[4:0] is equal to '0', *FIFO\_SAMPLES (2Fh)* (FIFO\_FTH) goes to '0'.

*FIFO\_SAMPLES (2Fh)* (FIFO\_OVR) is equal to '1' if a FIFO slot is overwritten.

*FIFO\_SAMPLES (2Fh)* (Diff[5:0]) contains stored data levels of unread samples. When Diff[5:0] is equal to '000000', FIFO is empty. When Diff[5:0] is equal to '100000', FIFO is full and the unread samples are 32.

To guarantee the correct acquisition of data during the switching into and out of FIFO, the first sample acquired must be discarded.

When the FIFO threshold status flag is '0'-logic, FIFO filling is lower than the threshold level and when '1'-logic, FIFO filling is equal to or higher than the threshold level.

### 5.2.1 Bypass mode

In Bypass mode (*FIFO\_CTRL (2Eh)* (FMode [2:0])= 000), the FIFO is not operational, no data is collected in FIFO memory, and it remains empty with the only actual sample available in the output registers.

Bypass mode is also used to reset the FIFO when in FIFO mode.

For each channel only the first address is used. When new data is available, the old data is overwritten.

### 5.2.2 FIFO mode

In FIFO mode (*FIFO\_CTRL (2Eh)*(FMode [2:0])= 001) data from the X, Y and Z channels are stored in the FIFO until it is full, when 32 unread samples are stored in memory, data collecting is stopped.

To reset the FIFO content, Bypass mode should be written in the *FIFO\_CTRL (2Eh)* register, setting the FMODE [2:0] bits to '000'. After this reset command, it is possible to restart FIFO mode, writing the value '001' in *FIFO\_CTRL (2Eh)*(FMODE [2:0]).

The FIFO buffer can memorize 32 slots of X, Y and Z data.

### 5.2.3 Continuous mode

Continuous mode (*FIFO\_CTRL (2Eh)* (FMode[2:0] = 110) provides a continuous FIFO update: when 32 unread samples are stored in memory, as new data arrives the oldest data is discarded and overwritten by the newer.

A FIFO threshold flag *FIFO\_SAMPLES (2Fh)* (FIFO\_FTH) is asserted when the number of unread samples in FIFO is greater than or equal to (*FIFO\_CTRL (2Eh)*FTH[4:0]).

It is possible to route *FIFO\_SAMPLES (2Fh)*(FTH) to the INT1 pin by writing the INT1\_FTH bit to '1' in register *CTRL4\_INT1 (23h)* or to the INT2 pin by writing the INT2\_FTH bit to '1' in register *CTRL5\_INT2 (24h)*.

If an overrun occurs, the oldest sample in FIFO is overwritten and the FIFO\_OVR flag in *FIFO\_SAMPLES (2Fh)* is asserted.

In order to empty the FIFO before it is full, it is also possible to pull from FIFO the number of unread samples available in *FIFO\_SAMPLES (2Fh)* (Diff[5:0]).

### 5.2.4 Continuous-to-FIFO mode

In Continuous-to-FIFO mode *FIFO\_CTRL (2Eh)*(FMode[2:0] = 011), FIFO operates in Continuous mode and FIFO mode starts upon an internal trigger event. When the FIFO is full, data collecting is stopped. The trigger could be wake-up, free-fall, 6D interrupt or any combination of these events, but every interrupt has to be routed on the corresponding pad to be used as a trigger.

Figure 8. Continuous-to-FIFO mode

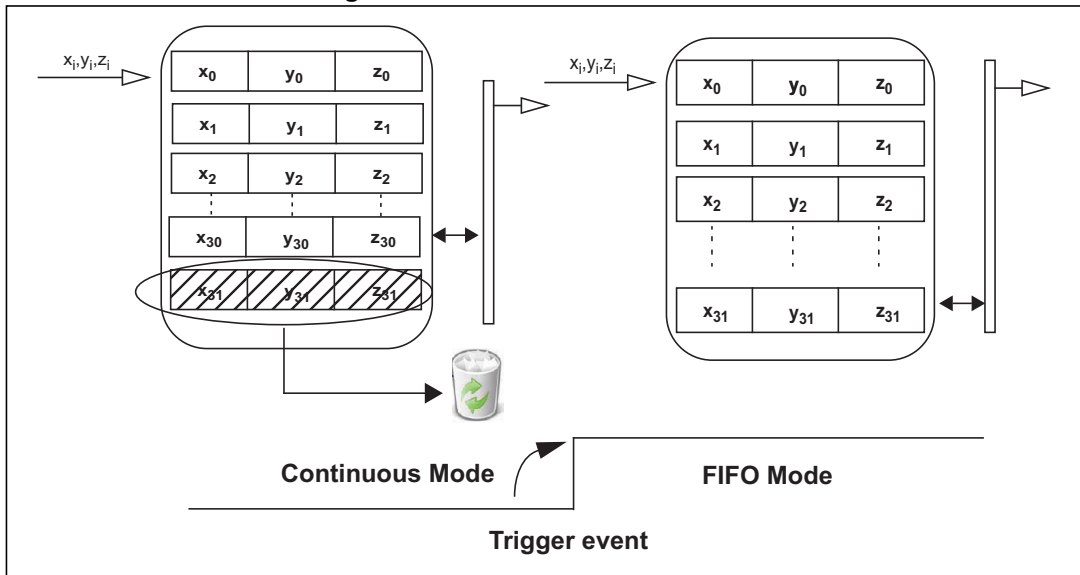
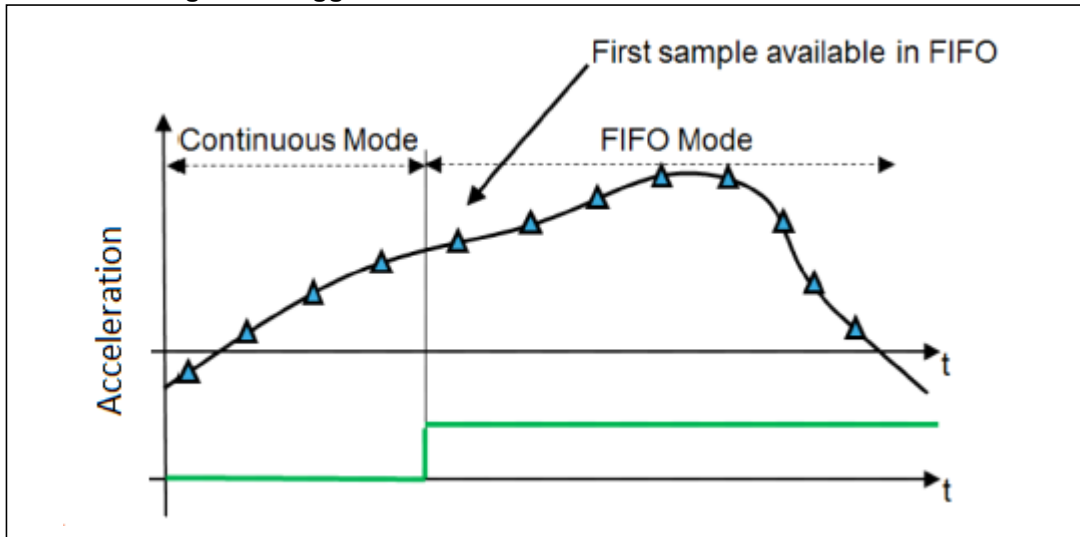


Figure 9. Trigger event to FIFO for Continuous-to-FIFO mode



### 5.2.5 Bypass-to-Continuous mode

In Bypass-to-Continuous mode (*FIFO\_CTRL (2Eh)*(FMode[2:0] = '100'), data measurement storage inside FIFO starts in Continuous mode upon an internal trigger event, then the sample that follows the trigger is available in FIFO. The trigger could be wake-up, free-fall, 6D interrupt or any combination of these events, but every interrupt has to be routed on the corresponding pad to be used as a trigger.

Figure 10. Bypass-to-Continuous mode

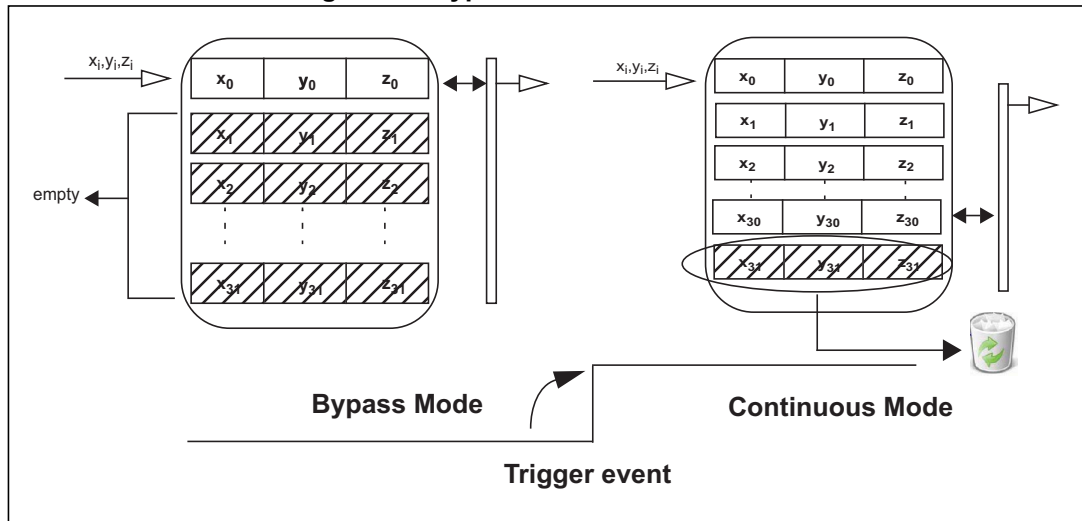
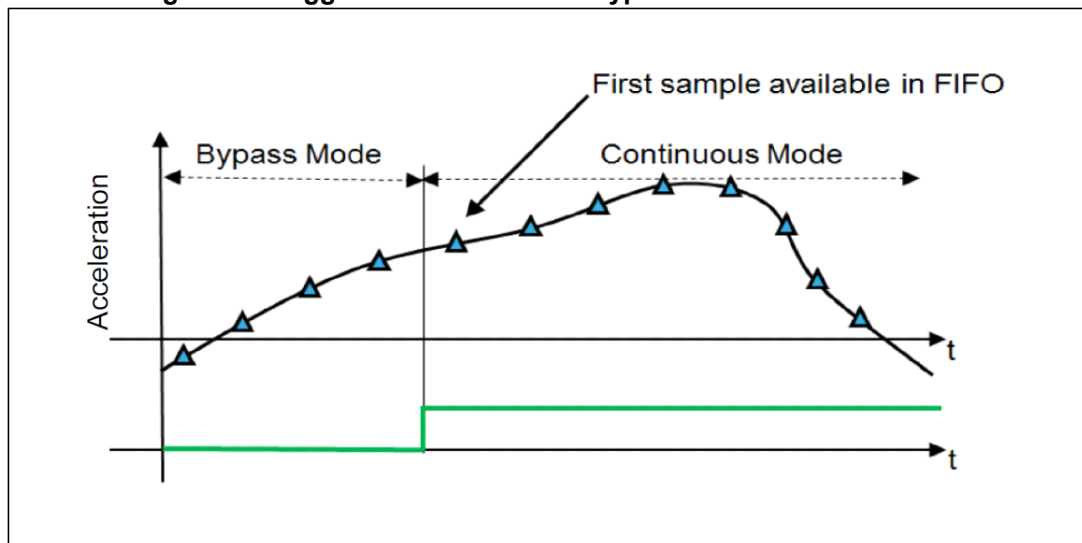


Figure 11. Trigger event to FIFO for Bypass-to-Continuous mode



## 6 Digital interfaces

The registers embedded inside the AIS2DW12 may be accessed through both the I<sup>2</sup>C and SPI serial interfaces. The latter may be SW configured to operate either in 3-wire or 4-wire interface mode.

The serial interfaces are mapped to the same pins. To select/exploit the I<sup>2</sup>C interface, the CS line must be tied high (i.e. connected to Vdd\_IO).

**Table 13. Serial interface pin description**

| Pin name | Pin description  |
|----------|--|
| CS       | SPI enable<br>I <sup>2</sup> C/SPI mode selection (1: SPI idle mode / I <sup>2</sup> C communication enabled; 0: SPI communication mode / I <sup>2</sup> C disabled) |
| SCL      | I <sup>2</sup> C serial clock (SCL)  |
| SPC      | SPI serial port clock (SPC)  |
| SDA      | I <sup>2</sup> C serial data (SDA)   |
| SDI      | SPI serial data input (SDI)  |
| SDO      | 3-wire interface serial data output (SDO)  |
| SA0      | I <sup>2</sup> C address selection (SA0)   |
| SDO      | SPI serial data output (SDO)   |

### 6.1 I<sup>2</sup>C serial interface

The AIS2DW12 I<sup>2</sup>C is a bus slave. The I<sup>2</sup>C is employed to write data into registers whose content can also be read back.

The relevant I<sup>2</sup>C terminology is given in the table below.

**Table 14. I<sup>2</sup>C terminology**

| Term        | Description  |
|-------------|--|
| Transmitter | The device which sends data to the bus   |
| Receiver    | The device which receives data from the bus  |
| Master      | The device which initiates a transfer, generates clock signals and terminates a transfer |
| Slave       | The device addressed by the master   |

There are two signals associated with the I<sup>2</sup>C bus: the serial clock line (SCL) and the Serial DAta line (SDA). The latter is a bidirectional line used for sending and receiving the data to/from the interface. Both the lines must be connected to Vdd\_IO through an external pull-up resistor. When the bus is free, both the lines are high.

The I<sup>2</sup>C interface is compliant with fast mode (400 kHz) I<sup>2</sup>C standards as well as with normal mode.

In order to disable the I<sup>2</sup>C block, *CTRL2 (21h)* (I2C\_DISABLE) = 1 must be set.

### 6.1.1 I<sup>2</sup>C operation

The transaction on the bus is started through a START (ST) signal. A START condition is defined as a high-to-low transition on the data line while the SCL line is held high. After this has been transmitted by the master, the bus is considered busy. The next byte of data transmitted after the start condition contains the address of the slave in the first 7 bits and the eighth bit tells whether the master is receiving data from the slave or transmitting data to the slave. When an address is sent, each device in the system compares the first seven bits after a start condition with its address. If they match, the device considers itself addressed by the master.

The Slave Address (SAD) associated to the AIS2DW12 is 001100xb where the x bit is modified by the SA0/SDO pin in order to modify the device address. If the SA0/SDO pin is connected to the supply voltage, the address is 0011001b, otherwise if the SA0/SDO pin is connected to ground, the address is 0011000b. This solution permits to connect and address two different accelerometers to the same I<sup>2</sup>C lines.

Data transfer with acknowledge is mandatory. The transmitter must release the SDA line during the acknowledge pulse. The receiver must then pull the data line low so that it remains stable low during the high period of the acknowledge clock pulse. A receiver which has been addressed is obliged to generate an acknowledge after each byte of data received.

The I<sup>2</sup>C embedded inside the AIS2DW12 behaves like a slave device and the following protocol must be adhered to. After the start condition (ST) a slave address is sent. Once a slave acknowledge (SAK) has been returned, an 8-bit sub-address (SUB) is transmitted: the 7 LSb represents the actual register address while the *CTRL2 (21h)* (IF\_ADD\_INC) bit defines the address increment.

The slave address is completed with a Read/Write bit. If the bit is '1' (Read), a repeated START (SR) condition must be issued after the two sub-address bytes. If the bit is '0' (Write) the master will transmit to the slave with direction unchanged. *Table 15* explains how the SAD+Read/Write bit pattern is composed, listing all the possible configurations.

**Table 15. SAD+Read/Write patterns**

| Command | SAD[6:1] | SAD[0] = SA0 | R/W | SAD+R/W        |
|---------|----------|--------------|-----|----------------|
| Read    | 001100   | 0            | 1   | 00110001 (31h) |
| Write   | 001100   | 0            | 0   | 00110000 (30h) |
| Read    | 001100   | 1            | 1   | 00110011 (33h) |
| Write   | 001100   | 1            | 0   | 00110010 (32h) |

**Table 16. Transfer when master is writing one byte to slave**

|        |    |         |     |     |     |      |     |    |
|--------|----|---------|-----|-----|-----|------|-----|----|
| Master | ST | SAD + W |     | SUB |     | DATA |     | SP |
| Slave  |    |         | SAK |     | SAK |      | SAK |    |

**Table 17. Transfer when master is writing multiple bytes to slave**

|        |    |         |     |     |     |      |     |      |     |    |
|--------|----|---------|-----|-----|-----|------|-----|------|-----|----|
| Master | ST | SAD + W |     | SUB |     | DATA |     | DATA |     | SP |
| Slave  |    |         | SAK |     | SAK |      | SAK |      | SAK |    |

**Table 18. Transfer when master is receiving (reading) one byte of data from slave**

|        |    |         |     |     |     |    |         |     |      |      |    |
|--------|----|---------|-----|-----|-----|----|---------|-----|------|------|----|
| Master | ST | SAD + W |     | SUB |     | SR | SAD + R |     |      | NMAK | SP |
| Slave  |    |         | SAK |     | SAK |    |         | SAK | DATA |      |    |

**Table 19. Transfer when master is receiving (reading) multiple bytes of data from slave**

|        |    |       |     |     |     |    |       |     |      |     |      |     |      |      |    |
|--------|----|-------|-----|-----|-----|----|-------|-----|------|-----|------|-----|------|------|----|
| Master | ST | SAD+W |     | SUB |     | SR | SAD+R |     |      | MAK |      | MAK |      | NMAK | SP |
| Slave  |    |       | SAK |     | SAK |    |       | SAK | DATA |     | DATA |     | DATA |      |    |

Data are transmitted in byte format (DATA). Each data transfer contains 8 bits. The number of bytes transferred per transfer is unlimited. Data is transferred with the Most Significant bit (MSb) first. If a receiver can't receive another complete byte of data until it has performed some other function, it can hold the clock line, SCL low to force the transmitter into a wait state. Data transfer only continues when the receiver is ready for another byte and releases the data line. If a slave receiver doesn't acknowledge the slave address (i.e. it is not able to receive because it is performing some real-time function) the data line must be left high by the slave. The master can then abort the transfer. A low-to-high transition on the SDA line while the SCL line is high is defined as a STOP condition. Each data transfer must be terminated by the generation of a STOP (SP) condition.

In the presented communication format MAK is Master acknowledge and NMAK is No Master Acknowledge.

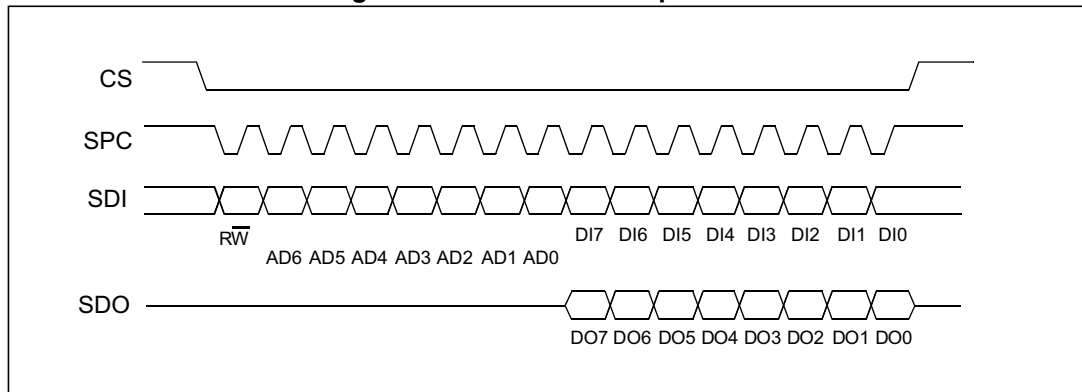


## 6.2 SPI bus interface

The AIS2DW12 SPI is a bus slave. The SPI allows writing to and reading from the registers of the device.

The serial interface interacts with the application using 4 wires: **CS**, **SPC**, **SDI** and **SDO**.

**Figure 12. Read and write protocol**



**CS** is the serial port enable and it is controlled by the SPI master. It goes low at the start of the transmission and goes back high at the end. **SPC** is the serial port clock and it is controlled by the SPI master. It is stopped high when **CS** is high (no transmission). **SDI** and **SDO** are respectively the serial port data input and output. Those lines are driven at the falling edge of **SPC** and should be captured at the rising edge of **SPC**.

Both the read register and write register commands are completed in 16 clock pulses or in multiples of 8 in case of multiple read/write bytes. Bit duration is the time between two falling edges of **SPC**. The first bit (bit 0) starts at the first falling edge of **SPC** after the falling edge of **CS** while the last bit (bit 15, bit 23, ...) starts at the last falling edge of **SPC** just before the rising edge of **CS**.

**bit 0:**  $\overline{RW}$  bit. When 0, the data DI(7:0) is written into the device. When 1, the data DO(7:0) from the device is read. In latter case, the chip will drive **SDO** at the start of bit 8.

**bit 1-7:** address AD(6:0). This is the address field of the indexed register.

**bit 8-15:** data DI(7:0) (write mode). This is the data that is written into the device (MSb first).

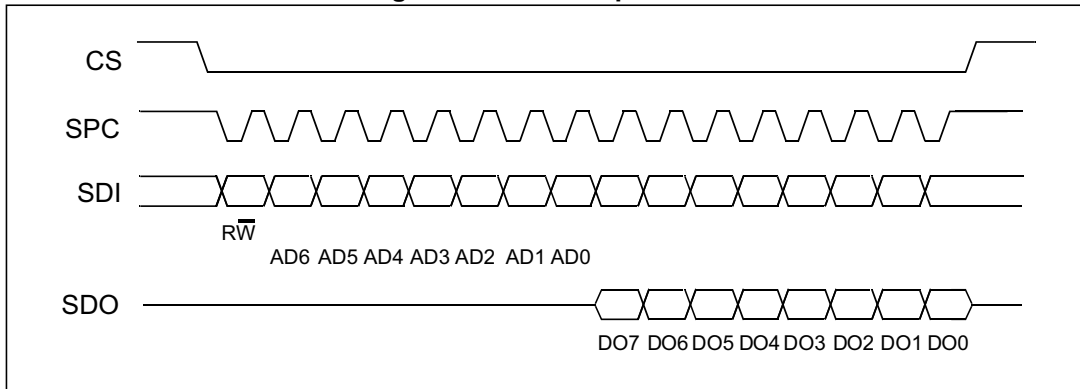
**bit 8-15:** data DO(7:0) (read mode). This is the data that is read from the device (MSb first).

In multiple read/write commands additional blocks of 8 clock periods will be added. When the [CTRL2 \(21h\)](#) (IF\_ADD\_INC) bit is '0', the address used to read/write data remains the same for every block. When the [CTRL2 \(21h\)](#) (IF\_ADD\_INC) bit is '1', the address used to read/write data is increased at every block.

The function and the behavior of **SDI** and **SDO** remain unchanged.

6.2.1 SPI read

Figure 13. SPI read protocol



The SPI read command is performed with 16 clock pulses. A multiple byte read command is performed by adding blocks of 8 clock pulses to the previous one.

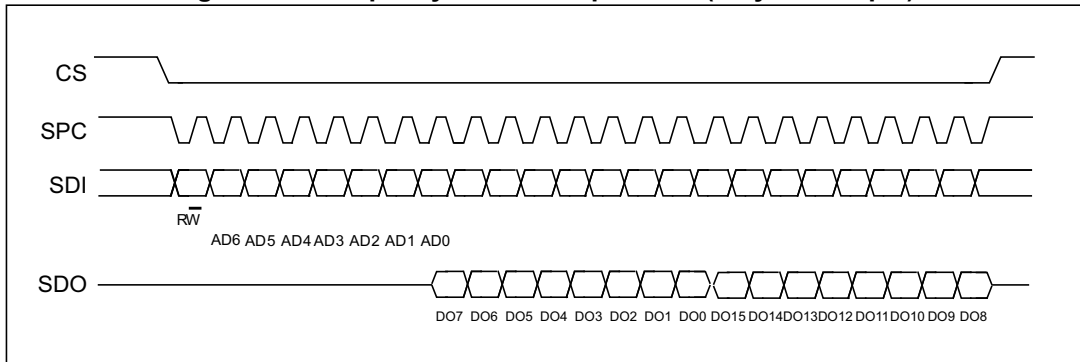
**bit 0:** READ bit. The value is 1.

**bit 1-7:** address AD(6:0). This is the address field of the indexed register.

**bit 8-15:** data DO(7:0) (read mode). This is the data that will be read from the device (MSb first).

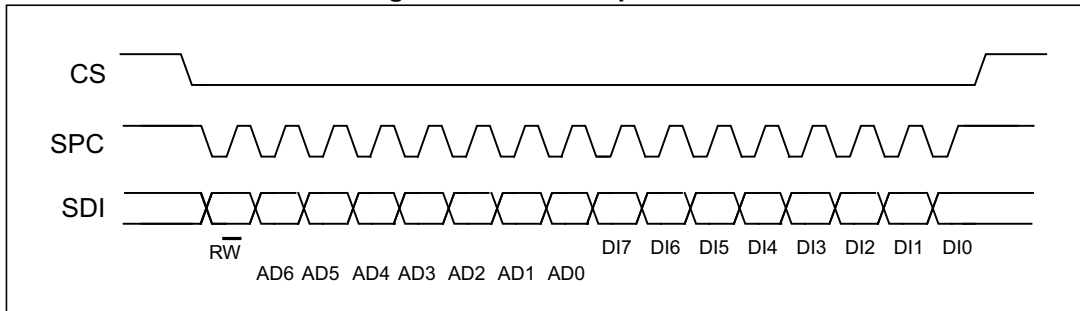
**bit 16-...** : data DO(...-8). Additional data in multiple byte reads.

Figure 14. Multiple byte SPI read protocol (2-byte example)



6.2.2 SPI write

Figure 15. SPI write protocol



The SPI write command is performed with 16 clock pulses. A multiple byte write command is performed by adding blocks of 8 clock pulses to the previous one.

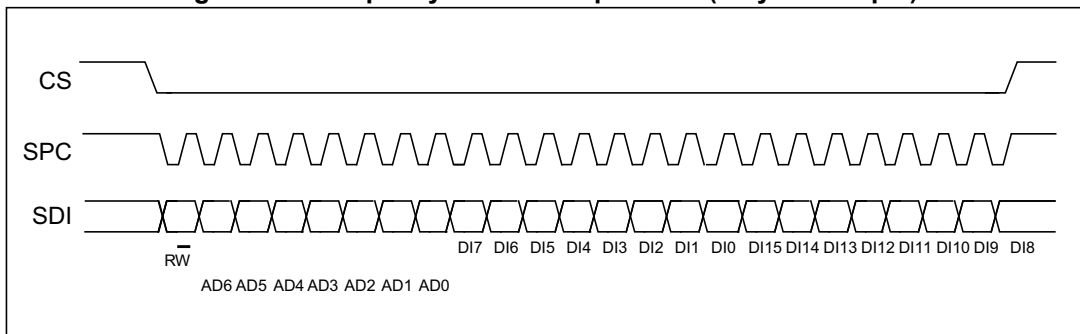
**bit 0:** WRITE bit. The value is 0.

**bit 1 -7:** address AD(6:0). This is the address field of the indexed register.

**bit 8-15:** data DI(7:0) (write mode). This is the data that is written inside the device (MSb first).

**bit 16-...** : data DI(...-8). Additional data in multiple byte writes.

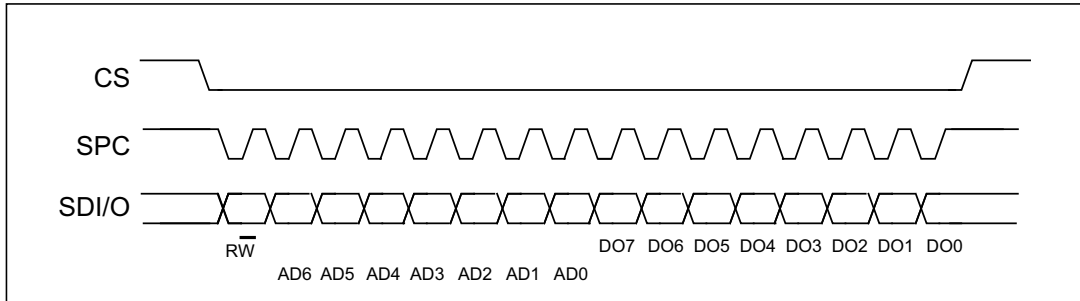
Figure 16. Multiple byte SPI write protocol (2-byte example)



### 6.2.3 SPI read in 3-wire mode

3-wire mode is entered by setting the *CTRL2 (21h)* (SIM) bit equal to '1' (SPI serial interface mode selection).

Figure 17. SPI read protocol in 3-wire mode



The SPI read command is performed with 16 clock pulses:

**bit 0:** READ bit. The value is 1.

**bit 1-7:** address AD(6:0). This is the address field of the indexed register.

**bit 8-15:** data DO(7:0) (read mode). This is the data that is read from the device (MSb first).

A multiple read command is also available in 3-wire mode.

## 7 Register mapping

The table given below provides a list of the 8-bit registers embedded in the device and the corresponding addresses.

**Table 20. Register map**

| Name         | Type <sup>(1)</sup> | Register address |          | Default  | Comment                             |
|--------------|---------------------|------------------|----------|----------|-------------------------------------|
|              |                     | Hex              | Binary   |          |                                     |
| OUT_T_L      | R                   | 0D               | 00001101 | 00000000 | Temp sensor output                  |
| OUT_T_H      | R                   | 0E               | 00001110 | 00000000 |                                     |
| WHO_AM_I     | R                   | 0F               | 00001111 | 01000100 | Who am I ID                         |
| RESERVED     | -                   | 10-1F            |          | -        | RESERVED                            |
| CTRL1        | R/W                 | 20               | 00100000 | 00000000 | Control registers                   |
| CTRL2        | R/W                 | 21               | 00100001 | 00000100 |                                     |
| CTRL3        | R/W                 | 22               | 00100010 | 00000000 |                                     |
| CTRL4_INT1   | R/W                 | 23               | 00100011 | 00000000 |                                     |
| CTRL5_INT2   | R/W                 | 24               | 00100100 | 00000000 |                                     |
| CTRL6        | R/W                 | 25               | 00100101 | 00000000 |                                     |
| OUT_T        | R                   | 26               | 00100110 | 00000000 | Temp sensor output                  |
| STATUS       | R                   | 27               | 00100111 | 00000000 | Status data register                |
| OUT_X_L      | R                   | 28               | 00101000 | 00000000 | Output registers                    |
| OUT_X_H      | R                   | 29               | 00101001 | 00000000 |                                     |
| OUT_Y_L      | R                   | 2A               | 00101010 | 00000000 |                                     |
| OUT_Y_H      | R                   | 2B               | 00101011 | 00000000 |                                     |
| OUT_Z_L      | R                   | 2C               | 00101100 | 00000000 |                                     |
| OUT_Z_H      | R                   | 2D               | 00101101 | 00000000 |                                     |
| FIFO_CTRL    | R/W                 | 2E               | 00101110 | 00000000 | FIFO control register               |
| FIFO_SAMPLES | R                   | 2F               | 00101111 | 00000000 | Unread samples stored in FIFO       |
| SIXD_THS     | R/W                 | 30               | 00110000 | 00000000 | 6D threshold                        |
| RESERVED     | -                   | 31-33            |          | -        | RESERVED                            |
| WAKE_UP_THS  | R/W                 | 34               | 00110100 | 00000000 | Inactivity enable, wakeup threshold |
| WAKE_UP_DUR  | R/W                 | 35               | 00110101 | 00000000 | Wakeup duration                     |
| FREE_FALL    | R/W                 | 36               | 00110110 | 00000000 | Free-fall configuration             |
| STATUS_DUP   | R                   | 37               | 00110111 | 00000000 | Status register                     |
| WAKE_UP_SRC  | R                   | 38               | 00111000 | 00000000 | Wakeup source                       |
| RESERVED     | -                   | 39               | 00111001 | -        | RESERVED                            |

Table 20. Register map (continued)

| Name        | Type <sup>(1)</sup> | Register address |          | Default  | Comment   |
|-------------|---------------------|------------------|----------|----------|-----------|
|             |                     | Hex              | Binary   |          |           |
| SIXD_SRC    | R                   | 3A               | 00111010 | 00000000 | 6D source |
| ALL_INT_SRC | R                   | 3B               | 00111011 | 00000000 |           |
| X_OFS_USR   | R/W                 | 3C               | 00111100 | 00000000 |           |
| Y_OFS_USR   | R/W                 | 3D               | 00111110 | 00000000 |           |
| Z_OFS_USR   | R/W                 | 3E               | 00000100 | 00000000 |           |
| CTRL_REG7   | R/W                 | 3F               | 00000100 | 00000000 |           |

1. R = read-only register, R/W = readable/writable register

Registers marked as *Reserved* must not be changed. Writing to those registers may cause permanent damage to the device.

The content of the registers that are loaded at boot should not be changed. They contain the factory calibration values. Their content is automatically restored when the device is powered up.

## 8 Register description

### 8.1 OUT\_T\_L (0Dh)

Temperature output register in 12-bit resolution (r).

**Table 21. OUT\_T\_L register**

|       |       |       |       |   |   |   |   |
|-------|-------|-------|-------|---|---|---|---|
| TEMP3 | TEMP2 | TEMP1 | TEMP0 | 0 | 0 | 0 | 0 |
|-------|-------|-------|-------|---|---|---|---|

**Table 22. OUT\_T\_L register description**

|           |  |
|-----------|--|
| TEMP[3:0] | The 8 least significant bits of the temperature sensor output. Sensitivity = 16 LSB/°C. Together with <i>OUT_T_H (0Eh)</i> , it forms the output value expressed as a 16-bit word in 2's complement. |
|-----------|--|

### 8.2 OUT\_T\_H (0Eh)

Temperature output register in 12-bit resolution (r).

**Table 23. OUT\_T\_H register**

|        |        |       |       |       |       |       |       |
|--------|--------|-------|-------|-------|-------|-------|-------|
| TEMP11 | TEMP10 | TEMP9 | TEMP8 | TEMP7 | TEMP6 | TEMP5 | TEMP4 |
|--------|--------|-------|-------|-------|-------|-------|-------|

**Table 24. OUT\_T\_H register description**

|            |  |
|------------|--|
| TEMP[11:4] | The 8 most significant bits of the temperature sensor output. Sensitivity = 16 LSB/°C. Together with <i>OUT_T_L (0Dh)</i> , it forms the output value expressed as a 16-bit word in 2's complement |
|------------|--|

### 8.3 WHO\_AM\_I (0Fh)

Who\_AM\_I register (r). This register is a read-only register. Its value is fixed at 44h.

**Table 25. WHO\_AM\_I register default values**

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
|---|---|---|---|---|---|---|---|

## 8.4 CTRL1 (20h)

Control register 1 (r/w)

**Table 26. Control register 1**

|      |      |      |      |          |          |          |          |
|------|------|------|------|----------|----------|----------|----------|
| ODR3 | ODR2 | ODR1 | ODR0 | OP_MODE1 | OP_MODE0 | PW_MODE1 | PW_MODE0 |
|------|------|------|------|----------|----------|----------|----------|

**Table 27. Control register 1 description**

|              |   |
|--------------|---|
| ODR[3:0]     | Output data rate and mode selection (see <a href="#">Table 28</a> ) |
| OP_MODE[1:0] | Operating mode selection (see <a href="#">Table 29</a> )            |
| PW_MODE[1:0] | Power mode selection (see <a href="#">Table 30</a> )                |

ODR[3:0] is used to set the power mode and ODR selection. The following table lists the bit settings for power-down mode and each available frequency.

**Table 28. Data rate configuration**

| ODR[3:0] | Power mode / data rate configuration |
|----------|--------------------------------------|
| 0000     | Power-down                           |
| 0001     | 1.6 Hz                               |
| 0010     | 12.5 Hz                              |
| 0011     | 25 Hz                                |
| 0100     | 50 Hz                                |
| 0101     | 100 Hz                               |

**Table 29. Operating mode selection**

| OP_MODE[1:0] | Mode and resolution  |
|--------------|--|
| 00           | Continuous Mode (12/14-bit resolution)                       |
| 01           | -  |
| 10           | Single data conversion on-demand mode (12/14-bit resolution) |
| 11           | -  |

**Table 30. Power mode selection**

| PW_MODE[1:0] | Power mode and resolution        |
|--------------|----------------------------------|
| 00           | Power Mode 1 (12-bit resolution) |
| 01           | Power Mode 2 (14-bit resolution) |
| 10           | Power Mode 3 (14-bit resolution) |
| 11           | Power Mode 4 (14-bit resolution) |



## 8.5 CTRL2 (21h)

Control register 2 (r/w)

**Table 31. Control register 2**

|      |            |                  |            |     |            |             |     |
|------|------------|------------------|------------|-----|------------|-------------|-----|
| BOOT | SOFT_RESET | 0 <sup>(1)</sup> | CS_PU_DISC | BDU | IF_ADD_INC | I2C_DISABLE | SIM |
|------|------------|------------------|------------|-----|------------|-------------|-----|

1. This bit must be set to '0' for the correct operation of the device.

**Table 32. Control register 2 description**

|             |  |
|-------------|--|
| BOOT        | Boot enables retrieving the correct trimming parameters from nonvolatile memory into registers where trimming parameters are stored.<br>Once the operation is over, this bit automatically returns to 0.<br>Default value: 0 (0: disabled; 1: enabled) |
| SOFT_RESET  | Soft reset acts as reset for all control registers, then goes to 0.<br>Default value: 0 (0: disabled; 1: enabled)  |
| CS_PU_DISC  | Disconnect CS pull-up. Default value: 0<br>(0: pull-up connected to CS pin;<br>1: pull-up disconnected to CS pin)  |
| BDU         | Block data update. Default value: 0<br>(0: continuous update; 1: output registers not updated until MSB and LSB read)  |
| IF_ADD_INC  | Register address automatically incremented during multiple byte access with a serial interface (I <sup>2</sup> C or SPI). Default value: 1 (0: disabled; 1: enabled)   |
| I2C_DISABLE | Disable I <sup>2</sup> C communication protocol. Default value: 0<br>(0: SPI and I <sup>2</sup> C interfaces enabled; 1: I <sup>2</sup> C mode disabled)   |
| SIM         | SPI serial interface mode selection. Default value: 0<br>0: 4-wire interface; 1: 3-wire interface  |

The BDU bit is used to inhibit the update of the output registers until both upper and lower register parts are read. In default mode (BDU = '0') the output register values are updated continuously. When the BDU is activated (BDU = '1'), the content of the output registers is not updated until both MSB and LSB are read which avoids reading values related to different sample times.

## 8.6 CTRL3 (22h)

Control register 3 (r/w)

**Table 33. Control register 3**

|     |     |       |     |           |   |              |            |
|-----|-----|-------|-----|-----------|---|--------------|------------|
| ST2 | ST1 | PP_OD | LIR | H_LACTIVE | 0 | SLP_MODE_SEL | SLP_MODE_1 |
|-----|-----|-------|-----|-----------|---|--------------|------------|

**Table 34. Control register 3 description**

|              |  |
|--------------|--|
| ST[2:1]      | Self-test enable. Default value: 00<br>(00: Self-test disabled; Other: see <a href="#">Table 35</a> )  |
| PP_OD        | Push-pull/open-drain selection on interrupt pad. Default value: 0<br>(0: push-pull; 1: open-drain)   |
| LIR          | Latched Interrupt. Switches between latched ('1'-logic) and pulsed ('0'-logic) mode for function source signals and interrupts routed to pins. Default value: 0<br>(0: interrupt request not latched; 1: interrupt request latched)  |
| H_LACTIVE    | Interrupt active high, low. Default value: 0<br>(0: active high; 1: active low)  |
| SLP_MODE_SEL | Single data conversion on demand mode selection:<br>0: enabled with external trigger on INT2;<br>1: enabled by I <sup>2</sup> C/SPI writing SLP_MODE_1 to 1.   |
| SLP_MODE_1   | Single data conversion on demand mode enable. When SLP_MODE_SEL = '1' and this bit is set to '1' logic, single data conversion on demand mode starts. When XL data are available in the registers, this bit is set to '0' automatically and the device is ready for another triggered session. |

**Table 35. Self-test mode selection**

| ST2 | ST1 | Self-test mode          |
|-----|-----|-------------------------|
| 0   | 0   | Normal mode             |
| 0   | 1   | Positive sign self-test |
| 1   | 0   | Negative sign self-test |
| 1   | 1   | -                       |

## 8.7 CTRL4\_INT1 (23h)

Control register 4 (r/w)

**Table 36. Control register 4**

|         |   |         |         |   |            |          |           |
|---------|---|---------|---------|---|------------|----------|-----------|
| INT1_6D | 0 | INT1_WU | INT1_FF | 0 | INT1_DIFF5 | INT1_FTH | INT1_DRDY |
|---------|---|---------|---------|---|------------|----------|-----------|

**Table 37. Control register 4 description**

|            |   |
|------------|---|
| INT1_6D    | 6D recognition is routed to INT1 pad. Default: 0<br>(0: disabled; 1: enabled)                 |
| INT1_WU    | Wakeup recognition is routed to INT1 pad. Default value: 0<br>(0: disabled; 1: enabled)       |
| INT1_FF    | Free-fall recognition is routed to INT1 pad. Default value: 0<br>(0: disabled; 1: enabled)    |
| INT1_DIFF5 | FIFO full recognition is routed to INT1 pad. Default value: 0<br>(0: disabled; 1: enabled)    |
| INT1_FTH   | FIFO threshold interrupt is routed to INT1 pad. Default value: 0<br>(0: disabled; 1: enabled) |
| INT1_DRDY  | Data-Ready is routed to INT1 pad. Default value: 0<br>(0: disabled; 1: enabled)               |

## 8.8 CTRL5\_INT2 (24h)

Control register 5 (r/w)

**Table 38. Control register 5**

|                  |                |           |             |          |            |          |           |
|------------------|----------------|-----------|-------------|----------|------------|----------|-----------|
| INT2_SLEEP_STATE | INT2_SLEEP_CHG | INT2_BOOT | INT2_DRDY_T | INT2_OVR | INT2_DIFF5 | INT2_FTH | INT2_DRDY |
|------------------|----------------|-----------|-------------|----------|------------|----------|-----------|

**Table 39. Control register 5 description**

|                  |  |
|------------------|--|
| INT2_SLEEP_STATE | Enable routing of SLEEP_STATE on INT2 pad. Default value: 0 (0: disabled; 1: enabled)      |
| INT2_SLEEP_CHG   | Sleep change status routed to INT2 pad. Default value: 0 (0: disabled; 1: enabled)         |
| INT2_BOOT        | Boot state routed to INT2 pad. Default value: 0 (0: disabled; 1: enabled)                  |
| INT2_DRDY_T      | Temperature data-ready is routed to INT2. Default value: 0 (0: disabled; 1: enabled)       |
| INT2_OVR         | FIFO overrun interrupt is routed to INT2 pad. Default value: 0 (0: disabled; 1: enabled)   |
| INT2_DIFF5       | FIFO full recognition is routed to INT2 pad. Default value: 0 (0: disabled; 1: enabled)    |
| INT2_FTH         | FIFO threshold interrupt is routed to INT2 pad. Default value: 0 (0: disabled; 1: enabled) |
| INT2_DRDY        | Data-ready is routed to INT2 pad. Default value: 0 (0: disabled; 1: enabled)               |

## 8.9 CTRL6 (25h)

Control register 6 (r/w)

**Table 40. Control register 6**

|          |          |     |     |     |   |   |   |
|----------|----------|-----|-----|-----|---|---|---|
| BW_FILT1 | BW_FILT0 | FS1 | FS0 | FDS | 0 | 0 | 0 |
|----------|----------|-----|-----|-----|---|---|---|

**Table 41. Control register 6 description**

|              |  |
|--------------|--|
| BW_FILT[1:0] | Bandwidth selection (see <a href="#">Table 42</a> )  |
| FS[1:0]      | Full-scale selection (see <a href="#">Table 45</a> )   |
| FDS          | Filtered data type selection. Default value: 0<br>(0: low-pass filter path selected;<br>1: high-pass filter path selected) |

**Table 42. Digital filtering cutoff selection (FDS bit set to '0')**

| BW_FILT[1:0] | Bandwidth selection  |
|--------------|--|
| 00           | LPF1 only<br>refer to <a href="#">Table 43: LPF1 cutoff (FDS bit set to '0')</a> |
| 01           | ODR/4  |
| 10           | ODR/10   |
| 11           | ODR/20   |

**Table 43. LPF1 cutoff (FDS bit set to '0')**

| Mode             | ODR selection | Cutoff [Hz] |
|------------------|---------------|-------------|
| Low-Power Mode 4 | @ each ODR    | 180         |
| Low-Power Mode 3 | @ each ODR    | 360         |
| Low-Power Mode 2 | @ each ODR    | 720         |
| Low-Power Mode 1 | @ each ODR    | 3200        |

**Table 44. Digital high-pass filter cutoff selection (FDS bit set to '1')**

| BW_FILT[1:0] | Bandwidth selection |
|--------------|---------------------|
| 00           | ODR/4               |
| 01           | ODR/4               |
| 10           | ODR/10              |
| 11           | ODR/20              |

**Table 45. Full-scale selection**

| FS[1:0] | Full-scale selection |
|---------|----------------------|
| 00      | ±2 g                 |
| 01      | ±4 g                 |

## 8.10 OUT\_T (26h)

Temperature output register in 8-bit resolution (r)

**Table 46. OUT\_T register**

|       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|
| TEMP7 | TEMP6 | TEMP5 | TEMP4 | TEMP3 | TEMP2 | TEMP1 | TEMP0 |
|-------|-------|-------|-------|-------|-------|-------|-------|

**Table 47. OUT\_T register description**

|           |  |
|-----------|--|
| TEMP[7:0] | Temperature sensor output data.<br>The value is expressed as two's complement sign. Sensitivity = 1°C/LSB<br>0 LSB represents T=25 °C ambient. |
|-----------|--|

## 8.11 STATUS (27h)

Status register (r).

**Table 48. STATUS register**

|          |       |             |   |   |       |       |      |
|----------|-------|-------------|---|---|-------|-------|------|
| FIFO_THS | WU_IA | SLEEP_STATE | 0 | 0 | 6D_IA | FF_IA | DRDY |
|----------|-------|-------------|---|---|-------|-------|------|

**Table 49. STATUS register description**

|             |  |
|-------------|--|
| FIFO_THS    | FIFO threshold status flag.<br>(0: FIFO filling is lower than threshold level;<br>1: FIFO filling is equal to or higher than the threshold level.) |
| WU_IA       | Wakeup event detection status.<br>(0: Wakeup event not detected; 1: Wakeup event detected)   |
| SLEEP_STATE | Sleep event status.<br>(0: Sleep event not detected; 1: Sleep event detected)  |
| 6D_IA       | Source of change in position portrait/landscape/face-up/face-down.<br>(0: no event detected; 1: a change in position detected)                     |
| FF_IA       | Free-fall event detection status.<br>(0: free-fall event not detected; 1: free-fall event detected)  |
| DRDY        | Data-ready status.<br>(0: not ready; 1: X-, Y- and Z-axis new data available)  |

## 8.12 OUT\_X\_L (28h)

X-axis LSB output register (r).

**Table 50. OUT\_X\_L register**

|      |      |      |      |                     |                     |   |   |
|------|------|------|------|---------------------|---------------------|---|---|
| X_L7 | X_L6 | X_L5 | X_L4 | X_L3 <sup>(1)</sup> | X_L2 <sup>(1)</sup> | 0 | 0 |
|------|------|------|------|---------------------|---------------------|---|---|

1. If Power Mode 1 is enabled, this bit is set to 0.

The 8 least significant bits of linear acceleration sensor X-axis output. Together with the [OUT\\_X\\_H \(29h\)](#) register, it forms the output value expressed as a 16-bit word in 2's complement.

## 8.13 OUT\_X\_H (29h)

X-axis MSB output register (r).

**Table 51. OUT\_X\_H register**

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| X_H7 | X_H6 | X_H5 | X_H4 | X_H3 | X_H2 | X_H1 | X_H0 |
|------|------|------|------|------|------|------|------|

The 8 most significant bits of linear acceleration sensor X-axis output. Together with the [OUT\\_X\\_L \(28h\)](#) register, it forms the output value expressed as a 16-bit word in 2's complement.

## 8.14 OUT\_Y\_L (2Ah)

Y-axis LSB output register (r).

**Table 52. OUT\_Y\_L register**

|      |      |      |      |                     |                     |   |   |
|------|------|------|------|---------------------|---------------------|---|---|
| Y_L7 | Y_L6 | Y_L5 | Y_L4 | Y_L3 <sup>(1)</sup> | Y_L2 <sup>(1)</sup> | 0 | 0 |
|------|------|------|------|---------------------|---------------------|---|---|

1. If Power Mode 1 is enabled, this bit is set to 0.

The 8 least significant bits of linear acceleration sensor Y-axis output. Together with the [OUT\\_Y\\_H \(2Bh\)](#) register, it forms the output value expressed as a 16-bit word in 2's complement.

## 8.15 OUT\_Y\_H (2Bh)

Y-axis MSB output register (r).

**Table 53. OUT\_Y\_H register**

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| Y_H7 | Y_H6 | Y_H5 | Y_H4 | Y_H3 | Y_H2 | Y_H1 | Y_H0 |
|------|------|------|------|------|------|------|------|

The 8 most significant bits of linear acceleration sensor Y-axis output. Together with the [OUT\\_Y\\_L \(2Ah\)](#) register, it forms the output value expressed as a 16-bit word in 2's complement.

### 8.16 OUT\_Z\_L (2Ch)

Z-axis LSB output register (r).

**Table 54. OUT\_Z\_L register**

|      |      |      |      |                     |                     |   |   |
|------|------|------|------|---------------------|---------------------|---|---|
| Z_L7 | Z_L6 | Z_L5 | Z_L4 | Z_L3 <sup>(1)</sup> | Z_L2 <sup>(1)</sup> | 0 | 0 |
|------|------|------|------|---------------------|---------------------|---|---|

1. If Power Mode 1 is enabled, this bit is set to 0.

The 8 least significant bits of linear acceleration sensor Z-axis output. Together with the [OUT\\_Z\\_H \(2Dh\)](#) register, it forms the output value expressed as a 16-bit word in 2's complement.

### 8.17 OUT\_Z\_H (2Dh)

Z-axis MSB output register (r).

**Table 55. OUT\_Z\_H register**

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| Z_H7 | Z_H6 | Z_H5 | Z_H4 | Z_H3 | Z_H2 | Z_H1 | Z_H0 |
|------|------|------|------|------|------|------|------|

The 8 most significant bits of linear acceleration sensor Z-axis output. Together with the [OUT\\_Z\\_L \(2Ch\)](#) register, it forms the output value expressed as a 16-bit word in 2's complement.

### 8.18 FIFO\_CTRL (2Eh)

FIFO control register (r/w).

**Table 56. FIFO\_CTRL register**

|        |        |        |      |      |      |      |      |
|--------|--------|--------|------|------|------|------|------|
| FMode2 | FMode1 | FMode0 | FTH4 | FTH3 | FTH2 | FTH1 | FTH0 |
|--------|--------|--------|------|------|------|------|------|

**Table 57. FIFO\_CTRL register description**

|            |   |
|------------|---|
| FMode[2:0] | FIFO mode selection bits. Default: 000. For further details refer to <a href="#">Table 58</a> |
| FTH[4:0]   | FIFO threshold level setting.   |

**Table 58. FIFO mode selection**

| FMode[2:0] | Mode description  |
|------------|---|
| 000        | Bypass mode: FIFO turned off  |
| 001        | FIFO mode: Stops collecting data when FIFO is full.                               |
| 010        | Reserved  |
| 011        | Continuous-to-FIFO: Stream mode until trigger is deasserted, then FIFO mode       |
| 100        | Bypass-to-Continuous: Bypass mode until trigger is deasserted, then FIFO mode     |
| 101        | Reserved  |
| 110        | Continuous mode: If the FIFO is full, the new sample overwrites the older sample. |
| 111        | Reserved  |



### 8.19 FIFO\_SAMPLES (2Fh)

FIFO\_SAMPLES control register (r).

**Table 59. FIFO\_SAMPLES register**

|          |          |       |       |       |       |       |       |
|----------|----------|-------|-------|-------|-------|-------|-------|
| FIFO_FTH | FIFO_OVR | Diff5 | Diff4 | Diff3 | Diff2 | Diff1 | Diff0 |
|----------|----------|-------|-------|-------|-------|-------|-------|

**Table 60. FIFO\_SAMPLES register description**

|           |  |
|-----------|--|
| FIFO_FTH  | FIFO threshold status flag.<br>(0: FIFO filling is lower than threshold level;<br>1: FIFO filling is equal to or higher than the threshold level.) |
| FIFO_OVR  | FIFO overrun status.<br>(0: FIFO is not completely filled;<br>1: FIFO is completely filled and at least one sample has been overwritten)           |
| Diff[5:0] | Represents the number of unread samples stored in FIFO.<br>(000000 = FIFO empty; 100000 = FIFO full, 32 unread samples).                           |

### 8.20 SIXD\_THS (30h)

6D threshold register (r/w).

**Table 61. SIXD\_THS register**

|       |         |         |   |   |   |   |   |
|-------|---------|---------|---|---|---|---|---|
| 4D_EN | 6D_THS1 | 6D_THS0 | 0 | 0 | 0 | 0 | 0 |
|-------|---------|---------|---|---|---|---|---|

**Table 62. SIXD\_THS register description**

|             |   |
|-------------|---|
| 4D_EN       | 4D detection portrait/landscape position enable.<br>(0: no position detected;<br>1: portrait/landscape detection and face-up/face-down position enabled). |
| 6D_THS[1:0] | Thresholds for 4D/6D function @ FS = ±2 g (refer to <a href="#">Table 63</a> )  |

**Table 63. 4D/6D threshold setting FS @ ±2 g**

| 6D_THS[1:0] | Threshold  |
|-------------|------------|
| 00          | 80 degrees |
| 01          | 70 degrees |
| 10          | 60 degrees |
| 11          | 50 degrees |

## 8.21 WAKE\_UP\_THS (34h)

Wakeup threshold register (r/w).

**Table 64. WAKE\_UP\_THS register**

|   |          |         |         |         |          |          |          |
|---|----------|---------|---------|---------|----------|----------|----------|
| 0 | SLEEP_ON | WK_THS5 | WK_THS4 | WK_THS3 | WK_THS 2 | WK_THS 1 | WK_THS 0 |
|---|----------|---------|---------|---------|----------|----------|----------|

**Table 65. WAKE\_UP\_THS register description**

|             |  |
|-------------|--|
| SLEEP_ON    | Sleep (inactivity) enable. Default value: 0<br>(0: sleep disabled; 1: sleep enabled) |
| WK_THS[5:0] | Wakeup threshold, 6-bit unsigned 1 LSB = 1/64 of FS. Default value: 000000           |

## 8.22 WAKE\_UP\_DUR (35h)

Wakeup and sleep duration configuration register (r/w).

**Table 66. WAKE\_UP\_DUR register**

|         |           |           |            |            |            |            |            |
|---------|-----------|-----------|------------|------------|------------|------------|------------|
| FF_DUR5 | WAKE_DUR1 | WAKE_DUR0 | STATIONARY | SLEEP_DUR3 | SLEEP_DUR2 | SLEEP_DUR1 | SLEEP_DUR0 |
|---------|-----------|-----------|------------|------------|------------|------------|------------|

**Table 67. WAKE\_UP\_DUR register description**

|                |  |
|----------------|--|
| FF_DUR5        | Free-fall duration. In conjunction with FF_DUR [4:0] bit in <a href="#">FREE_FALL (36h)</a> register. 1 LSB = 1 * 1/ODR                                    |
| WAKE_DUR[1:0]  | Wakeup duration. 1 LSB = 1 * 1/ODR   |
| STATIONARY     | Enable stationary detection / motion detection with no automatic ODR change when detecting stationary state. Default value: 0<br>(0: disabled; 1: enabled) |
| SLEEP_DUR[3:0] | Duration to go in sleep mode.<br>Default value is SLEEP_DUR[3:0] = 0000 (which is 16 * 1/ODR)<br>1 LSB = 512 * 1/ODR                                       |

## 8.23 FREE\_FALL (36h)

Free-fall duration and threshold configuration register (r/w).

**Table 68. FREE\_FALL register**

|         |         |         |         |         |         |         |         |
|---------|---------|---------|---------|---------|---------|---------|---------|
| FF_DUR4 | FF_DUR3 | FF_DUR2 | FF_DUR1 | FF_DUR0 | FF_THS2 | FF_THS1 | FF_THS0 |
|---------|---------|---------|---------|---------|---------|---------|---------|

**Table 69. FREE\_FALL register description**

|              |  |
|--------------|--|
| FF_DUR [4:0] | Free-fall duration. In conjunction with FF_DUR5 bit in <a href="#">WAKE_UP_DUR (35h)</a> register. 1 LSB = 1 * 1/ODR |
| FF_THS [2:0] | Free-fall threshold @ FS = $\pm 2 g$ (refer to <a href="#">Table 70</a> )  |

**Table 70. FREE\_FALL threshold decoding @  $\pm 2 g$  FS**

| FF_THS[2:0] | Threshold decoding (LSB) |
|-------------|--------------------------|
| 000         | 5                        |
| 001         | 7                        |
| 010         | 8                        |
| 011         | 10                       |
| 100         | 11                       |
| 101         | 13                       |
| 110         | 15                       |
| 111         | 16                       |

## 8.24 STATUS\_DUP (37h)

Event detection status register (r).

**Table 71. STATUS\_DUP register**

|     |        |                |   |   |       |       |      |
|-----|--------|----------------|---|---|-------|-------|------|
| OVR | DRDY_T | SLEEP_STATE_IA | 0 | 0 | 6D_IA | FF_IA | DRDY |
|-----|--------|----------------|---|---|-------|-------|------|

**Table 72. STATUS\_DUP register description**

|                |   |
|----------------|---|
| OVR            | FIFO overrun status flag.<br>(0: FIFO is not completely filled;<br>1: FIFO is completely filled and at least one sample has been overwritten) |
| DRDY_T         | Temperature status.<br>(0: data not available; 1: a new set of data is available)   |
| SLEEP_STATE_IA | Sleep event status.<br>(0: Sleep event not detected; 1: Sleep event detected)   |
| 6D_IA          | Source of change in position portrait/landscape/face-up/face-down.<br>(0: no event detected; 1: a change in position is detected)             |
| FF_IA          | Free-fall event detection status.<br>(0: free-fall event not detected; 1: free-fall event detected)   |
| DRDY           | Data-ready status.<br>(0: not ready; 1: X-, Y- and Z-axis new data available)   |

## 8.25 WAKE\_UP\_SRC (38h)

Wakeup source register (r).

**Table 73. WAKE\_UP\_SRC register**

|   |   |       |                |       |      |      |      |
|---|---|-------|----------------|-------|------|------|------|
| 0 | 0 | FF_IA | SLEEP_STATE IA | WU_IA | X_WU | Y_WU | Z_WU |
|---|---|-------|----------------|-------|------|------|------|

**Table 74. WAKE\_UP\_SRC register description**

|                |  |
|----------------|--|
| FF_IA          | Free-fall event detection status.<br>(0: FF event not detected; 1: FF event detected)                                  |
| SLEEP_STATE IA | Sleep event status.<br>(0: Sleep event not detected; 1: Sleep event detected)  |
| WU_IA          | Wakeup event detection status.<br>(0: Wakeup event not detected; 1: Wakeup event is detected)                          |
| X_WU           | Wakeup event detection status on X-axis.<br>(0: Wakeup event on X not detected; 1: Wakeup event on X-axis is detected) |
| Y_WU           | Wakeup event detection status on Y-axis.<br>(0: Wakeup event on Y not detected; 1: Wakeup event on Y-axis is detected) |
| Z_WU           | Wakeup event detection status on Z-axis.<br>(0: Wakeup event on Z not detected; 1: Wakeup event on Z-axis is detected) |

## 8.26 SIXD\_SRC (3Ah)

6D source register (r).

**Table 75. SIXD\_SRC register**

|   |       |    |    |    |    |    |    |
|---|-------|----|----|----|----|----|----|
| 0 | 6D_IA | ZH | ZL | YH | YL | XH | XL |
|---|-------|----|----|----|----|----|----|

**Table 76. SIXD\_SRC register description**

|       |   |
|-------|---|
| 6D_IA | Source of change in position portrait/landscape/face-up/face-down.<br>(0: no event detected; 1: a change in position is detected) |
| ZH    | ZH over threshold.<br>(0: ZH does not exceed the threshold; 1: ZH is over the threshold)  |
| ZL    | ZL over threshold.<br>(0: ZL does not exceed the threshold; 1: ZL is over the threshold)  |
| YH    | YH over threshold.<br>(0: YH does not exceed the threshold; 1: YH is over the threshold)  |
| YL    | YL over threshold.<br>(0: YL does not exceed the threshold; 1: YL is over the threshold)  |
| XH    | XH over threshold.<br>(0: XH does not exceed the threshold; 1: XH is over the threshold)  |
| XL    | XL over threshold.<br>(0: XL does not exceed the threshold; 1: XL is over the threshold)  |

## 8.27 ALL\_INT\_SRC (3Bh)

Reading this register, all related interrupt function flags routed to the INT pads are reset simultaneously.

**Table 77. ALL\_INT\_SRC register**

|   |   |                 |       |   |   |       |       |
|---|---|-----------------|-------|---|---|-------|-------|
| 0 | 0 | SLEEP_CHANGE_IA | 6D_IA | 0 | 0 | WU_IA | FF_IA |
|---|---|-----------------|-------|---|---|-------|-------|

**Table 78. ALL\_INT\_SRC register description**

|                 |  |
|-----------------|--|
| SLEEP_CHANGE_IA | Sleep change status.<br>(0: Sleep change not detected; 1: Sleep change detected)   |
| 6D_IA           | Source of change in position portrait/landscape/face-up/face-down.<br>(0: no event detected; 1: a change in position detected) |
| WU_IA           | Wakeup event detection status.<br>(0: wakeup event not detected; 1: wakeup event detected)                                     |
| FF_IA           | Free-fall event detection status.<br>(0: free-fall event not detected; 1: free-fall event detected)                            |

## 8.28 X\_OFS\_USR (3Ch)

Accelerometer X-axis user offset correction (r/w). The offset value set in the X\_OFS\_USR offset register is internally subtracted from the acceleration value measured on the X-axis.

**Table 79. X\_OFS\_USR register**

|             |             |             |             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| X_OFS_USR_7 | X_OFS_USR_6 | X_OFS_USR_5 | X_OFS_USR_4 | X_OFS_USR_3 | X_OFS_USR_2 | X_OFS_USR_1 | X_OFS_USR_0 |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|

**Table 80. X\_OFS\_USR register description**

|                 |  |
|-----------------|--|
| X_OFS_USR_[7:0] | Accelerometer X-axis user offset correction expressed in two's complement, weight depends on the USR_OFF_W bit in <a href="#">CTRL7 (3Fh)</a> . The value must be in the range [-127 127]. |
|-----------------|--|

## 8.29 Y\_OFS\_USR (3Dh)

Accelerometer Y-axis user offset correction (r/w). The offset value set in the Y\_OFS\_USR offset register is internally subtracted from the acceleration value measured on the Y-axis.

**Table 81. Y\_OFS\_USR register**

|             |             |             |             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Y_OFS_USR_7 | Y_OFS_USR_6 | Y_OFS_USR_5 | Y_OFS_USR_4 | Y_OFS_USR_3 | Y_OFS_USR_2 | Y_OFS_USR_1 | Y_OFS_USR_0 |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|

**Table 82. Y\_OFS\_USR register description**

|                 |  |
|-----------------|--|
| Y_OFS_USR_[7:0] | Accelerometer Y-axis user offset correction expressed in two's complement, weight depends on the USR_OFF_W bit in <a href="#">CTRL7 (3Fh)</a> . The value must be in the range [-127 127]. |
|-----------------|--|

### 8.30 Z\_OFS\_USR (3Eh)

Accelerometer Z-axis user offset correction (r/w). The offset value set in the Z\_OFS\_USR offset register is internally subtracted from the acceleration value measured on the Z-axis.

**Table 83. Z\_OFS\_USR register**

|             |             |             |             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Z_OFS_USR_7 | Z_OFS_USR_6 | Z_OFS_USR_5 | Z_OFS_USR_4 | Z_OFS_USR_3 | Z_OFS_USR_2 | Z_OFS_USR_1 | Z_OFS_USR_0 |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|

**Table 84. Z\_OFS\_USR register description**

|                 |  |
|-----------------|--|
| Z_OFS_USR_[7:0] | Accelerometer Z-axis user offset correction expressed in two's complement, weight depends on the USR_OFF_W bit in <a href="#">CTRL7 (3Fh)</a> . The value must be in the range [-127 127]. |
|-----------------|--|

### 8.31 CTRL7 (3Fh)

**Table 85. CTRL7 register**

|             |              |                   |                |               |           |             |            |
|-------------|--------------|-------------------|----------------|---------------|-----------|-------------|------------|
| DRDY_PULSED | INT2_ON_INT1 | INTERRUPTS_ENABLE | USR_OFF_ON_OUT | USR_OFF_ON_WU | USR_OFF_W | HP_REF_MODE | LPASS_ON6D |
|-------------|--------------|-------------------|----------------|---------------|-----------|-------------|------------|

**Table 86. CTRL7 register description**

|                   |  |
|-------------------|--|
| DRDY_PULSED       | Switches between latched and pulsed mode for data ready interrupt.<br>(0: latched mode is used; 1: pulsed mode enabled for data-ready)   |
| INT2_ON_INT1      | Signal routing.<br>(1: all signals available only on INT2 are routed on INT1)  |
| INTERRUPTS_ENABLE | Enable interrupts.   |
| USR_OFF_ON_OUT    | Enable application of user offset value on XL output data registers.<br>FDS bit in <a href="#">CTRL6 (25h)</a> must be set to '0'-logic (low-pass path selected).                          |
| USR_OFF_ON_WU     | Enable application of user offset value on XL data for wakeup function only.   |
| USR_OFF_W         | Selects the weight of the user offset words specified by X_OFS_USR_[7:0], Y_OFS_USR_[7:0] and Z_OFS_USR_[7:0] bits.<br>(0: 977 $\mu\text{g}/\text{LSB}$ ; 1: 15.6 $\text{mg}/\text{LSB}$ ) |
| HP_REF_MODE       | High-pass filter reference mode enable.<br>(0: high-pass filter reference mode disabled (default);<br>1: high-pass filter reference mode enabled)  |
| LPASS_ON6D        | (0: ODR/2 low pass filtered data sent to 6D interrupt function (default);<br>1: LPF2 output data sent to 6D interrupt function)  |

# 9 Package information

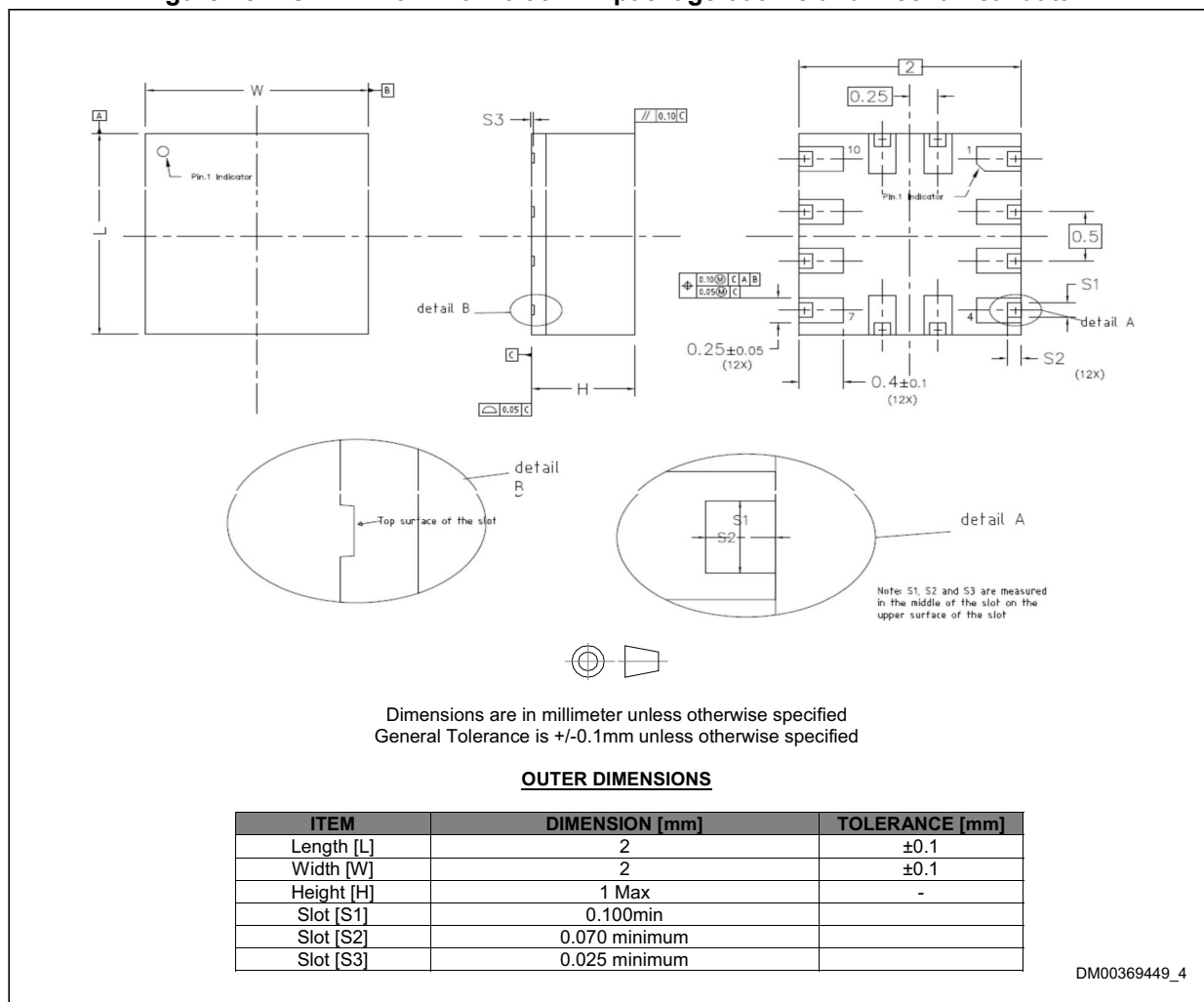
In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK is an ST trademark.

## 9.1 Soldering information

The LGA package is compliant with the ECOPACK, RoHS and “Green” standard. It is qualified for soldering heat resistance according to JEDEC J-STD-020. Land pattern and soldering recommendations are available at [www.st.com](http://www.st.com).

## 9.2 LGA-12 package information

Figure 18. LGA-12 2.0 x 2.0 x 0.93 mm package outline and mechanical data





### 9.3 LGA-12 package packing information

Figure 19. Carrier tape information for LGA-12 package

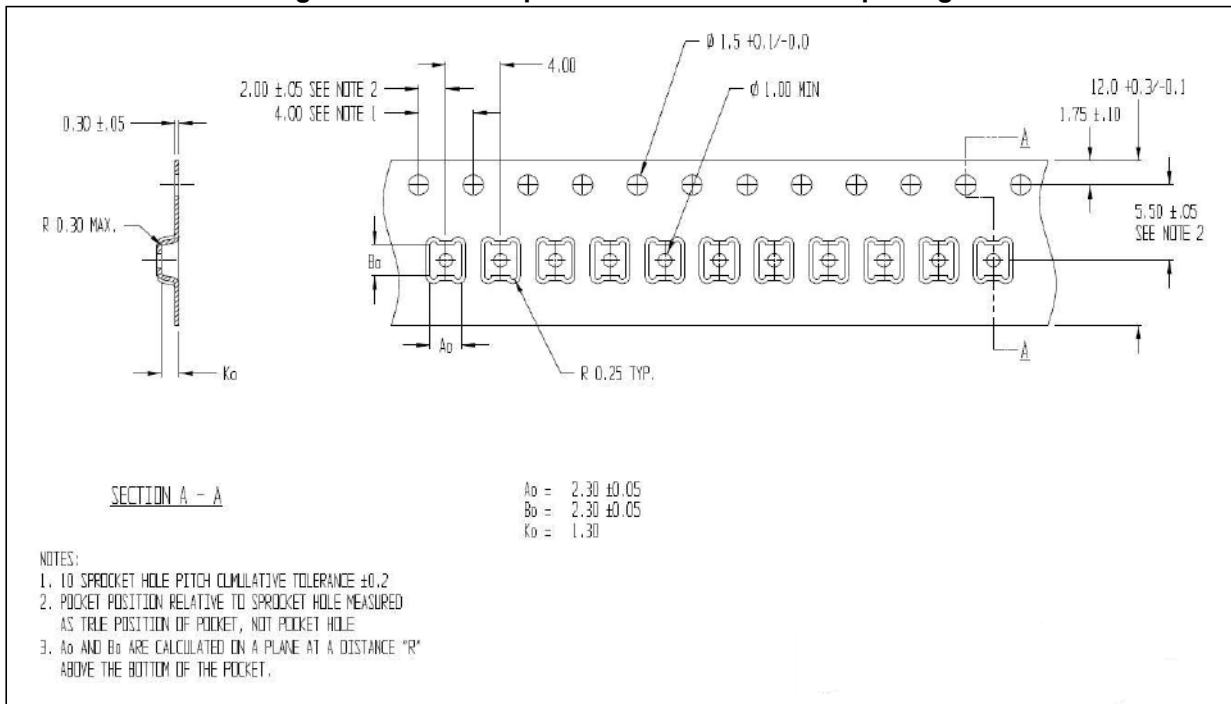


Figure 20. LGA-12 package orientation in carrier tape

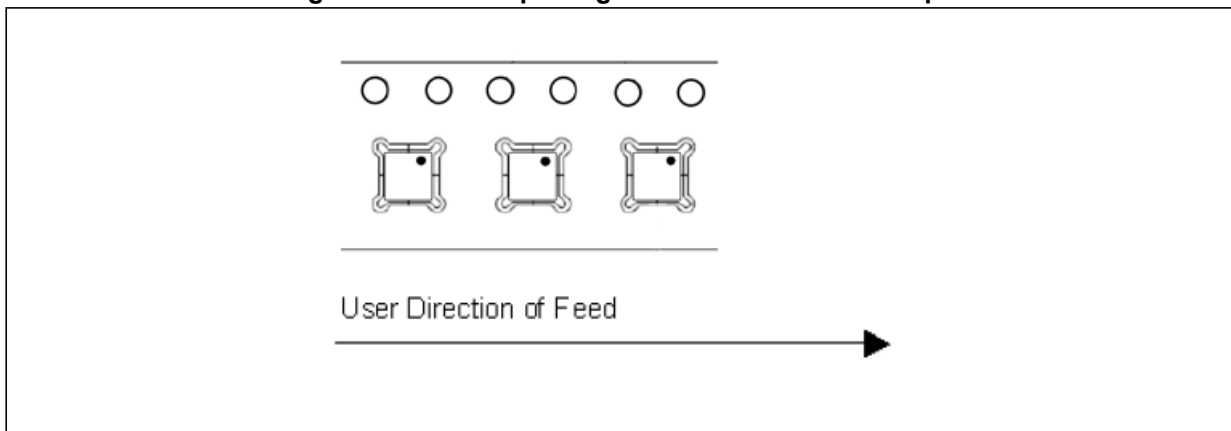


Figure 21. Reel information for carrier tape of LGA-12 package

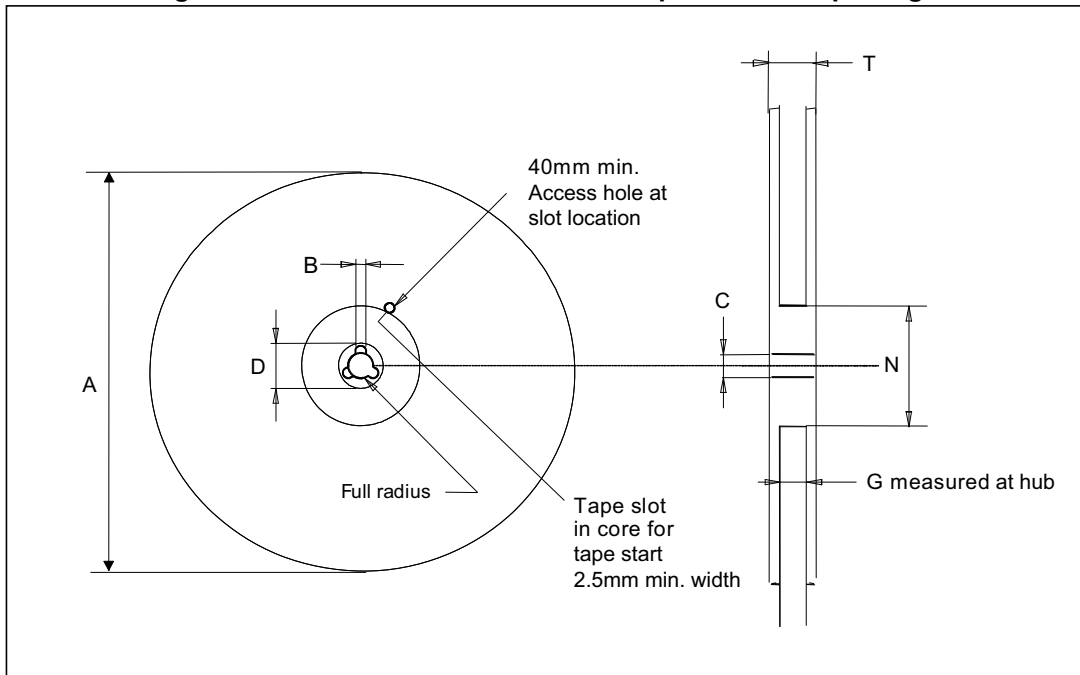


Table 87. Reel dimensions for carrier tape of LGA-12 package

| Reel dimensions (mm) |            |
|----------------------|------------|
| A (max)              | 330        |
| B (min)              | 1.5        |
| C                    | 13 ±0.25   |
| D (min)              | 20.2       |
| N (min)              | 60         |
| G                    | 12.4 +2/-0 |
| T (max)              | 18.4       |

## 10 Revision history

**Table 88. Document revision history**

| Date        | Revision | Changes              |
|-------------|----------|----------------------|
| 05-Jun-2019 | 3        | First public release |

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