da380

MEMS digital output motion sensor

low-power high performance 3-axes "DSC-XYZ" accelerometer

Key Features

- Supply voltage, 1.62V to 3.6V
- For 3x3x0.9 mm LGA-10 package
- User selectable range, ±2g, ±4g, ±8g, ±16g
- User selectable data output rate
- Digital I^2C output interface
- 14 bit resolution
- Low power consumption
- 1 Programmable interrupt generator with independent function for motion detection
- Free-fall detection
- Embedded self-test function
- Factory programmable offset and sensitivity
- RoHS compliant

Applications

- User interface for mobile phone and PMP
- Display orientation
- Gesture recognition
- Active/inactive monitoring
- Free-fall detection
- Double/ Click recognition
- Power management
- Vibration monitoring
- Inclination and tilt sensing
- Pedometer

Product Overview

The da380 sensor is the low power high performance capacitive three-axis linear accelerometer developed by micro-machined technology. The device is available in a 3x3x0.9 mm land grid array (LGA) and it is guaranteed to operate over an extended temperature range from -40°C to +85°C. The sensor element is fabricated by single crystal silicon with DRIE process and is protected by hermetically sealed silicon cap from the environment. The device features user selectable full scale of ±2g/ ±4g/ ±8g/ ±16g measurement range with data output rate from 1Hz to 1 kHz with signal condition, temperature compensation， self-test, motion detection imbedded. The da380 has a self-test mode for user to check the functioning of the sensor and a power-down mode that makes it good for handset power management. Flexible interrupt provided greatly simplify the algorithm for various motion status detections. Standard I^{2}C interface is used to communicate with the chip.

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1.1 Block diagram

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1.2 Pin description
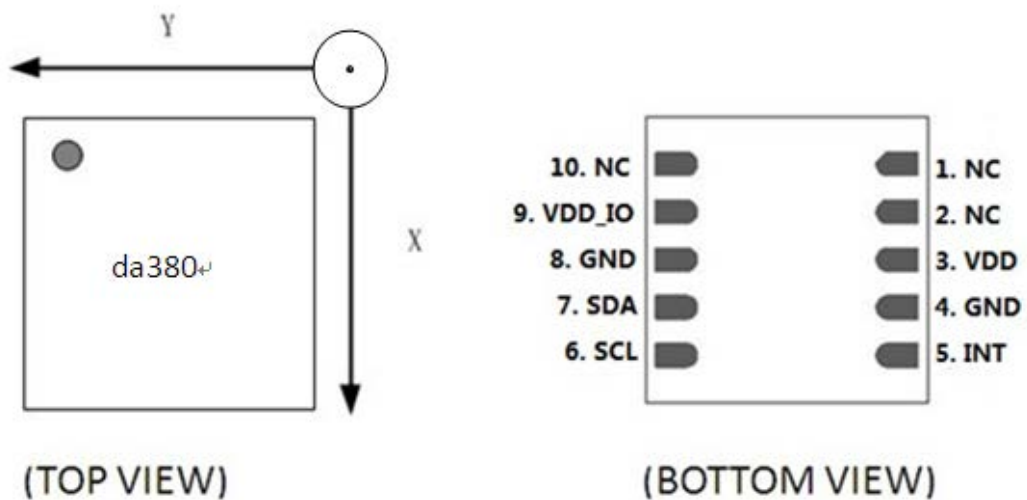
Figure 2 Pin Connections

Table 1. Pin description

Pin#	Name	Function
1	NC	Not connected
2	NC	Not connected
3	Vdd	Power supply
4	GND	0V supply
5	INT	Inertial interrupt
6	SCL	I2C serial clock (SCL)
7	SDA	I2C serial data (SDA)
8	GND	0V supply
9	Vdd_IO	Power supply for I/O pins
10	NC	Not connected

2 Mechanical and electrical specifications

2.1 Mechanical characteristics

Vdd = 2.5 V, T = 25 °C unless otherwise noted (a)

a. The product is factory calibrated at 2.5 V. The operational power supply range is from 1.62V to 3.6 V.

Table 2. Mechanical characteristic

Symbol	Parameter	Test conditions	Min	Type	Max	Unit
FS	Measurement range	FS bit set to 00		±2		g
		FS bit set to 01		±4		g
		FS bit set to 10		±8		g
		FS bit set to 11		±16		g
So	Sensitivity	FS bit set to 00		4096		LSB/g
		FS bit set to 01		2048		LSB/g
		FS bit set to 10		1024		LSB/g
		FS bit set to 11		512		LSB/g
TCSo	Sensitivity change vs. temperature	FS bit set to 00		0.01		%/°C
Tyoff	Typical zero-g level offset accuracy			70		mg
Tcoff	Zero-g level change vs. temperature	Max delta from 25°C		±0.44		mg/°C
An	Acceleration noise density	FS bit set to 00, Normal Mode, ODR = 1000Hz		150	200	ug/sqrt(Hz)
Vst	Self-test output change	X: FS bit set to 00		400		mg
		Y: FS bit set to 00		400		mg
		Z: FS bit set to 00		400		mg
Top	Operation temperature range		-40		85	°C

2.2 Electrical characteristics

Vdd = 2.5 V, T = 25 °C unless otherwise noted

Table 3. Electrical characteristics

Symbol	Parameter	Test conditions	Min	Typ.	Max	Unit
Vdd	Supply voltage		1.62	2.5	3.6	V
Vdd_IO	I/O Pins supply voltage		1.62		3.6	V
Idd	current consumption in normal mode	Top=25℃, ODR=1kHz		165		uA
Idd_lp	current consumption in low power mode	Top=25℃, ODR=250Hz, BW=500Hz		2		uA
Idd_sm	current consumption in suspend mode	Top=25℃		0.7		uA
VIH	Digital high level input voltage	I2C	0.7*Vdd_IO			V
VIL	Digital low level input voltage	I2C			0.3*Vdd_IO	V
VOH	high level output voltage		0.9*Vdd_IO			V
VOL	Low level output voltage				0.1*Vdd_IO	V
BW	System bandwidth		1.95		500	Hz
ODR	Output data rate		1		1000	Hz
Wake-up time	twu	From stand-by		1		ms
Start-up time	tsu	From power off		3		ms
PSRR	Power Supply Rejection Rate	Top=25℃			20	mg/V

2.3 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 4. Absolute maximum ratings

Parameter	Test conditions	Min	Max	Unit
Storage Temperature		-45	125	℃
Supply Voltage	Supply pins	-0.3	4.25	V
Supply Voltage	Logic pins	-0.3	Vdd_IO+0.3	V
ESD Rating	HMB,R=1.5k,C=100pF		±2	kV
Mechanical Shock	Duration<200us		10,000	g

Note: Supply voltage on any pin should never exceed 4.25V

This is a mechanical shock sensitive device, improper handling can cause permanent damages to the part.

This is an ESD sensitive device, improper handling can cause permanent damages to the part.

3   Communication interface

3.1 Communication interface Electrical specification

3.1.1 I2CElectrical specification

Table 5. Electrical specification of the I2C interface pins

Symbol	Parameter	Min	Max	Unit
f_{scl}	Clock frequency		400	kHz
t_{scl_l}	SCL low pulse	1.3		us
t_{scl_h}	SCL high pulse	0.6		us
T_{sda_setup}	SDA setup time	0.1		us
T_{sda_hold}	SDA hold time	0.0		us
t_{susta}	Setup Time for a repeated start condition	0.6		us
t_{hdsta}	Hold time for a start condition	0.6		us
t_{susto}	Setup Time for a stop condition	0.6		us
t_{buf}	Time before a new transmission can start	1.3		us

The figure below shows the definition of the I2C timing given in Table5:
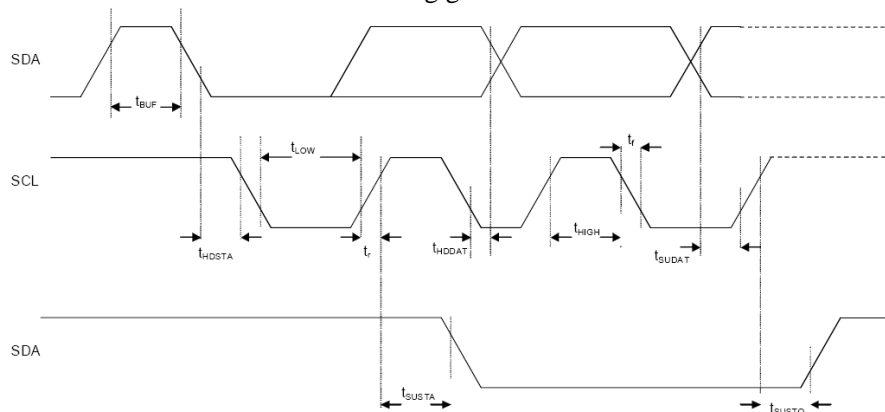
Figure 3 I2C Slave timing diagram

3.2 Digital interface operation

3.2.1 I2C Operation

I2C bus uses SCL and SDA as signal lines. Both lines are connected to VDDIO externally via pull-up resistors so that they are pulled high when the bus is free. The I2C device address of da380 is shown below.

Table 6. I2C Address

SAD$_6$	SAD$_5$	SAD$_4$	SAD$_3$	SAD$_2$	SAD$_1$	SAD$_0$	W/R
0	1	0	0	1	1	1	0/1

Table 7. SAD+Read/Write patterns

Command	SAD[6:1]	SAD[0]	R/W	SAD+R/W
Read	010011	1	1	01001111(4fh)
Write	010011	1	0	01001110(4eh)

The I2C interface protocol has special bus signal conditions. Start (S), stop (P) and binary data conditions are shown below. At start condition, SCL is high and SDA has a falling edge. Then the slave address is sent. After the 7 address bits, the direction control bit R/W selects the read or write operation. When a slave device recognizes that it is being addressed, it should acknowledge by pulling SDA low in the ninth SCL (ACK) cycle.

At stop condition, SCL is also high, but SDA has a rising edge. Data must be held stable at SDA when SCL is high. Data can change value at SDA only when SCL is low.
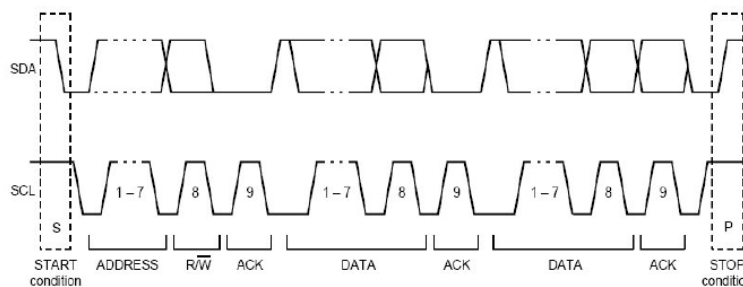
Figure 4 I2C Protocol

Table 8. Transfer when master is writing one byte to slave

Master	S	SAD+W		SUB		DATA		P
Slave			SAK		SAK		SAK	

Table 9. Transfer when master is writing multiple bytes to slave

Master	S	SAD+W		SUB		DATA		DATA		P
Slave			SAK		SAK		SAK		SAK	

Table 10. Transfer when master is receiving (reading) one byte of data from slave

Master	S	SAD+W		SUB		SR	SAD+R			NMASK	P
Slave			SAK		SAK				SAK	DATA		

Table 11. Transfer when master is receiving (reading) multiple bytes of data from slave

Master	S	SAD+W		SUB		SR	SAD+R			MAK		MAK		NMASK	P
Slave			SAK		SAK			SAK	DATA		DATA		DATA		

4   Terminology and functionality

4.1 Terminology

4.1.1 Sensitivity

Sensitivity describes the gain of the sensor and can be determined e.g. 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, ± 1 g acceleration is applied to the sensor. Subtract 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 also time. The sensitivity tolerance describes the range of sensitivities of a large population of sensors.

4.1.2 Zero-g level

Zero-g level offset (TyOff) 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 measure 0 g in X axis and 0 g in Y axis whereas the Z axis measure 1 g. The output is ideally in the middle of the dynamic range of the sensor (content of output data registers are 00h, data expressed as 2's complement number). A deviation from ideal value in this case is called Zero-g offset. Offset is to some extent a result of stress to 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 change vs. temperature". The Zero-g level tolerance (TyOff) describes the standard deviation of the range of Zero-g levels of a population of sensors.

4.2 Functionality

4.2.1 Power mode

The da380 has three different power modes. Besides normal mode, which represents the fully operational state of the device, there are two special energy saving modes: low-power mode and suspend mode.
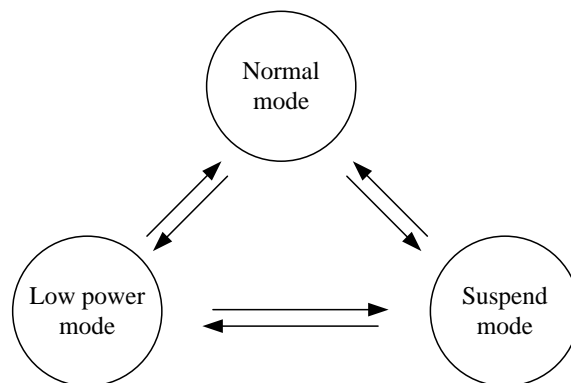
Figure 5 power mode

In normal mode, all parts of the electronic circuit are held powered-up and data acquisition is performed continuously. In suspend mode, the whole analog part, including the oscillator, Ana LDO, Dig LDO and Drive Buffer are all powered down, no data acquisition is performed and the only supported operation is to read/write the registers. Suspend mode is entered by writing '11' or '10' to the 'power_mode' bits.

In low power mode, the device is periodically switching between a sleep phase and a wake-up phase. The wake-up phase essentially corresponding to operation in normal mode with complete power-up of the circuitry. During the sleep phase the analog part except the oscillator is powered down.

During the wake-up phase, if a enabled interrupt is detected, the device stays in the wake-up phase as long as the interrupt condition endures (non-latched interrupt), or until the latch time expires (temporary interrupt), or until the interrupt is reset (latched interrupt). If no interrupt detected, the device enters the sleep phase.

4.2.2 Sensor data

The width of acceleration data is 14bits given in two's complement representation. The 14bits for each axis are split into an MSB part (one byte containing bits 13 to 6) and an LSB lower part (one byte containing bits 5 to 0 and a new_data flag).

4.2.3 Self-test

This feature permits to check the sensor functionality by applying electrostatic forces to the sensor core instead of external accelerations. By actually deflecting the seismic mass, the entire signal path of the sensor can be tested. Activating the self-test results in a static offset of the acceleration data; any external acceleration or gravitational force applied to the sensor during active self-test will be observed in the output as a superposition of both acceleration and self-test signal.

The self-test is activated individually for each axis by writing 1 to the register 'self_test_en'bits. It is possible to control the direction of the deflection though bit 'selt_test_sign' for each axis. The excitation occurs in positive (negative) direction if 'self_test_sign' = '0b' ('1b').

In order to ensure a proper interpretation of the self-test signal it is recommended to perform the self-test for both directions and then to calculate the difference of the resulting acceleration values. Table12 show the difference for each axis.

Table 12. Self-test difference values

	X-axis signal	Y-axis signal	Z-axis signal
Resulting difference value	+0.4g	+0.4g	+0.4g

4.2.4 Offset compensation

User performed offset calibration is released to users to compensate the after-board-mount offset, which can also compensate the 0-g offset from +/-500mg to +/-2.93mg.

4.2.5 Factory calibration

The IC interface is factory calibrated for sensitivity (So) and Zero-g level (TyOff). The trimming values are stored inside the device in a nonvolatile memory. The trimming parameters are downloaded into the registers after da380 reset (POR or software reset). This allows using the device without further calibration.

4.3 Interrupt controller

Interrupt engines are integrated in the da380. If the condition of an enabled interrupt is fulfilled, the corresponding status bit is set to 1 and the selected interrupt pin is activated. There is one interrupt pin, INT; interrupts can be freely mapped to this pin.

4.3.1 General features

An interrupt is cleared depending on the selected interrupt mode, which is common to all interrupts. There are three different interrupt modes: non-latched, latched and temporary. The mode is selected by the 'latch_int' bits according to table18.

Table 13. Interrupt mode selection

latch_int	Interrupt mode
0000	non-latched
0001	temporary latched 250ms
0010	temporary latched 500ms
0011	temporary latched 1s
0100	temporary latched 2s
0101	temporary latched 4s
0110	temporary latched 8s
0111	Latched
1000	non-latched
1001	temporary latched 1ms
1010	temporary latched 1ms
1011	temporary latched 2ms
1100	temporary latched 25ms
1101	temporary latched 50ms
1110	temporary latched 100ms
1111	Latched

An interrupt is generated if its activation condition is met. It can't be cleared as long as the activation condition is fulfilled. In the non-latched mode the interrupt status bit and the selected pin INT are cleared as soon as the activation condition is no more valid. Exceptions to this behavior are the new data and orientation, which are automatically reset after a fixed time.

In the latched mode an asserted interrupt status and the selected pin are cleared by writing 1 to bit 'reset_int'. If the activation condition still holds when it is cleared, the interrupt status is asserted again with the next change of the acceleration registers.

In the temporary mode an asserted interrupt and selected pin are cleared after a defined period of time. The behavior of the different interrupt modes is shown in figure10.
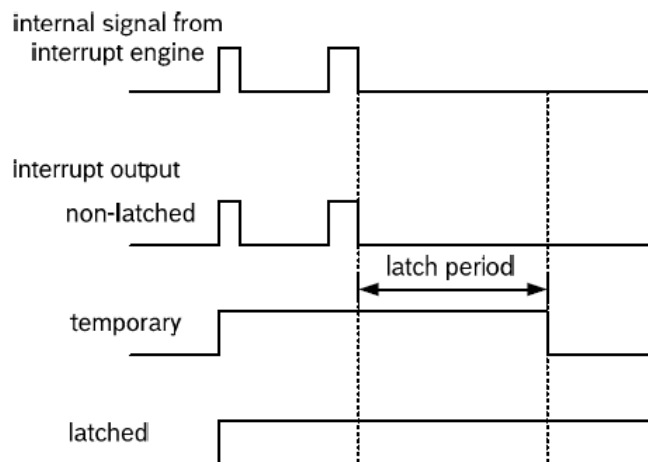
Figure 6 Interrupt mode

4.3.2 Mapping

The mapping of interrupts to the interrupt pins is done by registers 'interrupt_mapping' (0x19 and 0x1a), setting int_inttyp to 1 can map this type interrupt to INT pin.

4.3.3 Electrical behavior (INT to open-drive or push-pull)

The interrupt pin can be configured to show desired electrical behavior. The 'active' level for each pin is set by register bit int_lvl, if int_lvl = 0, then the pin INT is 0 active. Also the electric type of the interrupt pin can be selected. By setting int_od = 1, the interrupt pin output type can be set to be open-drive.

4.3.4 New data interrupt

This interrupt serves for synchronous reading of acceleration data. It is generated after an acceleration data was calculated. The interrupt is cleared automatically before the next acceleration data is ready.

4.3.5 Active detection

Active detection uses the slope between successive acceleration signals to detect changes in motion. An interrupt is generated when the slope (absolute value of acceleration difference) exceeds a preset threshold. The threshold is set with the value of register 'active_th' with the LSB corresponding to 16 LSB of acceleration data, that is 3.9mg in 2g-range, 7.8mg in 4g-range, 15.6mg in 8g-range and 31.3mg in 16g-range. And the maximum value is 1g in 2g-range, 2g in 4g-range, 4g in 8g-range and 8g in 16g-range.

The time difference between the successive acceleration signals depends is fixed to 1ms.
Active detection can be enabled (disabled) for each axis separately by writing '1' to bits 'active_en_x/y/z'. The active interrupt is generated if the slope of any of the enabled axes exceeds the threshold for ['active_dur'+1] consecutive times. As soon as the slopes of all enabled axes fall below this threshold for ['active_dur'+1] consecutive times, the interrupt is cleared unless the interrupt signal is latched.

The interrupt status is stored in bit 'active_int'. The bit 'active_first_x/y/z' record which axis triggered the active interrupt first and the sign of this acceleration data that triggered the interrupt is recorded in the bit 'active_sign'.

4.3.6 Tap detection

Tap detection has a functional similarity with a common laptop touch-pad or clicking keys of a computer mouse. A tap event is detected if a pre-defined pattern of the acceleration slope is fulfilled at least for one axis. Two different tap events are distinguished: A single tap is a single event within a certain time, followed by a certain quiet time. A double tap consists a first such event followed by a second event within a defined time.

Single tap interrupt is enabled by writing 1 to bit 's_tap_int_en' and double tap interrupt is enabled by writing 1 to bit

'd_tap_int_en'. The status of the single tap interrupt is stored in bit 's_tap_int' and the status of the double tap interrupt is stored in bit 'd_tap_int'.

The slope threshold for detecting a tap event is set by bits "tap_th" with the LSB corresponding to 256LSB of acceleration data that is 62.5mg in 2g-range, 125mg in 4g-range, 250mg in 8g-range, 500mg in 16g-range. And the maximum value equals to the full scale in each range.

In figure7 the meaning of different timing parameter is visualized.
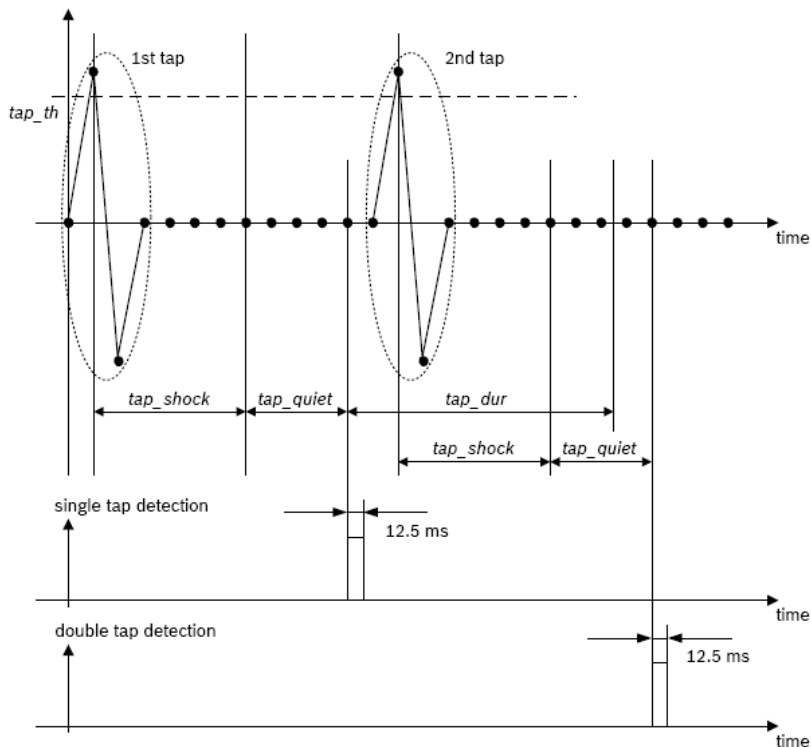
Figure 7 Timing of Tap detection

The parameter 'tap_shock' and 'tap_quiet' apply to both single and double tap detection, while 'tap_dur' applies to double detection only. Within the duration of 'tap_shock' any slope exceeding 'tap_th' after the first event is ignored, within the duration of 'tap_quiet' there must be no slope exceeding 'tap_th', otherwise the first event will be cancelled. A single tap is detected and the single tap interrupt is generated after the combination durations of 'tap_shock' and 'tap_quiet', if the corresponding slope conditions are fulfilled. The interrupt is cleared after a delay in non-latched mode.

A double tap is detected and the double tap interrupt is generated if an event fulfilling the conditions for a single tap occurs within the set duration in 'tap_dur' after the completion of the first tap event. The interrupt is cleared after a delay in non-latched mode.

The sign of the slope of the first tap which triggered the interrupt is stored in bit 'tap_sign' (0 means positive, 1 means negative). The axis which triggered the interrupt is indicated by bits 'tap_first_x/y/z'.

4.3.7 Orientation recognition

The orientation recognition feature informs on an orientation change of sensor with respect to the gravitation field vector 'g'. The measured acceleration vector components with respect to the gravitation field are defined as shown in figure 8.
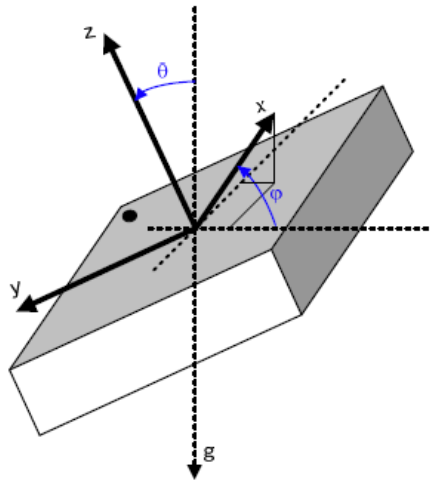
Figure 8 Definition of vector components

Therefore, the magnitudes of the acceleration vectors are calculated as follows:

$$acc\_x = 1g.\sin\theta \cdot \cos\varphi$$
$$acc\_y = -1g.\sin\theta \cdot \sin\varphi$$
$$acc\_z = 1g \cdot \cos\theta$$

Depending on the magnitudes of the acceleration vectors the orientation of the device in the space is determined and stored in the bits 'orient'. There are three orientation calculation modes with different thresholds for switching between different orientations: symmetrical, high-asymmetrical and low-asymmetrical. The mode is selected by setting the 'orient_mode' bits. For each orientation mode, the 'orient' bits have a different meaning as show in table 14 to table 15.

Table 14. meaning of 'orient' bits in symmetric mode

orient	Name	Angle	Condition
X00	Portrait upright	$315^o < \varphi < 45^o$	|acc_y| < |acc_x| - 'hyst' &acc_x>= 0
X01	Portrait upside down	$135^o < \varphi < 225^o$	|acc_y| < |acc_x| - 'hyst' &acc_x< 0
X10	Landscape left	$45^o < \varphi < 135^o$	|acc_y| >= |acc_x| + 'hyst' & acc_y < 0
X11	Landscape right	$225^o < \varphi < 315^o$	|acc_y| >= |acc_x| + 'hyst' & acc_y >= 0

Table 15. meaning of 'orient' bits in high-asymmetric mode

Orient	Name	Angle	Condition
X00	Portrait upright	$297^o < \varphi < 63^o$	|acc_y| < 2*|acc_x| - 'hyst' &acc_x>= 0
X01	Portrait upside down	$117^o < \varphi < 243^o$	|acc_y| < 2*|acc_x| - 'hyst' &acc_x< 0
X10	Landscape left	$63^o < \varphi < 117^o$	|acc_y| >= 2*|acc_x| + 'hyst' & acc_y < 0
X11	Landscape right	$243^o < \varphi < 297^o$	|acc_y| >= 2*|acc_x| + 'hyst' & acc_y >= 0

Table 16. meaning of 'orient' bits in low-asymmetric mode

Orient	Name	Angle	Condition
X00	Portrait upright	$333^o < \varphi < 27^o$	$|acc\_y| < 0.5*|acc\_x| -$ 'hyst' $\&acc\_x >= 0$
X01	Portrait upside down	$153^o < \varphi < 207^o$	$|acc\_y| < 0.5*|acc\_x| -$ 'hyst' $\&acc\_x < 0$
X10	Landscape left	$27^o < \varphi < 153^o$	$|acc\_y| >= 0.5*|acc\_x| +$ 'hyst' $\&$ $acc\_y < 0$
X11	Landscape right	$207^o < \varphi < 333^o$	$|acc\_y| >= 0.5*|acc\_x| +$ 'hyst' $\& acc\_y >= 0$

In the preceding tables, the parameter 'hyst' stands for a hysteresis which can be selected by bits 'orient_hyst'. 1LSB of 'orient_hyst' always corresponds to 62.5mg in any g-range.   The MSB of 'orient' bits contains information about the direction of the z-axis. It is set to 0(1) if ac_z>=0 (acc_z<0). The hysteresis for z axis is fixed to 0.2g.

The orient interrupt is enabled by writing 'orient_en' bit. The interrupt is generated if the value of 'orient' has changed. It is automatically cleared after one stable period of the orient value in non-latched mode. In temporary latched or latched mode, the orient value is kept fixed as long as the interrupt persists. After cleaning the interrupt, the 'orient' will updated with the next following value change.

The change of the 'orient' value and the generation of the interrupt can be blocked according to conditions selected by setting the value of bits 'orient_blocking' as described by table17.

Table 17. blocking conditions for orientation recognition

Orient_blocking	Conditions
00b	No blocking
01b	Z blocking
10b	Z blocking or acceleration slope in any axis > 0.2g
11b	No blocking

The Z blocking is defined by the following inequality：

$$| acc\_z |> z\_blocking$$

The parameter z_blocking of the above given equation stands for the contents of the 'z_blocking' bits. Hereby it is possible to define a blocking value between 0g and 0.9375g with an LSB = 0.0625g.

4.3.8 Freefall interrupt

This interrupt is based on the comparison of acceleration data against a low-g threshold. The interrupt is enabled by writing 1 to the bit 'freefall_en'. There are two modes available: single mode' and sum mode. In single mode the acceleration of each axis is compared with the threshold. In sum mode, the sum of absolute values of all accelerations $|acc\_x| + |acc\_y| + |acc\_z|$ is compared with the threshold. The mode is selected by the bit 'freefall_mode'. The freefall threshold is set through the 'freefall_th' bits with 1 LSB corresponding to an acceleration of 7.81mg. A hysteresis can be selected by setting the 'freefall_hy' bits with 1 LSB corresponding to 125mg.

The freefall interrupt is generated if the absolute values of the acceleration of all axes or their sum are lower than the threshold for at least the time defined by 'freefall_dur' bits. The interrupt is reset if the absolute value of at least one

axis or the sum is higher than the threshold plus the hysteresis for at least one data acquisition. The interrupt status is stored in bit 'freefall_int'.

5 Application hints
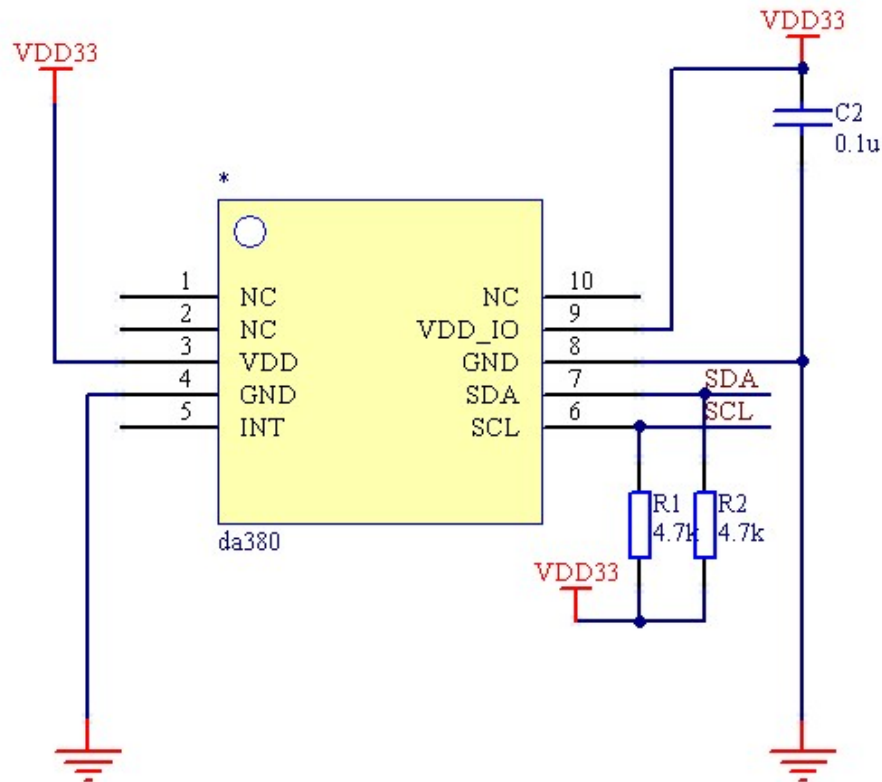
Figure 9 da380 I2C Electrical connection

The device core is supplied through Vdd line while the I/O pads are supplied through Vdd_IO line. Power supply decoupling capacitors (100 nF ceramic) should be placed as near as possible to VDD of the device (common design practice).

The functionality of the device and the measured acceleration data is selectable and accessible through the I2C interface. The functions, the threshold and the timing of the interrupt pin INT can be completely programmed by the user through the I2C interface.

6 Register mapping

The table given below provides a listing of the 8 bit registers embedded in the device and the related addresses:

Table 18. Register address map

Name	Type	Register address	Default	Soft Reset
I2C Configuration	RW	0x00	00H	NO
CHIPID	R	0x01	13H	NO
ACC_X_LSB	R	0x02	00H	YES
ACC_X_MSB	R	0x03	00H	YES
ACC_Y_LSB	R	0x04	00H	YES
ACC_Y_MSB	R	0x05	00H	YES
ACC_Z_LSB	R	0x06	00H	YES
ACC_Z_MSB	R	0x07	00H	YES
MOTION_FLAG	R	0x09	00H	YES
NEWDATA_FLAG	R	0x0A	00H	YES
TAP_ACTIVE_STATUS	R	0x0B	00H	YES
ORIENT_STATUS	R	0x0C	00H	YES
RESOLUTION_RANGE	RW	0x0F	00H	YES
ODR_AXIS	RW	0x10	0FH	YES
MODE_BW	RW	0x11	9EH	YES
SWAP_POLARITY	RW	0x12	00H	YES
INT_SET1	RW	0x16	10H	YES
INT_SET2	RW	0x17	00H	YES
INT_MAP1	RW	0x19	00H	YES
INT_MAP2	RW	0x1A	00H	YES
INT_CONFIG	RW	0x20	00H	YES
INT_LTACH	RW	0x21	00H	YES
FREEFALL_DUR	RW	0x22	09H	YES
FREEFALL_THS	RW	0x23	30H	YES
FREEFALL_HYST	RW	0x24	01H	YES
ACTIVE_DUR	RW	0x27	00H	YES
ACTIVE_THS	RW	0x28	14H	YES
TAP_DUR	RW	0x2A	04H	YES
TAP_THS	RW	0x2B	0AH	YES
ORIENT_HYST	RW	0x2C	18H	YES
Z_BLOCK	RW	0x2D	08H	YES
SELF_TEST	RW	0x32	00H	YES
CUSTOM_OFF_X	RW	0x38	00H	YES
CUSTOM_OFF_Y	RW	0x39	00H	YES
CUSTOM_OFF_Z	RW	0x3A	00H	YES
CUSTOM_FLAG	R	0x4E	00H	NO

CUSTOM_CODE	RW	0x4F	00H	YES
Z_CAL_EN	RW	0x50	00H	YES
Z_ROT_HODE_TM	RW	0x51	09H	YES
Z_ROT_DUR	RW	0x52	FFH	YES
ROT_TH_H	RW	0x53	45H	YES
ROT_TH_L	RW	0x54	35H	YES

7 Registers description

7.1 I2C Configuration (00H)

Table 19. I2C Configuration register

Default data: 0x00 Type: RW

Unused	Unused	Soft Reset	Unused	Unused	Unused	Unused	Unused

Table 20. I2C Configuration description

Soft Reset	0:soft reset disable; 1: soft reset enable

7.2 CHIPID (01h)

Table 21. CHIPID register

Default data: 0x13 Type: R

0	0	0	1	0	0	1	1

7.3 ACC_X_LSB (02H) , ACC_X_MSB (03H)

X-axis acceleration data, the value is expressed in two complement byte and are left justified.

Table 22. ACC_X_LSB register

Default data: 0x00 Type: R

D[5]	D[4]	D[3]	D[2]	D[1]	D[0]	Unused	Unused

Table 23. ACC_X_MSB register

Default data: 0x00 Type: R

D[13]	D[12]	D[11]	D[10]	D[9]	D[8]	D[7]	D[6]

7.4 ACC_Y_LSB (04H) , ACC_Y_MSB (05H)

Y-axis acceleration data, the value is expressed in two complement byte and are left justified.

Table 24. ACC_Y_LSB register

Default data: 0x00 Type: R

D[5]	D[4]	D[3]	D[2]	D[1]	D[0]	Unused	Unused

Table 25. ACC_Y_MSB register

Default data: 0x00 Type: R

D[13]	D[12]	D[11]	D[10]	D[9]	D[8]	D[7]	D[6]

7.5 ACC_Z_LSB (06H) , ACC_Z_MSB (07H)

Z-axis acceleration data, the value is expressed in two complement byte and are left justified.

Table 26. ACC_Z_LSB register

Default data: 0x00 Type: R

D[5]	D[4]	D[3]	D[2]	D[1]	D[0]	Unused	Unused

Table 27. ACC_Z_MSB register

Default data: 0x00 Type: R

D[13]	D[12]	D[11]	D[10]	D[9]	D[8]	D[7]	D[6]

7.6 MOTION_FLAG (09H)

Table 28. MOTION_FLAG register

Default data: 0x00 Type: R

unused	Orient_int	S_tap_int	D_tap_int	unused	Active_int	unused	Freefall_int

Table 29. MOTION_FLAG register description

Orient_int	0:no orient interrupt; 1:orient interrupt has occurred
S_tap_int	0:no single tap interrupt;1: single tap interrupt has occurred
D_tap_int	0:no double tap interrupt;1: double tap interrupt has occurred
Active_int	0:no active interrupt;1: active interrupt has occurred
Freefall_int	0:no freefall interrupt;1: freefall interrupt has occurred

7.7 NEWDATA_FLAG (0AH)

Table 30. NEWDATA_FLAG register

Default data: 0x00 Type: R

unused	unused	unused	unused	unused	unused	unused	New_data_int

Table 31. NEWDATA_FLAG register description

New_data_int	0:no new_data interrupt; 1:new_data interrupt has occurred

7.8 TAP_ACTIVE_STATUS (0BH)

Table 32. TAP_ACTIVE_STATUS register

Default data: 0x00 Type: R

Tap_sign	Tap_first_x	Tap_first_y	Tap_first_z	Active_sign	Active_first_x	Active_first_y	Active_first_z

Table 33. TAP_ACTIVE_STATUS register description

Tap_sign	Sign of the first tap that triggered interrupt 0:positive 1:negative
Tap_first_x	0: X is not the triggering axis of the tap interrupt 1: indicate X is the triggering axis of the tap interrupt.
Tap_first_y	0:Y is not the triggering axis of the tap interrupt 1: indicate Y is the triggering axis of the tap interrupt.
Tap_first_z	0:Z is not the triggering axis of the tap interrupt 1: indicate Z is the triggering axis of the tap interrupt.
Active_sign	active_sign: Sign of the 1st active interrupt. 0:positive, 1:negative
Active_first_x	0: X is not the triggering axis of the active interrupt 1: indicate X is the triggering axis of the active interrupt.
Active_first_y	0:Y is not the triggering axis of the active interrupt 1: indicate Y is the triggering axis of the active interrupt.
Active_first_z	0:Z is not the triggering axis of the active interrupt 1: indicate Z is the triggering axis of the active interrupt.

7.9 ORIENT_STATUS (0CH)

Table 34. ORIENT_STATUS register

Default data: 0x00 Type: R

unused	Orient[2]	Orient[1]	Orient[0]	unused	unused	unused	unused

Table 35. ORIENT_STATUS register description

Orient[2]	orientation value of 'z' axis. 0:upward looking, 1:downward looking
Orient[1:0]	orientation value of 'x', 'y' axes.

| 00: portrait upright, |
| 01: portrait upside down, |
| 10: landscape left |
| 11:landscape right |

7.10 RESOLUTION_RANGE (0FH)

Table 36. RESOLUTION_RANGE register

Default data: 0x00 Type: RW

unused	unused	unused	unused	Resolution[1]	Resolution[0]	FS[1]	FS[0]

Table 37. RESOLUTION_RANGE register description

Resolution[1:0]	00:14bit 01:12bit 10:10bit 11:8bit
FS[1:0]	FS: fullscale. 00: +/-2g. 01: +/-4g 10:+/-8g 11:+/-16g

7.11 ODR_AXIS (10H)

Table 38. ODR_AXIS register

Default data: 0x0F Type: RW

X-axis_disable	Y-axis_disable	Z-axis_disable	unused	ODR[3]	ODR[2]	ODR[1]	ODR[0]

Table 39. ODR_AXIS register description

X-axis_disable	Disable X axis. 0:enable X axis 1:disable X axis
Y-axis_disable	Disable Y axis. 0:enable Y axis 1:disable Y axis

Z-axis_disable	Disable Z axis. 0:enable Z axis 1:disable Z axis
ODR[3:0]	0000:1Hz (not available in normal mode) 0001:1.95Hz (not available in normal mode) 0010:3.9Hz 0011:7.81Hz 0100:15.63Hz 0101: 31.25Hz 0110: 62.5Hz 0111: 125Hz 1000: 250Hz 1001: 500Hz (not available in low power mode) 1010:1000Hz (not available in low power mode) 1011-1111:1000Hz

7.12 MODE_BW (11H)

Table 40. MODE_BW register

Default data: 0x9E Type: RW

pwr_mode [1]	pwr_mode [0]	unused	low_power _bw [3]	low_power_ bw [2]	low_power _bw[1]	low_power _bw[0]	unused

Table 41. MODE_BW register description

pwr_mode[1:0]	Power mode: 00:normal mode, 01: low power mode, 1x: suspend mode.
low_power_bw [3:0]	0000-0010:1.95Hz 0011:3.9Hz 0100:7.81Hz 0101:15.63Hz 0110:31.25Hz 0111:62.5Hz 1000:125Hz 1001:250Hz 1010:500Hz 1011-1111:500Hz

7.13 SWAP_POLARITY (12H)

Table 42. SWAP_POLARITY register

Default data: 0x00 Type: RW

Swap & Polarity register is OTP register too, OTP address:0x13

unused	unused	unused	unused	X_polarity	Y_polarity	Z_polarity	X_Y_swap

Table 43. SWAP_POLARITY register description

X_polarity	0: remain the polarity of X-axis.
	1: reverse the polarity of X-axis.
Y_polarity	0: remain the polarity of Y-axis.
	1: reverse the polarity of Y-axis.
Z_polarity	0: remain the polarity of Y-axis.
	1: reverse the polarity of Y-axis.
X_Y_swap	0: Don't need swap the output data for X/Y axis
	1: swap the output data for X/Y axis.

7.14 INT_SET1 (16H)

Table 44. INT_SET1 register

Default data: 0x00 Type: RW

unused	Orient_int_en	S_tap_int_en	d_tap_int_en	unused	active_int_en_z	active_int_en_y	active_int_en_x

Table 45. INT_SET1 register description

Orient_int_en	0: disable the orient interrupt.
	1:enable the orient interrupt.
S_tap_int_en	0: disable the single tap interrupt.
	1:enable the single tap interrupt.
d_tap_int_en	0: disable the double tap interrupt.
	1:enable the double tap interrupt.
active_int_en_z	0: disable the active interrupt for the z axis.
	1:enable the active interrupt for the z axis.
active_int_en_y	0: disable the active interrupt for the y axis.
	1:enable the active interrupt for the y axis.
active_int_en_x	0: disable the active interrupt for the x axis.
	1:enable the active interrupt for the x axis.

7.15 INT_SET2 (17H)

Table 46. INT_SET2 register

Default data: 0x00 Type: RW

unused	unused	unused	New_data_int_en	Freefall_int_en	unused	unused	unused

Table 47. INT_SET2 register description

New_data_int_en	0: disable the new data interrupt. 1:enable the new data interrupt.
Freefall_int_en	0: disable the freefall interrupt. 1:enable the freefall interrupt

7.16 INT_MAP1 (19H)

Table 48. INT_MAP1 register

Default data: 0x00 Type: RW

unused	Int_orient	Int_s_tap	Int_d_tap	unused	Int_active	unused	Int_freefall

Table 49. INT_MAP1 register description

Int_orient	0:doesn'tmapping orient interrupt to INT 1:mapping orient interrupt to INT
Int_s_tap	0: doesn't mapping single tap interrupt to INT 1: mapping single tap interrupt to INT
Int_d_tap	0: doesn't mapping double tap interrupt to INT 1: mapping double tap interrupt to INT
Int_active	0: doesn't mapping active interrupt to INT 1: mapping active interrupt to INT
Int_freefall	0: doesn't mapping freefall interrupt to INT 1: mapping freefall interrupt to INT

7.17 INT_MAP2 (1AH)

Table 50. INT_MAP2 register

Default data: 0x00 Type: RW

unused	unused	unused	unused	unused	unused	unused	Int_new_data

Table 51. INT_MAP2 register description

Int_new_data	0: doesn't mapping new data interrupt to INT 1: mapping new data interrupt to INT

7.18 INT_CONFIG (20H)

Table 52. INT_CONFIG register

Default data: 0x00 Type: RW

unused	unused	unused	unused	unused	unused	Int_od	Int_lvl

Table 53. INT_CONFIG register description

Int_od	0:select push-pull output for INT, 1: selects OD output for INT
Int_lvl	0:selects active level low for pin INT, 1: selects active level high for pin INT

7.19 INT_LTACH (21H)

Table 54. INT_LTACH register

Default data: 0x00 Type: RW

Reset_int	unused	unused	unused	Latch_int[3]	Latch_int[2]	Latch_int[1]	Latch_int[0]

Table 55. INT_LTACH register description

Reset_int	0: doesn't reset all latched int. 1: reset all latched int.
Latch_int[3:0]	0000: non-latched 0001: temporary latched 250ms 0010: temporary latched 500ms 0011: temporary latched 1s 0100: temporary latched 2s 0101: temporary latched 4s 0110: temporary latched 8s 0111: latched 1000: non-latched 1001: temporary latched 1ms 1010: temporary latched 1ms 1011: temporary latched 2ms 1100: temporary latched 25ms 1101: temporary latched 50ms 1110: temporary latched 100ms 1111: latched

7.20 FREEFALL_DUR (22H)

Table 56. FREEFALL_DUR register

Default data: 0x09 Type: RW

Freefall_dur [7]	Freefall_dur [6]	Freefall_dur [5]	Freefall_dur [4]	Freefall_dur [3]	Freefall_dur [2]	Freefall_dur [1]	Freefall_dur [0]

Table 57. FREEFALL_DUR register description

Freefall_dur[7:0]	Freefall duration time = (freefall_dur + 1) * 2ms ,

| LSB = 2mg |
| duration time range from 2ms to 512ms |
| default: 20ms |

7.21 FREEFALL_THS (23H)

Table 58. FREEFALL_THS register

Default data: 0x30 Type: RW

Freefall_th[7]	Freefall_th[6]	Freefall_th[5]	Freefall_th[4]	Freefall_th[3]	Freefall_th[2]	Freefall_th[1]	Freefall_th[0]

Table 59. FREEFALL_THS register description

Freefall_th[7:0]	Freefall threshold = freefall_th * 7.81mg.
	LSB = 7.81mg
	Default is 375mg

7.22 FREEFALL_HYST (24H)

Table 60. FREEFALL_HYST register

Default data: 0x01 Type: RW

unused	unused	unused	unused	unused	Freefall_mode	Freefall_hy[1]	Freefall_hy[0]

Table 61. FREEFALL_HYST register description

Freefall_mode	0: single mode.
	1: sum mode.
Freefall_hy[1:0]	Set the hysteresis for freefall detection.
	Free fall hysteresis time = freefall_hy* 125ms
	LSB = 125mg

7.23 ACTIVE_DUR (27H)

Table 62. ACTIVE_DUR register

Default data: 0x00 Type: RW

unused	unused	unused	unused	unused	unused	Active_dur[1]	Active_dur[0]

Table 63. ACTIVE_DUR register description

| Active_dur[1:0] | Active duration time = (active_dur + 1) ms. |

7.24 ACTIVE_THS (28H)

Table 64. ACTIVE_THS register

Default data: 0x14 Type: RW

Active_th[7]	Active_th[6]	Active_th[5]	Active_th[4]	Active_th[3]	Active_th[2]	Active_th[1]	Active_th[0]

Table 65. ACTIVE_THS register description

Active_th[7:0]	Threshold of active interrupt=Active_th*mg/LSB LSB = 3.91mg(2g range), LSB=7.81mg(4g range), LSB=15.625mg(8g range), LSB=31.25mg(16g range).

7.25 TAP_DUR (2AH)

Table 66. TAP_DUR register

Default data: 0x04 Type: RW

Tap_quiet	Tap_shock	unused	unused	unused	Tap_dur[2]	Tap_dur[1]	Tap_dur[0]

Table 67. TAP_DUR register description

Tap_quiet	0: tap quiet duration 30ms. 1:tap quiet duration 20ms.
Tap_shock	0: tap shock duration 50ms. 1: tap shock duration 70ms.
Tap_dur[2:0]	Tap duration selects the length of the time window for the second shock. 000: 50ms 001:100ms 010:150ms 011:200ms

	100:250ms
	101:375ms
	110:500ms
	111:700ms

7.26 TAP_THS (2BH)

Table 68. TAP_THS register

Default data: 0x0a Type: RW

unused	unused	unused	Tap_th [4]	Tap_th [3]	Tap_th [2]	Tap_th [1]	Tap_th [0]

Table 69. TAP_THS register description

Tap_th [4:0]	Threshold of tap interrupt=Tap_th*mg/LSB LSB = 62.5mg (2g range), LSB=125mg(4g range), LSB=250mg(8g range), LSB=500mg(16g range).

7.27 ORIENT_HYST (2CH)

Table 70. ORIENT_HYST register

Default data: 0x18 Type: RW

unused	Orient_hyst [2]	Orient_hyst [1]	Orient_hyst [0]	Orient_block [1]	Orient_block [0]	Orient_mode [1]	Orient_mode [0]

Table 71. ORIENT_HYST register description

Orient_hyst[2:0]	Set the hysteresis of the orientation interrupt Orientation hysteresis time = Orient_hyst * 62.5ms 1LSB = 62.5mg.
Orient_block[1:0]	00: no blocking 01: z blocking 10: z blocking or slope in any axis > 0.2g 11: no blocking
Orient_mode [1:0]	00:symmetrical 01: high-asymmetrical

| 10: low-asymmetrical |
| 11:synmmetrical |

7.28 Z_BLOCK (2DH)

Table 72. Z_BLOCK register

Default data: 0x08 Type: RW

unused	unused	unused	unused	Z_blocking[3]	Z_blocking[2]	Z_blocking[1]	Z_blocking[0]

Table 73. Z_BLOCK register description

Z_blocking[3:0]	Defines the blocking acc_z between 0g to 0.9375g degree. 1LSB=62.5mg

7.29 SELF_TEST (32H)

Table 74. SELF_TEST register

Default data: 0x00 Type: RW

unused	unused	unused	unused	unused	unused	self_test_sign	self_test_en

Table 75. SELF_TEST register description

self_test_sign	Set the sign of self test electrostatic excitation for each axis. 0: positive 1: negative.
self_test_en	0: disable self-test, 1: self-test enabled.

7.30 CUSTOM_OFF_X (38H)

Table 76. CUSTOM_OFF_X register

Default data: 0x00 Type: RW

CUSTOM_OFF_X register is OTP register too, OTP address:0x1D

Custom_offset_X[7]	Custom_offset_X[6]	Custom_offset_X[5]	Custom_offset_X[4]	Custom_offset_X[3]	Custom_offset_X[2]	Custom_offset_X[1]	Custom_offset_X[0]

Table 77. CUSTOM_OFF_X register description

Custom_offset_X[7:0]	customer offset compensation value for X axis LSB=3.9mg

7.31 CUSTOM_OFF_Y (39H)

Table 78. CUSTOM_OFF_Y register

Default data: 0x00 Type: RW

CUSTOM_OFF_Y register is OTP register too, OTP address:0x1E

Custom_of fset_Y[7]	Custom_of fset_Y[6]	Custom_of fset_Y[5]	Custom_of fset_Y[4]	Custom_of fset_Y[3]	Custom_of fset_Y[2]	Custom_of fset_Y[1]	Custom_of fset_Y[0]

Table 79. CUSTOM_OFF_Y register description

Custom_offset_Y[7:0]	customer offset compensation value for Y axis LSB=3.9mg

7.32 CUSTOM_OFF_Z (39H)

Table 80. CUSTOM_OFF_Z register

Default data: 0x00 Type: RW

CUSTOM_OFF_Z register is OTP register too, OTP address:0x1F

Custom_of fset_Z[7]	Custom_of fset_Z[6]	Custom_of fset_Z[5]	Custom_of fset_Z[4]	Custom_of fset_Z[3]	Custom_of fset_Z[2]	Custom_of fset_Z[1]	Custom_of fset_Z[0]

Table 81. CUSTOM_OFF_Z register description

Custom_offset_Z[7:0]	customer offset compensation value for Z axis LSB=3.9mg

7.33 CUSTOM_FLAG (4EH)

Table 82. CUSTOM_FLAG register

Default data: 0x00 Type: R

unused	unused	unused	unused	unused	unused	unused	Custom_OTP_programmed

Table 83. CUSTOM_FLAG register description

Custom_OTP_programmed	0: Custom OTP is not be programmed. 1: Indicate the custom OTP is already programmed and can't be programmed again.

7.34 CUSTOM_CODE (4FH)

Table 84. CUSTOM_CODE register

Default data: 0x00 Type: RW

Custom_OTP	Custom_OTP	Custom_OTP	Custom_OTP	Custom_OTP	Custom_OTP	Custom_Pre	unused

_program[5]	_program[4]	_program[3]	_program[2]	_program[1]	_program[0]	_program	

Table 85. CUSTOM_CODE register description

Custom_OTP_program	Write 0x9a to the register start customer OTP program

7.35 Z_ROT_HODE_TM (51H)

Table 86. Z_ROT_HODE_TM register

Default data: 0x09 Type: RW

z_rot_hold_time[7]	z_rot_hold_time[6]	z_rot_hold_time[5]	z_rot_hold_time[4]	z_rot_hold_time[3]	z_rot_hold_time[2]	z_rot_hold_time[1]	z_rot_hold_time[0]

Table 87. Z_ROT_HODE_TM register description

z_rot_hold_time[7:0]	Set the hold time for Z-axis rotation detecting. LSB = 1ms

7.36 Z_ROT_DUR (52H)

Table 88. Z_ROT_DUR register

Default data: 0xff Type: RW

z_rot_dur [7]	z_rot_dur [6]	z_rot_dur [5]	z_rot_dur [4]	z_rot_dur [3]	z_rot_dur [2]	z_rot_dur [1]	z_rot_dur [0]

Table 89. Z_ROT_DUR register description

z_rot_hold_time[7:0]	Set the duration time between twice z-axis rotating detecting. LSB = 4ms

7.37 ROT_TH_H (53H)

Table 90. ROT_TH_H register

Default data: 0x45 Type: RW

Rot_th_h [7]	Rot_th_h [6]	Rot_th_h [5]	Rot_th_h [4]	Rot_th_h [3]	Rot_th_h [2]	Rot_th_h [1]	Rot_th_h [0]

Table 91. ROT_TH_H register description

| Rot_th_h [7:0]	Set the higer threshold value for (X^2+Y^2) to indicate once Z-rotaion, LSB = 15.6mg

7.38 ROT_TH_L (54H)

Table 92. ROT_TH_L register

Default data: 0x35 Type: RW

Rot_th_l [7]	Rot_th_l[6]	Rot_th_l[5]	Rot_th_l[4]	Rot_th_l [3]	Rot_th_l [2]	Rot_th_l [1]	Rot_th_l [0]

Table 93. ROT_TH_L register description

Rot_th_l [7:0]	Set the lower threshold value for (X^2+Y^2) to indicate once Z-rotaion, LSB = 15.6mg

8   Package information
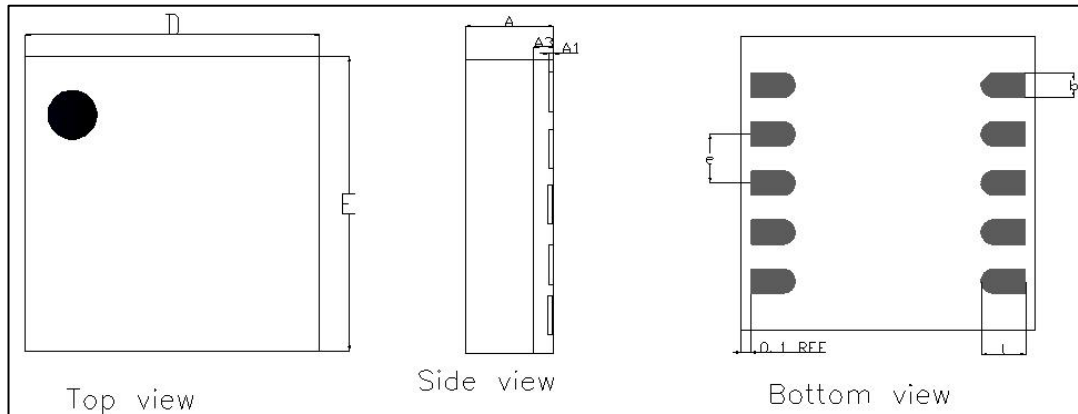
Figure 10 10 Pin LGA Mechanical data and package dimensions

Package outline dimensions (um)

COMMON DIMENSIONS(MM)			
PKG.	V: VERY THIN		
REF.	MIN.	NOM.	MAX
A	0.80	0.90	1.00
A1	0.00	–	0.05
A3	0.20 REF.		
D	2.90	3.00	3.10
E	2.90	3.00	3.10
L	0.40	0.45	0.50
b	0.20	0.25	0.30
e	0.5 BSC		

9 Revision history

Table 94. Document revision history

Date	Revision	Changes
08-Oct-2013	0.1	Initial release