苏州敏芯微电子技术股份有限公司
MEMSensing Microsystems (Suzhou, China) Co., Ltd.

Data Sheet

V 1.0 / Jan. 2016

MSA300

Digital Triaxial Accelerometer

GENERAL DESCRIPTION

MSA300 is a triaxial, low-g accelerometer with I2C/SPI digital output for consumer applications.

It has dynamically user selectable full scales of ±2g/±4g/±8g/±16g and allows acceleration measurements with output data rates from 1Hz to 500Hz.

MSA300 is available in an ultra small (2mmx2mm,height 1mm) LGA package and is guaranteed to operate over -40°C to +85°C.

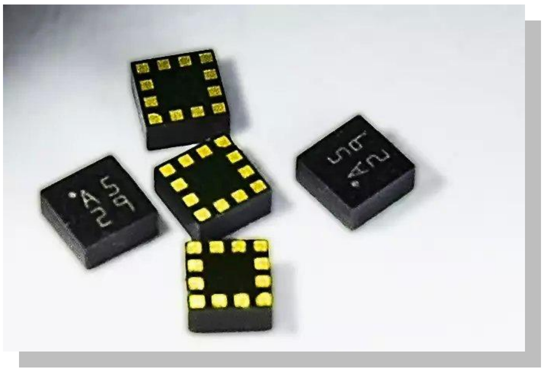
FEATURES

- Ultra small package 2x2x1 mm LGA-12 pins
- User selectable range, ±2g, ±4g, ±8g, ±16g
- 1.62V to 3.6V supply voltage,
- 1.2V to 3.6V IO supply voltage
- User selectable data output rate
- I2C/SPI(4-wire/3-wire)
- Two interrupt pins
- 14 bits resolution
- Low power consumption
- Factory programmed offset and sensitivity
- RoHS compliant

APPLICATIONS

- User interface for mobile phone and tablet
- Display orientation
- Gesture recognition
- Vibration monitoring
- Inclination and tilt sensing
- Pedometer
- Gaming
- Free fall detection

PRODUCT VIEW



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1. Pin Description

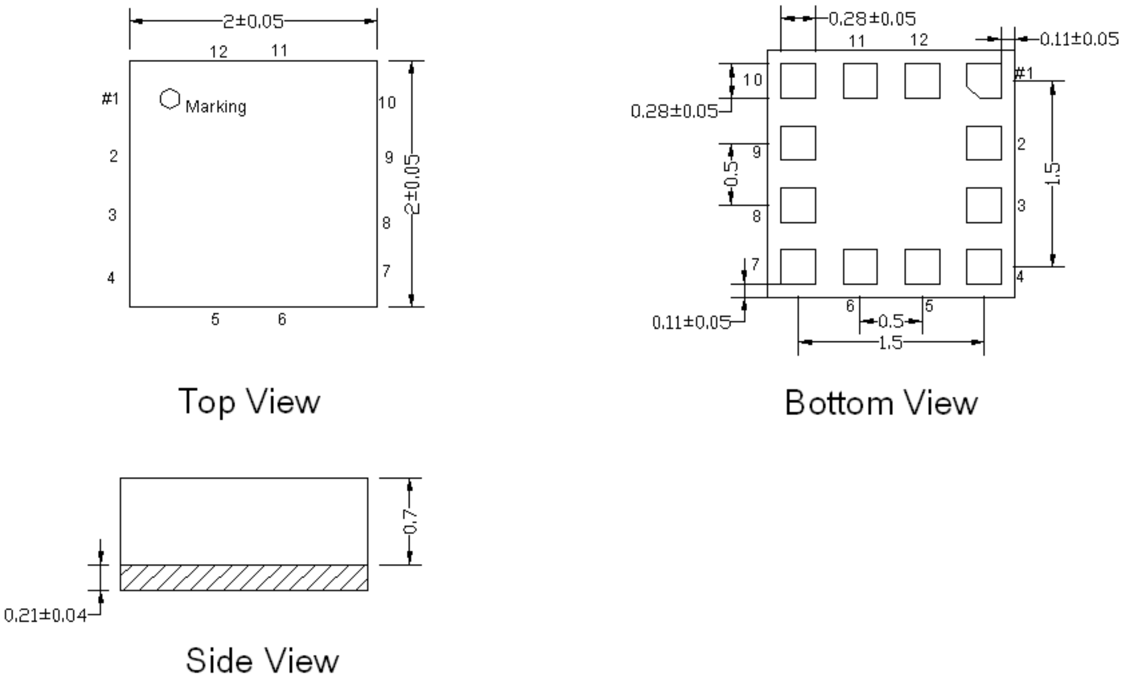


Figure 1: Pin Description

No.	Name	Function
1	SDO	Address for I2C,Data output in SPI(4-wire) mode
2	SDIO	Data input/output in I2C&SPI(3-wire) mode , Data input in SPI(4-wire) mode
3	VDDIO	IO Power supply
4	NC	Connected to GND recommended
5	INT1	Interrupt 1
6	INT2	Interrupt 2
7	VDD	Power supply
8	GNDIO	IO ground
9	GND	Ground
10	CSB	Chip select in SPI mode
11	PS	SPI/I2C selection, “1” I2C mode, “0” SPI mode
12	SCL	Clock for I2C&SPI interface

Table 1: Absolute Maximum Ratings

2. Specification

2.1 Absolute Maximum Ratings

Parameter	Maximum value	Unit
Supply Voltage	−0.3 to 3.6	V
Mechanical Shock	10,000	g
Operating Temperature	-40 to 85	°C
Storage Temperature	-40 to 125	°C

Table 2: Absolute Maximum Ratings

2.2 Sensor Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
FS	Full scale range			±2		g
				±4		g
				±8		g
				±16		g
S2g	Sensitivity	each axis at 25°C		4096		LSB/g
S4g		each axis at 25°C		2048		LSB/g
S8g		each axis at 25°C		1024		LSB/g
S16g		each axis at 25°C		512		LSB/g
TCS	Sensitivity Temperature Coefficient	FS=±2g		0.02		%/°C
Off	Zero g Offset @ 25°C, X/Y/Z axis	FS=±2g		±80		mg
TCO	Zero g Offset Temperature Coefficient	FS=±2g, -40 – +85 °C		±1		mg/°C
Nrms	Noise Density	FS=±2g		300		µg/√Hz
NL	Non-Linearity	FS=±2g, best straight line		2		%FS
Cs	Cross Axis Sensitivity	Between any two axes		2		%

Table 3: Sensor Characteristics

2.3 Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VDD	Supply Voltage		1.62	1.8	3.6	V
VDDIO	IO Supply Voltage		1.2	1.8	3.6	V
IDD	Supply Current	Normal operation		180		µA
IDDpd		Power down mode			1	µA
IDDlp		Low Power mode		2		µA
VIL	Voltage input low level	SPI&I2C			0.3VDDIO	V
VIH	Voltage input high level	SPI&I2C	0.7VDDIO			V
VOL	Voltage output low level				0.1VDDIO	V
VOH	Voltage output high level		0.9VDDIO			V
Twup	Wake up time	From power down mode		1		ms
Tsup	Start up time	From power off		3		ms
BW	Bandwidth		1.95		500	Hz
ODR	Output data rate		1		1000	Hz

Table 4: Sensor Characteristics

3. Function Blocks

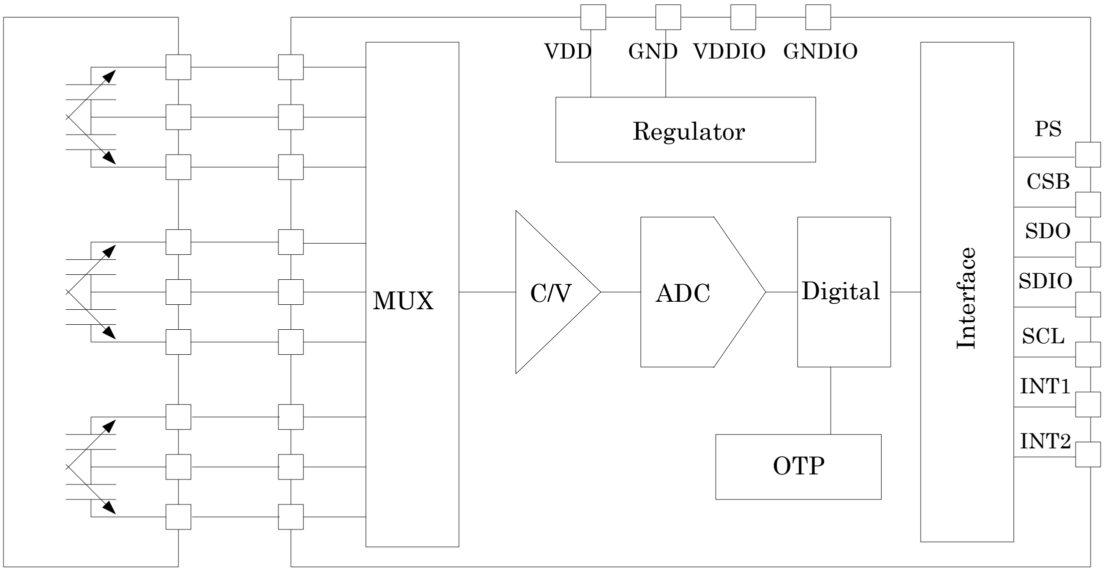


Figure 2: Package Outline Dimensions

4. Functional Description

4.1 Supply Voltage And Power Management

The MSA300 has two distinct power supply pins:

VDD is the main power supply for all internal analog and digital function blocks through several regulators.

VDDIO is a separate power supply pin exclusively used for digital I/O circuits.

There are no limitations on the voltage levels of both pins relative to each other, as long as each of them lies within its operation range ,Furthermore the device can be completely switched off (VDD=0V) while keeping the VDDIO supply on (VDDIO>0V).

4.2 Power Modes

The MSA300 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.

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, oscillators included, is powered down. No data acquisition is performed, the only supported operations are reading registers (latest acceleration data are kept). Suspend mode is entered by writing '11' or '10' to the (0x11) '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 corresponds to operation in normal mode with complete power-up of the circuitry. During the sleep phase the analog part ex-

cept the oscillators is powered down. is entered by writing '01' to the 'POWER_MODE' bits.

During the wake-up phase the number of samples required by any enabled interrupt is processed. If an 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 is detected, the device enters the sleep phase.

4.3 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).

The 'NEW_DATA_INT' bit is set when z_axis data is ready. It is reset when register (0x02) or (0x0A) is read. To enable 'NEW_DATA_INT' function, (0x17) 'DATA_INT_EN' should be set.

4.4 Bandwidth

The bandwidth of the acceleration data is always half of the update rate in normal mode and listed in below table.

ODR	**BW**
1000Hz (1010-1111)	500Hz
500Hz (1001)	250Hz
250Hz (1000)	125Hz
125Hz (0111)	62.5Hz
62.5Hz (0110)	31.25Hz
31.25Hz (0101)	15.63Hz
15.63Hz (0100)	7.81Hz
7.81Hz (0011)	3.9Hz
3.9Hz (0010)	1.95Hz

Table 5: bandwidth under different ODR and BW settings in normal mode

MSA300 supports four different acceleration measurement ranges, it is selected by setting (0x0F) as follows:

Range	0011	0101	1000	1100
Acceleration range	+/-2g	+/-4g	+/-8g	+/-16g

Table 6: acceleration measurement range

4.5 Interrupt Controller

Interrupt engines are integrated in the MSA300. Each interrupt can be independently enabled and configured. 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 are two interrupt pins, INT1 and INT2; interrupts can be freely mapped to any of these two pins. The pin state is a logic 'OR' combination of all mapped interrupts.

4.5.1 General fetures

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 the following table.

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

Table 7: Interrupt mode selection

An interrupt is generated if its activation condition is met. It cannot be cleared as long as the activation condition is fulfilled. In the non-latched mode the interrupt status bit and the selected pin (INT1 or INT2) 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 the following figure.

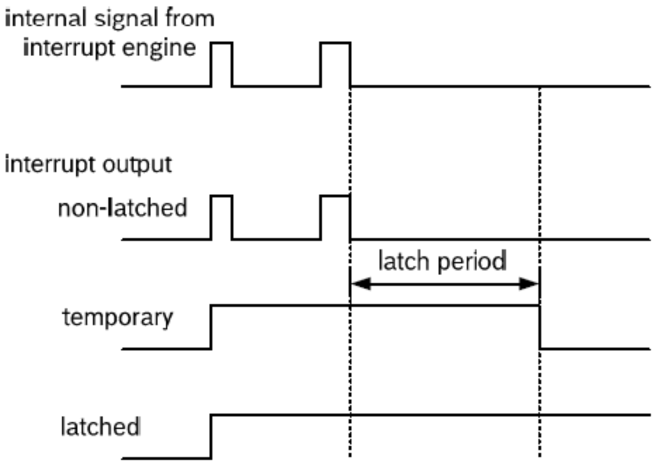


Figure 3: Interrupt mode

4.5.2 Mapping

The mapping of interrupts to the interrupt pins is done by register (0x19, 0x1A, 0x1B), setting int1_inttype (int1_orient/int1_s_tap/int1_freefall, etc) to 1 can map this type interrupt to INT1 pin and setting int2_inttype to 1 can map this type interrupt to INT2 pin.

4.5.3 Electrical behavior

Both interrupt pins can be configured to show desired electrical behavior. The 'active' level of each pin is determined by (0x20) 'INT1_LVL' and (0x20) 'INT2_LVL' bits. If (0x20) 'INT1_LVL' = '1' ('0') / (0x20) 'INT2_LVL' = '1' ('0'), then pin INT1 / pin INT2 is active '1' ('0'). In addition to that, also the electric type of the interrupt pins can be selected. By setting bits (0x20) 'INT1_OD' / (0x20) 'INT2_OD' to '0', the interrupt pin output type gets push-pull, by setting the configuration bits to '1', the output type gets open-drive.

4.5.4 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.

4.5.5 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 (0x28) 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 (0x09) 'ACTIVE_INT'. The bit (0x0B) '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 (0x0B) 'ACTIVE_SIGN'.

4.5.6 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 of a first such event followed by a second event within a defined time.

Single tap interrupt is enabled by writing 1 to bit (0x16) 'S_TAP_INT_EN' and double tap interrupt is enabled by writing 1 to bit (0x16) 'D_TAP_INT_EN'. The status of the single tap interrupt is stored in bit (0x09) 'S_TAP_INT' and the status of the double tap interrupt is stored in bit (0x09) 'D_TAP_INT'.

The slope threshold for detecting a tap event is set by bits (0x2B) "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 the following figure the meaning of different timing parameter is visualized.

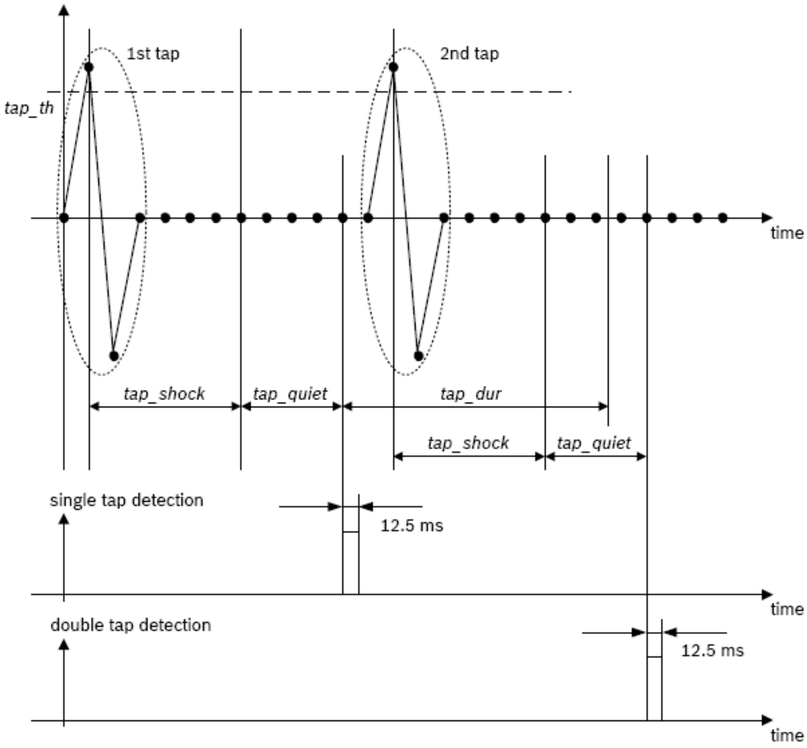


Figure 4: Timing of Tap detection

The parameter (0x2A) 'TAP_SHOCK' and (0x2A) 'TAP_QUIET' apply to both single and double tap detection, while (0x2A) 'TAP_DUR' applies to double detection only. Within the duration of (0x2A) 'TAP_SHOCK' any slope exceeding (0x2B) 'TAP_TH' after the first event is ignored, within the duration of (0x2A) '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 (0x2A) 'TAP_SHOCK' and (0x2A) 'TAP_QUIET', if the corresponding slope conditions are fulfilled. The interrupt is cleared after a delay of 12.5ms 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 (0x2A) 'TAP_DUR' after the completion of the first tap event. The interrupt is cleared after a delay of 12.5ms in non-latched mode.

The sign of the slope of the first tap which triggered the interrupt is stored in bit

(0x0B) 'TAP_SIGN' (0 means positive, 1 means negative). The axis which triggered the interrupt is indicated by bits (0x0B) 'TAP_FIRST_X/Y/Z'.

4.5.7 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 the following figure.

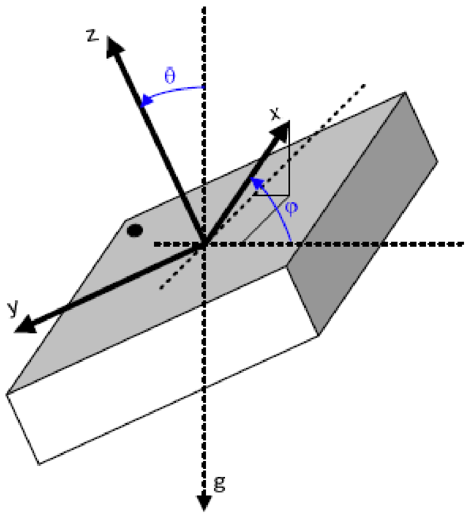


Figure 5: Definition of vector components

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 (0x0C) 'ORIENT'. There are three orientation calculation modes with different t thresholds for switching between different orientations: symmetrical, high-asymmetrical and low-asymmetrical. The mode is selected by setting the (0x2C) 'ORIENT_MODE' bits. For each orientation mode, the 'ORIENT' bits have a different meaning as show in below table.

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

Table 8: meaning of 'orient' bits in symmetric mode

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

Table 9: meaning of 'orient' bits in high-asymmetric mode

Orient	Name	Angle	Condition
X00	Portrait upright	$333^{\circ} < \varphi < 27^{\circ}$	|acc_y| < 0.5*|acc_x| - 'hyst' & acc_x >= 0
X01	Portrait upside down	$153^{\circ} < \varphi < 207^{\circ}$	|acc_y| < 0.5*|acc_x| - 'hyst' & acc_x < 0
X10	Landscape left	$27^{\circ} < \varphi < 153^{\circ}$	|acc_y| >= 0.5*|acc_x| + 'hyst' & acc_y < 0
X11	Landscape right	$207^{\circ} < \varphi < 333^{\circ}$	|acc_y| >= 0.5*|acc_x| + 'hyst' & acc_y >= 0

Table 10: meaning of 'orient' bits in low-asymmetric mode

In the preceding tables, the parameter 'HYST' stands for a hysteresis which can be selected by bits (0x2C) 'ORIENT_HYST'. 1LSB of (0x2C) '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 acc_z >=0 (acc_z<0). The hysteresis for z axis is fixed to 0.2g.

The orient interrupt is enabled by writing (0x16) '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 (0x2C) 'ORIENT_BLOCKING' as described by below table.

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

Table 11: blocking conditions for orientation recognition

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.

4.5.8 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 (0x17) '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 (0x22) '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 (0x09) 'FREEFALL_INT'.

5. Register Map

Address	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Default
0x00	4-WIRE	LSB FIRST	SOFT RESET			SOFT RESET	LSB FIRST	4-WIRE	0x00
0x01	PARTID[7:0]								0x00
0x02	ACC_X[5:0]								0x00
0x03	ACC_X[13:6]								0x00
0x04	ACC_Y[5:0]								0x00
0x05	ACC_Y[13:6]								0x00
0x06	ACC_Z[5:0]								0x00
0x07	ACC_Z[13:6]								0x00
0x09		ORIENT_INT	S_TAP_INT	D_TAP_INT		ACTIVE_INT		FREEFALL_INT	0x00
0x0A								NEW_DATA_INT	0x00
0x0B	TAP_SIGN	TAP_FIST_X	TAP_FIRST_Y	TAP_FIRST_Z	ACTIVE_SIGN	ACTIVE_FIST_X	ACTIVE_FIST_Y	ACTIVE_FIST_Z	0x00
0x0C		ORIENT[2:0]							0x00
0x0D			FIFO_ENTRIES[5:0]						0x00
0x0F					RESOLUTION[1:0]		FS[1:0]		0x00
0x10	X-AXIS_DIS	Y_AXIS_DIS	Z_AXIS_DIS		ODR[3:0]				0x0F
0x11	PWR_MODE			LOW_POWER_BW[3:0]					0x9E
0x12					X_POLARITY	Y_POLARITY	Z_POLARITY	X_Y_SWAP	0x00
0x16		ORIENT_INT_EN	S_TAP_INT_EN	D_TAP_INT_EN		ACTIVE_INT_EN_Z	ACTIVE_INT_EN_Y	ACTIVE_INT_EN_X	0x00
0x17		OVERRUN_INT_EN		DATA_INT_EN	FREEFALL_INT_EN				0x00
0x19		INT1_ORIENT	INT1_S_TAP	INT1_D_TAP		INT1_ACTIVE		INT1_FREEFALL	0x00
0x1A	INT2_NEW_DATA		INT2_OVERRUN			INT1_OVERRUN		INT1_NEW_DATA	0x00
0x1B		INT2_ORIENT	INT2_S_TAP	INT2_D_TAP		INT2_ACTIVE		INT2_FREEFALL	0x00
0x20					INT2_OD	INT2_LVL	INT1_OD	INT1_LVL	0x00
0x21	RESET_INT				LATCH_INT[3:0]				0x00
0x22	FREEFALL_DUR[7:0]								0x09
0x23	FREEFALL_TH[7:0]								0x30
0x24						FREEFALL_MODE	FREEFALL_HY[1:0]		0x01
0x27							ACTIVE_DUR[1:0]		0x00
0x28	ACTIVE_TH								0x14
0x2A	TAP_QUIET	TAP_SHOCK				TAP_DUR[2:0]			0x04
0x2B				TAP_TH[4:0]					0x0A
0x2C		ORIENT_HYST[2:0]			ORIENT_BLOCKING[1:0]		ORIENT_MODE[1:0]		0x18
0x2D					Z_BLOCKING[3:0]				0x08
0x38	OFFSET_X[7:0]								0x00
0x39	OFFSET_Y[7:0]								0x00
0x3A	OFFSET_Z[7:0]								0x00

6. Register Description

Register 0x00(Soft Reset) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
4-wire	LSB First	Soft Reset			Soft Reset	LSB First	4-wire	0X00

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

Reg 0x01(PartID):Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
PARTID[7:0]								0X00

Reg 0x02/0x03(X_axis Data LSB/MSB) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
ACC_X[5:0]								0X00
Acc_x[13:6]								0X00

Reg 0x04/0x05(Y_axis Data LSB/MSB) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
ACC_Y[5:0]								0X00
ACC_Y[13:6]								0X00

Reg 0x06/0x07(Z_axis Data LSB/MSB) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
ACC_Z[5:0]								0X00
ACC_Z[13:6]								0X00

Reg 0x09(Motion_Interrupt) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
	ORIENT_INT	S_TAP_INT	D_TAP_INT		ACTIVE_INT		FREEFALL_INT	0X00

ORIENT_INT: orientation interrupt status,0:inactive,1:active

S_TAP_INT: single tap interrupt status,0:inactive,1:active

D_TAP_INT: double tap interrupt status,0:inactive,1:active

ACTIVE_INT: active interrupt status,0:inactive,1:active

FREEFALL_INT: freefall interrupt status,0:inactive,1:active

Reg 0x0A(Data_Interrupt) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
							NEW_DATA_INT	0X00

NEW_DATA_INT: new data interrupt status,0:inactive,1:active

Reg 0x0B(Tape_Active_Status) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
TAP_SIGN	TAP_FIRST_X	TAP_FIRST_Y	TAP_FIRST_Z	ACTIVE_SIGN	ACTIVE_FIRST_X	ACTIVE_FIRST_Y	ACTIVE_FIRST_Z	0X00

TAP_SIGN: sign of tap triggering signal, 0:positive,1:negative

TAP_FIRST_X: tap interrupt triggered by x axis, 1:positive,0:negative

TAP_FIRST_Y: tap interrupt triggered by y axis, 1:positive,0:negative

TAP_FIRST_Z: tap interrupt triggered by z axis, 1:positive,0:negative

ACTIVE_SIGN: sign of active interrupt, 0:positive,1:negative

ACTIVE_FIRST_X: active interrupt triggered by x axis, 1:positive,0:negative

ACTIVE_FIRST_Y: active interrupt triggered by y axis, 1:positive,0:negative

ACTIVE_FIRST_Z: active interrupt triggered by z axis, 1:positive,0:negative

Reg 0x0C(Orientation _Status) :Read only

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
	ORIENT[2:0]							0X00

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 upsidedown

10:landscape left, 11:landscape right

Reg 0x0F(Resolution/Range)： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
				RESOLUTION[1:0]		FS[1:0]		0X00

RESOLUTION[1:0]: resolution of x/y/z axes, 00:14bit, 01:12bit, 10:10bit, 11:8bit

RANGE[1:0]: acceleration range of x/y/z axes, 00:+/-2g, 01:+/-4g, 10:+/-8g, 11:+/-16g

Reg0x10(ODR) : Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
X_AXIS_DIS	Y_AXIS_DIS	Z_AXIS_DIS		ODR[3:0]				0X0F

X_AXIS_DIS: 0:enable, 1:disable

Y_AXIS_DIS: 0:enable, 1:disable

Z_AXIS_DIS: 0:enable, 1:disable

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)

1010-1111:1000Hz (not available in low power mode)

Reg0x11(Power Mode/Bandwidth) : Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
PWR_MODE			LOW_POWER_BW[3:0]					0X9E

PWR_MODE: 00:normal mode, 01:low power mode, 10/11 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, 1010-1111:500Hz

Reg 0x12(Swap_Polarity) : Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
				X_POLARITY	Y_POLARITY	Z_POLARITY	X_Y_SWAP	0X00

X_POLARITY: the polarity of X axis, 0:not reverse, 1:reverse

Y_POLARITY: the polarity of Y axis, 0:not reverse, 1:reverse

Z_POLARITY: the polarity of Z axis, 0:not reverse, 1:reverse

X_Y_SWAP: output of X/Y axis, 0:not swap, 1:swap

Reg 0x16(Int_Set_0) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
	ORIENT_INT_EN	S_TAP_INT_EN	D_TAP_INT_EN		ACTIVE_INT_EN_Z	ACTIVE_INT_EN_Y	ACTIVE_INT_EN_X	0X00

ORIENT_INT_EN: orient interrupt, 0:disable, 1:enable

S_TAP_INT_EN: single tap interrupt, 0:disable, 1:enable

D_TAP_INT_EN: double tap interrupt, 0:disable, 1:enable

ACTIVE_INT_EN_Z: active interrupt for the z axis, 0:disable, 1:enable

ACTIVE_INT_EN_Y: active interrupt for the y axis, 0:disable, 1:enable

ACTIVE_INT_EN_X: active interrupt for the x axis, 0:disable, 1:enable

Reg 0x17(Int_Set_1) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
			DATA_INT_EN	FREEFALL_INT_EN				0X00

NEW_DATA_INT_EN: new data interrupt, 0:disable, 1:enable

FREEFALL_INT_EN: freefall interrupt, 0:disable, 1:enable

Reg 0x19(Int_Map_0) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
	INT1_ORIENT	INT1_S_TAP	INT1_D_TAP		INT1_ACTIVE		INT1_FREEFALL	0X00

INT1_ORIENT: map orientation interrupt to INT1, 0:disable, 1:enable

INT1_S_TAP: map single tap interrupt to INT1, 0:disable, 1:enable

INT1_D_TAP: map double tap interrupt to INT1, 0:disable, 1:enable

INT1_ACTIVE: map active interrupt to INT1, 0:disable, 1:enable

INT1_FREEFALL: map freefall interrupt to INT1, 0:disable, 1:enable

Reg 0x1A(Int_Map_1) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
INT2_NEW_DATA							INT1_NEW_DATA	0X00

INT2_NEW_DATA: map new data interrupt to INT2, 0:disable, 1:enable

INT1_NEW_DATA: map new data interrupt to INT1, 0:disable, 1:enable

Reg 0x1B (Int_Map_2) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
	INT2_ORIENT	INT2_S_TAP	INT2_D_TAP		INT2_ACTIVE	RESERVED	INT2_FREEFALL	0X00

INT2_ORIENT: map orientation interrupt to INT2, 0:disable, 1:enable

INT2_S_TAP: map single tap interrupt to INT2, 0:disable, 1:enable

INT2_D_TAP: map double tap interrupt to INT2, 0:disable, 1:enable

INT2_ACTIVE: map active interrupt to INT2, 0:disable, 1:enable

INT2_FREEFALL: map freefall interrupt to INT2, 0:disable, 1:enable

Reg 0x20 (Int_Map_2) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
				INT2_OD	INT2_LVL	INT1_OD	INT1_LVL	0X00

INT2_OD: select output for INT2, 0: push-pull, 1:OD

INT2_LVL: select active level for INT2, 0: low, 1:high

INT1_OD: select output for INT1, 0: push-pull, 1:OD

INT1_LVL: select active level for INT1, 0: low, 1:high

Reg 0x21 (Int_Latch) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
RESET_INT				LATCH_INT[3:0]				0X00

RESET_INT: reset or not, 1: reset all latched int, 0:not reset all latched int

LATCH_INT[3:0]: 0000: non-latched

0001: tempoary latched 250ms

0010: tempoary latched 500ms

0011: tempoary latched 1s

0100: tempoary latched 2s

0101: tempoary latched 4s

0110: tempoary latched 8s

0111: latched

1000: non-latched

1001: tempoary latched 1ms

1010: tempoary latched 1ms

1011: tempoary latched 2ms

1100: tempoary latched 25ms

1101: tempoary latched 50ms

1110: tempoary latched 100ms

1111: latched

Reg 0x22 (Freefall_Dur) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
FREEFALL_DUR[7:0]								0X09

FREEFALL_DUR[7:0]: delay_time is (FREEFALL_DUR[7:0] +1) ×2ms, range from 2ms to 512ms, the default delay time is 20ms

Reg 0x23 (Freefall_Th) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
FREEFALL_TH[7:0]								0X30

FREEFALL_TH[7:0]: threshold value is freefall_th[7:0] ×7.81mg, default value is 375mg

Reg 0x24 (Freefall_Hy) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
					FREEFALL_MODE	FREEFALL_HY[1:0]		0X01

FREEFALL_MODE: 0. single mode. 1,sum_mode..

FREEFALL_HY[1:0]: freefall hysteresis time is FREEFALL_HY[1:0] ×125mg

Reg 0x27 (Active_Dur) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
						ACTIVE_DUR[1:0]		0X00

ACTIVE_DUR[1:0]: active duration time is (ACTIVE_DUR[1:0]+1)ms

Reg 0x28(Active_Th) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
ACTIVE_TH[7:0]								0X14

ACTIVE_TH[7:0]: threshold of active interrupt

3.91mg/LSB(2g range)

7.81mg/LSB(4g range)

15.625mg/LSB(8g range)

31.25mg/LSB(16g range)

Reg 0x2A(Tap_Dur) : Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
TAP_QUIET	TAP_SHOCK				TAP_DUR[2:0]			0X04

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]: selects the length of the time window for the secend shock

000: 50ms. 001:100ms

010:150ms. 011:200ms

100:250ms, 101:375ms

110:500ms, 111:700ms

Reg 0x2B(Tap_Th) : Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
			TAP_DUR[4:0]					0X0a

TAP_TH[4:0]: threshold of tap interrupt.

62.5mg/LSB(2g range)

125mg/LSB(4g range)

250mg/LSB(8g range)

500mg/LSB(16g range)

Reg 0x2C(Orient_Hy) : Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
	ORIENT_HYST[2:0]			ORIENT_BLOCKING[2:0]		ORIENT_MODE[2:0]		0X18

ORIENT_HYST[2:0]: set the hysteresis of the orientation interrupt, 1LSB is 62.5mg.

ORIENT_BLOCK[1:0]: select the block mode

00: no blocking

01: z_axis blobking

10: z_axis blocking or slope in any axis > 0.2g

11: no blocking

ORIENT_MODE[1:0]: set the thresholds

00:symmetrical

01: high-asymmetrical

10: low-asymmetrical

11:synmmetrical

Reg 0x2D(Z_Block) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
				Z_BLOCKING[3:0]				0X08

Z_BLOCK[3:0]: defines the block acc_z between 0g to 1g

Reg 0x38/0x39/0x40 (Offset_compensation) ： Read/Write

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
OFFSET_X[7:0]								0X00
OFFSET_Y[7:0]								0X00
OFFSET_Z[7:0]								0X00

OFFSET_X[7:0]: the offset compensation value for X axis, 1LSB is 3.9mg

OFFSET_Y[7:0]: the offset compensation value for Y axis, 1LSB is 3.9mg

OFFSET_Z[7:0]: the offset compensation value for Z axis, 1LSB is 3.9mg

7. I2C Interface and Application Collection

7.1 I2C Interface

I2C bus uses SCL and SDIO 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 MSA300 is shown as following table. The LSB bit of the 7bits device address is configured via SDO pin.

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	W/R
0	1	0	0	1	1	SDO	0/1

Table 12: I2C Address.

I2C Address : 01001100 SDO pulled to GND, Write
01001101 SDO pulled to GND, Read
01001110 SDO pulled to VDDIO, Write
01001111 SDO pulled to VDDIO, Read

7.2 I2C Timing

Symbol	Parameter	Condition	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 condi-		0.6		us

	tion				
t_{susto}	Setup Time for a stop condition		0.6		us
t_{buf}	Time before a new transmission can start		1.3		us

Table 13: Electrical specification of the I2C interface pins

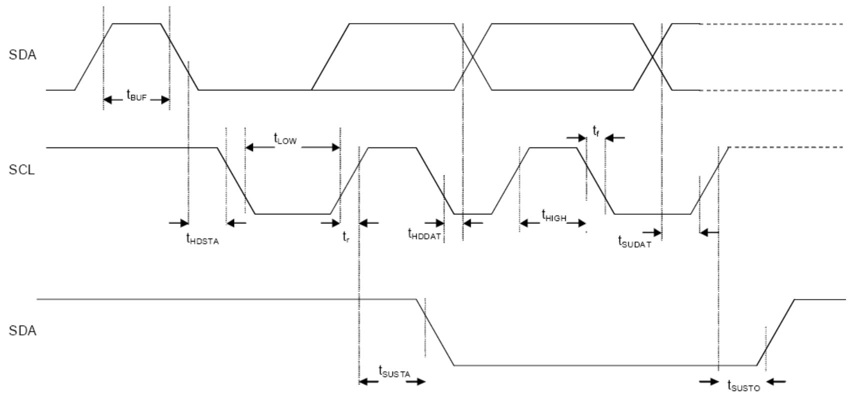


Figure 6: I2C Timing Diagram

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.

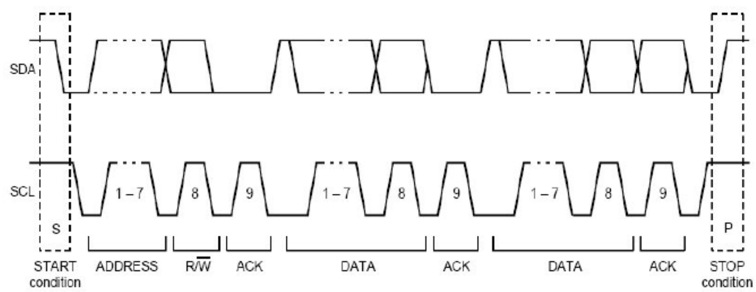


Figure 7: I2C Protocol

7.3 I2C Application collection

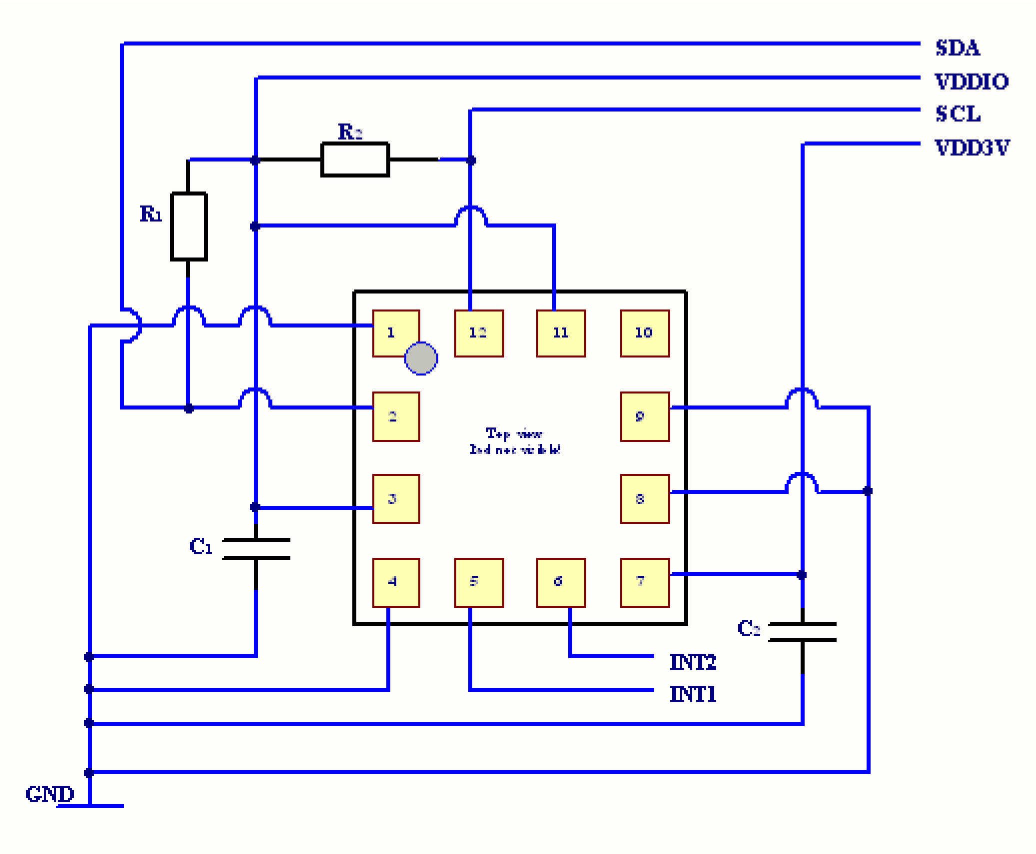


Figure 8: I2C application electrical collection

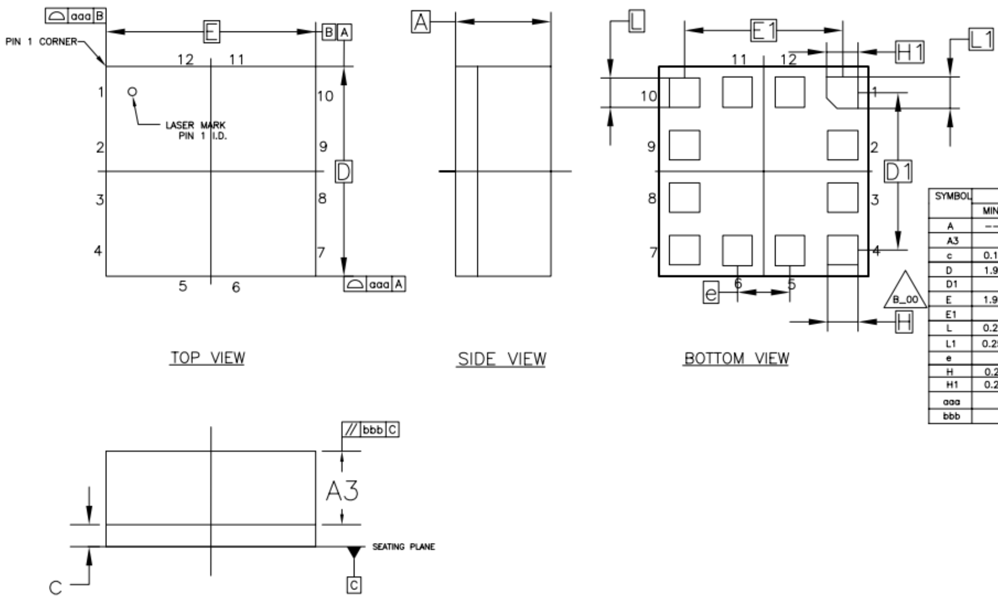
Note:

The recommended value for C1, C2 is 100nF.

The typical value for R1,R2 is 4.7kΩ pull up resistors.

8. Package Description

8.1 Outline Dimensions



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	---	---	1.00
A3	0.70 BASIC		
c	0.17	0.21	0.25
D	1.95	2.00	2.05
D1	1.50 BASIC		
E	1.95	2.00	2.05
E1	1.51 BASIC		
L	0.23	0.28	0.33
L1	0.25	0.30	0.35
e	0.50 BASIC		
H	0.24	0.29	0.34
H1	0.25	0.30	0.35
aaa	0.05		
bbb	0.20		

Figure 9: Package Pin Dimensions

8.2 Sensor orientation

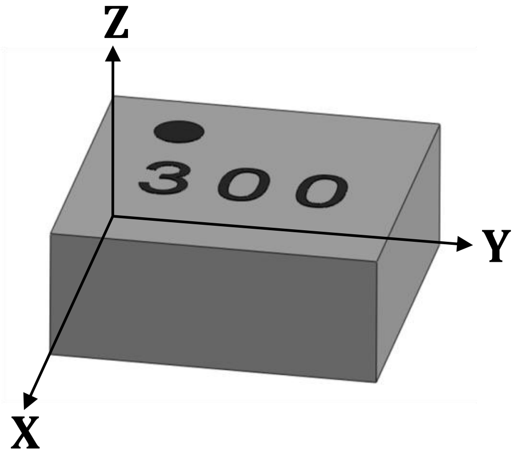


Figure 10: Orientation of sensing axis

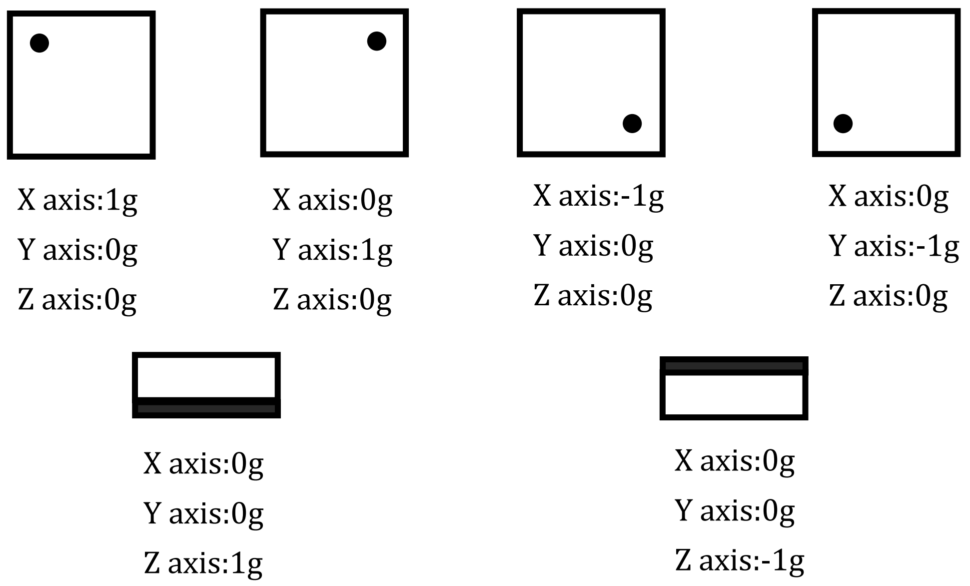
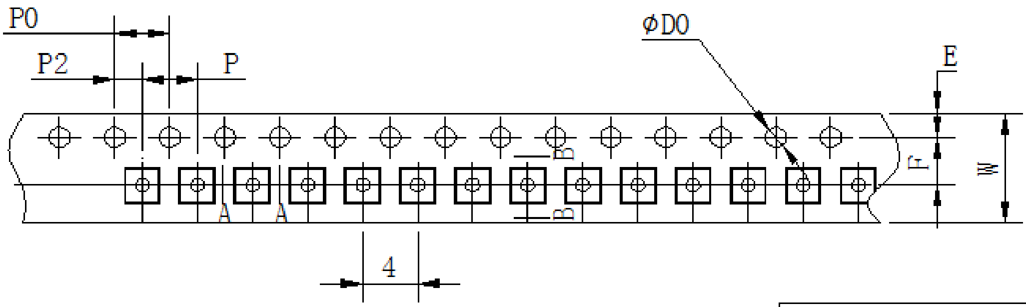
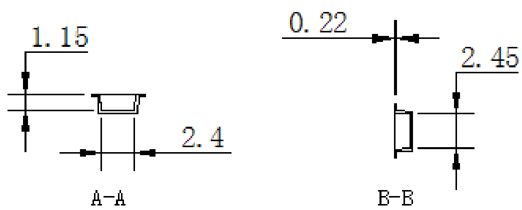


Figure 11: Output signal of sensing axis orientation

8.3 Tape and reel





Size	
E	1.75±0.10
F	5.50±0.10
P2	2.00±0.10
ØDo	1.50 +0.10 / −0.00
ØD1	1.20±0.10
Po	4.00±0.10
10Po	40.00±0.20
W	8.00±0.30
P	4.00±0.10
Ao	2.40±0.10
B0	2.45±0.10
K0	1.15±0.10
t	0.22±0.05

Figure 12: Tape and reel dimension in mm

Revision History

Revision	Subjects (major changes since last revision)	Date
1.0	Initial Release	2016-1-13

公司销售、技术支持联系方式	(http://www.memsensing.com)
MEMSensing Microsystems(Suzhou, China) Co., Ltd. No. 99 Jinji Lake Avenue, Bldg. NW-09, Suite 501, Suzhou Industrial Park, China 215123 Phone: +86 512 62956055 Fax: +86 512 62956056	苏州敏芯微电子技术股份有限公司 苏州工业园区金鸡湖大道 99 号，NW-09 楼，501 室 中国 215123 电话: +86 512 62956055 传真: +86 512 62956056