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iNEMO inertial module: always-on 3D accelerometer and 3D gyroscope

Datasheet - production data

LGA-14L
(2.5 x 3 x 0.83 mm) typ.

Features

- Power consumption: 0.85 mA in combo normal mode and 1.1 mA in combo high-performance mode up to 1.6 kHz.
- “Always-on” experience with low power consumption for both accelerometer and gyroscope
- Interface flexibility: selectable SPI (3/4-wire) or I^{2}C with the main processor
- Auxiliary SPI (3-wire) to support OIS applications
- EIS/OIS support
- Accelerometer ODR up to 6.66 kHz
- Gyroscope ODR up to 3.33 kHz
- Smart FIFO
- ±2/±4/±8/±16 *g* full scale
- ±125/±245/±500/±1000/±2000 dps full scale
- Analog supply voltage: 1.71 V to 3.6 V
- Independent IOs supply (1.62 V)
- Compact footprint, 2.5 mm x 3 mm x 0.83 mm
- SPI/I^{2}C serial interface data synchronization feature
- Embedded temperature sensor
- ECOPACK®, RoHS and “Green” compliant

Applications

- EIS and OIS for camera applications
- Collecting sensor data
- Motion tracking and gesture detection
- Pedometer, step detector and step counter
- Significant motion and tilt functions
- Indoor navigation
- IoT and connected devices
- Vibration monitoring and compensation

Description

The LSM6DS3H is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope performing at 1.1 mA (up to 1.6 kHz ODR) in high-performance mode and enabling always-on low-power features for an optimal motion experience for the consumer.

The LSM6DS3H supports main OS requirements, offering real, virtual and batch sensors with 4 kbyte FIFO + flexible 4 kbyte (FIFO or programmable) for dynamic data batching.

The LSM6DS3H gyroscope supports both OIS/EIS applications. The device can be connected to the camera module through a dedicated auxiliary SPI (Mode 3) while flexibility for the primary interface is available (I^{2}C/SPI).

ST’s family of MEMS sensor modules leverages the robust and mature manufacturing processes already used for the production of micromachined accelerometers and gyroscopes.

The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element.

The LSM6DS3H has a full-scale acceleration range of ±2/±4/±8/±16 *g* and an angular rate range of ±125/±245/±500/±1000/±2000 dps.

High robustness to mechanical shock makes the LSM6DS3H the preferred choice of system designers for the creation and manufacturing of reliable products.

The LSM6DS3H is available in a plastic land grid array (LGA) package.

Table 1. Device summary

Part number	Temp. range [°C]	Package	Packing
LSM6DS3H	-40 to +85	LGA-14L (2.5 x 3 x 0.83 mm)	Tray
LSM6DS3HTR	-40 to +85		Tape & Reel

Contents

List of tables

List of figures

1 Overview

The LSM6DS3H is a system-in-package featuring a high-performance 3-axis digital accelerometer and 3-axis digital gyroscope.

The integrated power-efficient modes are able to reduce the power consumption down to 1.1 mA in high-performance mode, combining always-on low-power features with superior sensing precision for an optimal motion experience for the consumer thanks to ultra-low noise performance for both the gyroscope and accelerometer.

The LSM6DS3H delivers best-in-class motion sensing that can detect orientation and gestures in order to empower application developers and consumers with features and capabilities that are more sophisticated than simply orienting their devices to portrait and landscape mode.

The event-detection interrupts enable efficient and reliable motion tracking and contextual awareness, implementing hardware recognition of free-fall events, 6D orientation, tap and double-tap sensing, activity or inactivity, and wakeup events.

The LSM6DS3H supports main OS requirements, offering real, virtual and batch mode sensors. In addition, the LSM6DS3H can efficiently run the sensor-related features specified in Android, saving power and enabling faster reaction time. In particular, the LSM6DS3H has been designed to implement hardware features such as significant motion, tilt, pedometer functions, timestamping and to support the data acquisition of an external magnetometer with ironing correction (hard, soft).

The LSM6DS3H offers hardware flexibility to connect the pins with different mode connections to external sensors to expand functionalities such as adding a sensor hub, auxiliary SPI, etc. The application processor connection is supported by both SPI and I^2C interfaces for complete interface flexibility.

Up to 8 kbyte of FIFO [4 kbyte FIFO + flexible 4 kbyte (FIFO or programmable)] with dynamic allocation of significant data (i.e. external sensors, timestamp, etc.) allows overall power saving of the system.

Like the entire portfolio of MEMS sensor modules, the LSM6DS3H leverages the robust and mature in-house manufacturing processes already used for the production of micromachined accelerometers and gyroscopes. The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element.

The LSM6DS3H is available in a small plastic land grid array (LGA) package of 2.5 x 3.0 x 0.83 mm to address ultra-compact solutions.

2 Embedded low-power features

The LSM6DS3H has been designed to be fully compliant with Android, featuring the following on-chip functions:

- 8 kbyte data buffering
  - 4 kbyte FIFO + flexible 4 kbyte (FIFO or programmable)
  - 100% efficiency with flexible configurations and partitioning
  - possibility to store timestamp
- Event-detection interrupts (fully configurable):
  - free-fall
  - wakeup
  - 6D orientation
  - tap and double-tap sensing
  - activity / inactivity recognition
- Specific IP blocks with negligible power consumption and high-performance:
  - pedometer functions: step detector and step counters
  - tilt (Android compliant, refer to *Section 2.1: Tilt detection* for additional info
  - significant motion (Android compliant)
- Sensor hub
  - up to 6 total sensors: 2 internal (accelerometer and gyroscope) and 4 external sensors
- Data rate synchronization with external trigger for reduced sensor access and enhanced fusion

2.1 Tilt detection

The tilt function helps to detect activity change and has been implemented in hardware using only the accelerometer to achieve both the targets of ultra-low power consumption and robustness during the short duration of dynamic accelerations.

It is based on a trigger of an event each time the device's tilt changes by an angle greater than 35 degrees from the start position.

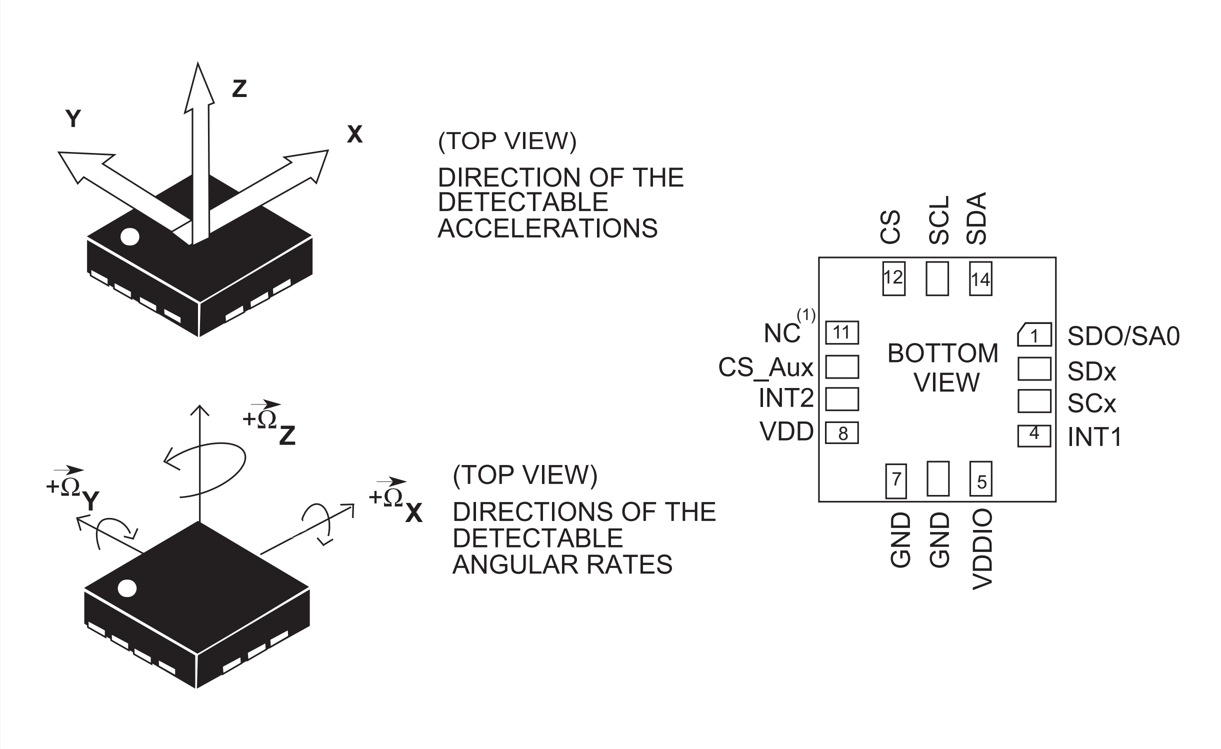
The tilt function can be used with different scenarios, for example:

a) Trigger when phone is in a front pants pocket and the user goes from sitting to standing or standing to sitting;

b) Doesn’t trigger when phone is in a front pants pocket and the user is walking, running or going upstairs.

3 Pin description

Figure 1. Pin connections



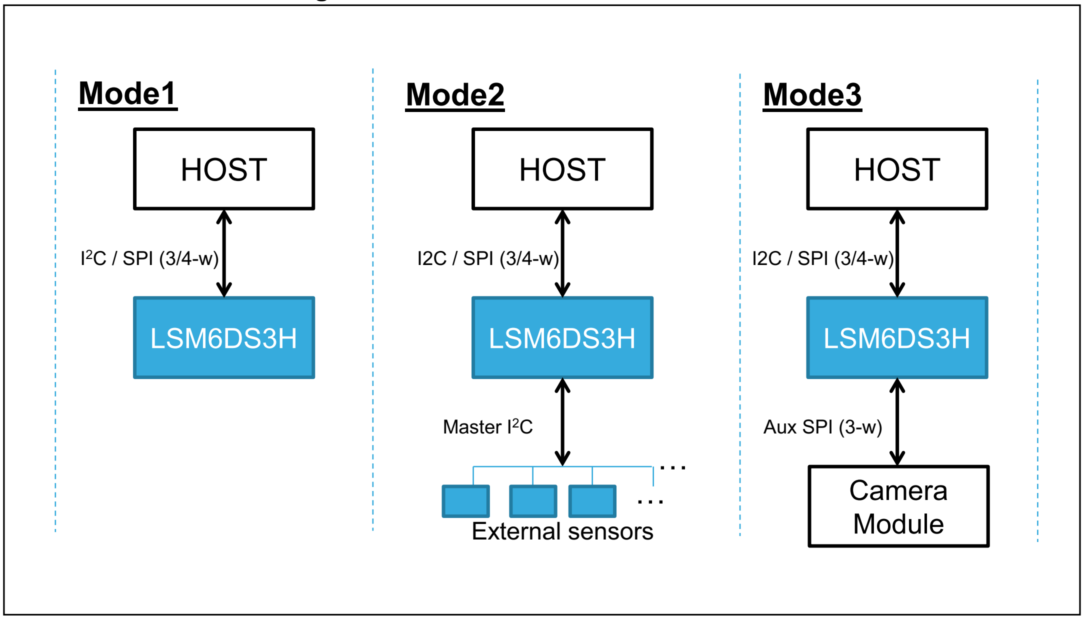
1. Leave pin electrically unconnected and soldered to PCB.

3.1 Pin connections

The LSM6DS3H offers the flexibility to connect the pins in order to have three different mode connections and functionalities. In detail:

- **Mode 1**: I^2C slave interface or SPI (3- and 4-wire) serial interface is available;
- **Mode 2**: I^2C slave interface or SPI (3- and 4-wire) serial interface and I^2C interface master for external sensors connections are available;
- **Mode 3**[(a)]: I^2C slave interface or SPI (3- and 4-wire) serial interface is available for the application processor interface while an auxiliary SPI (3-wire) serial interface for external sensor connections (i.e. camera module) is available.

Figure 2. LSM6DS3H connection modes



In the following table each mode is described for the pin connection and function.

a. In the primary SPI connection, the gyroscope output data is available in registers 22h to 27h with user-selected FS and ODR. In the auxiliary SPI connection, gyroscope output data is available in registers 22h to 27h @ 3.3 kHz and FS = 250 dps.

Table 2. Pin description

Pin#	Name	Mode 1 function	Mode 2 function	Mode 3 function
1	SDO/SA0	SPI 4-wire interface serial data output (SDO) I^2C least significant bit of the device address (SA0)	SPI 4-wire interface serial data output (SDO) I^2C least significant bit of the device address (SA0)	SPI 4-wire interface serial data output (SDO) I^2C least significant bit of the device address (SA0)
2	SDx	Connect to VDDIO or GND	I^2C serial data master (MSDA)	Auxiliary SPI 3-wire interface serial data input (SDI_Aux) and serial data output (SDO_Aux)
3	SCx	Connect to VDDIO or GND	I^2C serial clock master (MSCL)	Auxiliary SPI 3-wire interface serial port clock (SPC_Aux)
4	INT1	Programmable interrupt 1		
5	VDDIO(1)	Power supply for I/O pins		
6	GND	0 V supply		
7	GND	0 V supply		
8	VDD(2)	Power supply		
9	INT2	Programmable interrupt 2 (INT2)/ Data enable (DEN)	Programmable interrupt 2 (INT2)/ Data enable (DEN)/ I^2C master external synchronization signal (MDRDY)	Programmable interrupt 2 (INT2)/ Data enable (DEN)
10	CS_Aux	Leave unconnected(3)	Leave unconnected(3)	Auxiliary SPI 3-wire interface enable
11	NC(3)	Leave unconnected		
12	CS	I^2C/SPI mode selection (1: SPI idle mode / I^2C communication enabled; 0: SPI communication mode / I^2C disabled)	I^2C/SPI mode selection (1: SPI idle mode / I^2C communication enabled; 0: SPI communication mode / I^2C disabled)	I^2C/SPI mode selection (1: SPI idle mode / I^2C communication enabled; 0: SPI communication mode /I^2C disabled)
13	SCL	I^2C serial clock (SCL) SPI serial port clock (SPC)	I^2C serial clock (SCL) SPI serial port clock (SPC)	I^2C serial clock (SCL) SPI serial port clock (SPC)
14	SDA	I^2C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)	I^2C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)	I^2C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)

1. Recommended 100 nF filter capacitor.
2. Recommended 100 nF capacitor.
3. Leave pin electrically unconnected and soldered to PCB.

4 Module specifications

4.1 Mechanical characteristics

@ Vdd = 1.8 V, T = 25 °C unless otherwise noted.

Table 3. Mechanical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.(1)	Max.	Unit
LA_FS	Linear acceleration measurement range			±2		*g*
				±4		
				±8		
				±16		
G_FS	Angular rate measurement range			±125		dps
				±245		
				±500		
				±1000		
				±2000		
LA_So	Linear acceleration sensitivity(2)	FS = ±2		0.061		m*g*/LSB
		FS = ±4		0.122		
		FS = ±8		0.244		
		FS = ±16		0.488		
G_So	Angular rate sensitivity(3)	FS = ±125		4.375		mdps/LSB
		FS = ±245		8.75		
		FS = ±500		17.50		
		FS = ±1000		35		
		FS = ±2000		70		
LA_SoDr	Linear acceleration sensitivity change vs. temperature	from -40° to +85° delta from T=25°		±1		%
G_SoDr	Angular rate sensitivity change vs. temperature	from -40° to +85° delta from T=25°		±1.5		%
LA_TyOff	Linear acceleration typical zero-*g* level offset accuracy(4)			±40		m*g*
G_TyOff	Angular rate typical zero-rate level(4)			±10		dps
LA_OffDr	Linear acceleration zero-*g* level change vs. temperature			±0.5		m*g*/ °C
G_OffDr	Angular rate typical zero-rate level change vs. temperature			±0.05		dps/°C

Table 3. Mechanical characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.[1]	Max.	Unit
Rn	Rate noise density in high-performance mode[5]			6		mdps/√Hz
RnRMS	Gyroscope RMS noise in low-power mode[6]			120		mdps
An	Acceleration noise density in high-performance mode[7]	FS= ±2 *g*		90		µg/√Hz
		FS= ±4 *g*		90		µg/√Hz
		FS= ±8 *g*		110		µg/√Hz
		FS= ±16 *g*		180		µg/√Hz
RMS	Acceleration RMS noise in normal/low-power mode[8]	FS= ±2 *g*		1.7		m*g*(RMS)
		FS= ±4 *g*		2.0		m*g*(RMS)
		FS= ±8 *g*		2.7		m*g*(RMS)
		FS= ±16 *g*		4.4		m*g*(RMS)
LA_ODR	Linear acceleration output data rate			12.5 26 52 104 208 416 833 1666 3332 6664		Hz
G_ODR	Angular rate output data rate			12.5 26 52 104 208 416 833 1666 3332[9]		
Vst	Linear acceleration self-test output change[10][11]	FS = 2 *g*	90		1700	m*g*
	Angular rate self-test output change[12][13]	FS = 2000 dps	150		700	dps
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. Linear acceleration sensitivity after factory calibration test and trimming.
3. Angular rate sensitivity after factory calibration test and trimming.
4. Values after soldering.
5. RND (rate noise density) mode is independent of the ODR and FS setting.

6. Gyro noise RMS is independent of the ODR and FS setting.
7. Noise density in HP mode is the same for all ODRs.
8. Noise RMS in Normal/LP mode is the same for all the ODR RMS related to BW = ODR /2 (for ODR /9, typ value can be calculated by Typ *0.6)
9. To enable this ODR, refer to *CTRL4_C (13h)*.
10. The sign of the linear acceleration self-test output change is defined by the STx_XL bits in *CTRL5_C (14h)*, *Table 60* for all the axes.
11. The linear acceleration self-test output change is defined with the device in stationary condition as the absolute value of: OUTPUT[LSb] (self-test enabled) - OUTPUT[LSb] (self-test disabled). 1LSb = 0.061 m*g* at ±2 *g* full scale.
12. The sign of the angular rate self-test output change is defined by the STx_G bits in *CTRL5_C (14h)*, *Table 59* for all the axes.
13. The angular rate self-test output change is defined with the device in stationary condition as the absolute value of: OUTPUT[LSb] (self-test enabled) - OUTPUT[LSb] (self-test disabled). 1LSb = 70 mdps at ±2000 dps full scale.

4.2 Electrical characteristics

@ Vdd = 1.8 V, T = 25 °C unless otherwise noted.

Table 4. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.(1)	Max.	Unit
Vdd	Supply voltage		1.71	1.8	3.6	V
Vdd_IO	Power supply for I/O		1.62		Vdd + 0.1	V
IddHP	Gyroscope and accelerometer in high-performance mode	up to ODR = 1.6 kHz		1.1		mA
IddNM	Gyroscope and accelerometer in normal mode	ODR = 208 Hz		0.85		mA
IddLP	Gyroscope and accelerometer in low-power mode	ODR = 12.5 Hz		0.4		mA
LA_IddHP	Accelerometer current consumption in high-performance mode	up to ODR = 1.6 kHz		240		µA
LA_IddNM	Accelerometer current consumption in normal mode	ODR = 104 Hz		60		µA
LA_IddLM	Accelerometer current consumption in low-power mode	ODR = 12.5 Hz		10		µA
IddPD	Gyroscope and accelerometer in power down			6		µA
V_{IH}	Digital high-level input voltage		0.7 * VDD_IO			V
V_{IL}	Digital low-level input voltage				0.3 * VDD_IO	V
V_{OH}	High-level output voltage	I_{OH} = 4 mA (2)	VDD_IO - 0.2			V
V_{OL}	Low-level output voltage	I_{OL} = 4 mA (2)			0.2	V
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. 4 mA is the maximum driving capability, i.e. the maximum DC current that can be sourced/sunk by the digital pad in order to guarantee the correct digital output voltage levels V_{OH} and V_{OL}.

For details related to the LSM6DS3H operating modes, refer to *5.2: Gyroscope power modes* and *5.3: Accelerometer power modes*.

4.3 Temperature sensor characteristics

@ Vdd = 1.8 V, T = 25 °C unless otherwise noted.

Table 5. Temperature sensor characteristics

Symbol	Parameter	Test condition	Min.	Typ.(1)	Max.	Unit
TODR	Temperature refresh rate			52		Hz
Toff	Temperature offset(2)		-15		+15	°C
TSen	Temperature sensitivity			16		LSB/°C
TST	Temperature stabilization time(3)				500	µs
T_ADC_res	Temperature ADC resolution			12		bit
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. The output of the temperature sensor is 0 LSB (typ.) at 25 °C.
3. Time from power ON bit to valid data based on characterization data.

4.4 Communication interface characteristics

4.4.1 SPI - serial peripheral interface

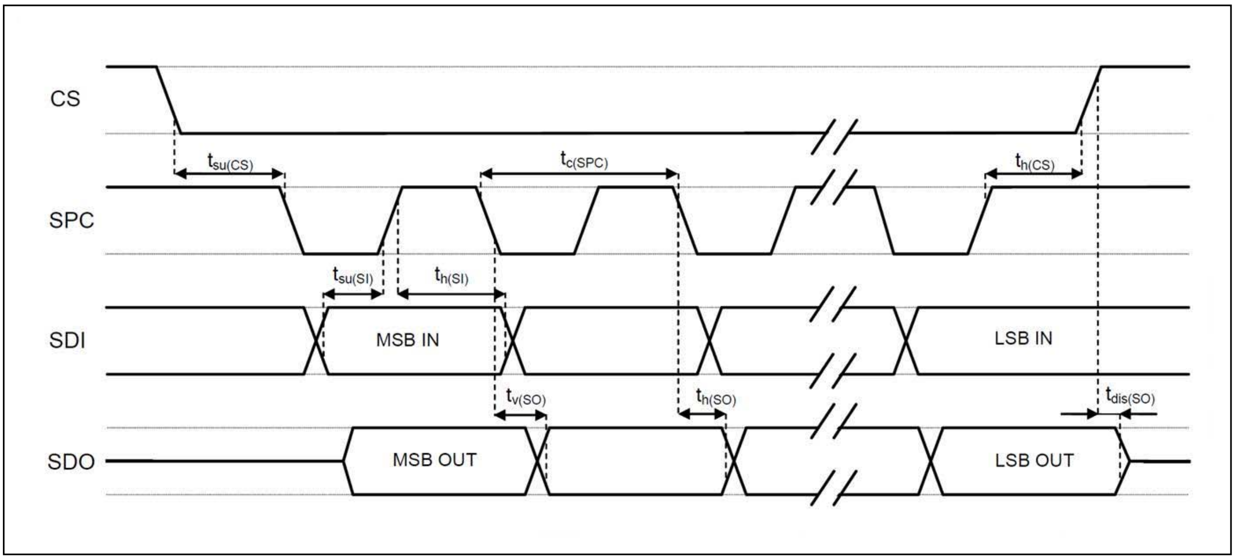
Subject to general operating conditions for Vdd and Top.

Table 6. SPI slave timing values

Symbol	Parameter	Value(1)		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	5		ns
$t_{h(CS)}$	CS hold time	20		
$t_{su(SI)}$	SDI input setup time	5		
$t_{h(SI)}$	SDI input hold time	15		
$t_{v(SO)}$	SDO valid output time		50	
$t_{h(SO)}$	SDO output hold time	5		
$t_{dis(SO)}$	SDO output disable time		50	

1. Values are guaranteed at 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·Vdd_IO and 0.8·Vdd_IO, for both input and output ports.