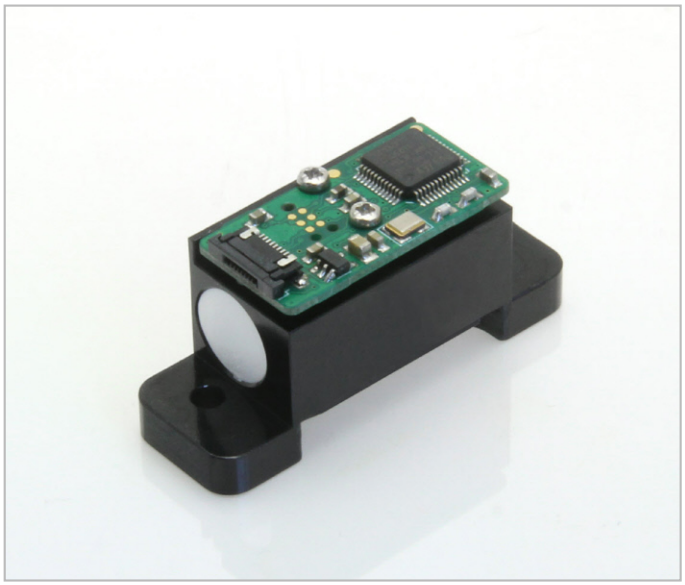
level developments

VSM : Vial Sensor Module, 0.1" Resolution, Linear Image

Features

- Ultra high precision levelling sensor
- Resolution less than <0.1 arc seconds
- Extremely low temperature drift (<0.5" per °C)
- Highly stable over time (<1" in one year)
- Measurement range ±10 arc minutes
- On board processor with 2 optional communications interfaces, UART & SPI
- Highly compact design with simple horizontal and vertical mounting arrangement options
- Adjustable settings including tare and damping
- 20 frames per second sample rate at full power, with low power sampling options and idle mode



Description

The VSM sensor combines a precision ground glass bubble vial with a high-resolution linear image sensor and all of the supporting electronics to provide a digital output of the angular and level position. The bubble vials are manufactured in our UK facility to world-leading standards, ensuring the highest resolution and best stability over time and temperature. These versatile modules can be applied in a wide range of applications such as structural monitoring devices, 3D laser scanning and LIDAR equipment. With a measurement resolution of <0.1 arc seconds and temperature stability of <0.5 arc seconds per °C, the price to performance ratio of this product is unparalleled. The flexible mounting and power options, along with the dual UART & SPI output interfaces, make it simple to integrate into any relevant application. Each unit is manufactured, calibrated, and individually tested in our UK factory to guarantee performance to the stated specifications.

General Specifications

Parameter	Value	Unit	Notes
Supply Voltage	5 3.3	V dc	The VSM can accept a 5V input using Pin 8, or a 3.3V input using pin 6. See page 5 for more Information.
Operating Current 0Hz (Idle Mode) 2Hz 5Hz 10Hz 20Hz	 8.38 9.20 10.4 12.3 16.3	mA	Power varies depending on sample rate mode, as shown on the left.
Operating Temperature	-20 to 70	°C	Maximum operating temperature range.
Storage Temperature	-40 to 80	°C	Maximum storage temperature range.
UART Baud Rate	38.4	Kbps	Can be factory configured to other standard values on request
UART Data Format	38.4, 8,1,N		1 start bit, 8 data bits, 1 stop bit, no parity
Stabilisation time	5	s	This is the time it takes for the bubble position to stabilise after a 1 arc minute step to within 1 arc second of the final position (at 20°C)
Mechanical shock	5000	G	Shock survival limit 5000G for 0.5ms
Weight	10	g	Not including cable
Connection pins	8		0.5mm pitch 8 pin FFC, see page 5 for more Information

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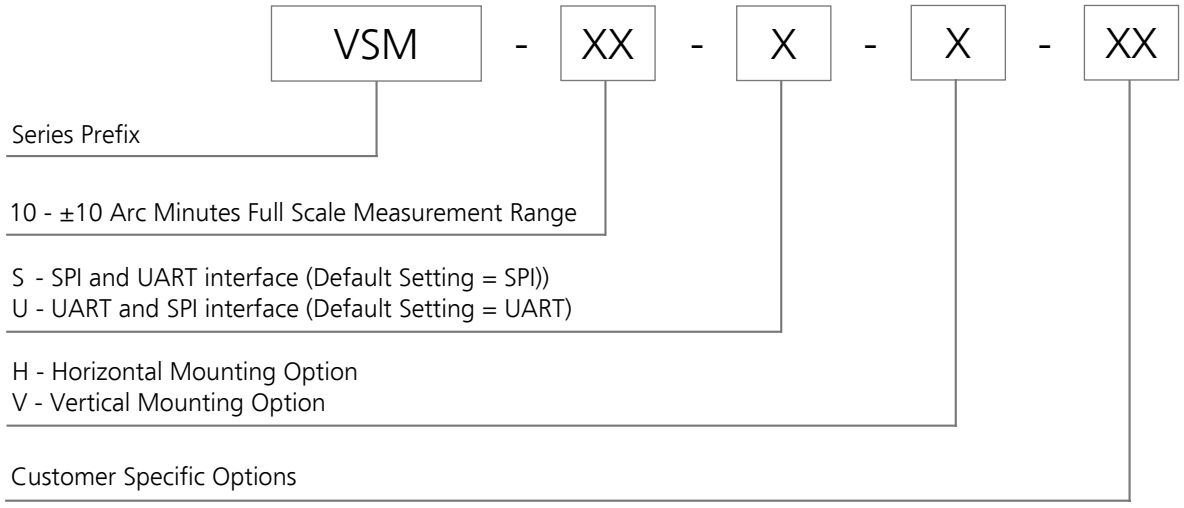
Performance Specifications

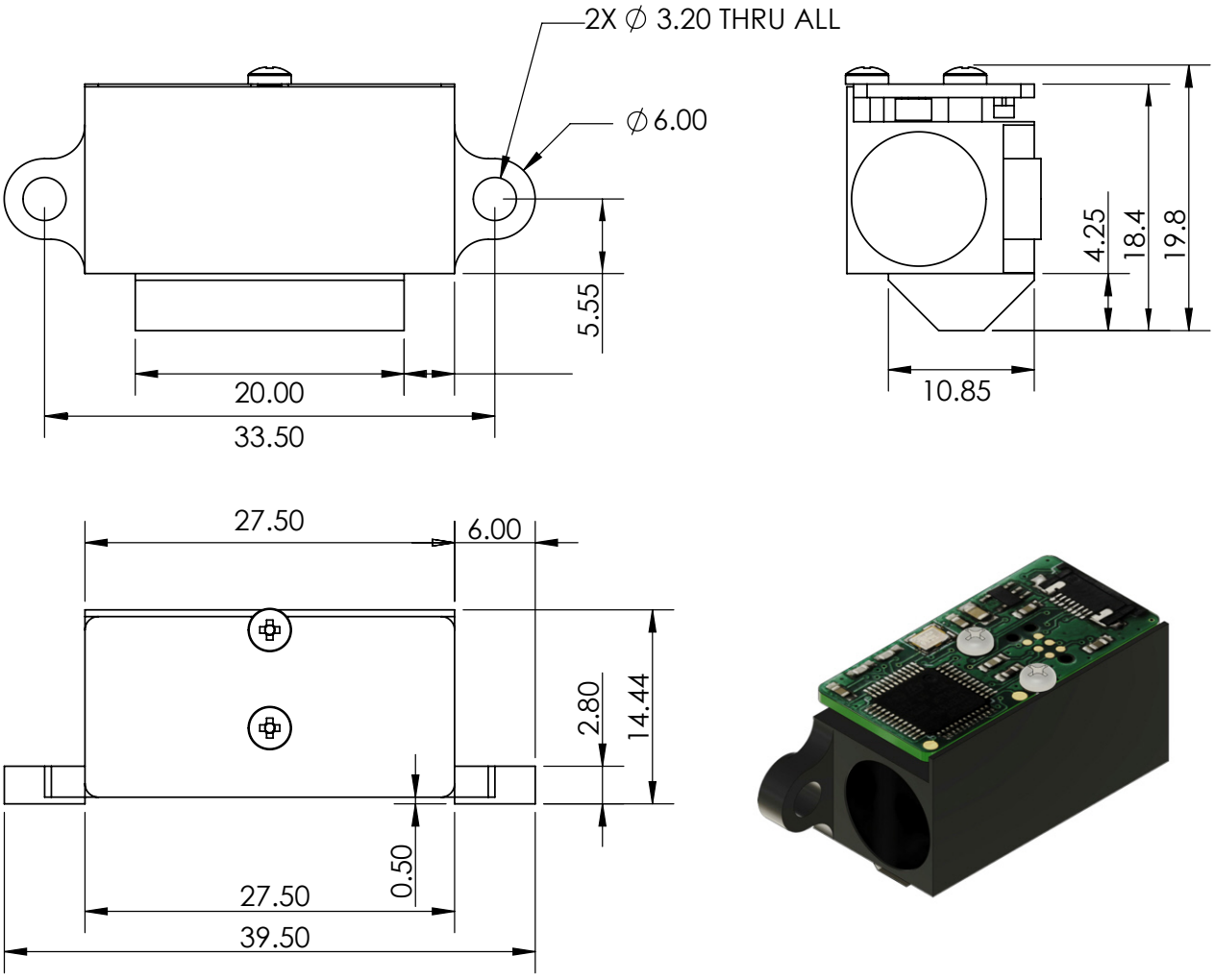
Parameter	Value	Unit
Measurement Range (Linear)	±7.5	' (arc minutes)
Measurement Range (Non-Linear)	±10	' (arc minutes)
Resolution	0.1	" (arc seconds)
Temperature Drift	0.5	"/°C (arc seconds per °C)
Accuracy	±5	" (arc seconds) in the range ±7.5'
Zero Bias Error	±2	' (arc minutes)
Long Term Stability	1	" (arc seconds)
Bi-directional repeatability	0.5	" (arc seconds)

Parameter	Notes
Measurement Range	Defines the linear measurement range of the sensor.
Resolution	The resolution of the device is the smallest measurable change in output.
Temperature Drift	When the sensor is in the null position (i.e. the bubble position is central to the linear array sensor) this is the maximum drift in position that will occur due to a change in temperature throughout the operating temperature range.
Accuracy	This is the maximum error between the measured and displayed value at any point in the linear measurement range.
Zero Bias Error	If the sensor is mounted exactly on the horizontal axis (relative to the aluminium housing), the output at this position reflects the zero bias error, which results from the parallelism and centricity of both the vial and the mounting in the housing.
Long term stability	The maximum change in zero bias of the device when used in normal operating conditions over a 1 year period.
Repeatability	The consistency of measurement when the same tilt angle is measured repeatedly under identical conditions.

Part Numbering

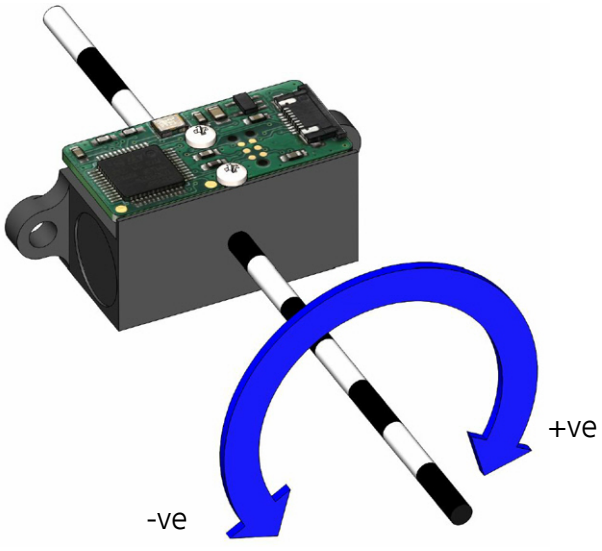


Vertical Mounting Option - Housing Drawing

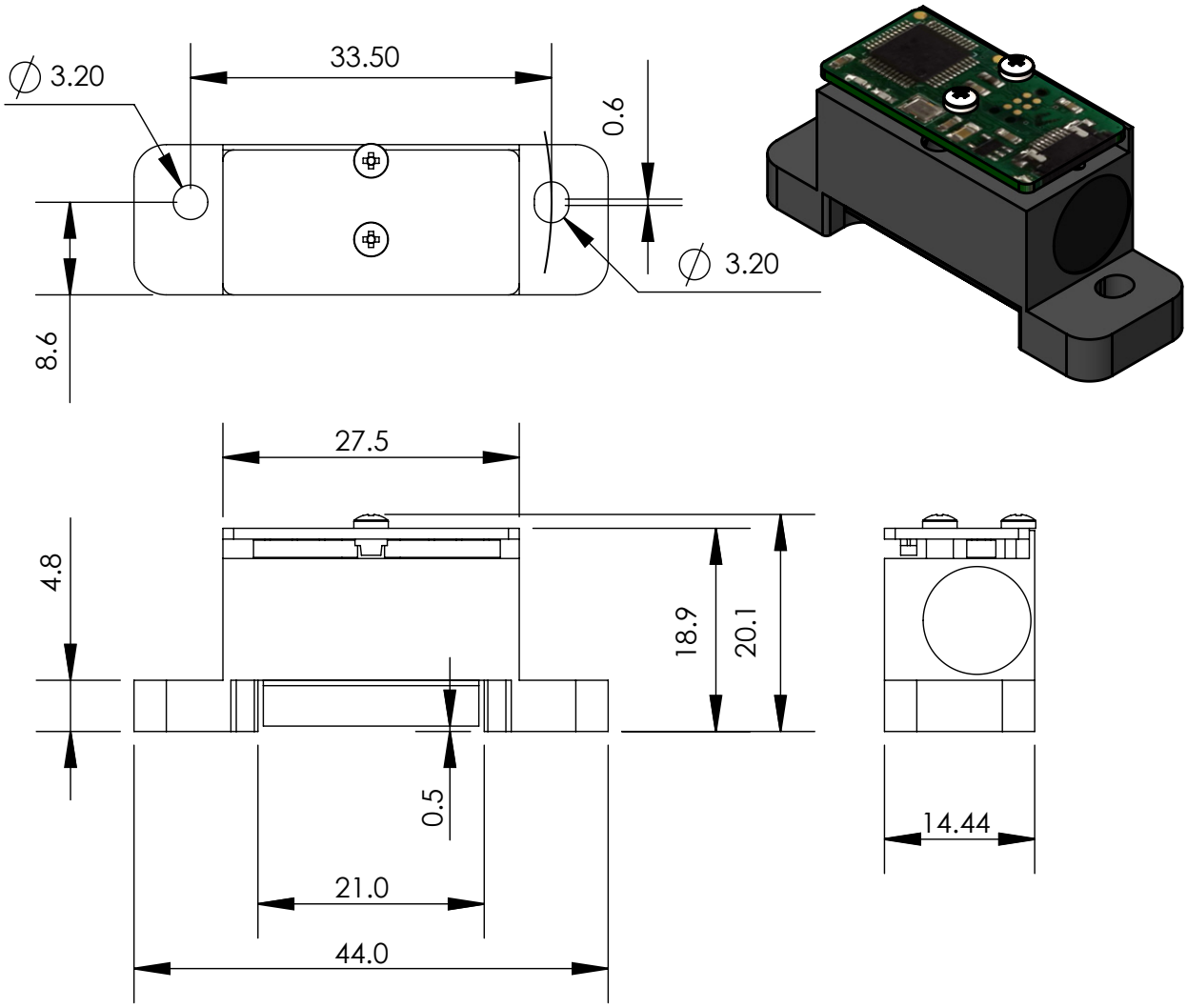


Vertical Mounting Option - Axis Direction and Mounting Orientation

Mounted on Vertical Surface

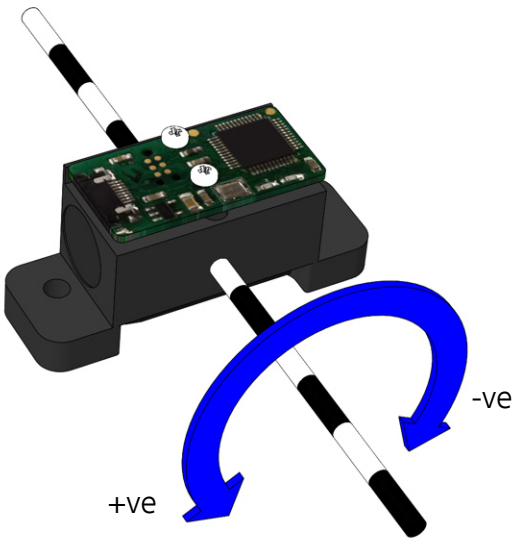


Horizontal Mounting Option - Housing Drawing

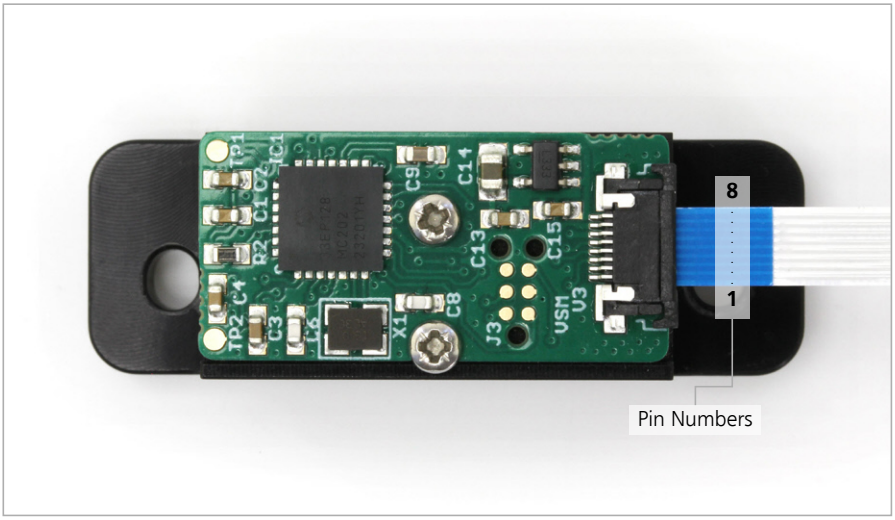


Horizontal Mounting Option - Axis Direction and Mounting Orientation

Mounted on Horizontal Surface



Connection details



Pin	Pin Name
8	5.0V Input
7	GND
6	3.3V Input
5	SPI MISO
4	SPI MOSI
3	SPI SCL
2	UART Rxd / SPI SS
1	UART Txd / SPI DRDY

Pin Specifications

The VSM connector provides pins for both UART and SPI communications, along with Ground, 5V input, and 3.3V input, as outlined in the table below. Although the UART and SPI pins are separate, SPI requires two additional pins (DRDY and SS). Due to the limited number of pins on the connector, it is not possible to use both interfaces simultaneously.

The pin functions are summarised below alongside the minimum, typical, and maximum operating voltages:

Pin	Pin Name	UART Function	SPI Function	Min	Typ.	Max	Abs Max	Pin Direction/Comment
1	UART Tx / SPI DRDY	Tx	DRDY	-	3.3V	5V	5.5V(2)	Output
2	UART Rx / SPI SS	Rx	SS	-	3.3V	5V	5.5V(2)	Input
3	SPI SCL	-	SCL	-	3.3V	5V	5.5V(2)	Input (Clock driven in Slave Mode)
4	SPI MOSI	-	MOSI	-	3.3V	5V	5.5V(2)	Input (VSM)
5	SPI MISO	-	MISO	-	3.3V	5V	5.5V(2)	Output (VSM)
6	3.3V Input	3.3V In/Out	3.3V In/Out	2.9V	3.3V	3.6V	4.0V(2)	Input Voltage, not regulated (1)
7	GND	GND	GND	-	-	-	-	Common Ground
8	5.0V Input	5.0V Input	5.0V Input	3.1V	5.0V	5.5V	36V(2)	Input Voltage, regulated (1)

Note 1: The 3.3V pin can be used as a direct input supply pin, however, this bypasses the on-board voltage regulator which can expose the device to damage in the event of external voltage spikes or over-voltage. Do not supply voltage to both 5V and 3.3V pins at the same time.
Note 2: Exceeding the absolute maximum limits can cause permanent damage. These are stress ratings only; operation at or beyond these conditions is not guaranteed and prolonged exposure may affect reliability. Powering the device at above 5.5V (pin 8) will impair performance.

UART Interface & Command Set

Data is transmitted and received over a UART interface in full duplex mode when connected using the UART connections shown on the previous page. Note that the VSM is shipped in UART mode by default, and can be switched into SPI mode using the "`set-spi`" command as shown in the table below. The default UART configuration is with the baud rate set to 38.4kbps, with 8 data bits, 1 stop bit and no parity.

All commands are lower case and 7 bytes long. The time between each character of the command must be less than 100ms otherwise the device will discard the command. The settings are all stored in non volatile memory and remembered after a power cycle..

Command	Description	Response Length	Response
`get---x`	Returns a one-time response of the bubble position in arc seconds x10 when Integer output is selected or with 1 decimal point for ASCII output.	2 bytes 8 bytes	`0x XX XX` `±1234.5<CR>`
`getinfo`	Get serial number	9 bytes	`00123456<CR>`
`setcasc`	Start continuous ASCII output of angle in arc seconds.	8 bytes	`±1234.5<CR>`
`stpcasc`	Stop continuous ASCII output.	2 bytes	`OK`

`str0020`
`str0010`
`str0005`
`Str0002`
`str0000`
	Set sampling rate to 20 samples per second (20Hz)
	Set sampling rate to 10 samples per second (10Hz)
	Set sampling rate to 5 samples per second (5Hz)
	Set sampling rate to 2 samples per second (2Hz)
	Set sampling rate to 0 samples per second (0Hz - Idle Mode)
		2 bytes	`OK`

`get-flt`	Returns the value of the current damping time in ms as an INT16	2 bytes	`0x XX XX`

`setflt1`
`setflt2`
`setflt3`
	Sets the low pass filter (damping) frequency to 0.125Hz
	Sets the low pass filter (damping) frequency to 0.25Hz
	Sets the low pass filter (damping) frequency to 0.5Hz
		2 bytes	`OK`

`setoasc`	Set output format to ASCII.	2 bytes	`OK`
`setoint`	Set output format to integer.	2 bytes	`OK`

`set-br1`
`set-br2`
`set-br3`
`set-br4`
`set-br5`
`set-br6`
`set-br7`
	Sets the UART (only) baud rate to 2400
	Sets the UART (only) baud rate to 4800
	Sets the UART (only) baud rate to 9600
	Sets the UART (only) baud rate to 19200
	Sets the UART (only) baud rate to 38400
	Sets the UART (only) baud rate to 57600
	Sets the UART (only) baud rate to 115200
		2 bytes	`OK`

`setzcur`	Tare function to zero the output based on the current position. This applies an offset on the final angle output.	2 bytes	`OK`
`setzfac`	Cancels tare function and resets zero to factory setting.	2 bytes	`OK`
`set-spi`	Set the VSM to communicate via SPI and disable UART. Note: The UART port must be disconnected immediately after sending this command in order for the SPI to operate.	2 bytes	`OK`

Serial Peripheral Interface (SPI) Details

The VSM acts as an SPI slave device when connected using the SPI connections described on page 5. However, the SPI instruction registers are only available when the SPI interface is enabled, and it is disabled (set to UART) by default. The SPI interface can be enabled by using the UART interface in conjunction with the UART control command "`set-spi`" as shown on page 6. The following sections detail the pin functions and timings of the SPI interface:

DRDY PIN - Data Ready Indicator:

This pin is set High to indicate that the SPI port is available to receive data, and Low when the device is busy. The processing time, when DRDY is low, is always 18.6ms, while the time available (high) will vary based on the selected sampling speed. Below is a timing table and a graph of the signal for reference.

Sample Rate	DRDY LOW (Busy)	DRDY HIGH (Available)	Units
20 Hz	18.6	31.4	ms
10 Hz	18.6	81.4	ms
5 Hz	18.6	181.4	ms
2 Hz	18.6	481.4	ms

DRDY Signal

SS PIN - Slave Select

The SS (slave select) pin acts as a typical SPI CS (chip select) pin, which enables the SPI communication when pulled Low. The device cannot receive/transmit SPI data when SS is set High.

SPI Timing Specifications

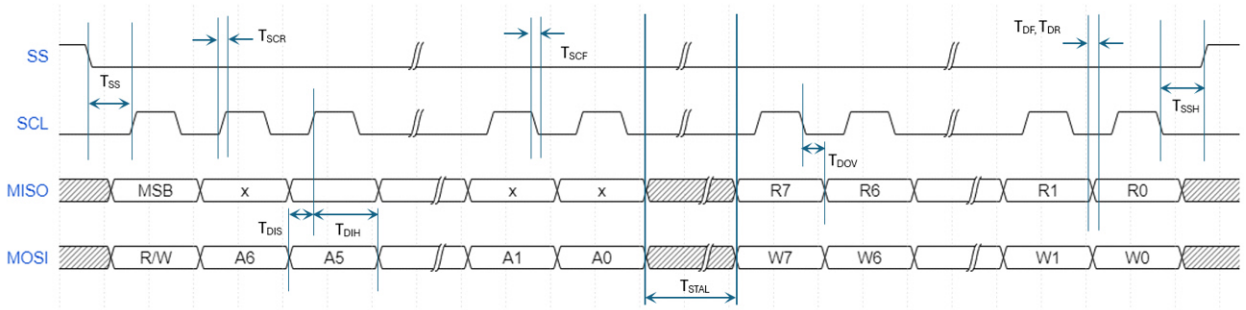
The following table specifies the key timing parameters for the SPI communication protocol, including minimum, typical, and maximum values to ensure reliable data transmission. See overleaf for a graphical representation of the SPI timing and sequence.

Parameter	Description	Min	Typical	Max	Unit
FSCLK	SCL Frequency (SPI clock)	10	500(1)	1000	kHz
TSTAL	Stall period between data bytes	2.2(2)			µs
TSS	Slave Select (or chip select) to SCL edge	1.0(3)			µs
TDOV	MISO (data out) valid after SCL edge		6	20	ns
TDIS	MOSI (data in) setup time before SCL rising edge	30			ns
TDIH	MOSI (data in) hold time after SCL rising edge	30			ns
TSCR	SCL rise time		5	10	ns
TSCF	SCL fall time		5	10	ns
TDF	MISO (data out) fall time		5	10	ns
TDR	MISO (data out) rise time		5	10	ns
TSSH	SS high after SCLK edge	2.2(2)			µs

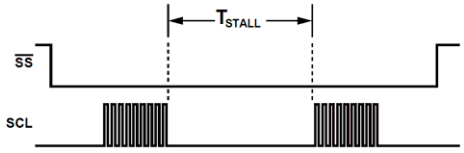
Note 1: Recommended operating frequency; higher frequencies are unnecessary due to the sensor's slow sampling rate
Note 2: Stall time is required to accommodate processing; it's recommended to wait the same period after the last byte before SS goes high
Note 3: Minimum time for the device to detect the falling edge of SS and start the internal state machine

SPI Timing Specifications (Continued)

The following timing diagrams show the signal interactions of the SPI lines, highlighting their timing relationships during data transmission:



SPI Timing and Sequence



Data Received (MOSI) Bit Sequence

SPI Registers Map

The table below details the SPI registers and functions. 'R' registers are read-only, while 'R/W' and 'W' allow read/write access. 'W' registers reset to 0x00 after receiving the 0x01 (enable) command, and always return zero when read.

Address	Name	Default	Access	Description
0x00	VSM_DEFAULTS	0x00	W	0x01 = Resets filter, sample rate & tare to default settings. (Remains in SPI mode)
0x01	RESERVED	–	-	
0x02	RESERVED	–	-	
0x03	FILTER	0x03	R/W	Filter index 1-3, set a value to configure, or read the current value using RW bit. 0x01 = 0.125Hz 0x02 = 0.25Hz 0x03 = 0.5Hz
0x04	RESERVED	–	-	
0x05	SAMPLE_RATE	0x0A	R/W	Set the sensor's sample rate: 0x00 = no sampling (idle) 0x02 = 02 samples per second 0x05 = 05 samples per second 0x0A = 10 samples per second 0x14 = 20 samples per second
0x06	RESERVED	–	-	
0x07	TARE_FUNCTION	0x00	R/W	0x00 = Tare Off / Disable Tare function (Default) - Clears any offset when sent 0x01 = Enable tare function - Saves current angle as the new zero offset
0x08	TARE_VALUE_L	0x00	R/W	Direct access to lower 8-bits of tare value (zero offset).
0x09	TARE_VALUE_H	0x00	R/W	Direct access to upper 8-bits of tare value; change applies after sending both register bytes.
0x10	ANGLE_L	0x00	R	Get lower 8-bits of current angle reading in arc seconds x10 (16-bit integer).
0x11	ANGLE_H	0x00	R	Get upper 8-bits of current angle reading in arc seconds.
0x20	UART_ENABLE	0x00	W	Exit SPI mode and enable UART mode using 0x01. Note: The VSM is shipped in UART mode by default. However, this register is set to 0x00 when entering SPI mode using UART command "set-spi" (page 6)