FSM30X Data Sheet

Overview

The FSM30X is a compact IMU module based on CEVA's Hillcrest Labs business unit's BNO08X 9-axis SiP. The FSM30X incorporates the BNO08X, a 32.768 kHz crystal and passive components into a compact module form factor that can be quickly and easily integrated into a design. The FSM30X provides all the motion based outputs available on the BNO08X. It does not support environmental sensors. The BNO08X datasheet is reference [3].

Pinout

The pinout of the FSM30X is shown in Figure 1.

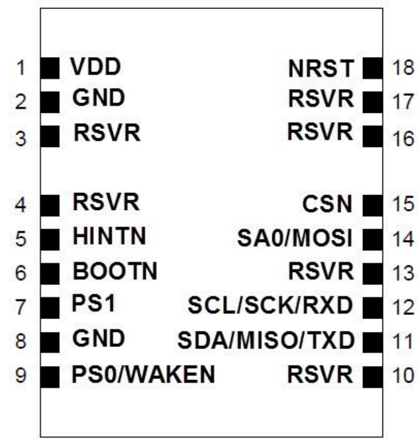


Figure 1: FSM30X Module

A description of each pin is listed in Figure 2. For pins with internal pullups/pulldowns the value of the pullup resistor is 34 kΩ and the value of the pulldown resistor is 6.2 kΩ.

Pin Number	Name	Mode	Description
1	VDD	Input	Supply voltage (2.4V to 3.6V)
2	GND	Input	Ground
3	Reserved	NC	Reserved. Do Not Connect
4	Reserved	NC	Reserved. Do Not Connect
5	HINTN	Output	Host interrupt
6	BOOTN	Input	Bootloader mode selection. Internal pullup.
7	PS1	Input	Protocol select 1. Internal pulldown.
8	GND	Input	Ground
9	PS0_WAKEN	Input	Protocol select 0. SPI mode processor wake input. Internal pullup.
10	Reserved	NC	Reserved. Do Not Connect
11	SDA/MISO/TXD	Bidirectional	Host Interface I^2C data, SPI data output or UART transmit data
12	SCL/SCK/RXD	Bidirectional	Host Interface I^2C clock, SPI clock or UART receive data
13	Reserved	NC	Reserved. Do Not Connect
14	SA0/MOSI	Input	Lower address bit of I2C device address. SPI data input. Internal pulldown.
15	CSN	Input	SPI chip select
16	Reserved	NC	Reserved. Do Not Connect
17	Reserved	NC	Reserved. Do Not Connect
18	NRST	Input	Reset. Internal pullup.

Figure 2: FSM30X Pin Descriptions

Host Interface Connectivity

The FSM30X supports all four of the host interfaces implemented by the BNO08X. Schematics showing typical connections for each interface are shown in the following figures.

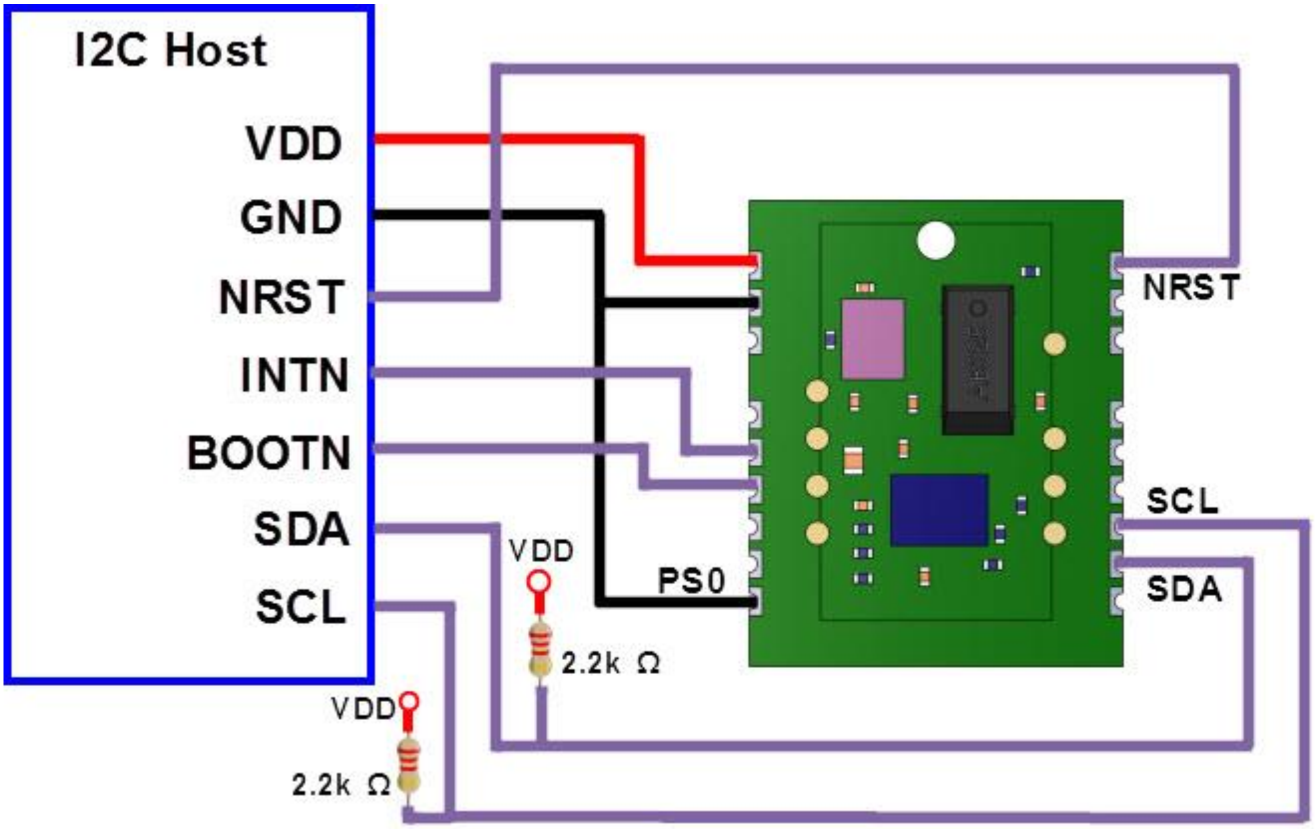


Figure 3: I2C Connection Example

As shown in Figure 3, the I2C bus requires pullup resistors. The value of these resistors should be in the range of 2.2 kΩ to 4.7 kΩ.

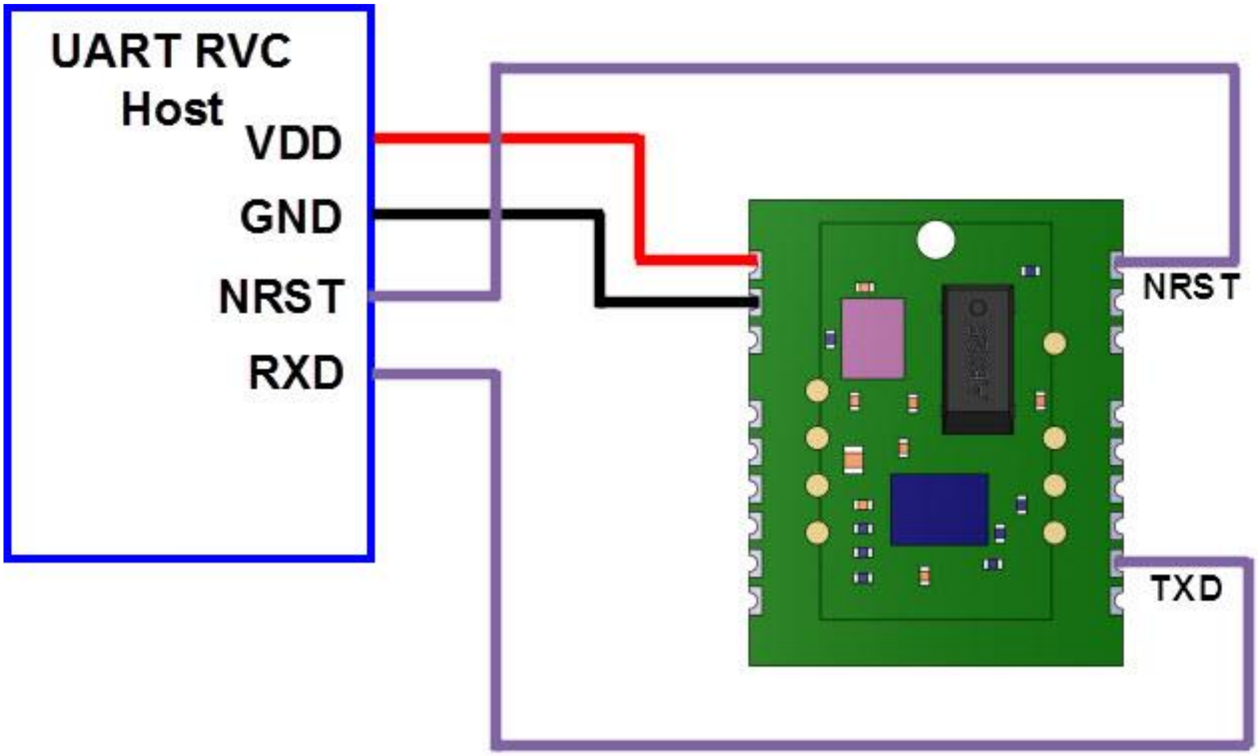


Figure 4: UART-RVC Connection Example

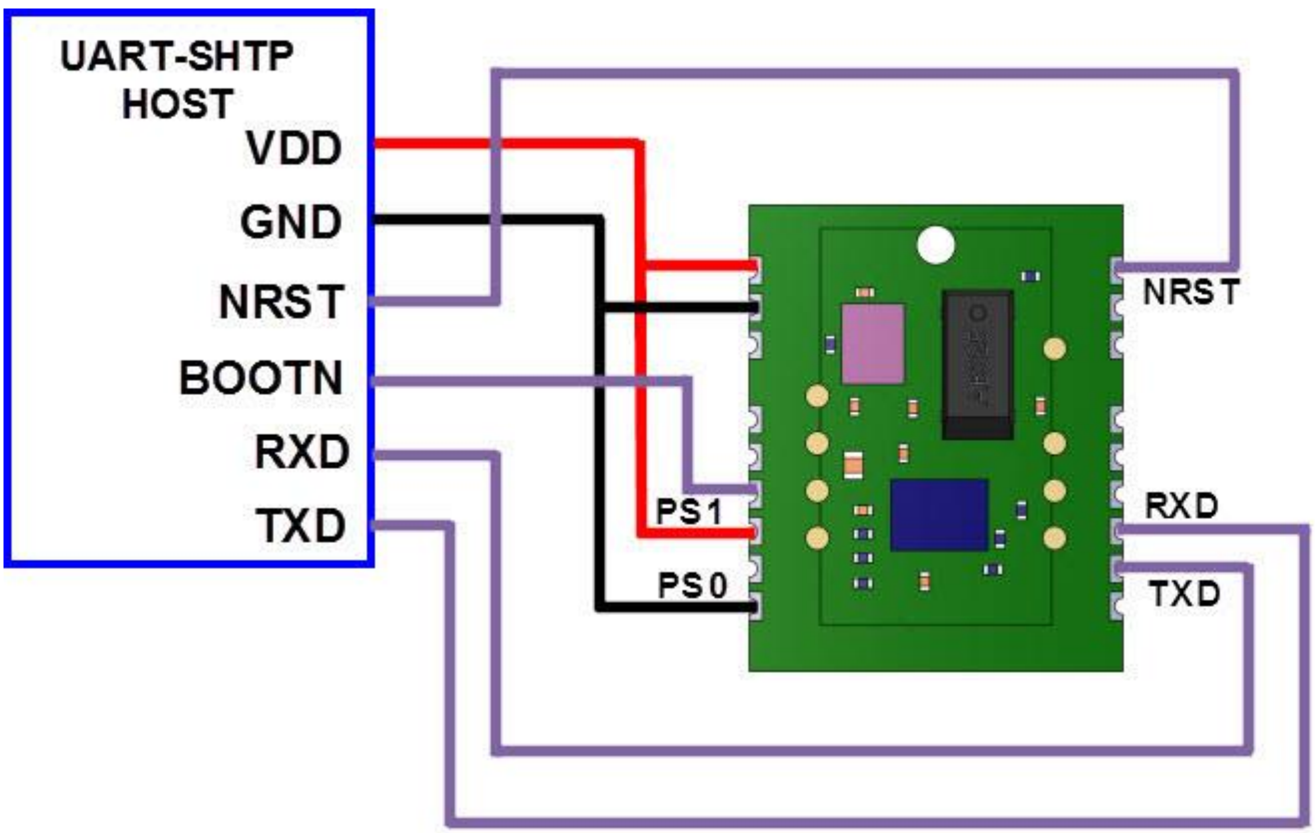


Figure 5: UART-SHTP Connection Example

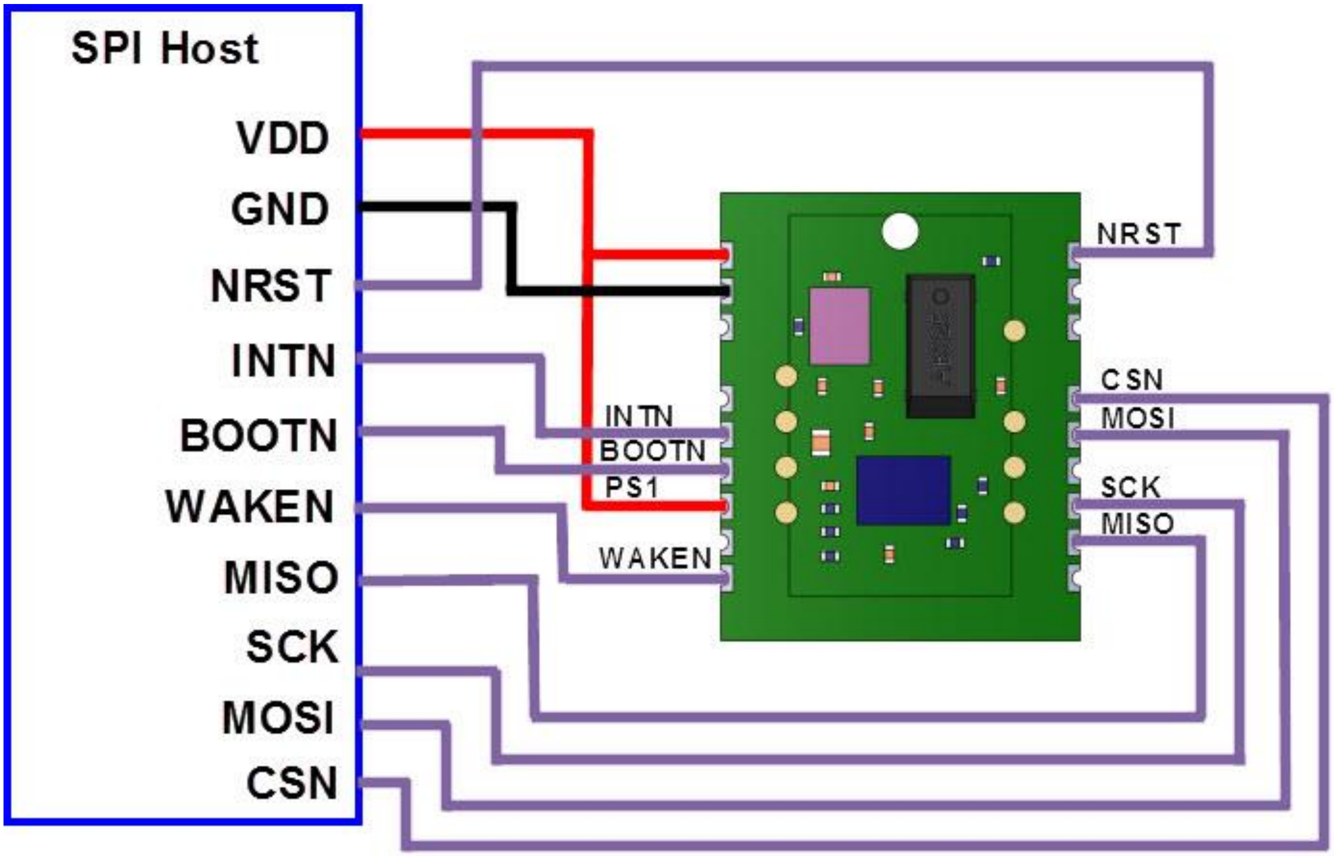


Figure 6: SPI Connection Example

FSM30X Coordinate System

The coordinate system for the FSM30X is shown in Figure 7. It is a right-handed coordinate system. Positive rotations are counter-clockwise.

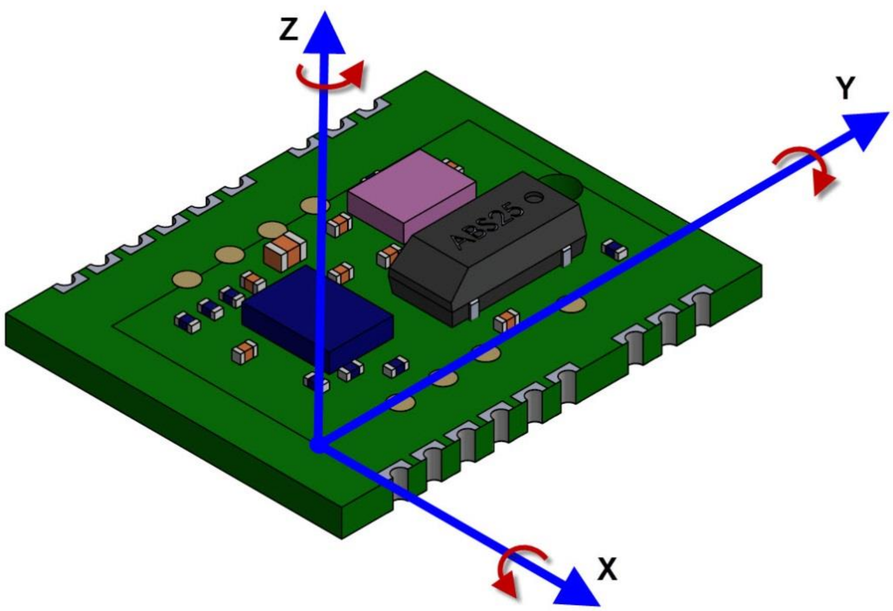


Figure 7: Coordinate System

FSM30X Characteristics

This section describes the electrical and performance characteristics of the FSM30X. All the FSM30X I/O pins meet CMOS and TTL requirements.

Note that the electrical and mechanical sections of the specification reported here are reproduced from the Bosch Sensortec BMF055 datasheet. The data in this section is reported for convenience, the reader is encouraged to consult the BMF055 datasheet [0] to verify all parameters.

Absolute Maximum Electrical Ratings

Exposure to maximum rating conditions for extended periods may affect device reliability.

Parameter	Symbol	Conditions	Rating	Unit
Voltage at supply pin	V_{DD}		-0.3 to 3.63	V
Voltage at any logic pin	$V_{non\text{-}supply}$		V_{DD}+0.3	V
Storage temperature	T_{rps}		-50 to +150	°C
Mechanical shock	$MechShock_{200\mu s}$	Duration ≤ 200µs	10,000	g
	$MechShock_{1ms}$	Duration ≤ 1.0ms	2,000	g
	$MechShock_{freefall}$	Free fall onto hard surfaces	1.8	m
ESD	ESD_{HBM}	HBM at any pin	2	kV
	ESD_{CDM}	CDM	500	V
	ESD_{MM}	MM	200	V

Figure 8: FSM30X Maximum Ratings

Recommended Operating Conditions

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply voltage	V_{DD}		2.4		3.6	V
Operating temperature			-40		85	°C

Figure 9: FSM30X Operating Conditions

Electrical Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input high voltage	V_{IH}	V_{DD}=2.4-2.7V	0.7			V_{DD}
		V_{DD}=2.7-3.6V	0.55			V_{DD}
Input low voltage	V_{IL}	V_{DD}=2.4-2.7V			0.25	V_{DD}
		V_{DD}=2.7-3.6V			0.3	V_{DD}
Output high voltage	V_{OH}	V_{DD} > 3V , I_{OH}=10mA	0.8	0.9		V_{DD}
Output low voltage	V_{OL}	V_{DD} > 3V, I_{OL}=20mA		0.1	0.2	V
POR Voltage threshold on VDD-IN rising	V_{DD_POT+}	V_{DD} falls at 1V/ms or slower		1.45		V
POR Voltage threshold on VDD-IN falling	V_{DD_POT-}			0.99		V

Figure 10: FSM30X Electrical Characteristics

Mechanical Characteristics

The sensors within the FSM30X are specified by Bosch Sensortec. The mechanical and electrical details of the raw sensors are specified in the BMF055 datasheet [0].

Performance Characteristics

FSM300

Each FSM300 module is calibrated for Z-axis gyro scale. This calibration improves the heading performance of the UART-RVC output. Figure 11 captures the performance of the FSM300's heading performance.

Parameter	Performance Metric	Typical	Max
Roll/Yaw	Resolution	0.01˚	
	Range	+/- 180 ˚	
Pitch	Resolution	0.01˚	
	Range	+/- 90 ˚	
Accelerometer	Range	+/- 2g	
	Resolution	1 mg	
	Scale error	1%	4%
	Zero-g offset	20 mg	
Gyroscope	Range	+/- 2000 ˚/s	
	Resolution	0.1 ˚/s	
	Z-axis scale error @25˚C	0.3%	1%
	X/Y-axis scale error @25˚C	1%	3%
	Scale error over temperature	0.03 %/˚C	0.07 %/˚C
	Z-axis gyro ZRO after stationary	0.01 ˚/s	
	Z-axis gyro ZRO over temperature	0.0017 ˚/s/˚C	0.0043 ˚/s/˚C
Startup time	UART reports from reset	125ms	
Composite Sensor	**Measurement**	**Performance Metric**	**Typical**
Rotation Vector	Dynamic	Rotation Error	3.5°
	Static	Rotation Error	1.0°
Gaming Rotation Vector	Dynamic	Non-heading Error	2.5°
	Static	Non-heading Error	1.0°
	Dynamic	Heading Drift	0.5°/min
Geomagnetic Rotation Vector	Dynamic	Rotation Error	4.5°
	Static	Rotation Error	1.0°
Gravity	Static	Angle Error	1.0°
Linear Acceleration	Dynamic	Accuracy	0.35 m/s^2
Magnetometer	Dynamic	Accuracy	1.4uT

Figure 11: FSM300 UART-RVC Performance

The gyro ZRO is the zero-rate offset and is the constant offset that is reported by the gyro when at rest. ZRO is constantly evaluated and corrected. The heading error estimate will vary in the short term based on gyro scale (or sensitivity) error and in the long term by the gyro ZRO.

For planar motions that only rotate about the Z-axis, the heading error can be determined from the following:

Heading Error Estimate = ScaleError * NonCancellingRotations + ZROError * time.

A cancelling rotation is a rotation in one direction followed by an opposite rotation. The result of the two rotations is that they cancel the effect of the scale error, hence any error attributable to scale is a function of the number of rotations in one direction being greater than in the opposite direction.

FSM305

Each FSM305 module is calibrated for 3D motion. This calibration improves performance across all outputs. Figure 12 captures the performance of the FSM305 when using an external clock or crystal. In addition, the range of the accelerometer is increased to ± 8g.

Composite Sensor	Measurement	Performance Metric	Typical
Rotation Vector	Dynamic	Rotation Error	3.0°
	Static	Rotation Error	1.0°
Gaming Rotation Vector	Dynamic	Non-heading Error	2.3°
	Static	Non-heading Error	1.0°
	Dynamic	Heading Drift	0.5°/min
Geomagnetic Rotation Vector	Dynamic	Rotation Error	3.5°
	Static	Rotation Error	1.0°
Gravity	Static	Angle Error	1.0°
Linear Acceleration	Dynamic	Accuracy	0.3 m/s^2
Accelerometer	Dynamic	Accuracy	0.12 m/s^2
Gyroscope	Dynamic	Accuracy	2.0°/s
Magnetometer	Dynamic	Accuracy	1.4uT

Figure 12: FSM305 Performance

The results above were generated by simulation. 210 physical devices were characterized and each of these models was subjected to simulated motion and the variation from truth catalogued. The rotation vector and geomagnetic rotation vector are highly dependent on the environmental conditions (specifically the magnetic field). In practice the rotation vector is typically accurate to 5˚ and the geomagnetic rotation vector to 10˚.

Power Consumption

The power consumption of the FSM30X is dependent on the configuration of the device including the sample rates of various sensors and even the environment in which the device is being used. The table below provides typical power consumption numbers for typical configurations. Measurements were taken with VDD at 3.0V.

Function	Sensor Rate(Hz)	Current (mA)	Power (mW)
Idle Power (reset)	—	0.479	1.437
UART-RVC mode	100	19.230	57.690
Rotation vector	100	11.431	34.293
Rotation vector	400	15.372	46.116
Game rotation vector	100	11.411	34.233
Geomagnetic rotation vector	100	7.973	23.920
Accelerometer	125	2.196	6.587
Accelerometer	500	7.197	21.592
Gyroscope	100	11.094	33.283
Gyroscope	400	14.965	44.894
Magnetometer	100	6.805	20.414
Gyro rotation vector	400	15.377	46.130
Gyro rotation vector	1000	16.268	48.805
Significant motion	On	0.900	2.700
Step detector	On	0.976	2.929
Tap detector	On	0.619	1.853
Shake detector	On	0.855	2.566
Stability classifier	100	11.127	33.380
Stability detector	On	0.632	1.895

Figure 13: Power Consumption

Packaging Information

Package Outline

The FSM30X is available in an 18-pin PCB module (20mm x 25mm) Units are in mm [inch]

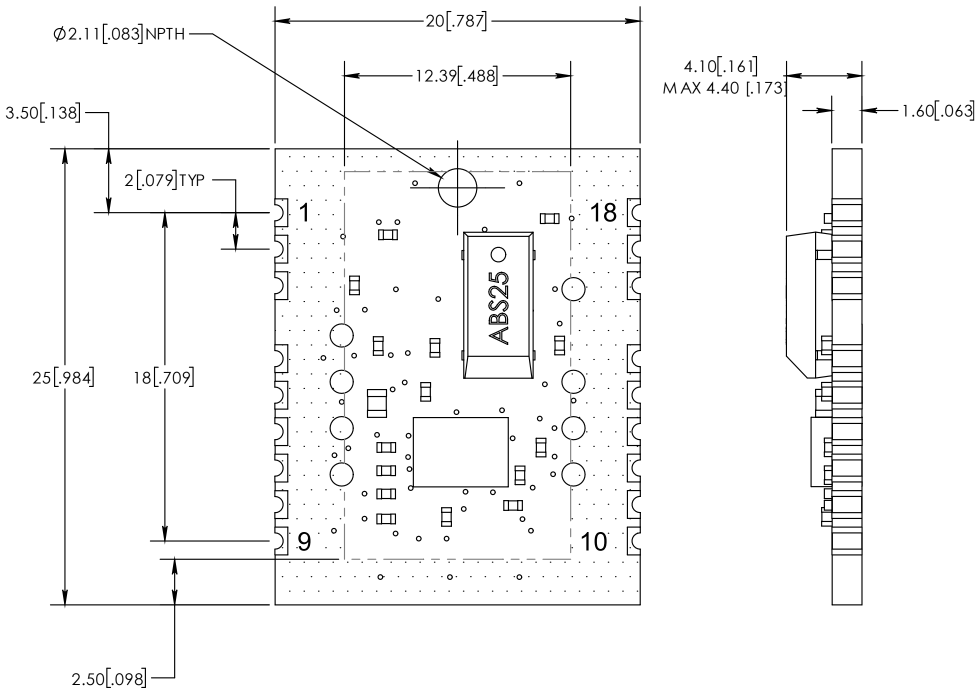


Figure 14: 18 pin module package outline (Top and Side View)

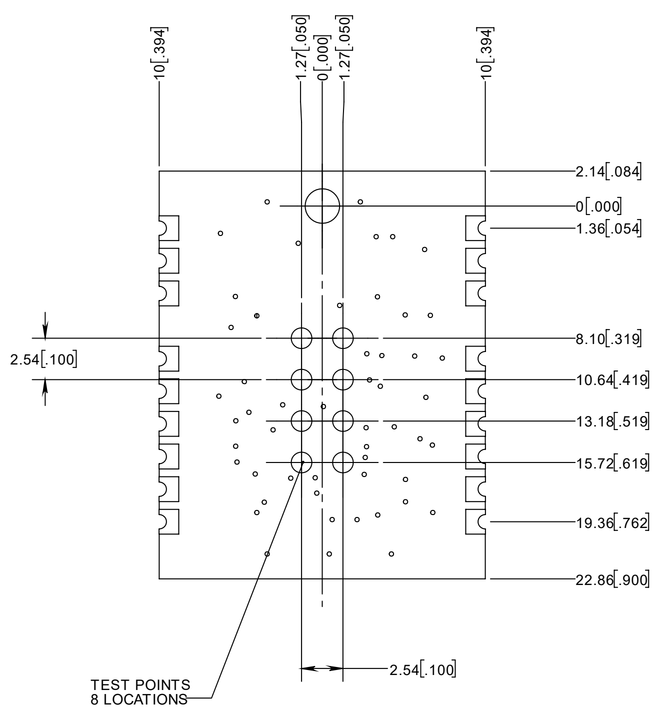


Figure 15: 18 pin module package outline (Bottom View)

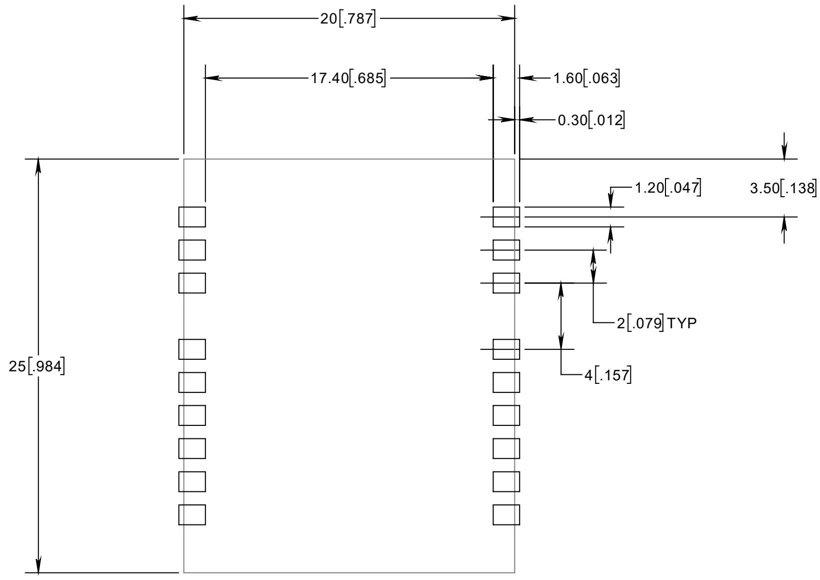
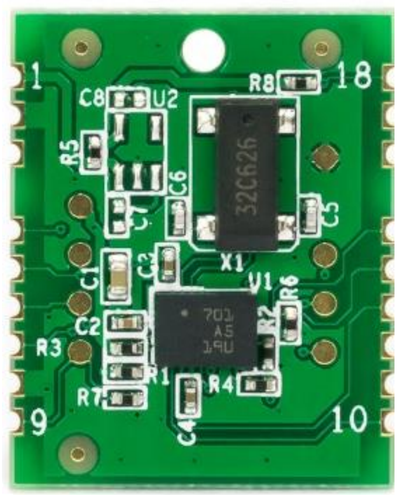


Figure 16: 18 pin module package footprint

Marking

The module pin identifiers are marked at each corner pin location.



Symbol	Name	Remark
1	Pin 1 identifier	VDD
9	Pin 9 identifier	PS0_WAKEN
10	Pin 10 identifier	RESERVED
18	Pin 18 identifier	NRST

Figure 17: Module pin identifiers markings

Soldering Guidelines

The moisture sensitivity level of the BNO08X sensors corresponds to JEDEC Level 1, see also

- IPC/JEDEC J-STD-020C "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices"
- IPC/JEDEC J-STD-033A "Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices"

The recommended solder reflow profile is shown below.

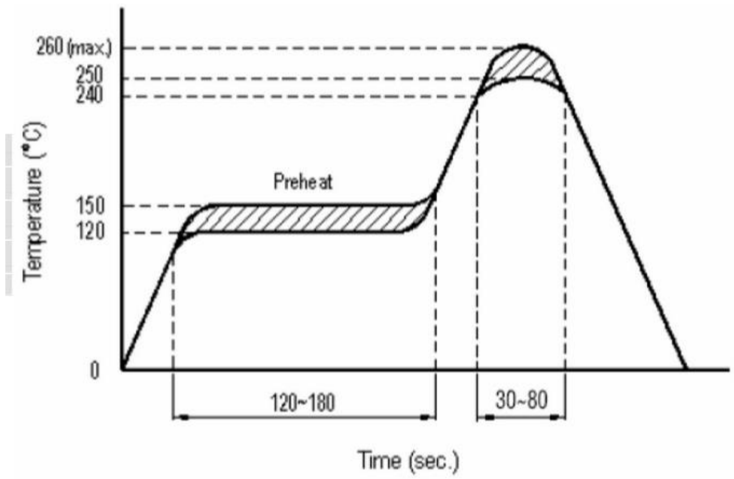


Figure 18: Recommended solder reflow profile

Handling Instructions

Micromechanical sensors are designed to sense acceleration with high accuracy even at low amplitudes and contain highly sensitive structures inside the sensor element. The MEMS sensor can tolerate mechanical shocks up to several thousand g's. However, these limits might be exceeded in conditions with extreme shock loads such as e.g. hammer blow on or next to the sensor, dropping of the sensor onto hard surfaces etc.
We recommend avoiding g-forces beyond the specified limits during transport, handling and mounting of the sensors in a defined and qualified installation process.

This device has built-in protections against high electrostatic discharges or electric fields (e.g. 2kV HBM); however, anti-static precautions should be taken as for any other CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the supply voltage range. Unused inputs must always be tied to a defined logic voltage level.

For more details on recommended handling, soldering and mounting please contact Hillcrest Labs and ask for the “Handling, soldering and mounting instructions” document [2]

Environmental Safety

The BNO08X sensor meets the requirements of the EC restriction of hazardous substances (RoHS and RoHS2) directive, see also:

- Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Halogen content

The BNO08X is halogen-free. For more details on the analysis results please contact Hillcrest Labs.

FSM30X Schematic

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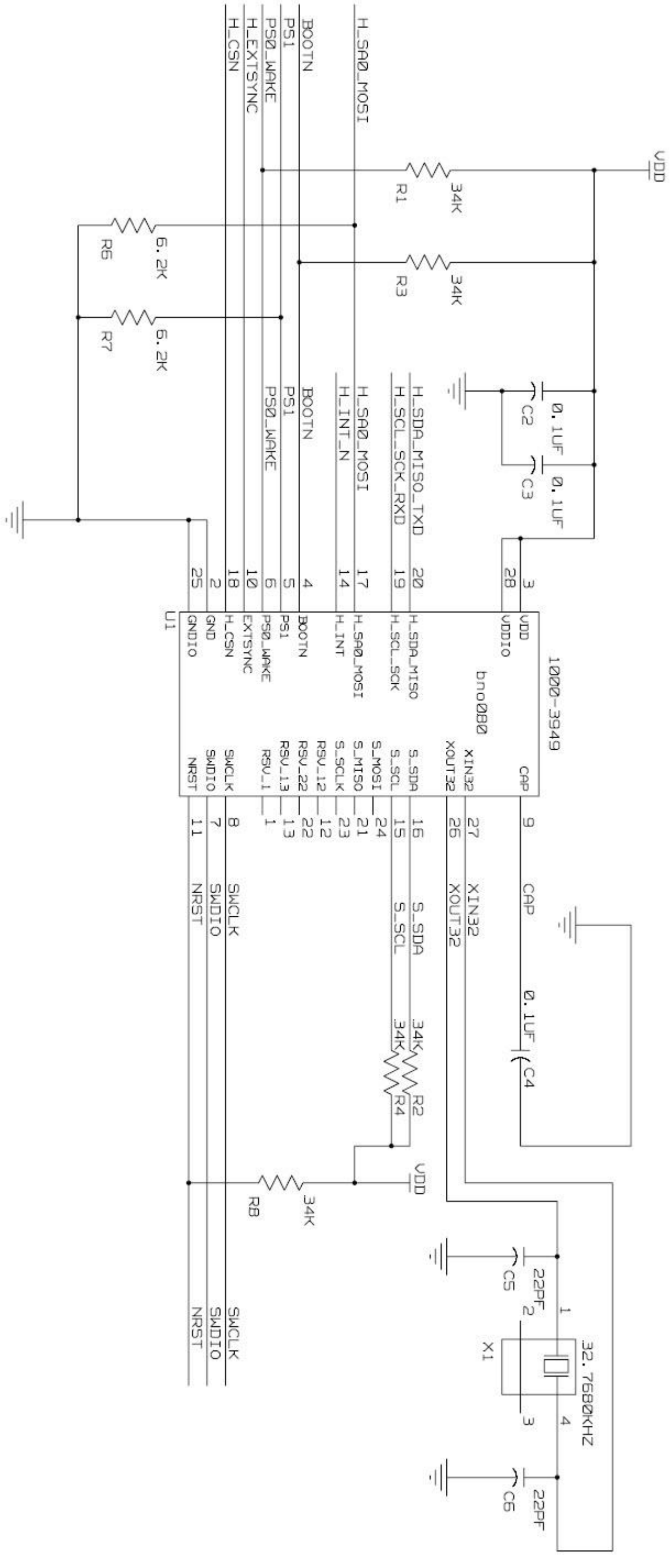

Figure 19: FSM30X Schematic

Bill of Materials

Qty	Title	Detail	Ref	Mfr	Mfr P/N
1	Crystal, 12.5pF, SMT	32.7680KHz::1uW:20ppm	X1	Citizen	CM200S32.768KDZFTR
1	Resistor	0'::1/16W:5%	R5	Yageo Corp	RC0402JR-070RL
3	Ceramic Capacitor	0.1uF:10V::10%	C2-C4	Taiyo Yuden Co.	LMK105BJ104KV-F
2	Ceramic Capacitor	22pF:50V::5%	C5,C6	Yageo Corp	CC0402JRNPO9BN220
1	Ceramic Capacitor	10uF:6.3V::20%	C1	TDK	C1608X5R0J106M
1	Tri Axis Gyro, Tri Axis Acc, Tri Axis Mag, BNO08X	:2.4-3.6V::	U1	Hillcrest Labs	BNO08X
5	Resistor	34K::1/16W:1%	R1-R4,R8	Yageo Corp	RC0402FR-0734KL
2	Resistor	6.2K::1/16W:1%	R6,R7	Yageo Corp	RC0402FR-076K2L

Version History

Version	Changes	Date
1.6	Removed reference to BNO080	May 19, 2023
1.5	Added max height/pin 1 location (Figure 14) Replaced outline w/ SVG (Figure 15) Added footprint (Figure 16)	October 7, 2022
1.4	Update References section	June 10, 2021
1.3	Update accelerometer range for FSP305	July 7, 2017
1.2	Add recommended solder profile (figure 17)	June 26, 2017
1.1	Add UART-RVC and stability classifier power consumption. Replaced picture in Figure 17. Update performance tables. Updated pull down resistor values.	June 23, 2017
1.0	Initial release	May 19, 2017

References

The reference(s) listed with external links are up to date at time of the latest revision, but are subject to change without notice. Please contact us if you need assistance (both in finding a document and general inquiries).

1. BMF055 datasheet, Bosch Sensortec. (https://www.bosch-sensortec.com/media/boschsensortec/downloads/datasheets/bst-bmf055-ds000.pdf)
2. BNO055 handling, soldering & mounting instructions. (https://www.bosch-sensortec.com/media/boschsensortec/downloads/handling_soldering_mounting_instructions/bst-bno055-hs000.pdf)
3. 1000-3927 – BNO08X Datasheet, Hillcrest Labs.

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