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Data Sheet

SCC2230-D08
Combined gyroscope and 3-axis accelerometer with digital SPI interface

Features

- ±125°/s Z-axis angular rate measurement range
- ±6g 3-axis acceleration measurement (XYZ) range
- −40°C…+125°C operating range
- 3.0V…3.6V supply voltage
- SPI digital interface
- Extensive self diagnostics features
- Size 15.0 x 8.5 x 4.3 mm (l × w × h)
- RoHS compliant robust SOIC plastic package suitable for lead free soldering process and SMD mounting
- Proven capacitive 3D-MEMS technology

Applications

SCC2230-D08 is targeted at applications demanding high stability with tough environmental requirements. Typical applications include:

- Inertial Measurement Units (IMUs) for highly demanding environments
- Platform stabilization and control
- Motion analysis and control
- Roll over detection
- Robotic control systems
- Machine control systems
- Navigation systems

Overview

The SCC2230-D08 is a combined high performance angular rate and accelerometer sensor component. It consists of Z-axis angular rate sensor and three axis accelerometer sensor based on Murata's proven capacitive 3D-MEMS technology. Signal processing is done in one mixed signal ASIC that provides angular rate and acceleration output via flexible SPI digital interface. Sensor elements and ASIC are packaged to 24 pin premolded plastic housing that guarantees reliable operation over product's lifetime.

The SCC2230-D08 is designed, manufactured and tested for high stability, reliability and quality requirements. The component has extremely stable output over wide range of temperature, humidity and vibration. The component has several advanced self diagnostics features, is suitable for SMD mounting and is compatible with RoHS and ELV directives.

TABLE OF CONTENTS

1 Introduction

This document contains essential technical information about the SCC2230-D08 sensor including specifications, SPI interface descriptions, user accessible register details, electrical properties and application information. This document should be used as a reference when designing in SCC2230-D08 component.

2 Specifications

2.1 General Specifications

General specifications for SCC2230-D08 component are presented in Table 1. All analog voltages are related to the potential at AVSS and all digital voltages are related to the potential at DVSS.

Table 1. General specifications.

Parameter	Condition	Min	Typ	Max	Units
Analog supply voltage: AVDD		3.0	3.3	3.6	V
Analog supply current: I_AVDD	Temperature range -40 ... +125 °C		15.2		mA
Digital supply voltage: DVDD		3.0	3.3	3.6	V
Digital supply current: I_DVDD	Temperature range -40 ... +125 °C		3.3		mA
Boost supply current: I_L1 (current through inductor L1, see Figure 27)	Mean value Peak value, T < 1µs Max. value during startup (T≤0.4ms)		4.0	11.5 110 60	mA mA mA
Total current, I_TOTAL	I_AVDD + I_DVDD + I_L1		22.5	31.5	mA
Total current reset	Total average current during reset			5	mA
Rise/fall time: AVDD, DVDD, Vin_BOOST (see Figure 27)				200	ms

2.2 Performance Specifications for Gyroscope

Table 2. Gyro performance specifications (DVDD=AVDD=3.3V, ambient temperature and ODR=2.3kHz unless otherwise specified).

Parameter	Condition	Min	Typ	Max	Units
Operating range	Measurement axis Z	-125		125	°/s
Offset (zero rate output)			0		LSB
Offset error (A		-1		1	°/s
Offset temperature drift (B	-40°C ... +125°C	-0.8		0.8	°/s
Offset short term bias stability			2		°/h
Angular random walk			0.40		$º/\sqrt{h}$
Sensitivity			50		LSB/(°/s)
Sensitivity error (C	-40°C ... +125°C	-2.5		2.5	%
Linearity error (D			±0.5		°/s
Integrated noise (RMS)	60Hz filter		0.08		$°/s_{RMS}$
Noise density			0.008		$(º/s)/\sqrt{Hz}$
Cross axis sensitivity (E	per axis	-1.5		1.5	%
G-sensitivity		-0.1		0.1	(°/s)/g
Shock sensitivity	50g, 6ms			2.0	°/s
Shock recovery				50	ms
Amplitude response	10Hz filter, -3dB frequency 60Hz filter, -3dB frequency		10 60		Hz Hz
Power on start-up time	10Hz filter 60Hz filter			750 620	ms ms
Recommended ODR (F			2300		Hz

Min/Max values are validation ±3 sigma variation limits from test population. Typical values are not guaranteed.

A) Includes offset calibration error and drift over lifetime.

B) Deviation from value at ambient temperature.

C) Includes calibration error, deviation from room temperature value and drift over lifetime.

D) Straight line through specified measurement range end points.

E) Cross axis sensitivity is the maximum sensitivity in the plane perpendicular to the measuring direction:

Cross axis for Y axis = Sensitivity Y / Sensitivity Z

Cross axis for X axis = Sensitivity X/ Sensitivity Z

F) ODR = Output Data Rate, see section 5.1.7 for more details.

2.3 Performance Specifications for Accelerometer

Table 3. Accelerometer performance specifications (DVDD=AVDD=3.3V, ambient temperature and ODR=2.3kHz unless otherwise specified).

Parameter	Condition	Min	Typ	Max	Unit
Measurement range	Measurement axes XYZ	-6		6	g
Offset (zero acceleration output)			0		LSB
Offset error (A		-20		20	mg
Offset temperature drift (B	-40°C ... +125°C	-18		18	mg
Sensitivity	Between ±3°		1962 0.029		LSB/g °/LSB
Sensitivity error (A		-1		1	%
Sensitivity temperature drift (B	-40°C ... +125°C	-1		1	%
Linearity error (C	-1g ... +1g range -6g ... +6g range		±5 ±50		mg mg
Integrated noise (RMS)	60Hz filter		2.7		mg_{RMS}
Noise density			270		$\mu g/\sqrt{Hz}$
Cross axis sensitivity (D		-0.5		0.5	%
Amplitude response	10Hz filter, -3dB frequency 60Hz filter, -3dB frequency		10 60		Hz Hz
Power on start-up time	10Hz filter 60Hz filter			450 320	ms ms
Recommended ODR (E			2300		Hz

Min/Max values are validation ±3 sigma variation limits from test population. Typical values are not guaranteed.

A) Includes calibration error and drift over lifetime.

B) Deviation from value at ambient temperature.

C) Straight line through specified measurement range end points.

D) Cross axis sensitivity is the maximum sensitivity in the plane perpendicular to the measuring direction. X-axis output cross axis sensitivity (cross axis for Y and Z-axis outputs are defined correspondingly):

Cross axis for Y axis = Sensitivity Y / Sensitivity X

Cross axis for Z axis = Sensitivity Z / Sensitivity X

E) ODR = Output Data Rate, see section 5.1.7 for more details.

2.4 Performance Specification for Temperature Sensor

Table 4. Temperature sensor performance specifications.

Parameter	Condition	Min.	Typ	Max.	Unit
Temperature signal range		-50		+150	°C
Temperature signal sensitivity	Temperature sensor output in 2's complement format		14.7		LSB/°C

Temperature is converted to °C with following equation:

$$\text{Temperature [°C]} = 60 + (\text{TEMP} / 14.7),$$

where TEMP is temperature sensor output register content in decimal format.

2.5 Absolute Maximum Ratings

Within the maximum ratings (Table 5), no damage to the component shall occur. Parametric values may deviate from specification, yet no functional deviation shall occur. All analog voltages are related to the potential at AVSS, all digital voltages are related to DVSS.

Table 5. Absolute maximum ratings.

Parameter	Remark	Min.	Typ	Max.	Unit
AVDD	Supply voltage analog circuitry	-0.3		4.3	V
DVDD	Supply voltage digital circuitry	-0.3		4.3	V
DIN/DOUT	Maximum voltage at digital input and output pins	-0.3		DVDD+0.3	V
VBoost, LBoost	Maximum voltage at high voltage input and output pins	-0.3		40	V
Topr	Operating temperature range	-40		125	°C
Tstg	Storage temperature range	-40		150	°C
ESD_HBM	ESD according Human Body Model (HBM), Q100-002	±2000			V
ESD_MM	ESD according Machine Model (MM), Q100-003	±200			V
ESD_CDM	ESD according Charged Device Model (CDM), Q100-011	±500 ±750 (corner pins)			V
US	Ultrasonic agitation (cleaning, welding, etc)	Prohibited			

2.6 Pin Description

The pinout for SCC2230-D08 is presented in Figure 1, while the pin descriptions can be found in Table 6.

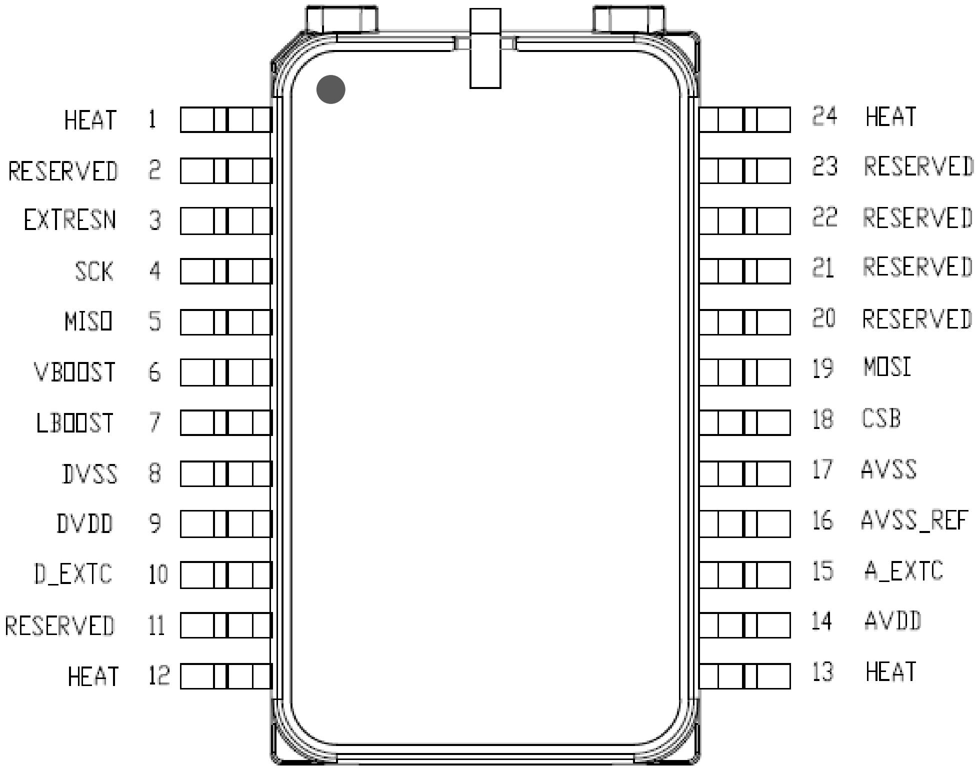


Figure 1. Pinout for SCC2230-D08.

Table 6. SCC2230-D08 pin descriptions.

Pin#	Name	Type	Description
1, 12, 13, 24	HEAT	-	Heat sink connection, connect externally to AVSS
2, 11	RESERVED	-	Factory use only, leave floating
3	EXTRESN	DIN	External Reset, 3.3V logic compatible Schmitt-trigger input with internal pull-up, LOW-HIGH transition causes system restart. Minimum low time 100us
4	SCK	DIN	CLK signal of SPI Interface
5	MISO	DOUT	Data Out of SPI Interface
6	VBOOST	AOUT_HV	External capacitor connection for high voltage analog supply, high voltage pad ≈20V
7	LBOOST	AIN_HV	Connection for inductor for high voltage generation, high voltage pad ≈20V
8	DVSS	GND	Digital Supply Return, connect externally to AVSS
9	DVDD	SUPPLY	Digital Supply Voltage
10	D_EXTC	AOUT	External capacitor connection for digital core (typ. 1.8V)
11	RESERVED	-	Factory use only, leave floating
14	AVDD	SUPPLY	Analog Supply voltage
15	A_EXTC	AOUT	External capacitor connection for positive reference voltage
16	AVSS_REF	GND	Analog reference ground, connect externally to AVSS
17	AVSS	GND	Analog Supply Return, connect externally to DVSS
18	CSB	DIN	Chip Select of SPI Interface, 3.3V logic compatible Schmitt-trigger input
19	MOSI	DIN	Data In of SPI Interface, 3.3V logic compatible Schmitt-trigger input
20	RESERVED	-	Factory use only, leave floating or connect to GND
21	RESERVED	-	Factory use only, leave floating or connect to GND
22	RESERVED	-	Factory use only, leave floating
23	RESERVED	-	Factory use only, leave floating

2.7 Typical performance characteristics

2.7.1 Gyro typical performance characteristics

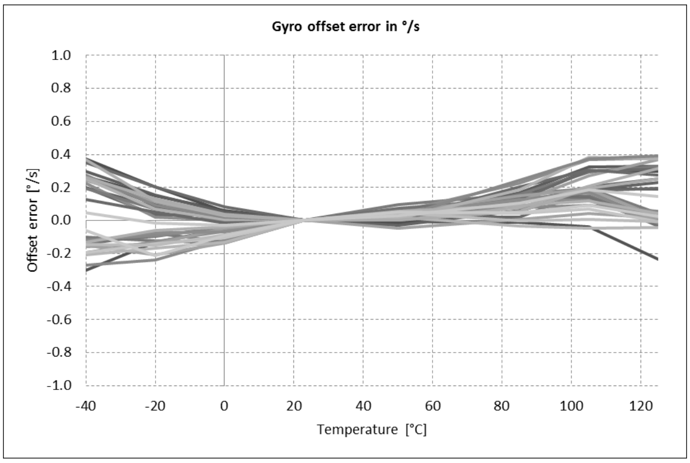


Figure 2. SCC2230-D08 gyro typical output temperature drift.

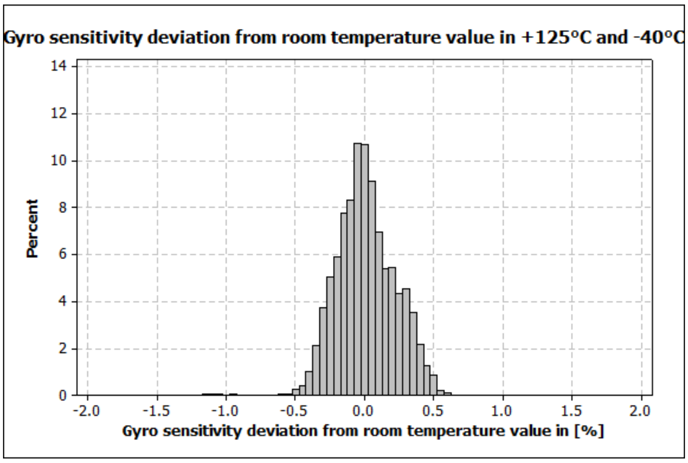


Figure 3. SCC2230-D08 gyro typical sensitivity deviation from room temperature value in %.

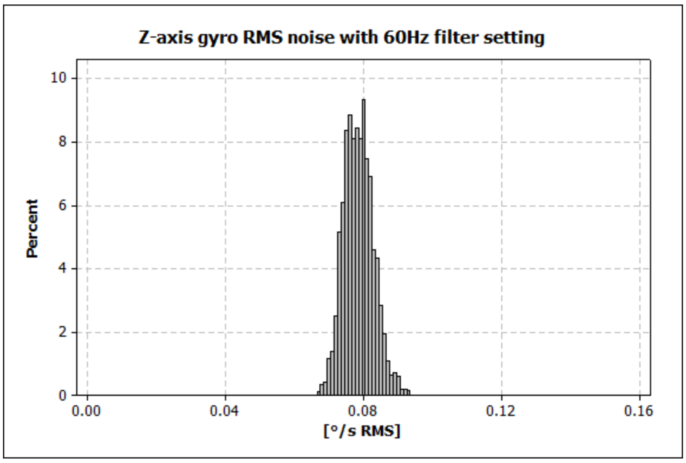


Figure 4. SCC2230-D08 gyro typical RMS noise in $°/s_{RMS}$.

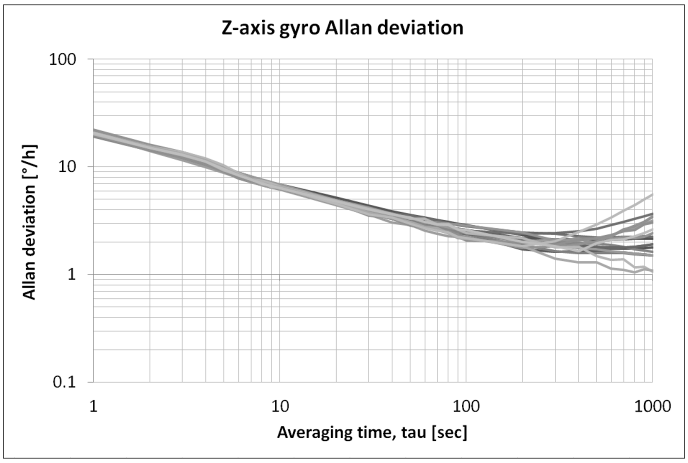


Figure 5. SCC2230-D08 gyro typical Allan deviation °/h.

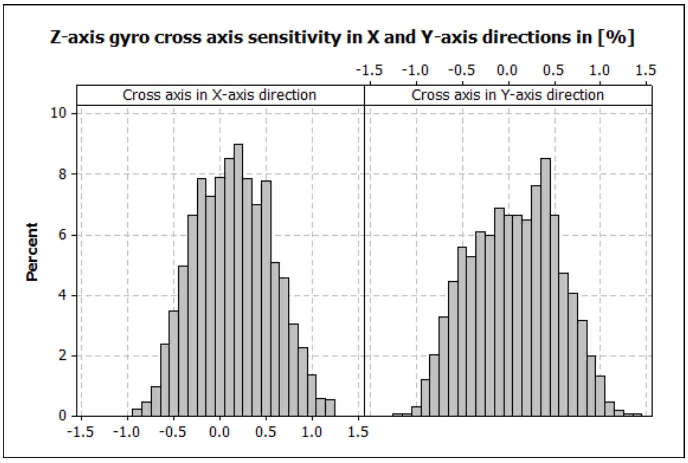


Figure 6. SCC2230-D08 gyro typical cross axis sensitivity in %.

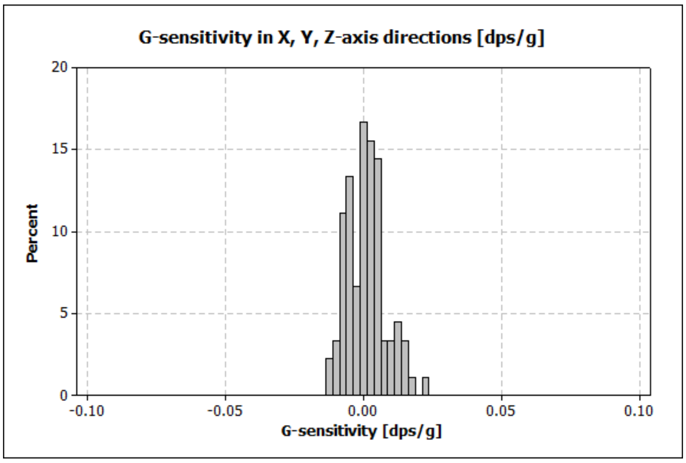
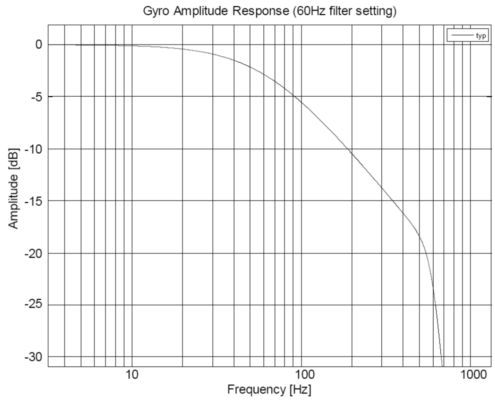


Figure 7. SCC2230-D08 gyro typical G-sensitivity in (°/s)/g.



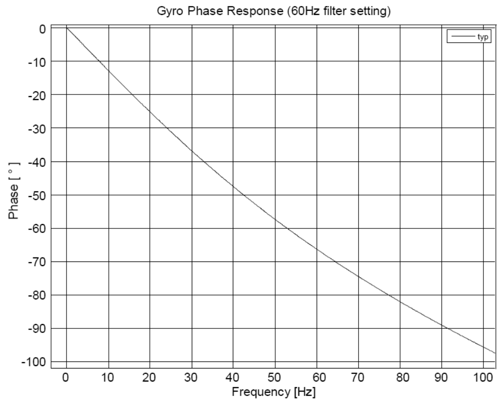
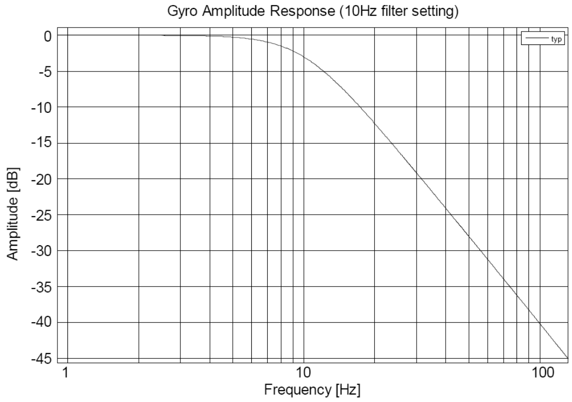


Figure 8. SCC2230-D08 gyro amplitude and phase response with 60Hz filter setting.



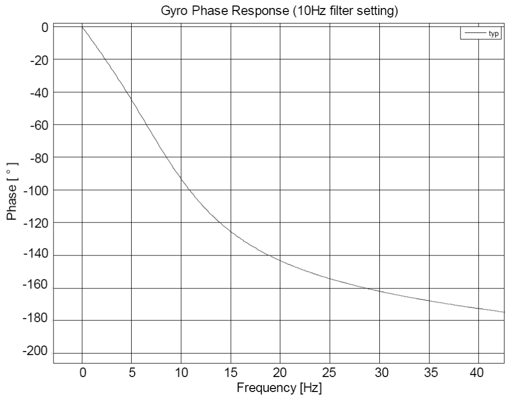


Figure 9. SCC2230-D08 gyro amplitude and phase response with 10Hz filter setting.

2.7.2 Accelerometer typical performance characteristics

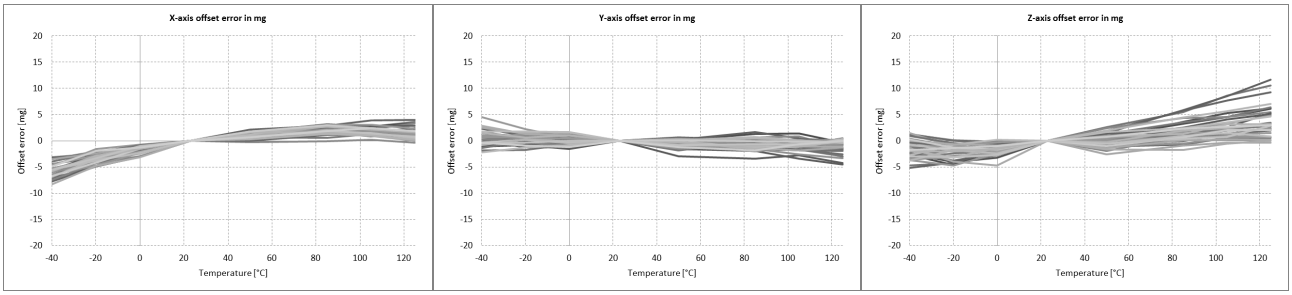


Figure 10. SCC2230-D08 accelerometer typical offset temperature drift mg (X-axis in +1g orientation).

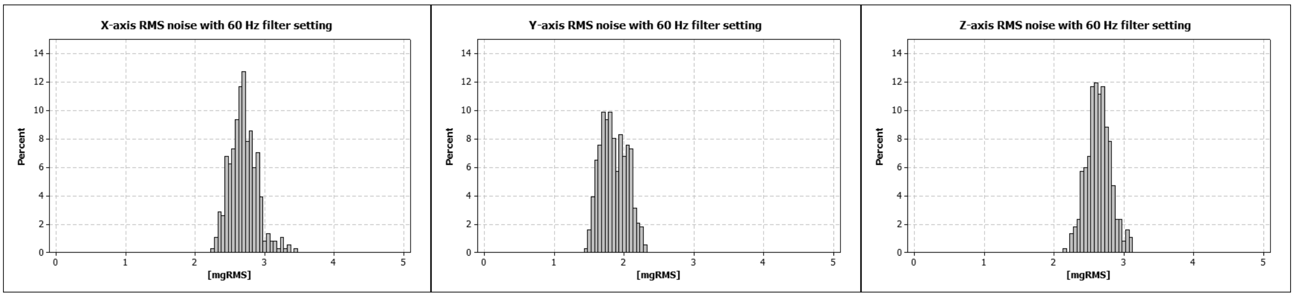


Figure 11. SCC2230-D08 accelerometer typical RMS noise in mg_{RMS}.

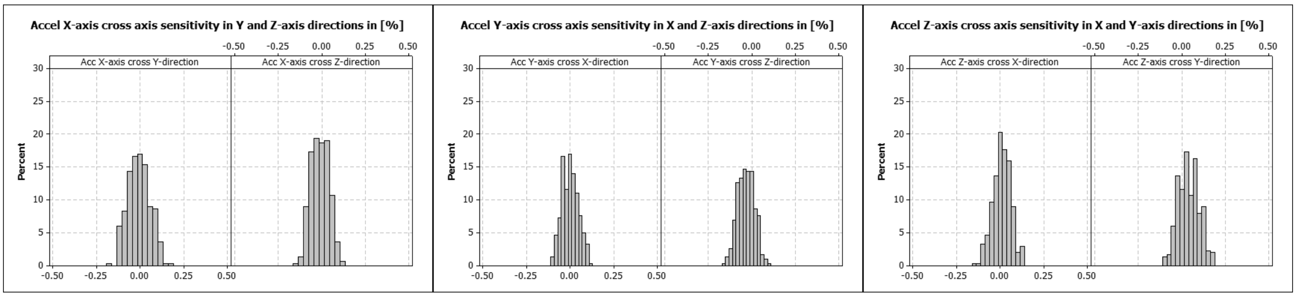


Figure 12. SCC2230-D08 accelerometer typical cross axis sensitivity in %.

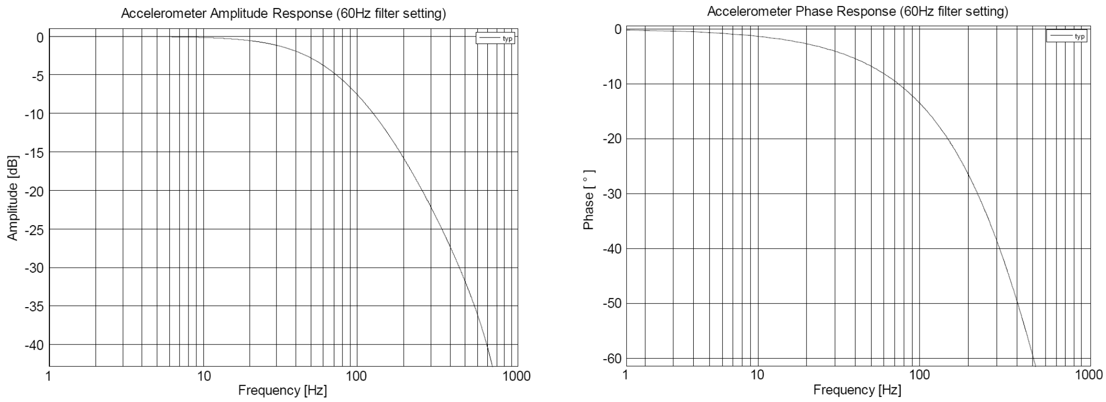


Figure 13. SCC2230-D08 accelerometer amplitude and phase response with 60Hz filter setting.

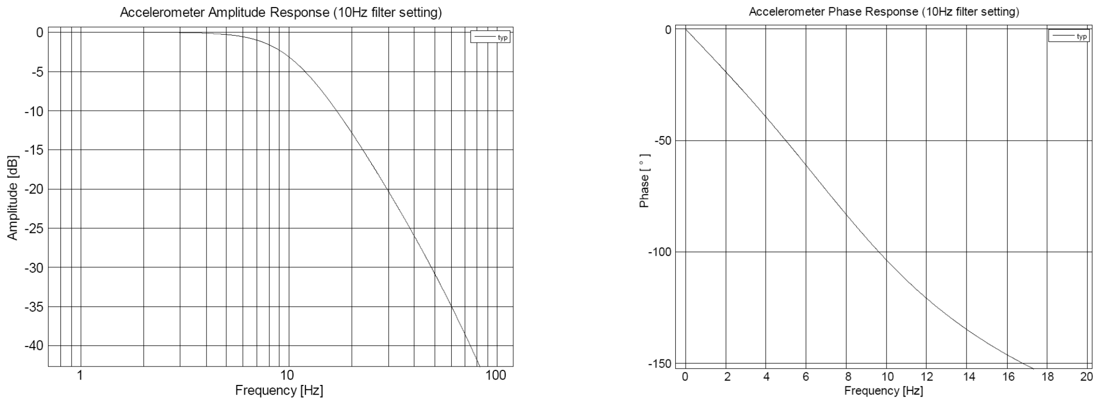


Figure 14. SCC2230-D08 accelerometer amplitude and phase response with 10Hz filter setting.

2.8 Digital I/O Specification

Table 7 describes the DC characteristics of SCC2230-D08 sensor SPI I/O pins. Supply voltage is 3.3 V unless otherwise specified. Current flowing into the circuit has a positive value.

Table 7. SPI DC characteristics.

Symbol	Description	Min.	Nom.	Max.	Unit
Serial Clock SCLK					
VinHigh	Input high voltage	2		DVDD+0.3	V
VinLow	Input low voltage	-0.3		0.8	V
Vhy	Input hysteresis	0.3			V
Ileak	Input leakage current, 0V ≤ Vin ≤ DVDD	-1		1	uA
Cin	Input capacitance			15	pF
Chip select CSB (Pull Up), low active					
VinHigh	Input high voltage	2		DVDD+0.3	V
VinLow	Input low voltage	-0.3		0.8	V
Vhy	Input hysteresis	0.3			V
Isource	Input current source (Pull Up), Vin = 0V	10		50	uA
Cin	Input capacitance			15	pF
Vin_open	Open circuit output voltage	2			V
Serial data input MOSI (Pull Down)					
VinHigh	Input high voltage	2		DVDD+0.3	V
VinLow	Input low voltage	-0.3		0.8	V
Vhy	Input hysteresis	0.3			V
Isource	Input current source (Pull Up), Vin = DVDD	10		50	uA
Cin	Input capacitance			15	pF
Vin_open	Open circuit output voltage			0.3	V
Serial data output MISO (Tri state)					
VoutHigh_-1mA	Output high voltage, Iout = -1mA	DVDD-0.5			V
VoutHigh_-50µA	Output high voltage, Iout = -50µA	DVDD-0.2			V
VinHigh_1mA	Output low voltage, Iout = +1mA			0.5	V
VinHigh_50µA	Output low voltage, Iout = +50µA			0.3	V
Iout_Hz	High impedance output current, 0V < VMISO < DVDD	-1		1	uA
Cld_miso	Capacitive load. The slope of the MISO output signal may need to be controlled to meet EMI requirements under specified load conditions.			200	pF

2.9 SPI AC Characteristics

The AC characteristics of SCC2230-D08 are defined in Figure 15 and Table 8.

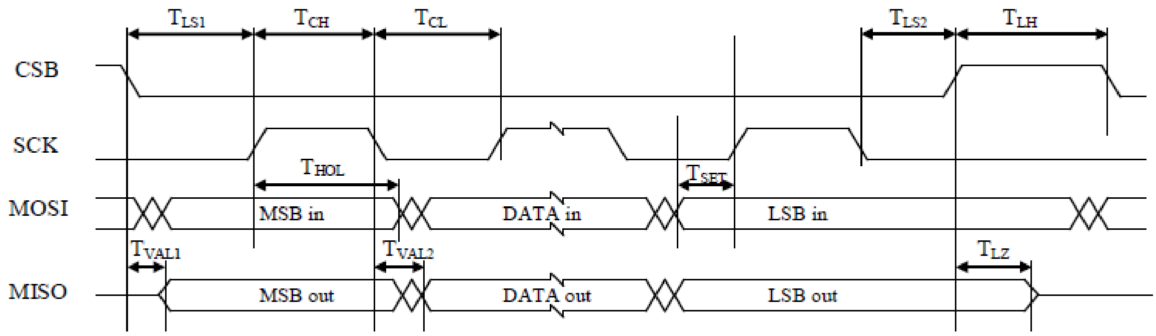


Figure 15. Timing diagram of SPI communication.

Table 8. SPI AC electrical characteristics.

Symbol	Description	Min.	Nom.	Max.	Unit
F_{SPI}	It is recommended to use maximum SCK frequency, see section 5.1.7 for more details.	0.1		8	MHz
T_{SPI}			$1/F_{SPI}$		
T_{CH}	High time: duration of logical high level at SCLK	45	$T_{SPI}/2$		ns
T_{CL}	Low time: duration of logical low level at SCLK	45	$T_{SPI}/2$		ns
T_{LS1}	Setup time CSB: time between the falling edge of CSB and the rising edge of SCLK	45	$T_{SPI}/2$		ns
T_{VAL1}	Delay time: time delay from the falling edge of CSB to data valid at MISO			30	ns
T_{SET}	Setup time at MOSI: setup time of MOSI before the rising edge of SCLK	15			ns
T_{HOL}	MOSI data hold time	8			ns
T_{VAL2}	Delay time: time delay from falling edge of SCLK to data valid at MISO			30	ns
T_{LS2}	Hold time of CSB: time between the falling edge of SCLK and the rising edge of CSB	45	$T_{SPI}/2$		ns
T_{LZ}	Tri-state delay time: time between the rising edge of CSB to MISO in Tri-state			15	ns
T_{LH}	Time between SPI cycles: minimum high time of CSB between two consecutive transfers	250			ns

2.10 Measurement Axis and Directions

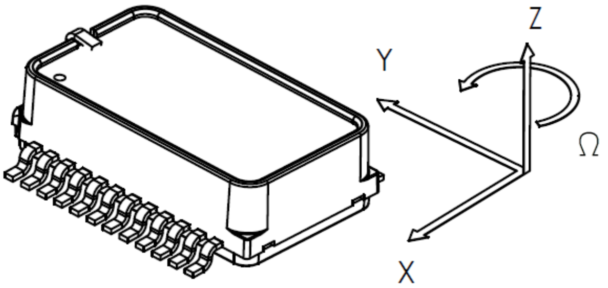
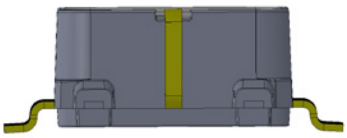
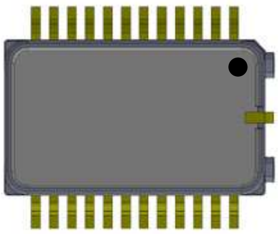
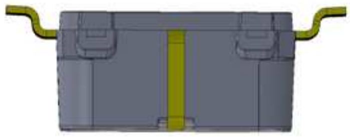
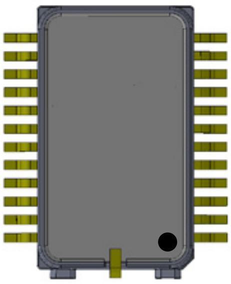
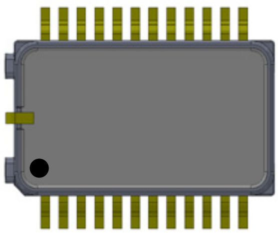
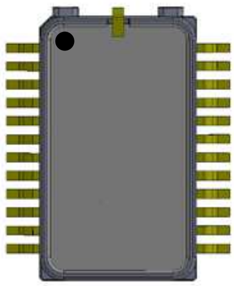


Figure 16. SCC2230-D08 measurement directions.

Table 9. SCC2230-D08 accelerometer measurement directions.

 x: 0g y: 0g z: +1g	 x: +1g y: 0g z: 0g	 x: 0g y: 0g z: -1g
 x: 0g y: -1g z: 0g	 x: -1g y: 0g z: 0g	 x: 0g y: +1g z: 0g

2.11 Package Characteristics

2.11.1 Package Outline Drawing

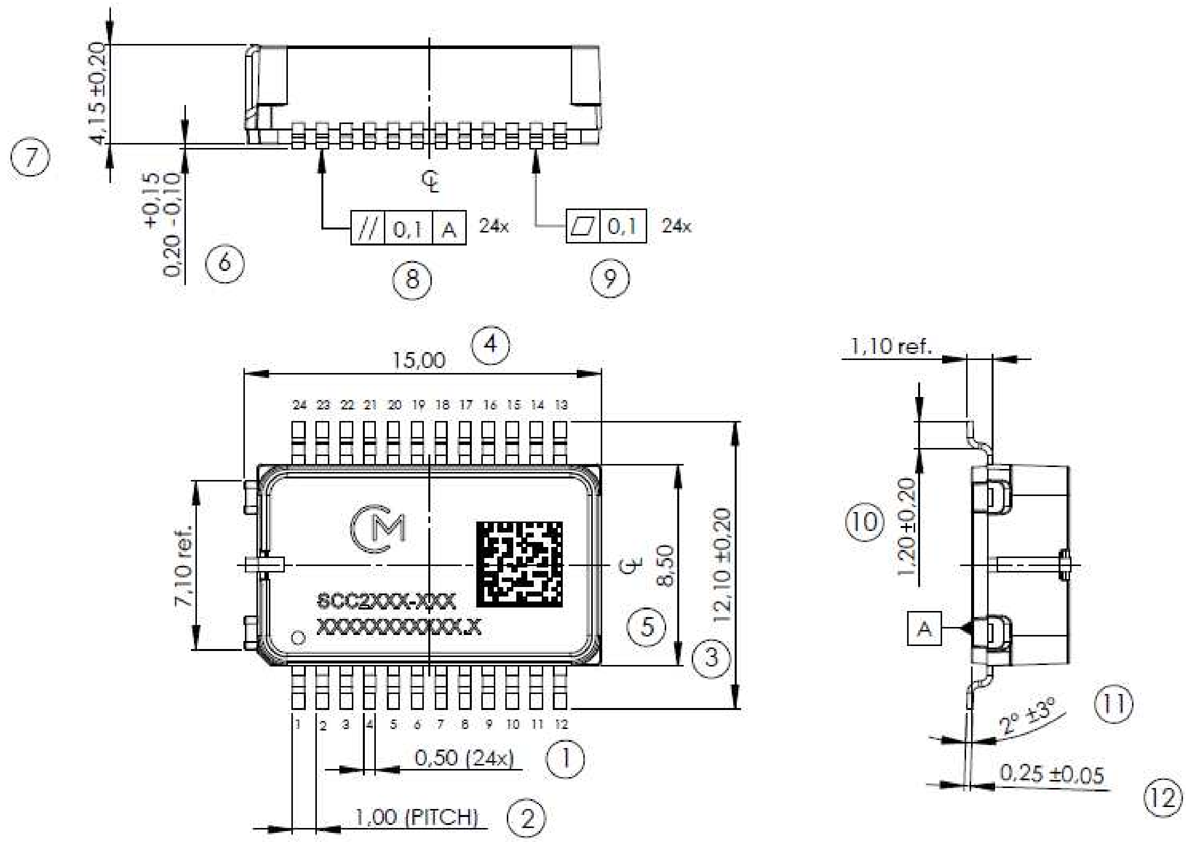


Figure 17. Package outline. The tolerances are according to ISO2768-f (see Table 10).

Table 10. Limits for linear measures (ISO2768-f).

Tolerance class	Limits in mm for nominal size in mm			
	0.5 to 3	Above 3 to 6	Above 6 to 30	Above 30 to 120
f (fine)	±0.05	±0.05	±0.1	±0.15

2.12 PCB Footprint

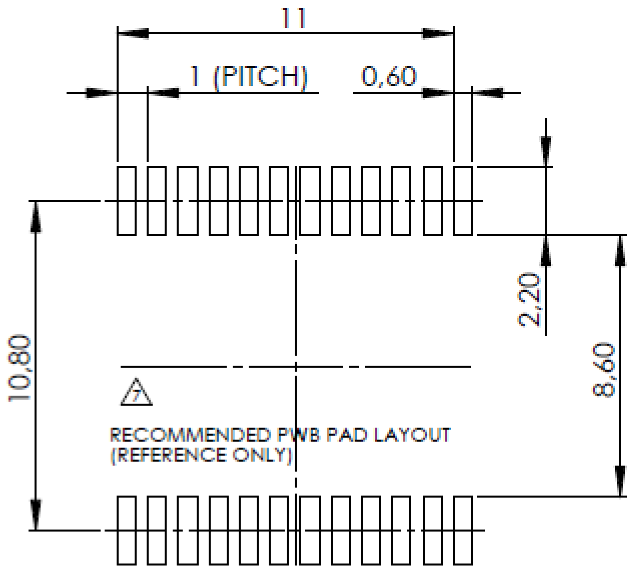


Figure 18. Recommended PWB pad layout for SCC2230-D08. The tolerances are according to ISO2768-f (see Table 10).

2.13 Abbreviations

ASIC	Application Specific Integrated Circuit
SPI	Serial Peripheral Interface
RT	Room Temperature
DPS	Degrees per second
FS	Full scale
CSB	Chip Select
SCK	Serial Clock
MOSI	Master Out Slave In
MISO	Master In Slave Out
MCU	Microcontroller

3 General Product Description

The SCC2230-D08 sensor consists of independent acceleration and angular rate sensing elements, and single Application-Specific Integrated Circuit (ASIC) used to sense and control those elements. Figure 19 contains an upper level block diagram of the component. The ASIC provides one common SPI interface used to control and read the accelerometer and the gyroscope.

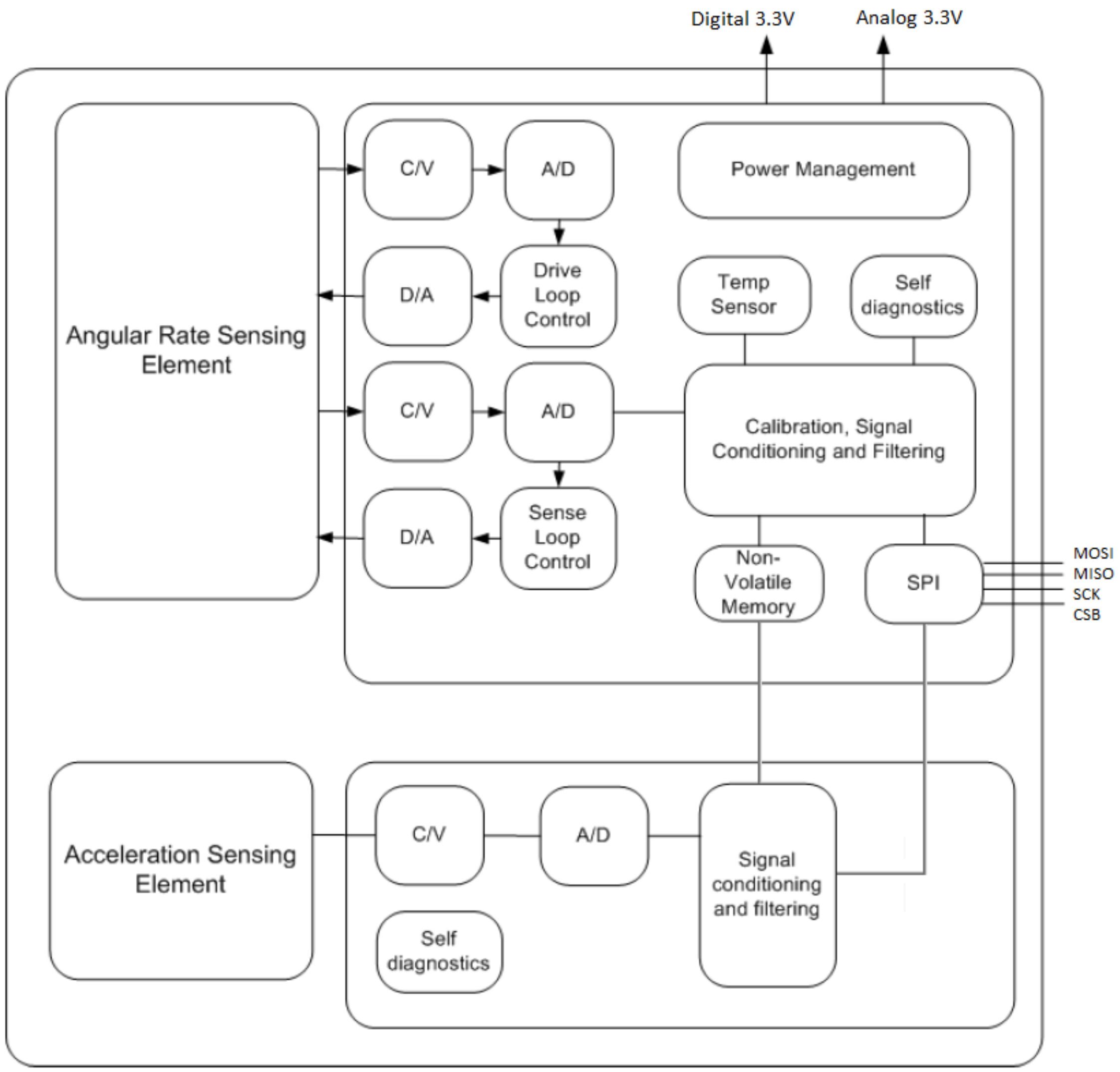


Figure 19. SCC2230-D08 component block diagram.

The angular rate and acceleration sensing elements are manufactured using Murata proprietary High Aspect Ratio (HAR) 3D-MEMS process, which enables making robust, extremely stable and low noise capacitive sensors.

The acceleration sensing element consists of four acceleration sensitive masses. Acceleration causes capacitance change that is converted into a voltage change in the signal conditioning ASIC.

The angular rate sensing element consists of moving masses that are purposely exited to in-plane drive motion. Rotation in sensitive direction causes in-plane movement that can be measured as capacitance change with the signal conditioning ASIC.

3.1 Factory Calibration

SCC2230-D08 sensors are factory calibrated. No separate calibration is required in the application. Parameters that are trimmed during production include sensitivities, offsets and frequency responses. Calibration parameters are stored to non-volatile memory during manufacturing. The parameters are read automatically from the internal non-volatile memory during the start-up.

It should be noted that assembly can cause minor offset/bias errors to the sensor output. If best possible offset/bias accuracy is required, system level offset/bias calibration (zeroing) after assembly is recommended.

4 Component Operation, Reset and Power Up

4.1 Component Operation

Simplified sensor power up sequence is shown in Figure 20 below. The SCC2230-D08 component has internal power-on reset circuit. It releases the internal reset-signal once the power supplies are within the specified range. After the reset, the sensor performs an internal startup sequence. During the startup sequence SCC2230-D08 reads configuration and calibration data from the non-volatile memory to volatile registers. 620ms after the power on or reset, sensor shall be able to provide valid acceleration and angular rate data, separate measurement mode activation is not needed.

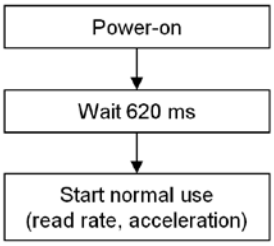


Figure 20. Simplified reset and power up sequence.

Sensor uses 60Hz low pass filter setting by default. In case the optional 10Hz low pass filter is used the filter setting can be set by writing the FLT bits to 01b in Status Summary register. See section 6.2.8 for more information on Status Summary register. Section 5.1.4 shows full SPI write frames for filter settings

SCC2230-D08 component has extensive internal failsafe diagnostics to detect over range and possible internal failures. If the internal failsafe diagnostics are used they should be enabled by clearing the status registers during component power up by following the sequence shown in section 4.2 (Figure 21).

4.2 Reset and Power Up Sequence For Enabling Internal Failsafe Diagnostics

Reset and power up sequence for enabling component internal failsafe diagnostics is shown below in Figure 21. After the reset, the sensor performs an internal startup sequence. 20ms after the reset the SPI bus becomes accessible and the output filter can be set to a desired value. If the filter is not set to a valid value (60Hz or 10Hz setting), the default setting (00b = 60Hz) is used and the S_OK_C flag in Status Summary Register will indicate a failure. In 750ms (10Hz filter setting) or in 620ms (60Hz filter selection) the accelerometer and the gyro shall be able to deliver valid data.

During the startup sequence the sensor performs a series of internal tests that will set various error flags in the sensor status registers and to clear them it is necessary to read all status registers after the startup sequence is complete.

Once startup sequence is completed, the SPI frame Return Status bits (RS bits) indicate sensor operation status. Normal operation is indicated with RS bit content of 01b. In case of failure Common Status register is read, then sensor should be reset and re-started.

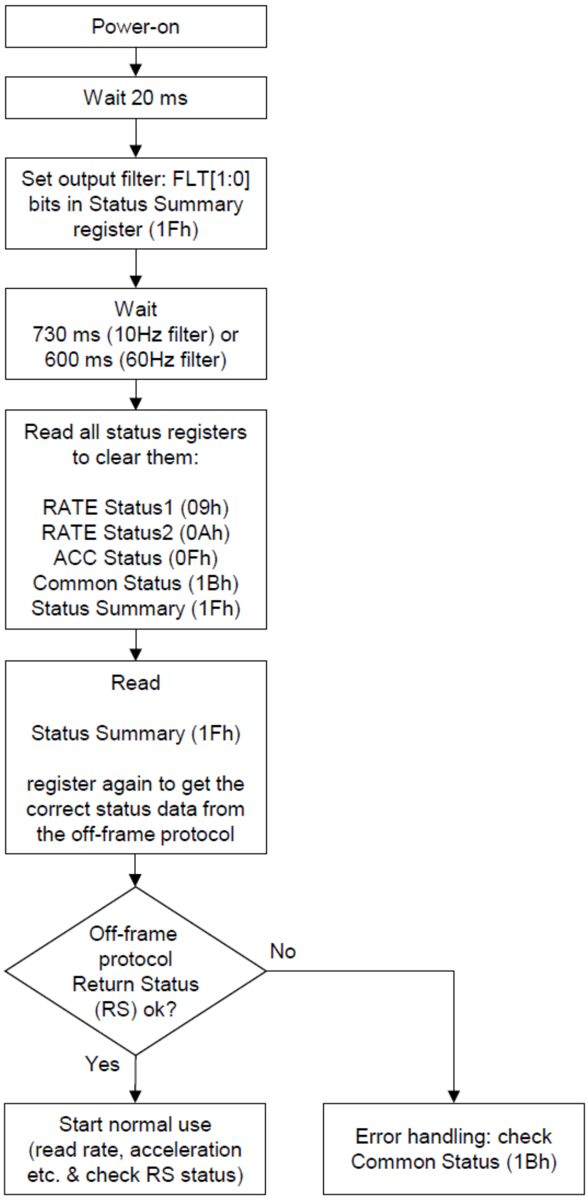


Figure 21. Reset and power up sequence for enabling internal failsafe diagnostics.

5 Component Interfacing

5.1 SPI Interface

5.1.1 General

The SCC2230-D08 has one common SPI interface for the accelerometer and the angular rate sensor. SPI communication transfers data between the SPI master and registers of the SCC2230-D08 ASIC. The SCC2230-D08 always operates as a slave device in master-slave operation mode. 3-wire SPI connection cannot be used.

SPI interface pins:

CSB	Chip Select (active low)	MCUP → ASIC
SCK	Serial Clock	MCU → ASIC
MOSI	Master Out Slave In	MCU → ASIC
MISO	Master In Slave Out	ASIC → MCU

5.1.2 Protocol

SPI communication uses off-frame protocol so each transfer has two phases.

The first phase contains the SPI command (Request) and the data (Response) of the previous command. The second phase contains the next Request and the Response to the Request of the first phase, see Figure 22.

Data word length is 32 bits, the data is transferred MSB first. The first response after reset is undefined and shall be discarded.

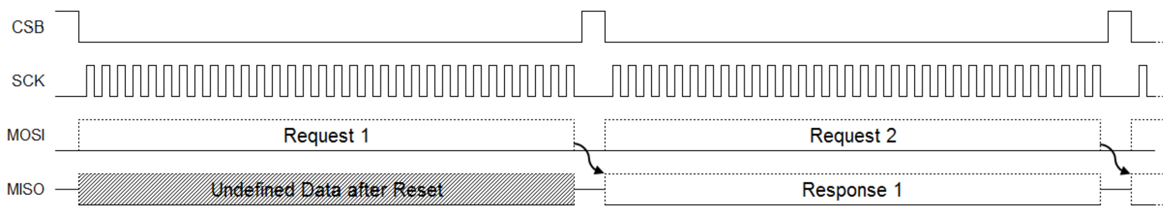


Figure 22. SPI protocol example.

The interleaved Request - Response cycle then continues as shown in Figure 23.

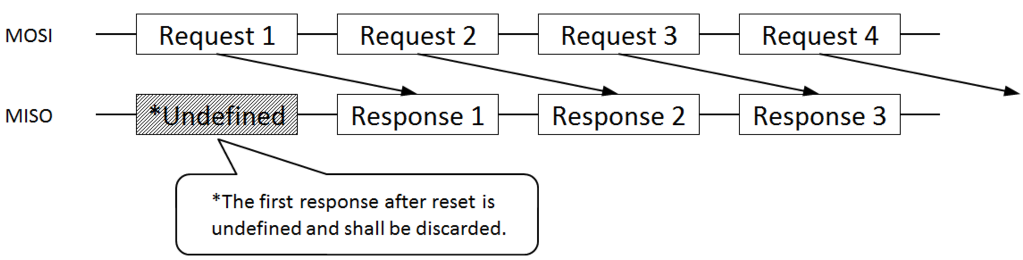


Figure 23. Request – Response frame relationship.

The SPI transmission is always started with the CSB falling edge and terminated with the CSB rising edge. The data is captured on the SCK's rising edge (MOSI line) and it is propagated on the SCK's falling edge (MISO line). This equals to SPI Mode 0 (CPOL = 0 and CPHA = 0), see Figure 24.

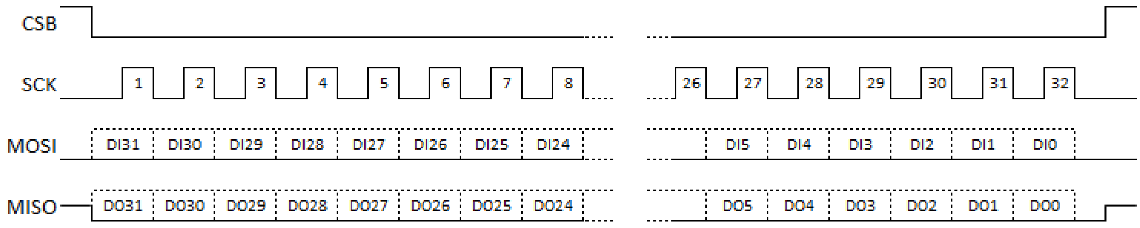


Figure 24. SPI Frame Format.

5.1.3 General Instruction format

The SPI frame is divided into four parts (See Figure 25 and Table 11):

1. Operation Code (OP)
2. Return status (RS, in MISO)
3. Data (DI, DO)
4. Checksum (CRC)

Unused bits shall be set to 0, this is important for the checksum calculation.

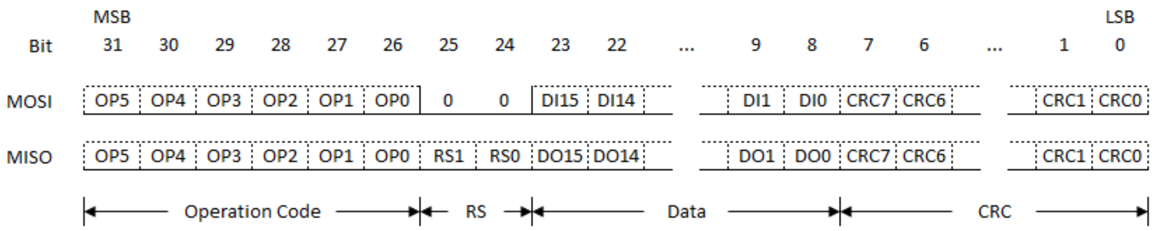


Figure 25. SPI instruction format.

Table 11. SPI bit definitions.

Bits	Name	MOSI	MISO
OP[5:0]	Operation code	Requested operation: • OP5: Write =1 / Read = 0 • OP[4:0] = Register address	Performed operation: • OP5: Write = 1 / Read = 0 • OP[4:0] = Register address
RS[1:0]	Return status	n.a.	Sensor status
D[15:0]	Data	Data to be written	Return data
CR[7:0]	Checksum	Checksum of MOSI bits [31:8]	Checksum of MISO bits [31:8]