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Data Sheet



SCC2230-E02 Combined gyroscope and 3-axis accelerometer with digital SPI interface

Features

- ±125°/s Z-axis angular rate measurement range
- ±2g 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-E02 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-E02 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-E02 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.



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1 Introduction

This document contains essential technical information about the SCC2230-E02 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-E02 component.

2 Specifications

2.1 General Specifications

General specifications for SCC2230-E02 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	Тур	Max	Units
Analog supply voltage: AVDD		3.0	3.3	3.6	V
Analog supplycurrent: 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
Boostsupplycurrent: I_L1	Mean value		4.0	11.5	mA
(current through inductor L1, see	Peak value, T < 1µs			110	mA
Figure 27)	Max. value during startup (T≤0.4ms)			60	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	Тур	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		⁰∕√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)∕√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

 $\label{eq:min} {\sf Min}/{\sf Max} \ v \ alues \ are \ v \ alidation \ \pm 3 \ sigma \ v \ ariation \ limits \ from \ test \ population. \ Ty \ pical \ v \ alues \ are \ not \ guaranteed.$

A) Includes off set 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	Тур	Max	Unit
Measurementrange	Measurement axes XYZ	-2		2	g
Offset (zero acceleration output)			0		LSB
Offset error ^{(A}		-16		16	mg
Offset temperature drift ^{(B}	-40°C +125°C	-10		10	mg
Sensitivity	Between ±3°		5886 0.010		LSB/g °/LSB
Sensitivity error ^{(A}		-1		1	%
Sensitivity temperature drift ^{(B}	-40°C +125°C	-1		1	%
Linearity error ^{(C}	-1g +1g range -2g +2g range		±5 ±10		mg mg
Integrated noise (RMS)	60Hz filter		1.2		mg _{RMS}
Noise density			120		µg/√Hz
Cross axis sensitivity ^{(D}	per axis	-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

 $\label{eq:minsteady} \textit{Min/Max} \ \textit{v} \ \textit{alues} \ \textit{are} \ \textit{v} \ \textit{alidation} \ \pm 3 \ \textit{sigma} \ \textit{v} \ \textit{ariation} \ \textit{limits} \ \textit{f} \ \textit{rom} \ \textit{test} \ \textit{population}. \ \textit{Ty pical} \ \textit{v} \ \textit{alues} \ \textit{are} \ \textit{not} \ \textit{guaranteed}.$

A) Includes calibration error and drift over lifetime.

B) Deviation from v alue 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.	Тур	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:

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

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.

Parameter	Remark	Min.	Тур	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 BodyModel (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)		Prohib	ited	

Table 5. Absolute maximum ratings.



2.6 Pin Description

The pinout for SCC2230-E02 is presented in Figure 1, while the pin descriptions can be found in Table 6.



Figure 1. Pinout for SCC2230-E02.



Pin#	Name	Туре	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

Table 6. SCC2230-E02 g	pin	descriptions.
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E



2.7 Typical performance characteristics

2.7.1 Gyro typical performance characteristics



Figure 2. SCC2230-E02 gyro typical offset temperature drift in °/s.



Figure 3. SCC2230-E02 gyro typical sensitivity deviation from room temperature value in %.



Figure 4. SCC2230-E02 gyro typical RMS noise in °/s_{RMS}.





Figure 5. SCC2230-E02 gyro typical Allan deviation in °/h.



Figure 6. SCC2230-E02 gyro typical cross axis sensitivity in %.



Figure 7. SCC2230-E02 gyro typical G-sensitivity in (°/s)/g.





Figure 8. SCC2230-E02 gyro amplitude and phase response with 60Hz filter setting.



Figure 9. SCC2230-E02 gyro amplitude and phase response with 10Hz filter setting.



2.7.2 Accelerometer typical performance characteristics



Figure 10. SCC2230-E02 accelerometer typical offset temperature drift in mg.



Figure 11. SCC2230-E02 accelerometer typical RMS noise in mg_{RMS}.



Figure 12. SCC2230-E02 accelerometer typical cross axis sensitivity in %.





Figure 13. SCC2230-E02 accelerometer amplitude and phase response with 60Hz filter setting.



Figure 14. SCC2230-E02 accelerometer amplitude and phase response with 10Hz filter setting.



2.8 Digital I/O Specification

Table 7 describes the DC characteristics of SCC2230-E02 sensor SPI I/O pins. Supply voltage is 3.3 V unless otherwise specified. Current flowing into the circuit has a positive value.

Symbol	Description	Min.	Nom.	Max.	Unit
Serial Clock SCI	К				
VinHigh	Input high voltage	2		DVDD+0.3	V
VinLow	Input low voltage	-0.3		0.8	V
Vhy	Input hysteresis	0.3			V
lleak	Input leakage current, $0V \le Vin \le DVDD$	-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
lsource	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
lsource	Input current source (Pull Up), Vin = DVDD	10		50	uA
Cin	Input capacitance			15	рF
Vin_open	Open circuit output voltage			0.3	V
Serial data outpu	ut MISO (Tri state)				
VoutHigh1mA	Output high voltage, lout = -1mA	DVDD-0.5			V
VoutHigh50µA	Output high voltage, lout = -50μ A	DVDD-0.2			V
VinHigh_1mA	Output low voltage, lout = +1mA			0.5	V
VinHigh_50µA	Output low voltage, lout = +50µA			0.3	V
lout_Hz	High impedance output current, 0V < VMISO < DVDD	-1		1	uA
Cld_miso	Capacitive load. The slope of the MISO output signal mayneed to be controlled to meet EMI requirements under specified load conditions.			200	pF

Table 7. SPI DC characteristics.



2.9 SPI AC Characteristics

The AC characteristics of SCC2230-E02 are defined in Figure 15 and Table 8.



Figure 15. Timing diagram of SPI communication.

Table 6. SFTAG 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}		
Т _{СН}	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
Т _{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-E02 measurement directions.



Table 9. SCC2230-E02 accelerometer measurement directions.



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	l imits	for	linear	measures	(ISO2768-f)	
Table	10.	LIIIIIIII	101	iiiieai	measures	(1302700-1)	1.

Tolerance	Limits in mm for nominal size in mm							
class	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-E02. The tolerances are according to ISO2768-f (see Table 10).

2.13 Abbreviations

ASIC	Application Specific Integrated Circu	it
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-E02 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-E02 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-E02 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-E02 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-E02 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-E02 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 the LOOPF_OK bit in Common Status register is failing, the 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-E02 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-E02 ASIC. The SCC2230-E02 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)	$MCU\toASIC$
SCK	Serial Clock	$MCU \to ASIC$
MOSI	Master Out Slave In	$MCU\toASIC$
MISO	Master In Slave Out	$ASIC \to MCU$

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.

CSB	7	
SCK_	1 2 3 4 5 6 7 8	26 27 28 29 30 31 32
MOSI_	DI31 DI30 DI29 DI28 DI27 DI26 DI25 DI24	DI5 DI4 DI3 DI2 DI1 DI0
MISO-	D031 D030 D029 D028 D027 D026 D025 D024	D05 D04 D03 D02 D01 D00

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)
- Return status (RS, in MISO)
 Data (DI, DO)
- 4. Checksum (CRC)

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

Bit	MSB 31	30	29	28	27	26	25	24	23	22		9	8	7	6		1	LSB 0
MOSI	OP5	OP4	OP3	OP2	OP1	OP0	0	0	DI15	DI14		DI1	DIO	CRC7	CRC6		CRC1	CRC0
MISO	OP5	OP4	OP3	OP2	OP1	OP0	RS1	RS0	DO15	DO14		DO1	DO0	CRC7	CRC6		CRC1	CRC0
	•	— o	perati	on Cod	e —	•	← RS	-			Data		-,			CRC		•

Figure 25. SPI instruction format.

Table	11.	SPI	bit definitions.
-------	-----	-----	------------------

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