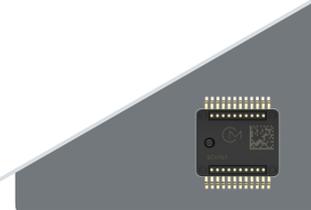
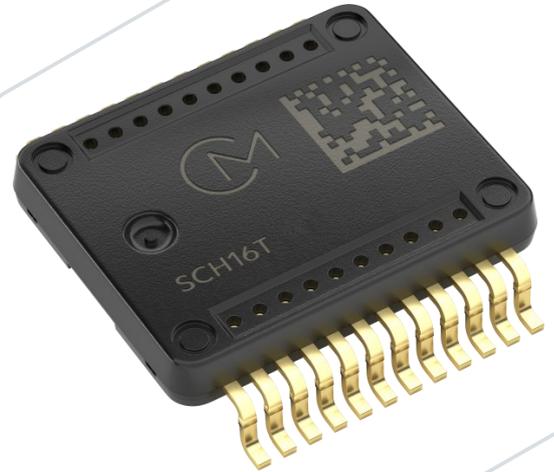


SCH16T-K20 Data Sheet

6-DOF Gyroscope and Accelerometer with Digital SPI Interface

Features

- Gyroscope measurement range ± 300 °/s
- Accelerometer measurement range ± 80 m/s² with saturation limit of ± 700 m/s² @1000 Hz
- Options for output interpolation and decimation
- Angular rate and acceleration low pass filters from 13 Hz to 370 Hz cut-off rate
- Data Ready output, timestamp index and SYNC input functions for clock domain synchronization
- -40...110 °C operating temperature range
- 3.0...3.6 V supply voltage, 1.7...3.6 V I/O supply voltage
- SafeSPI v2.0 interface
- 20-bit and 16-bit output data, selectable via SPI frame
- Advanced self-diagnostic system automatically reports sensor status in every SPI frame, leveraging over 200 internal monitoring signals
- 11.8 mm x 13.4 mm x 2.9 mm (l x w x h) SOIC-24
- Qualification based on AEC-Q100 standard
- Supports system level safety classification
- No restrictions on sensor array configurations



Applications

SCH16T-K20 is specifically developed for dynamic leveling with ultra-high-performance requirements.

Typical applications include:

- Heavy machine precision control and guidance
- Dynamic tilt measurement
- Platform stabilization and leveling
- Robotic motion control
- Camera image stabilization

Overview

The SCH16T-K20 is a combined high-performance 3-axis angular rate and 3-axis accelerometer. The angular rate and accelerometer sensor elements are based on Murata's proven capacitive 3D-MEMS technology. Signal processing is done by a single mixed-signal ASIC that provides angular rate and acceleration via a flexible SafeSPI v2.0 compliant digital interface. Sensor elements and ASIC are packaged to pre-molded SOIC 24-pin plastic housing that guarantees reliable operation over the product's lifetime.

The SCH16T-K20 is designed, manufactured, and tested for high stability, reliability, and quality requirements. The component has extremely stable output over temperature, humidity, and vibration. The component has several advanced self-diagnostic features, is suitable for SMD mounting and is compatible with RoHS and ELV directives.

SCH16T

1 Introduction

This document contains essential technical information about the SCH16T series 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 the SCH16T series sensor.

2 Product and packing quantity information

Table 1 Murata offers products in different packing sizes and types

| Product series | Part number | Description | Part number with packing mark | Packing type | Quantity |
|----------------|-------------|--|-------------------------------|----------------------|----------|
| SCH16T | SCH16T-K20 | 6-DOF Gyroscope and Accelerometer with Digital SPI Interface, Gyroscope ± 300 °/s, Accelerometer ± 80 m/s ² | SCH16T-K20-PCB | Sample package, Bulk | 1 pc |
| | | | SCH16T-K20-004 | | 4 pcs |
| | | | SCH16T-K20-1 | Tape & Reel | 100 pcs |
| | | | SCH16T-K20-10 | Tape & Reel | 1000 pcs |

3 Specifications

3.1 Abbreviations

| | |
|----------|--|
| ACC | Accelerometer |
| ARS | Angular Rate Sensor (gyroscope) |
| ASIC | Application Specific Integrated Circuit |
| AEC-Q100 | Automotive Electronics Council Failure Mechanism Based Stress Test Qualification For Integrated Circuits |
| CS | Chip Select |
| DOF | Degrees of Freedom |
| DPS | Degrees per Second |
| DRY | Data Ready |
| F_PRIM | Gyroscope Primary Frequency |
| FIFO | First In First Out |
| FREQ | Frequency |
| Gyro | Gyroscope |
| LPM | Low Power Mode |
| LPF | Low-Pass Filter |
| MCLK | Master Clock |
| MCU | Microcontroller Unit |
| MEMS | Micro-Electro-Mechanical System |
| MISO | Master In Slave Out |
| MOSI | Master Out Slave In |
| MSL3 | Moisture Sensitivity Level 3 (Moisture and reflow preconditioning) |
| ODR | Output Data Rate |
| PD | Pull Down |
| POR | Power on Reset |
| PU | Pull Up |
| RT | Room Temperature 25 °C |
| SCK | Serial Clock |
| SPI | Serial Peripheral Interface |
| SYNC | Synchronization |

SCH16T

3.2 General specifications

Table 2 General specifications

| Parameter | Min | Nom | Max | Unit |
|--|-------|-----------------------|-------|------|
| Operating temperature ⁽¹⁾ | -40 | | 110 | °C |
| Supply voltage | 3.0 | 3.3 | 3.6 | V |
| Digital I/O supply ⁽²⁾ | 1.7 | | 3.6 | V |
| Total supply current | 36 | 41 | 47 | mA |
| Low power mode current consumption | | | 10 | mA |
| Gyro primary frequency, F_PRIM | 22.1 | 23.6 | 25.1 | kHz |
| Output update rate (ODR) - Interpolated outputs (F_PRIM X 16) | 353.6 | 377.6 | 401.6 | kHz |
| Output update rate (ODR) - Decimated outputs | | 23.6/X ⁽³⁾ | | kHz |
| Component master clock, MCLK | | 1024 x F_PRIM | | kHz |
| Turn on time ⁽⁴⁾ | | | 250 | ms |
| Weight | | 0.612 | | gram |
| Threshold of Power On Reset (POR) POR_TH_H/L for supply voltage | 2.4 | | 2.9 | V |
| Threshold of Power On Reset (POR) POR_TH_H/L for digital I/O supply voltage | 1.2 | | 1.55 | V |
| POR hysteresis window, difference between POR levels when voltage drops or rises. Applies for both supply and digital I/O supply voltage | 0.125 | | 0.3 | V |

1) Specifications are valid within the temperature range

2) Can exceed supply voltage

3) Decimation ratio X is selectable from the following options: 2, 4, 8, 16 and 32

4) After voltage supplies are within specification

3.3 Absolute maximum ratings

Murata guarantees sensor operation without parameter related damage or functional deviation within these maximum ratings. However, output values are specified only for conditions specified in the chapters *Gyroscope performance specifications* and *Accelerometer performance specifications*. All voltages are related to the potential at GND.

Table 3 Absolute maximum ratings

| Parameter | Remark | Min | Nom | Max | Unit |
|----------------------|---|------|------------|------|------|
| Supply voltage | Supply voltage (pins V3P3, VDDIO) | -0.3 | | 3.63 | V |
| Storage temperature | No damage to the component will occur up to max 24 hours within these maximum ratings | -50 | | 150 | °C |
| Mechanical shock | t ≤ 0.5 ms, XYZ Axis. Tested according to AEC-Q100 requirements. | 3000 | | | g |
| Drop test | Drop to concrete surface, tested according to AEC-Q100 requirements. | 1.2 | | | m |
| ESD_HBM | ESD according to Human Body Model (HBM), Q100-002 | 2000 | | | V |
| ESD_CDM center pins | Center pins ESD according to Charged Device Model (CDM), Q100-011 | 500 | | | V |
| ESD_CDM corner pins | corner pins ESD according to Charged Device Model (CDM), Q100-011 | 750 | | | V |
| Ultrasonic agitation | Cleaning, welding, etc. | | Prohibited | | |

SCH16T

3.4 Gyroscope performance specifications

Table 4 Performance specifications are valid for all measurement axes, up to ± 300 °/s measurement range on all outputs, supply voltage = 3.3 V and at 25 °C unless otherwise specified

| Parameter | Condition | Min (-3 σ) | Typical | Max (+3 σ) | Unit |
|---|---|--------------------|--------------|--------------------|---------------------------|
| Dynamic range ^{A)} | Default sensitivity | | ± 327.68 | | °/s |
| Offset ^{B)} | -40 °C ... +85 °C | -0.1 | ± 0.01 | 0.1 | °/s |
| | XY axis, -40 °C ... +110 °C | -0.4 | ± 0.1 | 0.4 | |
| | Z axis, -40 °C ... +110 °C | -0.1 | ± 0.01 | 0.1 | |
| Offset drift over lifetime ^{C)} | After HTOL 1000 h | -0.05 | | 0.05 | °/s |
| Offset drift velocity ^{D)} | -40 °C ... +85 °C, 0.5 K/min | -0.01 | | 0.01 | (°/s)/min |
| | -40 °C ... +85 °C, 5 K/min | -0.05 | | 0.05 | |
| Default sensitivity ^{E)} | Nominal value, 16-bit mode | | 100 | | LSB/(°/s) |
| | Nominal value, 20-bit mode | | 1600 | | |
| Sensitivity error ^{F)} | -40 °C ... +110 °C | -0.25 | ± 0.05 | 0.25 | % |
| Sensitivity error drift over lifetime ^{G)} | After HTOL 1000 h | -0.2 | | 0.2 | % |
| Linearity error ^{H)} | ± 300 °/s, -40 °C ... +110 °C | -0.15 | ± 0.05 | 0.15 | °/s |
| | ± 100 °/s, -40 °C ... +110 °C | -0.04 | ± 0.01 | 0.04 | |
| Noise density | XY axis | | 0.0004 | 0.00045 | (°/s)/ $\sqrt{\text{Hz}}$ |
| | Z axis | | 0.0006 | 0.00066 | |
| Angle random walk ^{I)} | XY axis | | 0.015 | 0.019 | °/h |
| | Z axis | | 0.025 | 0.028 | |
| Bias instability ^{J)} | Allan deviation minimum divided by 0.664 | | 0.3 | 0.5 | °/h |
| Cross-axis sensitivity ^{K)} | -40 °C ... +110 °C, orthogonality error between rate axes | -0.15 | | 0.15 | % |
| | -40 °C ... +110 °C, absolute to package reference | -1 | | 1 | |
| G-sensitivity ^{L)} | For constant gravity input | -0.00075 | | 0.00075 | (°/s)/g |

Notes:

- Specified Min/Max values contain ± 3 sigma variation limits of original test population. Typical values are validation population mean (unless otherwise specified). Min/Max and typical values are not guaranteed, values represent validation population characteristics.
- Specification is valid after 24 hours from reflow.
- Each system design including SCH16T series component must be evaluated by the customer in advance to guarantee proper functionality during operation.

Table 5 Gyroscope parameter definitions

| Symbol | Description |
|--------|---|
| A) | Measurement range is the rotation speed range where the performance specifications are valid. Dynamic range is the sensor output range where the output is not saturated. Output saturation is indicated by saturation flags documented in chapter 7.3.4 <i>Saturation status summary</i> . Dynamic and measurement ranges are affected by user configurable sensitivity settings. |
| B) | Offset is the sensor output deviation from zero at zero rate and acceleration. Offset over temperature is determined over one temperature sweep in the specified temperature range. |
| C) | Offset drift over lifetime is estimated from offset drift from initial offset before MSL3 treatment to offset after 1000 hours of high temperature operating life (HTOL) test at 125 °C and maximum supply voltages. |
| D) | Offset drift velocity is the change rate of the zero-rate offset for predefined temperature gradients within a specified temperature range. |
| E) | Default sensitivity used in factory calibration. Sensitivity is affected by user configurable sensitivity settings defined in chapter 7.4.2 <i>Dynamic range and decimation</i> $\text{Sensitivity} = \frac{\text{AR}_{\text{meas}}(\Omega_{\text{max}}) - \text{AR}_{\text{meas}}(\Omega_{\text{min}})}{\Omega_{\text{max}} - \Omega_{\text{min}}}$ Where: Ω_{max} = applied angular rate at 100 °/s Ω_{min} = applied angular rate at -100 °/s $\text{AR}_{\text{meas}}(\Omega_n)$ = measured angular rate at Ω_n [LSB] Sensor outputs data in 2's complement format. |
| F) | Sensitivity error = $\frac{\text{Sensitivity} - \text{nominal sensitivity}}{\text{nominal sensitivity}} \times 100 \%$ Sensitivity error over temperature is determined over one temperature sweep in specified temperature range. |
| G) | Sensitivity error drift over lifetime is estimated from sensitivity drift during 1000 hours of high temperature operating life (HTOL) test at 125 °C and maximum supply voltages. Drift in percentage points. |
| H) | Linearity error is the maximum deviation from the best fit straight line defined by the measured values at the specified range end points. Best fit linear model uses a least-squares linear fit. |
| I) | Angle random walk is the white noise term estimated from Allan deviation at tau = 1 s. |
| J) | Bias instability is the Allan deviation minimum divided by 0.664. Measured with 13 Hz low pass filter setting, 200 Hz sample rate and fifteen-minute stabilization time before data collection starts to permit full thermal stabilization. |
| K) | Cross-axis sensitivity is the sensitivity on axes other than the intended axis of rotation. $\text{Cross - axis sensitivity} = \frac{\text{AR}_{\text{meas}}}{\Omega_{\text{other}}} \times 100 \%$ Where: Ω_{other} = applied angular rate along an axis other than the measured axis AR_{meas} = the measured angular rate Murata calibrates gyroscope and accelerometer axes at component calibration line and therefore orthogonality error is the residual cross-axis error after system level orientation against fixed acceleration (gravity). |
| L) | Angular rate offset sensitivity in respect to orientation in the earth gravitation. This value is only measured from orientations that are not affected by the earth's rotation (0.004 °/s) and therefore, is not verified in all orientations. Can not be extrapolated beyond gravitation. |

3.5 Accelerometer performance specifications

Table 6 Performance specifications are valid for all measurement axes, up to $\pm 80 \text{ m/s}^2$ measurement range on all outputs, supply voltage = 3.3 V and at 25 °C unless otherwise specified

| Parameter | Condition | Min (-3 σ) | Typical | Max (+3 σ) | Unit |
|---|--|--------------------|-------------|--------------------|------------------------------------|
| Dynamic range ^{A)} | All outputs, default sensitivity | ± 110 | | | m/s^2 |
| Offset ^{B)} | XY, -40 °C ... +110 °C, zeroed drift from 25 °C | -0.01 | ± 0.005 | 0.01 | m/s^2 |
| | Z, -40 °C ... +110 °C, zeroed drift from 25 °C | -0.02 | ± 0.01 | 0.02 | |
| | XY, -40 °C ... +110 °C | -0.03 | ± 0.01 | 0.03 | |
| | Z, -40 °C ... +110 °C | -0.04 | ± 0.02 | 0.04 | |
| Offset drift over lifetime ^{C)} | After HTOL 1000 h | | TBD | | m/s^2 |
| Offset drift velocity ^{D)} | -40 °C ... +110 °C, 0.5 K/min | -0.0015 | | 0.0015 | $(\text{m/s}^2)/\text{min}$ |
| | -40 °C ... +110 °C, 5 K/min | -0.005 | | 0.005 | |
| Default sensitivity ^{E)} | Nominal value, 16-bit mode | | 250 | | LSB/ (m/s^2) |
| | Nominal value, 20-bit mode | | 4000 | | |
| Sensitivity error ^{F)} | XY, -40 °C ... +110 °C | -0.05 | ± 0.01 | 0.05 | % |
| | Z, -40 °C ... +110 °C | -0.07 | ± 0.02 | 0.07 | |
| Sensitivity error drift over lifetime ^{G)} | After HTOL 1000 h | | TBD | | % |
| Linearity error ^{H)} | $\pm 80 \text{ m/s}^2$, -40 °C ... +110 °C | -0.15 | ± 0.05 | 0.15 | m/s^2 |
| | $\pm 10 \text{ m/s}^2$, -40 °C ... +110 °C | -0.01 | ± 0.005 | 0.01 | |
| Noise density | XY | | 0.37 | | $(\text{mm/s}^2)/\sqrt{\text{Hz}}$ |
| | Z | | 0.33 | | |
| Velocity random walk ^{I)} | XY | | 16 | | $(\text{mm/s})/\sqrt{\text{h}}$ |
| | Z | | 14 | | |
| Bias instability ^{J)} | Allan deviation minimum divided by 0.664 | | 0.13 | 0.20 | mm/s^2 |
| Cross-axis sensitivity ^{K)} | -40 °C ... +110 °C, orthogonality error between ACC axes | -0.15 | | 0.15 | % |
| | -40 °C ... +110 °C, absolute to package reference | -1 | | 1 | |

Notes:

- Specified Min/Max values contain ± 3 sigma variation limits of original test population. Typical values are validation population mean (unless otherwise specified). Min/Max and typical values are not guaranteed, values represent validation population characteristics.
- Specification is valid after 24 hours from reflow.
- Each system design including SCH16T series component must be evaluated by the customer in advance to guarantee proper functionality during operation.
- A factor of 102 can be used when converting m/s^2 to milli-g. Actual gravity depends on sensor location on Earth.

SCH16T

Table 7 Accelerometer parameter definitions

| Symbol | Description |
|--------|---|
| A) | Measurement range is the acceleration range where the performance specifications are valid. Dynamic range is the sensor output range where the output is not saturated. Output saturation is indicated by saturation flags documented in chapter 7.3.4 <i>Saturation status summary</i> . Dynamic and measurement ranges are affected by user configurable sensitivity settings. |
| B) | Offset is the sensor output deviation from zero at zero rate and acceleration. Offset over temperature is determined over one temperature sweep in the specified temperature range. $\text{Offset} = \frac{\text{ACC}_{\text{meas}}(a_{+1g}) + \text{ACC}_{\text{meas}}(a_{-1g})}{2}$ a_{+1g} = applied acceleration at +1 g (i.e., +1 g gravity of manufacturing location) a_{-1g} = applied acceleration at -1 g (i.e., -1 g gravity of manufacturing location) $\text{ACC}_{\text{meas}}(a_n)$ = measured acceleration at a_n [m/s ²] |
| C) | Offset drift over lifetime is estimated from offset drift from initial offset before MSL3 treatment to offset after 1000 hours of high temperature operating life (HTOL) test at 125 °C and maximum supply voltages. |
| D) | Offset drift velocity is the change rate of the zero-acceleration offset for predefined temperature gradients within a specified temperature range. |
| E) | Default sensitivity used in factory calibration. Sensitivity is affected by user configurable sensitivity settings defined in chapter 7.4.2 <i>Dynamic range and decimation</i> $\text{Sensitivity} = \frac{\text{ACC}_{\text{meas}}(a_{+1g}) - \text{ACC}_{\text{meas}}(a_{-1g})}{a_{+1g} - a_{-1g}}$ a_{+1g} = applied acceleration at +1 g (i.e., +1 g gravity of manufacturing location) a_{-1g} = applied acceleration at -1 g (i.e., -1 g gravity of manufacturing location) $\text{ACC}_{\text{meas}}(a_n)$ = measured acceleration at a_n [LSB] Sensor outputs data in 2's complement format. |
| F) | Sensitivity error = $\frac{\text{Sensitivity} - \text{nominal sensitivity}}{\text{nominal sensitivity}} \times 100 \%$ Sensitivity error over temperature is determined over one temperature sweep in specified temperature range. |
| G) | Sensitivity error drift over lifetime is estimated from sensitivity drift during 1000 hours of high temperature operating life (HTOL) test at 125 °C and maximum supply voltages. Drift in percentage points. |
| H) | Linearity error is the maximum deviation from the best fit straight line defined by the measured values at the specified range end points. Best fit linear model uses a least-squares linear fit. |
| I) | Velocity random walk is the white noise term estimated from Allan deviation at $\tau = 1$ s. |
| J) | Bias instability is the Allan deviation minimum divided by 0.664. Measured with 13 Hz low pass filter setting, 200 Hz sample rate and fifteen-minute stabilization time before data collection starts to permit full thermal stabilization. |
| K) | Cross-axis sensitivity is the sensitivity on axes other than the intended axis of acceleration. $\text{Cross-axis sensitivity} = \frac{\text{ACC}_{\text{meas}}}{a_{\text{other}}} \times 100 \%$ Where: a_{other} = applied acceleration along an axis other than the measured axis ACC_{meas} = the measured acceleration Murata calibrates gyroscope and accelerometer axes at component calibration line and therefore orthogonality error is the residual cross-axis error after system level orientation against fixed acceleration (gravity). |

SCH16T

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