KTH5701 Series

Low Power, High Precision
3D Hall Sensor

Technical Support
sales.global@conntek.com.cn

2024- 8- 22

Disclaimer

The information in this document is provided by Quanzhou KTsense Microelectronics Co., Ltd. (泉州昆泰芯微电子科技有限公司) (hereafter referred to as "KTsense Micro") on an "as is" basis for informational purposes only. KTsense Micro does not guarantee the accuracy of the information contained herein or the outcomes of its implementation. KTsense Micro assumes no liability for any errors or inaccuracies that may be present in this document. Users assume full responsibility for the application of the practices outlined in this document.

KTsense Micro owns the registered trademark CONNTEK, under which the CONNTEK brand sensors are marketed.

This document comes without any warranties, express or implied, including but not limited to warranties of merchantability, satisfactory quality, non-infringement, and fitness for a particular purpose. KTsense Micro, along with its employees, agents, and affiliates, is not liable for any losses arising from the use or reliance on this document.

This document is subject to change without prior notice and should not be construed as a commitment by KTsense Micro. Users should ensure they have the latest version of the relevant information before placing orders or integrating the product into their systems.

Users must evaluate the suitability of the product described in this document for their specific applications, including the required level of reliability and fitness for purpose.

This document and the described product may be subject to export control regulations. Export may require prior authorization from the competent authorities. The product is not intended, authorized, or warranted for use in applications requiring extended temperature ranges or unusual environmental conditions. High reliability applications, such as medical life-support or aviation systems, are specifically excluded.

The product may not be used for the development, production, maintenance, or storage of:

1. Chemical, biological, or nuclear weapons, including missile systems for such weapons.
2. Civil firearms, including spare parts or ammunition.
3. Defense-related products or materials for military or law enforcement use.
4. Applications that could cause serious harm to persons or property and that can be used as a means of violence in armed conflicts or similar situations.

No licenses or rights to any intellectual property of KTsense Micro or third parties are granted.

If this document is marked as "confidential"or similar, or if the content is reasonably understood to be confidential, the recipient must not disclose any part of the document to third parties without the express written consent of KTsense Micro. The recipient must take all necessary measures to maintain the confidentiality of the document, using at least the same degree of care as they use to protect their own confidential information, but no less than a reasonable degree of care. The recipient may only disclose the document to employees on a need-to-know basis, provided they are bound by confidentiality terms similar to those in this disclaimer. The document may only be used for the purpose for which it was received and may not be used for commercial purposes or to the detriment of KTsense Micro or its customers. These confidentiality obligations will last indefinitely but in any case, for no less than 10 years from the receipt of the document.

This disclaimer is governed by the laws of China, and any disputes arising from it will be subject to the exclusive jurisdiction of the courts in Shenzhen, China.

The invalidity of any provision in this disclaimer does not affect the validity of the remaining provisions. Previous versions of this document are repealed.

Copyright

Contact Information

For the latest version of this document, go to our website at https://en.conntek.com.cn/.

For additional information, please contact our Direct Sales team and get help for your specific needs:

Region	Contact Information
Overseas	Email: sales.global@conntek.com.cn
China	Email: sales@conntek.com.cn

Table of Contents

1 Product Features

- 3D (X, Y, Z axis) magnetic field output
- CORDIC algorithm angle output[1]
- XY axis typical operating range: ± 130 mT
- Z axis typical operating range: ± 80 mT
- Temperature (T) output
- Supports absolute position detection
- XY, XZ, YZ axis plane angle output
- High precision 16-bit ADC output
- Supports button detection function
- Optional SPI or I^2C communication interface
- Supports wake-up and measurement trigger modes
- Operating voltage: 2.8 V ~ 5.5 V
- IO supply voltage as low as 1.8 V
- Operating temperature of AQ2 for industrial applications: $-40\,°C \sim +105\,°C$
- Operating temperature of AQ3 for consumer applications: $-40\,°C \sim +85\,°C$

[1] Note: When using the angle output function of the chip, it is recommended that the magnetic induction intensity of the corresponding two axes of the plane is greater than 20 mT.

2 Typical Applications

- Knobs & Joysticks
- Linear position detection
- 3D position and angle detection
- Non-contact magnetic field measurement
- Low power magnetic encoders

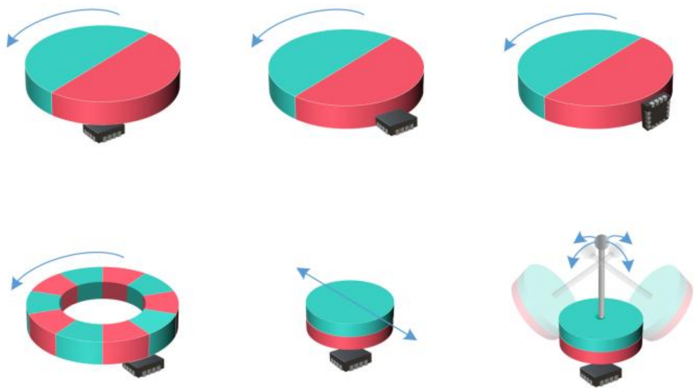


Figure 1: Typical Applications of KTH5701 Series

3 Overview

The KTH5701 is a digital output 3D Hall sensor chip that integrates three independent Hall sensors for the X, Y, and Z axes. The signal chain uses a high precision operational amplifier and a 16-bit ADC to convert the analog signals into digital outputs. The external host can read the measurement data through SPI or I^2C modes. Additionally, the chip integrates a temperature sensor for magnetic field temperature compensation.

The KTH5701 supports continuous sensing mode, wake-up sleep mode, and single measurement mode, making it suitable for various application scenarios. The BUTT_OUT pin is used to detect the button function between the magnet and the chip, and can also be configured as a trigger mode to trigger a single measurement.

The KTH5701 also integrates the CORDIC algorithm to support plane angle output (XY plane, XZ plane, YZ plane). The amplitude adjustment register greatly facilitates common knob applications in both on-axis and off-axis configurations. It supports magnetic field threshold detection for the selected plane (XY plane, XZ plane, YZ plane), allowing the same chip to detect both knob and button scenarios simultaneously.

This product features high integration and flexible application, making it widely applicable in various scenarios.

4 Functional Block Diagram

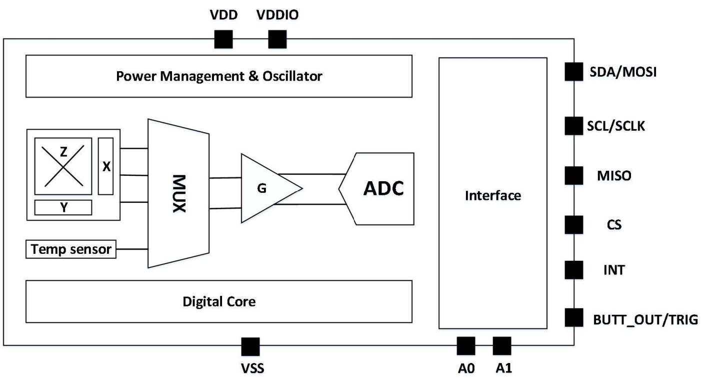


Figure 2: Functional Block Diagram of KTH5701 Series

Device Model	Package	Package Size (Nominal Value)
KTH5701	QFN 3.00×3.00 mm - 16L	3.00 mm $\times$ 3.00 mm
KTH5701	DFN 2.00×2.50 mm - 8L	2.00 mm $\times$ 2.50 mm

Table 1: Device Package Information

5 Pin Definitions

5.1 QFN3×3-16L Package

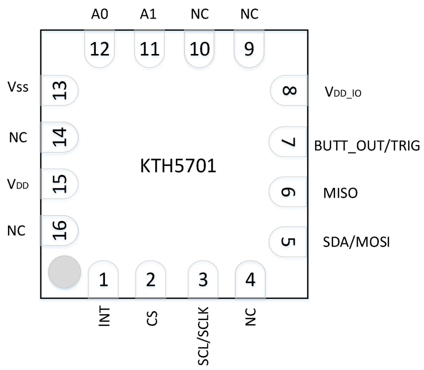


Figure 3: QFN3×3-16L Package Pin Configuration

Pin No.	Name	Description	Type
1	INT	Data ready or Wake-up & Sleep Mode interrupt signal	Output
2	CS	I^2C mode: Pull-up to V_{DD_IO} SPI mode: Controlled by SPI master, active low	Input
3	SCL/SCLK	I^2C or SPI clock signal	Input
5	SDA/MOSI	I^2C data input/output or SPI data	Input/Output
6	MISO	SPI data output. When only using SPI three pin data transfer, MISO and MOSI need to be shorted	Output
7	BUTT_OUT/TRIG	BUTT_OUT button function output or TRIG single measurement signal	Input/Output
8	V_{DD_IO}	IO power supply	Power
11	A1	I^2C device address input A1	Input
12	A0	I^2C device address input A0	Input
13	V_{SS}	Ground	Ground
15	V_{DD}	Power supply	Power
Others	NC	Not Connected	-

Table 2: Pin Definitions for QFN3×3-16L

5.2 DFN2×2.5-8L Package

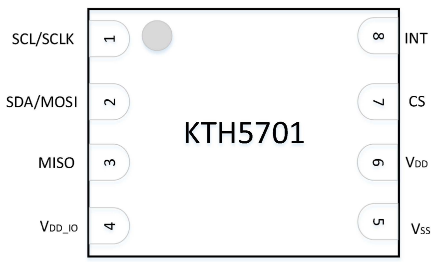


Figure 4: DFN2×2.5-8L Package Pin Configuration

Pin No.	Name	Description	Type
1	INT	Data ready or Wake-up & Sleep Mode interrupt signal	Output
2	CS	I^2C mode: Pull-up to V_{DD_IO} SPI mode: Controlled by SPI master, active low	Input
3	SCL/SCLK	I^2C or SPI clock signal	Input
4	SDA/MOSI	I^2C data input/output or SPI data	Input/Output
5	MISO	SPI data output. When only using SPI three pin data transfer, MISO and MOSI need to be shorted	Output
6	BUTT_OUT/TRIG	BUTT_OUT button function output or TRIG single measurement signal	Input/Output
7	V_{DD_IO}	IO power supply	Power
8	V_{SS}	Ground	Ground
Others	NC	Not Connected	-

Table 3: Pin Definitions for DFN2×2.5-8L

6 Specifications

6.1 Absolute Maximum Ratings

Parameter	Description	Min	Max	Unit
V_{DD}	Power supply voltage	-0.3	6.0	V
V_{DD_IO}	IO power supply voltage	-0.3	6.0	V
V_{IN}	Input voltage on any pin	-0.3	V_{DD_IO} + 0.3	V
T_{STG}	Storage temperature	-55	150	°C
T_J	Junction temperature	-40	125	°C

Table 4: Absolute Maximum Ratings

6.2 Recommended Operating Conditions

Parameter	Description	Min	Typ	Max	Unit
V_{DD}	Power supply voltage	2.8	3.3	5.5	V
V_{DD_IO}	IO power supply voltage	1.8	3.3	V_{DD}	V
T_A	Operating ambient temperature of AQ2 (industrial application)	-40	25	105	°C
T_A	Operating ambient temperature of AQ3 (consumer application)	-40	25	85	°C

Table 5: Recommended Operating Conditions

6.3 Electrical Characteristics

Parameter	Description	Test Conditions	Min	Typ	Max	Unit
V_{DD}	Chip supply voltage		2.8	3.3	5.5	V
V_{DD_IO}	Digital IO supply voltage		1.8		V_{DD}	V
$I_{DD,CONVXY}$	X or Y axis measurement current	V_{DD} = 3.3 V		4.89		mA
$I_{DD,CONVZ}$	Z axis measurement current	V_{DD} = 3.3 V		3.87		mA
$I_{DD,CONVT}$	Temperature measurement current	V_{DD} = 3.3 V		2.58		mA
$I_{DD,STBY}$	Continuous sensing mode standby current	V_{DD} = 3.3 V		61.7		μA
$I_{DD,WAKE\_STBY}$	Wake-up sleep mode standby current	V_{DD} = 3.3 V		2.4		μA
$I_{DD,IDLE}$	Idle state current	V_{DD} = 3.3 V		1.4		μA

Table 6: Electrical Characteristics

6.4 Magnetic Characteristics

Parameter	Description	Test Conditions	Min	Typ	Max	Unit
M_{xy_range}	Magnetic field linear range	@gain=20	−130		130	mT
M_{z_range}	Magnetic field linear range		−80		80	mT
$SENS_X$	X axis sensitivity			65.5		LSB/mT
$SENS_Y$	Y axis sensitivity			65.5		LSB/mT
$SENS_Z$	Z axis sensitivity			102		LSB/mT
N_{RMSxy}	XY axis RMS noise	@gain=20		0.2		mT
		magnOsr=0		0.03		mT
		digCtrl=0		0.01		mT
N_{RMSxy}		@gain=20		0.2		mT
		magnOsr=3		0.03		mT
		digCtrl=0		0.01		mT
N_{RMSxy}		@gain=20		0.2		mT
		magnOsr=3		0.03		mT
		digCtrl=4		0.01		mT
N_{RMSz}	Z axis RMS noise	@gain=20		0.1		mT
		magnOsr=0		0.02		mT
		digCtrl=0		0.01		mT
N_{RMSz}		@gain=20		0.1		mT
		magnOsr=3		0.02		mT
		digCtrl=0		0.01		mT
N_{RMSz}		@gain=20		0.1		mT
		magnOsr=3		0.02		mT
		digCtrl=4		0.01		mT
A_{ERRxy}	XY plane rotation $360°$ angle error	@B=40 mT		$\pm1°$		Degree
A_{ERRxz}	XZ plane rotation $360°$ angle error	magnOsr=3		$\pm1°$		Degree
A_{ERRyz}	YZ plane rotation $360°$ angle error	digCtrl=4		$\pm1°$		Degree

Table 7: Magnetic Characteristics

6.5 Timing Parameters

Parameter	Description	Min	Typ	Max	Unit
T_{start}	Chip start-up time		4		ms
T_{CONVM}	Single axis magnetic field measurement time (programmable)	165	$69 + 32 \times 2^{magnOsr} \times (2 + 2^{digCtrl})$	33349	μs
T_{CONVT}	Temperature measurement time (programmable)	165	$69 + 96 \times 2^{tempOsr}$	837	μs
T_{CONV_END}	Time from measurement end to analog enable off		108		μs
T_{active}	Time from idle mode to measurement start		220		μs
$T_{Continuous}$	Time to complete one measurement in continuous sensing mode when $measTime = 0$		$m \times T_{CONVM} + T_{CONVT} + T_{CONV\_END}$		μs
T_{wakeUp}	Time to complete one measurement in wake-up sleep mode when $measTime = 0$		$m \times T_{CONVM} + T_{CONVT} + T_{CONV\_END}$		μs
T_{single}	Time to complete one measurement in single conversion mode		$T_{active} + m \times T_{CONVM} + T_{CONVT} + T_{CONV\_END}$		μs

Table 8: Timing Parameters

7 Magnetic Field Sensing Direction

KTH5701 can sense magnetic fields from the X, Y, and Z axes. The Hall elements in the XY direction are sensitive to magnetic fields parallel to the package, while the Z direction elements are sensitive to magnetic fields perpendicular to the package. As shown in Figure 5, the Hall elements in each direction are sensitive to both the N and S poles.

When the chip is in a magnet-free environment, the three-axis magnetic field output value is 32768. When the magnetic field direction is consistent with the arrow direction shown in the figure, the axis output value is greater than 32768. When the magnetic field direction is opposite to the arrow direction shown in the figure, the axis output value is less than 32768.

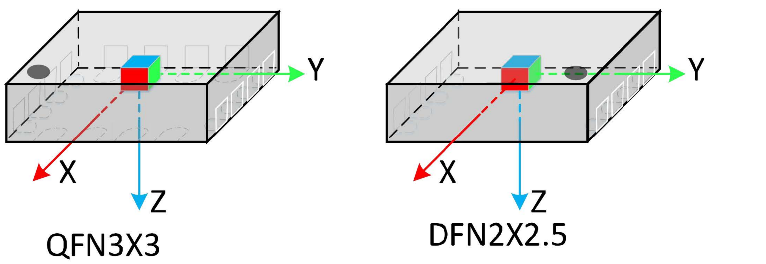


Figure 5: Hall Element Sensitivity Directions for Positive ADC Output in Each Axis

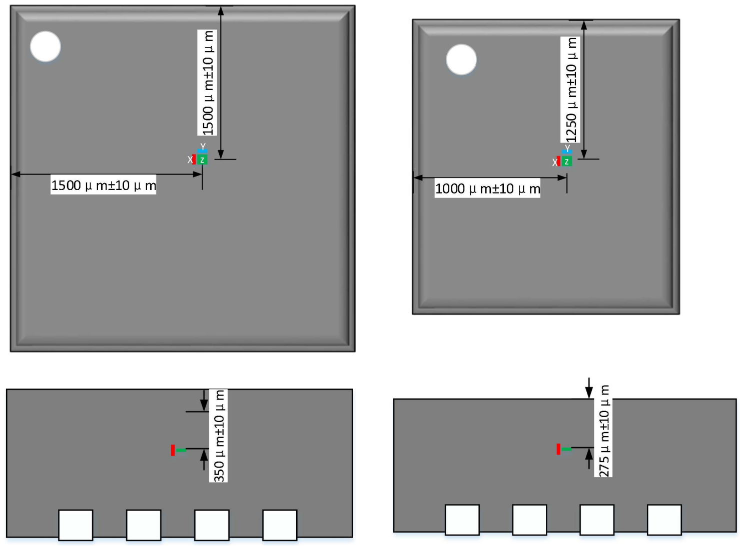


Figure 6: Relative Positions of Hall Elements in Each Axis within the Package

Note:

- The sensor output of 32768 in a magnet-free condition does not account for the offset, temperature drift, and noise of the Hall device and signal chain.

8 Measurement Modes Description

The KTH5701 series supports multiple operating modes. This product can be used in continuous sensing mode, wake-up & sleep mode, and single conversion mode.

8.1 Measurement Function Overview

Measurement Function	Description
Continuous Sensing Mode	The chip continuously measures the channels selected in $ZYXT$.
Wake-up & Sleep Mode	When the difference between the current measurement items ZYX and the set reference value exceeds the set threshold in the corresponding register, the INT pin is set to high.
Single Conversion Mode	The chip performs a single measurement of the selected channels in $ZYXT$.
Idle Mode	The chip exits the current mode and enters idle state.

Table 9: Measurement Function Overview

8.2 Continuous Sensing Mode

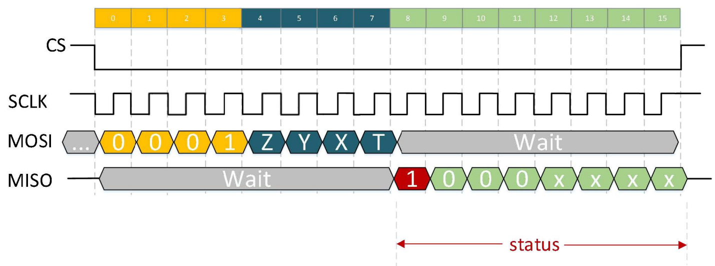


Figure 7: Continuous Sensing Mode SPI Communication Diagram

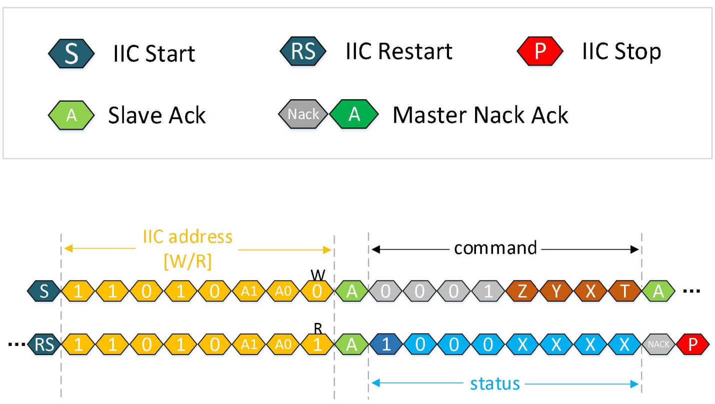


Figure 8: Continuous Sensing Mode I^{2}C Communication Diagram

After the host sends a command to the chip to enter continuous sensing mode, the chip will continuously measure the items selected by the host ($ZYXT$) until the host sends an idle mode command. The selection of the measurement items is related to the last four bits of the command sent by the host, corresponding to the sequence of the lower half-byte as $ZYXT$. Setting the corresponding bit to 1 will measure that item. For example, if the host sends the binary command 00011001, the chip enters continuous sensing mode and continuously measures the Z and T items until the host sends an idle mode command.

In scenarios requiring continuous acquisition of magnetic field/temperature data around the chip with less stringent power consumption requirements, it is recommended to use continuous sensing mode.

In continuous sensing mode, the chip's data readback function needs to be used in conjunction with the INT pin. When the chip is measuring the selected items, the INT pin is low, and the host cannot read back the measurement results. It needs to wait for the INT pin to be set high before reading back the data. After the chip completes a measurement of the selected items, the INT pin is set high, and the data readback frame (data Read Frame) can be used to read back the measurement data of the selected items. After the host reads back the measurement items, the INT pin is pulled low. If the host does not read back the measurement items, the INT pin will remain high for a certain period and will be pulled low at the start of the next measurement. The duration of the high state is related to the setting of $measTime$ in register $0x1D$. When the INT pin is high, it indicates that the chip has completed a measurement, and the data readback frame (data Read Frame) can be used to read the measurement items. When the INT pin is low, it indicates that the chip is measuring the selected items and data cannot be read.

When the chip enters continuous sensing mode, it adopts intermittent measurement to reduce power consumption. The chip will automatically continue to measure the corresponding items, and the interval between two measurements is controlled by $measTime$. The measurement time of the corresponding items is controlled by the parameters $tempOsr$, $magnOsr$, and $digCtrl$.

8.3 Wake-up & Sleep Mode

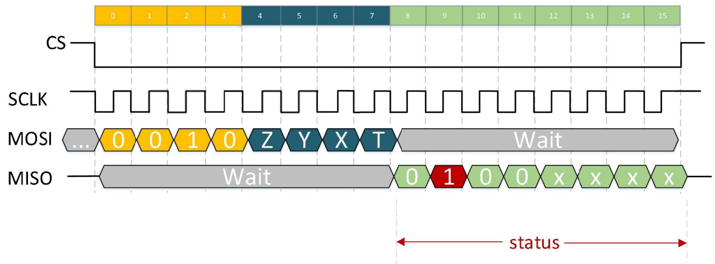


Figure 9: Wake-up & Sleep Mode SPI Communication Diagram

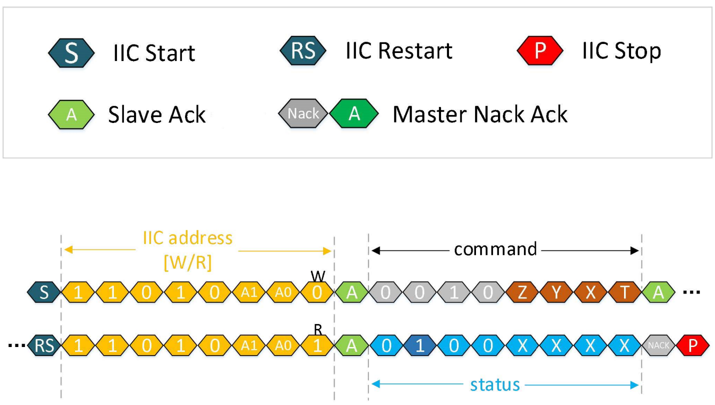


Figure 10: Wake-up & Sleep Mode I^2C Communication Diagram

After the host sends a command to the chip to enter wake-up & sleep mode, the chip will be in a low-power measurement mode, measuring the selected items ($ZYXT$) at a certain frequency until the host sends an idle mode command. The selection of the measurement items is related to the last four bits of the command sent by the host, corresponding to the sequence of the lower half-byte as $ZYXT$. Setting the corresponding bit to 1 will measure that item. For example, if the host sends the binary command 00101000, the chip enters wake-up & sleep mode and continuously measures the Z item until the host sends an idle mode command.

In wake-up & sleep mode, when the intensity of one of the measurement items around the chip changes, and the difference between the current intensity and the reference value exceeds the set threshold in the threshold register, the INT pin will be set high. The INT pin will not actively go low. For example, if the chip sends a wake-up & sleep mode command ($0x28$), and at some point, the difference between the Z-axis magnetic induction intensity around the chip and the reference value exceeds the value set in the Z-axis threshold register ($wzTh$), the INT pin will be set high. After the host reads the measurement data through the data readback frame (data Read Frame), the INT pin is pulled low; otherwise, it remains high. The INT pin will not actively go low. The setting of the reference value is related to the registers $reg0x19$ wakeSel and $reg0x1A$ wakeDiff, see the register description for details.

8.4 Single Conversion Mode

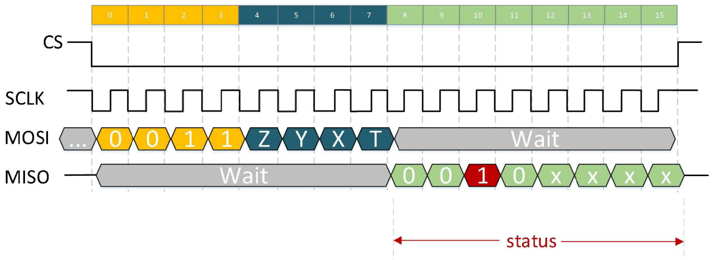


Figure 11: Single Conversion Mode SPI Communication Diagram

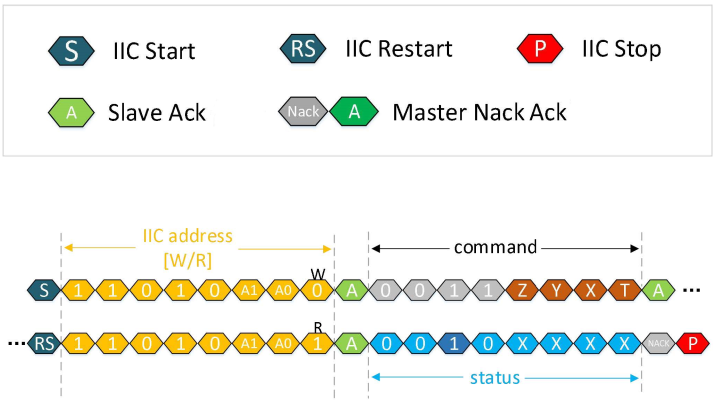


Figure 12: Single Conversion Mode I^{2}C Communication Diagram

After the host sends a command to the chip to enter single conversion mode, the chip will perform a single measurement of the selected items ($ZYXT$) and then automatically return to idle state, which is equivalent to sending an idle mode command. That is, the chip does not need to send an idle mode command to return to idle mode after completing a single measurement. The selection of the measurement items is related to the last four bits of the command sent by the host, corresponding to the sequence of the lower half-byte as $ZYXT$. Setting the corresponding bit to 1 will measure that item. For example, if the host sends the binary command 00111001, the chip performs a single measurement of the Z and T items.

8.5 Idle Mode

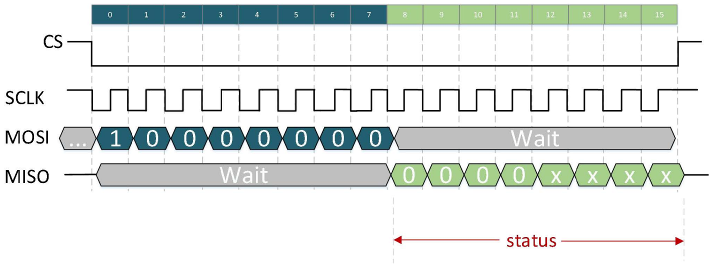


Figure 13: Idle Mode SPI Communication Diagram

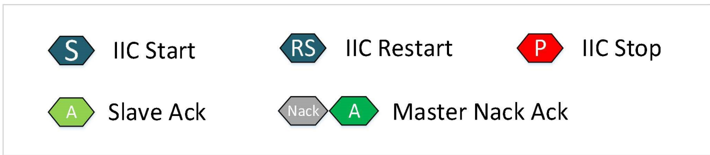


Figure 14: Idle Mode I²C Communication Diagram

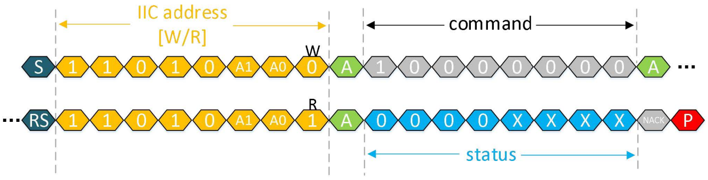


Figure 15: Idle Mode I²C Communication Diagram

After the host sends a command to the chip to enter idle mode, the chip will enter an idle state. When the chip is in continuous sensing mode or wake-up & sleep mode, it cannot perform operations other than the data readback frame, such as reading and writing registers. To perform other operations on the chip, it is necessary to send an idle mode command first to make the chip enter an idle state. However, after sending the idle mode command, subsequent commands cannot be executed immediately. It is necessary to wait for the current measurement to be completed before entering idle mode from continuous sensing mode or wake-up & sleep mode. If other operations are needed, it is necessary to wait for a measurement time delay before proceeding. The time to complete a measurement is related to the $tempOsr$, $magnOsr$, and $digCtrl$ parameters configured in the chip, see the timing parameters section for specific calculation methods.

For example, for a write register command:

- Step 1: Send idle mode command
- Step 2: Wait for the measurement time to complete
- Step 3: Send write register command

Note: The idle state refers to the state where the chip is not in any measurement mode. The standby state refers to the state where the chip is in a measurement mode but in an interval between measurements.

9 Reset

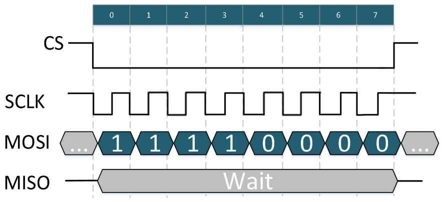


Figure 16: Reset Chip SPI Communication Diagram

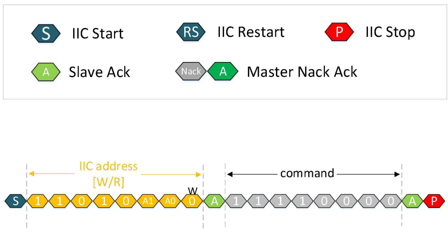


Figure 17: Reset Chip I²C Communication Diagram

The internal register configuration is reset to the default state. If the chip is in continuous sensing mode or wake-up sleep mode, you need to send the idle mode command to return the chip to idle mode before resetting the chip.

10 Status

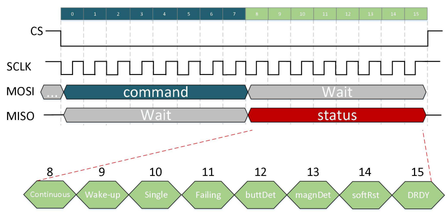


Figure 18: Chip Running Status SPI Description

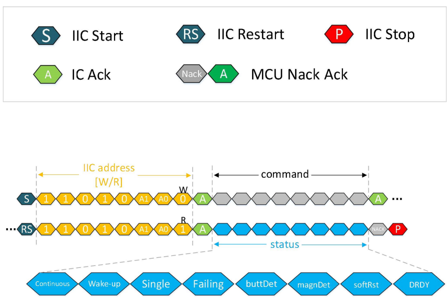


Figure 19: Chip Running Status I²C Description

Except for resetting the chip, after sending any other command, the chip will return the status of the chip.

- **Continuous:** This bit is set to 1 when the chip is in continuous sensing mode. When the host sends the continuous sensing mode command, the returned status will have this bit set to 1. When the chip is in continuous sensing mode, using the measurement data readback frame (data Read Frame) to read back the measurement data will also set this bit to 1.
- **Wake-up:** This bit is set to 1 when the chip is in wake-up sleep mode. When the host sends the wake-up sleep mode command, the returned status will have this bit set to 1. When the chip is in wake-up sleep mode, using the measurement data readback frame (data Read Frame) to read back the measurement data will also set this bit to 1.
- **Single:** This bit is set to 1 when the chip is in single conversion mode. When the host sends the single conversion mode command, or the host sends a high pulse to the $TRIG$ pin of the chip, this bit will be set to 1 in the returned status. After completing a single measurement, the chip returns to idle mode, and this bit is cleared to 0 in subsequent returned status.
- **Failing:** This bit is set to 1 when the current command is invalid. If another measurement command is sent during any measurement state, the $Failing$ bit will be set to 1. For example, if a single conversion command is sent during continuous sensing mode, the $Failing$ bit will be set to 1. If a read/write register operation is performed during continuous sensing mode, the $Failing$ bit will also be set to 1, indicating a command error. When the chip is in continuous sensing measurement and the INT pin is low, indicating that the chip is measuring the selected items, the $Failing$ bit will be set to 1, and data readback cannot be performed.
- **buttDet:** This bit is set to 1 when the chip detects the button function. When the register configuration $trigPushSel$ is set to 1, and the related configuration register (address $0x1F$) is configured, if the chip detects that the selected plane magnetic field value exceeds the value set in the register at address $0x1F$, the returned status will have this bit set to 1, and the $BUTT\_OUT/TRIG$ pin will be set to 1.
- **magnDet:** This bit is set to 1 when the current magnetic induction strength detected by the chip exceeds the threshold magnetic field set in the register at address $0x1F$. When $absPushEn$ is set to 0, if the current magnetic field exceeds the value set in $pushConfig[15:13]$ in the register at address $0x1F$, the returned status will have this bit set to 1.
- **softRst:** After the host sends the reset command to the IC, the IC does not immediately return the status. Therefore, the status returned after the chip receives any command for the first time can be used to determine whether the reset was successful. If the chip is successfully reset, this bit will be set to 1, and after returning the status once, this bit will be cleared to 0, that is, when the chip receives any command for the second time after the reset, this bit in the status will be 0.
- **DRDY:** After the host sends the continuous sensing mode command to the chip, this bit will be set to 1 after each measurement is completed. After reading the data once, this bit will be cleared to 0. After the host sends the single conversion mode command

to the chip, this bit will be set to 1 after the measurement is completed. After reading the data once, this bit will be cleared to 0. After the host sends the wake-up sleep mode command to the chip, when the detected magnetic field change exceeds the set threshold, this bit will be set to 1. After reading the data once, this bit will be cleared to 0.

11 Data Read Frame

After the chip completes a measurement, the measurement data readback frame (Data Read Frame) can also be used to read back the chip running status (Status) and all measurement data.

In continuous sensing mode, the measurement data readback frame (Data Read Frame) needs to be used with the

$$INT$$

pin, otherwise, there will be a data readback failure.

As shown in the figure below, after the host sends the data readback command to the chip, the chip will return all the measurement values of the selected measurement items to the host at once.

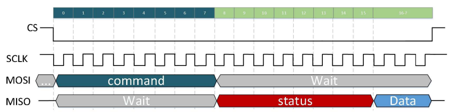


Figure 20: Data Read Frame SPI Communication Diagram

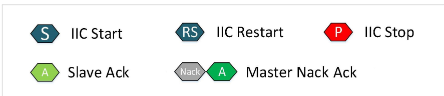


Figure 21: Data Read Frame Illustration

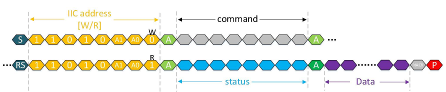


Figure 22: Data Read Frame I^{2}C Communication Diagram

11.1 TXYZ Readback Mode

When the register angMagnSel is set to 0, the host can send a single data readback command to read back the Z: Z-axis magnetic induction strength, Y: Y-axis magnetic induction strength, X: X-axis magnetic induction strength, and T: current temperature. The returned magnetic field data is a 16-bit unsigned number. Ideally, if there is no magnetic field around the chip, the three-axis magnetic field output values of the chip are all 32768. The command sending part is shown in the figure below, and the complete communication format is shown in Figures 23 and 24.

Taking the X-axis magnetic induction strength as an example, the current X-axis magnetic induction strength

$$B_x = \frac{X[15:8] \ll 8 + X[7:0] - 32768}{SENS_X}, unit: \text{in mT}.$$

When the exact magnetic field value is not needed, the current X-axis magnetic induction strength can usually be represented by

$$X[15:8] \ll 8 + X[7:0] - 32768$$

. The sign calculated represents the direction of the projection of the current magnetic field on the axis. The method to determine the current magnetic field is shown in the chip magnetic field sensing direction.

For example, if the chip returns the parameter

$$X[15:8] = 0x95$$

,

$$X[7:0] = 0x32$$

, and the gain is set to 20 times, then

$$B_x = \frac{0x9532 - 32768}{65.5} = \frac{38194 - 32768}{65.5} = 82.8, unit \text{in mT}.$$

When the exact magnetic field value is not needed,

$$0x9532 - 32768 = 5426$$

can be used to represent the current X-axis magnetic induction strength.

Similarly, the calculation method for the magnetic induction strengths of the other two axes can be obtained.

Note: The sensor output value of 32768 in a non-magnetic condition does not consider the offset, temperature drift, and noise effects of the Hall device and signal chain.

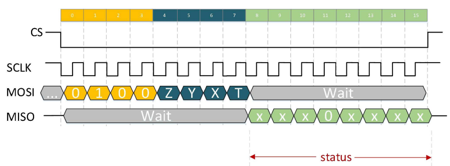


Figure 23: TXYZ Read Frame SPI Communication Diagram

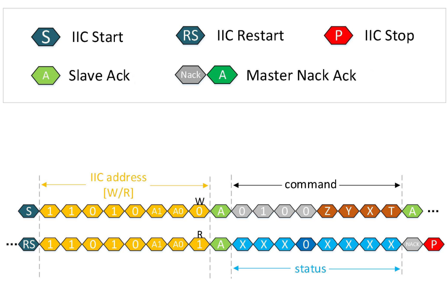


Figure 24: TXYZ Read Frame I^{2}C Communication Diagram

The chip returns the data of the selected measurement items according to the selection of ZYXT. When all four measurement data are selected, the data is returned in the order of Status, T, X, Y, and Z. When only part of the measurement items are selected, the unselected parts will be skipped, and the data will not be returned. For example, if TY is selected, the data is returned in the order of Status, T, and Y.

The following is an example of command sending and data returning when all four measurement data of ZYXT are selected.

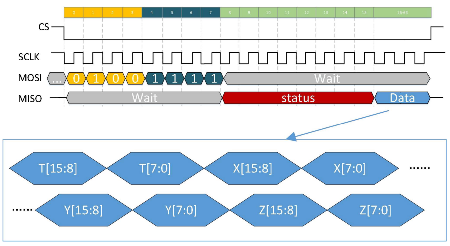


Figure 25: TXYZ Full Readback SPI Communication Diagram

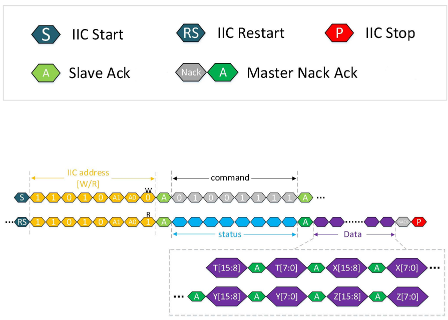


Figure 26: TXYZ Full Readback I^{2}C Communication Diagram

The following is an example of command sending and data returning when only YT is selected.

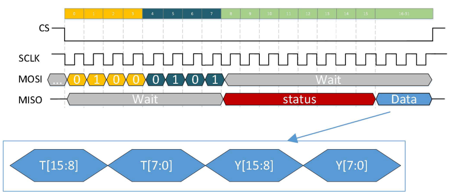


Figure 27: YT Readback SPI Communication Diagram

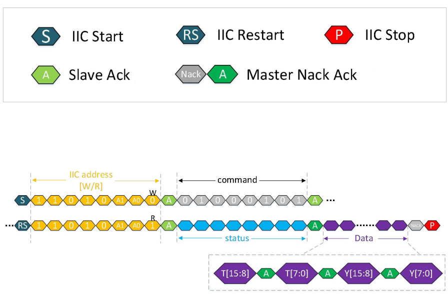


Figure 28: YT Readback I^{2}C Communication Diagram

11.2 TABZ Readback Mode

When the register angMagnSel is set to 1, the host can send a single data readback command to read back the Z: Z-axis magnetic induction strength, B: the magnetic field value of the selected plane calculated by the CORDIC algorithm, A: the angle of the selected plane, and T: the current temperature. The command sending part is shown in the figure below, and the complete communication format is shown in Figures 29 and 30.

The returned 16-bit angle value, each LSB corresponds to an angle of:

$$\frac{360°}{2^{16}}$$

For example, if the returned values are

$$A[15:8] = 0x90$$

and

$$A[7:0] = 0x30$$

, then

$$A[15:0] = 0x9030$$

, and the angle of the selected plane magnetic field is:

$$= A[15:0] \times \frac{360°}{2^{16}} = 0x9030 \times \frac{360°}{2^{16}}$$

Since the magnetic field value is calculated by the CORDIC algorithm, the actual corresponding value of the magnetic induction strength should be:

$$\frac{B[15:0] \times 0.60725}{Sensitivity}$$

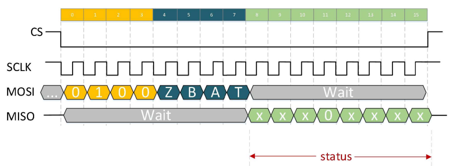


Figure 29: TABZ Read Frame SPI Communication Diagram

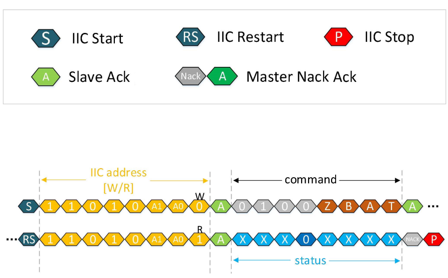


Figure 30: TABZ Read Frame I^{2}C Communication Diagram

The chip returns the data of the selected measurement items according to the selection of ZBAT. When all four measurement data are selected, the data is returned in the order of Status, T, A, B, and Z. When only part of the measurement items are selected, the unselected parts will be skipped, and the data will not be returned. For example, if BT is selected, the data is returned in the order of Status, T, and B.

The following is an example of command sending and data returning when all four measurement data of ZBAT are selected.

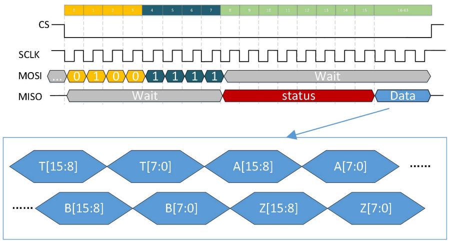


Figure 31: TABZ Full Readback SPI Communication Diagram

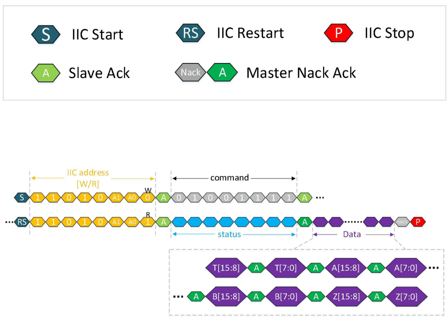


Figure 32: TABZ Full Readback I^{2}C Communication Diagram

The following is an example of command sending and data returning when only BT is selected.

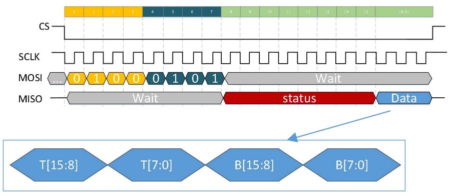


Figure 33: BT Readback SPI Communication Diagram

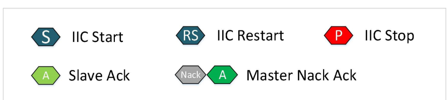


Figure 34: BT Readback SPI Communication Diagram

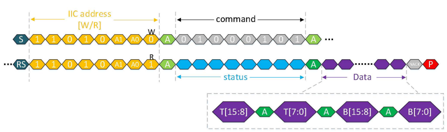
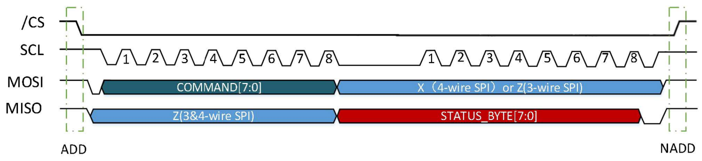


Figure 35: BT Readback I^{2}C Communication Diagram

12 SPI Communication Mode

Note: The following parameters are measured at room temperature $25°$C, $V_{DD} = 3.3$ V.

The design uses SPI mode 3: CPHA=1 (data changes on the first edge, sampled on the second edge), CPOL=1 (inactive state is high level).



Electrical Parameter	Symbol	Min	Max	Unit
SPI Clock Cycle	t_c(SPC)	200		ns
SPI Clock Cycle	t_c(SPC)		5	MHz
CS Setup Time	t_{su}(CS)	5		ns
CS Hold Time	t_h(CS)	10		ns
SDI Input Setup Time	t_{su}(SI)	5		ns
SDI Input Hold Time	t_h(SI)	15		ns
SDO Valid Output Time	t_v(SO)		50	ns
SDO Output Hold Time	t_h(SO)	5		ns
SDO Output Disable Time	t_{dis}(SO)		50	ns

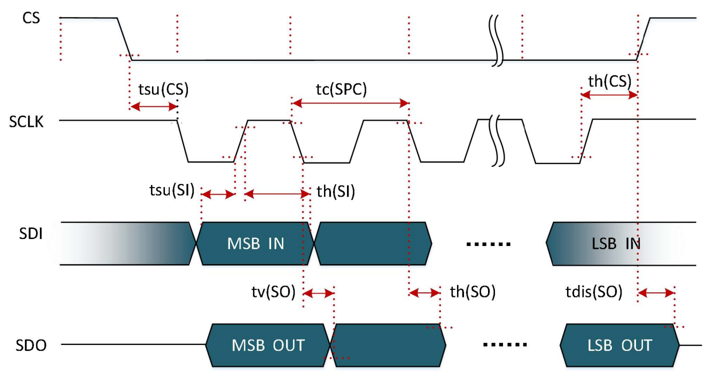


Figure 36: SPI Timing Diagram

13 I²C Communication Mode

Note: The following parameters are measured at room temperature $25°$C, $V_{DD} = 3.3$ V.

Electrical Parameter	Symbol	Standard Mode		Fast Mode		Unit
		Min	Max	Min	Max	
SCL Clock Frequency	f(SCL)		100		400	kHz
SCL Clock Low Time	t_w(SCLL)	4.7		1.3		μs
SCL Clock High Time	t_w(SCLH)	4.0		0.6		μs
SDA Setup Time	t_{su}(SDA)	250		100		ns
SDA Data Hold Time	t_h(SDA)		3.45		0.9	μs
SDA and SCL Rise Time	t_r(SDA), t_r(SCL)		1000		300	ns
SDA and SCL Fall Time	t_f(SDA), t_f(SCL)		300		300	ns
START Condition Hold Time	t_h(ST)	4.0		0.6		μs
REPEATED START Condition Setup Time	t_{su}(SR)	4.7		0.6		μs
STOP Condition Setup Time	t_{su}(SP)	4.0		0.6		μs
Bus Free Time Between STOP and START Condition	t_w(SP:ST)	4.7		1.3		μs

Table 10: I²C Communication Electrical Parameters

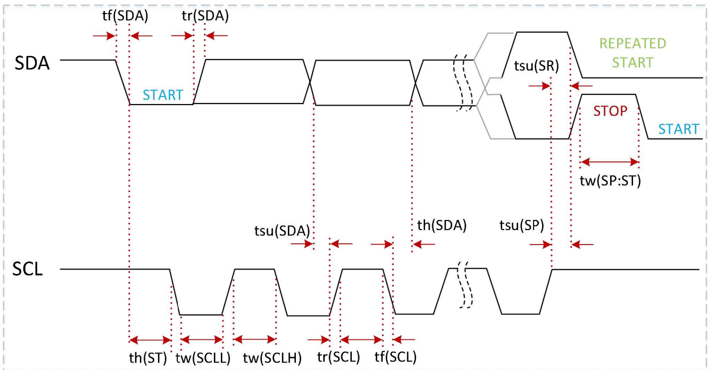


Figure 37: I²C Timing Diagram

14 Special Pin Descriptions

INT Pin

When the host sends a continuous sensing mode or single conversion mode command to the chip, the INT pin will be set to 1 after the chip completes the corresponding measurement item. The INT pin remains high until the host sends a read command and reads back the measurement data. When the chip is in continuous sensing mode, if the INT pin is high, it indicates that the chip has completed the measurement of the selected item, and the measurement data can be read back. If the host sends a data readback command to the chip, the INT pin will be pulled low. Otherwise, the INT pin will remain high for a certain period of time until the chip starts the next measurement. This high level holding time is related to the setting of the register 0x1D, measTime. When the chip starts the next measurement of the selected item, the INT pin will remain low. After completing this measurement, the INT pin will be set to

1. When the chip is in continuous sensing mode, the measurement data readback must be used with the INT pin.

After the host sends the wake-up sleep mode command to the chip, if the change in the measurement item around the chip exceeds the change threshold set in the register, the INT pin will be set to 1 and will remain high until the host sends a read command and reads back the measurement data.

BUTT_OUT/TRIG Pin

When the host configures this pin as a button output pin (trigPushSel = 1), if the chip detects that the magnetic field of the selected plane increases and exceeds the set threshold, the BUTT_OUT/TRIG pin will be set to 1. It should be noted that this function detects the magnetic field of the selected plane. When sending the measurement command, the corresponding two axes of the selected plane need to be selected. For example, if the XY plane magnetic induction intensity change is to be detected, both the X and Y axes need to be selected.

When the host configures this pin as a single conversion trigger pin (trigPushSel = 0, extTrig = 1), and the host sends a high pulse to the BUTT_OUT/TRIG pin, the chip will perform a single conversion, equivalent to the host sending a single conversion command to the chip. This pin should not be left floating and needs to be kept low after the external trigger is completed.

15 Register Read/Write Descriptions

Upon power-up, the chip performs internal initialization. Once the power supply stabilizes, the values from the OTP are read into the corresponding registers. The OTP reading is completed within 4 ms after power-up. Communication is not allowed within these 4 ms. After initialization is complete, the chip enters idle mode, and communication and measurement are allowed.

When reading or writing registers, the register address should be left-shifted by two bits, as shown in the figure.

15.1 SPI Communication

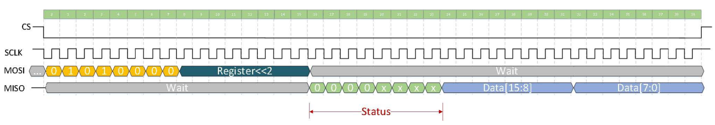


Figure 38: Register Read SPI Timing Diagram

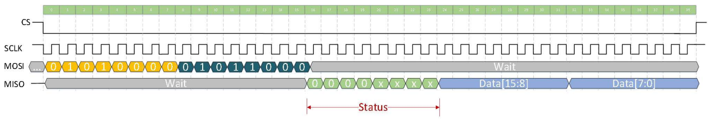


Figure 39: Register Read 0x16 SPI Timing Diagram

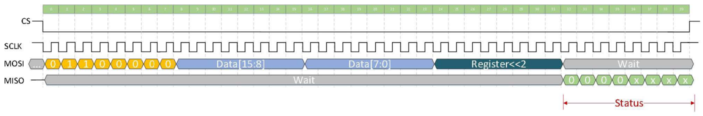


Figure 40: Register Write SPI Timing Diagram

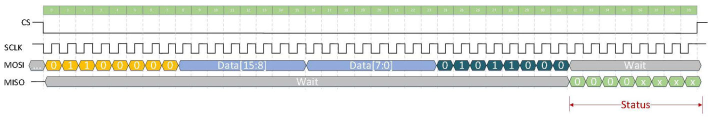
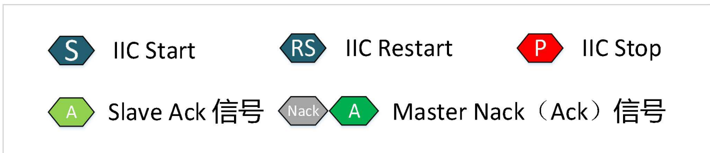


Figure 41: Register Write 0x16 SPI Timing Diagram

15.2 I²C Communication



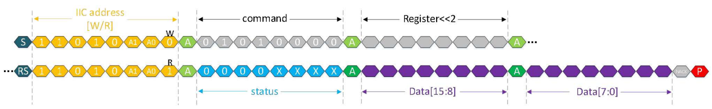


Figure 42: Register Read I²C Timing Diagram

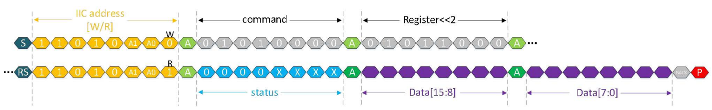


Figure 43: Register Read 0x16 I²C Timing Diagram

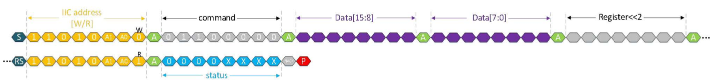


Figure 44: Register Write I²C Timing Diagram

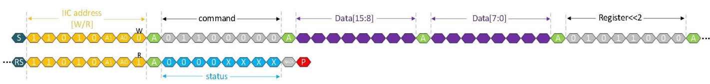


Figure 45: Register Write 0x16 I²C Timing Diagram

16 OTP Programming

The KTH5701 series sensor includes One-Time Programmable (OTP) memory, which allows the user to program certain configuration parameters permanently. This section describes the OTP programming procedure, the precautions to be taken, and the methods for verifying the programmed values.

The programming process takes approximately 1.6 ms to write to a single address. Only one address can be programmed at a time. The following steps outline the OTP programming procedure at a room temperature of $25°$C:

16.1 Programming Procedure

1. **Preparation:** Ensure the power supply is stable and the environment is free from electrical noise. Connect the sensor to the programming interface.
2. **Power Supply:**
   - V_{DD} supply: $5.5 \sim 5.7$ V
   - V_{DDIO} supply: 3.3 V
3. **Step 1:** Write $0x3337$ to register address 12.
4. **Step 2:** Write the value to be programmed to register address 11 (e.g., to write $0xFFFF$ to register address 25, write $0xFFFF$ to register address 11).
5. **Step 3:** Write $0x43$ to register address 9 to set the programming current.
6. **Step 4:** Write the address to be programmed to register address 10 (e.g., to write $0xFFFF$ to register address 25, write 25 to register address 10).
7. **Step 5:** Write $0x0001$ to register address 8 to start programming.
8. **Step 6:** The programming time is approximately 1.6 ms. After programming is complete, proceed to the next step. If no further programming is needed, clear the values in registers 9 to 12 to prevent accidental programming.

16.2 Verification Procedure

To verify whether the programming was successful, follow these steps:

1. **Step 1:** Write $0x3337$ to register address 12.
2. **Step 2:** Write $0x50$ to register address 9.
3. **Step 3:** Write $0x01$ to register address 7.
4. **Step 4:** Read back the programmed value from the target register and confirm whether the programming was successful.

16.3 Precautions

- **Stable Power Supply:** Ensure the power supply is stable and within the specified voltage range during the entire programming process.
- **Environmental Conditions:** Perform OTP programming in a noise-free environment to avoid data corruption.
- **Verification:** Always verify the programmed values before finalizing the OTP programming to ensure accuracy.
- **Irreversible Process:** OTP programming is irreversible. Ensure that the correct values are being programmed as changes cannot be made once the programming is finalized.

17 Package Dimensions

17.1 QFN3×3-16L Package

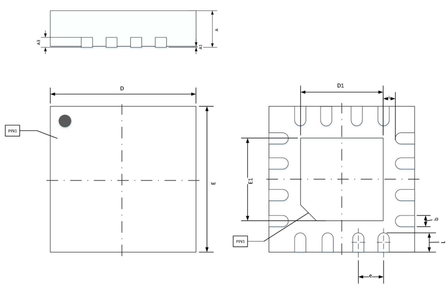
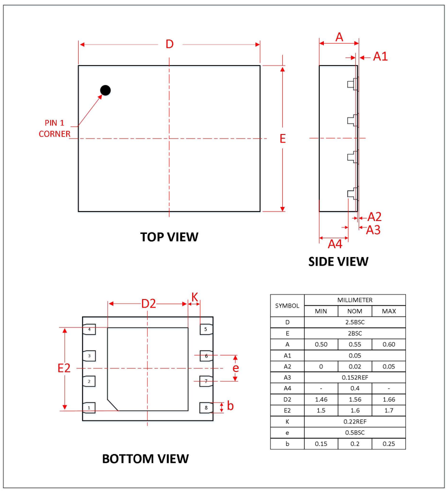


Figure 46: QFN3×3-16L Package Dimensions

Identifier	Min	Max	Unit
A	0.700	0.800	mm
A1	0.000	0.050	mm
A3	0.203		mm
D	2.900	3.100	mm
E	2.900	3.100	mm
D1	1.350	1.550	mm
E1	1.350	1.550	mm
k	0.375		mm
b	0.200	0.300	mm
e	0.500		mm
l	0.300	0.500	mm

Table 11: QFN3×3-16L Package Dimensions

17.2 DFN2×2.5-8L Package



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
D	2.5BSC		
E	2BSC		
A	0.50	0.55	0.60
A1	0.05		
A2	0	0.02	0.05
A3	0.152REF		
A4	-	0.4	-
D2	1.46	1.56	1.66
E2	1.5	1.6	1.7
K	0.22REF		
e	0.5BSC		
b	0.15	0.2	0.25

Figure 47: DFN2×2.5-8L Package Dimensions

18 Reference Circuits

Note: To ensure communication stability, it is essential to use a combination of $0.1\,\mu$F and $10\,\mu$F capacitors, and the capacitors should be as close to the chip's VDD as possible. The A0 and A1 pins must be properly connected according to the application requirements.

18.1 QFN3×3-16L Package SPI Communication

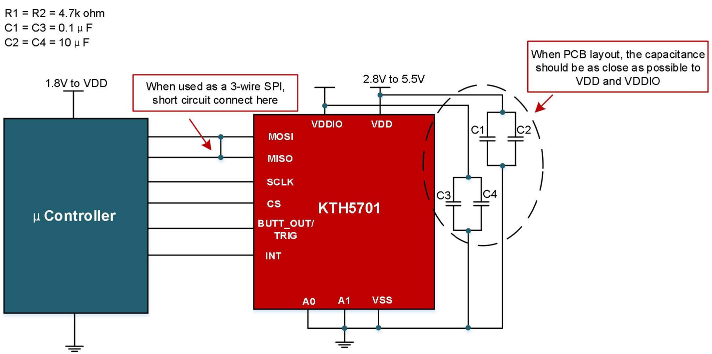


Figure 48: QFN3×3-16L SPI Communication Reference Circuit

18.2 QFN3×3-16L Package I2C Communication

Note: The I2C communication also requires careful placement of the $0.1\,\mu$F and $10\,\mu$F capacitors close to the VDD pin for stability.

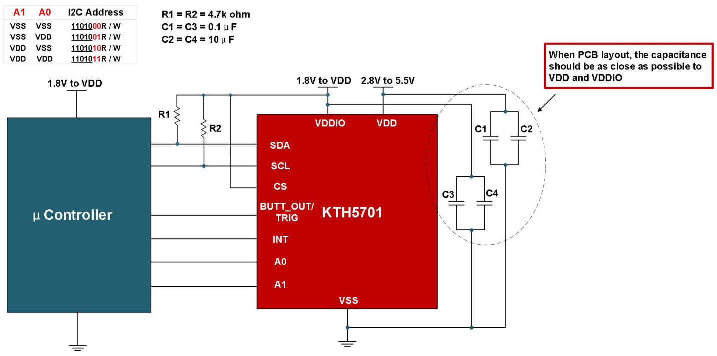


Figure 49: QFN3×3-16L I2C Communication Reference Circuit

18.3 DFN2×2.5-8L Package I2C Communication

Note: Ensure that the capacitors and resistors are placed as close to the chip as possible to minimize noise and ensure signal integrity.

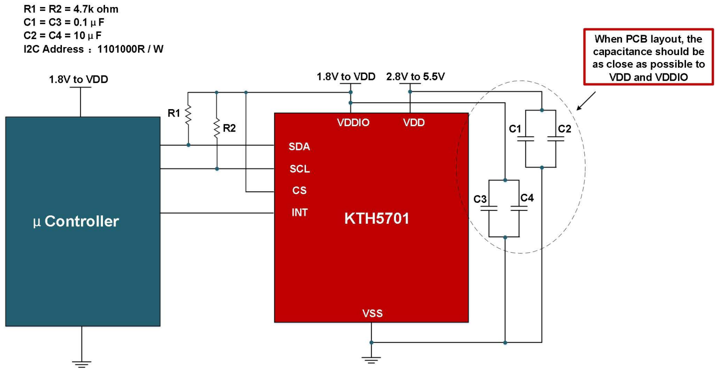


Figure 50: DFN2×2.5-8L I2C Communication Reference Circuit

19 Ordering Information

Model Number	Package Type	Operating Temperature	Application Scenario	Number of Pins
KTH5701AQ2QNS	QFN 3×3-16L	$-40°C \sim +105°C$	Industrial	16
KTH5701AQ3QNS	QFN 3×3-16L	$-40°C \sim +85°C$	Consumer	16
KTH5701AQ2DNE	DFN 2×2.5-8L	$-40°C \sim +105°C$	Industrial	8
KTH5701AQ3DNE	DFN 2×2.5-8L	$-40°C \sim +85°C$	Consumer	8

Table 12: Ordering Information for KTH5701 Series

20 Tape and Reel Information

20.1 QFN3×3-16L

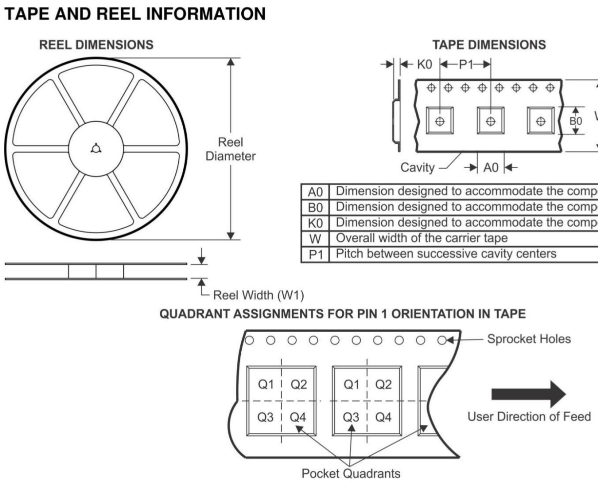


Figure 51: QFN3×3-16L Tape and Reel Diagram

Package Type	Pins	SPQ	Reel Diameter	Reel Inner Width	A_0	B_0	K_0	P_1	W	Pin1 Direction
QFN3×3-16L	16	5000	330	12.4	3.35	3.35	1.13	8.00	12.00	Q1

Table 13: QFN3×3-16L Tape and Reel Information, dimension unit in millimeter

20.2 DFN2×2.5-8L

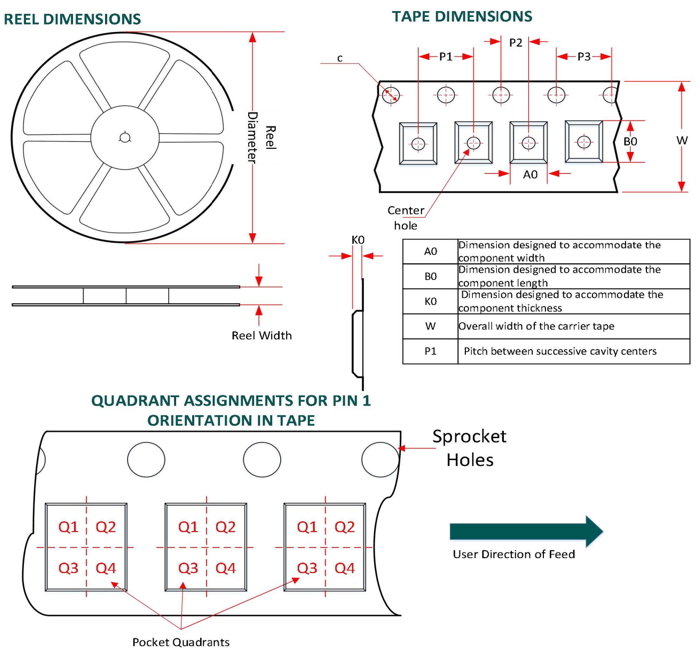


Figure 52: DFN2×2.5-8L Tape and Reel Diagram

Package Type	Pins	SPQ	Reel Diameter	Reel Inner Width	A_0	B_0	K_0	P_1	P_2	P_3	W	Pin1 Direction
DFN2×2.5-8L	8	4000	180	9.5	2.25	2.75	0.70	4.00	2.00	4.00	8.00	Q2

Table 14: DFN2×2.5-8L Tape and Reel Information, dimension unit in millimeter