KTH7801

16-bit Programmable non-contact Hall magnetic encoders with ABZ and PWM outputs

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1 Product Factsheet

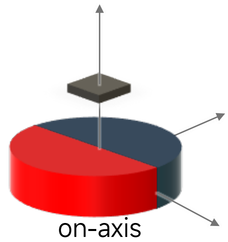
Features

- 16-bit resolution absolute angle output
- High precision (< ±0.35° accuracy error)
- Suitable for on-axis and off-axis non-contact scenarios
- Ultra-low latency (1 µs data updates)
- SPI communication: angle reading, register read / write
- SSI communication: angle reading
- Programmable 4-4096 steps / turn ABZ output
- PWM 14-bit angle output
- AEC-Q100 standard qualified
- Built-in programmable memory (MTP)
- Magnetic field strength diagnosis / alarm
- Operating voltage: 3.3V to 5V
- Operating temperature range: -40°C to 125°C
- QFN-16L package: 3mm × 3mm and SOP-8 4.9mm × 6mm

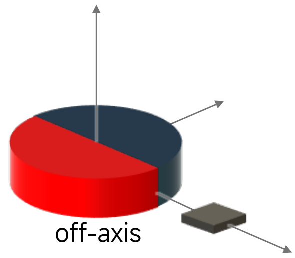
Presentation

The KTH7801 is a high-precision absolute angle Hall sensor chip offering up to 16-bit resolution for accurate angle measurements in both on-axis and off-axis configurations. Capable of handling rotational speeds ranging from 0 to 120,000 rpm, the KTH7801 ensures rapid and precise angle output, making it a robust choice for applications requiring accurate angle measurement and speed control.

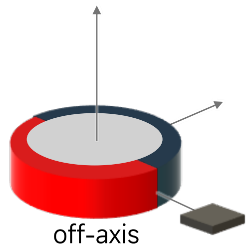
The KTH7801 provides multiple flexible angle output modes to meet diverse application needs. First, it supports a programmable ABZ quadrature pulse output with up to 4096 steps per revolution, delivering high-resolution position data. Additionally, the 4-wire SPI interface facilitates efficient angle reading and device communication. The KTH7801 also supports a 2-wire SSI output, simplifying system design and integration.



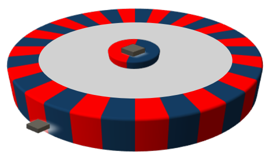
on-axis



off-axis



off-axis



multi-pole

Typical Applications

- Absolute position sensor
- Brushless DC motor
- Off-axis angle measurement
- Automotive Angle Control
- Closed-Loop Stepper Motor
- Barrier gates

To further enhance its practical application, the KTH7801 features built-in magnetic field strength detection. Users can program high and low magnetic field thresholds, enabling real-time monitoring and adjustment. This functionality helps to select the optimal magnet and determine the appropriate installation setup, ensuring stable operation.

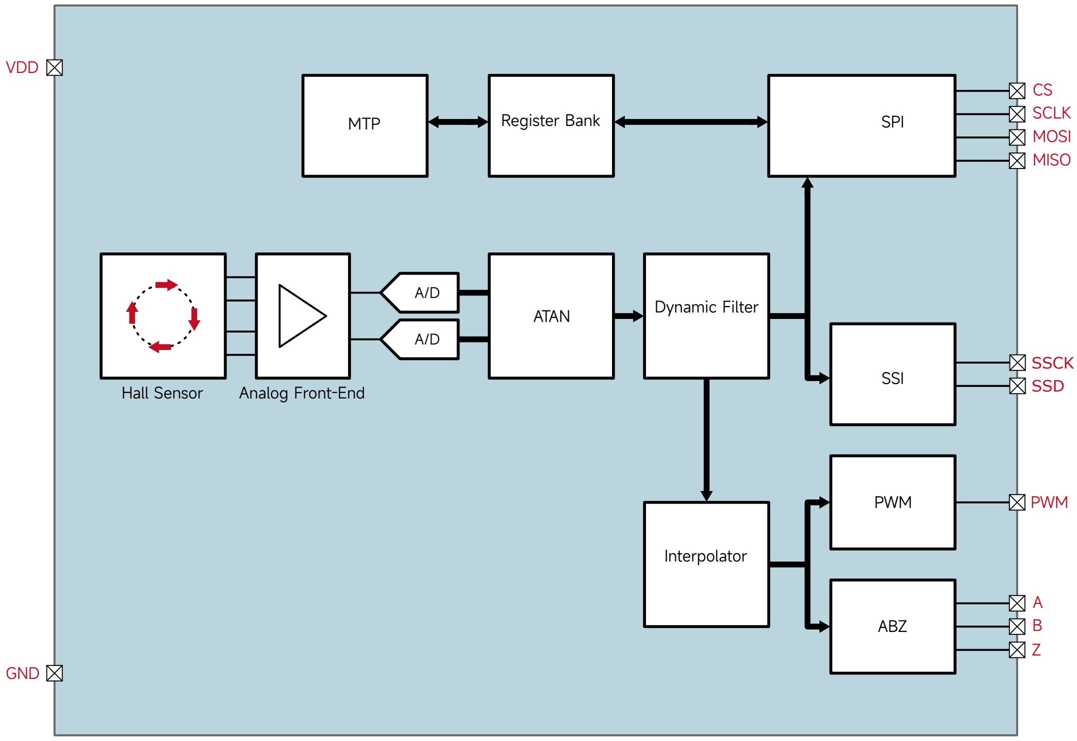
Moreover, the KTH7801 incorporates Memory-Programmable Technology (MPT) to store critical configuration parameters. Users can save settings such as the zero-angle position, ABZ encoder configurations, and magnetic field detection thresholds, allowing for adaptable performance across various operational environments.

In summary, the KTH7801 is engineered to provide versatility, accuracy, and adaptability, making it a reliable solution for a wide range of angle measurement and control applications.

2 Overview

2.1 System Architecture

Figure 1: Top diagram



The KTH7801 is a Hall angle encoder that integrates Hall elements, analog-to-digital converters (ADC), and various modules for precise angle measurement and digital signal output.

The Hall element in the encoder generates voltage signals, which are converted into two orthogonal digital signals through the ADC. These signals are then processed by the ATAN module to obtain a 16-bit digital angle. The digital angle is further adjusted through zero-point setting, rotation direction setting, and filtering.

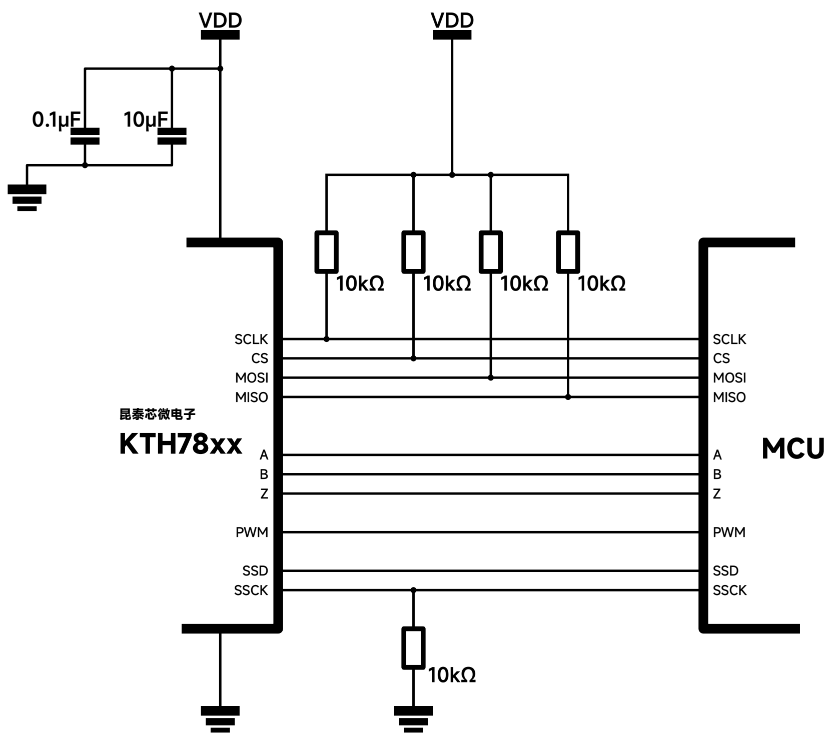
The encoder's output interface can directly provide the filtered angle data through SPI and SSI communication, allowing the user to read it directly using an MCU or other circuits. Additionally, the angle can also be represented through PWM modulation, with the angle value reflected by the duty cycle.

To enhance the update rate, the filtered angle can be further processed by an interpolator and output to the ABZ angle encoder module, converting the angle into the desired encoded signal.

Moreover, various operating parameters of the system are stored in a multi-time programmable (MTP) memory, which can be modified through SPI commands to meet different application requirements.

2.2 Recommended Application Circuit

Figure 2: Recommended Application Circuit



Note: The pull-up and pull-down resistors shown in the diagram can be optionally added or removed by the user. For automotive applications, it is recommended to add a TVS diode to the power supply to protect the circuit from transient high-voltage spikes.

2.3 Pin Definitions

Figure 3: QFN-16L 3mmx3mm

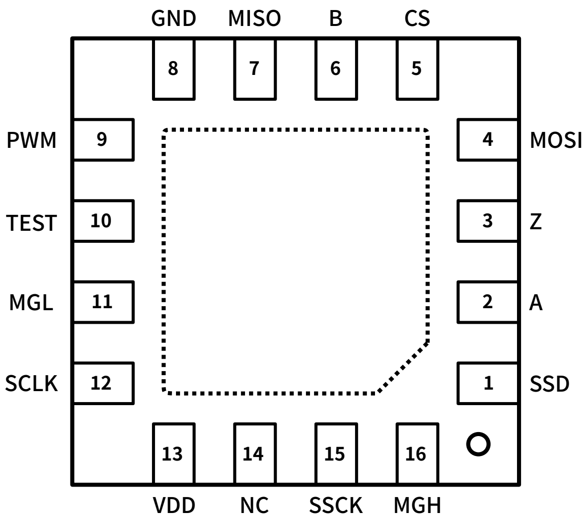


Table 1: Pin Functions

N.	Name	Function
1	SSD	SSI Data Output
2	A	One of the ABZ incremental output signals
3	Z	One of the ABZ incremental output signals
4	MOSI	SPI Master Data Output (pull-up to VDD if not used)
5	CS	SPI Chip Select (pull-up to VDD if not used)
6	B	One of the ABZ incremental coding signals
7	MISO	SPI Slave Data Output
8	GND	Ground
9	PWM	Pulse Width Modulation
10	TEST	Factory Testing (pull-down to GND)
11	MGL	Low Magnetic Field Strength
12	SCLK	SPI Clock (pull-up to VDD if not used)
13	VDD	Power Supply Input
14	NC	Not Connected
15	SSCK	SSI Data Clock Input (pull-down to GND if not used)
16	MGH	High Magnetic Field Strength

Figure 4: SOP-8 4.9mmx6mm

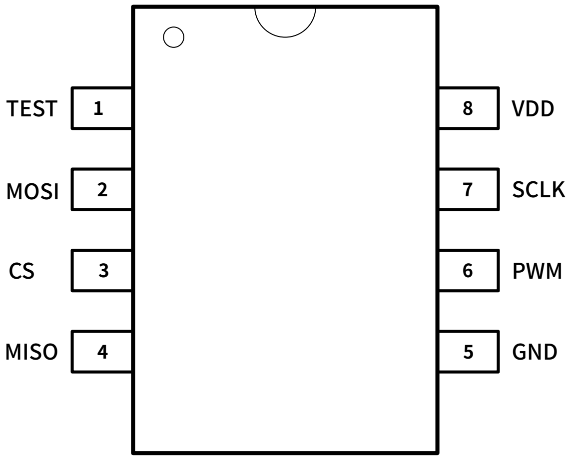


Table 2: Pin Functions

Num.	Name	Function
1	TEST	TEST pin floating during operation
2	MOSI	SPI Master Data Output (pull-up to VDD if not used)
3	CS	SPI Chip Select (pull-up to VDD if not used)
4	MISO	SPI Slave Data Output
5	GND	Ground
6	PWM	Pulse Width Modulation
7	SCLK	SPI Clock (pull-up to VDD if not used)
8	VDD	Power Supply Input

For the KTH7801 product utilizing a QFN-16L 3x3mm package, it is mandatory to directly connect the TEST pin to the Ground (GND).

Conversely, for the KTH7801 product with a SOP-8 4.9mm×6mm package, the TEST pin should be left floating during operation.

The KTH7801 product is available in two package formats: QFN-16L and SOP-8, with pin definitions as described above. Due to the reduced pin count in the SOP-8 package, the number of output signals is correspondingly reduced.

The KTH7801 offers a wide range of pin functionalities, including ABZ-encoded incremental output, Pulse Width Modulation (PWM) output, as well as SSI and SPI communication capabilities.

2.4 16-bit Binary Encoding of Angles

The KTH7801 encoder represents angle values using a 16-bit binary encoding scheme. By converting angle values into a 16-bit binary form, precise representation of angles can be achieved. For instance, angle values can be expressed as integers in binary form, ranging from 0 to 65535. In general, the angles discussed in this document are represented using 16-bit binary encoding.

The relationship between the 16-bit binary value and the corresponding angle output (ranging from 0° to 360°) can be expressed mathematically as:

$$\text{Angle Output (0° to 360°)} = \frac{\text{16-bit binary value}}{2^{16}} \times 360 \quad (1)$$

Equation 1 demonstrates how the 16-bit binary value can be converted to its corresponding angle output. The division by 2^{16} normalizes the binary value to a range between 0 and 1, which is then multiplied by 360 to obtain the angle output in degrees. This encoding scheme allows for accurate representation and measurement of angles using the KTH7801 encoder.

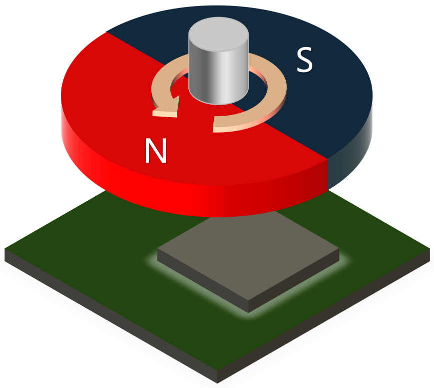
2.5 On-Axis Magnet Installation Recommendation

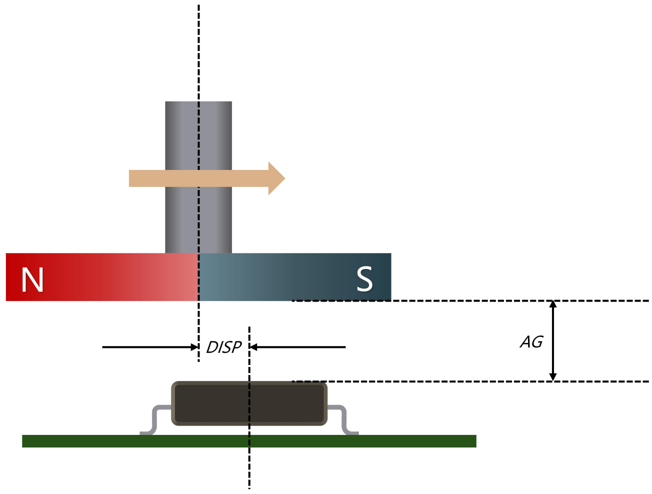
Table 3: On-Axis Magnet Installation Recommendation

Para.	Description	Min	Typ.	Max	Unit
D_{mag}	Radial Magnet Diameter		10	30	mm
T_{mag}	Recommended Magnet Thickness		2.5	5	mm
B_{pk}	Chip Operating Magnetic Field	30		150	mT
AG	Air Gap		1.0	5.0	mm
RS	Rotational Speed			120	krpm
$DISP$	Installation Deviation		0.3	1.0	mm
TC_{mag1}	Temperature Coefficient of NdFeB Magnet		-0.120		%/°C
TC_{mag2}	Temperature Coefficient of SmCo Magnet		-0.035		%/°C

Note: It is recommended to use NdFeB or SmCo magnets.

Figure 5: On-Axis Magnet Chip Placement





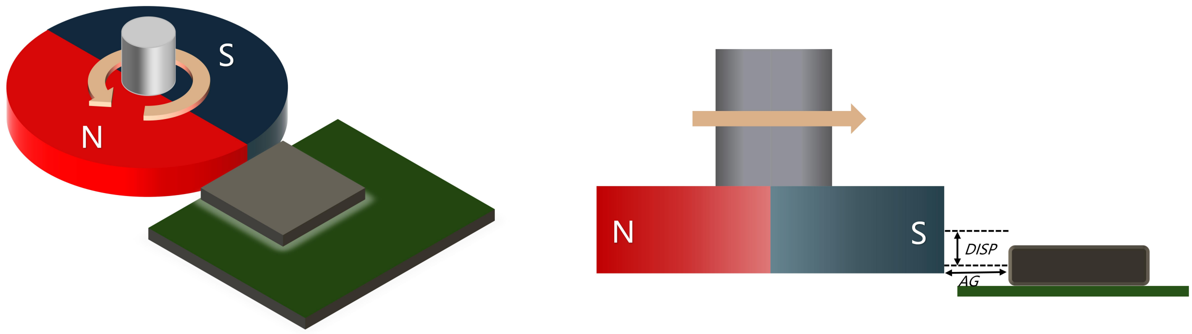
2.6 Off-Axis Magnet Installation Recommendation

Table 4: Off-Axis Magnet Installation Recommendation

Para.	Description	Min	Typ.	Max	Unit
D_{mag}	Radial Magnet or Magnetic Ring Diameter		10	30	mm
T_{mag}	Recommended Magnet Thickness		2.5	5	mm
B_{pk}	Chip Operating Magnetic Field	30		150	mT
AG	Air Gap		0.5	5	mm
RS	Rotational Speed			120	krpm
$DISP$	Installation Deviation		0.5	2	mm

Note: It is recommended to use NdFeB or SmCo magnets.

Figure 6: Off-Axis Magnet Chip Placement



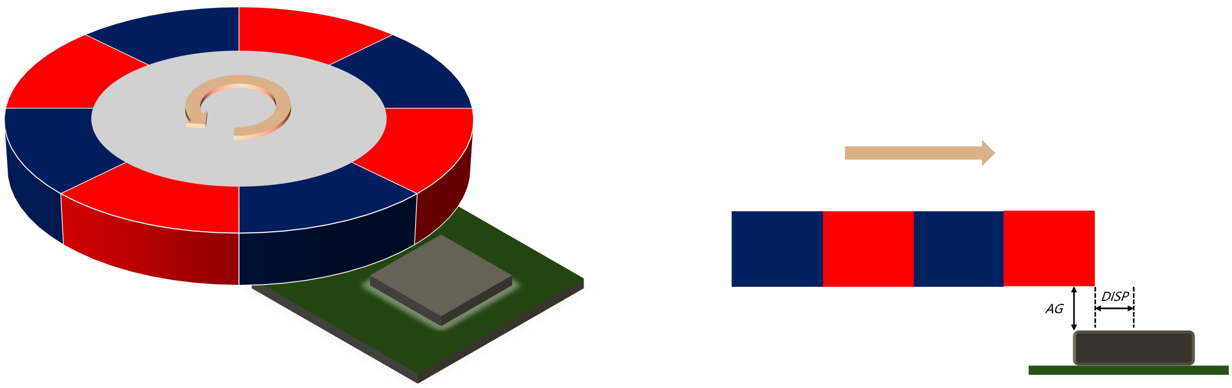
2.7 Multi-Pole Magnet Installation Recommendation

Table 5: Multi-Pole Magnet Installation Recommendation

Para.	Description	Min	Typ.	Max	Unit
W_{mag}	Multi-Pole Magnet Pole Width (Single Pole Width)	2		10	mm
T_{mag}	Recommended Magnet Thickness		2	5	mm
B_{pk}	Chip Operating Magnetic Field	30		150	mT
AG	Air Gap		0.5	3	mm
RS	Rotational Speed			120	krpm
$DISP$	Distance Between Chip Center and Magnet Edge	0.8	1.0	5.0	mm

Note: It is recommended to use NdFeB or SmCo magnets. In multi-pole applications, there is no restriction on the magnetic ring diameter. Due to the complexity, it is advisable to consult our FAE team for magnetic field simulation to find the optimal placement.

Figure 7: Multi-Pole Magnet Chip Placement



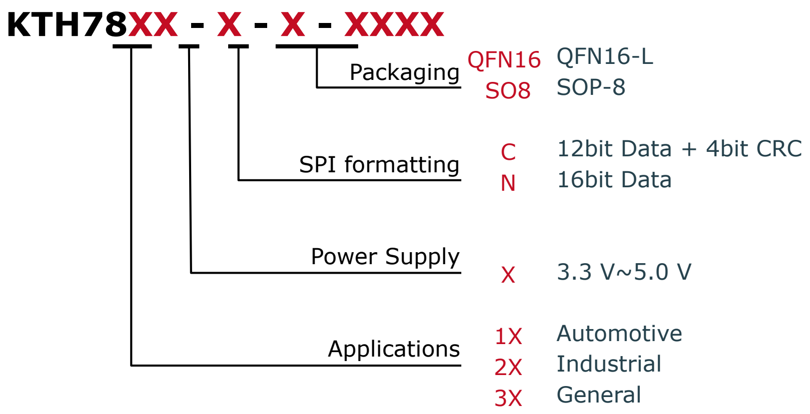
2.8 Register Configuration

Address	7 (MSB)	6	5	4	3	2	1	0 (LSB)
0x00	Z(7:0)							
0x01	Z(15:8)							
0x02	GAINtrim(7:0)							
0x03							Ytrim	Xtrim
0x04	PPT(1:0)		ZL(1:0)		ZD(1:0)			
0x05	PPT(9:2)							
0x06	mgh(2:0)			mgl(2:0)				
0x07	NPP(2:0)							
0x08	ABZ_LIMIT(2:0)							
0x09	RD							

Table 6: Parameter Description

Symbol	Default Value (Decimal)	Name	Description
ABZ_LIMIT(2:0)	0	ABZ Output Bandwidth, Default Maximum Frequency 16MHz	Section 7.1 ABZ Output Resolution
GAINtrim(7:0)	2	Sensitivity Modulation Coefficient	Section 9.4 Sensor Off-Axis Application Calibration
Xtrim	0	Reduce X-Axis Hall Sensitivity	Section 9.4 Sensor Off-Axis Application Calibration
Ytrim	1	Reduce Y-Axis Hall Sensitivity	Section 9.4 Sensor Off-Axis Application Calibration
mgh(2:0)	7	Magnetic Field High Alarm Threshold, Default Max Value Alarm	Section 9.3 Threshold Detection Settings
mgl(2:0)	0	Magnetic Field Low Alarm Threshold, Default Min Value Alarm	Section 9.3 Threshold Detection Settings
PPT(9:0)	1023	ABZ Resolution, Default 1024 Lines, 4096 Steps/Turn	Section 7.1 ABZ Output Resolution
RD	1	Rotation Direction Setting, Default Forward Rotation as 1	Section 9.3 Threshold Detection Settings
Z(15:0)	0	Zero Position Setting, Default is 0	Section 9.2 Zero Point Setting
ZL(1:0)	0	Z Signal Width of ABZ, Default is 0	Section 7.3 Zero Index Signal Z
ZD(1:0)	0	Z Signal Phase of ABZ, Default is 0	Section 7.3 Zero Index Signal Z

3 Product model number composition



4 Key Parameters

Table 7: Key Specifications @3.3V Supply

Parameter	Minimum	Typical	Maximum
Operating Voltage	3.0V	3.3V	3.6V
Magnetic Field Strength	30mT	60mT	150mT
Operating Current		11.6mA	
Start-up Time		1ms	
Latency Time		1us	
Output Noise (1 sigma)		0.015°	
Temperature Drift		0.002° / °C	
Nonlinearity Error		±0.35°	
Rotational Speed			120000rpm
ESD (HBM)		±5KV	

Table 8: Key Specifications @5V Supply

Parameter	Minimum	Typical	Maximum
Operating Voltage	4.5V	5V	5.5V
Magnetic Field Strength	30mT	60mT	150mT
Operating Current		13.6mA	
Start-up Time		1ms	
Latency Time		1us	
Output Noise (1 sigma)		0.015°	
Temperature Drift		0.002° / °C	
Nonlinearity Error		±0.35°	
Rotational Speed			120000rpm
ESD (HBM)		±5KV	

5 SPI

The KTH7801 product uses an SPI interface to achieve reliable and efficient data communication between the microcontroller and peripherals. The SPI communication operates in mode 3 (CPOL = 1 and CPHA = 1), supporting functions such as reading the angle, reading configuration registers, and writing to configuration registers.

5.1 SPI timing

Figure 8: SPI Timing Diagram

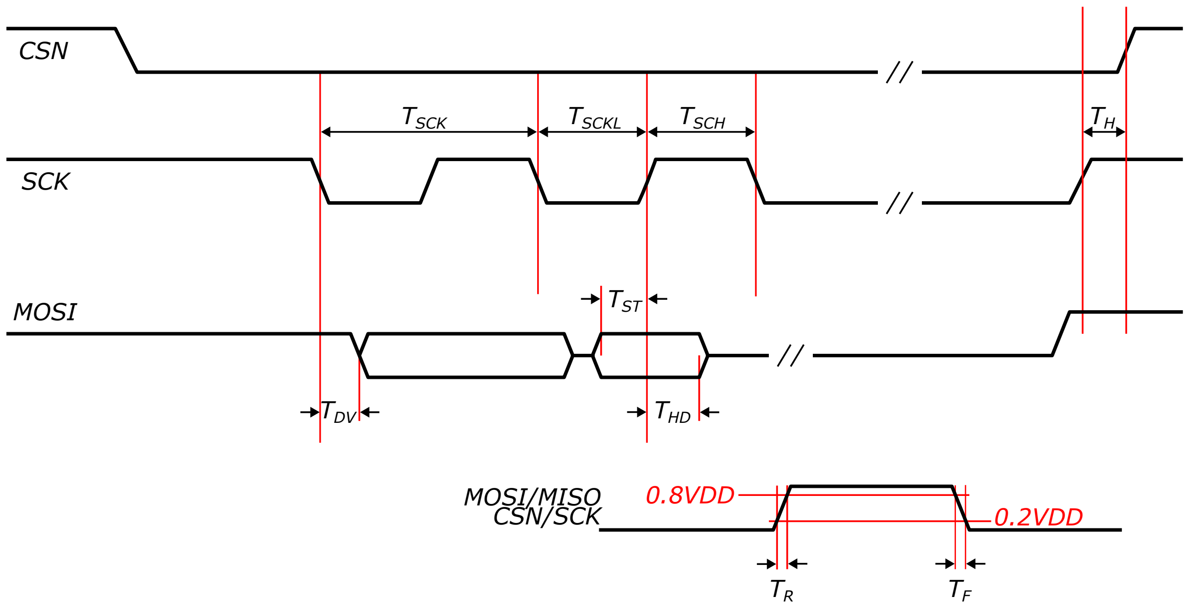


Figure 8 presents an SPI timing diagram, while Table 9 provides detailed information on the SPI timing parameters of the KTH7801 product under a 20pF load condition. This table includes symbols, descriptions, and the minimum, typical, and maximum values for each parameter, expressed in nanoseconds (ns). These parameters play a crucial role in defining the timing requirements for SPI communication, ensuring dependable data transfer between microcontrollers and peripheral devices when utilizing the KTH7801 product.

Table 9: SPI Timing Parameters (with 20pF Load Condition)

Symbol	Description	Min. Value	Typical Value	Max. Value	Unit
T_{SCK}	SCK Clock Period	100			ns
T_{SCKL}	Low Period of SCK Clock	50			ns
T_{SCKH}	High Period of SCK Clock	50			ns
T_H	Time interval between SCK and CSN rising edges	120			ns
T_R	Rise Time of Digital signal		10		ns
T_F	Fall Time of Digital signal		10		ns
T_{DV}	Data Valid Time of MISO			50	ns
T_{ST}	Setup Time of MOSI Data	50			ns
T_{HD}	Hold time of MOSI Data	50			ns

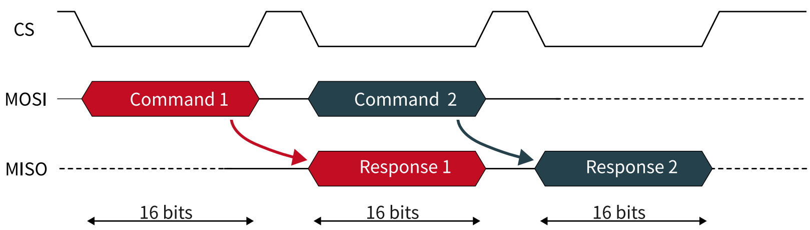
The KTH7801 product employs the SPI interface, operating in CPOL = 1 and CPHA = 1 mode, to facilitate communication between microcontrollers and peripheral devices. Conforming to the SPI international standard, the interface incorporates four lines: SCK, MOSI, MISO, and CSN. Data transmission occurs through fixed-length 16-bit packets.

The SPI timing parameter table serves as a valuable resource for comprehending the correct utilization and debugging of hardware and firmware designs pertaining to the SPI interface. Adhering to these timing parameters is critical to ensuring reliable data communication through meticulous hardware and firmware design.

All aforementioned SPI parameters are implemented in the provided hardware and firmware, allowing users to configure and optimize them based on their specific application requirements. Our technical support team is readily available to assist users with any challenges encountered during usage.

In summary, the SPI interface of the KTH7801 product is a robust and versatile communication tool, suitable for a wide range of microcontrollers and peripheral devices. By comprehending and effectively employing these SPI timing parameters, users can maximize the product's performance and fulfill their specific application needs.

Figure 9: SPI Command-Response Overlapped Structure



SPI communication adopts an overlapped structure that allows the transmission of a response from the previous command while sending the next command. Figure 9 illustrates an example of a single-device setup, where the host controls a KTH7801 slave device.

5.2 Reading Registers via SPI

opcode		address						null							
0	1	ADR[5:0]						0	0	0	0	0	0	0	0
15 MSB	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0 LSB

The operation of reading registers involves two 16-bit frames.

The first frame is the write request frame, comprising a 2-bit write command, a 6-bit register address, and 8 bits of zero padding. The second frame is the returned register value, formatted as $XXXX - XXXX - 0000 - 0000$.

The table above presents the instruction format for this operation. Starting from the most significant bit (MSB), the first 2 bits represent the opcode, the operation code of the instruction. The subsequent 6 bits denote the address, specifying the register's location. The remaining blank section represents invalid bits, padded with zeros.

5.3 Register Writing via SPI

opcode		address						written word							
1	0	ADR[5:0]						WRD[7:0]							
15 MSB	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0 LSB

The KTH7801 chip provides the capability to write to registers via the SPI bus. Registers are programmable 8-bit storage units used to store specific configuration and control parameters, allowing customization of the chip's behavior and functionality.

The process of writing to registers via SPI involves two 16-bit frames. The first frame is the write request frame, consisting of a 2-bit write command (10), followed by a 6-bit register address and an 8-bit value. The write command instructs the chip to perform the write operation, the register address specifies which register to write to, and the value represents the data to be written. Data transmission starts from the Most Significant Bit (MSB).

The second frame is the returned acknowledgment frame, containing the value of the newly written register. The frame format is $XXXX - XXXX - 0000 - 0000$. This acknowledgment frame serves as a response from the chip, confirming the successful writing of data into the register.

During the process of writing to registers via SPI, it is important to note that a minimum wait time of 20 milliseconds between the first frame and the second frame is required. This wait time ensures that the written data is correctly stored in the chip's non-volatile memory. Failing to wait for an adequate amount of time after the write request may result in reading the previous value of the register. Therefore, it is crucial to adhere to this wait time when performing register writing operations.

It is worth mentioning that this wait time is applicable only to write operations. For read register or read angle operations, no wait time is required.

The register values of the KTH7801 chip are automatically loaded during power-up as they are stored in the chip's non-volatile memory. This means that even after a power loss and subsequent power-up, the configuration and control parameters stored in the registers will remain unchanged without the need for reconfiguration.

To ensure long-term stability and reliability of the registers, the memory design of the KTH7801 chip is carefully engineered to withstand 1,000 write cycles and maintain reliable operation even in environments with a temperature of up to 125°C.

By utilizing register writing via SPI, you can easily configure and fine-tune various functionalities and behaviors of the KTH7801 chip to meet your specific requirements.

5.4 Read Absolute Angle via SPI

When using SPI for reading the absolute angle from the KTH7801 angle sensor, the following general steps and principles are involved:

(1) Set Communication Parameters: First, ensure that the SPI communication parameters between the master device and the KTH7801 angle sensor are configured consistently.

This includes parameters such as clock frequency, data width, and other relevant settings.

(2) Trigger Read Operation: The master device initiates the read operation by pulling the chip select (CS) signal low and sending the appropriate read position command via MOSI. Pulling the chip select signal low signals the sensor to prepare for data transmission to the output buffer.

(3) Data Transmission and Reception Process: Every microsecond, a new data bit is transmitted to the output buffer. The sensor sends the data bit to the master device serially through the MISO pin. The master device controls the data reception by utilizing the clock signal, ensuring the accurate reception of each data bit.

(4) Angle Value Interpretation: Once the master device sends a sufficient number of clock counts, the KTH7801 sensor responds and provides angle data. By interpreting the received data, the corresponding absolute angle value can be obtained.

During the transmission process, it is recommended to keep the MOSI line at a low logic level to prevent interference signals such as 01, 10, and others, which could interrupt the transmission of angle data. This precautionary measure helps to ensure the stability and accuracy of the transmission.

To optimize the angle reading process and ensure that no information is lost, it is possible to reduce the number of clock counts. When a data output length of 12 bits is required, only 12 clock counts are needed to obtain the complete sensor resolution.

If a lower resolution is desired, the angle value can be read by sending fewer clock counts as the most significant bit is transmitted first. This method is known as the fast read mode, where the KTH7801 sensor continuously sends the same data until the data is refreshed. The fast read mode can improve the reading speed.

For a clearer understanding, the following diagram illustrates the process of reading the absolute angle via SPI:

Figure 10: SPI Read Absolute Angle Process

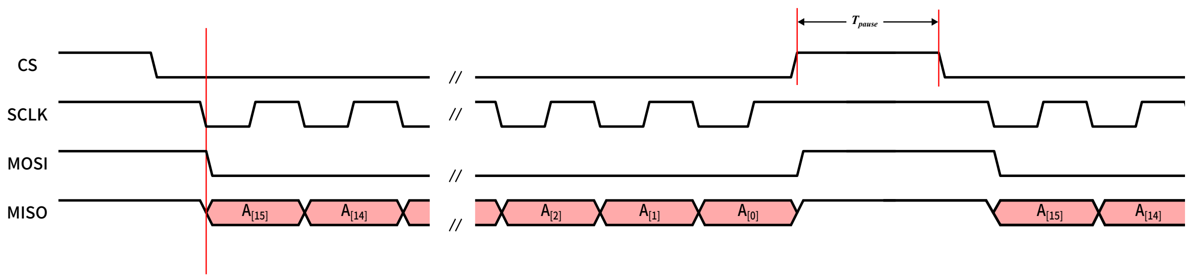
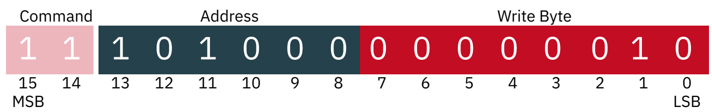


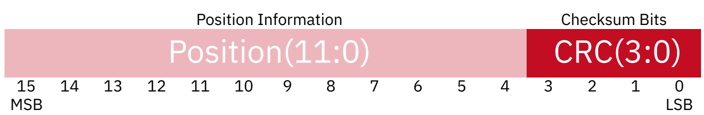
Figure 10 shows the connection between the master device and the KTH7801 angle sensor, illustrating the sequence of data bit transmission and reception. Note: The time interval T_{pause} between two consecutive communications must be greater than 150ns.

5.5 Disabling Register Configuration Functionality



During normal operation, the register configurations are preset, and the chip can be configured via SPI to only allow reading of angle data while blocking any register configuration changes, preventing external interference from affecting the register settings. The KTH7801 provides a WRDIS register, which, when set to 1, disables any register configuration. By sending the command $1110 - 1000 - 0000 - 0010$, the register settings can be locked, and no further read/ write operations on the registers are allowed through SPI. To reconfigure the registers, the chip must be powered off and on again.

5.6 SPI Output CRC Check



If you choose the version of the chip with SPI output and CRC check, by sending the read position command mentioned in the previous section, you can receive SPI output information with a CRC check on the MISO pin. The output frame format is shown above, where the first 12 bits are position data (MSB first), followed by a 4-bit CRC check word. The CRC check follows the CRC-4/ITU standard with a polynomial of $X^4 + X + 1$, an initial value of 00, a final XOR value of 00, input reflected (true), and output reflected (true). For example, if the position data is 0FF and the CRC check value is 2, the received data would be 0FF2. If you need assistance with CRC check code implementation, please contact our FAE team.

6 Angle Reading via SSI

SSI (Synchronous Serial Interface) is a synchronous serial interface protocol used for data transfer between digital systems.

Figure 11: SSI Interface Timing Diagram

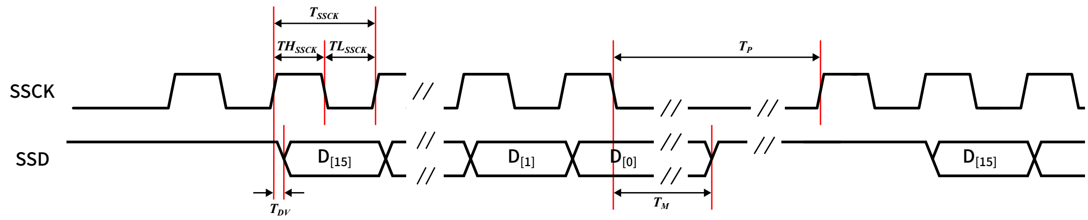


Table 10: SSI Interface Timing Parameters

Symbol	Description	Typical Value	Maximum Value	Unit
t_{DV}	SSD Data Valid Time		15	ns
T_{DV}	SSCK Clock Period	0.66	16	µs
TL_{SSCK}	Low Period of SSCK Clock	0.33	8	µs
TH_{SSCK}	High Period of SSCK Clock	0.33	8	µs
T_M	SSD Monoflop Time	33		µs
T_p	Pause Time	53		µs

Table 10 shows the timing specifications for the SSI interface.

T_M represents the Monoflop Time, also known as the timeout period. It sets a time limit during data transfer to determine the maximum duration of the data transfer. If the data transfer is not completed or does not reach the next state within the specified T_M time, it will be considered a timeout. A timeout may indicate a transfer error or other issues that require appropriate error handling. By properly setting T_M, timely detection and handling of transfer anomalies can be ensured, thereby improving the reliability and stability of the system.

T_P represents the Pause Time, which is the interval during which the system waits after the completion of data transfer before entering the next state. The Pause Time is used to stabilize data transfer, wait for device readiness, or perform other necessary operations. During T_P, the system can perform necessary verification, processing, or preparation work to ensure smooth progress of the next round of transfer. By properly setting T_P, efficient utilization of system resources and good transfer performance can be achieved.

When reading the angle via SSI with the KTH7801 , the data bits are transmitted in a high-order priority. Every microsecond, a new data bit is transferred to the output buffer. The read operation is triggered by raising the SSCK signal. A complete read requires a maximum of 17 clock cycles. The first clock cycle is a virtual clock used to initiate the transfer. The most significant bit of the data is transmitted in the second clock cycle. If the data length is less than 16 bits, the output data is extended to a full 16 bits by padding with zeros. Therefore, angle reading can be done in less than 16 clock cycles. When a trigger event is detected, the data will be held in the output buffer until the falling edge of the LSB bit 0 and the monoflop time have passed.

The KTH7801 operates as a slave device to an external SSI master and supports only angle reading operations. It is not possible to read or write registers via the SSI interface.

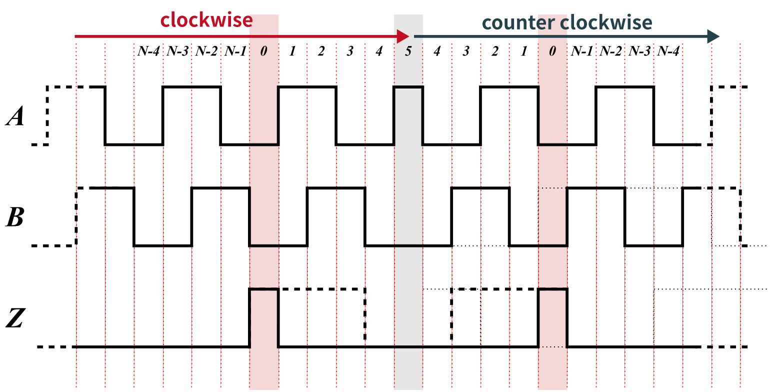
7 ABZ Output

The KTH7801 provides angle position output through the incremental interface ABZ. The ABZ interface is configured with a resolution of 12 bits, which means there are 4096 steps per revolution or 1024 pulse periods per revolution (PPT) for the AB signals.

The phase difference between the A and B signals can indicate the direction of rotation. In the clockwise direction, the A signal leads and the B signal follows, while in the counterclockwise direction, the B signal leads and the A signal follows. During power-up, all three ABZ signals will be held at a high level.

When the magnet located directly above the chip (from a top view perspective) rotates counterclockwise (CCW), the rising edge of the B signal will lead the rising edge of the A signal by 1/4 of a period. Conversely, when rotating clockwise (CW), the rising edge of the A signal will lead the rising edge of the B signal by 1/4 of a period. The phase difference between the A and B signals changes with the direction of rotation of the magnet.

Figure 12: ABZ Output Timing



Register	7 (MSB)	6	5	4	3	2	1	0 (LSB)
0x04	PPT(1:0)		ZL(1:0)		ZD(1:0)			
0x05	PPT(9:2)							
0x08						ABZLIMIT(1:0)		

7.1 ABZ Output Resolution

The KTH7801 's ABZ incremental output can provide angle position output with a customizable integer resolution of up to 1024 pulse periods per revolution (PPT). The resolution can be defined by programming the MTP bits **PPT(9:0)** within the chip. Refer to Table 11 for the corresponding resolutions in pulses per revolution and steps per revolution.

Table 11: ABZ Resolution for PPT

PPT(9:0)	ABZ Resolution Pulses/Turn	ABZ Resolution Steps/Turn
0	1	4
1	2	8
2	3	12
...	...	...
1021	1022	4088
1022	1023	4092
1023	1024	4096

7.2 ABZ Output Frequency Setting

The maximum output frequency for the ABZ output of the KTH7801 is 16 MHz. The highest output frequency can be adjusted by setting the ABZLIMIT parameter. Refer to Table 12 for the corresponding highest output frequencies.

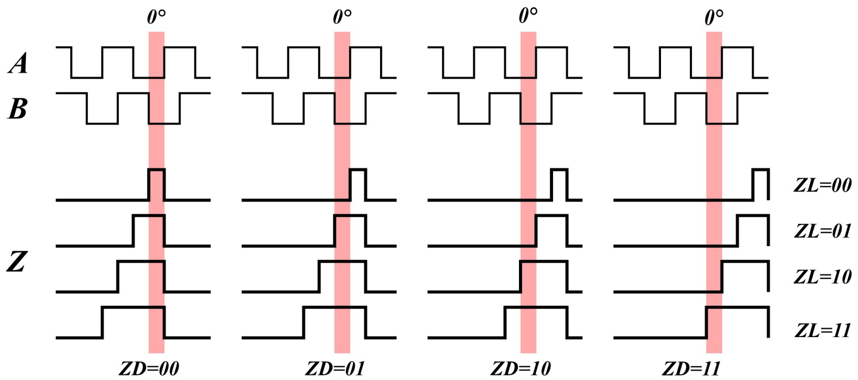
Table 12: ABZLIMIT Setting for Highest Output Frequency

ABZLIMIT	Highest Frequency
0	16 MHz
1	8 MHz
2	4 MHz
3	2 MHz
4	1 MHz
5	0.5 MHz
6	0.25 MHz
7	0.125 MHz

7.3 Zero Index Signal Z

The Z signal (also known as the index signal or zero reference signal) has a rising edge that occurs once per revolution at the zero position. The position and width of the Z signal can be programmed using the **ZL(1:0)** and **ZD(1:0)** bits in register 0x4. By default, both ZL and ZD parameters are set to 00.

Figure 13: Width (ZL) and Position (ZD) of the Z Signal in ABZ



7.4 ABZ Hysteresis

ABZ incremental output hysteresis refers to the introduction of a lag effect on the ABZ output signals to prevent false transitions and improve the system's immunity to interference. Hysteresis means that the output signal must exceed a specific threshold before changing its state. This lag effect helps reduce the impact of noise and other interferences on the output signal. When the input signal changes, the output signal does not immediately follow the change but requires surpassing a threshold to change its state. Setting this threshold makes the system less sensitive to small noise and interferences, thereby enhancing stability and accuracy.

By introducing ABZ incremental output hysteresis, errors can be reduced, and the system's immunity to interference can be improved. This is particularly important for applications that require high precision and stability, especially in noisy environments or in the presence of interferences. By introducing ABZ incremental output hysteresis, errors can be reduced, and the system's immunity to interference can be improved. This is particularly important for applications that require high precision and stability, especially in noisy environments or in the presence of interferences.

8 PWM Absolute Position Output

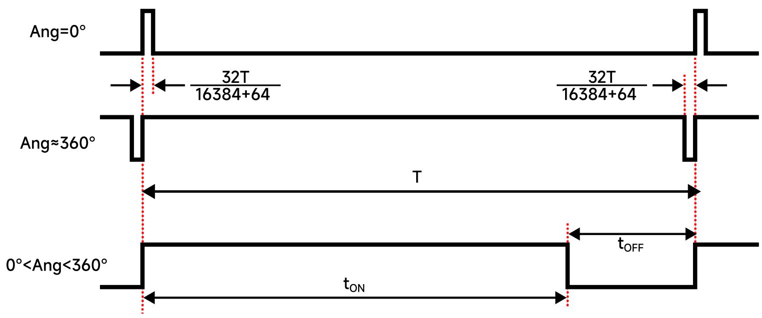
The KTH7801 provides a single-line 14-bit absolute value PWM output mode, as shown in Figure 14. The PWM output is the default output form of pin 9.

The logic signal of the PWM output is directly proportional to the magnetic angle, with a PWM frequency of 972 Hz. An angle of 0° corresponds to a duty cycle of $32/(16384+64)$, and an angle of 360° corresponds to a duty cycle of $(16384+32)/(16384+64)$. The resolution is 14 bits. The angle corresponding to any duty cycle can be calculated using Equation 2.

$$Ang = \frac{360}{16384}\left[\frac{(16384+64)\cdot t_{ON}}{t_{ON}+t_{OFF}} - 32\right] \tag{2}$$

where Ang is the angle in degrees, t_{ON} is the ON time of the PWM signal, and t_{OFF} is the OFF time of the PWM signal.

Figure 14: PWM Timing

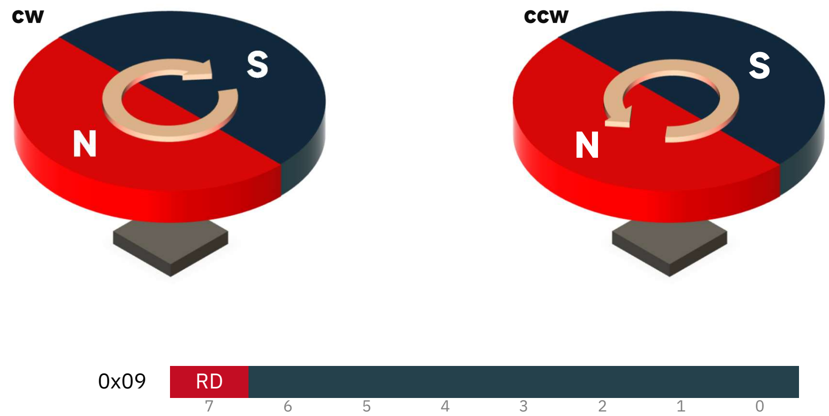


9 System Operation Settings

9.1 Rotation Direction

The RD register defines the relationship between the output angle increment and the rotation direction. By default, RD=1, when the magnet (viewed from above) rotates clockwise (CW) when viewed from above, the output angle of the chip increases.

Figure 15: Rotation Direction



9.2 Zero Point Setting

The register **Z(15:0)** defines the zero position, and this value applies to all types of angle outputs. The sensor's zero position can be programmed with 16-bit resolution.

When RD (rotation direction) is set to 1, the output angle of the sensor can be calculated using the following formula, where the 16-bit binary number is the value currently read by SPI, and the desired angle is the angle (0-360°) that the user expects after changing the Z(15:0) register:

$$Z = \text{NOT}\left(\text{16-bit binary value} - \left(\frac{\text{Desired Angle}}{360}\right) \times 2^{16}\right) + 1 \tag{3}$$

When RD (rotation direction) is set to 0, the output angle of the sensor can be calculated using the following formula, where the 16-bit binary number is the value currently read by SPI, and the desired angle is the angle (0-360°) that the user expects after changing the Z(15:0) register:

$$Z = \text{16-bit binary value} - \left(\frac{\text{Desired Angle}}{360}\right) \times 2^{16} \qquad (4)$$

For example, when RD (rotation direction) is set to 1 and the 16-bit binary value is 16384 (i.e., SPI output angle is 90 degrees), setting Z(15:0) to the complement of 16384 (bitwise NOT plus 1), which is 49152, results in an output value of 0 (output angle of 0 degrees). When RD (rotation direction) is set to 0 and the 16-bit binary value is 16384 (i.e., SPI output angle is 90 degrees), setting Z(15:0) to 16384 results in an output value of 0 (output angle of 0 degrees).

Register	7	6	5	4	3	2	1	0
0x00	Z(7:0)							
0x01	Z(15:8)							

9.3 Threshold Detection Settings

To facilitate user applications, the KTH7801 series allows for the configuration of both low threshold magnetic field alarms (mgl) and high threshold magnetic field alarms (mgh). For example, when mgh(2:0) is set to 1, if the magnetic field exceeds 34mT, the MGH pin will be pulled high. When the magnetic field decreases below 28mT, the MGH pin will be pulled low. Similarly, when mgl(2:0) is set to 0, if the magnetic field falls below 18mT, the MGL pin will be pulled high, and when the magnetic field increases above 24mT, the MGL pin will be pulled low.

The threshold detection settings are configured using the following register:

Register	7	6	5	4	3	2	1	0
0x06	mgh(2:0)			mgl(2:0)				

The values of mgh(2:0) and mgl(2:0) correspond to specific magnetic field thresholds and pin behavior. The table below illustrates the corresponding magnetic field intensities for each threshold configuration:

Table 13: Magnetic Field Intensity Corresponding to High and Low Threshold Alarms

mgh(2:0)	MGH Rising	MGH Falling	mgl(2:0)	MGL Rising	MGL Falling
0	23mT	16mT	0	18mT	24mT
1	34mT	28mT	1	30mT	36mT
2	47mT	40m	2	42mT	48mT
3	58mT	52mT	3	54mT	60mT
4	70mT	63mT	4	65mT	71mT
5	81mT	75mT	5	77mT	83mT
6	92mT	86mT	6	88mT	94mT
7	103mT	97mT	7	99mT	105mT

9.4 Sensor Off-Axis Application Calibration

When we install the KTH7801 sensor at the center position of a magnet or when the design requires the sensor to be mounted on the side of the magnet's center, there is a deviation between the sensor's output magnetic field strength and the magnet's position. This is due to the non-linear relationship between the sensor's output and the actual magnet position, which is caused by the uneven distribution of the magnetic field on the magnet's surface, resulting in a non-linear relationship between the sensor's output and the actual magnet position. One of the main reasons is that the tangential magnetic field (along the direction of the magnet's surface) is usually weaker than the radial magnetic field (perpendicular to the magnet's surface), as shown in Figures 16 and 17.

Figure 16: Illustration of Sensor Located in Tangential Magnetic Field

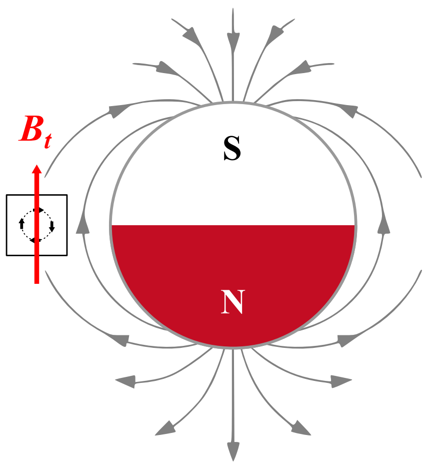
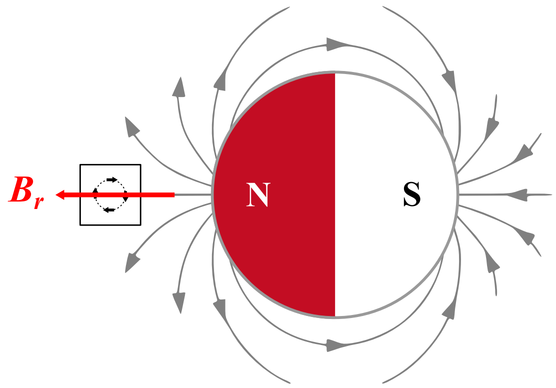


Figure 17: Illustration of Sensor Located in Radial Magnetic Field



To better calibrate the sensor and detect the magnet's position, the KTH7801 introduces the concept of magnetic field ratio μ, which is an important parameter used to describe the relationship between magnetic field intensity and the actual magnet position. The magnetic field ratio μ represents the ratio between the maximum radial magnetic field B_r and the maximum tangential magnetic field B_t, and it is calculated as follows:

$$\mu = \frac{B_r}{B_t} \tag{5}$$

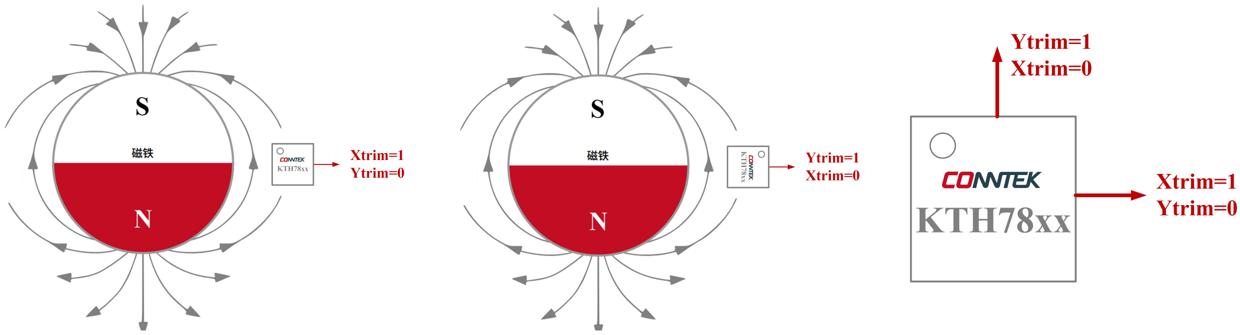
To simplify the calibration process, the KTH7801 introduces two parameters: Xtrim, Ytrim, and GAINtrim(7:0):

Register	7	6	5	4	3	2	1	0
0x02	GAINtrim(7:0)							
0x03							Ytrim	Xtrim

These parameters are used to adjust the sensitivity of the sensor in the X and Y directions for precise calibration.

By default, the sensitivity of the X-axis and Y-axis is the same. If it is necessary to reduce the sensitivity of the signal in the X-axis direction while keeping the Y-axis direction unchanged, you can set the Xtrim parameter to 1 and the Ytrim parameter to 0. Conversely, if it is necessary to reduce the sensitivity of the signal in the Y-axis direction while keeping the X-axis direction unchanged, you can set the Xtrim parameter to 0 and the Ytrim parameter to 1. The chip placement direction and the settings of the Xtrim and Ytrim parameters are shown in Figure 18, where the red arrow represents the direction of the radial magnetic field.

Figure 18: Illustration of Chip Placement and Xtrim, Ytrim Parameter Settings



The specific reduction in sensitivity is determined by the GAINtrim(7:0) parameter, which is an 8-bit integer ranging from 0 to 255. A smaller GAINtrim value represents a smaller reduction in sensitivity. In normal conditions, where the radial and tangential magnetic field strengths are the same and the magnetic field ratio μ is 1, no adjustment is needed, and the GAINtrim(7:0) parameter should be set to 0. In an off-axis application where the chip is placed directly to the right of the magnet, the radial field is approximately twice the tangential field, meaning μ is 2. In such a case, as shown in Table 14, the recommended GAINtrim(7:0) value is 128.

Additionally, another method for calculating the GAINtrim(7:0) parameter involves magnetic field simulation. Our company can provide simulations to help customers determine the appropriate GAINtrim(7:0) parameter.

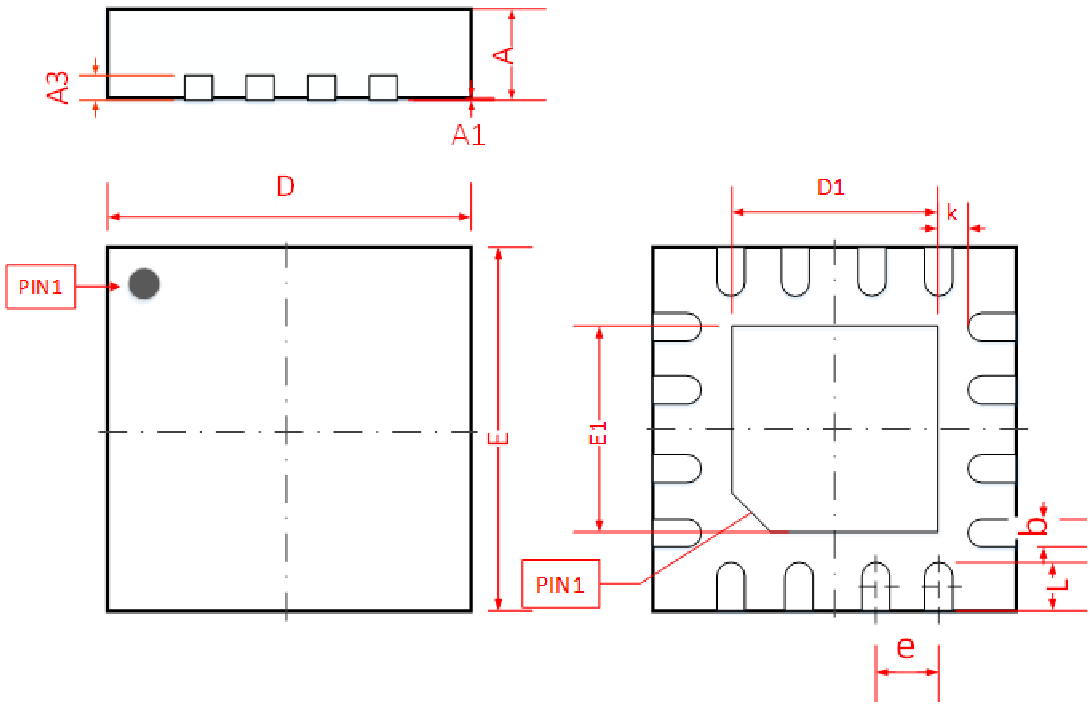
Table 14 lists some specific examples of GAINtrim settings, showing the magnetic field ratio μ and the corresponding GAINtrim(7:0) values under different conditions. Depending on the actual requirements and application scenarios, you can choose the appropriate GAINtrim setting to achieve the desired sensitivity reduction.

Magnetic Field Ratio μ	**Register GAINtrim(7:0)**
1.0	0
1.5	85
2.0	128
2.5	154
3.0	171
3.5	183
4.0	192
4.5	199
5.0	205

Table 14: Examples of GAINtrim Settings

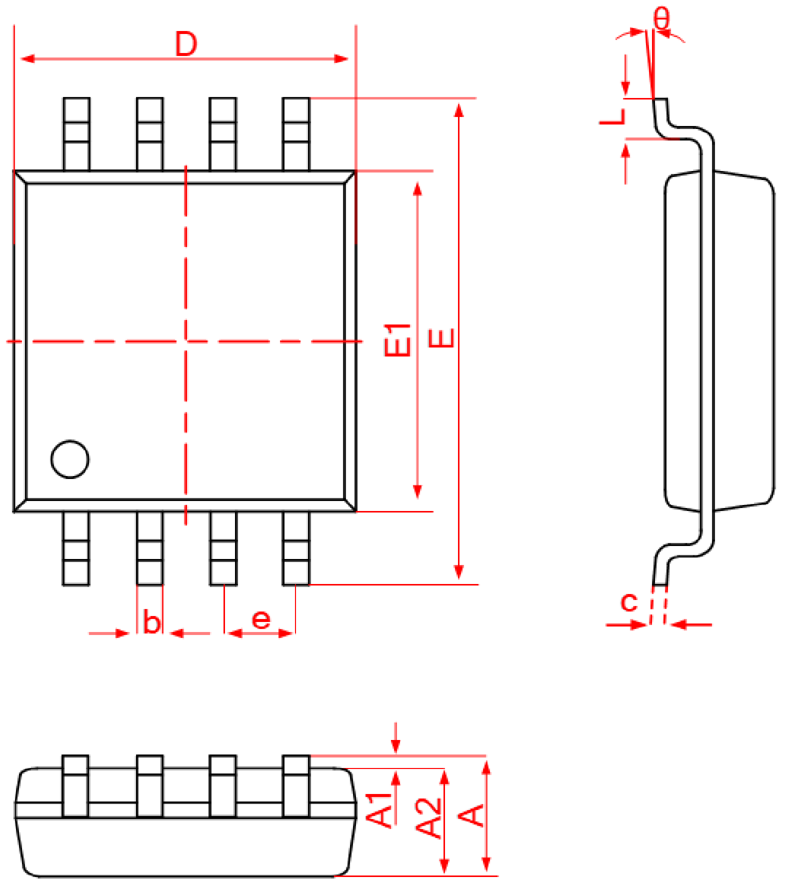
10 Packaging

The KTH7801 sensor is available in a specific package to ensure proper protection and compatibility with various applications. The packaging information is provided in Figure 19 and Figure 20.



Symbol	Dimensions in Millimeters	
	Min	Max
A	0.700	0.800
A1	0.000	0.050
A3	0.203REF.	
D	2.900	3.100
E	2.900	3.100
D1	1.350	1.550
E1	1.350	1.550
k	0.375REF.	
b	0.200	0.300
e	0.500BSC.	
l	0.300	0.500

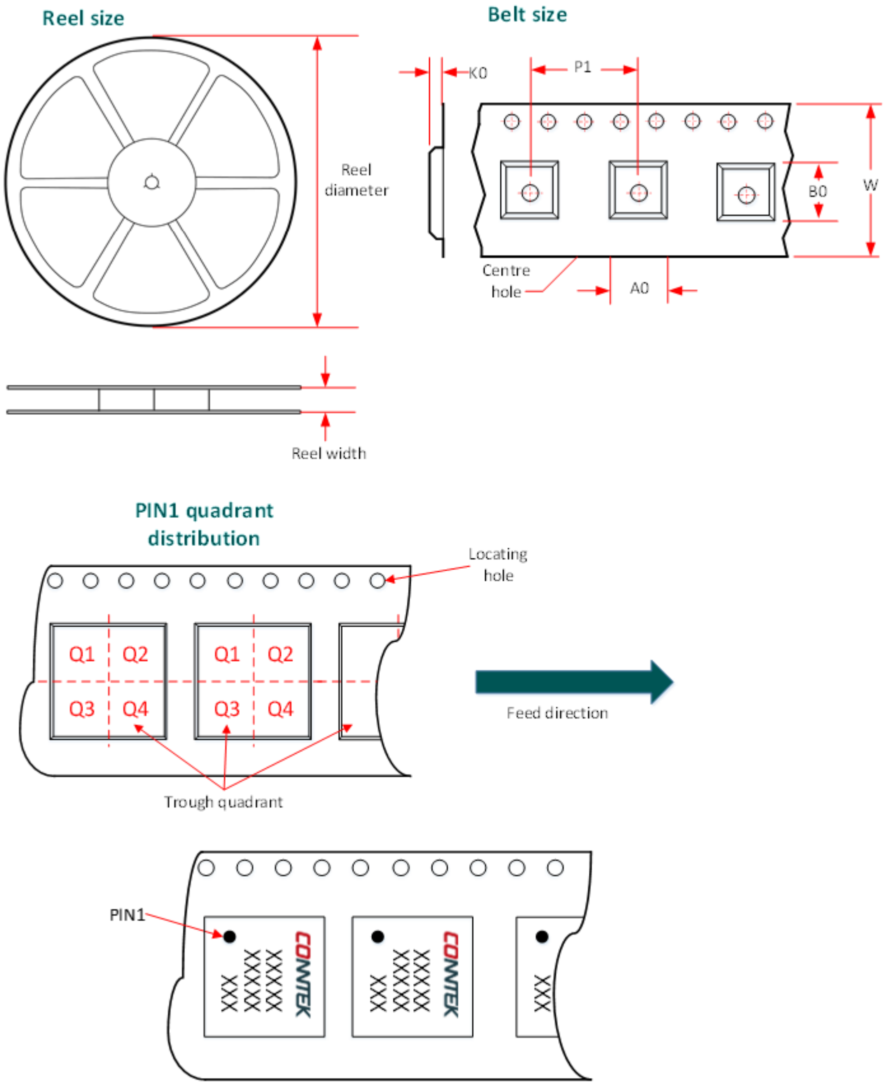
Figure 19: QFN-16L Packaging Information for KTH7801



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	1.35	1.75	0.53	0.069
A1	0.100	0.250	0.004	0.010
A2	1.35	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 TYP.		0.050 TYP.	
L	0.400	0.800	0.016	0.031
θ	0°	8°	0°	8°

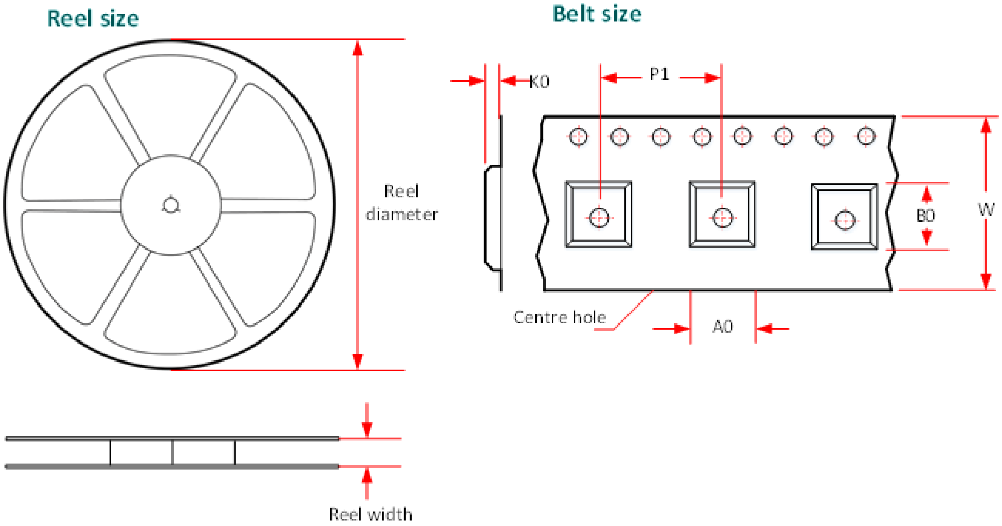
Figure 20: SOP-8 Packaging Information for KTH7801

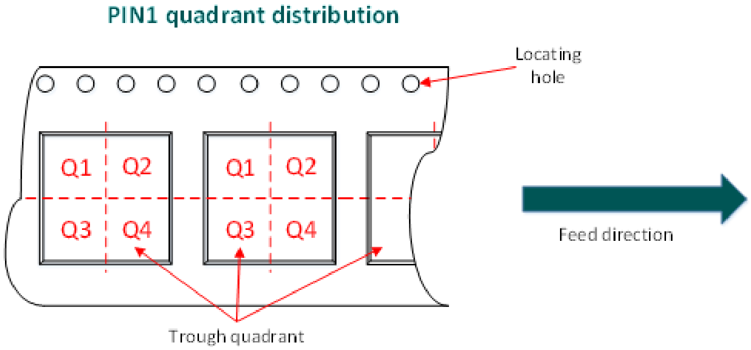
11 Tape and Reel Information

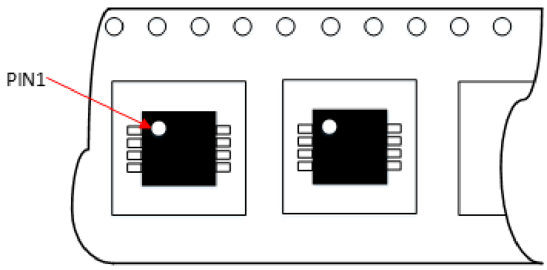


Package Type	Pins	SPQ	Reel diameter	Reel width	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 方向
QFN3*3-16L	16	5000	330	12.4	3.35	3.35	1.13	8.00	12.00	Q1

Figure 21: QFN-16L Tape and Reel Information for KTH7801







Package Type	Pins	SPQ	Reel diameter	Reel width	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 方向
SOP8	8	4000	330	13	6.60	5.3	2.1	8.00	12.00	Q1

Figure 22: SOP-8 Tape and Reel Information for KTH7801

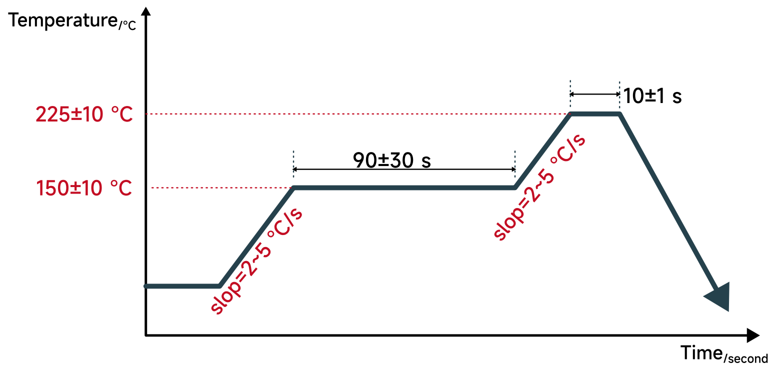


Figure 23: Soldering Temperature Profile for KTH7801

12 Selection Guide

Table 15: Model List

Model	Noise (1 sigma)	Output Interface	Time Constant τ (ms)	Operating Magnetic Field	Application Scenario
KTH7801	0.015°	SPI, SSI, PWM, ABZ	0.51	30-150mT	Automotive
KTH7802	0.015°	SPI, ABZ, UVW	0.51	30-150mT	Automotive
KTH7803	0.004°	SPI, SSI, PWM, ABZ	16.3	30-150mT	Automotive

13 Ordering Information

Table 16: Ordering Information

Model	Package Type	Operating Temperature	Application Scenario	Pin Count	CRC Check Available
KTH7801-X-N-QN16	QFN3x3-16L	-40°C to 125°C	Automotive	16	No
KTH7801-X-N-SOP8	SOP-8	-40°C to 125°C	Automotive	8	No
KTH7801-X-C-QN16	QFN3x3-16L	-40°C to 125°C	Automotive	16	Yes
KTH7801-X-C-SOP8	SOP-8	-40°C to 125°C	Automotive	8	Yes
KTH7803-X-N-QN16	QFN3x3-16L	-40°C to 125°C	Automotive	16	No

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