

KTH7111 Series

16-bit High-Speed High-Precision
Off-Axis Magnetic Encoder
Programmable Multi-Interface Angle Sensor
with ABZ/UVW/PWM/SPI/SSI Outputs

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1 Product Information

1.1 Features

The KTH7111 is a high-performance magnetic encoder with the following key features:

- 16-bit high-resolution absolute angle output
- Off-axis application supported, with post-calibration INL error less than $\pm 0.2^\circ$
- Supports both single-pole and multi-pole magnetic sources
- Ultra-low latency with a data update rate of $1\ \mu\text{s}$
- SPI communication interface with data rates up to 10 Mbps
- SSI interface supporting up to 5 Mbps for angle output
- Programmable ABZ incremental output with 4 to 16384 steps per revolution
- Programmable UVW output for 1 to 32 pole pairs
- 12-bit PWM angle output, frequency adjustable, supports calibration status indication
- Operating voltage: from 3.3 V to 5 V
- Operating temperature range: -40°C to 125°C
- Package: QFN3x3-16L

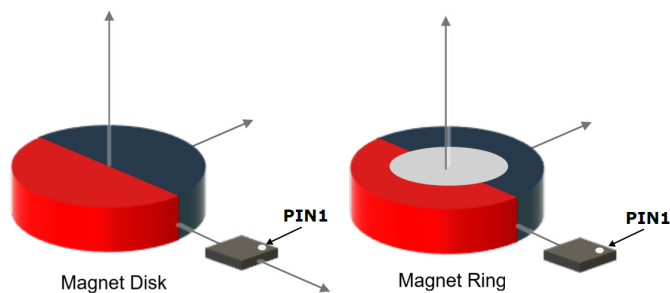


Figure 1: Off-axis Configuration Examples: Magnet Ring (left) and Magnet Disk (right)

1.2 Typical Applications

- Absolute angular position detection
- Brushless DC motor control
- Off-axis angle measurement systems
- Closed-loop stepper motor control systems
- Platform automatic door systems in rail transportation

1.3 General Description

The KTH7111 is a high-speed, high-precision magnetic encoder equipped with an advanced automatic nonlinearity calibration (ANLC) engine.

Users can initiate the calibration either by register configuration or via external pin trigger. The internal controller automatically measures non-linear errors and calculates the compensation parameters. The calibration results are stored in internal MTP (Multi-Time Programmable) memory.

This calibration mechanism requires no external computation and can significantly enhance the linearity of angle measurement, achieving absolute accuracy better than $\pm 0.2^\circ$.

The encoder supports multiple interface modes to suit various applications:

- **SPI Interface:** A 3-wire SPI bus (CPOL=1, CPHA=1) is provided for reading 16-bit angle data, accessing internal registers, and configuring parameters. Data transmission includes an 8-bit CRC for error checking. This SPI interface does not support multiple CS lines; instead, multiple SDA lines can be connected to a microcontroller for data access.
- **ABZ Incremental Output:** Programmable ABZ quadrature signal output with resolutions up to 16384 steps/rev. It supports absolute position initialization upon power-up by emitting a sequence of AB pulses.
- **SSI Interface:** Supports two-wire synchronous serial communication with up to 5 Mbps data rate for absolute angle output.
- **PWM Output:** Offers a PWM signal with adjustable frequency (120 Hz to 3.8 kHz), and uses pulse width modulation to indicate angle or calibration status.
- **UVW Commutation Signal:** Programmable commutation outputs for 1 to 32 pole-pair configurations, ideal for BLDC applications.

These interface modes provide flexible and robust integration options for a wide range of system designs.

2 System Overview

2.1 System Architecture

The KTH7111 integrates Hall sensors, analog front-end, analog-to-digital converters, and a digital signal chain to perform angle measurement and output digital signals.

The Hall sensors detect magnetic fields and generate analog voltages. These are converted into two orthogonal digital signals via ADCs. The angle is calculated using an arctangent (ATAN) module, producing a 16-bit angle value. The angle is then processed through zero offset, rotation direction setting, and filtering.

Filtered angle data can be output directly via SPI or SSI interfaces. Alternatively, the angle can be converted into PWM signals based on duty cycle.

To enhance refresh rate, the filtered angle passes through an interpola-

tor and is then output to the ABZ encoder module, which converts angle into quadrature incremental signals.

All system parameters are stored in non-volatile multi-time programmable (MTP) memory. Parameters can be configured via the SPI interface.

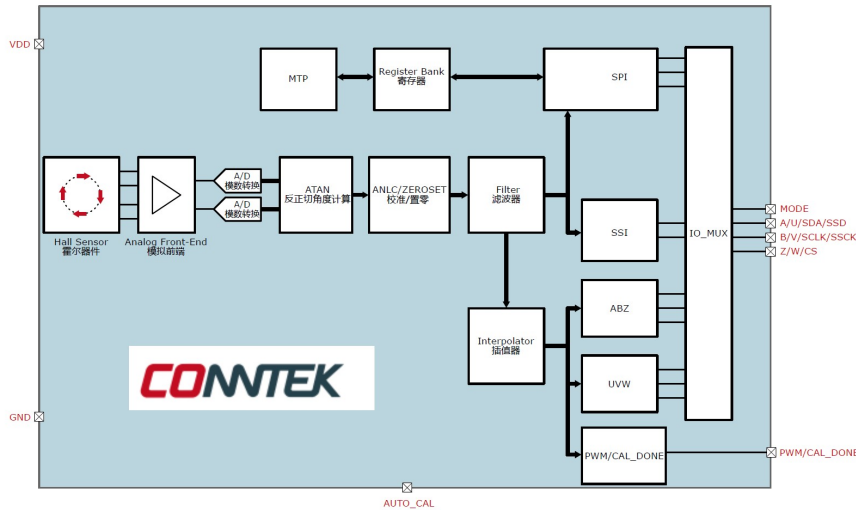


Figure 2: Functional Block Diagram

2.2 Recommended Application Circuit

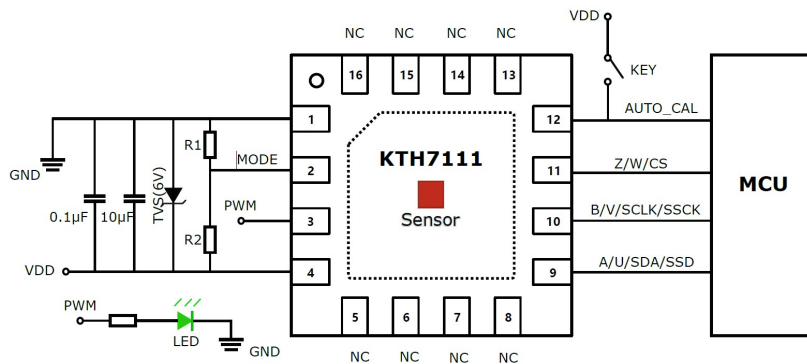


Figure 3: Recommended Application Circuit

- R1 and R2 are 5.1 kΩ pull-up resistors. Soldering R1 only enables 3-wire SPI. Soldering R2 only enables ABZ/UVW/SSI output.
- AUTO_CAL pin can be externally triggered.
- PWM output can be connected to an LED to indicate calibration completion.

2.3 Pin Definition

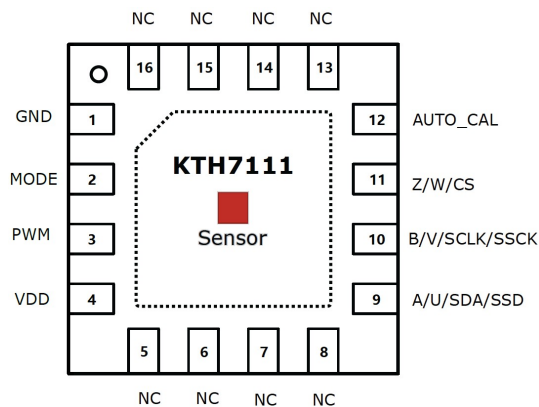


Figure 4: QFN-16L Package Pinout

Pin	Name	Function
1	GND	Ground
2	MODE	Output interface control pin
3	PWM	PWM signal output
4	VDD	Power supply input
5–8	NC	No connection, leave floating
9	A/U/SDA/SSD	Function defined by MODE and IO_MUX
10	B/V/SCLK/SSCK	Function defined by MODE and IO_MUX
11	Z/W/CS	Function defined by MODE and IO_MUX
12	AUTO_CAL	Calibration trigger input, active high
13–16	NC	No connection, leave floating
17	T-PAD	Thermal pad, connect to GND

Table 1: Pin Functions of KTH7111

2.4 Interface Mode Selection

The output interface is configured by Pin 2 (MODE) and the IO_MUX register at address 0x10.

MODE (Pin 2)	IO_MUX[2:0]	Pin 9	Pin 10	Pin 11
Low	Any	SDA	SCLK	CS
High	0	A	B	Z
High	1	U	V	W
High	2	SSD	SSCK	Z

Table 2: Interface Selection via MODE Pin and IO_MUX Register

When MODE is low, Pins 9–11 operate as 3-wire SPI. When MODE is high, the function is determined by IO_MUX[2:0]:

- IO_MUX = 0: ABZ output

- IO_MUX = 1: UVW output
- IO_MUX = 2: SSD output

2.5 16-bit Binary Angle Encoding

The angle is represented using a 16-bit binary value ranging from 0 to 65535, which corresponds to 0° to 360°.

$$\text{Angle (degrees)} = \frac{\text{Binary Value} \times 360}{2^{16}}$$

All angle outputs in this datasheet use this encoding format unless otherwise specified.

3 Key Parameters

Parameter	Min	Typ	Max
Supply Voltage	3.0 V	3.3 V	5.0 V
Magnetic Field Strength	30 mT	60 mT	150 mT
Operating Current	—	16 mA	—
Start-up Time	—	20 ms	—
Data Latency	—	1 μ s	—
Output Noise (1 sigma)	—	0.015°	—
Integral Nonlinearity	—	$\pm 0.2^\circ$	—
Maximum Rotational Speed	—	—	120000 rpm
ESD Protection (HBM)	—	± 5 kV	—

Table 3: Key Electrical and Performance Parameters @ 3.3 V Supply

4 Magnet Installation Guide

4.1 Off-Axis Magnet Installation

Parameter	Description	Min	Typ	Max	Unit
D_{mag}	Diameter of radially magnetized magnet or ring	—	10	30	mm
T_{mag}	Recommended magnet thickness	—	2.5	5	mm
B_{pk}	Magnetic field at chip location	30	—	150	mT
A_{G}	Air gap between magnet and chip	—	0.5	5	mm
R_{S}	Maximum rotational speed	—	—	120	krpm
Δ_{disp}	Installation offset tolerance	—	0.5	2.0	mm

Table 4: Off-Axis Magnet Installation Parameters

- Recommended magnetic materials: NdFeB or SmCo.

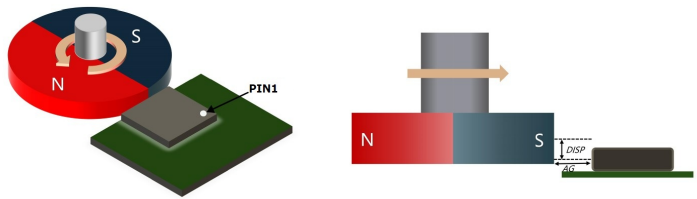


Figure 5: Recommended Chip Placement for Off-Axis Magnet

4.2 Multi-Pole Magnet Installation

Parameter	Description	Min	Typ	Max	Unit
W_{mag}	Pole width of multi-pole magnet	2	—	10	mm
T_{mag}	Recommended magnet thickness	—	2	5	mm
B_{pk}	Magnetic field at chip location	30	—	150	mT
A_G	Air gap between magnet and chip	—	0.5	3	mm
R_S	Maximum rotational speed	—	—	120	krpm
Δ_{edge}	Distance from chip center to magnet edge	0.8	1.0	5.0	mm

Table 5: Multi-Pole Magnet Installation Parameters

- Recommended magnetic materials: NdFeB or SmCo.
- Outer diameter is not limited.
- For optimal performance, magnetic simulation is recommended. Please contact us by email.

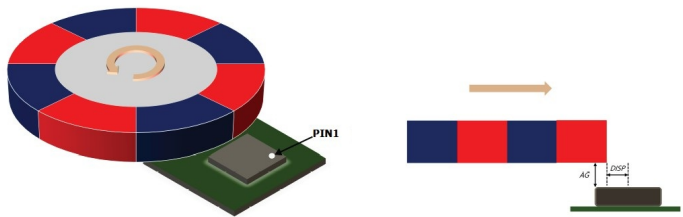


Figure 6: Recommended Placement for Multi-Pole Magnet

5 Register Configuration

5.1 Register Map

Address	Register	Default value
0x00	ZERO[7:0]	0x00
0x01	ZERO[15:8]	0x00
0x02	RD AUTO_ZERO_SET Z_PHASE[1:0] Z_EDGE Z_WID[2:0]	0x00
0x03	PPT[7:0]	0xFF
0x04	RESERVE PPT[11:8]	0x03
0x05	ABZ_START_T[3:0] ABZ_START_MODE ABZLIMIT_F[2:0]	0x00
0x06	RAM_HYS[7:0]	0x07
0x07	RESERVE RAM_HYS[14:8]	0x00
0x08	RESERVE NPP[4:0]	0x00
0x09	PWM_F[7:0]	/
0x0A	PWM_F[15:8]	/
0x0D	FW[7:0]	0x88
0x10	RESERVE IO_MUX	0x00
0x16	RESERVE REG_CAL ANLC_EN RESERVE	0x04
0x72	RESERVE ANLC_STATUS[1:0] RESERVE	0x00

Figure 7: Detailed Register Bit Field Layout

5.2 Register Description

Symbol	Default (dec)	Description
ZERO[15:0]	0	Zero angle offset setting
RD	1	Rotation direction: 1 for CW
AUTO_ZERO_SET	0	Set to 1 to force output angle to zero
Z_PHASE[1:0]	0	Z signal phase for ABZ
Z_EDGE	0	0: rising edge of Z at zero angle, 1: falling edge
Z_WID[2:0]	0	Z signal width in LSBs
PPT[11:0]	1023	ABZ resolution, default 1024 lines (4096 steps/rev)
ABZ_START_T[3:0]	2	ABZ output delay, default 20ms
ABZ_START_MODE	0	1: absolute ABZ startup mode
ABZLIMIT_F[2:0]	0	ABZ max frequency limit, default 16MHz
RAM_HYS[14:0]	7	Hysteresis configuration for angle output
NPP[4:0]	0	UVW pole pair count, default 1
PWM_F	—	PWM output frequency (factory calibrated to 1kHz)
FW[7:0]	136	Filter depth, default 0x88
IO_MUX	0	0: ABZ, 1: UVW, 2: SSI output
REG_CAL	0	Set to 1 to initiate self-calibration
ANLC_EN	1	Enable calibration effect on angle output
ANLC_STATUS[1:0]	0	0: Not started
RESERVE	0	Reserved, do not modify

Table 6: Register Parameter Descriptions

6 SPI Interface

KTH7111 employs a three-wire SPI communication protocol, operating in Mode 3 (CPOL = 1, CPHA = 1). This serial interface allows reading the absolute angle, accessing internal registers, and programming the MTP (Multiple-Time Programmable) memory. The maximum supported SPI communication speed is 10 Mbps.

6.1 SPI Timing

The SPI timing diagram is shown in Figure 8. All timing parameters are measured under a load condition of 20 pF.

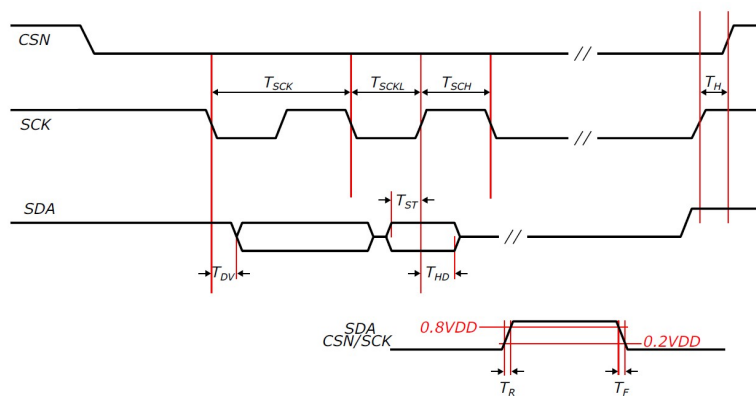


Figure 8: SPI Timing Diagram

Table 7: SPI Timing Parameters (20 pF Load)

Symbol	Description	Min (ns)	Typ (ns)	Max (ns)
T_{SCK}	Clock period	100	—	—
T_{SCKL}	Clock low duration	50	—	—
T_{SCKH}	Clock high duration	50	—	—
T_H	Time from $SCK \uparrow$ to $CSN \uparrow$	120	—	—
T_R	Signal rise time	—	10	—
T_F	Signal fall time	—	10	—
T_{DV}	MISO data valid time	—	—	50
T_{ST}	MOSI setup time	50	—	—
T_{HD}	MOSI hold time	50	—	—

6.2 Reading Absolute Angle via SPI

To read the absolute angle from the sensor, the following SPI sequence should be used:

1. Send 8-bit command: `0x00`
2. Receive 16-bit angle data followed by an 8-bit CRC
3. Ensure inter-frame delay is greater than 150 ns

The CRC follows the CRC-8/ITU standard:

- Polynomial: $x^8 + x^2 + x + 1$ (0x07)
- Initial value: 0x00
- Final XOR value: 0x55

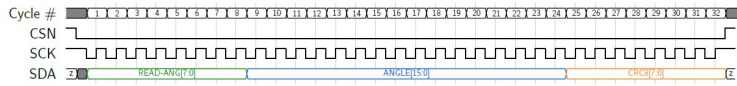


Figure 9: SPI Read Angle Sequence

6.3 Register Access Control

KTH7111 implements a locking mechanism for write access to its registers to ensure safe operation.

- Upon power-up, registers are locked and cannot be modified.
- Send 32-bit unlock key: 0x20240101
- Send 32-bit lock key: 0x20241231 to re-enable protection
- Register and angle read operations are always allowed

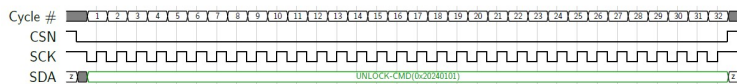


Figure 10: Unlocking Registers via SPI

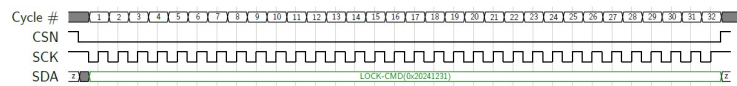


Figure 11: Locking Registers via SPI

6.4 Reading Registers

To read a register:

1. Send command 0x11 followed by the 8-bit register address
2. Receive 8-bit register value and 8-bit CRC
3. Ensure a delay of at least 150 ns between transactions



Figure 12: Register Read Operation via SPI

6.5 Writing Registers

To write to a register:

1. Unlock the registers with key 0x20240101

2. Send command `0x33`, followed by the register address and the new value
3. Device echoes back the written value in the same frame
4. The 24th clock high duration must exceed 100 ns
5. Delay between transactions should be at least 150 ns

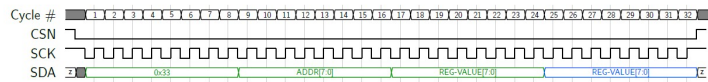


Figure 13: Register Write Operation via SPI

6.6 Writing Registers to MTP

All register writes are volatile unless explicitly saved to MTP (non-volatile memory). Use the following steps to burn MTP:

1. Ensure register access is unlocked
2. Send 24-bit MTP burn command: `0x2255AA`
3. Wait at least 400 ms before any further SPI operation

Important precautions:

- MTP write is irreversible
- Validate all parameters before writing
- Do not power off during programming
- Use only verified and tested firmware for MTP operations

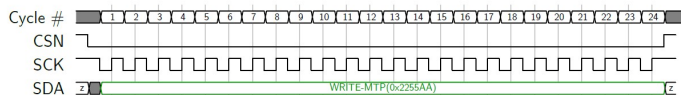


Figure 14: Writing Registers to MTP via SPI

7 SSI Interface

KTH7111 supports the SSI (Synchronous Serial Interface) protocol for absolute angle readout.

The device functions as an **SSI slave** and exclusively supports **angle data transmission only**. **Register read or write operations are not supported via SSI**. The transmitted data is **MSB-first**, meaning the most significant bit of the angle data is sent first.

7.1 Timing Diagram

The standard SSI interface uses two signal lines:

- **SSCK**: Clock input from the master

- **SSD:** Serial data output from the sensor

The timing relationship between SSCK and SSD is shown in Figure 15.

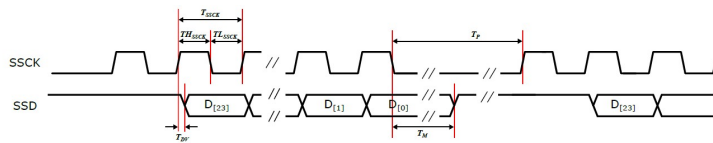


Figure 15: SSI Timing Diagram

7.2 Timing Parameters

The electrical timing requirements for SSI communication are shown in Table 8. These values ensure proper synchronization between the host controller and the KTH7111 device.

Table 8: SSI Timing Parameters

Symbol	Description	Min	Max	Unit
t_{DV}	SSD data valid delay	—	15	ns
T_{SSCK}	SSCK clock period	0.2	10	μ s
T_{LSSCK}	SSCK low level duration	0.1	5	μ s
T_{HSSCK}	SSCK high level duration	0.1	5	μ s
T_M	Monoflop timeout	10	—	μ s
T_P	Inter-frame pause time	16	—	μ s

7.3 Data Frame Format

Each SSI data frame consists of:

- 16-bit absolute angle value
- 8-bit CRC code using the CRC-8/ITU standard

Data is shifted out synchronously on the falling edge of SSCK, with MSB transmitted first.

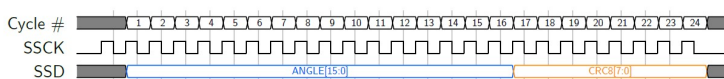


Figure 16: Standard SSI Angle Read Sequence

8 ABZ Interface

KTH7111 provides angular position output through the incremental ABZ interface. The interface is configured for 14-bit resolution, corresponding to 16384 steps per revolution, or 4096 pulse periods (PPT) per revolution on the AB signals.

The phase difference between signals A and B indicates the direction of rotation. In clockwise rotation, signal A leads and signal B follows. In

Address	Register	Default value
0x03	PPT[7:0]	0xFF
0x04	RESERVE PPT[11:8]	0x03
0x05	ABZ_START_T[3:0] ABZ_START_MODE ABZLIMIT_F[2:0]	0x00

Figure 17: ABZ Output Related Register Settings

counterclockwise rotation, signal B leads and signal A follows. During power-on, all three ABZ signals are held high.

When the magnet above the center of the chip (viewed from top) rotates counterclockwise (CCW), the rising edge of signal B leads that of signal A by 1/4 cycle. Conversely, during clockwise (CW) rotation, the rising edge of signal A leads that of signal B by 1/4 cycle. The phase relationship between A and B reverses as the rotation direction changes.

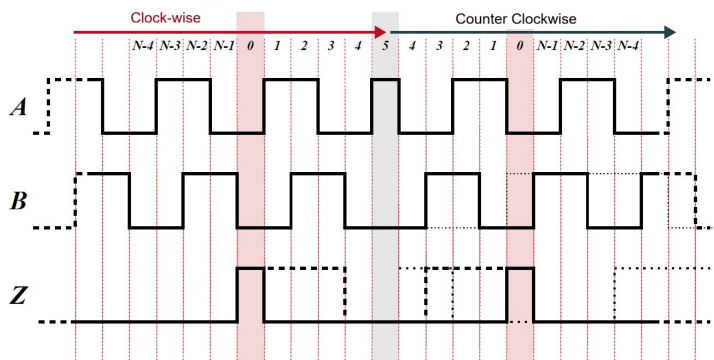


Figure 18: ABZ Output Timing Diagram

8.1 ABZ Output Resolution

The ABZ incremental interface of KTH7111 can support any integer resolution up to 4096 pulse periods per revolution. Users can program the internal MTP field PPT[13:0] to set a custom resolution. Common values are shown below:

Table 9: ABZ Resolution vs. PPT Settings

PPT(11:0)	Pulse/Rev (PPT)	Steps/Rev
0	1	4
1	2	8
2	3	12
⋮	⋮	⋮
4093	4094	16376
4094	4095	16380
4095	4096	16384

8.2 ABZ Output Frequency Limiting

The maximum AB edge output frequency is 16 MHz. This can be reduced by configuring the `ABZLIMIT` parameter, as shown below:

Table 10: ABZ Frequency Limit Settings

ABZLIMIT	Max Edge Frequency
0	16 MHz
1	8 MHz
2	4 MHz
3	2 MHz
4	1 MHz

8.3 ABZ Startup Mode

KTH7111 supports two ABZ startup modes, selectable via the `ABZ_START_MODE` register:

- **Normal startup** (`ABZ_START_MODE = 0`): ABZ signals output incremental pulses immediately after power-on.
- **Absolute startup** (`ABZ_START_MODE = 1`): ABZ outputs a burst of pulses indicating the absolute position at startup.

In absolute startup mode, one clock after `ABZ_EN` is enabled, the device captures the current angle as an absolute position. It then outputs a series of AB pulses to represent this angle.

$$\text{Pulse Count} = \left(\frac{\min(\text{Angle}, 65536 - \text{Angle})}{65536} \right) \times \text{PPT}$$

For example, if the angle is 90° (16384 in count) and `PPT = 511`, then AB outputs 128 pulses. If the angle is greater than 180° , the AB output is reversed, counting down from 360° .

8.4 ABZ Startup Delay

The ABZ startup delay can be configured using the `ABZ_START_T[3:0]` register. Typical settings are:

Table 11: ABZ Startup Delay Settings

ABZ_START_T[3:0]	Delay Time
1	10 ms
2	20 ms (default)
3	30 ms
4	40 ms
5	50 ms
6	75 ms
7	100 ms

This setting helps prevent false ABZ signals during system power-up instability.

9 UVW Output

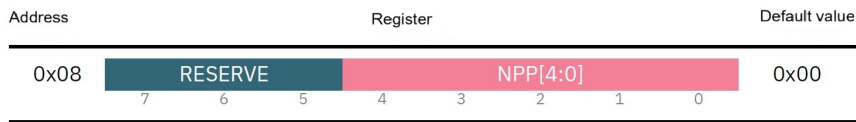


Figure 19: UVW Output Register Configuration

UVW output signals simulate three Hall switches used for commutation in three-phase motors. As shown in Figure 20, the three logic signals have 50% duty cycle and 120° phase difference.

If the motor has more pole pairs than the target magnet, KTH7111 can divide one electrical rotation into multiple commutation steps to generate multiple UVW periods.

The parameter register 0x7 uses `NPP[4:0]` to configure the simulated pole-pair number and UVW switching step angle.

Table 12 describes the NPP configuration:

Table 12: UVW Pole-Pair Configuration: NPP[4:0]

NPP(4:0)	Pole Pairs	States Per Turn
00000	1	6
00001	2	12
00010	3	18
00011	4	24
00100	5	30
00101	6	36
00110	7	42
00111	8	48
⋮	⋮	⋮
11110	31	186
11111	32	192

For example, with a four-pole (two pole-pair) motor, the UVW commutation step is 30° per state, as shown in Figure 21.

9.1 UVW Startup Delay

The startup timing of UVW output is the same as ABZ output. It is controlled by the `abz_start_t[3:0]` parameter. This ensures UVW outputs are enabled only after the system becomes stable during power-up.

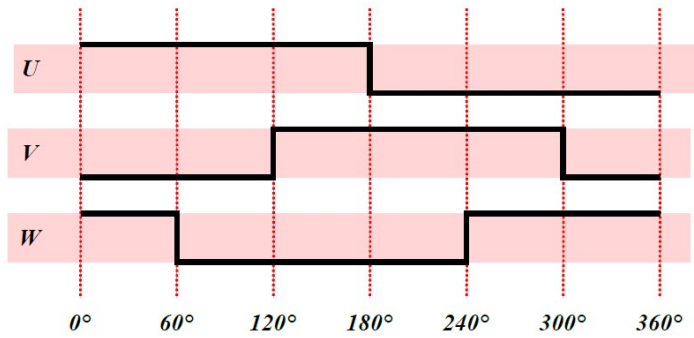


Figure 20: UVW Output for One Pole Pair

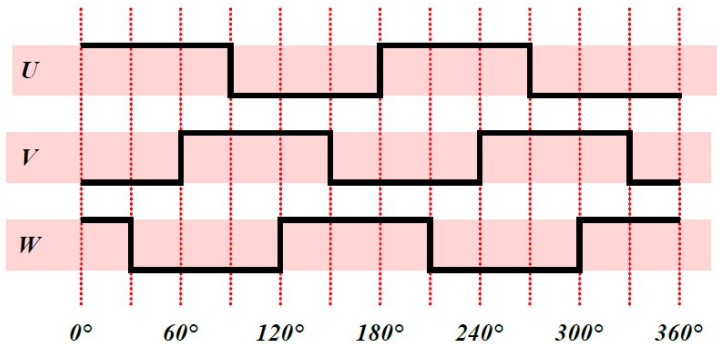


Figure 21: UVW Output for Two Pole Pairs

9.2 UVW and Z Signal Phase Relationship

The UVW signals are phase-aligned with the Z signal edge. This alignment ensures proper commutation synchronization with the electrical zero reference position.

10 PWM Absolute Output

KTH7111 provides a single-wire PWM absolute angle output mode. PWM is the default output function on pin 9, as shown in Figure 22.

Address	Register	Default value
0x09	PWM_F[7:0]	/
0x0A	PWM_F[15:8]	/

Figure 22: PWM Register Diagram

10.1 PWM Frequency Setting

The PWM output frequency is controlled by the 16-bit parameter `pwm_f`. The relationship between frequency and `pwm_f` is given by:

$$\text{PWM(Hz)} = \frac{(120.284 - 3846.0)}{65536.0} \cdot \text{pwm_f} + 3846.0$$

Typical settings:

- $\text{pwm_f} = 0$: Output frequency is 3846 Hz
- $\text{pwm_f} = 65535$: Output frequency is 120.284 Hz

The required frequency accuracy is $\pm 5\%$.

10.2 PWM Resolution and Angle Calculation

The PWM signal duty cycle is proportional to the magnetic angle. The output resolution is 12 bits.

- When duty cycle is $\frac{32}{4096+64}$, the angle is 0°
- When duty cycle is $\frac{4096+32}{4096+64}$, the angle is 360°

The formula to calculate angle from duty cycle is:

$$\text{Ang} = \frac{360}{4096} \left(\frac{(4096 + 64) \cdot t_{\text{ON}}}{t_{\text{ON}} + t_{\text{OFF}}} - 32 \right)$$

where:

- t_{ON} : PWM high level time - t_{OFF} : PWM low level time

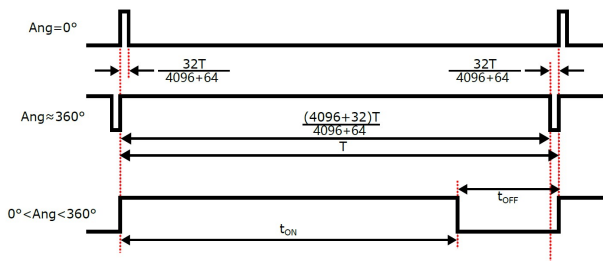


Figure 23: PWM Output Timing Diagram

10.3 PWM Status Indication During Non-Linear Calibration

During automatic nonlinear calibration, the PWM output indicates calibration status:

- 3.8 Hz with 50% duty cycle: calibration in progress
- Constant high level: calibration successful
- Constant low level: calibration failed

After calibration, when the `auto_cal` signal is pulled low, PWM returns to normal angle output mode.

10.4 PWM Startup Delay

The PWM output is also affected by the `abz_start_t[3:0]` parameter. This ensures that PWM signals start only after system stabilization upon power-up.

11 Off-axis Sensor Application and Calibration

When the KTH7111 sensor is installed with an offset from the magnet's center, or intentionally positioned to the side of the axis, the magnetic field strength detected by the sensor no longer maintains a linear relationship with the rotation angle. This non-linearity arises mainly from the non-uniform magnetic field distribution on the magnet's surface. In particular, the tangential magnetic field (along the surface) is usually weaker than the radial field (perpendicular to the surface), resulting in angular output deviations.

To reduce customer configuration effort, the encoder is pre-configured by default at the factory to support a typical off-axis installation structure. Customers should follow the chip orientation and magnet positioning as illustrated in Figure 24 during installation, ensuring that the output angle reflects the actual mechanical angle as accurately as possible.

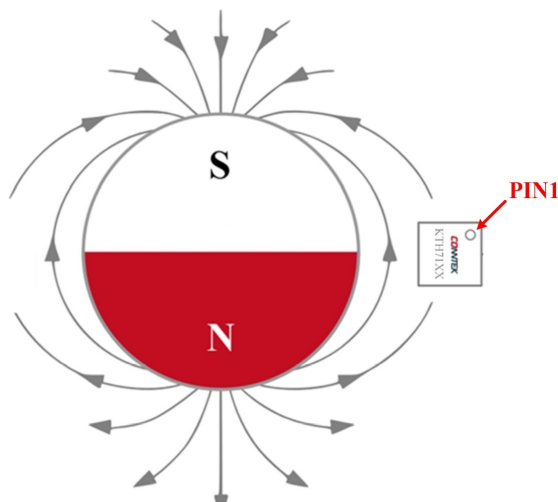


Figure 24: Chip orientation and magnet position for off-axis configuration

In addition, ConnTek can provide magnetic field simulation services to help customers evaluate whether the magnet structure meets the application requirements during the development stage.

12 Automatic Nonlinearity Calibration

KTH7111 includes an automatic nonlinearity calibration (ANLC) function. It effectively compensates for nonlinearity errors that occur due to installation offsets or imperfect magnetic field distribution, improving an-

Address	Register								Default value
0x16	RESERVE		REG_CAL	ANLC_EN	RESERVE				0x04
0x72	RESERVE		ANLC_STATUS[1:0]		RESERVE				0x00

Figure 25: Registers related to ANLC (Auto Nonlinearity Calibration)

gle measurement accuracy.

12.1 Calibration Principle

During calibration, the system collects angle error data at 16 evenly spaced points within one full rotation. Using these points, the chip calculates correction parameters and applies real-time output compensation.

During the calibration process, the PWM output flashes at 3.8 Hz with a 50% duty cycle to indicate that calibration is in progress. Once calibration is complete, the PWM output returns to normal operation.

12.2 Calibration Status

The register `ANLC_STATUS[1:0]` reflects the current calibration state:

Table 13: Calibration Status via `ANLC_STATUS[1:0]`

Value	Description
0	Calibration not started
1	Calibration in progress
2	Calibration failed
3	Calibration completed

12.3 Calibration Methods

KTH7111 supports two ways to trigger ANLC:

1. **Register-triggered:** Set `REG_CAL` to 1 to start nonlinearity calibration.
2. **Pin-triggered:** Pull the `AUTO_CAL` pin high and hold for a period. The system will automatically determine whether to perform zero position setting or ANLC based on the angle behavior.

12.4 Calibration Guidelines

To ensure optimal calibration results:

1. Keep the magnetic field stable and avoid movement between the magnet and sensor.
2. Maintain a constant rotation speed during calibration. A recommended speed is 100 to 1000 rpm. Too high or too low speed may affect the result.
3. Perform calibration under actual application conditions to capture

real-world error.

- For off-axis installations, configure `GAINTRIM` parameters before ANLC.
- After calibration, parameters are automatically written to MTP and will be retained after power-off.

13 System Operation Settings

Address	Register	Default value
0x00	ZERO[7:0]	0x00
0x01	ZERO[15:8]	0x00
0x02	RD AUTO_ZERO_SET Z_PHASE[1:0] Z_EDGE Z_WID[2:0]	0x00
0x06	RAM_HYS[7:0]	0x07
0x07	RESERVE RAM_HYS[14:8]	0x00
0x0D	FW[7:0]	0x88

Figure 26: System Operation Related Registers

13.1 Rotation Direction

The rotation direction is configured via the `RD` bit in register `0x02`. It determines whether clockwise or counter-clockwise rotation increases the output angle.

- When `RD = 1` (default): Viewed from above the chip, clockwise rotation increases the output angle.
- When `RD = 0`: Counter-clockwise rotation increases the output angle.

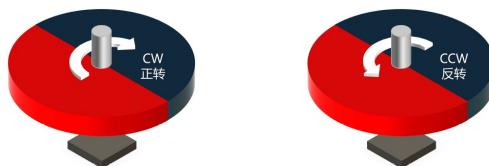


Figure 27: Rotation Direction and Angle Output Relationship

13.2 Zero Position Setting

The chip supports both automatic and manual zero alignment.

13.2.1 Automatic Zero Setting

Method 1: Register Triggered Setting `AUTO_ZERO_SET = 1` will trigger zero alignment. The chip executes:

- Calculate:

$$\text{zero_set_angle} = \begin{cases} \text{ZERO} - \text{angle}, & \text{if } \text{RD} = 1 \\ \text{ZERO} + \text{angle}, & \text{if } \text{RD} = 0 \end{cases}$$

2. Write result to ZERO[15:0] register.
3. Write to MTP.
4. AUTO_ZERO_SET bit clears automatically.

Method 2: Pin Triggered Pulling AUTO_CAL pin high for more than 2 s will trigger zero setting:

- The chip captures the current angle as zero.
- Writes it to MTP memory.

13.2.2 Manual Zero Position Setting

Manual zero setting is implemented by directly writing to the ZERO[15:0] register.

- Register range: 0 to 65535, representing 0° to 360°
- Written value takes effect immediately and affects all output interfaces
- Value is volatile and will be lost on power-off unless saved via MTP programming

The effect of the ZERO value on angle output is as follows:

- If RD = 0:

$$\text{Angle}_{\text{out}} = \text{Angle}_{\text{raw}} - \text{ZERO}$$
- If RD = 1:

$$\text{Angle}_{\text{out}} = \text{Angle}_{\text{raw}} + \text{ZERO} - 65536$$

Table 14: Comparison of Zero Setting Methods

Method	Advantages	Disadvantages
Register-based ZERO setting	Simple operation, automatic saving, no communication required	Requires SPI access
AUTO_CAL pin based setting	No communication, easy to use	Requires additional control pin
Manual ZERO register setting	High accuracy, flexible setting	Must be saved via SPI, more complex

The ZERO[15:0] register defines the zero position and applies to all output types with 16-bit resolution.

ZERO Value Calculation

- If RD = 1:

$$\text{ZERO} = 2^{16} - \left(\frac{\text{Desired Angle}}{360^\circ} \times 2^{16} \right) + 1$$
- If RD = 0:

$$\text{ZERO} = \left(\frac{\text{Desired Angle}}{360^\circ} \times 2^{16} \right)$$

Example If RD = 1 and SPI outputs 16384 (i.e., 90°), set ZERO = 49152, output becomes 0°. If RD = 0 and SPI outputs 16384, set ZERO = 16384, output becomes 0°

13.3 Hysteresis

Hysteresis prevents false triggering and improves anti-noise capability by introducing an intentional delay. The system will only output changes when signal deviation exceeds a defined threshold.

- Applies to all output interfaces
- Configured via RAM_HYS[14:0]
- 1 LSB = $\frac{360^\circ}{32768} \approx 0.01099^\circ$
- Default value: 7 → 0.07693°

Table 15: Hysteresis Parameter Configuration Table

RAM_HYS[14:0]	Hysteresis Angle (°)	Description
0	0	No hysteresis
1	0.01099	Minimum hysteresis
2	0.02197	
4	0.04395	
7	0.07693	
8	0.08789	Default
16	0.17578	
32	0.35156	
64	0.70313	
128	1.40625	
		Maximum hysteresis

The hysteresis angle is calculated as:

$$\text{Hysteresis Angle} = \frac{\text{RAM_HYS} \times 360^\circ}{32768}$$

13.4 Digital Filter

The depth of the digital filter affects both noise immunity and system dynamic response. It is configured by the FW[7:0] register.

- Higher filter level → higher effective resolution
- Lower filter level → faster response
- Default value: 0x88

Table 16: Effective Resolution vs. Filter Depth

FW [7 : 0]	Filter Level	Effective Resolution (bit)
0x00	0	9.5
0x11	1	10
0x33	3	11
0x77	7	12
0x88	8	13
0xAA	10	14
0xFF	15	15

14 Product Selection Guide

Table 17: Product Selection Table

Model	Noise (1 sigma)	Output Interface	Time Constant τ (ms)	Operating Magnetic Field	Application
KTH7111	0.015°	SPI, SSI, PWM, ABZ	0.51	30–150 mT	Industrial Automation

15 Ordering Information

Table 18: Ordering Information

Model	Package Type	Operating Temperature	Application	Number of Pins	CRC Check
KTH7111-QN16	QFN3×3-16L	−40°C to 125°C	Industrial Automation	16	No

16 QFN-16L Package Information

16.1 Package Drawing

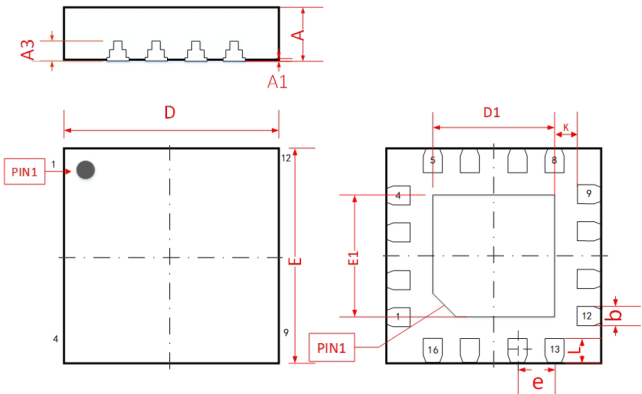


Figure 28: QFN-16L Mechanical Drawing

16.2 Mechanical Dimensions

Table 19: QFN-16L Package Dimensions (Unit: mm)

Symbol	Min	Typ	Max
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3	0.203 REF		
D	3.00 BSC		
E	3.00 BSC		
D1	1.50	1.65	1.80
E1	1.50	1.65	1.80
k	0.385 BSC		
b	0.18	0.24	0.30
e	0.50 BSC		
L	0.19	0.29	0.39

17 QFN-16L Tape and Reel Information

17.1 Package Drawing

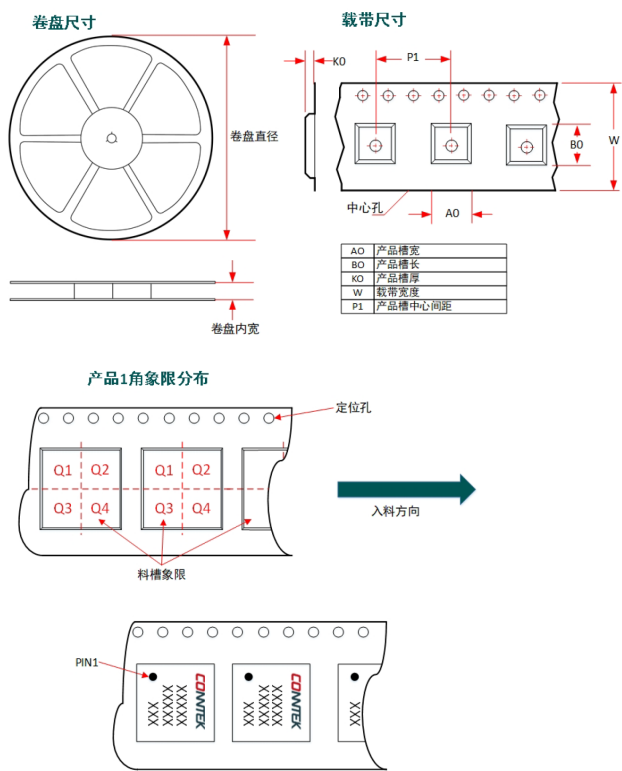


Figure 29: QFN-16L Tape and Reel Mechanical Drawing

17.2 Tape Dimensions

Table 20: Carrier Tape and Reel Parameters

Package Type	Pins	SPQ	Reel Diameter	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)
QFN3×3-16L	16	5000	330	12.4	3.35	1.13	8.00	12.00

18 Reflow Soldering Temperature Profile

The recommended reflow soldering profile is shown below. It follows a standard ramp-soak-peak process.

18.1 Profile Parameters

- Preheat stage: $150^{\circ}\text{C} \pm 10^{\circ}\text{C}$ for 90 ± 30 seconds
- Ramp-up slope: $2\text{--}5^{\circ}\text{C/s}$
- Peak temperature: $255^{\circ}\text{C} \pm 10^{\circ}\text{C}$ for 10 ± 1 seconds
- Cooling rate: $2\text{--}5^{\circ}\text{C/s}$

18.2 Temperature Curve

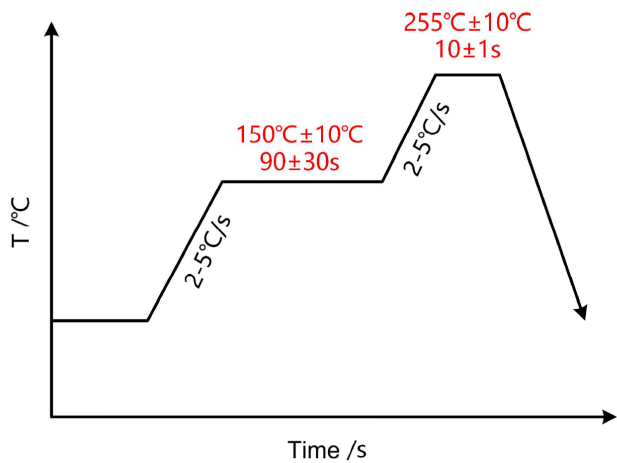


Figure 30: Reflow Soldering Temperature Curve