

# TMR3102P

## TMR Magnetic Rotary Encoder

### Description

The TMR3102P is a contactless, high-precision, and high-speed magnetic rotary encoder sensor, which integrated with tunneling magnetoresistance (TMR) sensors and CMOS digital signal processing circuitry.

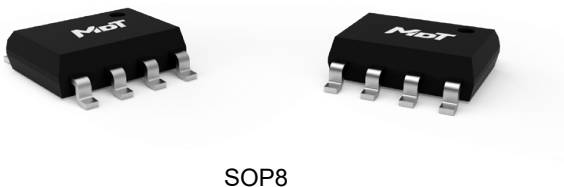
The TMR3102P senses the single pole-pair magnet rotation above the chip by TMR sensors, collects the rotating magnetic field signal, transmits it to the digital processing unit, and calculates the rotation angle. TMR3102P outputs 12-bit absolute position signal through SPI communication protocol. At the same time, it is able to output analog and PWM signals, with rotational speed up to 20,000 RPM.

### Features and Benefits

- Tunneling magnetoresistance (TMR) technology
- Contactless measurement
- Available in Analog and PWM interfaces output
- 12-bit absolute position output in SPI mode
- Programmable zero position
- Angular repeatability  $< \pm 0.2^\circ$
- Speeds up to 20,000 RPM
- Adaptive supply voltage: 3.3 V to 5 V

### Applications

- Contactless angular position measurement
- Brushless motor position sensing
- Rotary speed sensing
- Rotary angular sensing



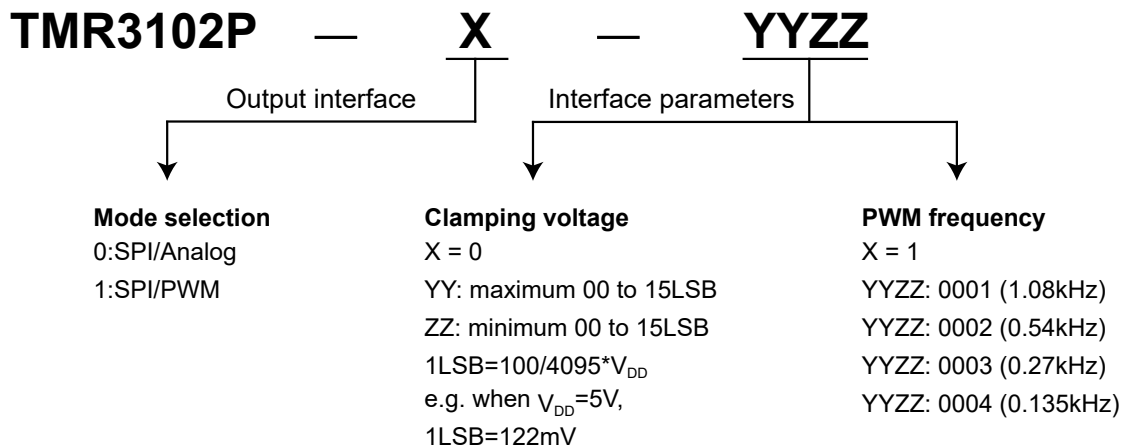
SOP8



## Selection Guide

| Part Number(*)  | Output Interface | SPI Interface Voltage | Operating Temperature | Package | Packing Form |
|-----------------|------------------|-----------------------|-----------------------|---------|--------------|
| TMR3102P-0-0000 | SPI / Analog     | 3.3 V to 5.0 V        | -40 °C to 125 °C      | SOP8    | Tape & Reel  |

Note: \*Please contact MDT local sales representative for more model's information.



## Catalogue

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## 1. Pin Configuration

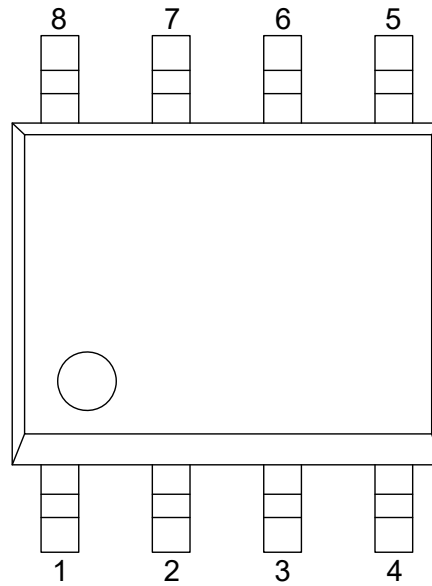


Figure 1. Pin configuration (SOP8)

| Pin Number | Name            | Input/Output | Signal type       | Function                           |
|------------|-----------------|--------------|-------------------|------------------------------------|
| 1          | OUT             | Output       | Analog or digital | Analog linear output or PWM output |
| 2          | MISO            | Output       | Digital           | SPI data out                       |
| 3          | MOSI            | Input        | Digital           | SPI data in                        |
| 4          | SCLK            | Input        | Digital           | SPI clock                          |
| 5          | CS              | Input        | Digital           | SPI chip select                    |
| 6          | V <sub>DD</sub> | Input        | Power supply      | Power supply                       |
| 7          | GND             | Input        | GND               | GND                                |
| 8          | ERROR           | Output       | Digital           | Error signal                       |

## 2. Absolute Maximum Ratings

| Parameter                     | Symbol    | Min. | Max. | Unit |
|-------------------------------|-----------|------|------|------|
| Supply voltage                | $V_{DD}$  | -    | 6    | V    |
| Magnetic flux density         | B         | -    | 4000 | Gs   |
| Operating ambient temperature | $T_A$     | -40  | 125  | °C   |
| Storage ambient temperature   | $T_{STG}$ | -40  | 150  | °C   |
| Ambient humidity (no dew)     | HMD       | 10   | 90   | %RH  |
| ESD performance (HBM)         | $V_{ESD}$ | -    | 2    | kV   |

The Absolute Maximum Rating parameters is only a condition to ensure that the chip is not permanently damaged. For normal operating conditions, please refer to Electrical Specifications.

## 3. Electrical Specifications

$V_{DD} = 3.3\text{ V to }5\text{ V}$ ,  $T_A = 25\text{ °C}$

| Parameter           | Symbol     | Condition      | Min.  | Typ. | Max.     | Unit |
|---------------------|------------|----------------|-------|------|----------|------|
| Supply voltage      | $V_{DD}$   | -              | 3.3   | -    | 5        | V    |
| Supply current      | $I_{DD}$   | No output load | -     | 8    | 10       | mA   |
| MISO output voltage | $V_{OUT}$  | -              | -0.3  | -    | $V_{DD}$ | V    |
| MISO output current | $I_{OUT1}$ | -              | -1.25 | -    | 1.25     | mA   |
| Input voltage       | $V_{IN1}$  | MOSI, CS, SCLK | -0.3  | -    | $V_{DD}$ | V    |

## 4. Signal Conversion Specifications

| Parameter                                    | Symbol        | Condition      | Min. | Typ. | Max.   | Unit |
|--|---------------|----------------|------|------|--------|------|
| Measurement range                            | $A_{range}$   | -              | 0    | -    | 360    | Deg  |
| Absolute resolution                          | $RES_{SDC}$   | -              | -    | 12   | -      | bit  |
| Nonlinearity error                           | $INL_{OPT}$   | -              | -    | -    | ±1     | Deg  |
| Nonlinearity error in full temperature range | $INL_{drift}$ | -40°C to 125°C | -    | -    | ±1.2   | Deg  |
| Differential nonlinearity                    | DNL           | -              | -    | -    | ±0.132 | Deg  |
| Hysteresis                                   | Hyst          | -              | -    | -    | ±0.308 | Deg  |
| Repeatability                                | $A_{REPEAT}$  | -              | -    | -    | ±0.2   | Deg  |
| Output delay                                 | $T_D$         | -              | -    | 5    | 10     | µs   |
| Rotation speed                               | $R_{speed}$   | -              | -    | -    | 20000  | RPM  |

## 5. Digital Interface Signals

CS, SCLK, MOSI, MISO

| Parameter               | Symbol      | Condition | Min. | Typ. | Max. | Unit |
|-------------------------|-------------|-----------|------|------|------|------|
| Input threshold high    | $V_{I(HI)}$ | -         | 3.3  | -    | -    | V    |
| Input threshold low     | $V_{I(LO)}$ | -         | -    | -    | 1    | V    |
| Output threshold high   | $V_{O(HI)}$ | I = 1 mA  | 4.5  | -    | -    | V    |
| Output threshold low    | $V_{O(LO)}$ | I = 1 mA  | -    | -    | 0.5  | V    |
| Output load capacitance | $C_L$       | -         | -    | -    | 100  | pF   |

## 6. Analog Output Characteristics

| Parameter   | Symbol        | Condition | Min. | Typ.  | Max.      | Unit       |
|---|---------------|-----------|------|-------|-----------|------------|
| Output load resistance                                    | $R_L$         | -         | -    | 10    | -         | k $\Omega$ |
| Output load capacitance                                   | $C_L$         | -         | -    | 10    | -         | nF         |
| Minimum resolution of digital-to-analog conversion        | $DAC_{LSB}$   | 12bit     | -    | 0.024 | -         | % $V_{DD}$ |
| Integral nonlinearity of digital-to-analog conversion     | $DAC_{INL}$   | -         | -    | -     | $\pm 1.5$ | Deg        |
| Differential nonlinearity of digital-to-analog conversion | $DAC_{DNL}$   | -         | -    | -     | $\pm 0.5$ | Deg        |
| Analog output noise                                       | $DAC_{noise}$ | -         | -    | -     | $\pm 2$   | LSB        |
| Proportional error  | $E_{rm}$      | -         | -0.3 | -     | 0.3       | %          |

## 7. PWM Characteristics

| Parameter     | Symbol     | Condition    | Min. | Typ.                          | Max. | Unit    |
|---------------|------------|--------------|------|-------------------------------|------|---------|
| PWM frequency | $F_{PWM}$  | Programmable | -10% | 1.08<br>0.54<br>0.27<br>0.135 | +10% | kHz     |
| Rise time     | $T_{rise}$ | 10 nF load   | -    | -                             | 1    | $\mu$ s |
| Fall time     | $T_{fall}$ | 10 nF load   | -    | -                             | 1    | $\mu$ s |

## 8. Magnetic Field Specification

Recommended magnet: cylindrical NdFeB magnet,  $\phi 6\text{mm} \times 2.5\text{mm}$ , radial magnetization

| Parameter                                    | Symbol              | Condition                              | Min.  | Typ. | Max. | Unit |
|--|---------------------|--|-------|------|------|------|
| Diameter of magnet                           | $d_{\text{mag}}$    | -                                      | 3.0   | 6.0  | 20   | mm   |
| Thickness of magnet                          | $t_{\text{mag}}$    | -                                      | -     | 2.5  | -    | mm   |
| Mounting distance                            | $D_{\text{in}}$     | Recommend magnet ( $\phi 6\text{mm}$ ) | -     | 6    | -    | mm   |
| Magnetic field                               | $H_{\text{ext}}$    | Sensor surface                         | -     | 300  | -    | Gs   |
| Center deviation between magnet and sensor   | $x_{\text{dis}}$    | -                                      | -     | -    | 0.25 | mm   |
| Center deviation between sensor and package  | $x_{\text{pac}}$    | -                                      | -0.15 | -    | 0.15 | mm   |
| Angle deviation of the sensor within package | $\phi_{\text{pac}}$ | -                                      | -3    | -    | 3    | Deg  |
| Sensor to package clearance                  | $h_{\text{pac}}$    | -                                      | -     | 0.4  | -    | mm   |

## 9. Output mode

### 9.1 SPI output

TMR3102P provides the 4-wire SPI interface for user programming in common mode 1 (CPOL=0, CPHA=1). Data communication is only enabled when the CS pin is set to “L”. The MOSI pin carries the serial input data that will be written to the IC upon the falling edge of the SCLK signal. The serial output data is available to read at the MISO pin upon the rising edge of the SCLK signal.

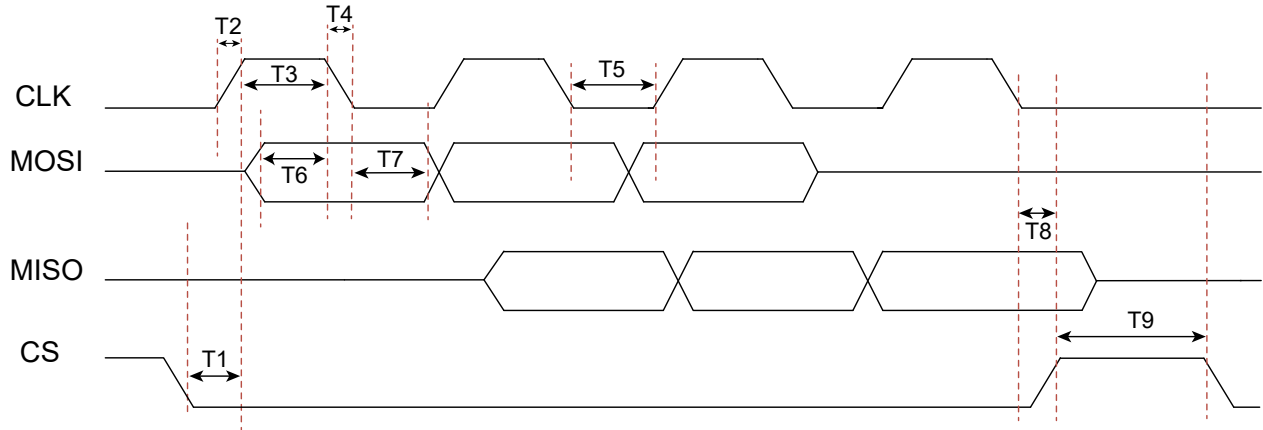


Figure 2. SPI timing diagram

| Signal | Definition                       | Min. | Typ. | Max. | Unit |
|--------|----------------------------------|------|------|------|------|
| T1     | SPI start-up time                | -    | 150  | -    | ns   |
| T2/T4  | Clock signal rising/falling time | -    | -    | 25   | ns   |
| T3     | Clock signal HIGH period         | 150  | -    | -    | ns   |
| T5     | Clock signal LOW period          | 150  | -    | -    | ns   |
| T6     | Input signal setup time          | 100  | -    | -    | ns   |
| T7     | Input signal sampling hold time  | 100  | -    | -    | ns   |
| T8     | SPI closing time                 | -    | 150  | -    | ns   |
| T9     | SPI reading interval             | 4    | -    | -    | μs   |

Reading angular values

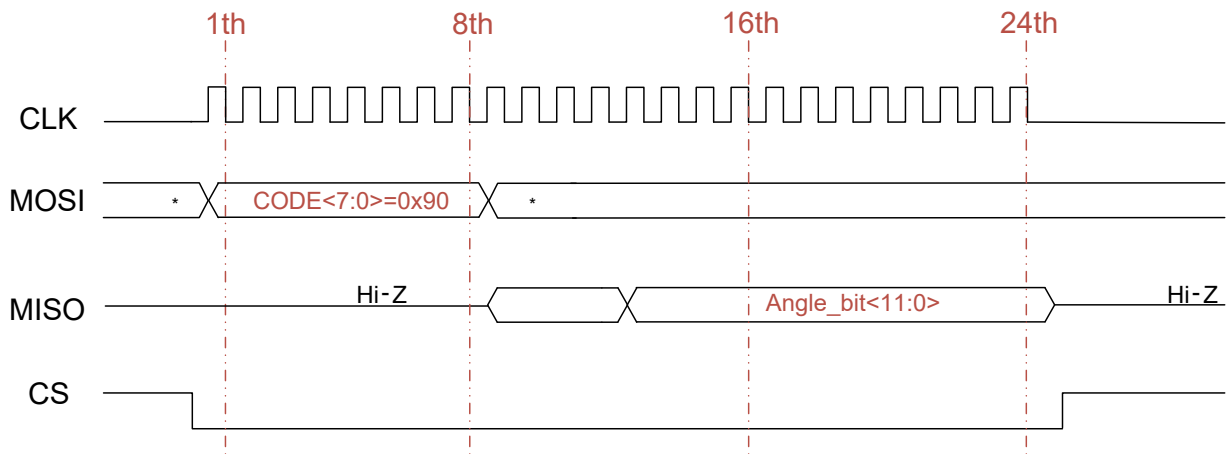


Figure 3. SPI timing diagram in reading angular values

Opcode<7:0>=0x90 (MSB first), angular value output <11:0> (MSB first)

The absolute angular value  $\theta$  in  $0^\circ$  to  $360^\circ$  can be calculated from the equation below:

$$\theta = \frac{\sum_{i=0}^{11} 2^{Angle\langle i \rangle}}{4096} \times 360^\circ$$



## 9.2 Analog output

TMR3102P integrates a 12-bit ADC to convert absolute angle to linear analog output. The output mode needs to be programmed to be an analog voltage output as shown in Figure 4.

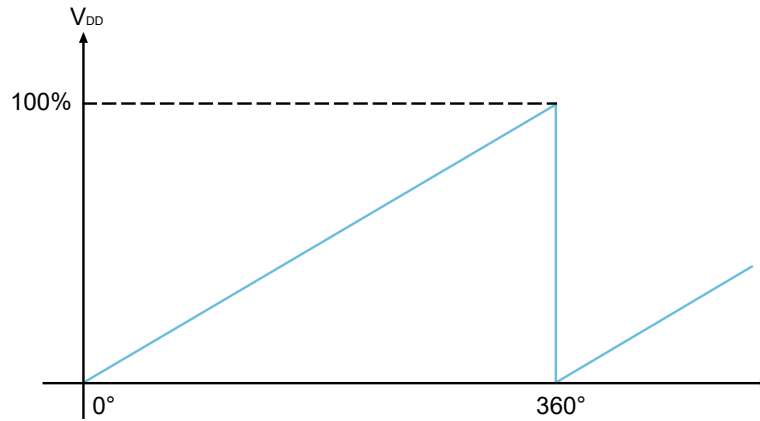


Figure 4. Waveform of analog output

A typical application circuit for analog mode is provided in Figure 5. It is recommended to connect an external decoupling capacitor C1 (typical value 10nF, maximum 100nF) and pull-up resistor R1 (typical value 10k $\Omega$ ) for analog output circuit to obtain better performance.

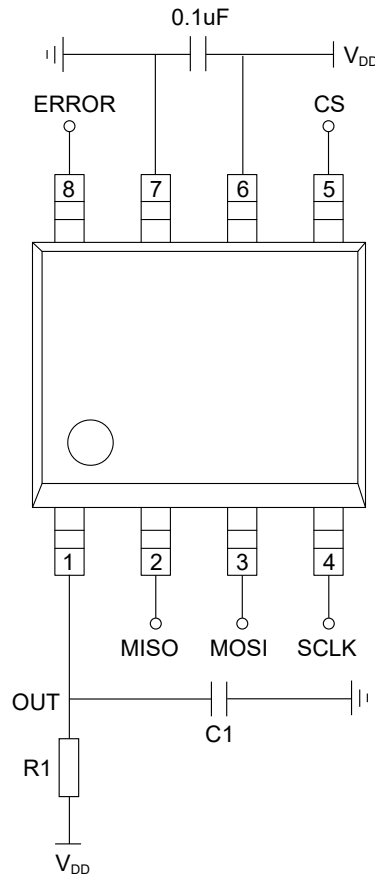


Figure 5. Schematic circuit of analog mode

The high clamping voltage (Clamp\_High) and low clamping voltage (Clamp\_Low) of analog output characteristic curves are both programmable as shown in Figure 6.

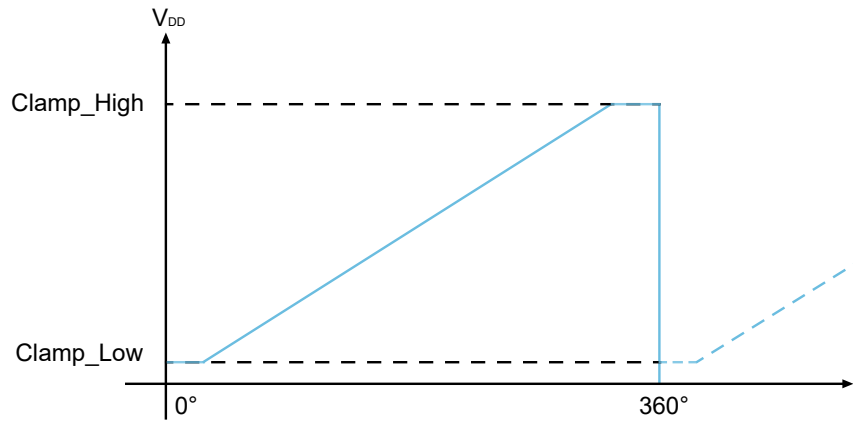


Figure 6. Schematic of clamping voltage in analog waveform

The xMR310X calibration kit and corresponding host computer software is provided for the convenience of customer calibration and settings. The clamping voltage in analog mode of TMR3102P sensor can be set by this xMR310X calibration kit.

### 9.3 PWM output

TMR3102P supports pulse width modulation (PWM) output. The duty cycle of PWM is a logic signal which proportional to the magnetic field angle. The duty cycle is limited by the minimum value (1/4096 of the period) and the maximum value (4095/4096 of the period), so the duty cycle varies from 1/4096 to 4095/4096 with the resolution of 12-bits. Figure 7 shows one period of the PWM signal, and the period (T) is  $1/F_{PWM}$ .

$F_{PWM}$  supports 1.08 kHz, 0.54 kHz, 0.27 kHz, and 0.135 kHz these four frequencies.

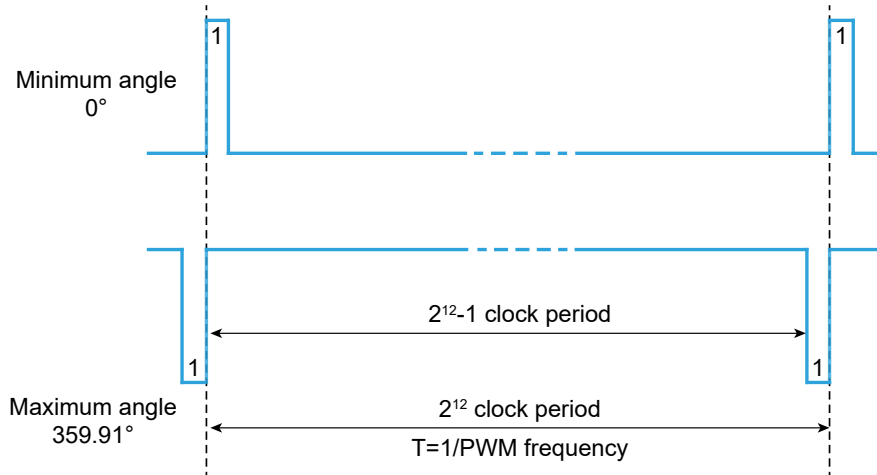


Figure 7. Waveform of PWM mode output signal

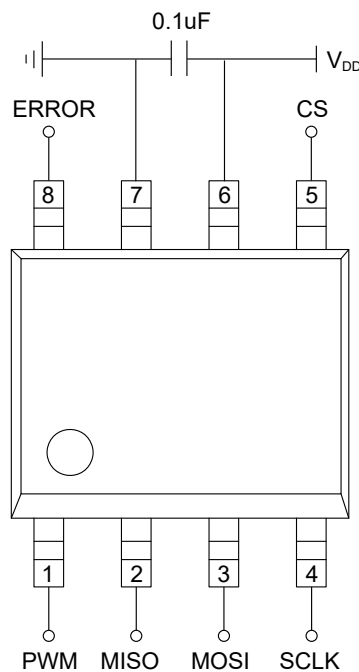


Figure 8. Schematic circuit of PWM mode

The xMR310X calibration kit and corresponding host computer software is provided for the convenience of customer calibration and settings. The output mode and the PWM frequency of TMR3102P sensor can be set by this xMR310X calibration kit.

## 10. Mechanical Angle Orientation

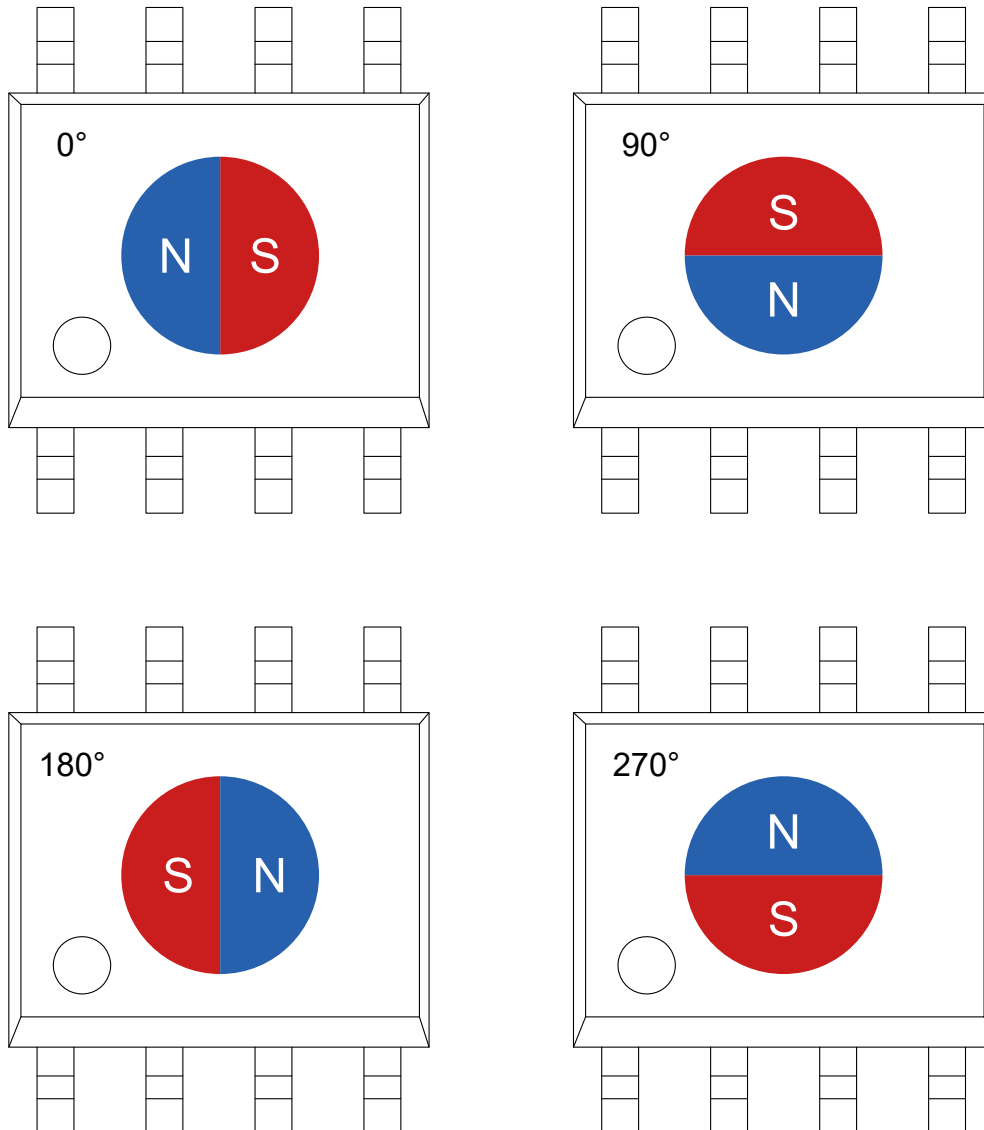


Figure 9. Definition of the magnetic field orientation measured by TMR312P

## 11. Dimensions

### SOP8 Package

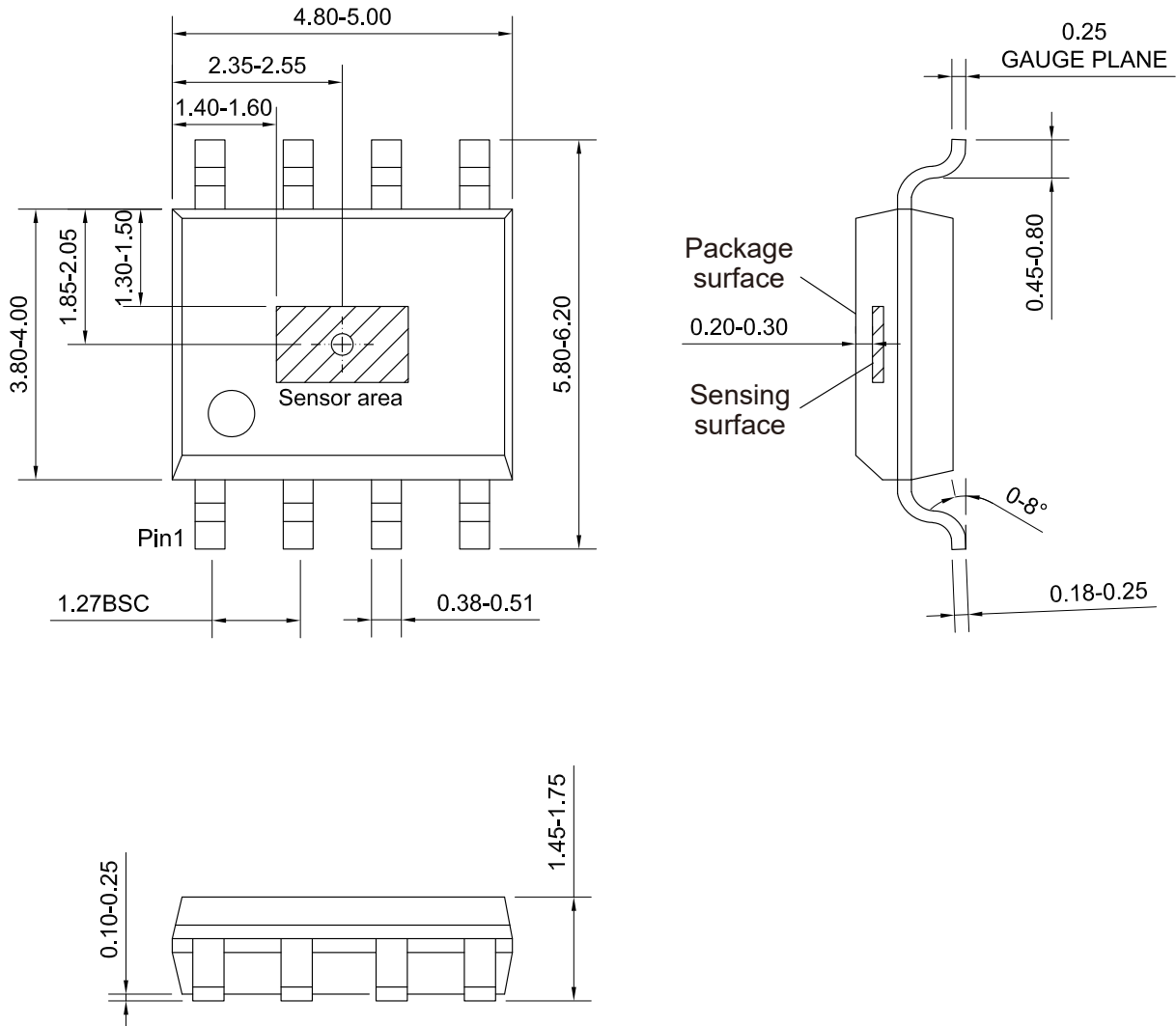


Figure 10. Package outline of SOP8 (unit: mm)

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