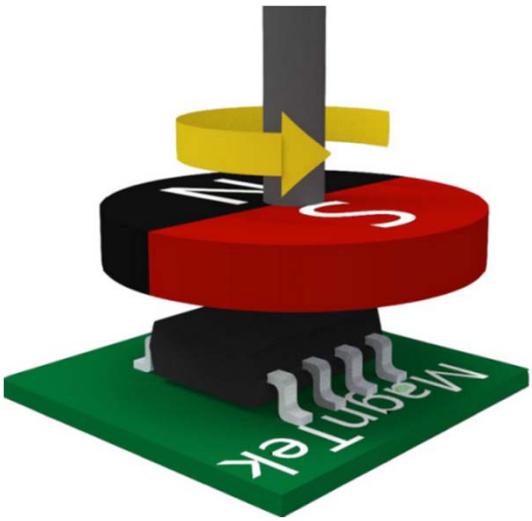
# MT6816

## Zero Latency Magnetic Angle Position Sensor IC

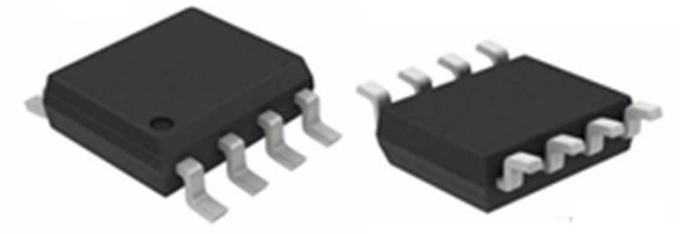
## Features and Benefits

- Based on advanced AMR Technology with 0~360° Full Range Angle Sensing
- 14 bit Core Resolution
- Maximum Rotation Speed 25,000 RPM
- Output Propagation Delay <2 us
- -40~125℃ Industry Operating Temperature Range
- Output Interface: ABZ、UVW， PWM or SPI
- Incremental ABZ Resolution 1~1024 Pulses per Revolution User Programmable
- UVW Output Resolution 1~16 Pole-Pairs per Revolution User Programmable
- SOP-8 Package




## Applications

- Absolute Angle Position Sensor
- BLDC Motor Control
- Servo Motor Control
- Stepping Motor Control
- Optical Encoder Replacement



## General Description

The MagnTek rotary position sensor MT6816 is an IC based on advanced AMR technology. A rotating magnetic field in the x-y sensor plane delivers two sinusoidal output signals which indicating the angle (α) between the sensor and the magnetic field direction.

The sensor is only sensitive to the magnetic field direction in x-y plane as the sensing element output is specially designed to be independent from the magnet field strength. This allows the device to be less sensitive to magnet variations, stray magnetic fields, air gap changes and off-axis misalignment.

The incremental ABZ output mode is available in this sensor series, making the chip suitable to replace various optical encoders. The maximum resolution is 4096 steps or 1024 pulses per revolution

A standard SPI (3-Wire or 4-Wire) interface allows a host microcontroller to read out the 14-bit absolute angle position data from MT6816. The absolute angle position is also provided as a 12bit PWM output.

# Table of Contents

# 1. Pin Configuration

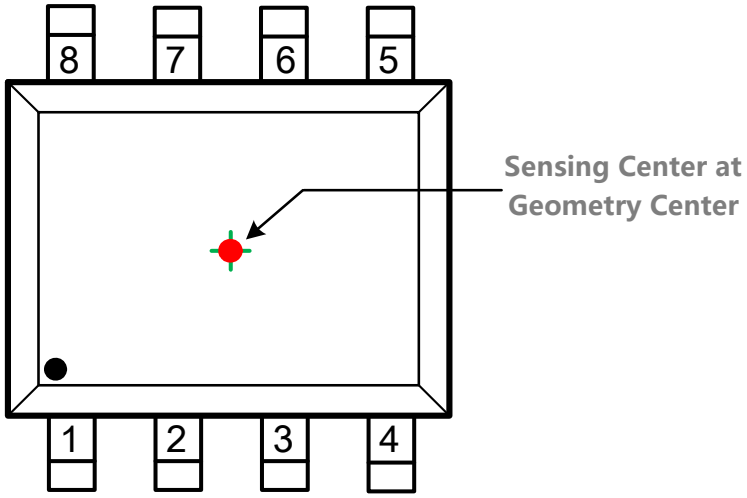



*Figure 1: Pin Configuration of MT6816(SOP-8) Package*

### Pin List

| Name | # | Type | Description |
|---|---|---|---|
| CSN | 1 | Digital Input | SPI Chip Selection |
| HVPP | 2 | Power Supply | OTP Programming Supply（7V）or SPI Enable |
| OUT | 3 | Digital Output | PWM Output |
| VDD | 4 | Power Supply | 3.3~5.0V Supply |
| A/U | 5 | Digital Input/output | Incremental Signal A/U or SPI MOSI(4-Wire), SDAT(3-Wire) |
| B/V | 6 | Digital Input/output | Incremental Signal B/V or SPI MISO(4-Wire) |
| Z/W | 7 | Digital Input | Incremental Signal Z/W or SPI Clock |
| GND | 8 | Ground | Ground |

### Family Members

| Part Number | Description |
|---|---|
| MT6816CT | SOP-8 Package, Tube Pack (100pcs/Tube) or Tape & Reel Pack (3000pcs/Reel) |

***SOP-8 Reflow Sensitivity Classification: MSL-3***

## 2. Functional Diagram

The MT6816 is manufactured in a CMOS standard process and uses advanced magnet sensing technology to sense the magnetic field distribution across the surface of the chip. The integrated magnetic sensing element array is placed around the center of the device and delivers a voltage representation of the magnetic field at the surface of the IC.

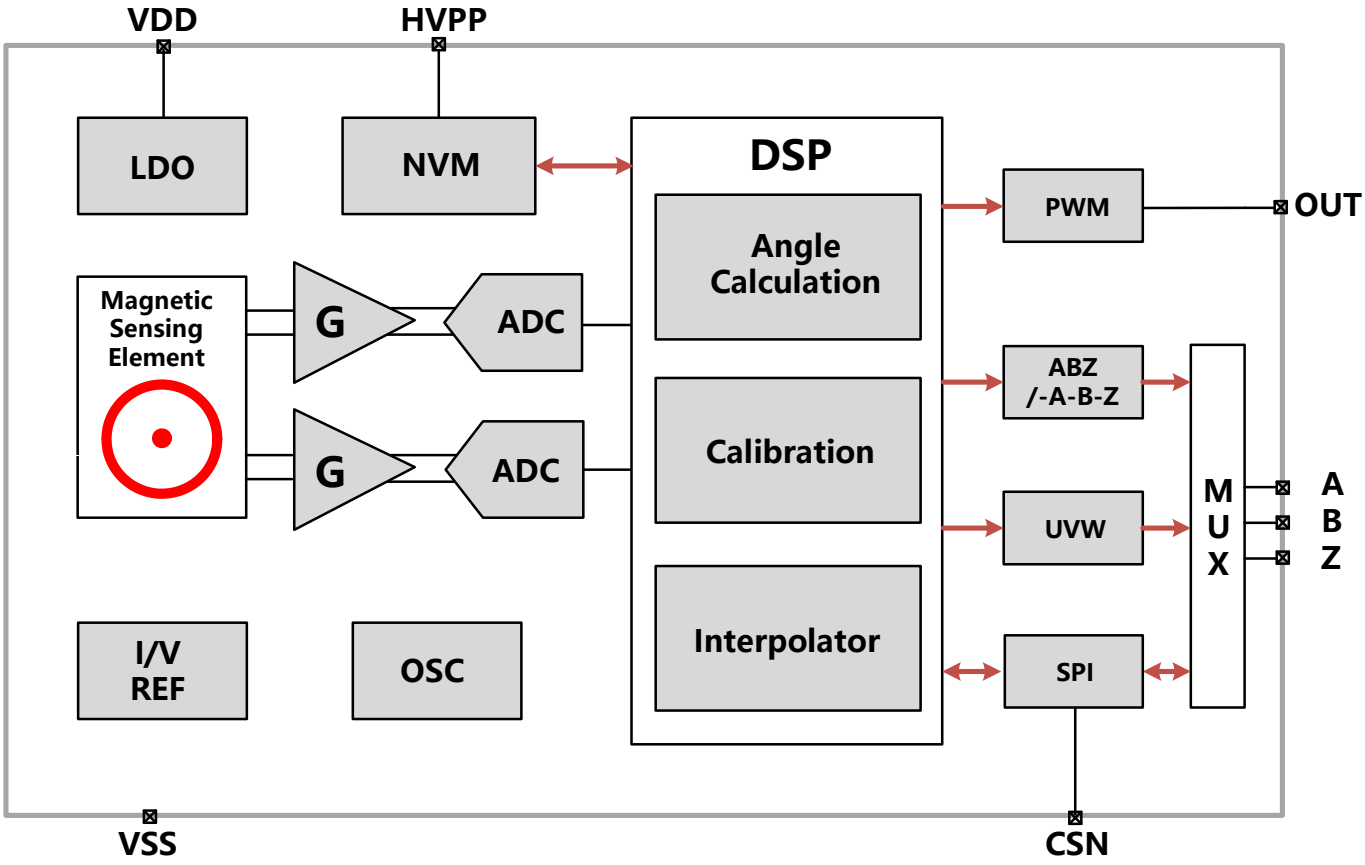



*Figure 2: Block Diagram*

Figure 2 shows a simplified block diagram of the chip, consisting of the magnetic sensing element modeled by two interleaved Wheatstone bridges to generate cosine and sine signals, gain stages, analog-to-digital converters (ADC) for signal conditioning, and a digital signal processing (DSP) unit for encoding. Other supporting blocks such as LDO, etc. are also included.

## 3. Absolute Maximum Ratings (Non-Operating)

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under "Operating Conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

| Parameter | Min. | Max. | Unit | Notes |
|---|---|---|---|---|
| DC Voltage at Pin VDD | -0.5 | 6.5 | V | |
| DC Voltage at Pin HVPP | -0.5 | 8 | V | |
| Terminal Voltage at Input and Output Pins | -0.5 | VDD | V | ABZ, OUT |
| Output Current at Output Pins | -20 | 20 | mA | ABZ, OUT |
| Storage Temperature | -55 | 150 | ℃ | |
| Electrostatic Discharge (CDM) | - | ±1.0 | KV | |
| Electrostatic Discharge (HBM) | - | ±3.0 | KV | |

## 4. Operating Conditions

| Parameter | Min. | Max. | Unit |
|---|---|---|---|
| DC Voltage at Pin VDD | 3.0 | 5.5 | V |
| DC Voltage at Pin HVPP (If Used) | 6.75 | 7.25 | V |
| Magnetic Flux Density Range | 30 | 1,000 | mT |
| Rotation Speed | - | 25,000 | RPM |
| Operating Temperature | -40 | 125 | ℃ |

## 5. Electrical Characteristics

Operation conditions: Ta=-40 to 125℃, VDD=3.0~5.5V unless otherwise noted.

| Symbol1 | Parameter | Conditions/Notes | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| VDD | Supply Voltage | - | 3.0 | 3.3~5.0 | 5.5 | V |
| HVPP | Supply Voltage | - | 6.75 | 7.0 | 7.25 | V |
| Idd | Supply Current | - | 5 | 10 | 15 | mA |
| LSB | Resolution (ABZ Mode) | N Steps per Cycle | - | 360°/N | - | ° |
| INL | Integral Non-Linearity | Note(1) | - | ±0.75 | ±1.5 | ° |
| DNL | Differential Non-Linearity (ABZ Mode), Figure 3 | @1000 PPR | - | ±0.01 | - | ° |
| TN | Transition Noise (ABZ Mode) | 25℃, HYST=4 Note(2) | - | 0.01 | - | °rms |
| Hyst | Hysteresis (ABZ Mode) | HYST=0 Note(2) | - | 0.022 | - | ° |
| $T_{PwrUp}$ | Power-Up Time | VDD Ramp<10us | - | 16 | - | ms |
| $T_{Delay}$ | Propagation Delay | | - | 1 | 3 | us |

Note (1): The typical error value can be achieved at room temperature and with no off-axis misalignment error. The maximum error value can be achieved over operation temperature range, at maximum air gap and with worst-case off-axis misalignment error.

Note (2): HYST could be set to: 0=1LSB, 1=2LSB, 2=4LSB, 3=8LSB, 4=0LSB, 5=0.25LSB, 6=0.5LSB, 7=1LSB. Here $1LSB=360°/2^{14}=0.022°$.

| PWM Output Characteristics | | Conditions/Notes | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| FPWM | PWM Frequency | Programmable | - | 971.1/485.6 | - | Hz |
| $T_{Rise}$ | Rising Time | $C_L$=1nF | - | - | 1 | us |
| $T_{Fall}$ | Falling Time | $C_L$=1nF | - | - | 1 | us |

| Digital I/O Characteristics (Push-Pull Type in Normal Mode) | | | | | | |
|---|---|---|---|---|---|---|
| **Symbol** | **Parameter** | **Conditions/Notes** | **Min.** | **Typ.** | **Max.** | **Unit** |
| $V_{IH}$ | High Level Input Voltage | - | 0.7*VDD | - | - | V |
| $V_{IL}$ | Low Level Input Voltage | - | - | - | 0.3*VDD | V |
| $V_{OH}$ | GPIO Output High Level | Push-pull (Iout=2mA) | VDD-0.25 | - | - | V |
| $V_{OL}$ | GPIO Output Low Level | Push-pull (Iout=2mA) | - | - | 0.25 | V |

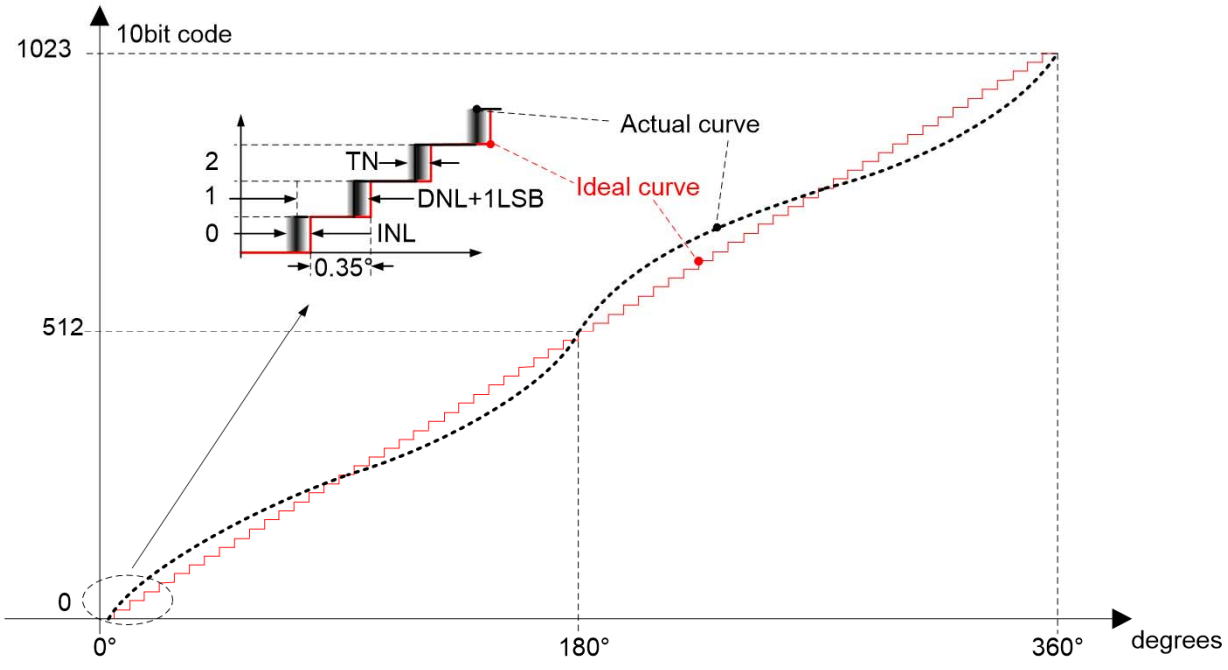



*Figure 3: Drawing Illustration INL, DNL and TN (for 10 bit case)*

## 6. Magnetic Input Specifications

Operation conditions: Ta=-40 to 125℃, VDD=3.0~5.5V unless otherwise noted, two-pole cylindrical diametrically magnetized source.

| Symbol | Parameter | Conditions/Notes | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Dmag | Diameter of Magnet | Recommended Magnet: Ø10mm x 2.5mm for Cylindrical Magnets | - | 10 | - | mm |
| Tmag | Thickness of Magnet | - | - | 2.5 | - | mm |
| Bpk | Magnetic Input Field Amplitude | Measure at the IC Surface | 30 | - | 1,000 | mT |
| AG | Air Gap | Magnetic to IC Surface Distance | - | 2.0 | 3.0 | mm |
| RS | Rotation Speed | | - | - | 25,000 | RPM |
| DISP | Off Axis Misalignment | Misalignment Error Between Sensor Sensing Center and Magnet Axis (See Figure 4) | - | - | 0.3 | mm |
| TCmag1 | Recommended Magnet Material and Temperature Drift Coefficient | NdFeB (Neodymium Iron Boron) | - | -0.12 | - | %/℃ |
| TCmag2 | | SmCo (Samarium Cobalt) | - | -0.035 | - | |

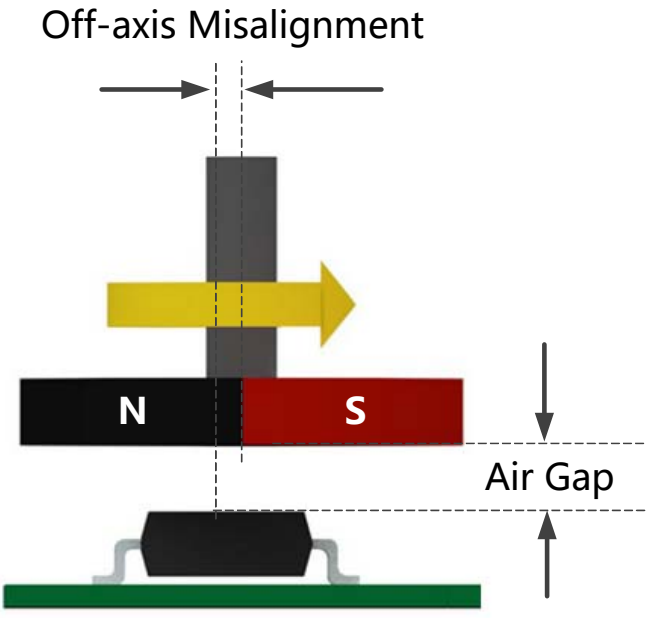



*Figure 4: Magnet Arrangement*

# 7. Output Mode

The MT6816 provides ABZ, UVW and PWM signals at output pins, and also 14-bit absolute angle position data could be transferred by SPI interface (Both 3-Wire and 4-Wire modes).

## 7.1 I/O Pin Configuration

For SOP-8 package, ABZ, UVW, PWM and SPI Interface are configured as below table.

***I/O Pin Configuration***

| Pin# | 3-Wire SPI | 4-Wire SPI | ABZ+PWM | UVW+PWM |
|---|---|---|---|---|
| **1** | CSN | CSN | VDD | VDD |
| **3** | PWM | PWM | PWM | PWM |
| **5** | SDAT | MOSI | A | U |
| **6** | - | MISO | B | V |
| **7** | SCK | SCK | Z | W |

## 7.2 Reference Circuit for ABZ, UVW and PWM Mode

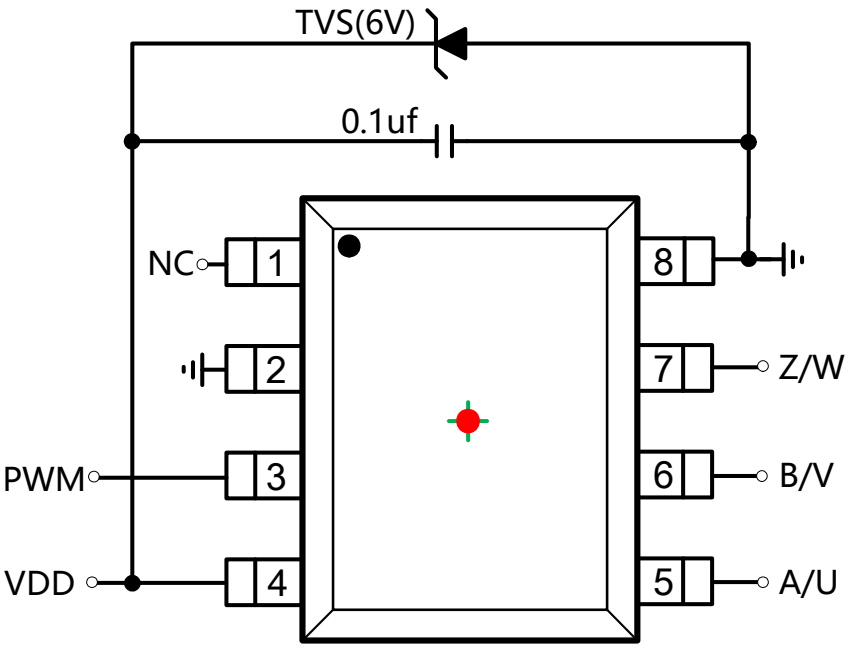



*Figure 5: ABZ, UVW and PWM Output Reference Circuit w/o MTP Programming*

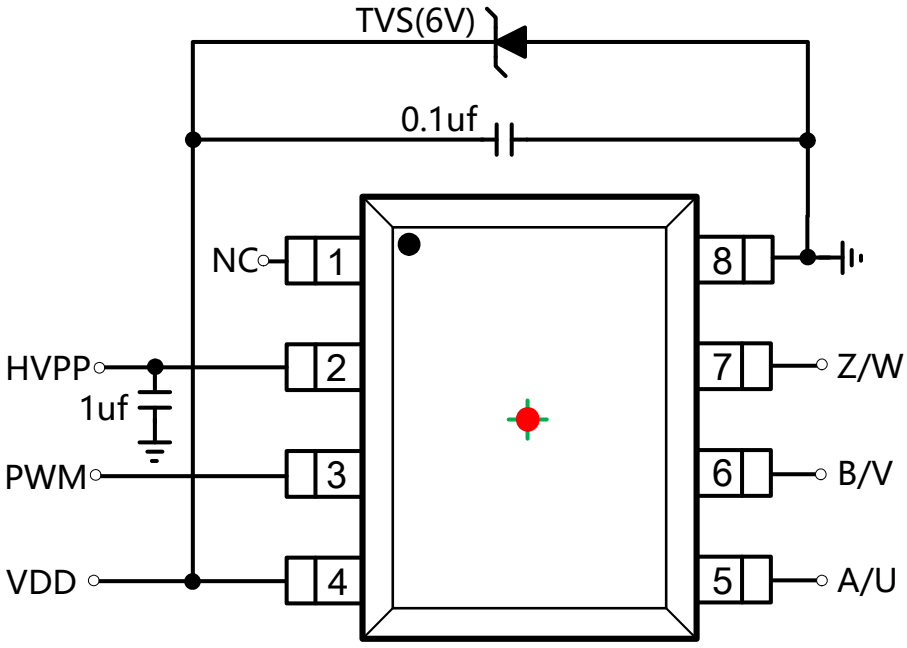



*Figure 6: ABZ, UVW and PWM Output Reference Circuit w/i MTP Programming*

## 7.3 Quadrature A,B and Zero-Position Output (ABZ Mode)

As shown in Figure 7, when the magnet rotates counter-clock-wise (CCW), output B leads output A by 1/4 cycle, when the magnet rotates clock-wise (CW), output A leads output B by 1/4 cycle (or 1 LSB). Output Z indicates the zero position of the magnet.

After chip power-on, the ABZ output is blocked for 16ms to guarantee proper output.

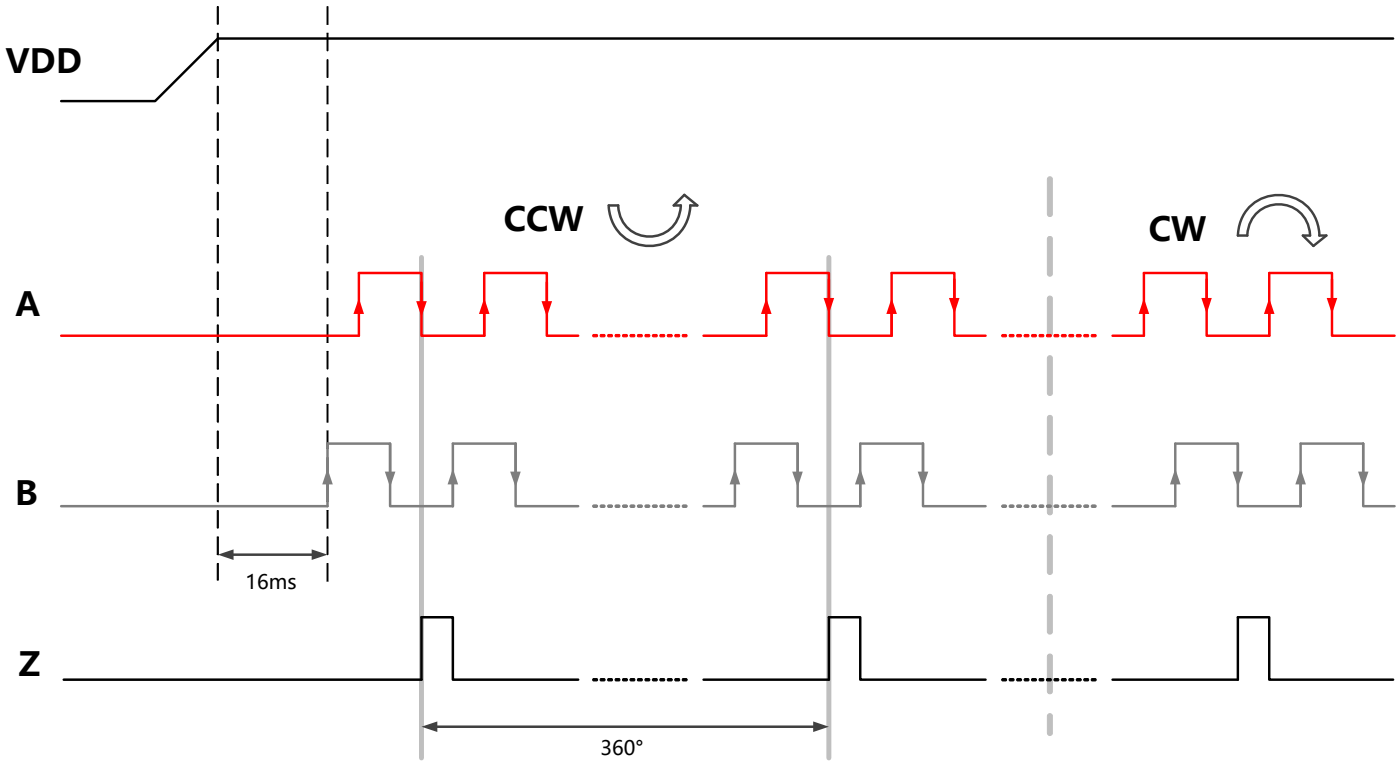



*Figure 7: ABZ output with VDD power on*

Output Z indicates the zero position of the magnet and the pulse width of Z is selectable as 1, 2, 4, 8, 12, 16 LSBs and 180° as shown in Figure 8 and Figure 9. It is guaranteed that one Z pulse is generated for every rotation. The zero position is user programmable。

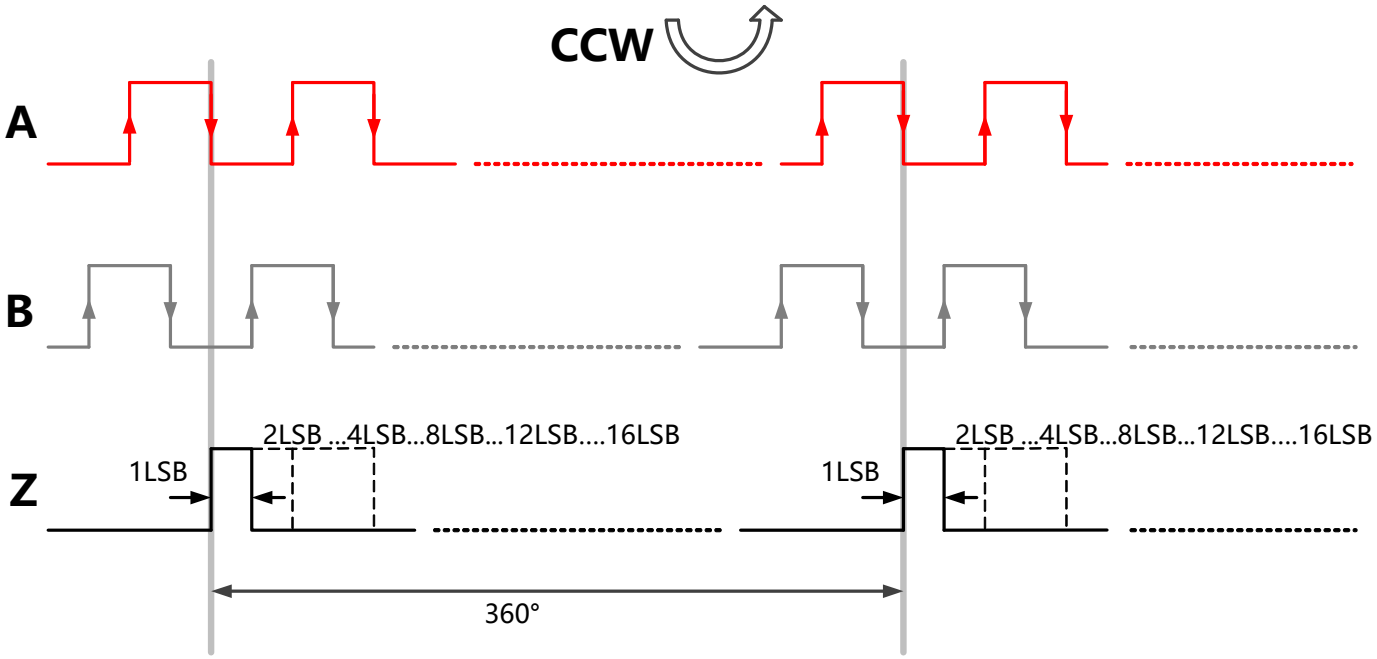



*Figure 8: Typical ABZ Output w/i Z pules width=1,2,4,8,12 and 16 LSBs*

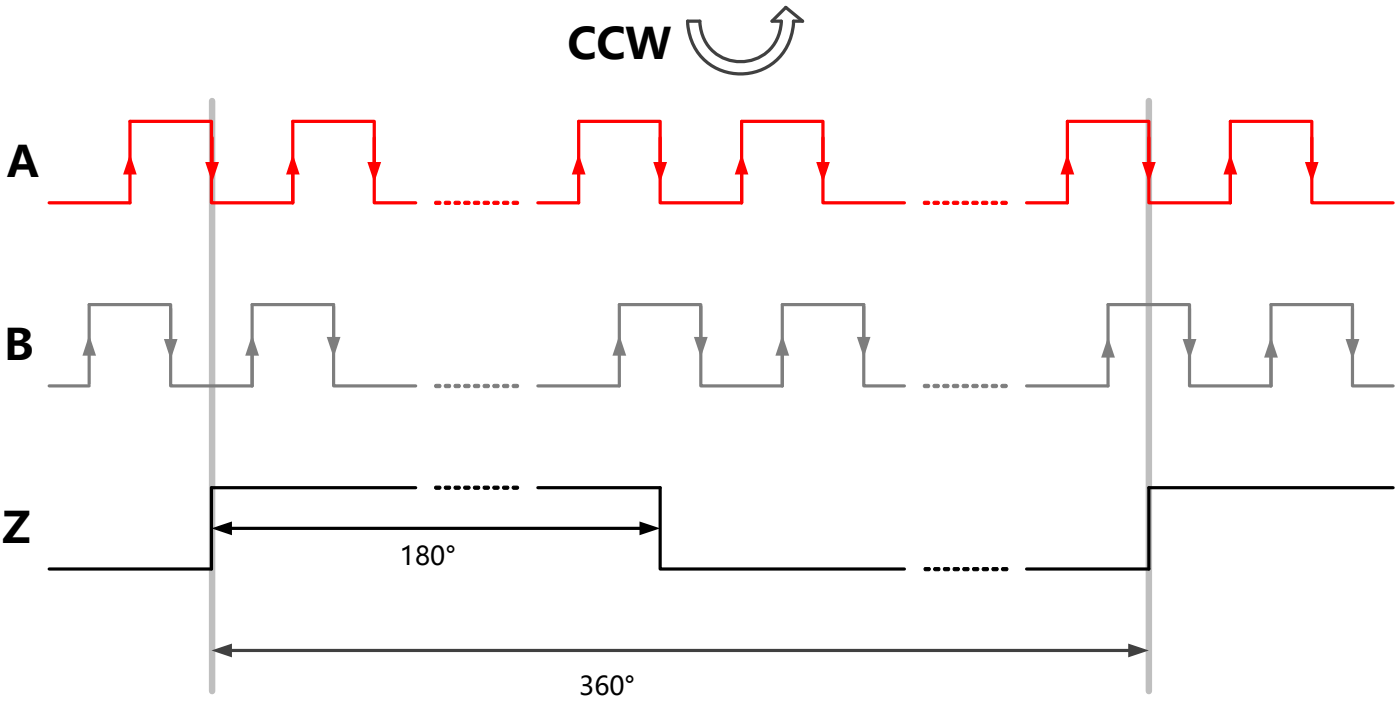
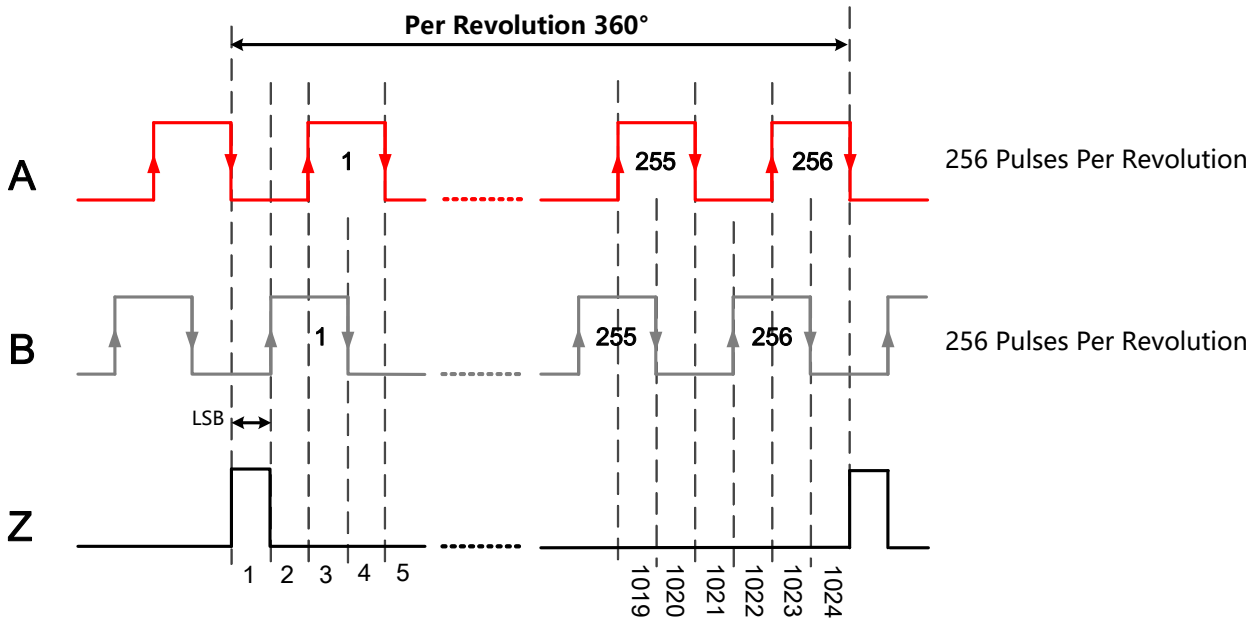


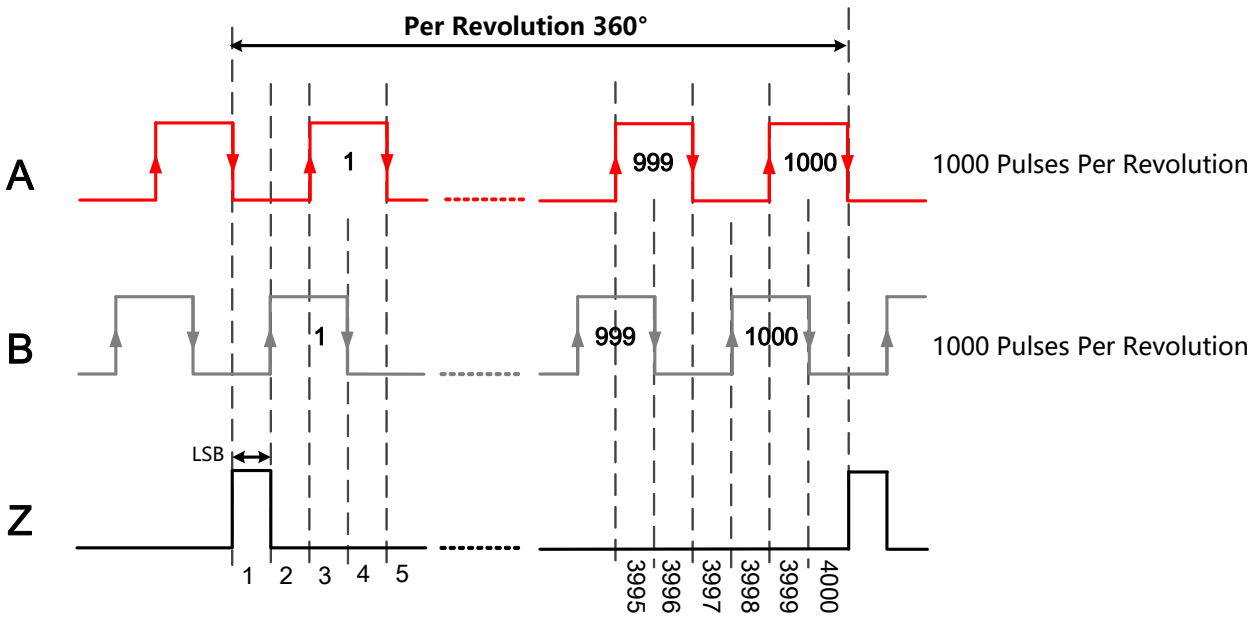

*Figure 9: Typical ABZ Output w/i Z pules width=180°*

ABZ resolution is user programmable from 1~1024 PPR. The relationship between binary bits, LSBs and PPR resolution of ABZ output are shown in Figure 10 and Figure 11.




10 bit=$2^{10}$ LSBs=1024 Steps=256 PPR

***Figure 10: ABZ Output Resolution=10 bit***




1000 PPR=4000 Steps

***Figure 11: ABZ Output Resolution=1000 PPR***

The Z/Index pulse width could be programmed

***Z/Index Pulse Width Register (MTP)***

| Reg. Z_Pulse_Width<2:0> | Width (LSBs) | Reg. Z_Pulse_Width<2:0> | Width (LSBs) |
|---|---|---|---|
| **000** | 1 | **100** | 12 |
| **001** | 2 | **101** | 16 |
| **010** | 4 | **110** | 180° |
| **011** | 8 | **111** | 1 |

The mechanical zero position could be programmed, it is a 12 bits data for 0~360°.

***Zero Position Register (MTP)***

| Register | bit7 | bit6 | bit5 | bit4 | bit3 | bit2 | bit1 | bit0 |
|---|---|---|---|---|---|---|---|---|
| **Zero_MSB** | NA | NA | NA | NA | Zero<11:8> | | | |
| **Zero_LSB** | Zero<7:0> | | | | | | | |

The resolution of ABZ could be programmed by a 10 bit register ‘ABZ_RES’

***ABZ Resolution Register (OTP)***

| Register | bit7 | bit6 | bit5 | bit4 | bit3 | bit2 | bit1 | bit0 |
|---|---|---|---|---|---|---|---|---|
| **ABZ_RES** | NA | NA | NA | NA | NA | NA | ABZ_RES<9:8> | |
| **ABZ_RES** | ABZ_RES<7:0> | | | | | | | |

## 7.4 UVW Output Mode

The MT6816 provides U, V and W pulses which are 120° (electrical) out of phase as shown in Figure 12. The cycles of UVW per rotation can be programmed.

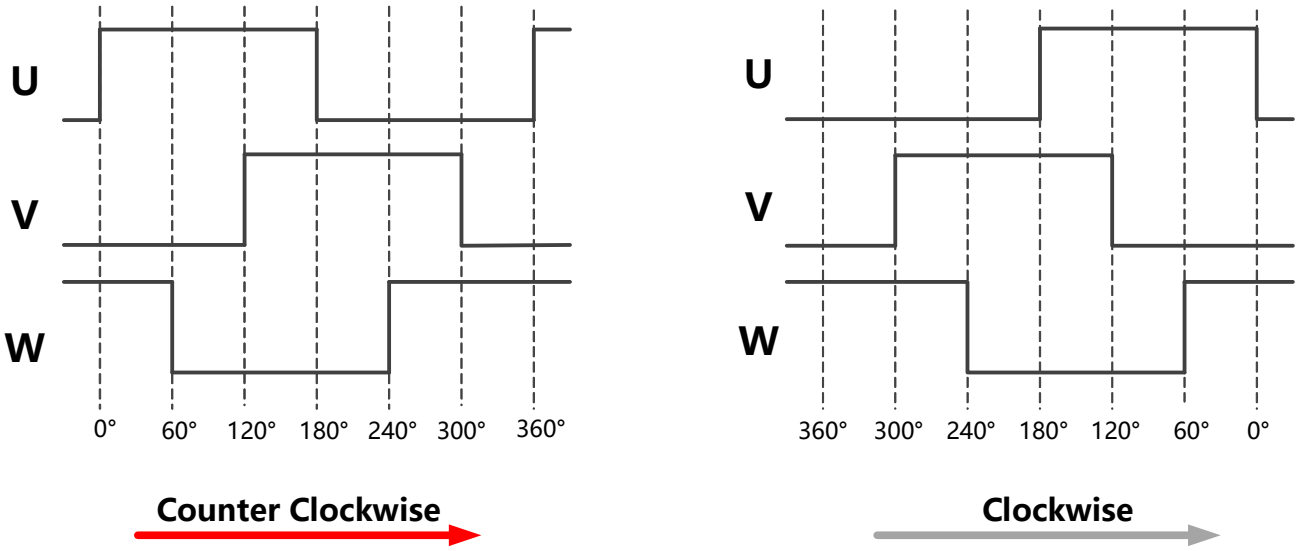



*Figure 12: Typical Output Waveform for UVW Mode*

***UVW Pole Pairs Register (OTP)***

| Reg. UVW_RES<3:0> | UVW Pole Pairs |
|---|---|
| 0000 | 1 |
| 0001 | 2 |
| 0010 | 3 |
| 0011 | 4 |
| 0100 | 5 |
| 0101 | 6 |
| 0110 | 7 |
| 0111 | 8 |
| 1000 | 9 |
| 1001 | 10 |
| 1010 | 11 |
| 1011 | 12 |
| 1100 | 13 |
| 1101 | 14 |
| 1110 | 15 |
| 1111 | 16 |

## 7.5 Pulse Width Modulation (PWM) Output Mode

The MT6816 provides a digital Pulse Width Modulation (PWM) output, whose duty cycle is proportional to the measured angle as shown in Figure 13. PWM is a default output of Pin.10.

The PWM output consists of a frame of 4119 PWM clock periods. The angle data is represented with 12 bit resolution in the frame. One PWM clock period represents 0.088° and has a typical duration of 250ns which also could be programmed to be 125ns.

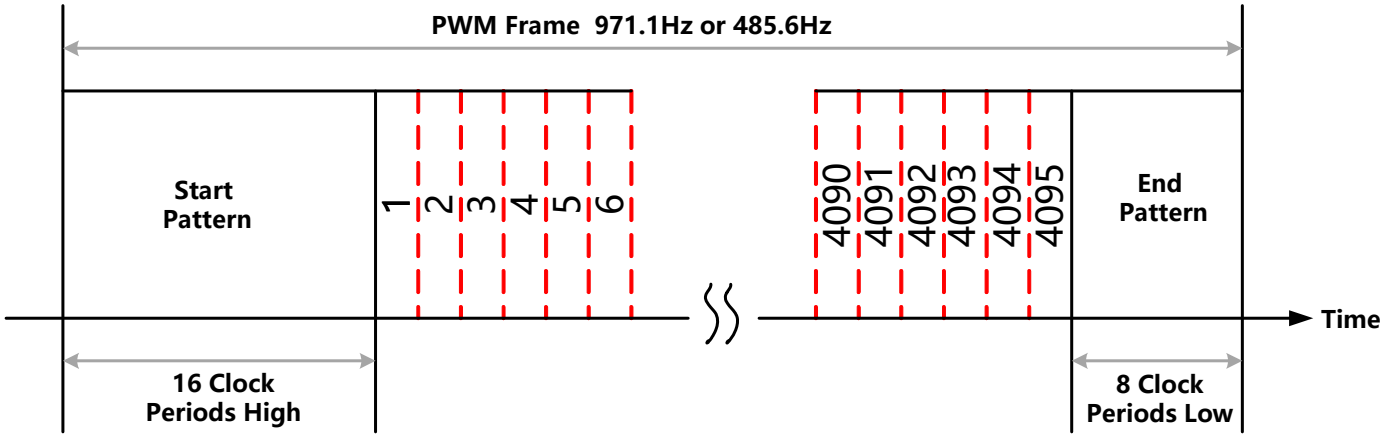



*Figure 13: PWM Output Frame*

***PWM Frequency (OTP)***

| Reg. PWM_Freq | PWM Frame Frequency |
|---|---|
| **0** | 971.1 Hz |
| **1** | 485.6 Hz |

## 7.6 SPI Interface

The MT6816 also provides a 4-Wire or 3-Wire SPI (Register 'SPI_Mode' should be programmed to 'High' to enable 3-Wire SPI Mode) interface for a host MCU to read back digital absolute angle information from its internal registers.

### 7.6.1 SPI Reference Circuit

The reference circuit for SPI interface is shown in Figure 14 and Figure 15.

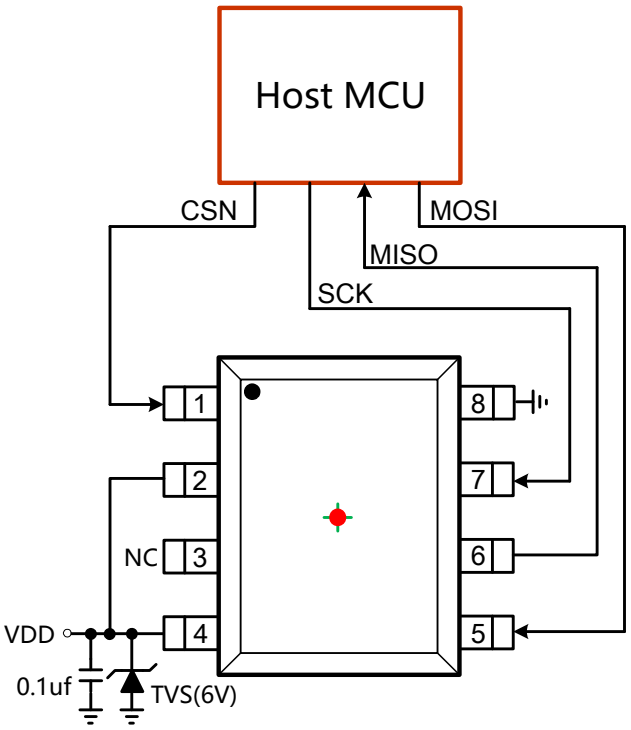



*Figure 14: 4-Wire SPI Reference Circuit*

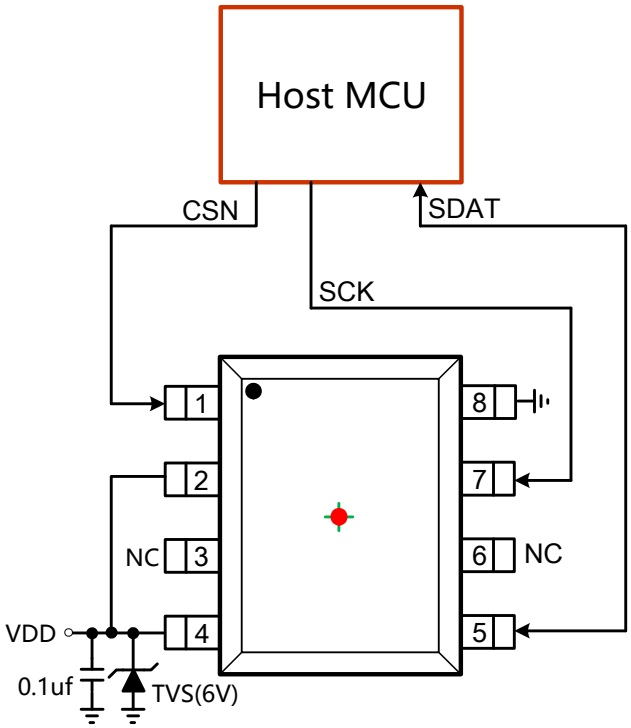



*Figure 15: 3-Wire SPI Reference Circuit*

***SPI Mode Register (OTP)***

| Reg. SPI_Mode | SPI Interface |
|---|---|
| **0** | 4-Wire Mode |
| **1** | 3-Wire Mode |

## 7.6.2 SPI Timing Diagram

The MT6816 SPI uses mode=3 (CPOL=1, CPHA=1) to exchange data. As shown in Figure 16, a data transfer starts with the falling edge of CSN. The MT6816 samples data on the rising edge of SCK, and the data transfer finally stops with the rising edge of CSN.

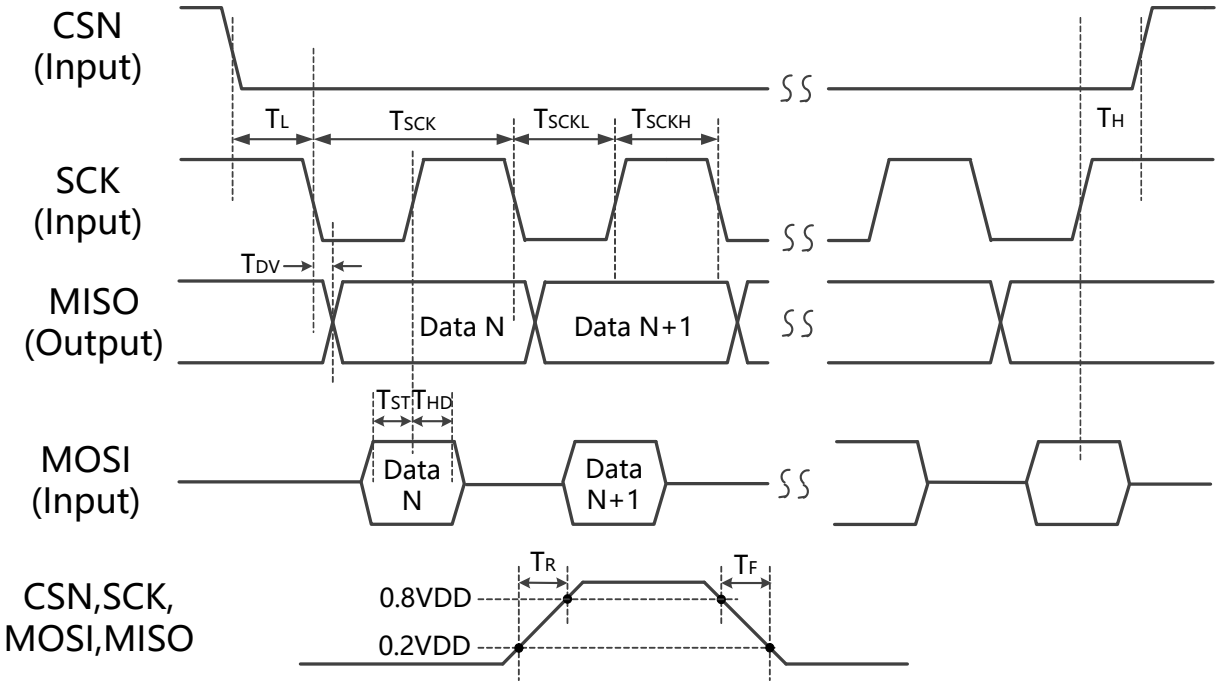



***Figure 16: SPI Timing Diagram***

***SPI Timing Parameter***

| Symbol | Notes | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| $T_L$ | Time between CSN falling edge and SCK falling edge | 100 | | - | ns |
| $T_{SCK}$ | Clock period | 64 | | - | ns |
| $T_{SCKL}$ | Low period of clock | 30 | | - | ns |
| $T_{SCKH}$ | High period of clock | 30 | | - | ns |
| $T_H$ | Time between SCK last rising edge and CSN rising edge | 0.5•TSCK | | - | ns |
| $T_R$ | Rise Time of Digital Signal (with 20pf Loading Condition) | - | 10 | - | ns |
| $T_F$ | Fall Time of Digital Signal (with 20pf Loading Condition) | - | 10 | - | ns |
| $T_{DV}$ | Data valid time of MISO (with 20pf Loading Condition) | - | - | 15 | ns |
| $T_{ST}$ | Setup time of MOSI data | 10 | - | - | ns |
| $T_{HD}$ | Hold time of MOSI data | 10 | - | - | ns |

### 7.6.3 4-Wire SPI Mode

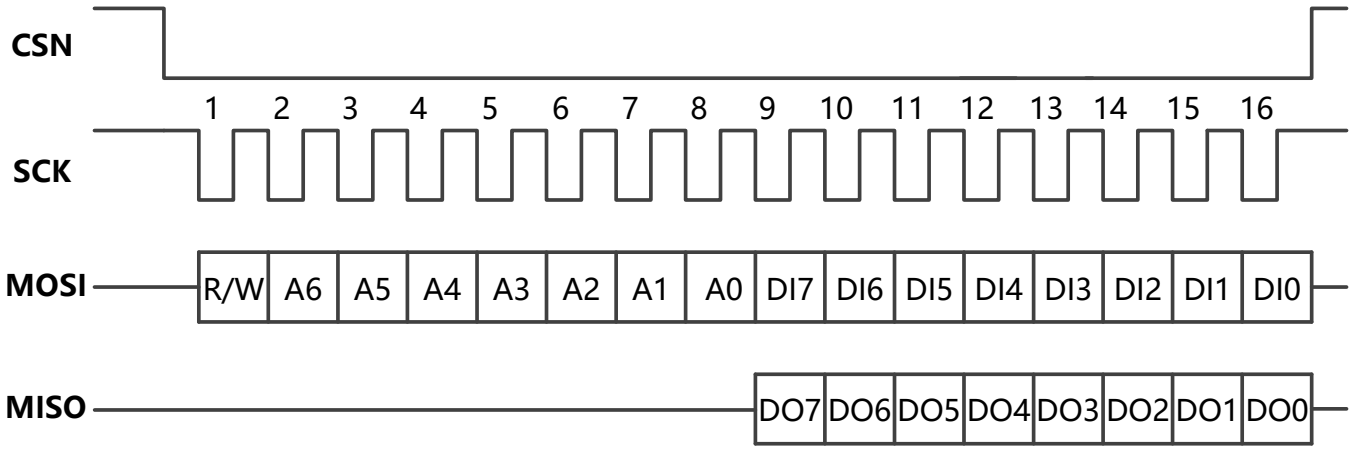



*Figure 17: 4-Wire SPI Timing*

An SPI data transfer starts with the falling edge of CSN and stops at the rising edge of CSN. SCK is the Serial Port Clock and it is controlled by the SPI master, it is high when there is no SPI transmission. MOSI (master output slave input) and MISO (master input slave output) is the Serial Port Data Input and Output, it is driven at the falling edge of SCK and should be captured at the rising edge of SCK.

**Bit 0**: Read/Write command bit, when it is Low, the data DI7~DI0 is written into the device, when it is High, the data DO7~DO0 from the device is read.

**Bit 1-7**: Address A6~A0. This is the address field of the indexed register.

**Bit 8-15**: Data DI7~DI0 (write mode). This is the data that will be written into the device (MSB first).

**Bit 8-15**: Data DO7~DO0 (read mode). This is the data that will be read from the device (MSB first).

### 7.6.4 3-Wire SPI Mode

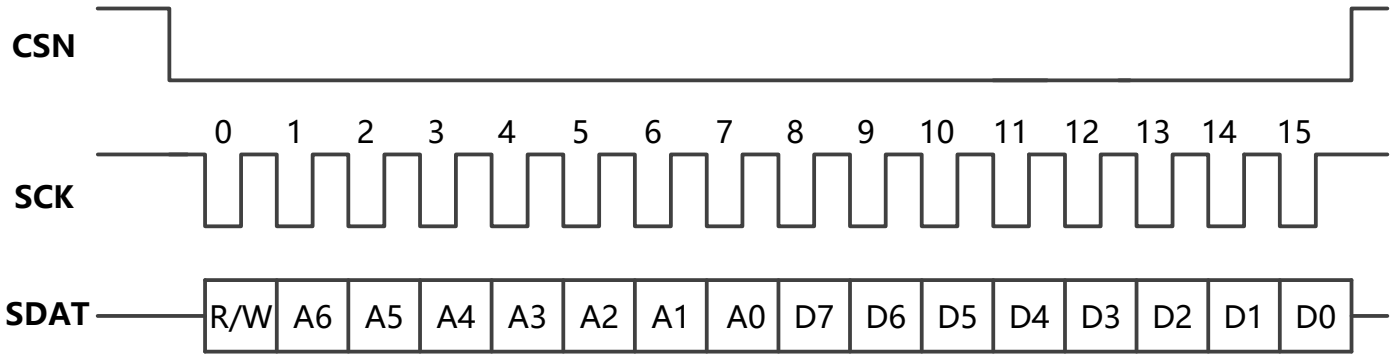



*Figure 18: 3-Wire SPI Timing*

An SPI data transfer starts with the falling edge of CSN and stops at the rising edge of CSN. SCK is the Serial Port Clock and it is controlled by the SPI master, it is high when there is no SPI transmission. SDAT is the Serial Port Data Input and Output, and it is driven at the falling edge of SCK and should be captured at the rising edge of SCK.

**Bit 0**: Read/Write command bit. When it is Low, the data D7~D0 is written into the device. When it is High, the data D7~D0 from the device is read.

**Bit 1-7**: address A6~A0. This is the address field of the indexed register.

**Bit 8-15**: data D7~D0 (write mode). This is the data that will be written into the device (MSB first).

**Bit 8-15**: data D7~D0 (read mode). This is the data that will be read from the device (MSB first).

### 7.6.5 SPI Read Angle Register (e.g. 4-Wire SPI)

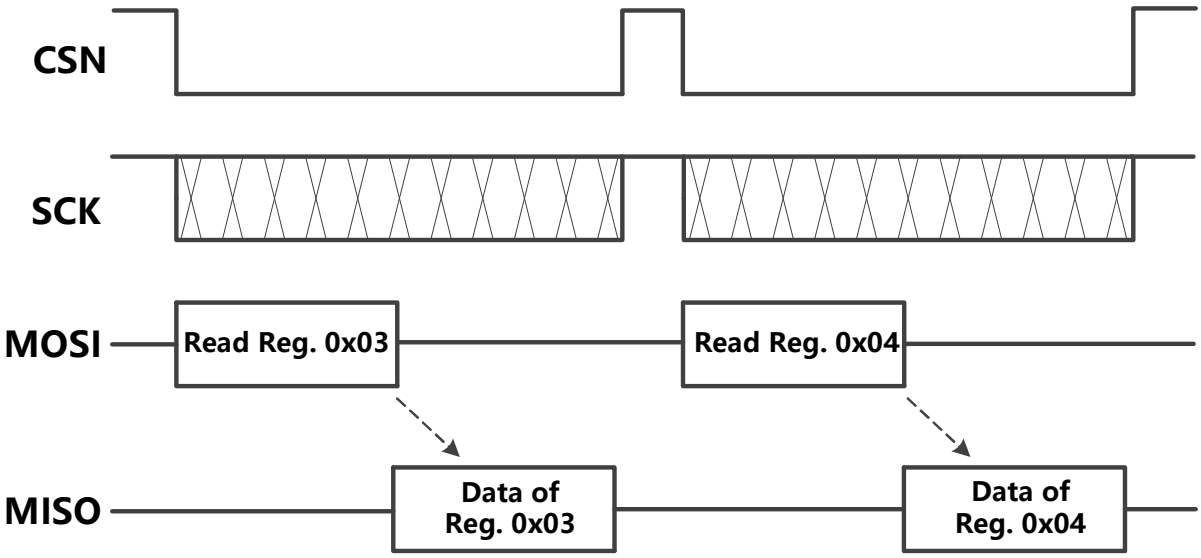



*Figure 19: 4-Wire SPI Read Angle Register*

***Angle Data Register***

| Reg. Address | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|---|
| **0x03** | Angle<13:6> | | | | | | | |
| **0x04** | Angle<5:0> | | | | | | No_Mag_Warning | PC |

0~360° absolute angle θ could be calculated by the below formula:

$$\theta = \frac{\sum_{i=0}^{13} Angle<i> \cdot 2^i}{16384} \bullet 360°$$

Bit 0x04[1] is a diagnosed bit for not enough magnet flux density. When the MT6816 could not detect enough magnetic field for proper operation, this bit is set to high.

Bit 0x04[0] is a parity check bit and it follows even check rule. If 0x03[7:0] and 0x04[7:1] totally have even number of logic high, 0x04[0]=0. If 0x03[7:0] and 0x04[7:1] totally have odd number of logic high, 0x04[0]=1.

The MT6816 also provides 3-Wire SPI read mode as shown in Figure 20.

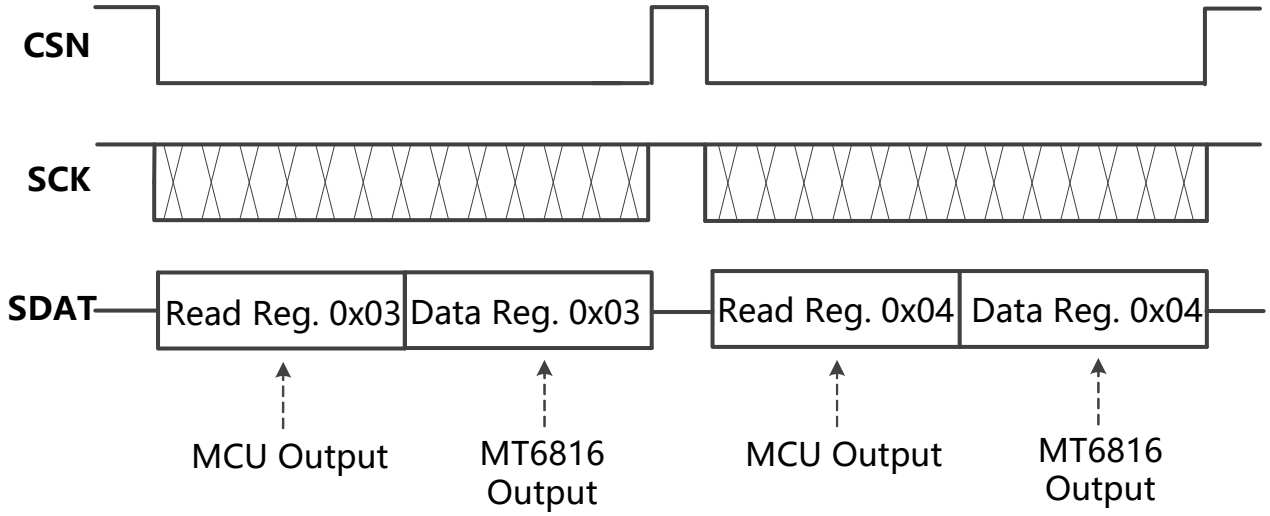
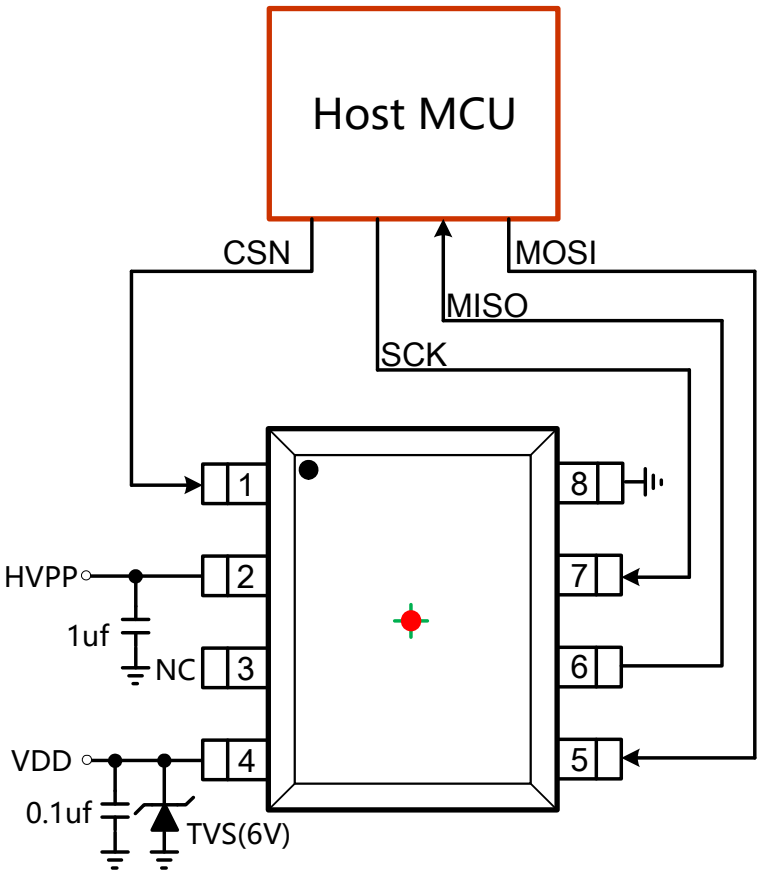



*Figure 20: 3-Wire SPI Read Angle Registers*

# 8. MTP Programming

MT6816 have a build in MTP memory for customer to program resolution, zero position, z-pulse width and etc. parameters. MTP programming needs SPI communication and a 7V DC supply for HVPP pin. If customer wants to know the detail programming method, please contact MagnTek's sales office for technical supporting.



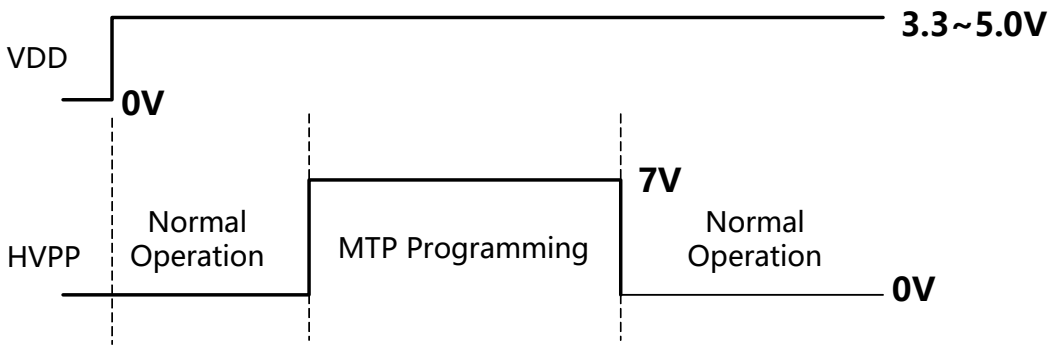
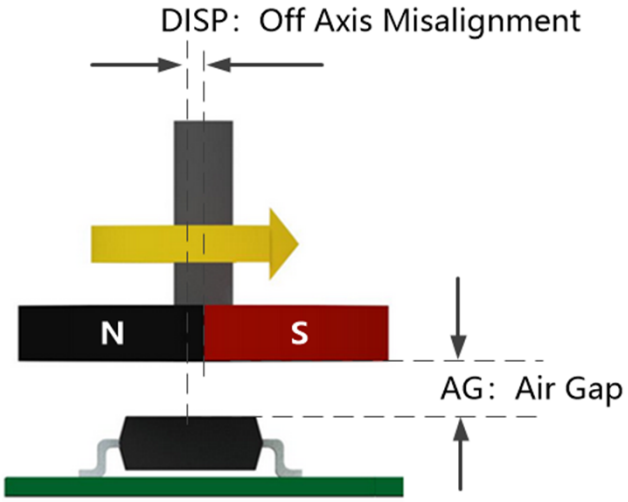
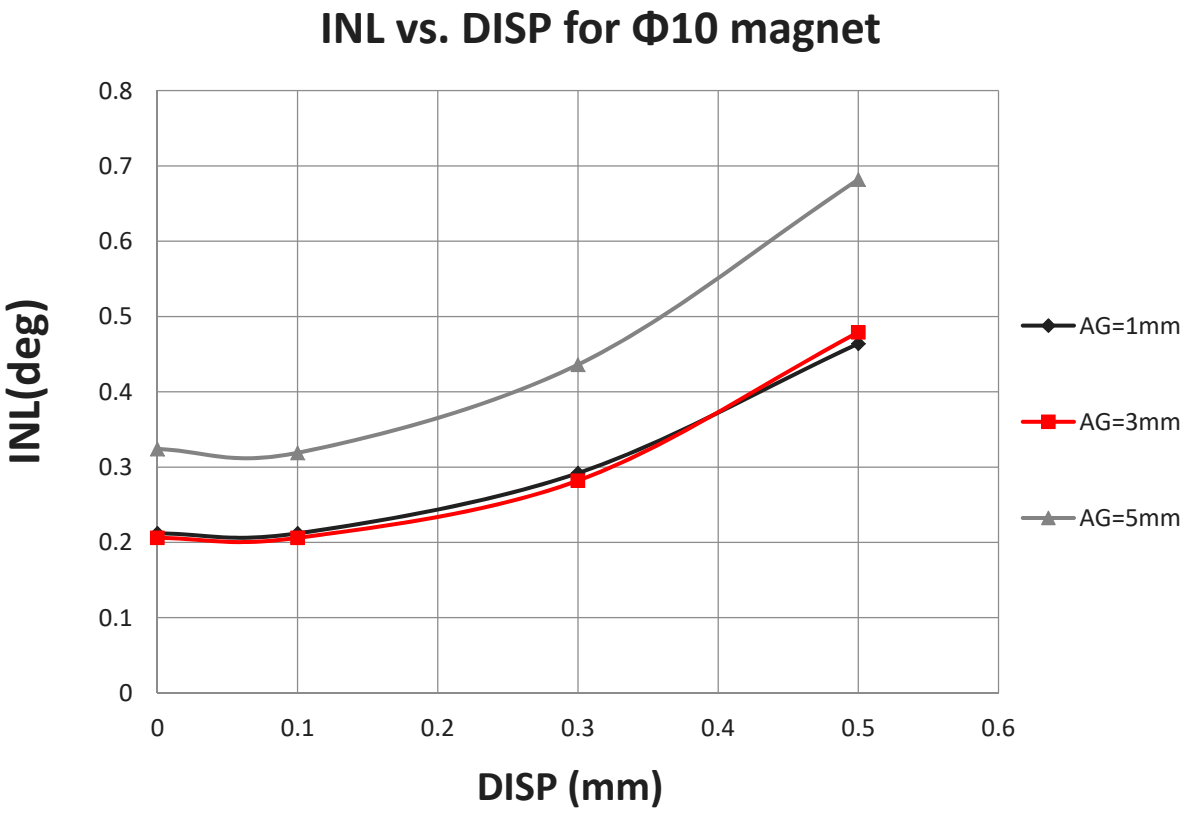




*Figure 21: MTP Programming*

# 9. Magnet Placement

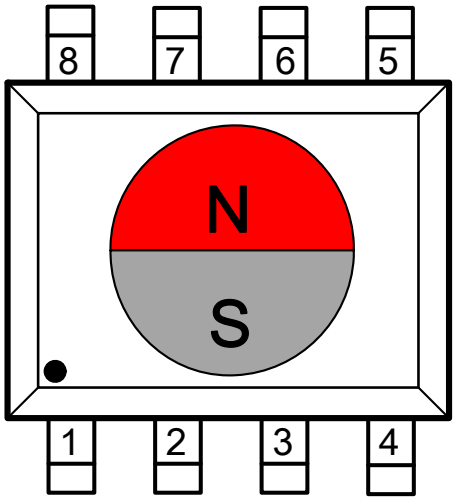
It is required that the magnet' s center axis be aligned with the sensing element center of MT6816 with the air-gap as small as possible. Any misalignment introduces additional angle error and big air-gap also weakens the magnet field which could be sensed by the device. Magnets with larger diameter are more tolerant to DISP (off-axis misalignment) and big AG (air-gap between Magnet and device).



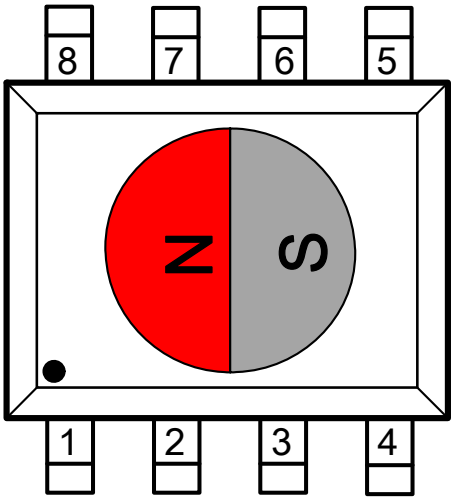



## 10. Mechanical Angle Direction

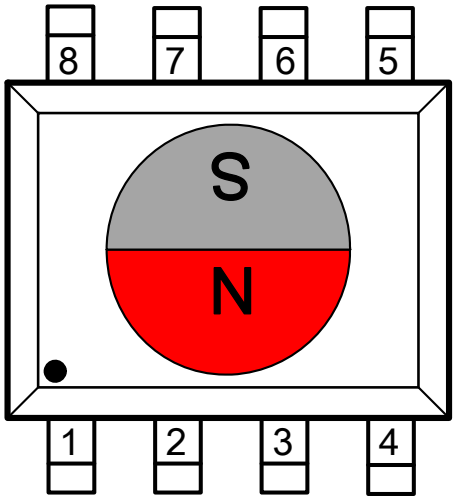
0 degree



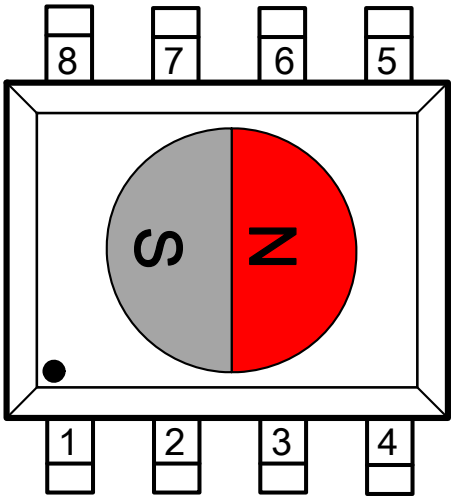

90 degree




180 degree

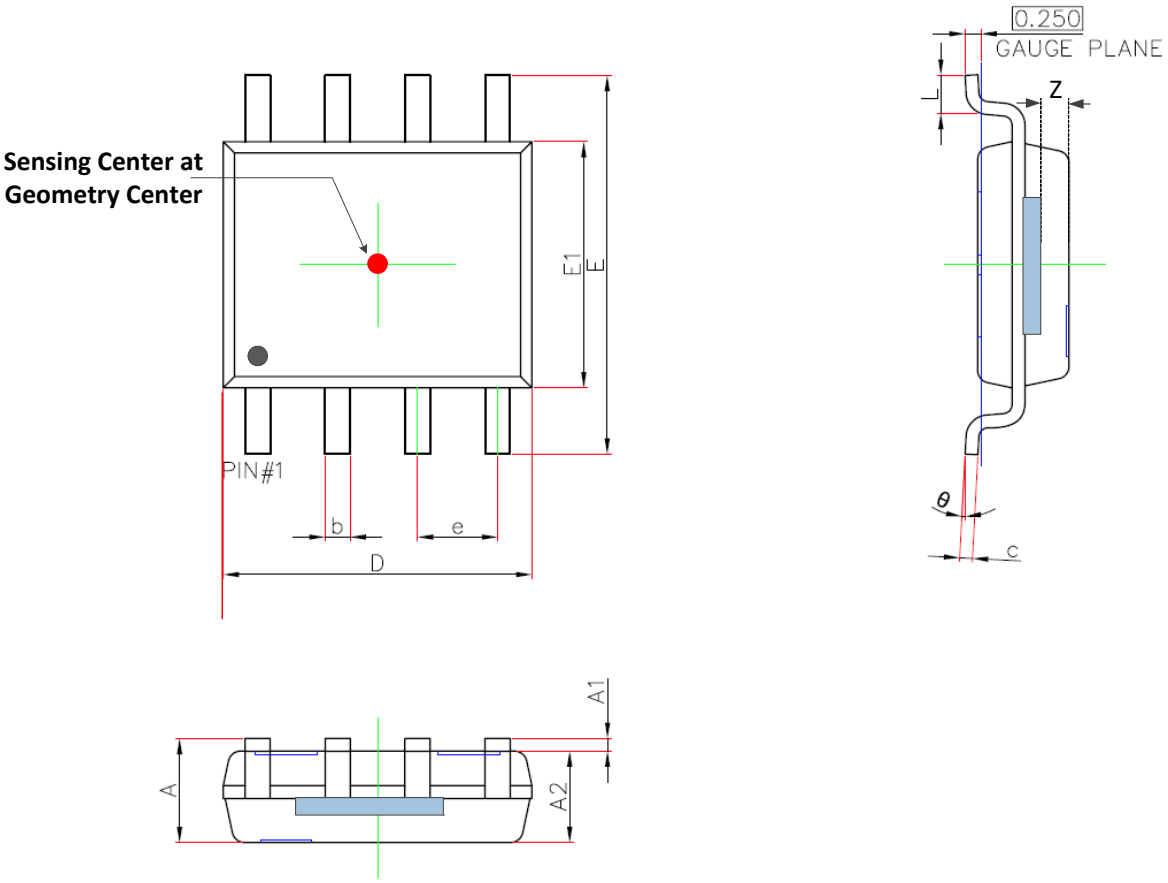



270 degree




**Top View**

# 11. Package Information




| Symbol | Dimensions in Millimeters | | Dimensions in Inches | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max |
| **A** | 1.450 | 1.750 | 0.057 | 0.069 |
| **A1** | 0.100 | 0.250 | 0.004 | 0.010 |
| **A2** | 1.350 | 1.550 | 0.053 | 0.061 |
| **b** | 0.330 | 0.510 | 0.013 | 0.020 |
| **c** | 0.170 | 0.250 | 0.007 | 0.010 |
| **D** | 4.700 | 5.100 | 0.185 | 0.201 |
| **E** | 5.800 | 6.200 | 0.228 | 0.244 |
| **E1** | 3.800 | 4.000 | 0.150 | 0.157 |
| **e** | 1.270(BSC) | | 0.050(BSC) | |
| **L** | 0.400 | 1.270 | 0.016 | 0.050 |
| **θ** | 0° | 8° | 0° | 8° |
| **Z** | 0.420 | 0.620 | 0.016 | 0.024 |

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# 13. Revision History

| Revision Number | Date | Comments |
|---|---|---|
| 1.0 | 2019.06 | Initial Release |
| 1.1 | 2019.06 | Correction ‘CCW’ Arrow Direciton |
| 1.2 | 2019.07 | Update ESD(CDM) Information<br>Update Package Information<br>Update SPI Reference Circuit<br>Update SPI Read Data Operation<br>Update PWM Frame Frequency |
| 1.3 | 2019.09 | Update ABZ, UVW, PWM Reference Circuit |
| 1.4 | 2019.12 | Update SPI Timing Parameter |

单击下面可查看定价，库存，交付和生命周期等信息

>>Magntek(麦歌恩)