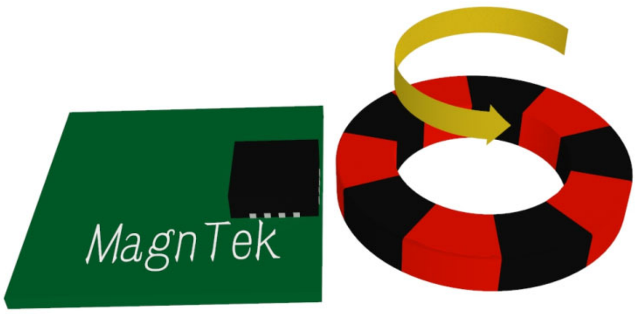
MT6818

Off-Axis/On-Axis Magnetic Encoder IC

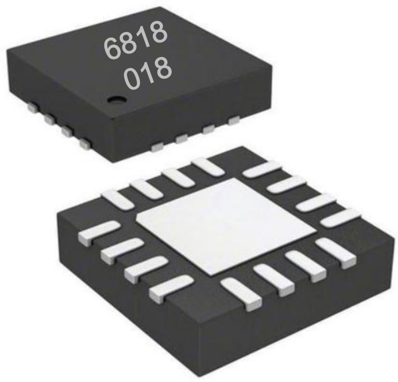
Features and Benefits

- Based on advanced AMR Technology with 0~360° Full Range Angle Sensing
- Off-Axis and On-Axis Applications
- 14-bit Core Resolution
- Maximum Rotation Speed 25,000 RPM
- Output Propagation Delay <2 us
- Output Interface: ABZ、PWM or SPI
- ABZ Resolution 1~1024 Pulses per Revolution (PPR) User Programmable
- RoHS Compliant 2011/65/EU



Applications

- General Angle Position Measurement
- BLDC Motor Control
- Stepping or Servo Motor Control
- Robotics



General Description

The MagnTek rotary position sensor MT6818 is an IC based on advanced AMR technology. A special designed AMR bridge enables MT6818 to be suitable for not only On-Axis applications, but also off-Axis applications.

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 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 MT6818. The absolute angle position is also provided as a 12bit PWM output.

Table of Contents

1. Pin Configuration

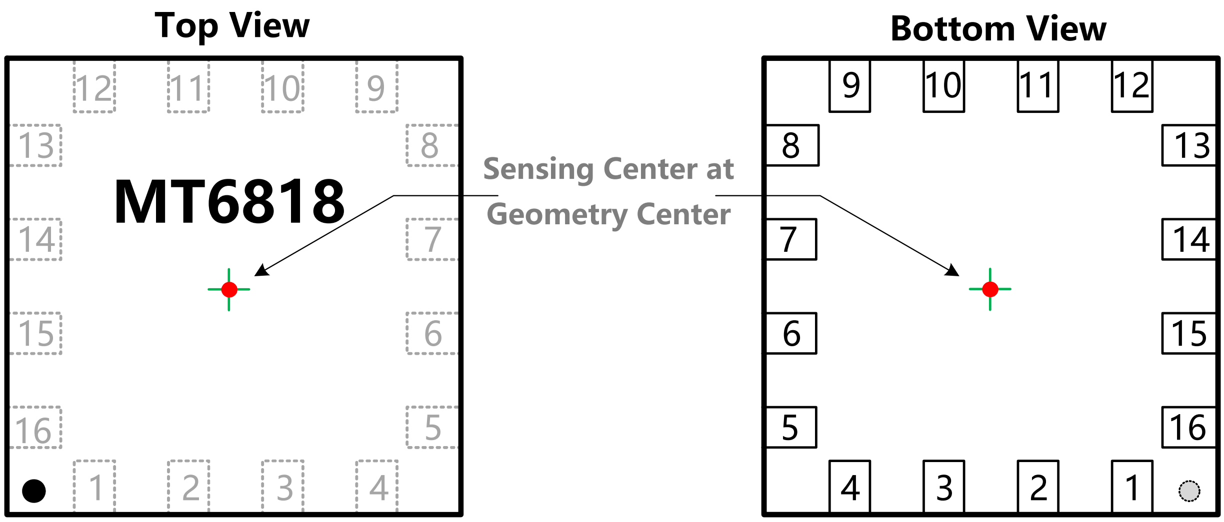


Figure 1: Pin Configuration of MT6818(QFN-16) Package

Pin List

Name	#	Type	Description
W	1	Digital Output	Incremental Signal W
HVPP	2	Power Supply	MTP Programming Supply. If Do Not Use, Connect to VSS.
MISO	3	Digital Input/output	SPI MISO(4-Wire)
MOSI	4	Digital Input/output	SPI MOSI(4-Wire), SDAT(3-Wire)
CSN	5	Power Supply	SPI Chip Selection
SCK	6	Digital Input	SPI Clock
OUT	7	Digital Output	PWM Output
VDD	8	Power Supply	3.3~5.0V Supply
TEST	9	Digital Input	Test Pin
VSS	10	Power Supply	Ground
ERR	11	Digital Output	Error Output
Z	12	Digital Output	Incremental Signal Z
A	13	Digital Output	Incremental Signal A
B	14	Digital Output	Incremental Signal B
V	15	Digital Output	Incremental Signal V
U	16	Digital Output	Incremental Signal U

Family Members

Part Number	Description
MT6818QT	QFN-16 Package, Tape & Reel Pack (1000pcs/Reel)

****MT6818 QFN Package Reflow Sensitivity Classification: MSL-3***

2. Functional Diagram

The MT6818 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.

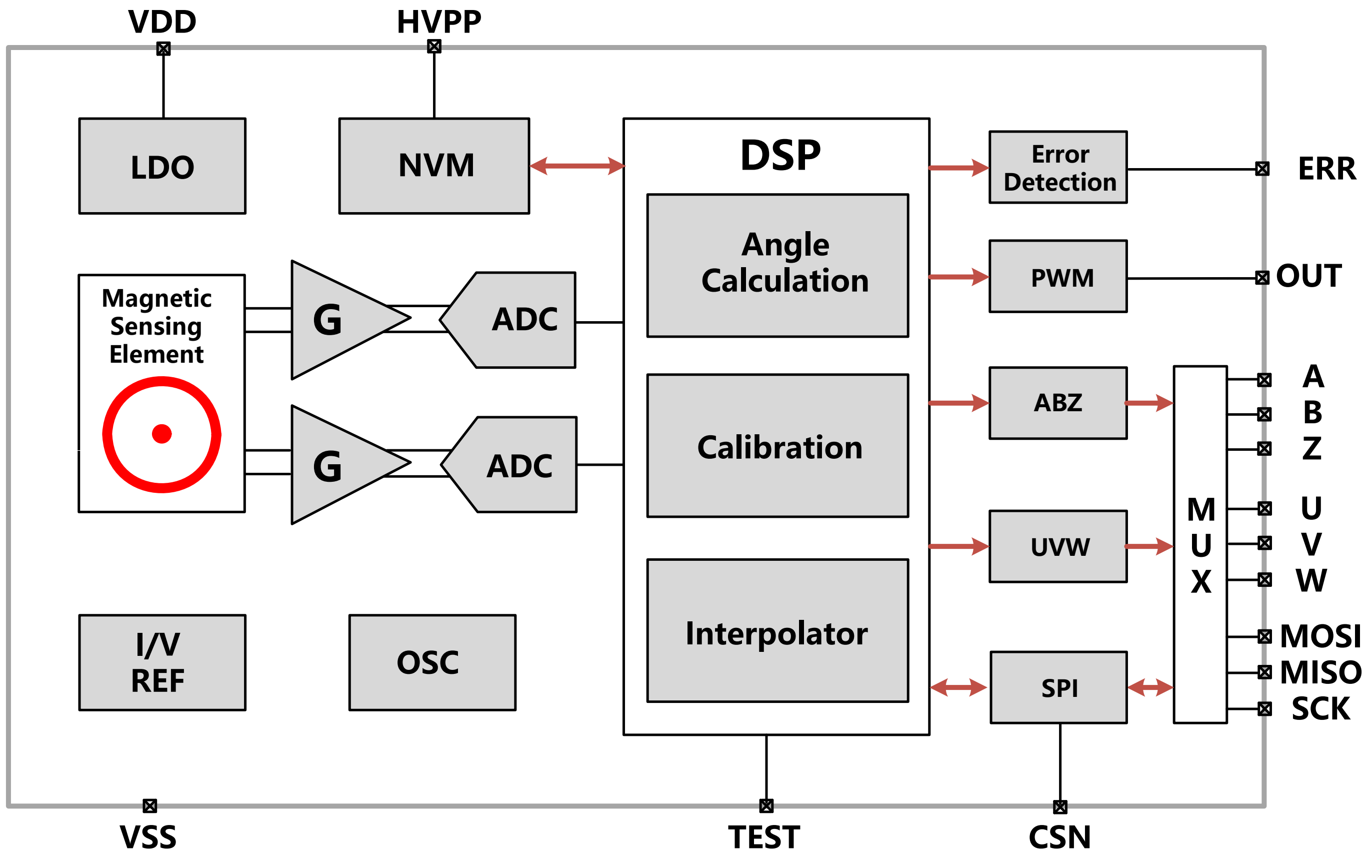


Figure 2: Block Diagram

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 (One Pole-Pair Magnet)	-	25,000	RPM
Operating Temperature	-40	125	℃

5. Electrical Characteristics

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

Symbol	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	On-Axis Application, Note(1)	-	±0.8	±1.5	°
DNL	Differential Non-Linearity (ABZ Mode), Figure 3	On-Axis Application @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 misalignment error. The maximum error value can be achieved over operation temperature range, at maximum air gap and with worst-case 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

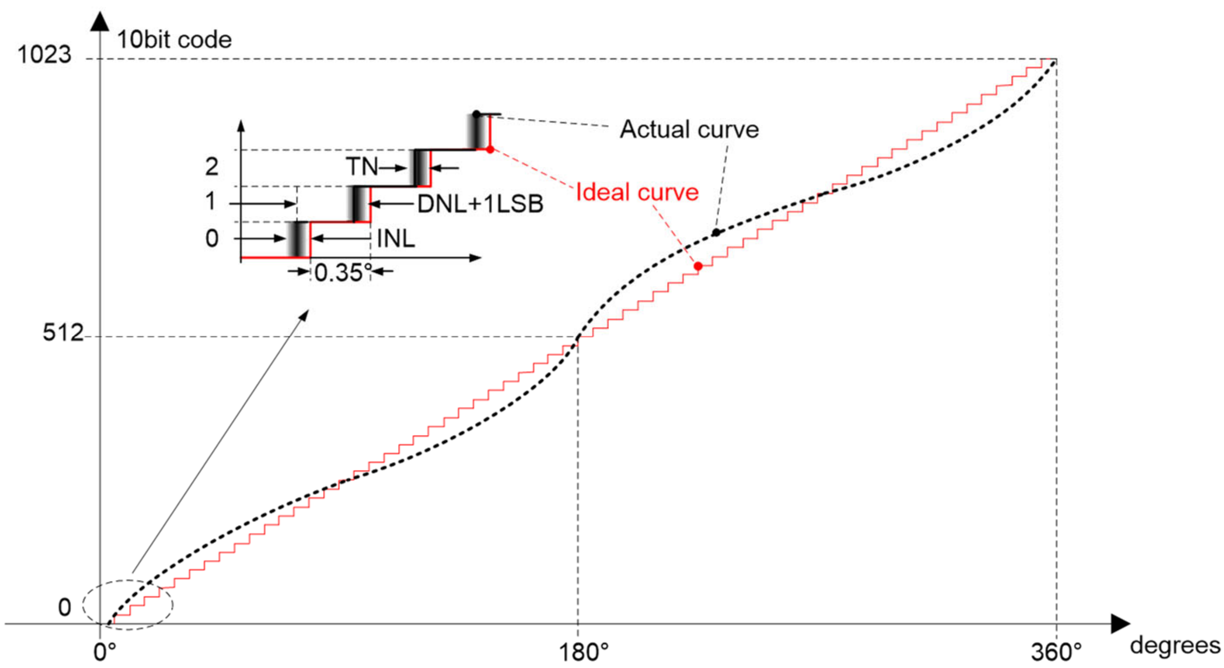
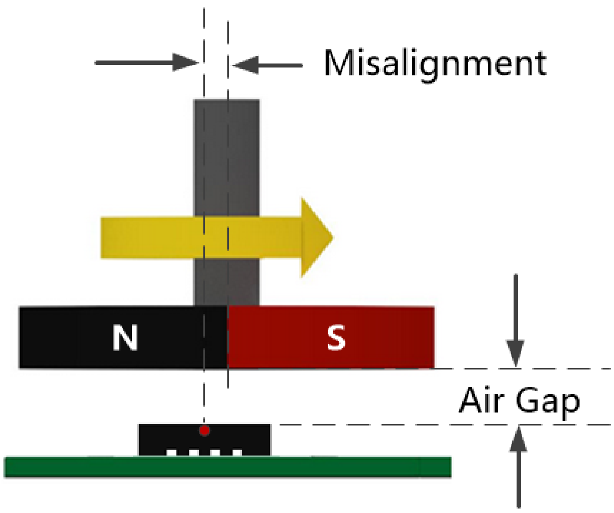


Figure 3: Drawing Illustration INL, DNL and TN (for 10 bit case)

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 (for On-Axis application)	Recommended Magnet: Ø10mm x 2.5mm for Cylindrical Magnets	-	10	-	mm
Tmag	Thickness of Magnet		-	1.5	-	mm
Bpk	Magnetic Input Field Amplitude	Measure at the IC Surface	30	-	1,000	mT
AG	Air Gap	Magnetic to IC Surface Distance	-	1.0	3.0	mm
RS	Rotation Speed	One Pole-Pair Magnet	-	-	25,000	RPM
DISP	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	-	%/℃



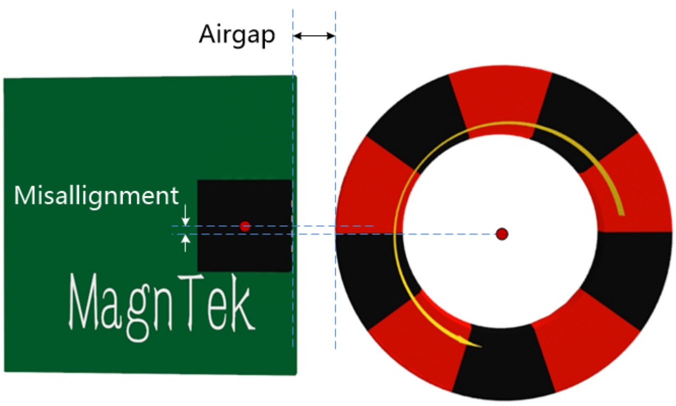


Figure 4: Magnet Arrangement

7. Output Mode

The MT6818 provides ABZ, UVW and PWM signals at output pins, and 14-bit absolute angle position data could be transferred by SPI interface (Both 3-Wire and 4-Wire modes).

7.1 Reference Circuit for ABZ, UVW and PWM Mode

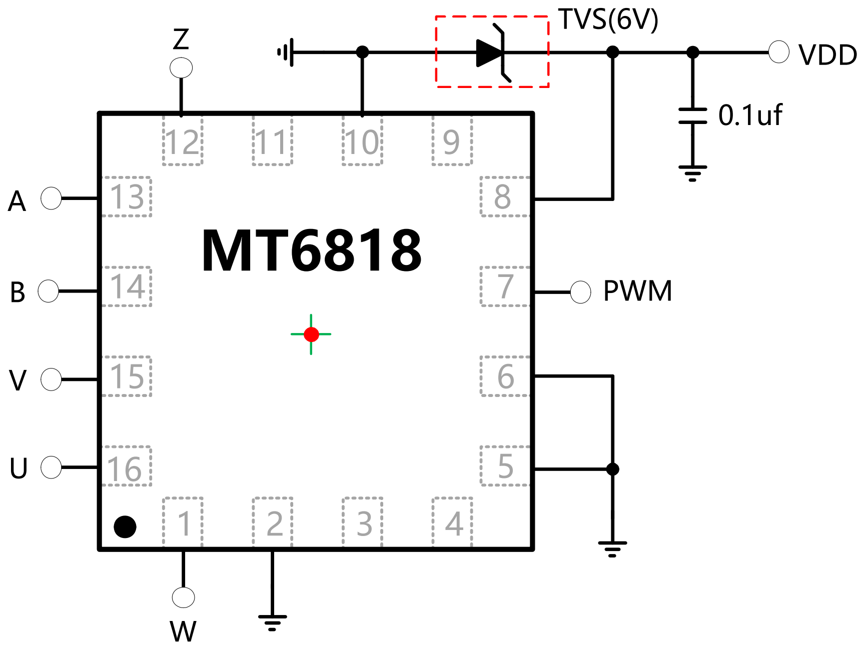


Figure 5: ABZ and PWM Output Reference Circuit without MTP Programming

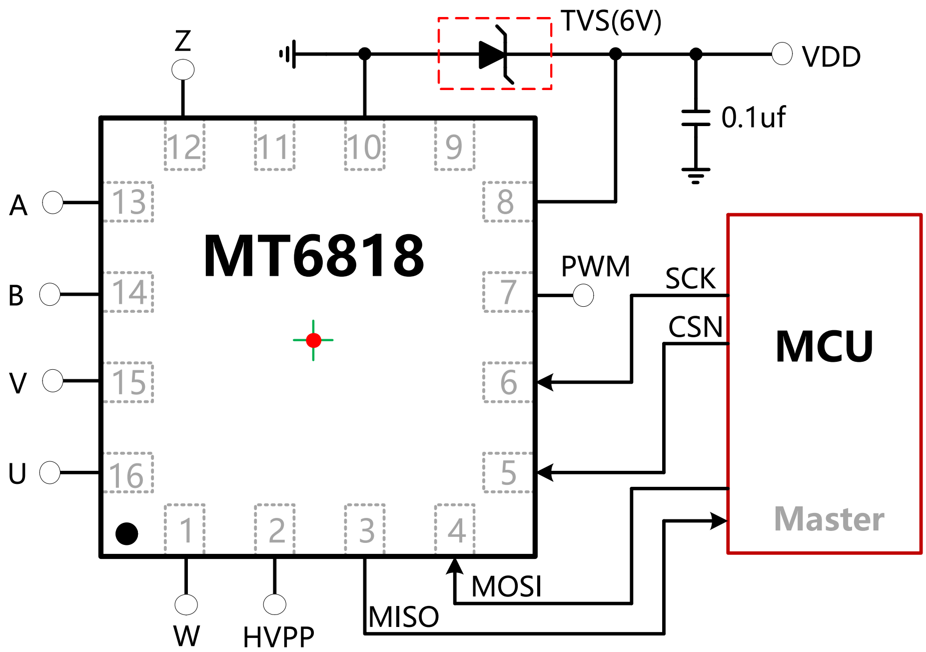


Figure 6: ABZ and PWM Output Reference Circuit with MTP Programming

7.2 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.

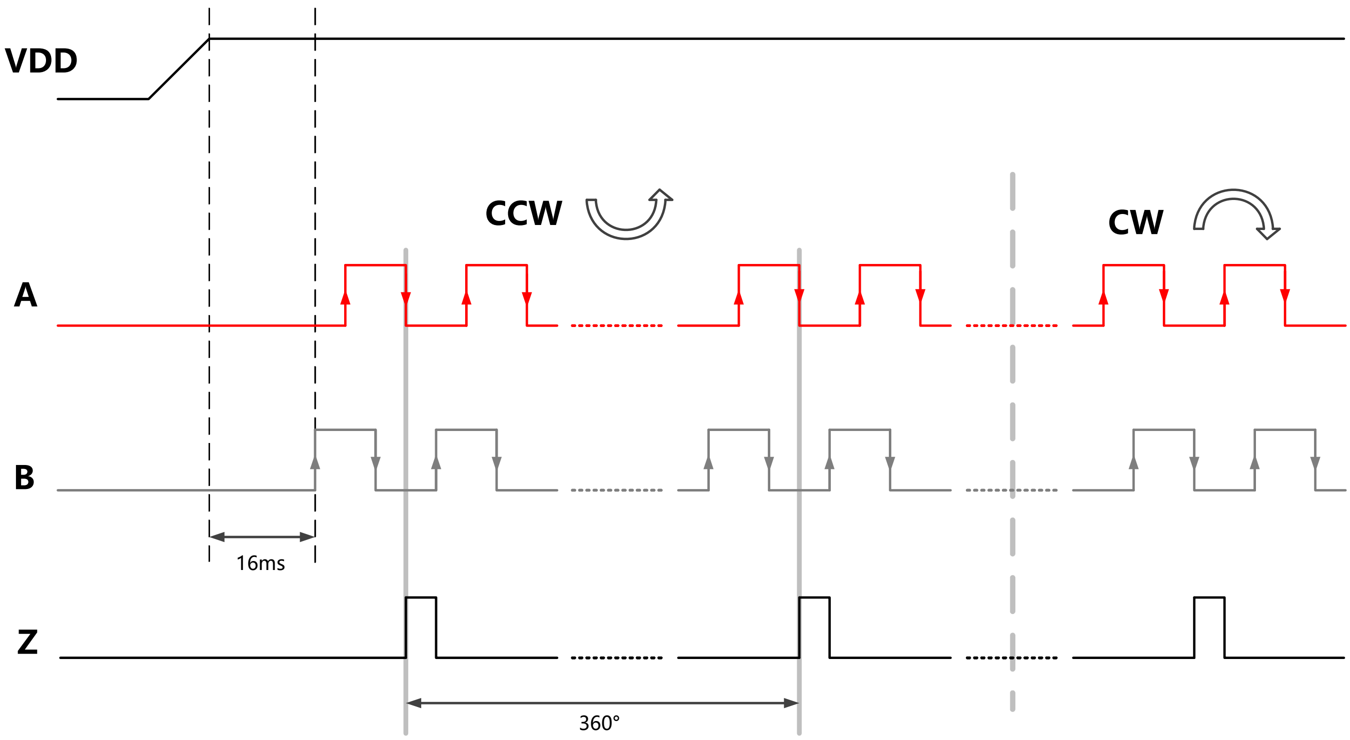


Figure 7: ABZ output with VDD power on

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。

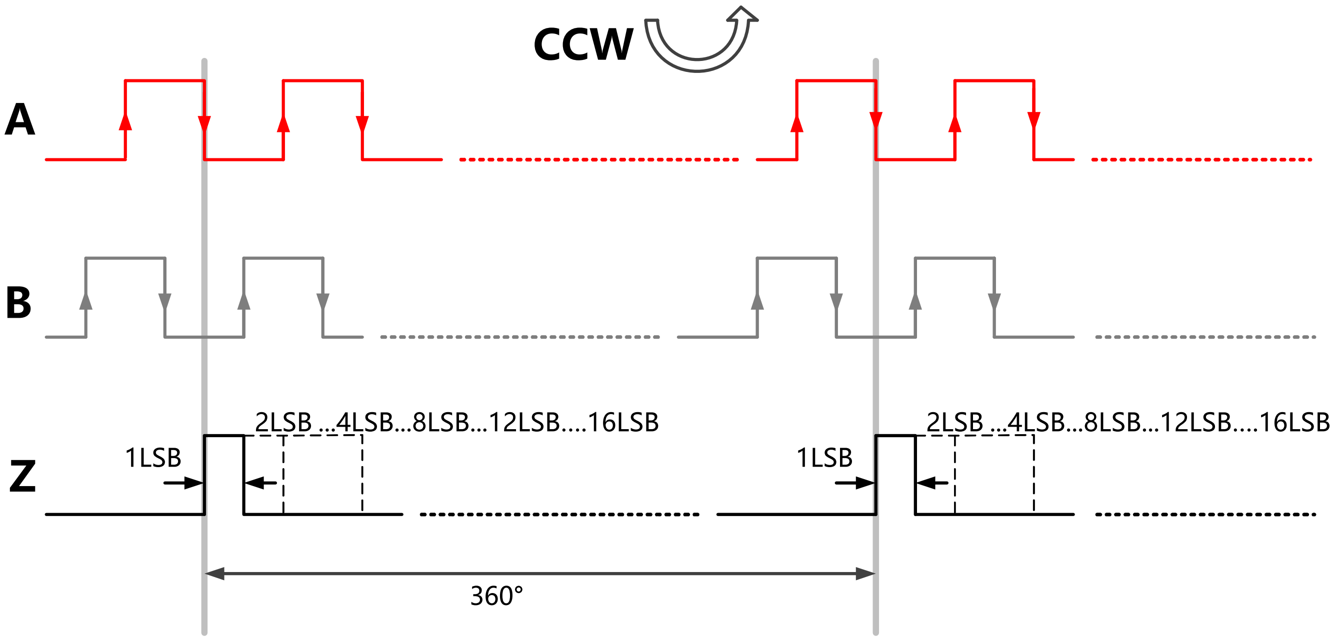


Figure 8: Typical ABZ Output w/i Z pules width=1,2,4,8,12 and 16 LSBs

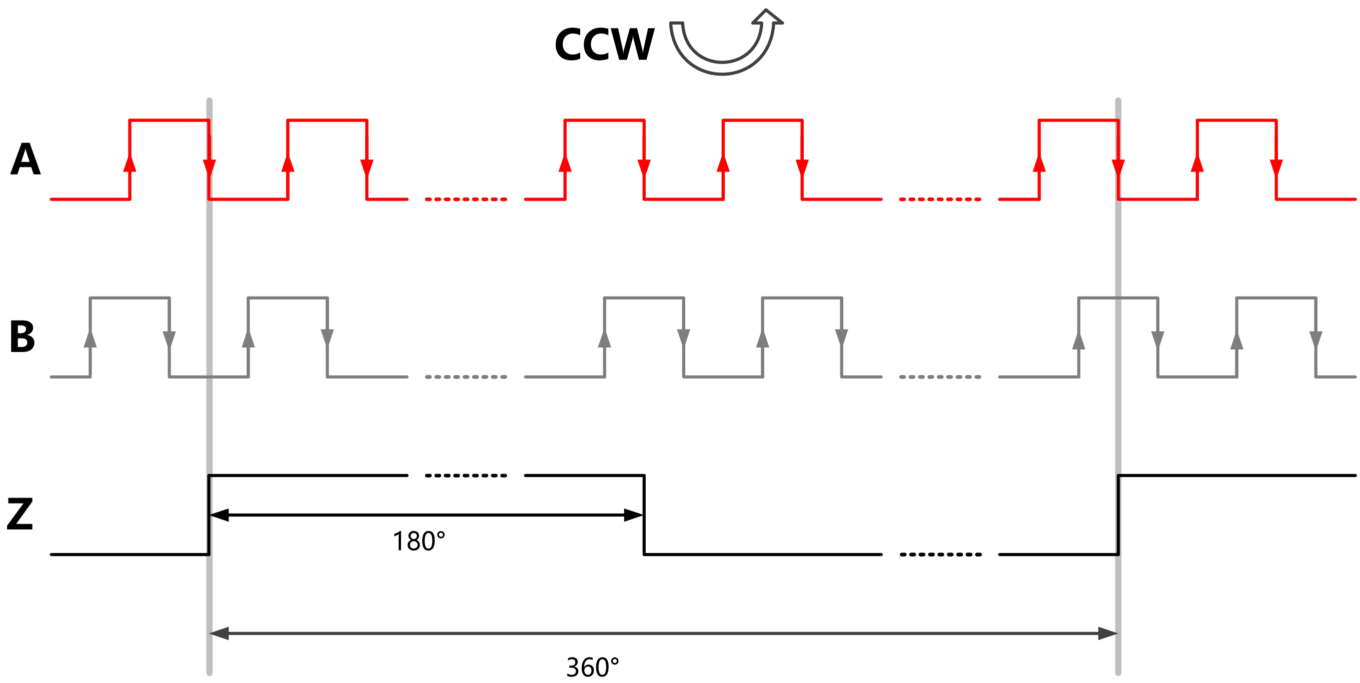


Figure 9: Typical ABZ Output w/i Z pules width=180°

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.

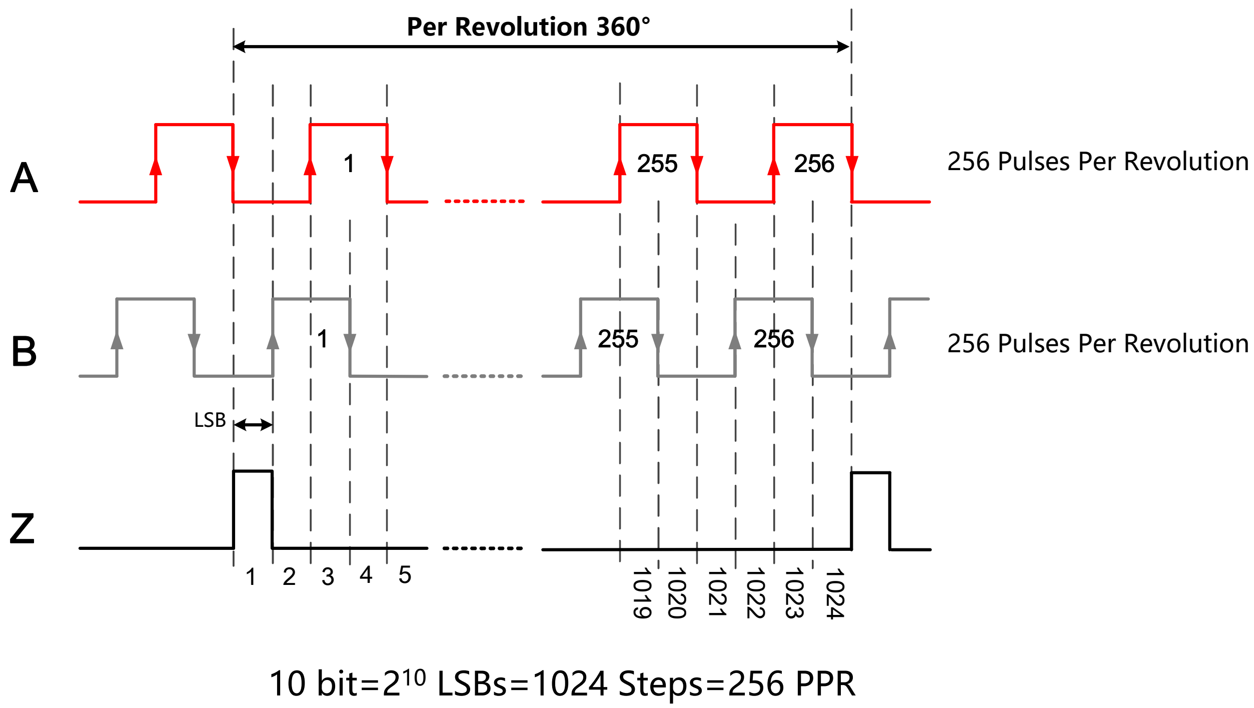


Figure 10: ABZ Output Resolution=10 bit

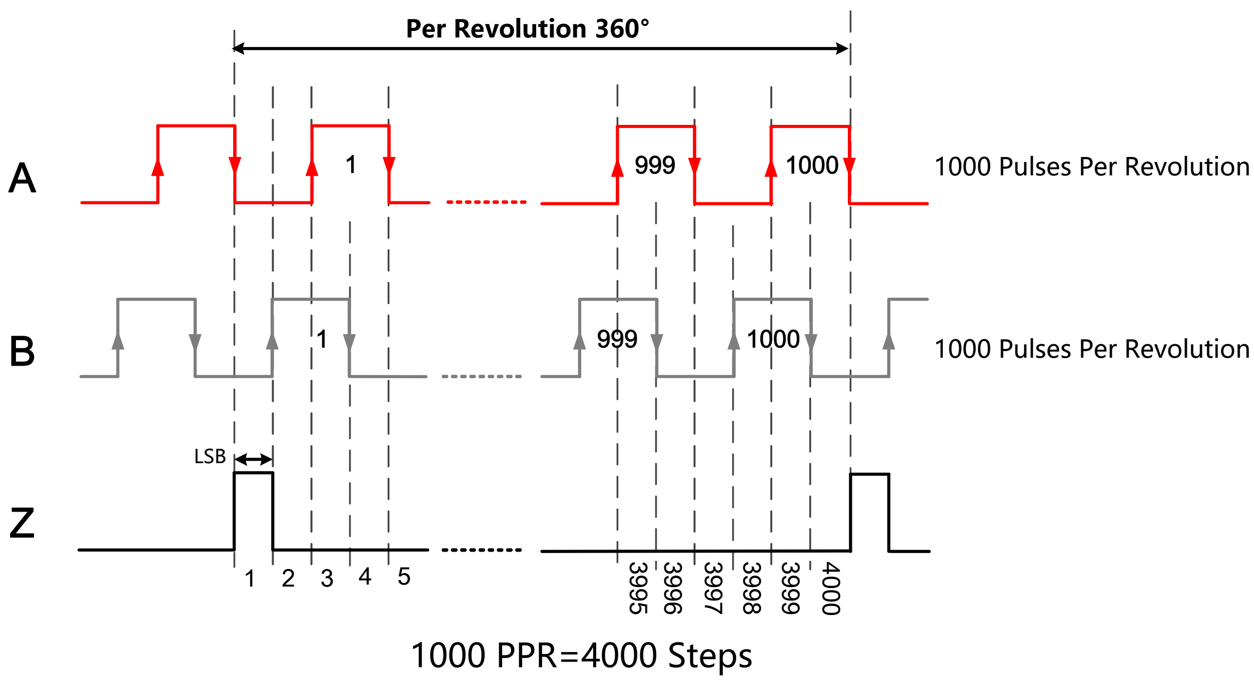


Figure 11: ABZ Output Resolution=1000 PPR

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 (MTP)

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>							

7.3 UVW Output Mode

The MT6825 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.

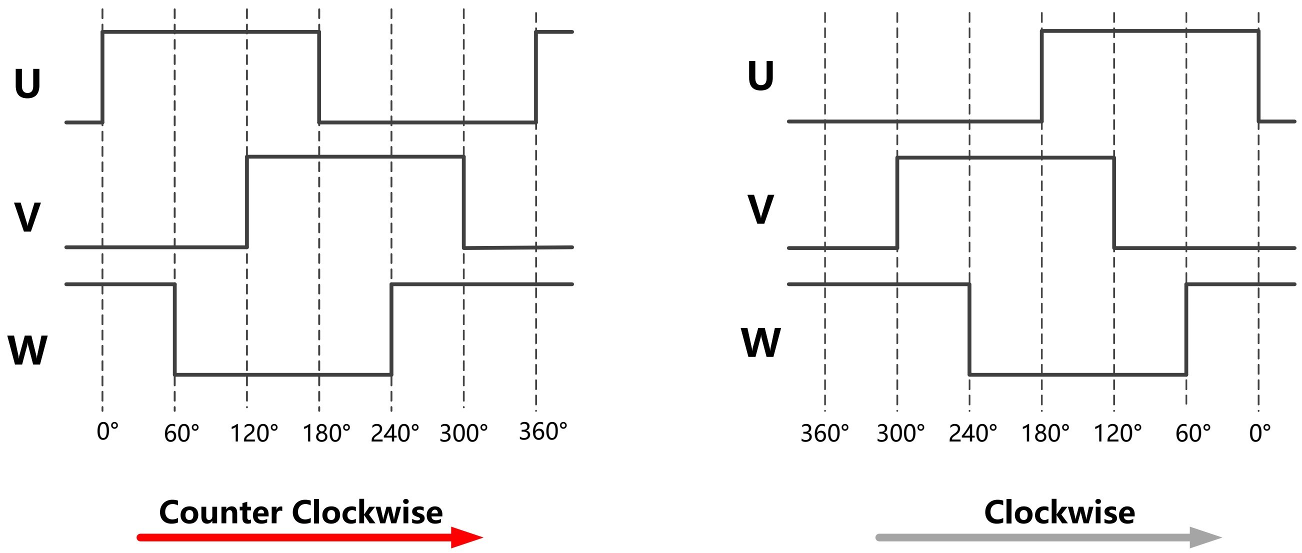


Figure 12: Typical Output Waveform for UVW Mode

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

7.3 Pulse Width Modulation (PWM) Output Mode

The MT6818 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.

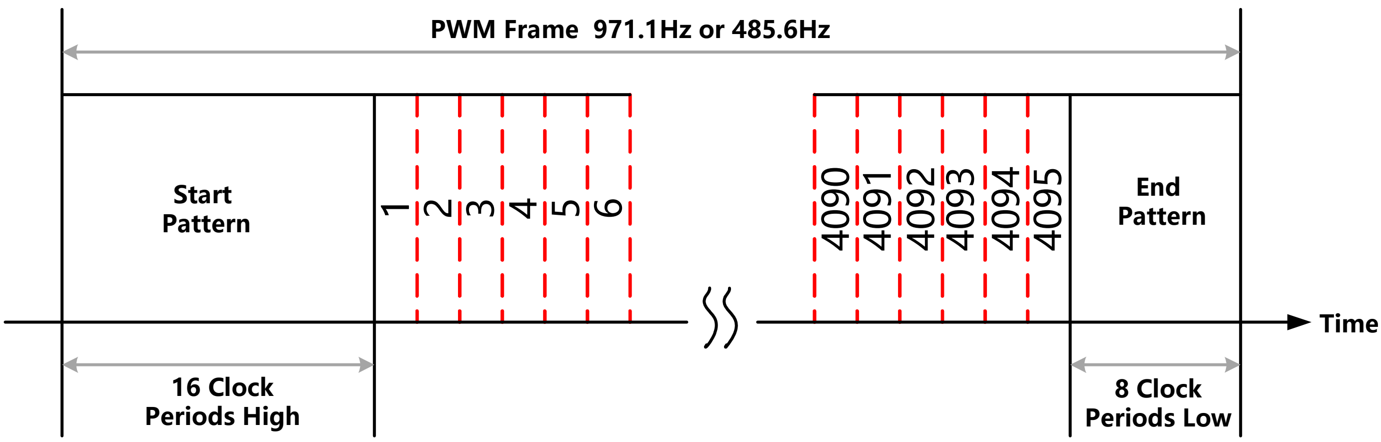


Figure 13: PWM Output Frame

PWM Frequency (MTP)

Reg. PWM_Freq	PWM Frame Frequency
0	971.1 Hz
1	485.6 Hz

7.4 SPI Interface

The MT6818 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.

7.4.1 SPI Reference Circuit

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

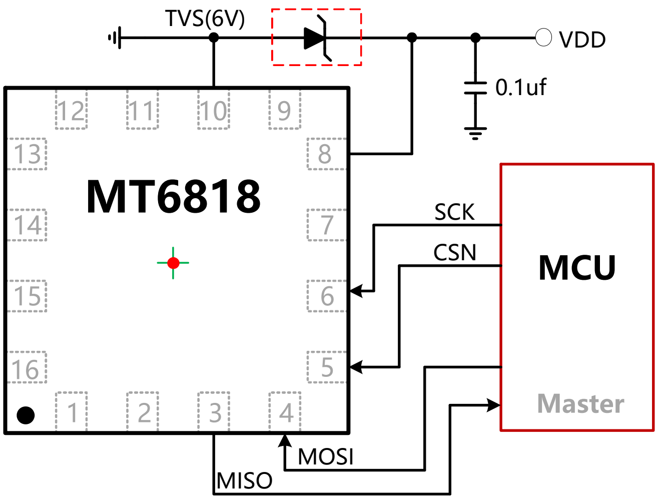


Figure 14: 4-Wire SPI Reference Circuit

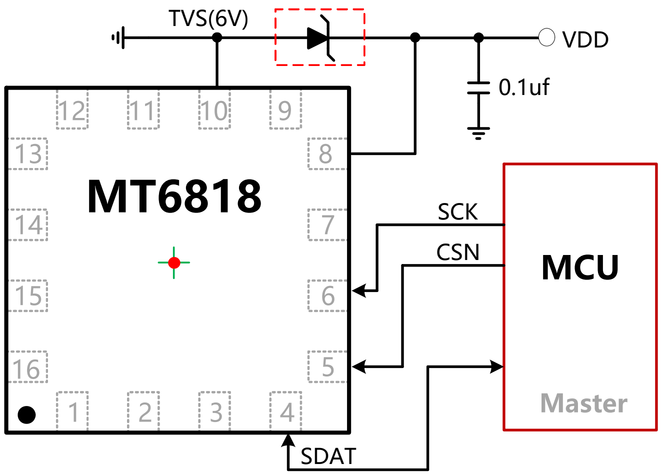


Figure 15: 3-Wire SPI Reference Circuit

SPI Mode Register (OTP)

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

7.4.2 SPI Timing Diagram

The MT6818 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 MT6818 samples data on the rising edge of SCK, and the data transfer finally stops with the rising edge of CSN.

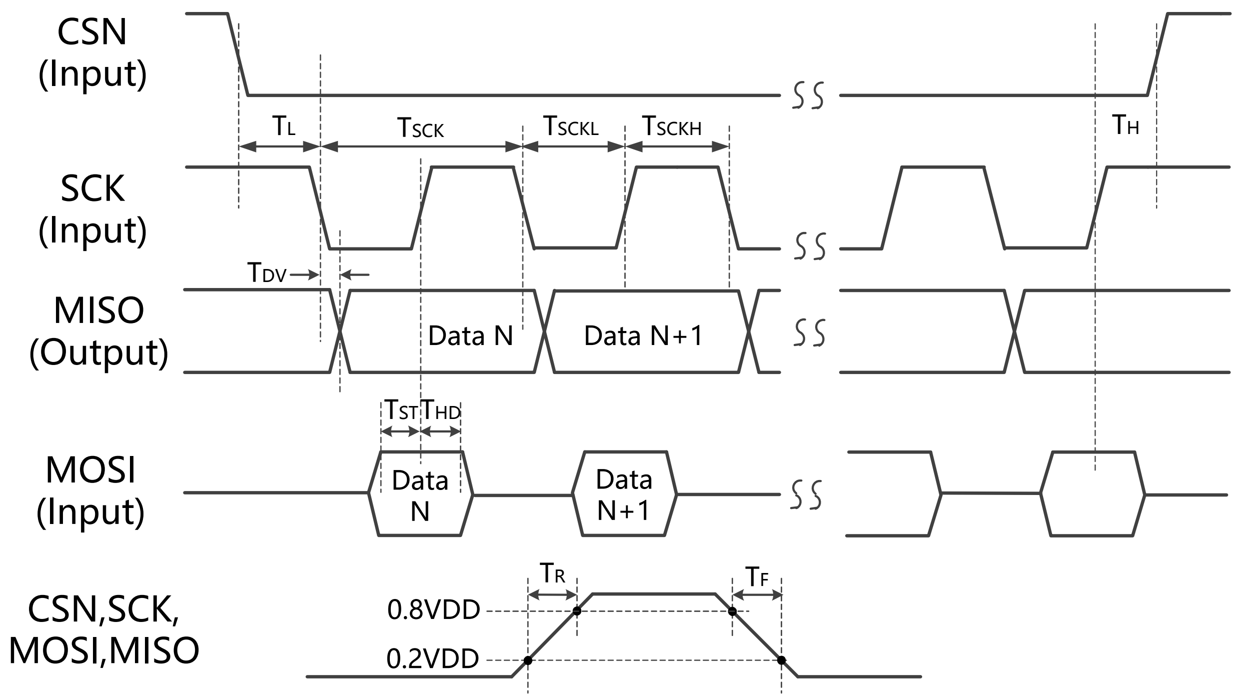


Figure 16: SPI Timing Diagram

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	$0.5 \cdot T_{SCK}$		-	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

7.4.3 4-Wire SPI Mode

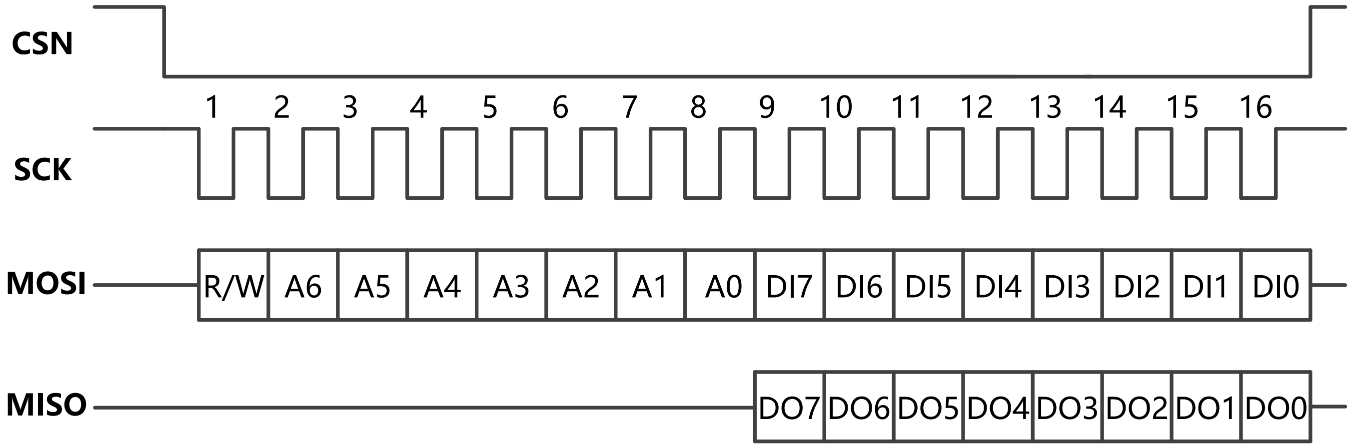


Figure 17: 4-Wire SPI Timing

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).

7.4.4 3-Wire SPI Mode

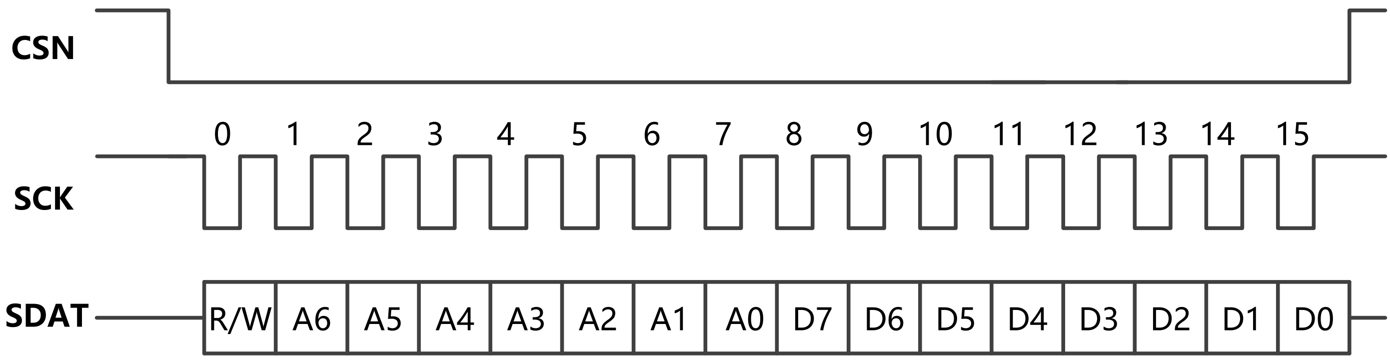


Figure 18: 3-Wire SPI Timing

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).

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

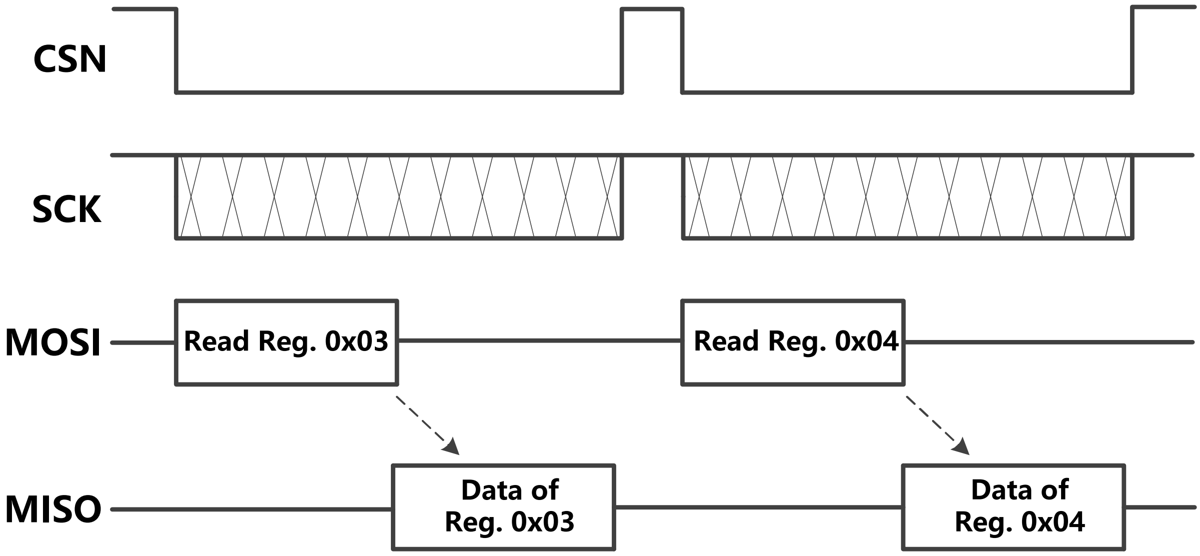


Figure 19: 4-Wire SPI Read Angle Register

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:

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

Bit 0x04[1] is a diagnosed bit for not enough magnet flux density. When the MT6818 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 MT6818 also provides 3-Wire SPI read mode as shown in Figure 20.

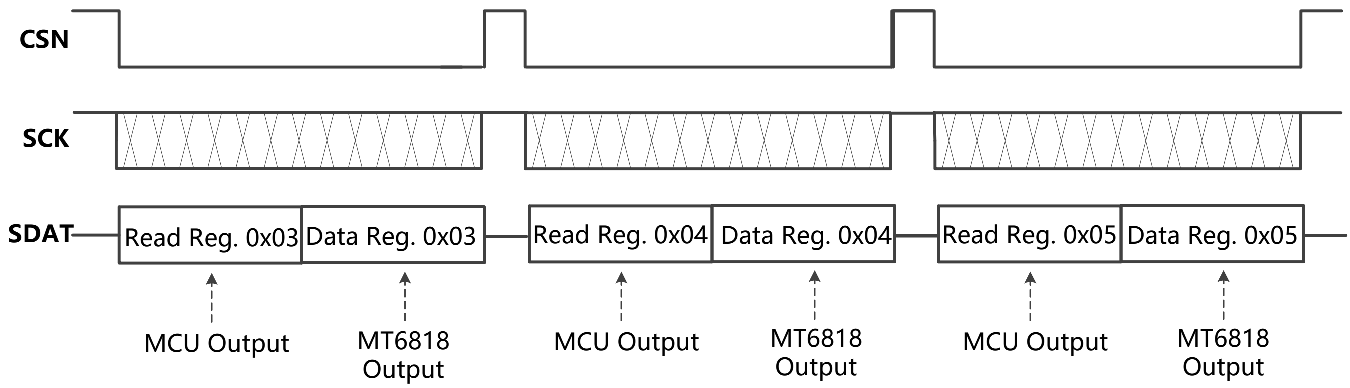


Figure 20: 3-Wire SPI Read Angle Registers

7.5 Off-Axis Application

The MT6818 is designed for both on-Axis and off-Axis applications. If the on-Axis position is not available, the sensor can be positioned away from the rotation axis of a ring magnet (see Figure 21). In this case, the magnetic field angle is no longer directly proportional to the mechanical angle. The MT6818 can be adjusted to calibration for this effect and recover the linear relation between the mechanical angle and the sensor output. With multiple pole pair magnets, the MT6818 indicates multiple rotations for each mechanical turn.

Figure 21: Off-Axis Applications with Ring Magnet

For off-Axis application, we recommend MT6818 and ring magnet placed as shown in Figure 22..

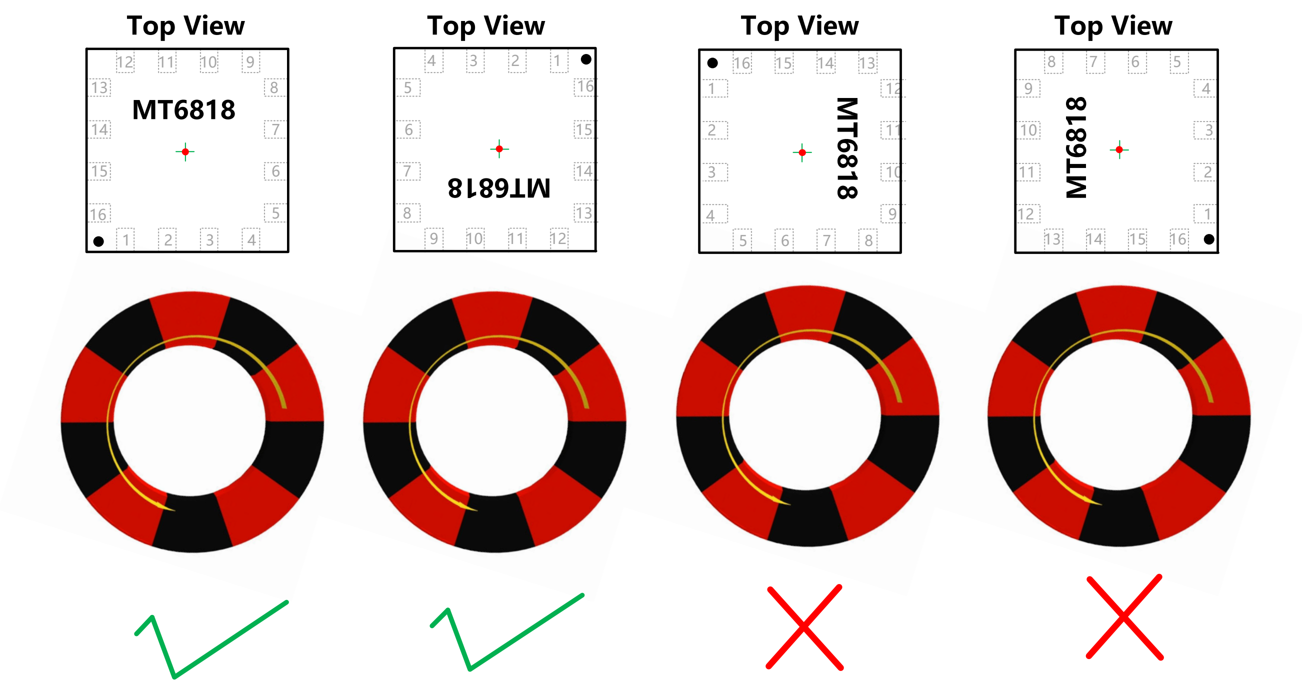


Figure 22: Off-Axis Ring Magnet & MT6818 Placement

7.6 Off-Axis Calibration

Different from on-Axis application, off-axis application with ring magnet introduces more variables like inner/outer diameter of ring magnet, different Z position between chip and ring magnet, and etc. Only Factory calibration is not enough to cover these variables, so MT6818 allows customer to do extra on-line calibration after chip mounting and ring magnet assembling.

For multiple pole-pairs ring magnet (like 4 pole-pairs and above), INL could be calibrated to be less<±1° after customer on-line calibration. Please contact Magntek to get the calibration method.

But for one pole-pair ring magnet, because of serious distortion of magnetic field as shown in Figure 23, the INL will be worse than the case of multiple ring magnet.

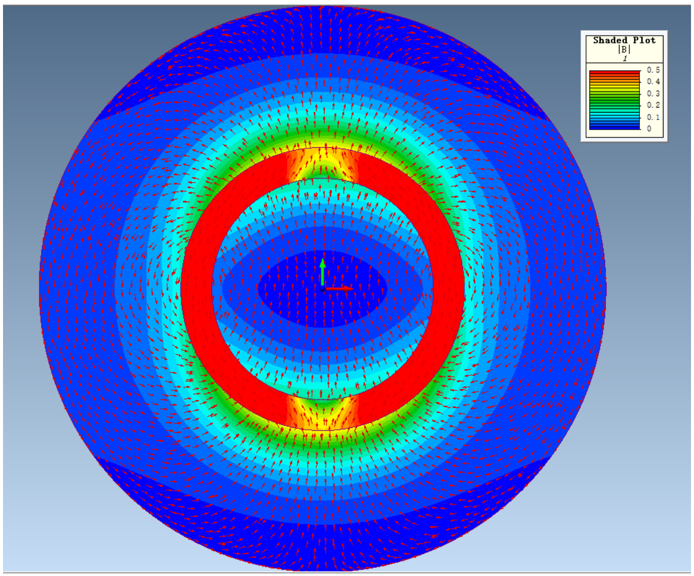
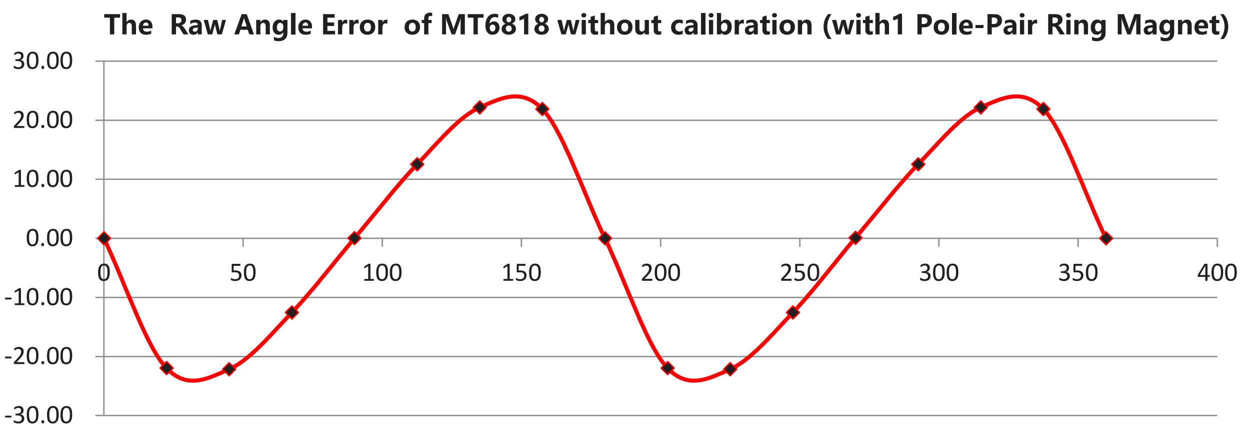
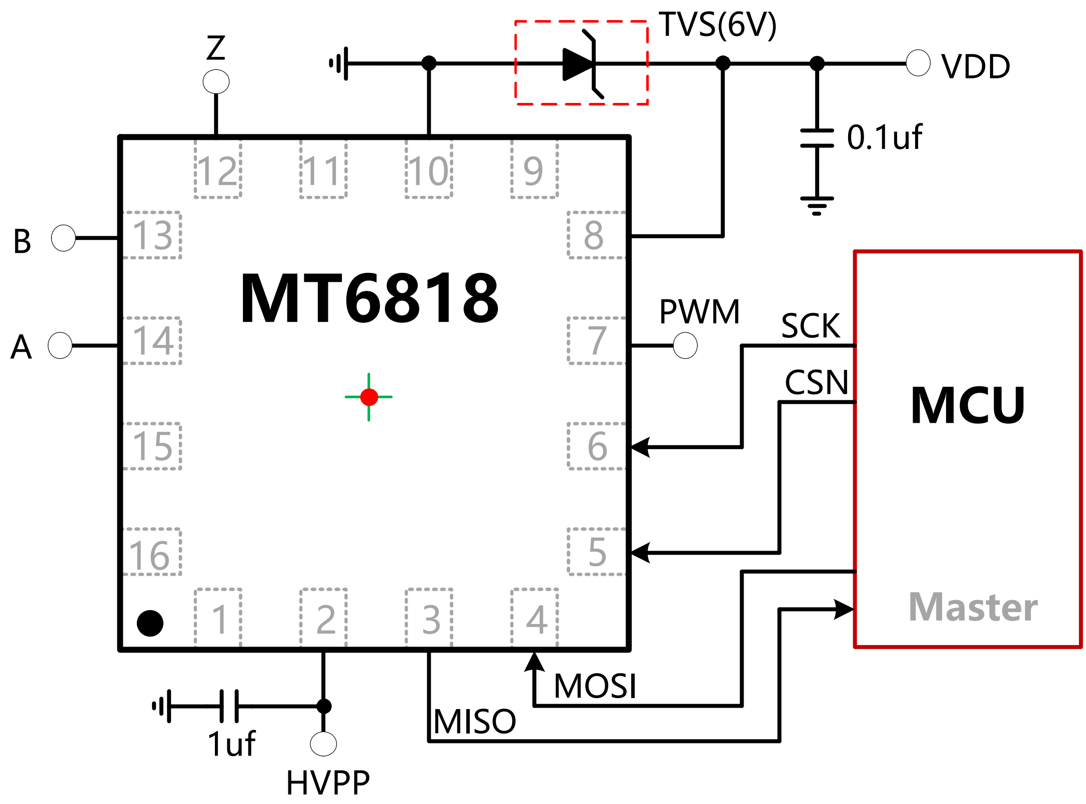


Figure 23: One Pole-Pair Ring Magnet Magnetic Field



8. MTP Programming

MT6818 have a build in MTP memory for customer to program resolution, zero position, z-pulse width, Off-Axis INL calibration 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.



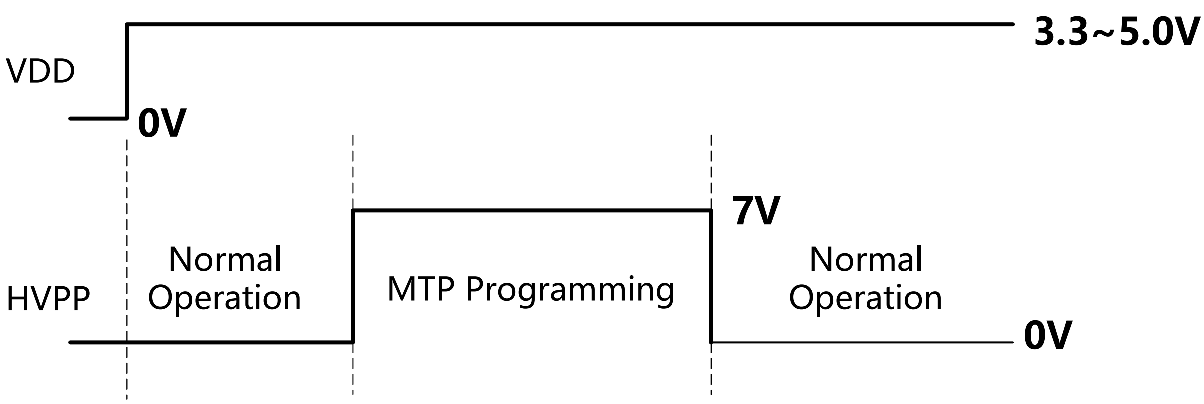
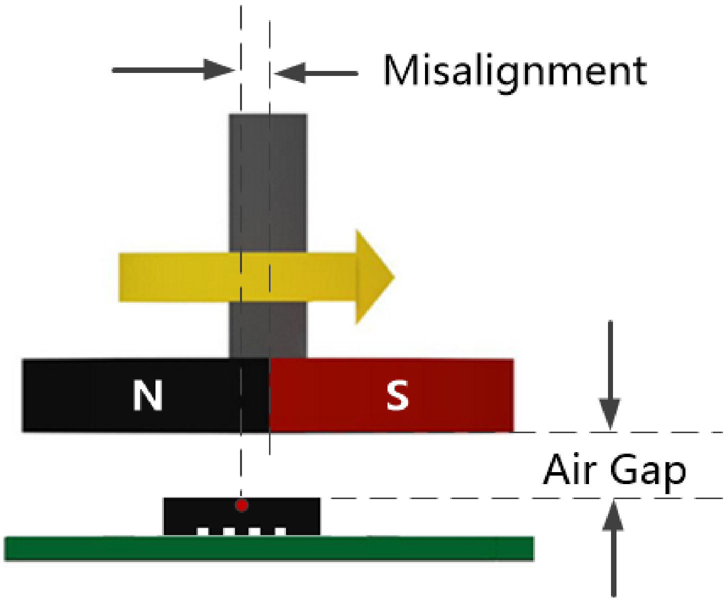


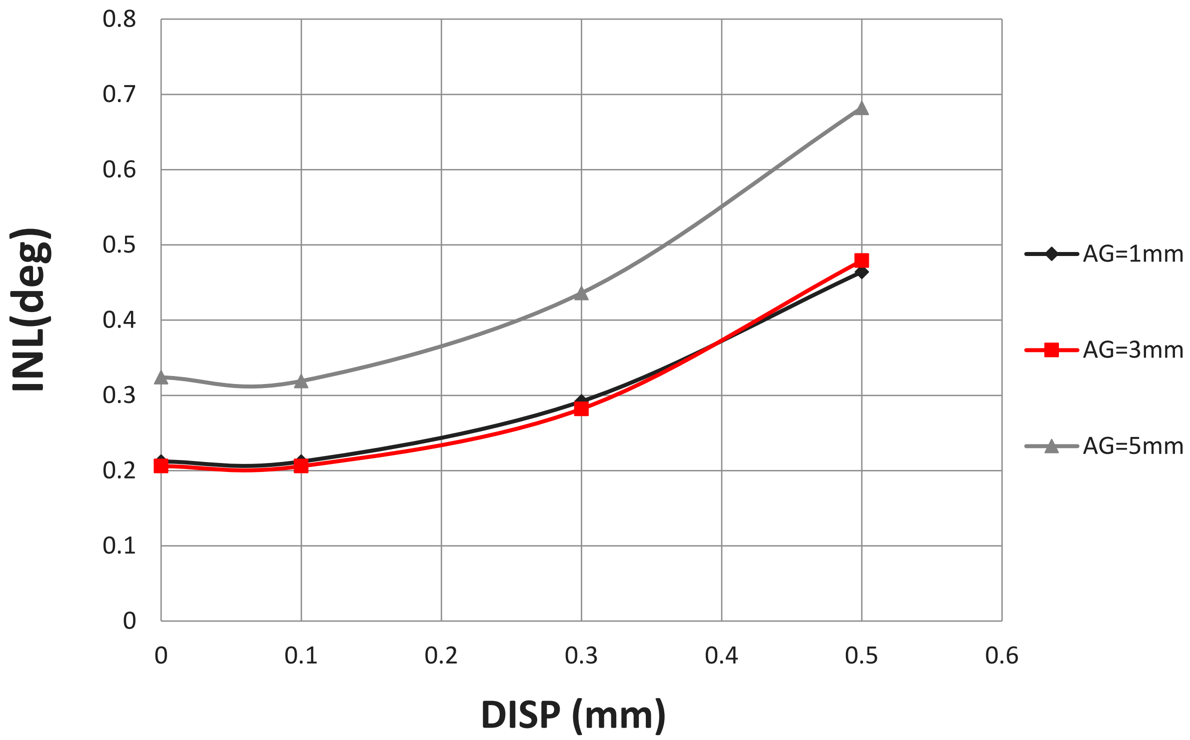
Figure 24: MTP Programming

9. Magnet Placement

It is required that the magnet's center axis be aligned with the sensing element center of MT6818 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 (misalignment) and big AG (air-gap between Magnet and device).

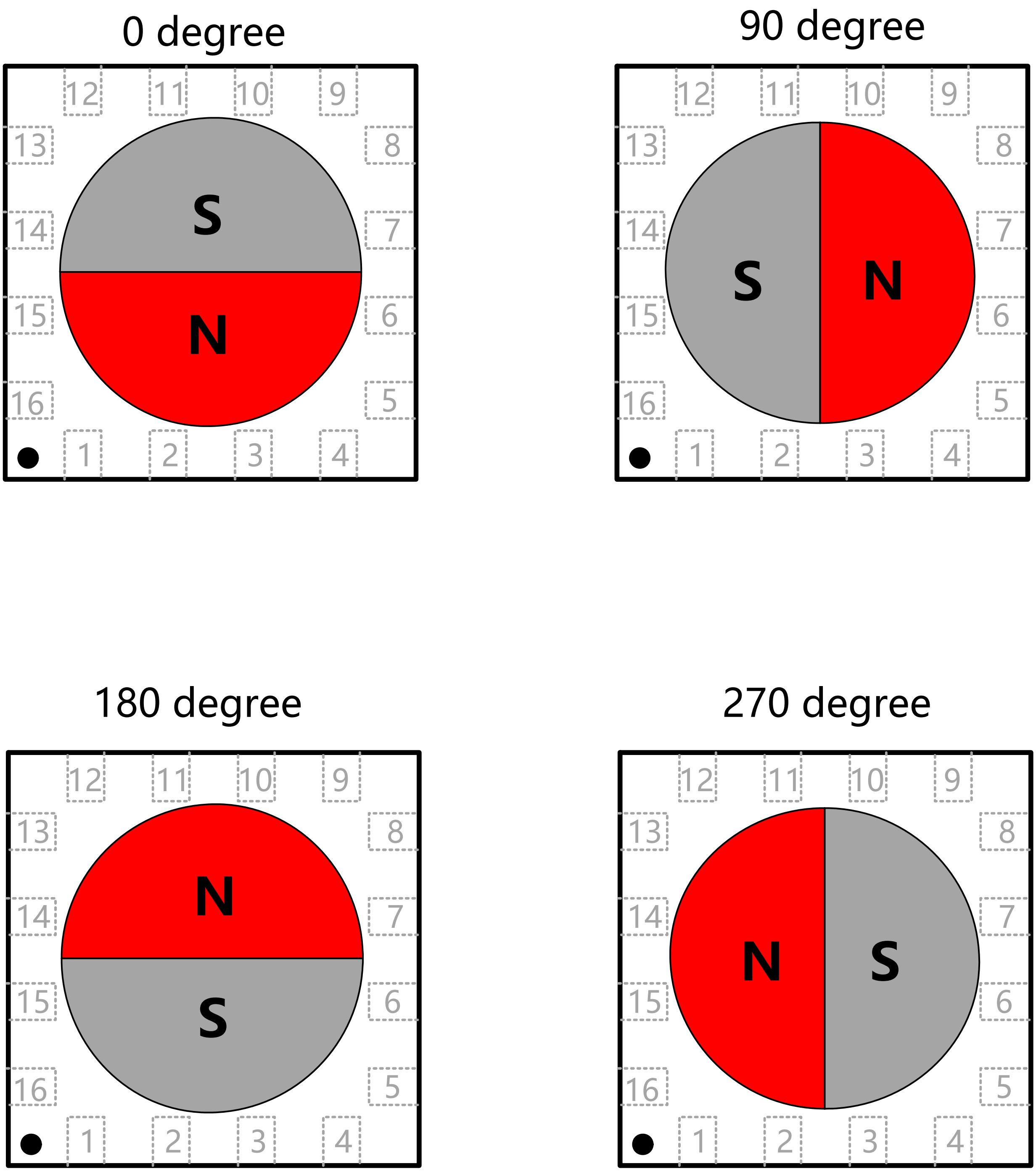


INL vs. DISP for On-Axis Φ10mm magnet

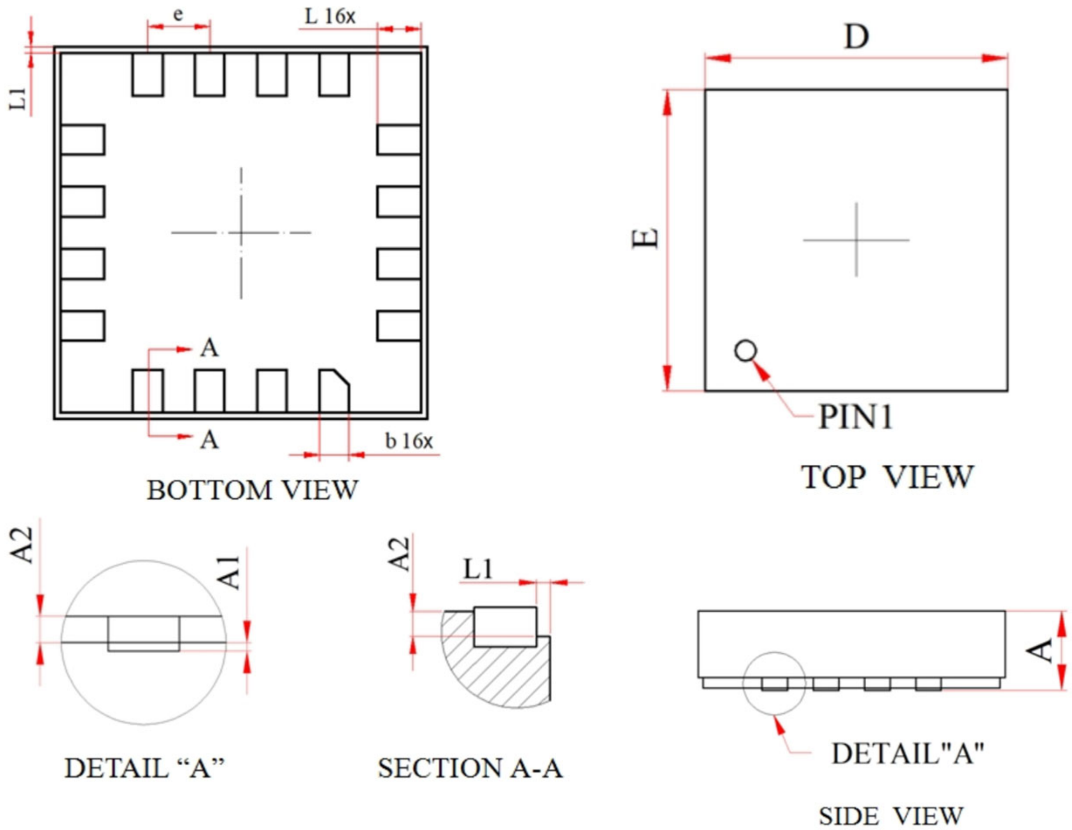


10. Mechanical Angle Direction

Top View



11. Package Information



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max
A	0.700	0.800	0.028	0.031
A1	-	0.005	-	0.000
A2	0.080	0.250	0.003	0.010
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
b	0.190	0.290	0.007	0.009
e	0.500 BSC		0.020 BSC	
L	0.300	0.400	0.012	0.016
L1	0.010	0.090	0.001	0.004

12. Copy Rights and Disclaimer

For the latest version of this document, please visit our website: www.magntek.com.cn

13. Revision History

Revision Number	Date	Comments
1.0	2020.03	Initial Release
1.1	2020.04	Update System Block Diagram
1.2	2020.05	Update Package Information
1.3	2020.06	Update ABZ, UVW and PWM Output Reference Circuit