



MagAlpha MAQ800

8-Bit Angle Encoder with Push-Button Function, AEC-Q100 Qualified

DESCRIPTION

The MAQ800 is an automotive-grade, easy-to-use, magnetic angle encoder with a digital output designed to replace analogic potentiometers or rotary switches. The MAQ800 is for slow operation in human-machine interfaces (HMIs) and manual controls where the rotating speed is below 200rpm. The sensor detects the absolute angular position of a permanent magnet attached to a rotating shaft.

Magnet shapes and configurations are very flexible. Typically, the MAQ800 is used with a diametrically magnetized cylinder with a 2mm to 8mm diameter.

The MAQ800 features configurable magnetic field strength thresholds, which allow for the implementation of a push or pull button function. These are output as two logic signals.

The on-chip non-volatile memory (NVM) stores configurable parameters, such as the reference zero angle position and magnetic field detection threshold.

The MAQ800 is available in a QFN-16 (3mmx3mm) package.

FEATURES

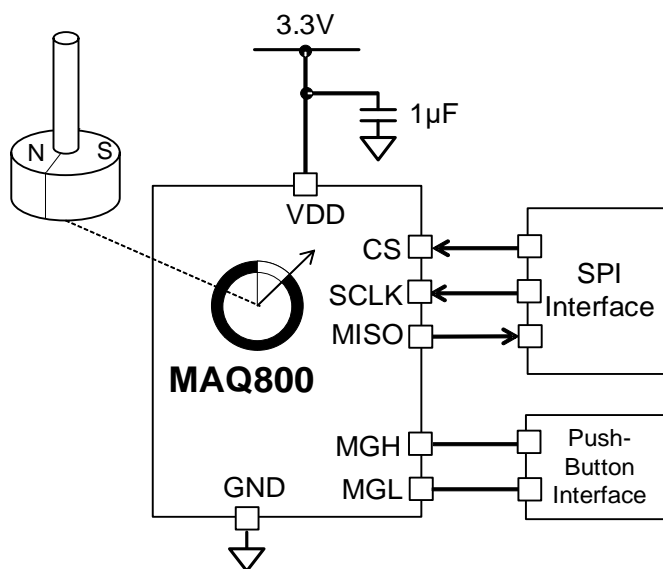
- 8-Bit Resolution Absolute Angle Encoder
- Contactless Sensing for Long Life with No Wear
- Serial Peripheral Interface (SPI) and Synchronous Serial Interface (SSI)
- Configurable Magnetic Field Strength Detection for Push/Pull Button Detection
- 3.3V, 12mA Supply
- -40°C to +125°C Operating Temperature
- Available in a QFN-16 (3mmx3mm) Package
- Available in AEC-Q100 Grade 1

APPLICATIONS

- Rotary Knob Control Interfaces
- Manual Controls
- Encoders
- Automotive
- White Goods

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TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MAQ800GQE-AEC1	QFN-16 (3mmx3mm)	See Below	1

* For Tape & Reel, add suffix -Z (e.g. MAQ800GQE-AEC1-Z).

TOP MARKING

CAJY

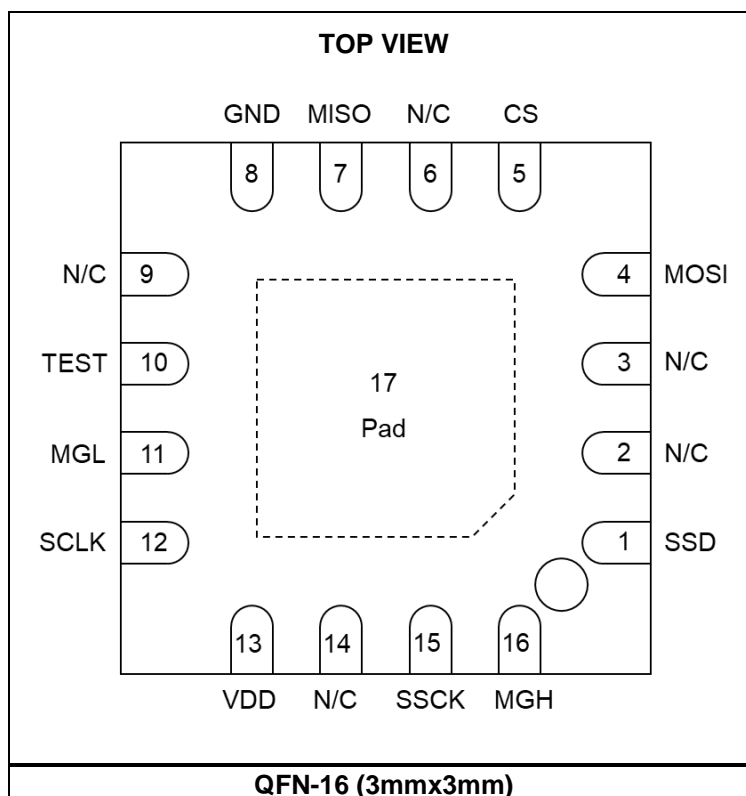
LLLL

CAJ: Product code of MAQ800GQE-AEC1

Y: Year code

LLLL: Lot number

PACKAGE REFERENCE



PIN FUNCTIONS

Pin #	Name	Description
1	SSD	Data out (SSI).
2, 3, 6, 9, 14	NC	No connection. Do not connect the NC pin.
4	MOSI	Data in (SPI). The MOSI pin has an internal pull-down resistor.
5	CS	Chip select (SPI). The CS pin has an internal pull-up resistor.
7	MISO	Data out (SPI). The MISO pin has an internal pull-down resistor that is enabled at a high-impedance state.
8	GND	Supply ground.
10	TEST	Factory use only. Connect the TEST pin to ground.
11	MGL	Digital output indicating when the field strength is below the MGLT level.
12	SCLK	Clock (SPI). The SCLK pin has an internal pull-down resistor.
13	VDD	3.3V supply.
15	SSCK	Clock (SSI). The SSCK pin has an internal pull-down resistor.
16	MGH	Digital output indicating when the field strength exceeds the MGHT level.
17	PAD	Exposed pad.

ABSOLUTE MAXIMUM RATINGS ⁽¹⁾

Supply voltage -0.5V to +4.6V
 Input pin voltage (V_{IN}) -0.5V to +6V
 Output pin voltage (V_{OUT}) -0.5V to +4.6V
 Continuous power dissipation ($T_A = 25^{\circ}\text{C}$) ⁽²⁾
 2.0W
 Junction temperature (T_J) 125°C
 Lead temperature 260°C
 Storage temperature -65°C to +150°C

ESD Ratings

Human body model (HBM) ±2000V
 Charged-device model (CDM) ±1500V

Thermal Resistance ⁽³⁾ θ_{JA} θ_{JC}
 QFN-16 (3mmx3mm) 50 12... °C/W

Notes:

- 1) Exceeding these ratings may damage the device.
- 2) The maximum allowable power dissipation is a function of the maximum junction temperature, T_J (MAX), the junction-to-ambient thermal resistance, θ_{JA} , and the ambient temperature, T_A . The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = $(T_J$ (MAX) - T_A) / θ_{JA} .
- 3) Measured on a JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

Parameter	Symbol	Condition	Min	Typ	Max	Units
Recommended Operating Conditions						
Supply voltage	V _{DD}		3.0	3.3	3.6	V
Supply current	I _{DD}		10.2	11.7	13.8	mA
Operating temperature	T _{OP}		-40		+125	°C
Applied magnetic field	B		30	60		mT

GENERAL CHARACTERISTICS

$V_{DD} = 3.3V$, $45mT < B < 100mT$, $T_A = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Resolution						
Effective resolution		3 σ deviation from the noise distribution	8			bits
Noise root mean square (rms)			0.005	0.01	0.02	deg
Refresh rate			850	980	1100	kHz
Data output length			8		8	bits
Response Time						
Start-up time ⁽⁴⁾					20	ms
Latency ⁽⁵⁾		Constant speed propagation delay		4		ms
Filter cutoff frequency ⁽⁴⁾	f_{CUTOFF}			90		Hz
Accuracy						
INL at 25°C		At room temperature and across the full field range		0.7		deg
INL between -40°C to +125°C ⁽⁵⁾		Across the full temperature range and field range		1.1		deg
Output Drift						
Temperature-induced drift at room temperature ⁽⁵⁾				0.015	0.04	deg/°C
Temperature-induced variation ⁽⁵⁾		From 25°C to 85°C		0.5	1.2	deg
		From 25°C to 125°C		1.0	2.1	deg
Drift induced by magnetic field ⁽⁵⁾				0.005		deg/mT
Drift induced by voltage supply ⁽⁵⁾					0.3	deg/V
Magnetic Field Detection Thresholds						
Accuracy ⁽⁵⁾				5		mT
Hysteresis ⁽⁵⁾	MagHys			6		mT
Temperature drift ⁽⁵⁾				-600		ppm/°C
Digital Input/Output (I/O)						
Input high voltage	V_{IH}		2.5		5.5	V
Input low voltage	V_{IL}		-0.3		+0.8	V
Output low voltage ⁽⁵⁾	V_{OL}	$V_{OL} = 4mA$			0.4	V
Output high voltage ⁽⁵⁾	V_{OH}	$V_{OH} = 4mA$	2.4			V
Pull-up resistor	R_{PU}		46	66	97	k Ω
Pull-down resistor	R_{PD}		43	55	97	k Ω
Rising edge slew rate ⁽⁴⁾	t_R	$C_L = 50pF$		0.7		V/ns
Falling edge slew rate ⁽⁴⁾	t_F	$C_L = 50pF$		0.7		V/ns

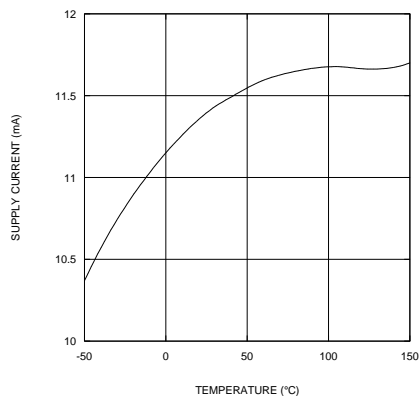
Notes:

- 4) Guaranteed by design.
5) Guaranteed by characterization testing.

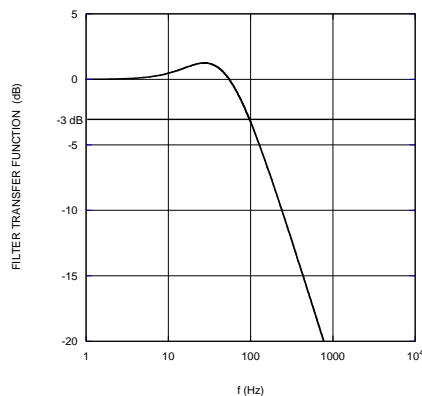
TYPICAL CHARACTERISTICS

$V_{DD} = 3.3V$, $T_A = 25^\circ C$, unless otherwise noted.

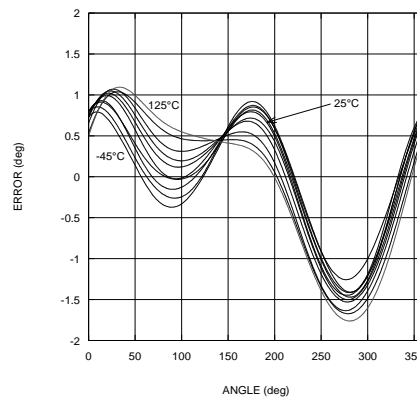
Current Consumption at $V_{DD} = 3.3V$



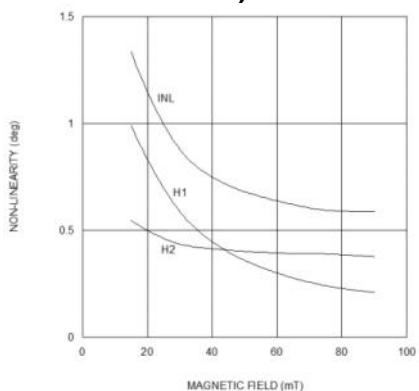
Filter Transfer Function



Error Curves at 50mT



Nonlinearity (INL and Harmonics)



FUNCTIONAL BLOCK DIAGRAM

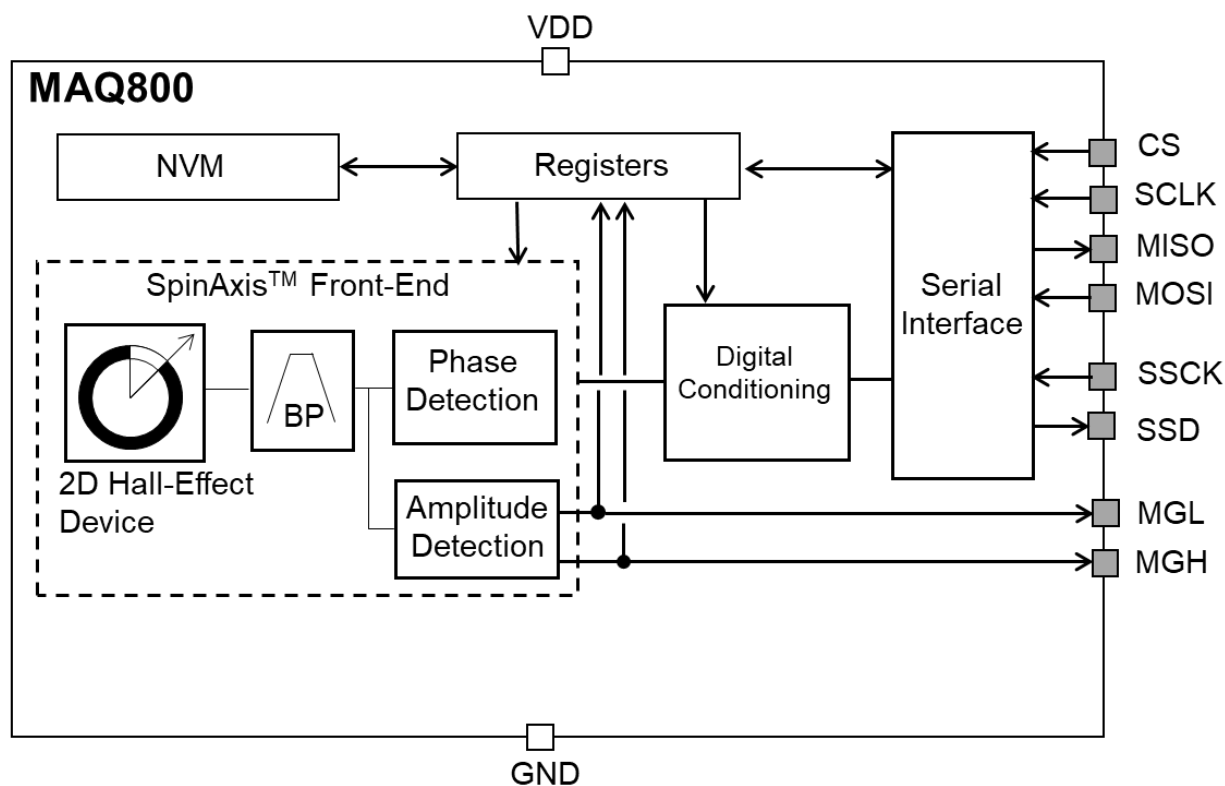


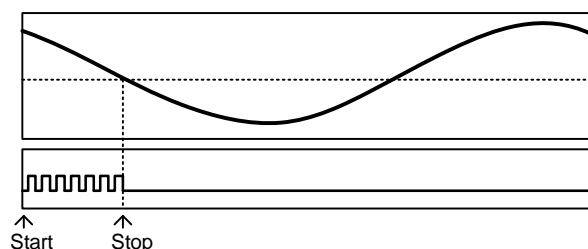
Figure 1: Functional Block Diagram

OPERATION

Sensor Front-End

The magnetic field is detected with integrated Hall devices located in the center of the package. The angle is measured using the SpinAxis™ method, which directly digitizes the direction of the field without complex arctangent computation or feedback loop-based circuits (interpolators).

The SpinAxis™ method is based on phase detection and generates a sinusoidal signal with a phase that represents the angle of the magnetic field. The angle is then obtained by a time-to-digital converter, which measures the time between the zero crossing of the sinusoidal signal and the edge of a constant waveform (see Figure 2). The time-to-digital is output from the front-end to the digital conditioning block.



Top: Sine Waveform
Bottom: Time-to-Digital Converter Clock
Figure 2: Phase Detection Method

The front-end output delivers a digital number that is proportional to the angle of the magnetic field at the rate of 1MHz in a straightforward and open-loop manner.

Digital Filtering

The front-end signal is further treated to achieve the final effective resolution. This treatment does not add any latency under steady conditions. The filter transfer function can be calculated with Equation (1):

$$H(s) = \frac{1 + 2\tau s}{(1 + \tau s)^2} \quad (1)$$

Where τ is the filter time constant, which is related to the cutoff frequency and can be estimated with Equation (2):

$$\tau = 0.38 / f_{\text{CUTOFF}} \quad (2)$$

See the General Characteristics section on page 4 for the value of f_{CUTOFF} .

Sensor – Magnet Mounting

The MAQ800's sensitive area (where the Hall devices are placed) is confined within a region less than 100μm wide, and it has multiple integrated Hall devices. This volume is located both horizontally and vertically, within 50μm of the center of the QFN package. The sensor detects the angle of the magnetic field projected in a plane parallel to the package's upper surface. This means that the only relevant magnetic field is the in-plane component (X and Y components) in the middle point of the package.

By default, when looking at the top of the package, the angle increases when the magnetic field rotates clockwise. Figure 3 shows the zero angle of the sensor that has not been configured, where the plus sign indicates the sensitive point. Both the rotation direction and the zero angle can be configured.

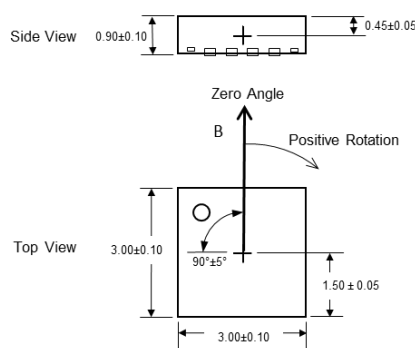


Figure 3: Detection Point and Default Positive Direction

This type of detection provides flexibility for the angular encoder design. The sensor only requires the magnetic vector to lie within the sensor plane, with a field amplitude of at least 30mT. Note that the MAQ800 can work with fields below 30mT, but the linearity and resolution performance may deviate from the specifications.

The most straightforward mounting method is to place the MAQ800 sensor on the rotation axis of a permanent magnet (e.g. a diametrically magnetized cylinder (see Figure 4 on page 8).

The recommended magnet is a Neodymium alloy (N35) cylinder with dimensions of Ø5mmx3mm, inserted into an aluminum shaft with a 1.5mm air gap between the magnet and the sensor (surface of the package). For excellent linearity, the sensor is positioned with a precision of 0.5mm.

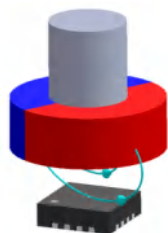


Figure 4: End-of-Shaft Mounting

Figure 5 shows an example of sensor and magnet mounting in a contactless switch assembly. A Neodymium alloy magnet is inserted into an aluminum shaft. The air gap between the magnet and the sensor is 1mm, and the sensor is positioned on the rotation axis with a precision of 0.5mm.

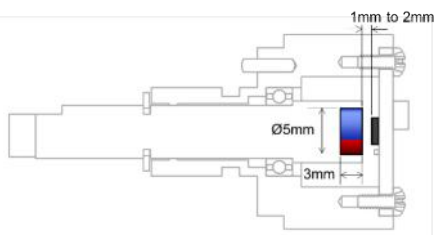


Figure 5: Potentiometer-Like Assembly

Electrical Mounting and Power Supply Decoupling

It is recommended to place a 1µF decoupling capacitor close to the sensor with a low-impedance path to GND (see Figure 6).

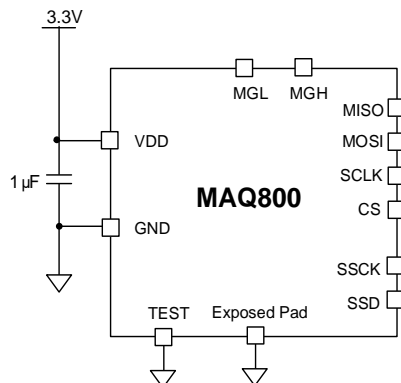


Figure 6: Supply Decoupling Connection

In general, the MAQ800 works well with or without the exposed pad connected. It is

recommended that the exposed pad be connected to ground for optimal electric, thermal, and mechanical conditions.

Serial Interface

The sensor supports the serial peripheral interface (SPI) standard for angle reading and register configurations. The synchronous serial interface (SSI) bus can be used for angle reading, but the MAQ800 does not support configuring via the SSI.

Serial Peripheral Interface (SPI)

The SPI is a four-wire, synchronous, serial communication interface. The MAQ800 supports SPI mode 3 and mode 0 (see Table 1 and Table 2). The SPI mode (0 or 3) is detected automatically by the sensor, and does not require additional action. There is no minimum clock rate. Real-world data rates depend on the PCB layout quality and signal trace length.

Table 1 shows the SPI specifications.

Table 1: SPI Specification

	Mode 0	Mode 3
SCLK Idle State	Low	High
Data Capture	On SCLK rising edge	
Data Transmission	On SCLK falling edge	
CS Idle State	High	
Data Order	MSB first	

Table 2 shows the SPI standard.

Table 2: SPI Standard

	Mode 0	Mode 3
CPOL	0	1
CPHA	0	1
Data Order (DORD)	0 (MSB first)	

All commands to the MAQ800 (whether for writing or reading register content) must be transferred through the SPI MOSI pin and must be 16 bits long. See the SPI Communication section on page 10 for more details.

Figure 7 on page 9 shows the SPI timing diagram.

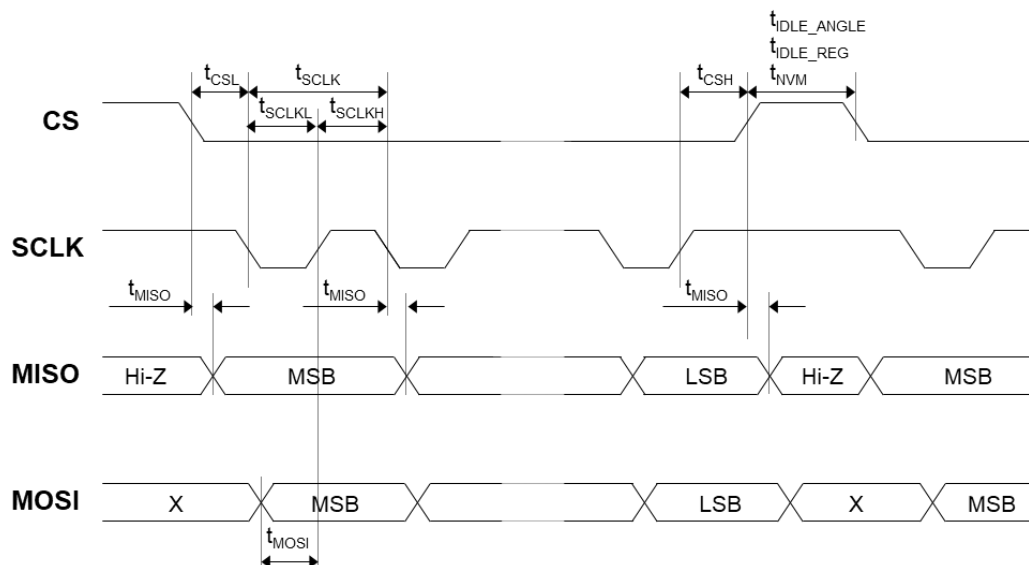


Figure 7: SPI Timing Diagram

Figure 8 shows the minimum idle time.

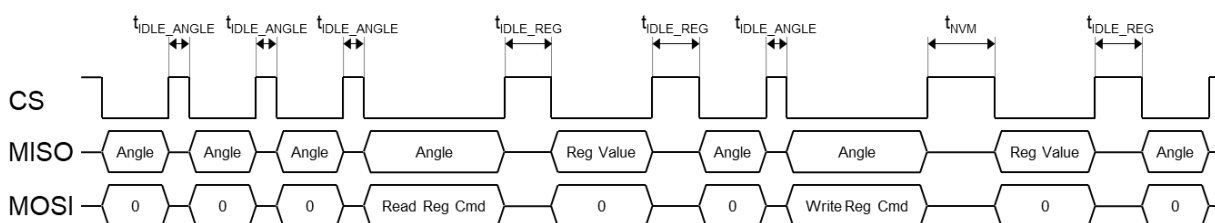


Figure 8: Minimum Idle Time

Table 3 shows the SPI timing.

Table 3: SPI Timing

Parameter ⁽⁶⁾	Description	Min	Max	Units
t_{IDLE_ANGLE}	Idle time between two subsequent angle transmissions.	150		ns
t_{IDLE_REG}	Idle time before and after a register readout.	750		ns
t_{NVM}	Idle time between a write command and a register readout (delay necessary for NVM update).	20		ms
t_{CSL}	Time between the CS falling edge and SCLK falling edge.	80		ns
t_{SCLK}	SCLK period.	40		ns
t_{SCLKL}	Low level of the SCLK signal.	20		ns
t_{SCLKH}	High level of the SCLK signal.	20		ns
t_{CSH}	Time between the SCLK rising edge and CS rising edge.	25		ns
t_{MISO}	SCLK setting edge to data output valid.		15	ns
t_{MOSI}	Data input valid to the SCLK reading edge.	15		ns

Note:

6) All values are guaranteed by design.

SPI Communication

The MAQ800 supports three types of SPI operation:

- Read angle
- Read configuration register
- Write configuration register

Each operation has a specific frame structure, described below.

SPI Read Angle

Every 1μs, new data is transferred into the output buffer. The master device triggers the reading by pulling CS low. When a trigger event is detected, the data remains in the output buffer until the CS signal de-asserts (see Table 4).

Table 4: Sensor Data Timing

Event	Action
CS falling edge	Start reading and freeze the output buffer
CS rising edge	Release the output buffer

Figure 9 shows a full SPI angle reading.

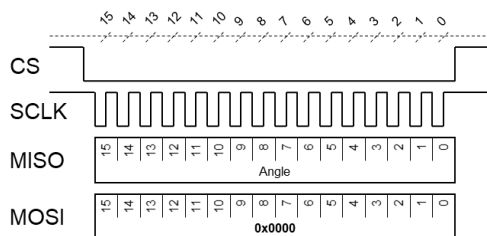


Figure 9: Diagram of a Full 16-Bit SPI Angle Reading

Figure 10 shows a partial SPI angle reading.

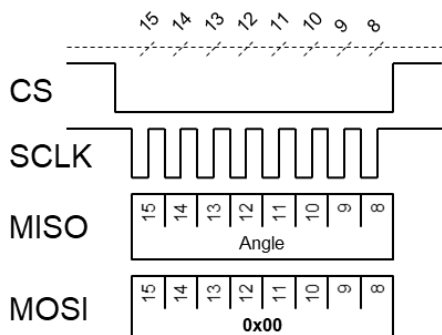
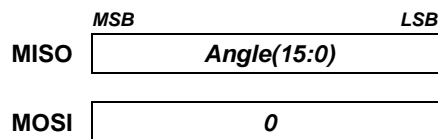


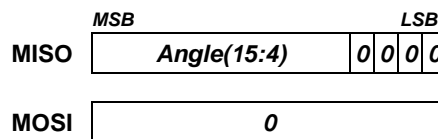
Figure 10: Diagram of a Partial 8-Bit SPI Angle Reading

A full angle reading requires 16 clock pulses. The sensor's MISO line returns:

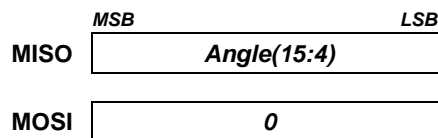


The MagAlpha family has sensors with different features and resolution levels. For the data output length and the number of useful bits delivered at the serial output, see the General Characteristics section on page 4. If the data length is shorter than 16 bits, the rest of the bits sent are 0.

For example, a data output length of 12 bits means that the serial output delivers a 12-bit angle value with four 0's padded at the end (MISO state remains 0). If the master sends 16 clock counts, the MagAlpha replies with:



Therefore, angle reading can be optimized without any loss of information by reducing the number of clock counts. For the 12-bit data output length, only 12 clock counts are required to obtain the full sensor resolution:



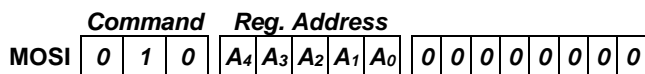
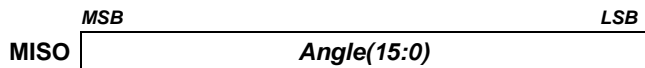
If less resolution is needed, the angle can be read by sending even fewer clock counts (since the MSB is first).

In case of a fast reading, the MagAlpha continues sending the same data until the data is refreshed (see the refresh rate in the General Characteristics table on page 4).

SPI Read Register

A read register operation consists of two 16-bit frames. The first frame sends a read request, which contains the 3-bit read command (010) followed by the 5-bit register address. The second frame returns the 8-bit register value (MSB). The last 8 bits of the frame must all be set to 0.

The first 16-bit SPI frame (read request) is:



The second 16-bit SPI frame (response) is:

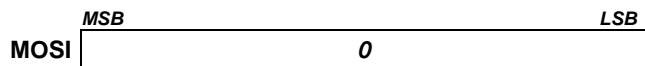
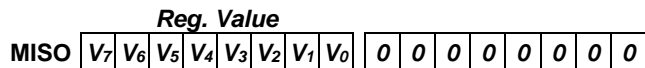
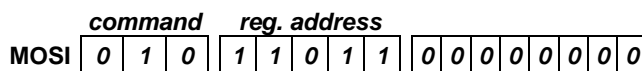
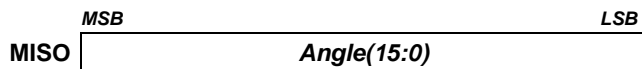


Figure 11 shows a complete transmission.

For example, to obtain the value of the magnetic level high and low flags (MGH and

MGL, respectively), read register 27 (bit[6] and bit[7]) by sending the following first frame:



In the second frame, the MagAlpha replies:

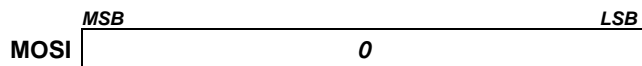
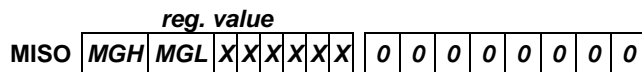


Figure 12 shows a complete example.

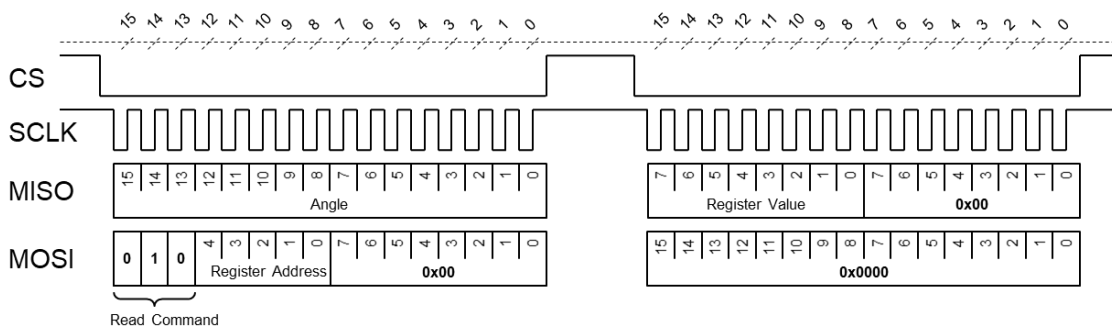


Figure 11: 16-Bit Frames Read Register Operation

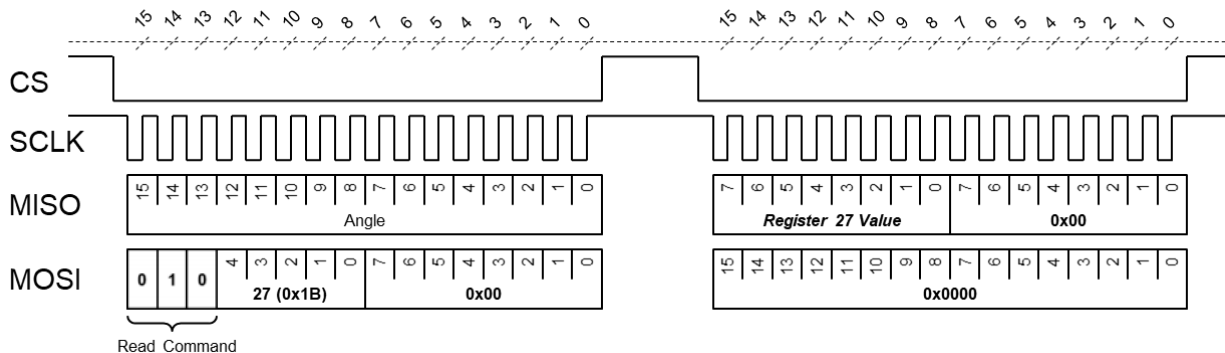


Figure 12: Example – Read the MGH and MGL Flags on Register 27, Bit[7] and Bit[6]

SPI Write Register

Table 7 on page 15 shows the configurable 8-bit registers. Data written to these registers are stored in the on-chip NVM and are automatically reloaded during start-up. Table 8 on page 15 shows the factory default register values.

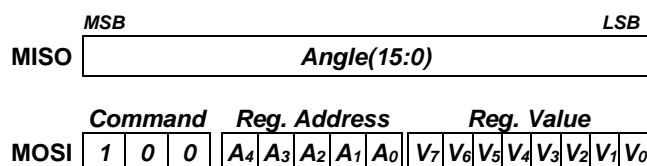
A write register operation consists of two 16-bit frames. The first frame sends a write request,

which contains the 3-bit write command (100) followed by the 5-bit register address and the 8-bit value (MSB first). The second frame returns the newly written register value (acknowledge).

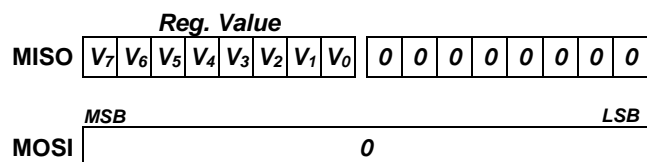
The on-chip memory is guaranteed to endure 1,000 write cycles at 25°C.

It is critical to wait 20ms between the first and second frame, as this is the time it takes to write to the NVM. Failure to implement this waiting period can result in the register's previous value being read. Note that this delay is only required after a write request. A read register request and a read angle do not require this wait time.

The first 16-bit SPI frame (write request) is:

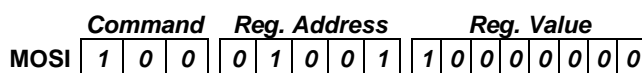
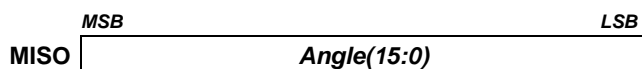


The second 16-bit SPI frame (response) is:



The read-back register content can be used to verify the register programming.

For example, to set the value of the output rotation direction (RD) to counterclockwise (high), write to register 9 by sending the following first frame:



Send the second frame after 20ms of waiting time (see Figure 8 on page 9). If the register is written correctly, the reply is:

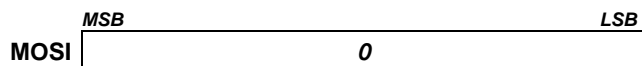
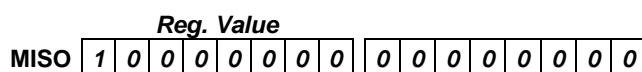


Figure 13 shows a complete transmission overview. Figure 14 on page 13 shows a complete example.

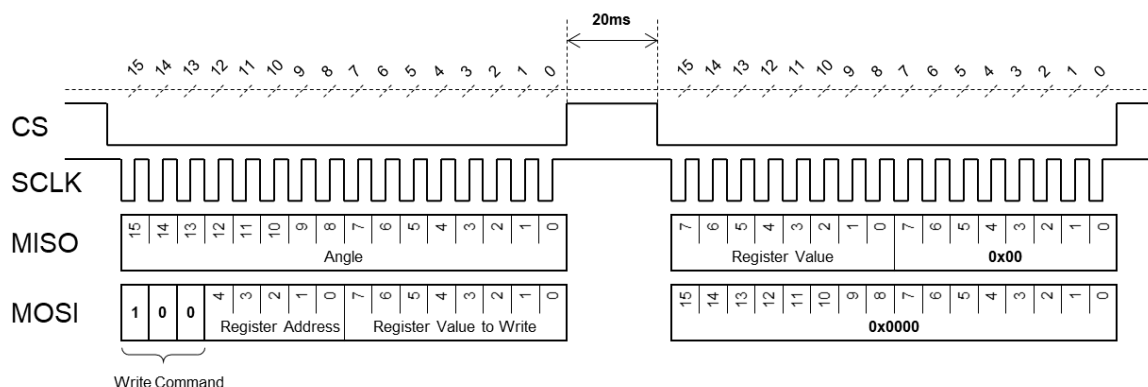


Figure 13: Overview of Two 16-Bit Frames for Write Register Operation

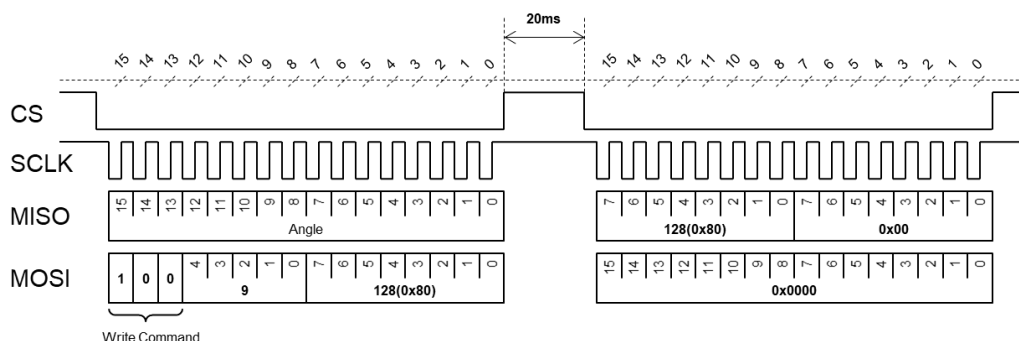


Figure 14: Example – Write Output Rotation Direction (RD) to Counterclockwise (High), on Register 9, Bit[7]

Synchronous Serial Interface (SSI)

The SSI is a 2-wire, synchronous serial interface for reading data only. The MAQ800 operates as a slave to the external SSI master and only supports angle reading. It is not possible to read or write to registers using the SSI.

SSI Communication

Unlike the SPI, the MAQ800's SSI only supports angle reading operation. It is not possible to read or write to registers using the SSI.

SSI. Figure 15 shows SSI timing communication.

The SSI implemented in this sensor is different from the standard SSI. For this reason, the MAQ800 may not work with regular SSI devices.

The MAQ800 uses an SSI with a low SSCK idle state instead of the high SSCK idle state used in the standard protocol. This sensor also requires a dummy rising edge on the SSCK signal at the beginning of the SSI frame, while the standard SSI does not.

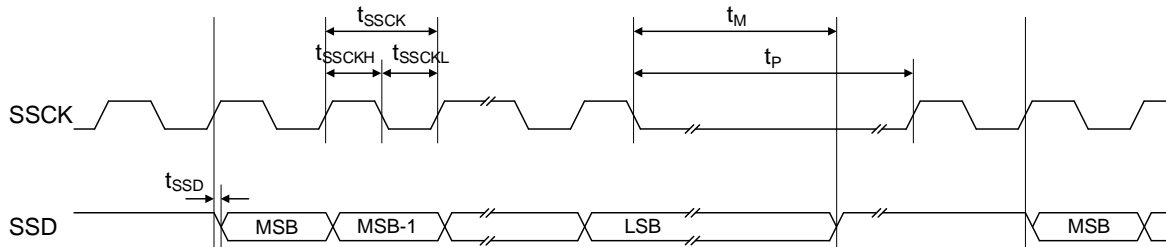


Figure 15: SSI Timing

Table 5 shows SSI timing communication.

Table 5: SSI Timing

Parameter	Description	Min	Max	Units
tSSD			15	ns
tSSCK	SSCK period	0.2	16	μs
tSSCKL	Low level of the SSCK signal	0.1	8	μs
tSSCKH	High level of the SSCK signal	0.1	8	μs
tM	Transfer timeout (monoflop time)	25		μs
tP	Dead time: the SSCK high time for next data reading	40		μs

SSI Read Angle

The transmitted bit order starts with the MSB and ends with the LSB. Every 1 μ s, new data is transferred into the output buffer. The master device triggers the reading by pulling SSCK down. Just like with an SPI reading, a full

reading requires 16 clock counts. If the data length is shorter than 16 bits, the 16-bit output word is completed with zeros. Therefore, reading can also be performed with fewer than 16 clock counts (see Figure 16).

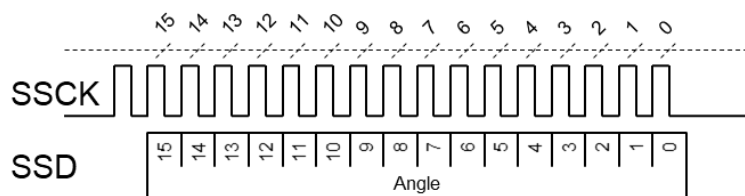


Figure 16: Full 16-Bit SSI Angle Reading

If a trigger event is detected, the data remains in the output buffer until the clock's rising edge for the LSB (bit[0]) and the transfer timeout time has passed. Table 6 shows the sensor data timing.

Table 6: Sensor Data Timing

Trigger Event	Release of the output buffer
First SSCK Falling Edge	SSCK rising edge + timeout (t_M) (see Figure 15 on page 13)

Figure 17 shows the timing diagram for consecutive angle readings.

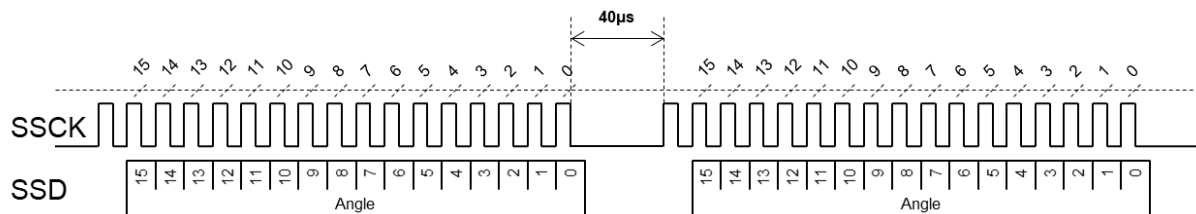


Figure 17: Two Consecutive 16-Bit SSI Angle Readings with the Required Dead Time between the Frames

REGISTER MAP

Table 7: Register Map

#	Hex	Bin.	Bit[7] MSB	Bit[6]	Bit[5]	Bit[4]	Bit[3]	Bit[2]	Bit[1]	Bit[0] LSB
0	0x0	00000	Z(7:0)							
1	0x1	00001	Z(15:8)							
6	0x6	00110	MGLT(2:0)			MGHT(2:0)			-	-
9	0x9	01001	RD	-	-	-	-	-	-	-
27	0x1B	11011	MGH	MGL	-	-	-	-	-	-

Table 8: Factory Default Values

#	Hex	Bin.	Bit[7] MSB	Bit[6]	Bit[5]	Bit[4]	Bit[3]	Bit[2]	Bit[1]	Bit[0] LSB
0	0x0	00000	0	0	0	0	0	0	0	0
1	0x1	00001	0	0	0	0	0	0	0	0
6	0x6	00110	0	0	0	1	1	1	0	0
9	0x9	01001	0	0	0	0	0	0	0	0

Table 9: Configuration Parameters

Parameters	Symbol	Number of Bits	Description	See Table
Zero setting	Z	16	Sets the zero position.	10
Magnetic field high threshold	MGHT	3	Sets the field strength high threshold.	14
Magnetic field low threshold	MGLT	3	Sets the field strength low threshold.	14
Rotation direction	RD	1	Determines the sensor's positive direction.	12

REGISTER SETTINGS

Zero Setting

The MAQ800's zero position (a_0) can be configured with 16 bits of resolution. The angle streamed out by the MAQ800 (a_{OUT}) can be calculated with Equation (3):

$$a_{OUT} = a_{RAW} - a_0 \quad (3)$$

Where a_{RAW} is the raw angle provided by the MagAlpha front-end.

The parameter $Z(15:0)$, which is zero by default, is the complementary angle of the zero setting. In decimal format, it can be estimated with Equation (4):

$$a_0 = 2^{16} - Z(15:0) \quad (4)$$

Table 10 shows the zero-setting parameter.

Table 10: Zero-Setting Parameter

Z(15:0)	Zero Pos. (a_0) (16-Bit Dec.)	Zero Pos. (a_0) (Deg)
0	65536	360.000
1	65535	359.995
2	65534	359.989
...
65534	2	0.011
65535	1	0.005

Example

To set the zero position to 20 degrees, the $Z(15:0)$ parameter must be equal to the complementary angle, calculated with Equation (5):

$$Z(15:0) = 2^{16} - \frac{20\text{deg}}{360\text{deg}} 2^{16} = 61895 \quad (5)$$

In binary format, this value is written as 1111 0001 1100 0111. Table 11 shows the contents of register 0 and register 1 for this example.

Table 11: Register Content

Reg	Bit[7]	Bit[6]	Bit[5]	Bit[4]	Bit[3]	Bit[2]	Bit[1]	Bit[0]
0	1	1	0	0	0	1	1	1
1	1	1	1	1	0	0	0	1

Rotation Direction (RD)

By default, when looking at the top of the package, the angle increases when the magnetic field rotates clockwise (CW) (see Figure 18 and Table 12). Figure 18 shows the positive rotation direction of the magnetic field.

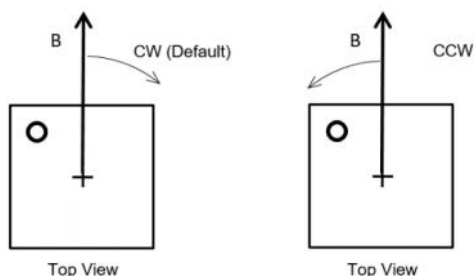


Figure 18: Positive Rotation Direction of the Magnetic Field

Table 12 shows the rotation direction parameter.

Table 12: Rotation Direction Parameter

RD	Positive Direction
0	Clockwise (CW)
1	Counterclockwise (CCW)

Magnetic Field Thresholds

Push-Button Detection

The MAQ800 has two threshold options (MGHT or MGLT), which are complementary in operation. The flag MGH becomes TRUE (logic 1) if the magnetic field increases above MGHT. The flag MGL becomes TRUE (logic 1) if the magnetic field falls below MGLT (see Figure 19 on page 18).

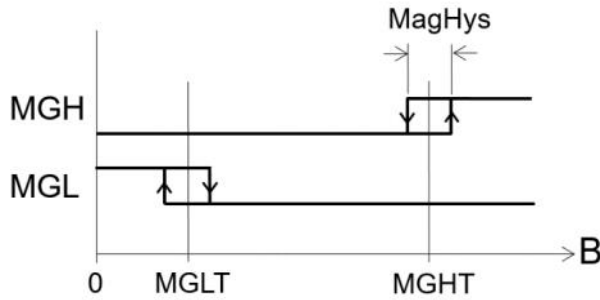


Figure 19: MGH and MGL Signals as a Function of the Field Strength

The MGL and MGH flags can be used to detect an approaching magnet (e.g. when a button is pressed).

Consider a 5mmx3mm N35 magnet. If the MGHT threshold is set to binary 110 (106mT to 112mT), the MGH signal is set to logic high when the sensor-to-magnet air gap is smaller than 1mm (see Figure 20).

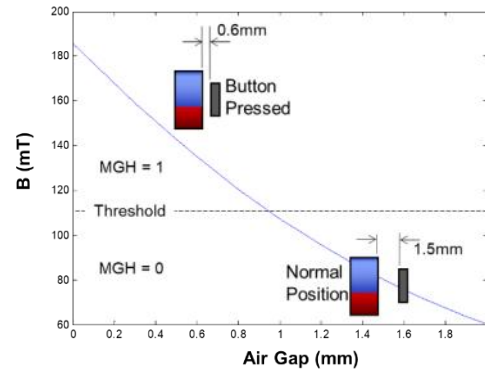


Figure 20: Magnetic Field as a Function of the Air Gap (Threshold Set to 110mT)

This function makes it possible to implement a push or pull action.

MagHys is the hysteresis on the MGH and MGL signals (see the General Characteristics section on page 4). The MGLT and MGHT thresholds are coded on 3 bits and stored in register 6 (see Table 13).

Table 13: Register 6

Reg	Bit[7]	Bit[6]	Bit[5]	Bit[4]	Bit[3]	Bit[2]	Bit[1]	Bit[0]
6	MGLT			MGHT			-	-

The 3-bit values for MGLT and MGHT correspond to the magnetic field (see Table 14).

Table 14: MGLT and MGHT (Binary to mT)

MGLT or MGHT ⁽⁸⁾	Field Threshold (mT) ⁽⁷⁾	
	Low-to-High Magnetic Field	High-to-Low Magnetic Field
000	26	20
001	41	35
010	56	50
011	70	64
100	84	78
101	98	92
110	112	106
111	126	120

Notes:

- 7) Valid when $V_{DD} = 3.3V$. If V_{DD} is different, then the field threshold is scaled by a factor $V_{DD} / 3.3V$.
 8) MGLT can exceed MGHT.

The alarm flags for MGH and MGL can be read via register 27, bit[7] and bit[6], respectively. The MGH and MGL logic states are also provided by the digital output pins (pin 16 and pin 11, respectively).

To read the MGL and MGH flags via the SPI, send the 8-bit command write to register 27:

Command	Reg. Address	MSB	Value	LSB
0 1 0	1 1 0 1 1	0	0 0 0 0 0 0 0 0	0

The MAQ800 answers with the register 27 content in the next transmission:

Register 27, Bits[7:0]							
MGH	MGL	x	x	MG1L	MG2L	x	x

The logic state of the MGL and MGH flags have no effect on the angle output.

MGL Application Note

Pulses with a duration between 1.3μs and 1.5μs appear randomly on the MGL signal. They appear on both the pin and in the register (register 27, bit[6]).

These pulses appear around angle values of 44°, 138°, 224°, and 318° (sensor output), or within an interval of ±1.5° around these values. These pulses have an amplitude of 3.3V (V_{DD}).

The minimum interval between two pulses is 100μs.

MGL Workarounds

1. Invert the MGH signal to replace MGL. The MGL and MGH magnetic thresholds only differ by a small hysteresis (see Table 14 on page 17). An inverted MGH signal can be used to replace the MGL output in the application.
2. Read the MGL signal level twice. Using two readings that are between 2μs and 100μs apart allows the user to distinguish erroneous transitions from real transitions. Table 15 shows examples of different cases.

Table 15: MGL Multiple Readings Workaround

	MGL First Reading	MGL Second Reading (e.g. 20μs after the First Reading)	True MGL Value
Case 1	0	Second reading is not needed	0
Case 2	1	1	1
Case 3	1	0	0

3. Read register 27 with the SPI and compute a corrected MGL value using MG1L and MG2L. The corrected MGL signal is not MG1L or MG2L. This means that the corrected MGL must be set to 1 only when both MG1L and MG2L are equal to 0. See the C implementation below:

```
correctedMGL = !(MG1L | MG2L)
```

TYPICAL APPLICATION CIRCUITS

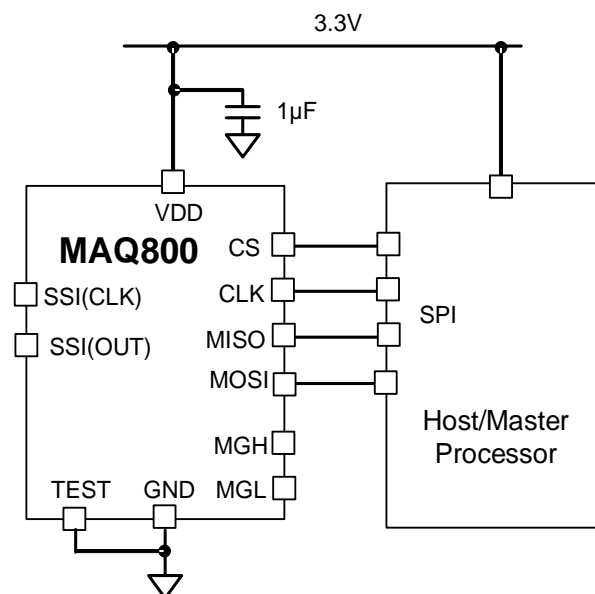


Figure 21: Typical Application Circuit Using SPI Interface

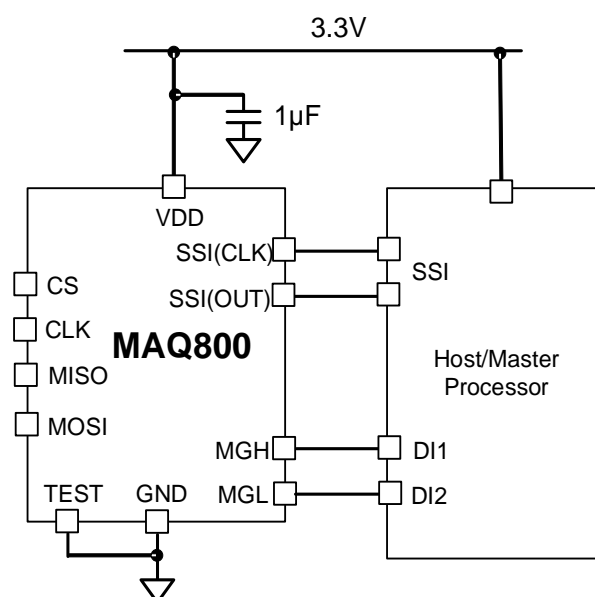


Figure 22: Typical Application Circuit Using SSI Interface and Output Signals (MGL and MGH)

APPENDIX A: DEFINITIONS

Resolution (3 σ Noise Level)

This is the smallest angle increment distinguishable from the noise. The resolution is measured by computing three times σ (the standard deviation in degrees) taken over 1,000 data points at a constant position. The resolution in bits is obtained with: $\log_2(360/6\sigma)$.

Refresh Rate

Rate at which new data points are stored in the output buffer.

Latency

The time elapsed between the instant when the data is ready to be read, and the instant at which the shaft passes that position. The lag in degrees can be calculated with (latency x v), where v is the angular velocity in deg/s.

Start-Up Time

Time until the sensor delivers valid data starting at start-up.

Maximum deviation between the average sensor output (at a fixed position) and the true mechanical angle (see Figure A1).

Integral Nonlinearity (INL)

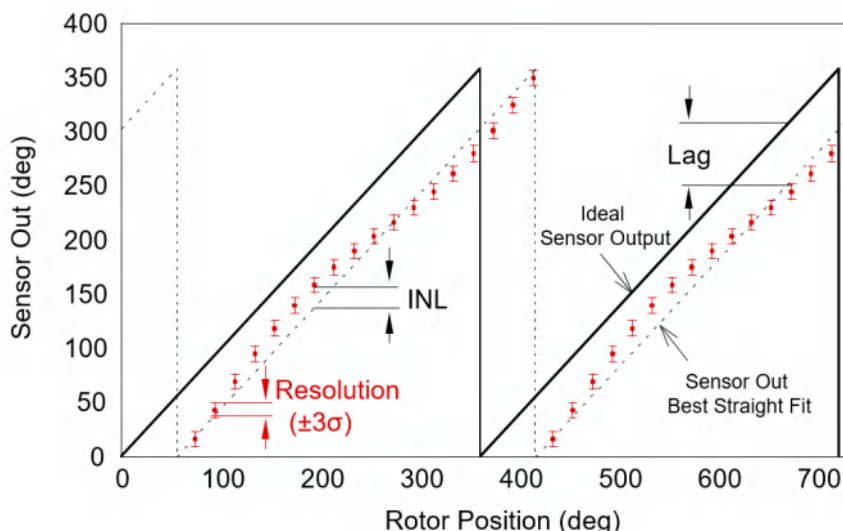


Figure A1: Resolution, INL, Lag

INL can be obtained from the error curve $err(a) = out(a) - a$, where $out(a)$ is the average across 1,000 sensor outputs and a is the mechanical angle indicated by a high-precision encoder ($<0.001^\circ$). INL is then calculated with Equation (A1):

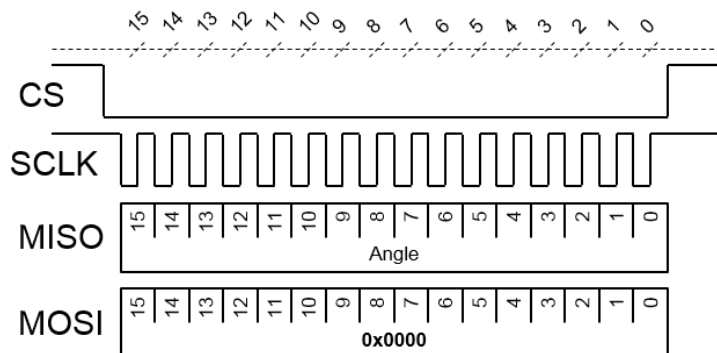
$$INL = \frac{\max(err(a)) - \min(err(a))}{2} \quad (A1)$$

Drift

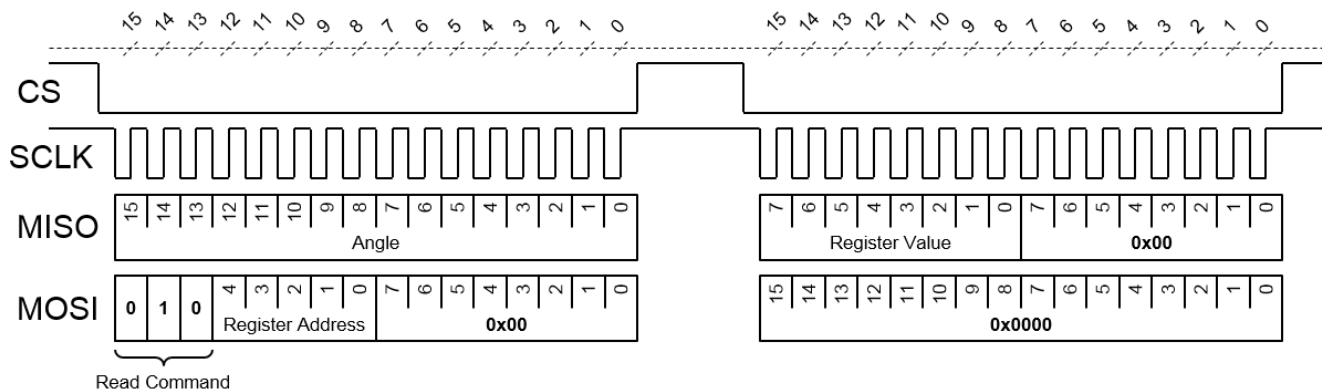
Angle variation rate when one parameter changes (e.g. temperature and V_{DD}) and all the other parameters (including the shaft angle) stay constant.

APPENDIX B: SPI COMMUNICATION CHEATSHEET

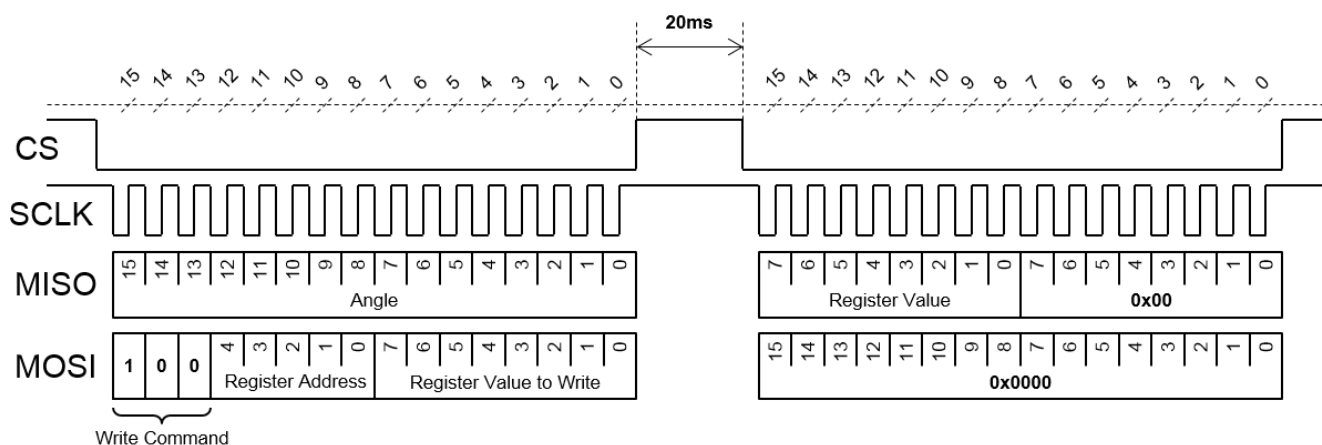
Read Angle



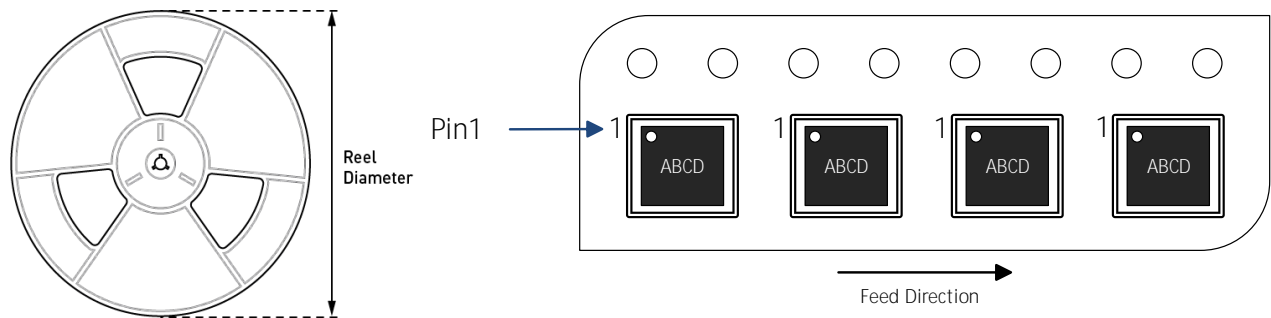
Read Register



Write Register



CARRIER INFORMATION



Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MAQ800GQE-AEC1-Z	QFN-16 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	8/14/2023	Initial Release	-

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