



The Future of Analog IC Technology®

# MagAlpha MA800

## 8-Bit Contactless Angle Encoder with Push Button Function

### DESCRIPTION

The MA800 is an easy-to-use, magnetic, angle encoder with a digital output designed to replace analog potentiometers or rotary switches. The MA800 is designed for slow operation such as human-machine interface, manual controls, etc. where the rotating speed remains below 200 rpm. The sensor detects the absolute angular position of a permanent magnet attached to a rotating shaft.

The magnet shapes and configurations are very flexible. Typically, the MA800 is used with a diametrically magnetized cylinder of 2 - 8mm in diameter.

The MA800 features programmable magnetic field strength thresholds, which allow for the implementation of a push or pull button function. These are output as two logic signals.

On-chip non-volatile memory provides storage for the configuration parameters, including the reference zero angle position and magnetic field detection threshold settings.

### FEATURES

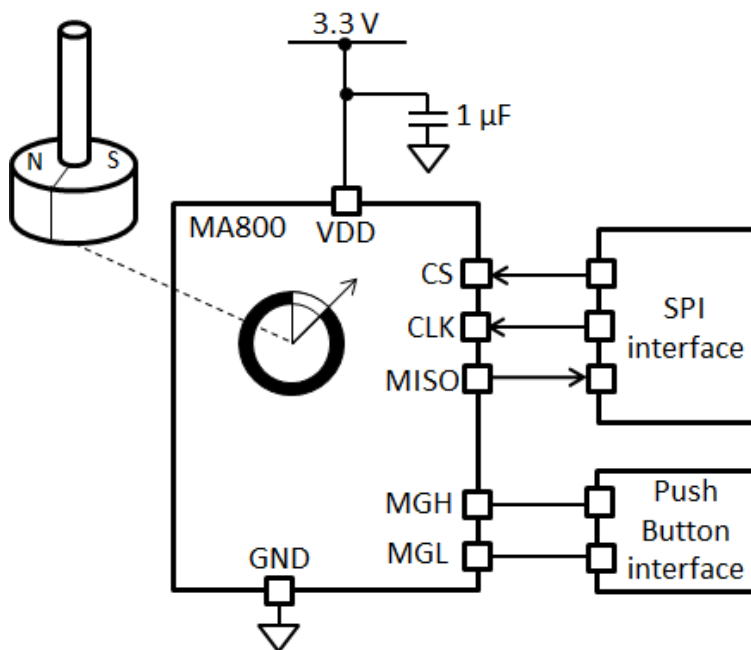
- 8-Bit Resolution Absolute Angle Encoder
- Contactless Sensing for Long Life with No Wear
- SPI and SSI Serial Interface
- Programmable Magnetic Field Strength Detection for Push/Pull Button Detection
- 3.3V, 12mA Supply
- -40 to +125°C Operating Temperature
- Available in a QFN-16 (3mmx3mm) Package

### APPLICATIONS

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

All MPS parts are lead-free, halogen-free, and adhere to the RoHS directive. For MPS green status, visit the MPS website under Quality Assurance. "MPS", the MPS logo, and "Simple, Easy Solutions" are registered trademarks of Monolithic Power Systems, Inc. or its subsidiaries.

### TYPICAL APPLICATION



### ORDERING INFORMATION

Part Number*	Package	Top Marking
MA800GQ	QFN-16 (3mmx3mm)	See Below

\* For Tape & Reel, add suffix -Z (e.g. MA800GQ-Z)

### TOP MARKING

**AXVY**

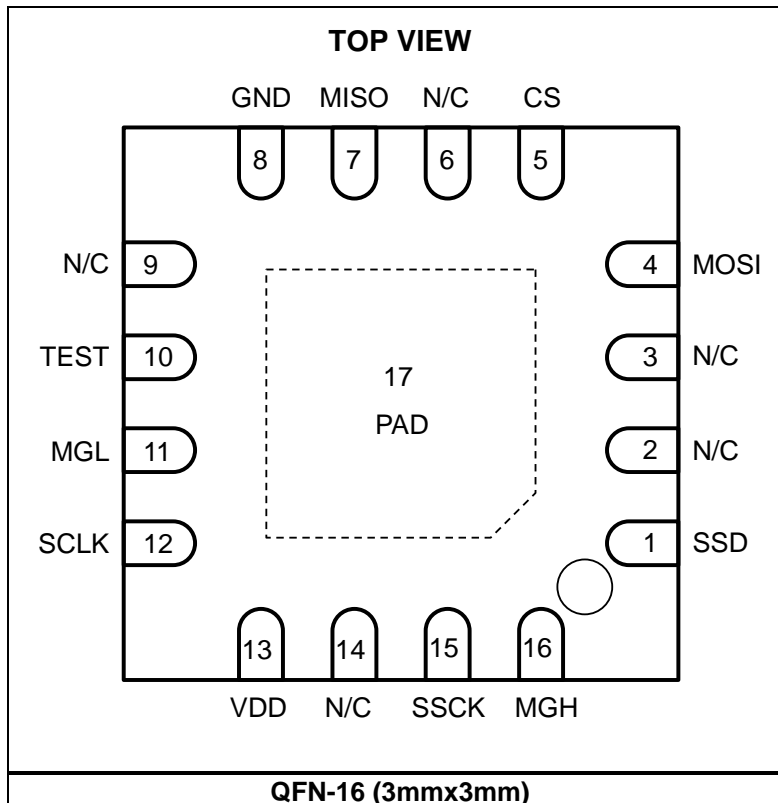
**LLL**

AXV: Product code of MA800GQ

Y: Year code

LLL: Lot number

### PACKAGE REFERENCE



**ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup>**

Supply voltage .....	-0.5V to +4.6V
Input pin voltage (V <sub>I</sub> ) .....	-0.5V to +6.0V
Output pin voltage (V <sub>O</sub> ) .....	-0.5V to +4.6V
Continuous power dissipation (T <sub>A</sub> = +25°C) <sup>(2)</sup>	2.0W
Junction temperature .....	125°C
Lead temperature .....	260°C
Storage temperature .....	-65°C to 150°C

<b>Thermal Resistance <sup>(3)</sup></b>	<b><math>\theta_{JA}</math></b>	<b><math>\theta_{JC}</math></b>
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<sub>J</sub> (MAX), the junction-to-ambient thermal resistance  $\theta_{JA}$ , and the ambient temperature T<sub>A</sub>. The maximum allowable continuous power dissipation at any ambient temperature is calculated by  $P_D (MAX) = (T_J (MAX) - T_A) / \theta_{JA}$ .
- 3) Measured on JESD51-7, 4-layer PCB.

**ELECTRICAL CHARACTERISTICS**

Parameter	Symbol	Condition	Min	Typ	Max	Units
<b>Recommended Operating Conditions</b>						
Supply voltage	V <sub>DD</sub>		3.0	3.3	3.6	V
Supply current	I <sub>DD</sub>		10.2	11.7	13.8	mA
Operating temperature	T <sub>op</sub>		-40		125	°C
Applied magnetic field	B		30	60		mT

**GENERAL CHARACTERISTICS**
**VDD = 3.3V, 45mT < B < 100mT, temp = -40°C to +125°C, unless otherwise noted.**

Parameter	Symbol	Condition	Min	Typ	Max	Units
<b>Resolution</b>						
Effective resolution		3 $\sigma$ deviation of the noise distribution	8			bits
Noise rms			0.005	0.01	0.02	deg
Refresh rate			850	980	1100	kHz
Data output length			8		8	bits
<b>Response Time</b>						
Power-up time <sup>(4)</sup>					20	ms
Latency <sup>(5)</sup>		Constant speed propagation delay		4		ms
Filter cutoff frequency <sup>(4)</sup>	Fcutoff			90		Hz
<b>Accuracy</b>						
INL at 25°C		At room temperature over the full field range		0.7		deg
INL between -40°C to +125°C <sup>(5)</sup>		Over the full temperature range and field range		1.1		deg
<b>Output Drift</b>						
Temperature induced drift at room temperature <sup>(5)</sup>				0.015	0.04	deg/°C
Temperature induced variation <sup>(5)</sup>		From 25°C to 85°C		0.5	1.2	deg
		From 25°C to 125°C		1.0	2.1	deg
Magnetic field induced <sup>(5)</sup>				0.005		deg/mT
Voltage supply induced <sup>(5)</sup>					0.3	deg/V
<b>Magnetic Field Detection Thresholds</b>						
Accuracy <sup>(5)</sup>				5		mT
Hysteresis <sup>(5)</sup>	MagHys			6		mT
Temperature drift <sup>(5)</sup>				-600		ppm/°C
<b>Digital I/O</b>						
Input high voltage	V <sub>IH</sub>		2.5		5.5	V
Input low voltage	V <sub>IL</sub>		-0.3		0.8	V
Output low voltage <sup>(5)</sup>	V <sub>OL</sub>	V <sub>OL</sub> = 4mA			0.4	V
Output high voltage <sup>(5)</sup>	V <sub>OH</sub>	V <sub>OH</sub> = 4mA	2.4			V
Pull-up resistor	R <sub>PU</sub>		46	66	97	k $\Omega$
Pull-down resistor	R <sub>PD</sub>		43	55	97	k $\Omega$
Rising edge slew rate <sup>(4)</sup>	T <sub>R</sub>	CL = 50pF		0.7		V/ns
Falling edge slew rate <sup>(4)</sup>	T <sub>F</sub>	CL = 50pF		0.7		V/ns

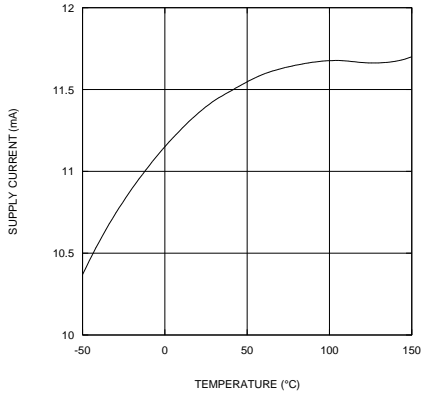
**NOTES:**

- 4) Guaranteed by design.  
5) Guaranteed by characteristic test.

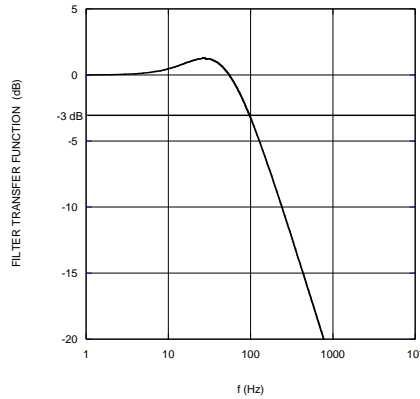
**TYPICAL CHARACTERISTICS**

VDD = 3.3V, Temp = 25°C, unless otherwise noted.

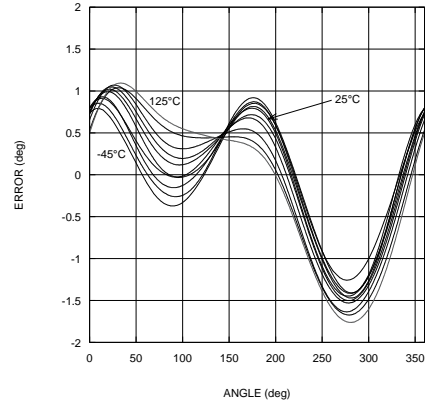
**Current Consumption at VDD = 3.3V**



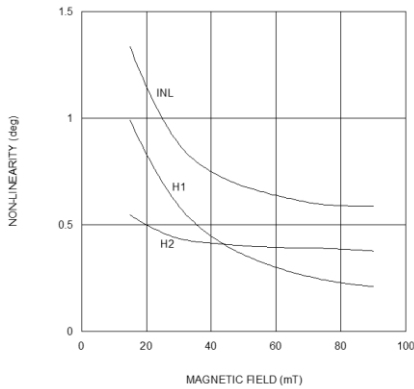
**Filter Transfer Function**



**Error Curves at 50mT**



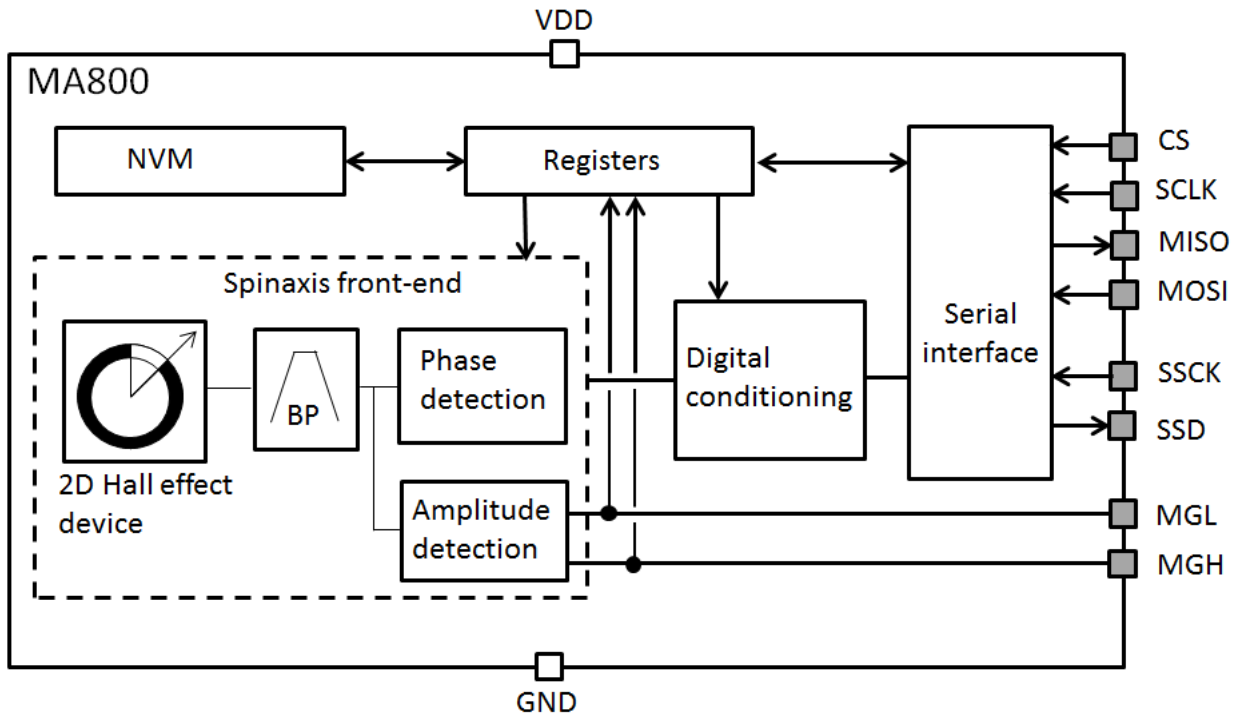
**Non-Linearity (INL and Harmonics)**



**PIN FUNCTIONS**

Package Pin #	Name	Description
1	SSD	<b>Data out (SSI).</b>
2, 3, 6, 9, 14	NC	<b>No connection.</b> Leave NC unconnected.
4	MOSI	<b>Data in (SPI).</b> MOSI has an internal pull-down resistor.
5	CS	<b>Chip select (SPI).</b> CS has an internal pull-up resistor.
7	MISO	<b>Data out (SPI).</b> MISO has an internal pull-down resistor that is enabled at a high impedance state.
8	GND	<b>Supply ground.</b>
10	TEST	<b>Factory use only.</b> Connect TEST to ground.
11	MGL	<b>Digital output indicating field strength below MGLT level.</b>
12	SCLK	<b>Clock (SPI).</b> SCLK has an internal pull-down resistor.
13	VDD	<b>3.3V supply.</b>
15	SSCK	<b>Clock (SSI).</b> SSCK has an internal pull-down resistor.
16	MGH	<b>Digital output indicating field strength above MGHT level.</b>
17	PAD	<b>Exposed pad.</b>

**BLOCK DIAGRAM**



**Figure 1: Functional Block Diagram**

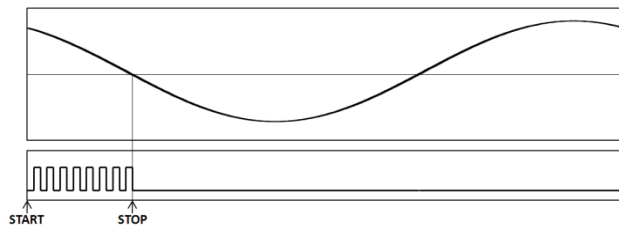


## OPERATION

### 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 digitizes the direction of the field directly without complex arctangent computations 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: Clock of the Time-to-Digital Converter**

**Figure 2: Phase Detection Method**

The output of the front-end delivers a digital number 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 in steady conditions. The filter transfer function can be calculated with Equation (1):

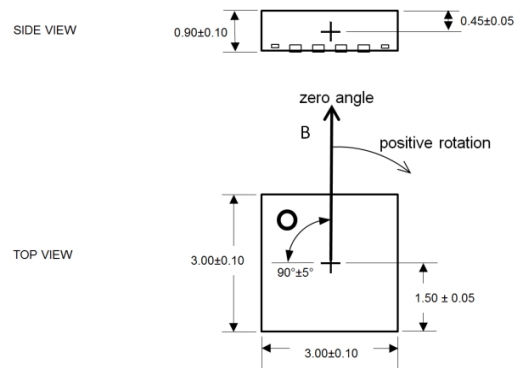
$$H(s) = \frac{1 + 2\tau s}{(1 + \tau s)^2} \quad (1)$$

Where  $\tau$  is the filter time constant related to the cutoff frequency by  $\tau = 0.38/F_{cutoff}$ . See the General Characteristics table on page 5 for the value of *F<sub>cutoff</sub>*.

### Sensor – Magnet Mounting

The sensitive volume of the MA800 is confined in a region less than 100 $\mu$ m wide and has multiple integrated Hall devices. This volume is located both horizontally and vertically within 50 $\mu$ m 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 unprogrammed sensor, where the cross indicates the sensitive point. Both the rotation direction and the zero angle can be programmed.



**Figure 3: Detection Point and Default Positive Direction**

This type of detection provides flexibility for the design of an angular encoder. The sensor only requires the magnetic vector to lie essentially within the sensor plane with a field amplitude of at least 30mT. Note that the MA800 can work with fields smaller than 30mT, but the linearity and resolution performance may deviate from the specifications. The most straightforward mounting method is to place the MA800 sensor on the rotation axis of a permanent magnet (i.e.: a diametrically magnetized cylinder) (see Figure 4). The recommended magnet is a Neodymium alloy (N35) cylinder with dimensions  $\varnothing 5 \times 3$ mm inserted into an aluminum shaft with a 1.5mm air gap between the magnet and the sensor (surface of package). For good linearity, the sensor is positioned with a precision of 0.5mm.

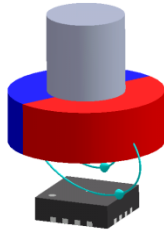
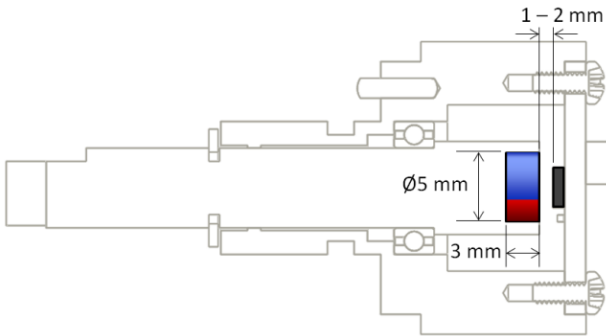
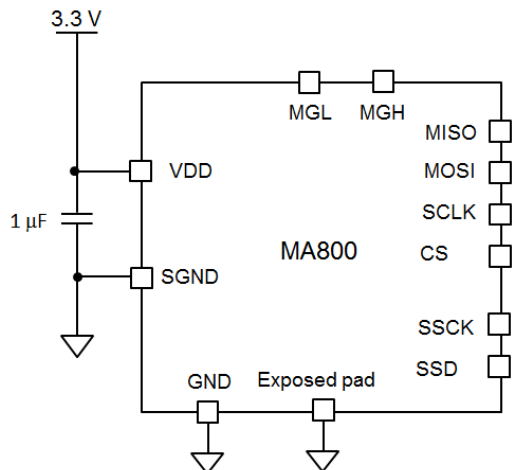

**Figure 4: End-of-Shaft Mounting**

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 1.0mm. The sensor is positioned on the rotation axis with a precision of 0.5mm.


**Figure 5: Example of 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: Connection for Supply Decoupling**

In general, the MagAlpha works well with or without the exposed pad connected to anything. For optimum conditions (electrically, thermally, and mechanically), it is recommended that the exposed pad be connected to ground.

### Serial Interface

The sensor supports the SPI serial interface for angle reading and register programming. Alternatively, the SSI bus can be used for angle reading (programming through SSI is not supported).

### SPI

SPI is a four-wire, synchronous, serial communication interface. The MagAlpha 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 therefore does not require any action from the user. The maximum clock rate supported on SPI is 25MHz. There is no minimum clock rate. Note that real-life data rates depend on the PCB layout quality and signal trace length. See Figure 7 and Table 3 for SPI timing.

All commands to the MagAlpha (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 12 for details.

**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: SPI Standard**

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

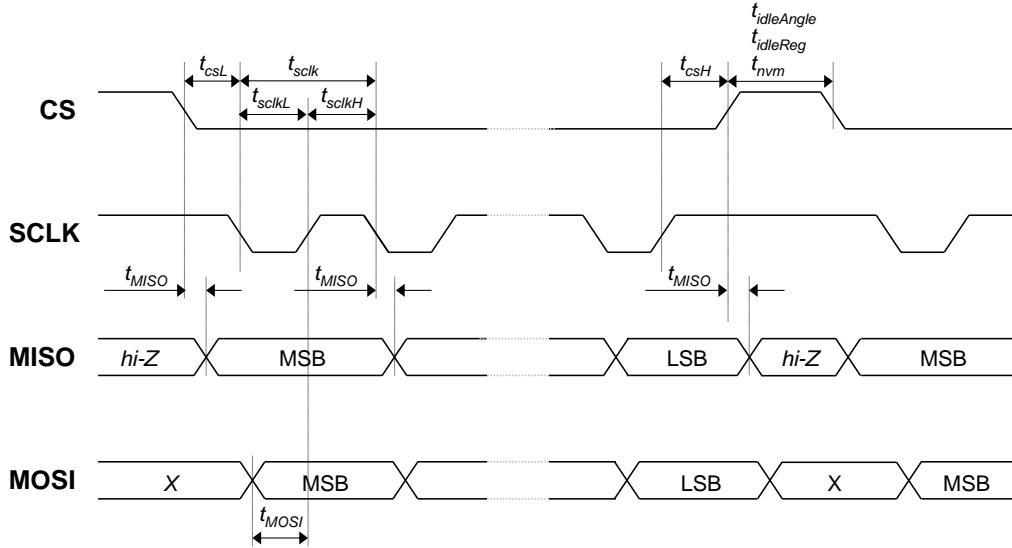


Figure 7: SPI Timing Diagram

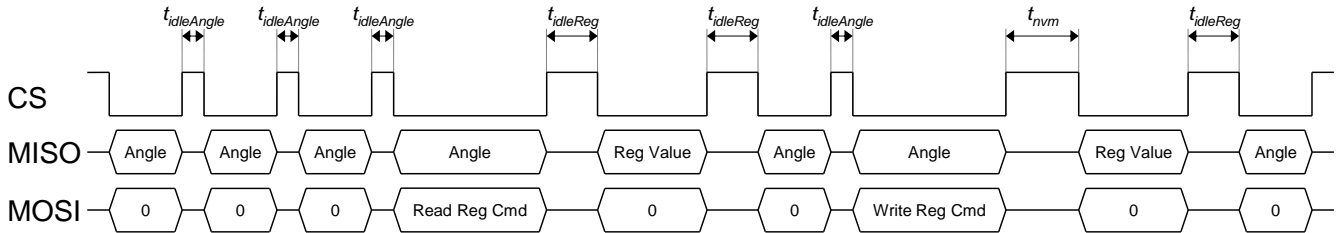


Figure 8: Minimum Idle Time

Table 3: SPI Timing

Parameter <sup>(6)</sup>	Description	Min	Max	Unit
$t_{idleAngle}$	Idle time between two subsequent angle transmissions	150		ns
$t_{idleReg}$	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 non-volatile memory update)	20		ms
$t_{csL}$	Time between CS falling edge and SCLK falling edge	80		ns
$t_{skl}$	SCLK period	40		ns
$t_{sklL}$	Low level of SCLK signal	20		ns
$t_{sklH}$	High level of SCLK signal	20		ns
$t_{csH}$	Time between 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 SCLK reading edge	15		ns

NOTE:

6) All values are guaranteed by design.

### SPI Communication

The sensor supports three types of SPI operation:

- Read angle
- Read configuration register
- Write configuration register

Each operation has a specific frame structure described below.

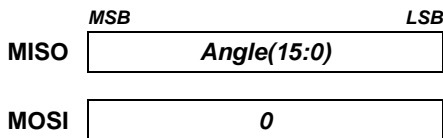
#### SPI Read Angle

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 is de-asserted (see Table 4).

**Table 4: Sensor Data Timing**

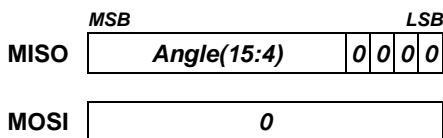
Event	Action
CS falling edge	Start reading and freeze output buffer
CS rising edge	Release of the output buffer

See Figure 9 for a diagram of a full SPI angle reading. See Figure 10 for a diagram of a partial SPI angle reading. A full angle reading requires 16 clock pulses. The sensor MISO line returns:

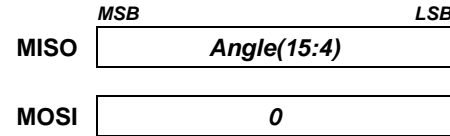


The MagAlpha family has sensors with different features and levels of resolution. Check the data output length in the General Characteristics table on page 5 for the number of useful bits delivered at the serial output. If the data length is smaller than 16, the rest of the bits sent are zeros.

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

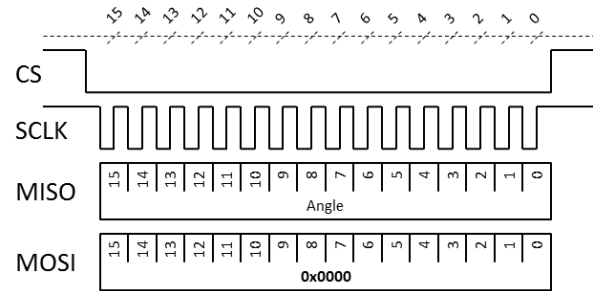


Therefore, angle reading can be optimized without any loss of information by reducing the number of clock counts. In the case of a 12-bit data output length, only 12 clock counts are required to get the full sensor resolution.

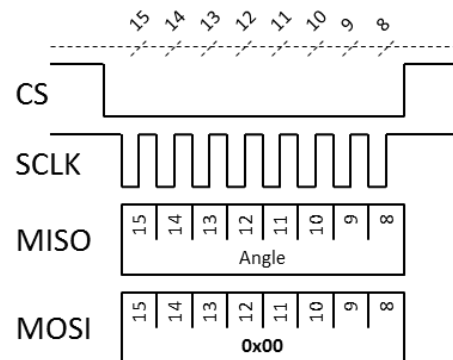


If less resolution is needed, the angle can be read by sending even fewer clock counts (since the MSB is first).

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 5).



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

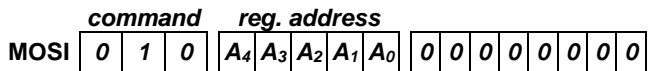
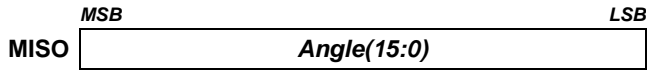


**Figure 10: Diagram of a Partial 8-Bit SPI Angle Reading**

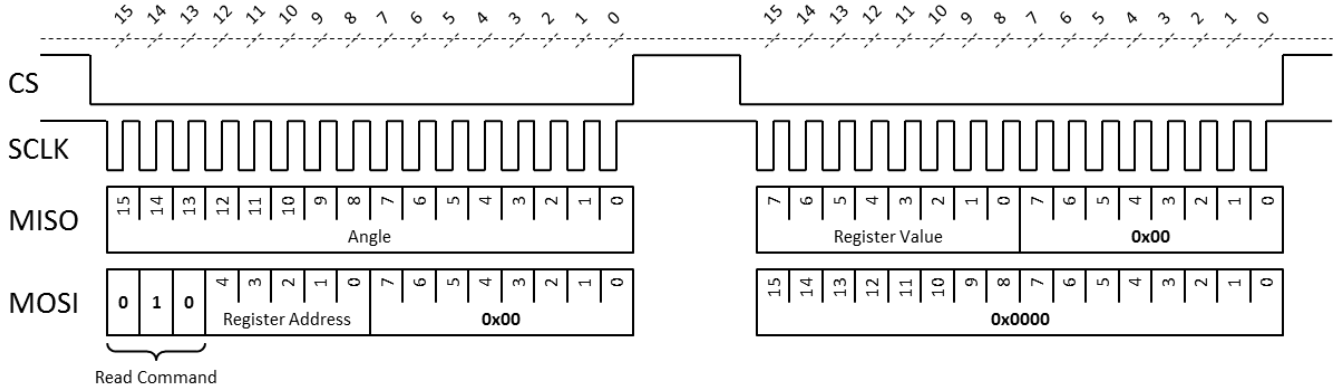
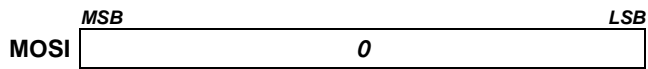
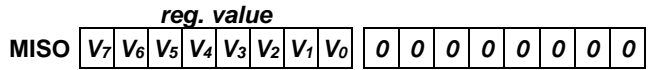
**SPI Read Register**

A read register operation is constituted 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 last eight bits of the frame must all be set to zero. The second frame returns the 8-bit register value (MSB byte).

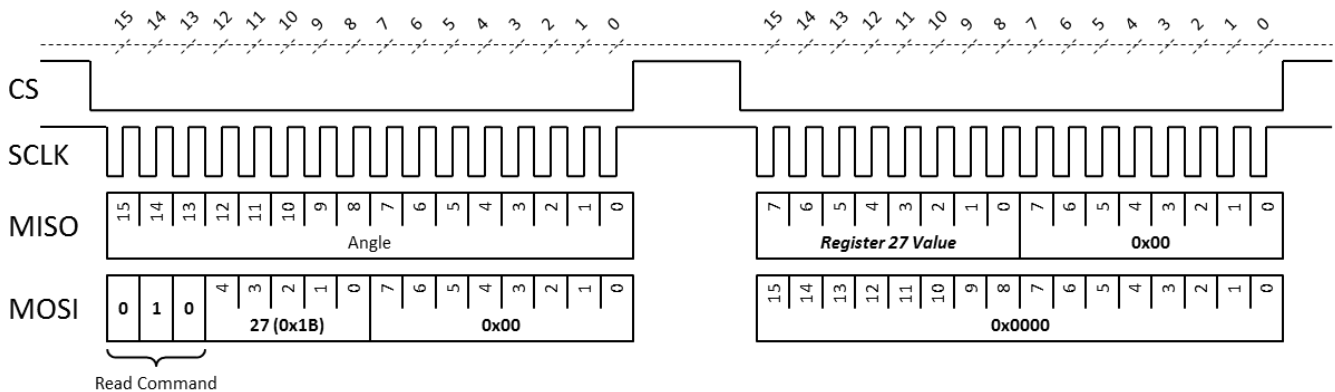
The first 16-bit SPI frame (read request) is:



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



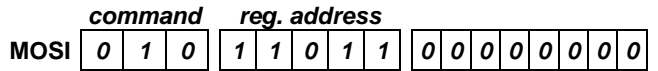
**Figure 11: 16-Bit Frames Read Register Operation**



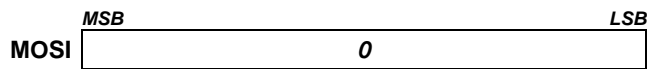
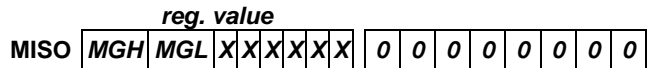
**Figure 12: Example Read Magnetic Level Flags High and Low (MGL, MGH) on Register 27, Bit 6 to Bit 7**

See Figure 11 for a complete transmission.

For example, to get the value of the magnetic level high and low flags (MGL and MGH), read register 27 (bit 6, bit 7) by sending the following first frame:



In the second frame, the MagAlpha replies:



See Figure 12 for a complete example.

**SPI Write Register**

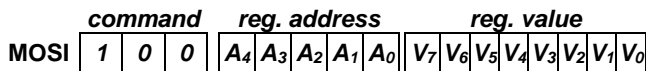
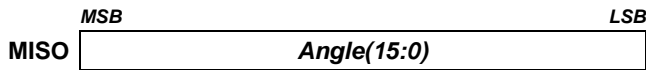
Table 7 shows the programmable 8-bit registers. Data written to these registers are stored in the on-chip non-volatile memory and reloaded during power-on automatically. The factory default register values are shown in Table 8.

A write register operation is constituted 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).

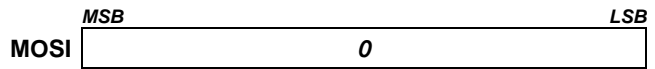
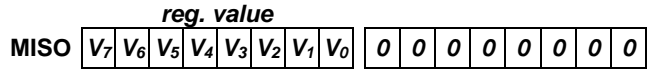
The on-chip memory is guaranteed to endure 1,000 write cycles at 25°C.

It is critical to wait 20ms between the first and second frame. This is the time taken to write the non-volatile memory. Failure to implement this wait period results in the register’s previous value being read. Note that this delay is only required after a write request. A read register request and read angle do not require this wait time.

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

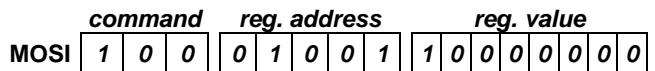
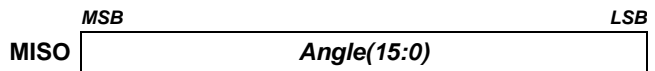


The second 16-bit SPI frame (response) is:

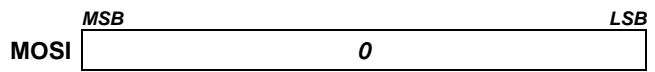
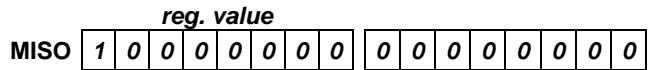


The read-back register content can be used to verify the register programming. See Figure 13 for a complete transmission overview.

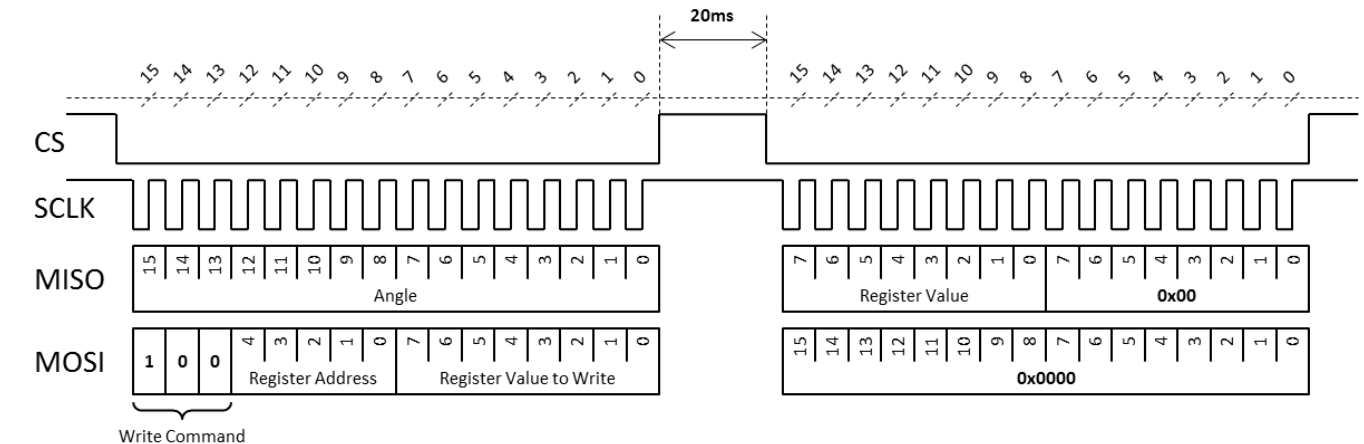
For example, to set the value of the output rotation direction (RD) to counterclockwise (high), write register 9 by sending the following first frame:



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



See Figure 14 for a complete example.



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

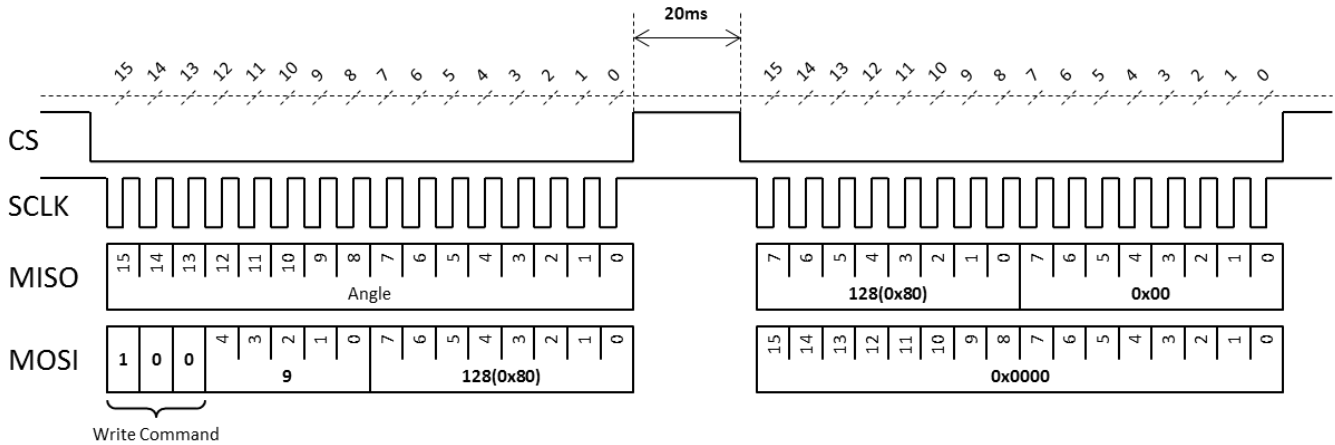


Figure 14: Example Write Output Rotation Direction (RD) to Counterclockwise (High) on Register 9, Bit 7

**SSI**

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

**SSI Communication**

Unlike SPI, the sensor SSI supports angle reading operation only. It is not possible to read or write registers using SSI. Figure 15 and Table 5 show the SSI timing communication.

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

This sensor 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.

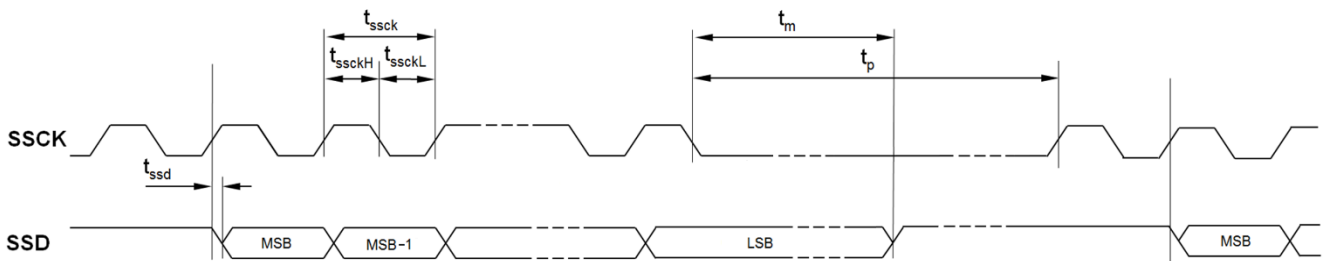


Figure 15: SSI Timing

Table 5: SSI Timing

Parameter	Description	Min	Max	Units
t <sub>ssd</sub>			15	ns
t <sub>ssck</sub>	SSCK period	0.2	16	µs
t <sub>ssckL</sub>	Low level of SSCK signal	0.1	8	µs
t <sub>ssckH</sub>	High level of SSCK signal	0.1	8	µs
t <sub>m</sub>	Transfer timeout (monoflop time)	25		µs
t <sub>p</sub>	Dead time: SSCK high time for next data reading	40		µs



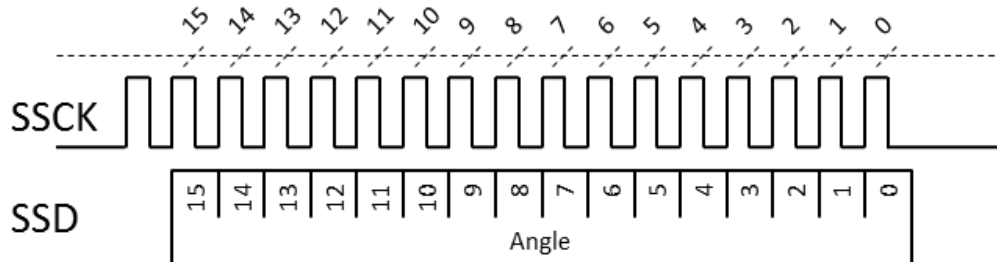
**SSI Read Angle**

The bit order of the transmitted data is MSB first and LSB last. Every 1μs, 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, but if the data length is less than 16, the 16-bit output word is completed by zeros. Therefore, reading can also be performed with fewer than 16 clock counts (see Figure 16). When a trigger event is detected, the data remains in the output buffer until the clock rising edge for the LSB bit 0 and the transfer time out time has passed. See Table 6 for sensor data timing.

When a trigger event is detected, the data remains in the output buffer until the clock rising edge for the LSB bit 0 and the transfer time out time has passed. See Table 6 for sensor data timing.

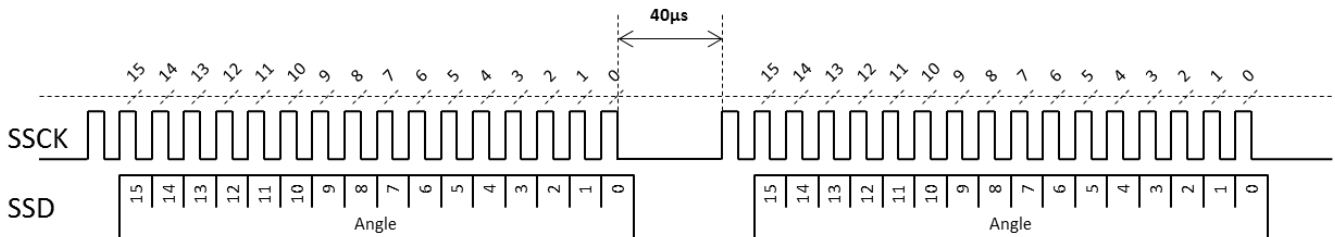
**Table 6: Sensor Data Timing**

Trigger event	Release of the output buffer
First SSCK falling edge	SSCK rising edge + time out $t_m$ (Fig 15)



**Figure 16: Full 16-Bit SSI Angle Reading**

For consecutive angle readings, see the timing diagram in Figure 17.



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



**REGISTER MAP**
**Table 7: Register Map**

No	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**

No	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: Programming Parameters**

Parameters	Symbol	Number of Bits	Description	See Table
Zero setting	Z	16	Set 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 positive direction	12

## REGISTER SETTINGS

### Zero Setting

The zero position of the MagAlpha ( $a_0$ ) can be programmed with 16 bits of resolution. The angle streamed out by the MagAlpha ( $a_{out}$ ) is given by Equation (2):

$$a_{out} = a_{raw} - a_0 \quad (2)$$

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. It can be written in decimals using Equation (3):

$$a_0 = 2^{16} - Z(15:0) \quad (3)$$

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 deg, the Z(15:0) parameter must be equal to the complementary angle shown in Equation (4):

$$Z(15:0) = 2^{16} - \frac{20\text{deg}}{360\text{deg}} 2^{16} = 61895 \quad (4)$$

In binary, this is written as 1111 0001 1100 0111.

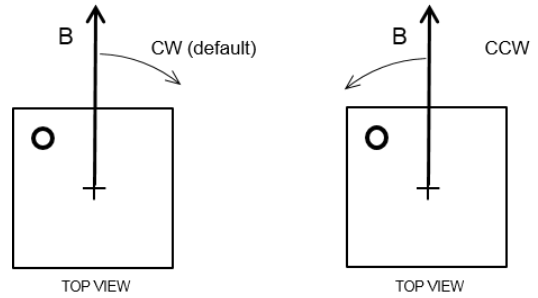
Table 11 shows the content of registers 0 and 1.

**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

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: Positive Rotation Direction of the Magnetic Field**

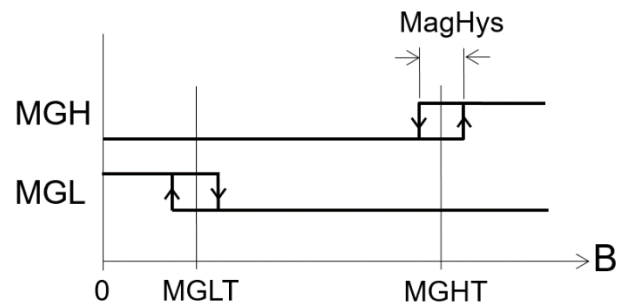
**Table 12: Rotation Direction Parameter**

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

### Magnetic Field Thresholds

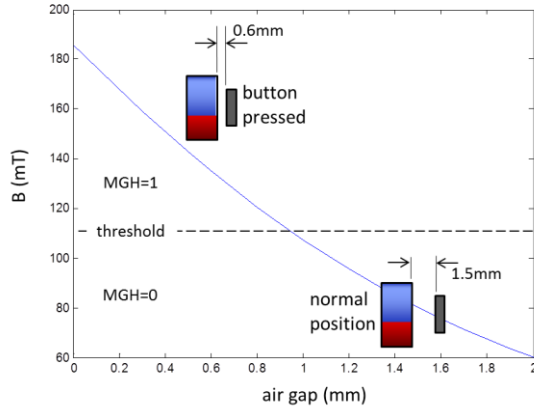
#### Push Button Detection

The MA800 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).



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

The MGL and MGH flags can be used for detecting an approaching magnet (e.g.: when a button is pressed). With the 5mmx3mm magnet example, if the MGHT threshold is set to binary 110 (106 - 112mT), the MGH signal is set to logic high when the sensor-magnet airgap is smaller than 1.0mm (see Figure 20).



**Figure 20: Magnetic Field Produced by a 5mmx3mm N35 Magnet as a Function of the Airgap with Threshold Set to 110mT**

In this way, it is possible to implement a push or pull action.

MagHys, the hysteresis on the signals MGH and MGL, is indicated in the General Characteristics table on page 5. The MGLT and MGHT thresholds are coded on three 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 of MGLT and MGHT correspond to the magnetic field (see Table 14).

**Table 14: MGLT and MGHT Binary to mT Relation**

MGLT or MGHT <sup>(8)</sup>	Field threshold in mT <sup>(7)</sup>	
	From low to high magnetic field	From 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 for VDD = 3.3V. If different, then the field threshold is scaled by the factor VDD/3.3V.
- 8) MGLT can have a larger value than MGHT.

The alarm flags (MGL and MGH) can be read in register 27 (bit 6 and bit 7), and their logic state is also given at the digital output pins 11 and 16.

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 MA800 answers with the register 27 content in the next transmission:

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

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

**MGL Application Note**

Pulses with a duration of about 1.3µs to 1.5µs appear randomly in the MGL signal. They appear on both the pin and register values (Register 27, bit 6).

These pulses appear around angle values of 44, 138, 224, and 318 degrees (sensor output) or in an interval of ±1.5 degrees around these values. These pulses have an amplitude of 3.3V (VDD). 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). 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, which must be between 2µs and 100µs apart, allows the user to distinguish erroneous from real transitions. Table 15 on page 20 shows examples of different cases.
3. Read register 27 with the SPI and compute a corrected MGL value using MG1L and MG2L. The corrected MGL signal = 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)
```

**Table 15: MGL Multiple Readings Workaround**

	<b>MGL First Reading</b>	<b>MGL Second Reading (e.g. 20<math>\mu</math>s After the First Reading)</b>	<b>True MGL Value</b>
Case 1	0	Second reading is not needed	0
Case 2	1	1	1
Case 3	1	0	0

TYPICAL APPLICATION CIRCUITS

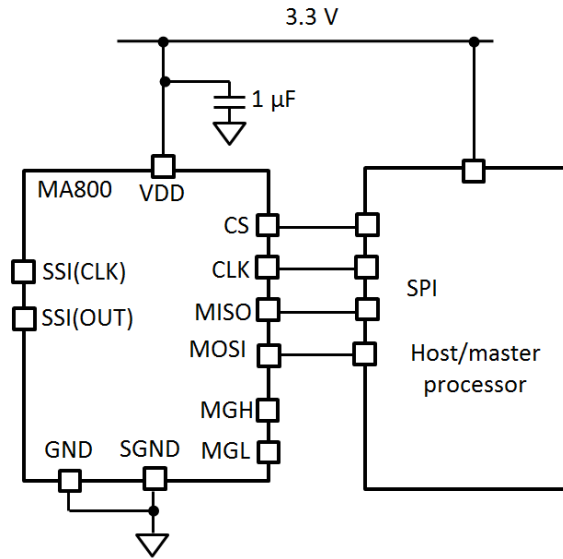


Figure 21: Typical Configurations using SPI Interface

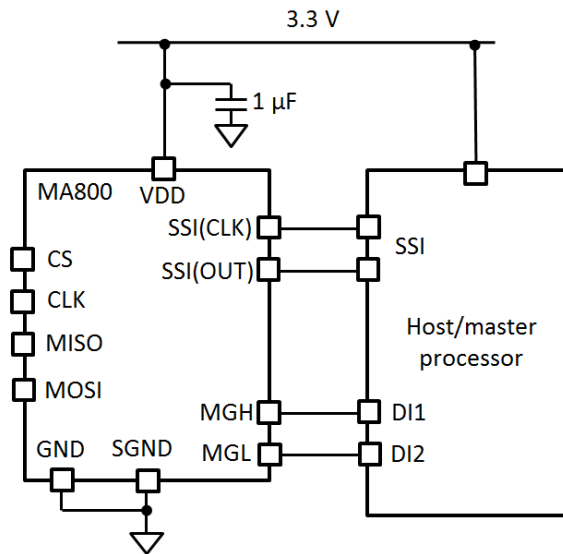
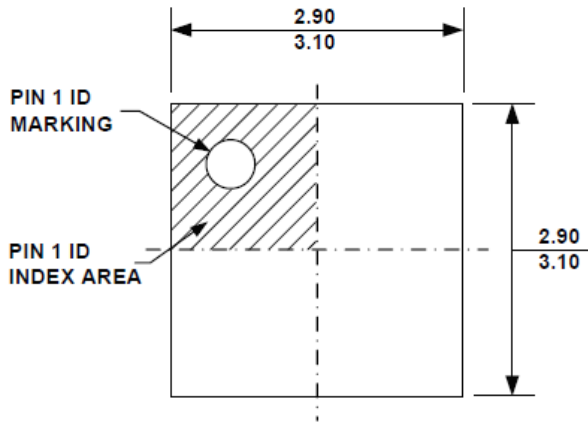


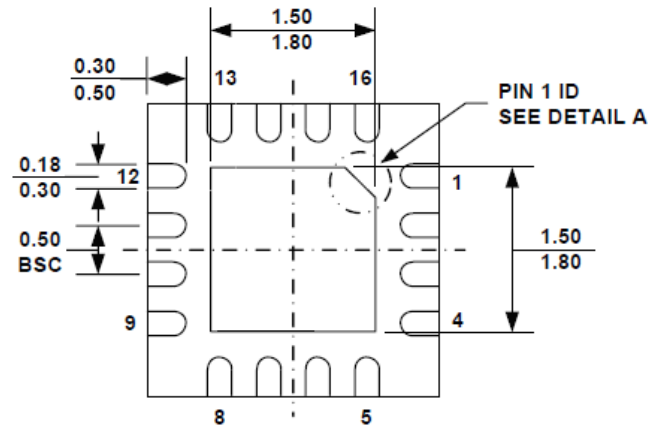
Figure 22: Typical Configuration Using SSI Interface and Output Signals MGL, MGH

**PACKAGE INFORMATION**

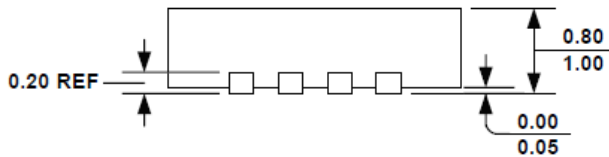
**QFN-16 (3mmx3mm)**



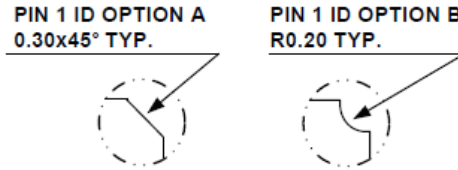
**TOP VIEW**



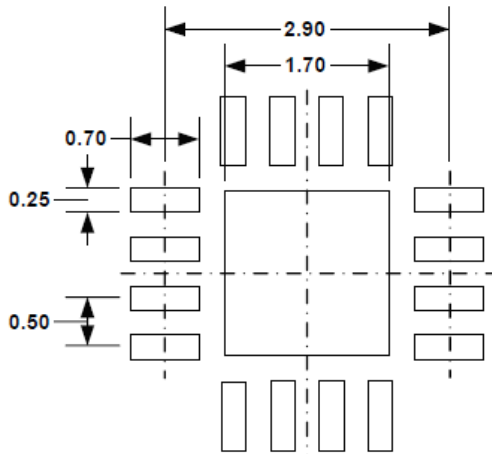
**BOTTOM VIEW**



**SIDE VIEW**



**DETAIL A**



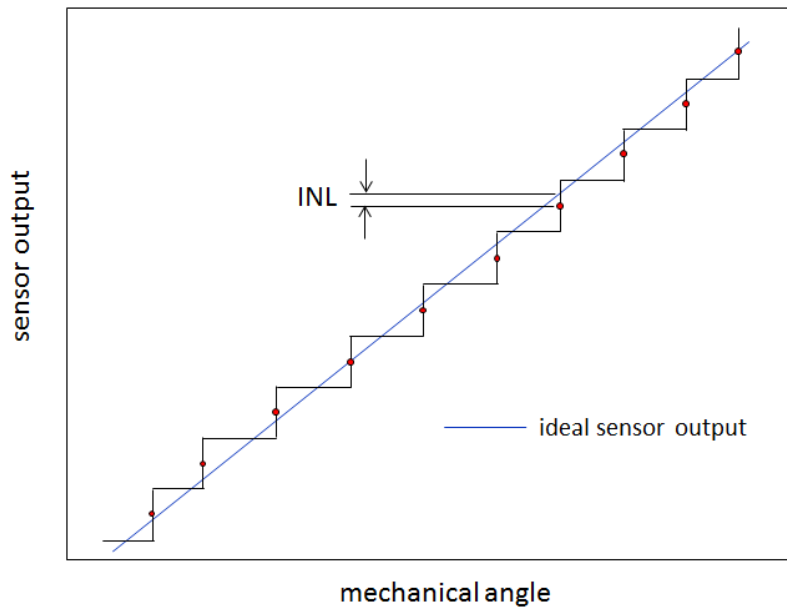
**RECOMMENDED LAND PATTERN**

**NOTE:**

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
- 3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX.
- 4) DRAWING CONFORMS TO JEDEC MO-220, VARIATION VEED-4.
- 5) DRAWING IS NOT TO SCALE.

**APPENDIX A: DEFINITIONS**

- Resolution ( $3\sigma$  noise level)**    Smallest angle increment distinguishable from the noise. The resolution is measured by computing three times  $\sigma$  (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**    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 is  $lag = latency \cdot v$ , where  $v$  is the angular velocity in deg/s.
  
- Power-Up Time**    Time until the sensor delivers valid data starting at power-up.
  
- Integral Non-Linearity (INL)**    Maximum deviation between the average sensor output (at a fixed position) and the true mechanical angle.

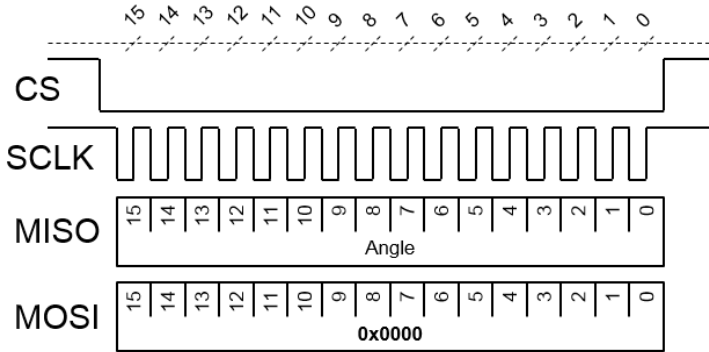


**Figure A1: Integral Non-Linearity**

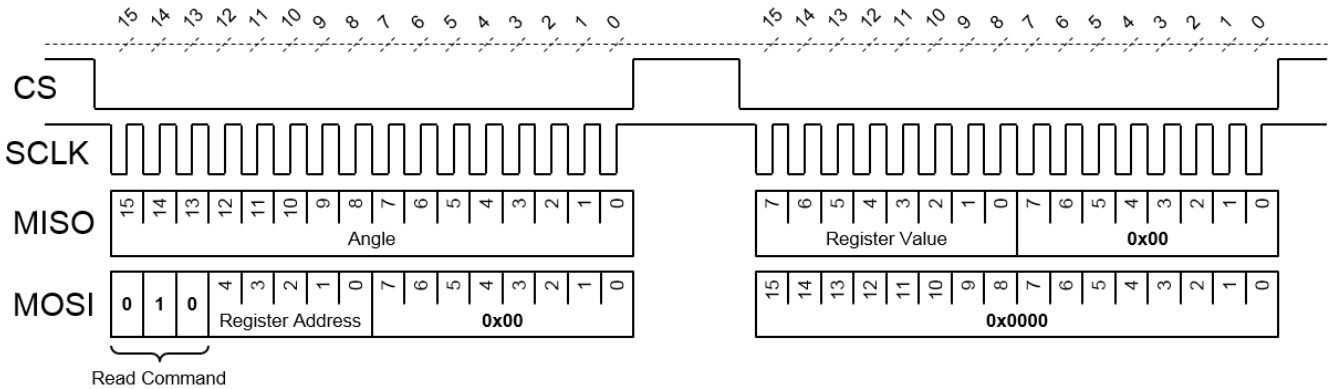
- Drift**    Angle variation rate when one parameter is changed (e.g.: temperature, VDD) and all the others, including the shaft angle, are maintained constant.

## APPENDIX B: SPI COMMUNICATION CHEATSHEET

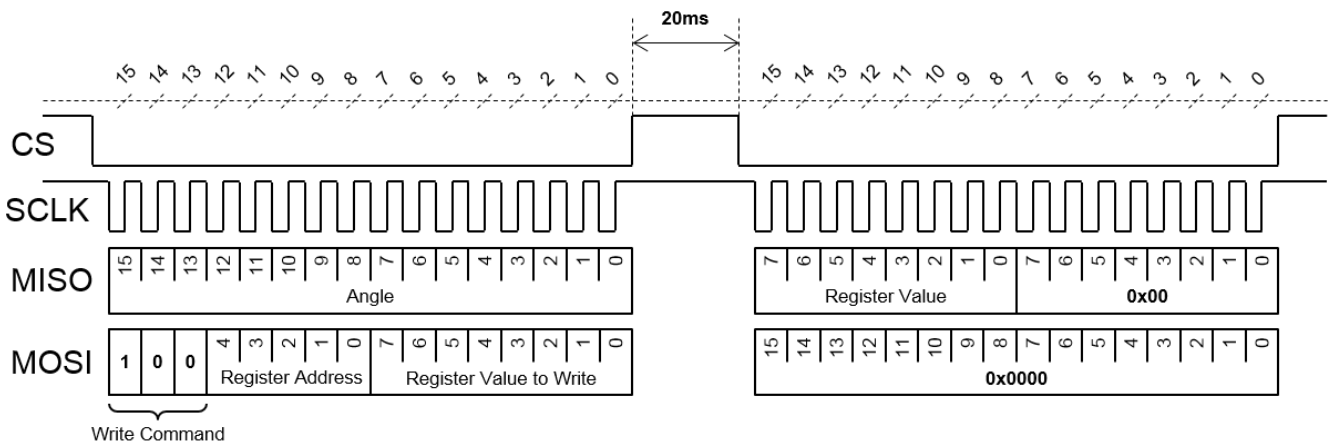
### Read Angle



### Read Register



### Write Register





**REVISION HISTORY**

Revision #	Revision Date	Description	Pages Updated
1.0	8/29/2017	Initial Release	-
1.01	10/13/2017	Removed the “2” in the denominator in Equation (1).	9
		Removed the “□” after “Bit” in Table 11.	18
		Removed the “□” after “Bit” in Table 13.	19
1.02	6/15/2018	Update the description on page 1.	1
		Updated EC table.	5
1.1	8/8/2022	Updated legal notice.	1
		Updated orderable suffix from “-Z” to “-Z”.	2
		Updated Non-Linearity plot.	6
		Add information regarding the non-standard SSI interface in the SSI Communication section.	15
		Updated minimum SSI limits for SSCK period, Low level of SSCK signal, and High level of SSCK signal in Table 5.	15
		Updated Figure 19.	18
		Added MGL Application Note and MGL Workarounds sections and Table 15.	19–20
Minor formatting updates.	All		

**Notice:** The information in this document is subject to change without notice. Users should warrant and guarantee that third-party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.