MagAlpha MA850

8-Bit Contactless Angle Encoder with PWM Output and Push Button Function

DESCRIPTION

The MA850 is an easy-to-use, magnetic, angle encoder with a digital output designed to replace analogic potentiometers or rotary switches. The MA850 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 and outputs a PWM waveform with 8-bit resolution.

The magnet shapes and configurations are very flexible. Typically, the MA850 is used with a diametrically magnetized cylinder of 2 - 8mm in diameter.

The MA850 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 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 Serial Interface for Chip Configuration
- Programmable Magnetic Field Strength Detection for Push/Pull Button Detection
- 3.3V, 12mA Supply
- PWM Output
- -40 to +125°C Operating Temperature
- Available in a QFN-16 (3mmx3mm) Package

APPLICATIONS

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

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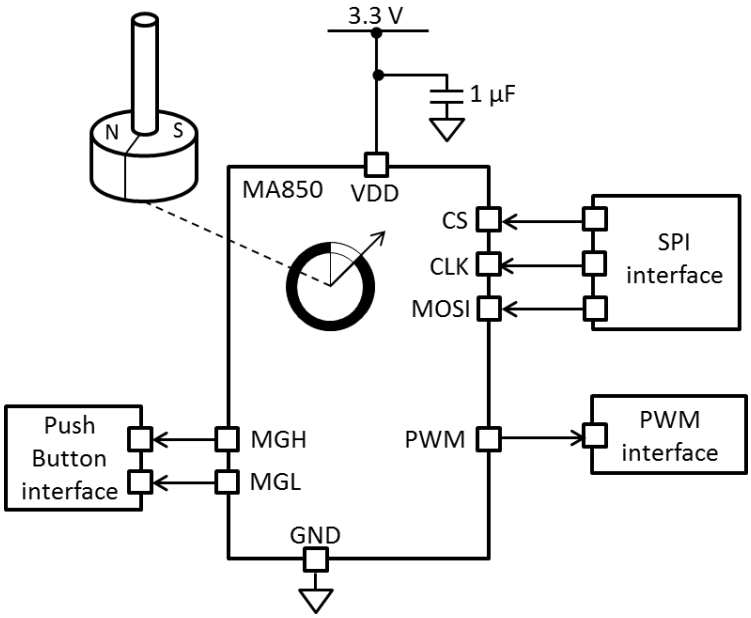
TYPICAL APPLICATION



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ORDERING INFORMATION

Part Number*	Package	Top Marking
MA850GQ	QFN-16 (3mmx3mm)	*See Below*

* For Tape & Reel, add suffix -Z (e.g. MA850GQ-Z)

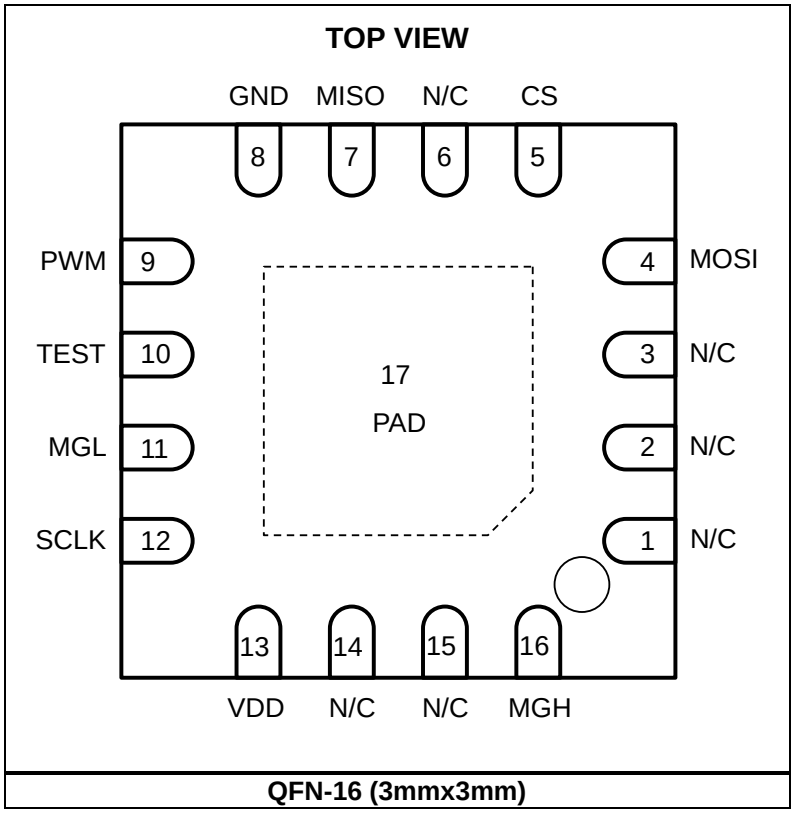
TOP MARKING

AXZY

LLL

AXZ: Product code of MA850GQ
Y: Year code
LLL: Lot number

PACKAGE REFERENCE



QFN-16 (3mmx3mm)

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ABSOLUTE MAXIMUM RATINGS (1)

Supply voltage ..... -0.5V to +4.6V
Input pin voltage (V_I) ..... -0.5V to +6.0V
Output pin voltage (V_O) ..... -0.5V to +4.6V
Continuous power dissipation (T_A = +25°C) (2) 2.0W
Junction temperature ..... 125°C
Lead temperature ..... 260°C
Storage temperature ..... -65°C to 150°C

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 JESD51-7, 4-layer PCB.

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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	Top		-40		125	°C
Applied magnetic field	B		30	60		mT

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GENERAL CHARACTERISTICS

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

Parameter	Symbol	Condition	Min	Typ	Max	Units
Resolution						
Effective resolution		3σ 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
Response Time						
Power-up time (4)					20	ms
Latency (5)		Constant speed propagation delay		4		ms
Filter cutoff frequency (4)	Fcutoff			90		Hz
Accuracy						
INL at 25°C		At room temperature over the full field range		0.7		deg
INL between -40°C to +125°C (5)		Over 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
Magnetic field induced (5)				0.005		deg/mT
Voltage supply induced (5)					0.3	deg/V
PWM Output						
PWM frequency			42	50	56	kHz
PWM resolution			8			bit
Absolute Output – Serial						
Refresh rate			850	980	1100	kHz
Data output length			8		8	bit
Magnetic Field Detection Thresholds						
Accuracy (5)				5		mT
Hysteresis (5)	MagHys			6		mT
Temperature drift (5)				-600		ppm/°C
Digital I/O						
Input high voltage	VIH		2.5		5.5	V
Input low voltage	VIL		-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	RPU		46	66	97	kΩ
Pull-down resistor	RPD		43	55	97	kΩ
Rising edge slew rate (4)	TR	CL = 50pF		0.7		V/ns
Falling edge slew rate (4)	TF	CL = 50pF		0.7		V/ns

NOTES:

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

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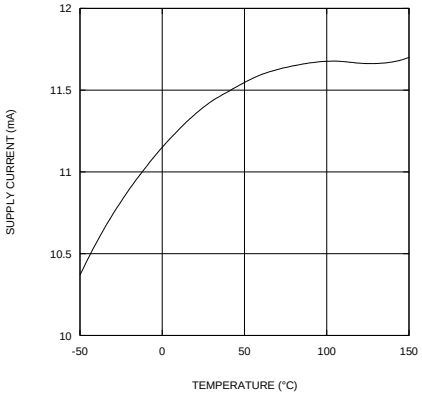
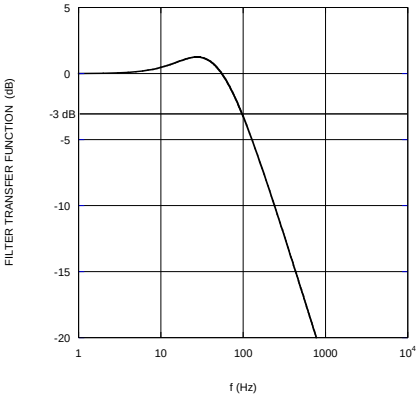
TYPICAL CHARACTERISTICS

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

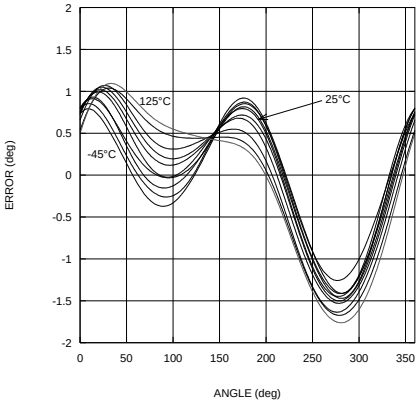
Current Consumption at VDD = 3.3V



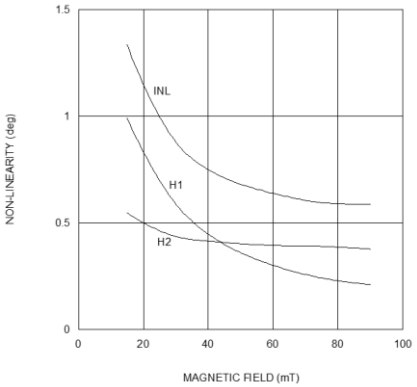
Filter Transfer Function



Error Curves at 50mT



Non-Linearity (INL and Harmonics)



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PIN FUNCTIONS

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

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BLOCK DIAGRAM

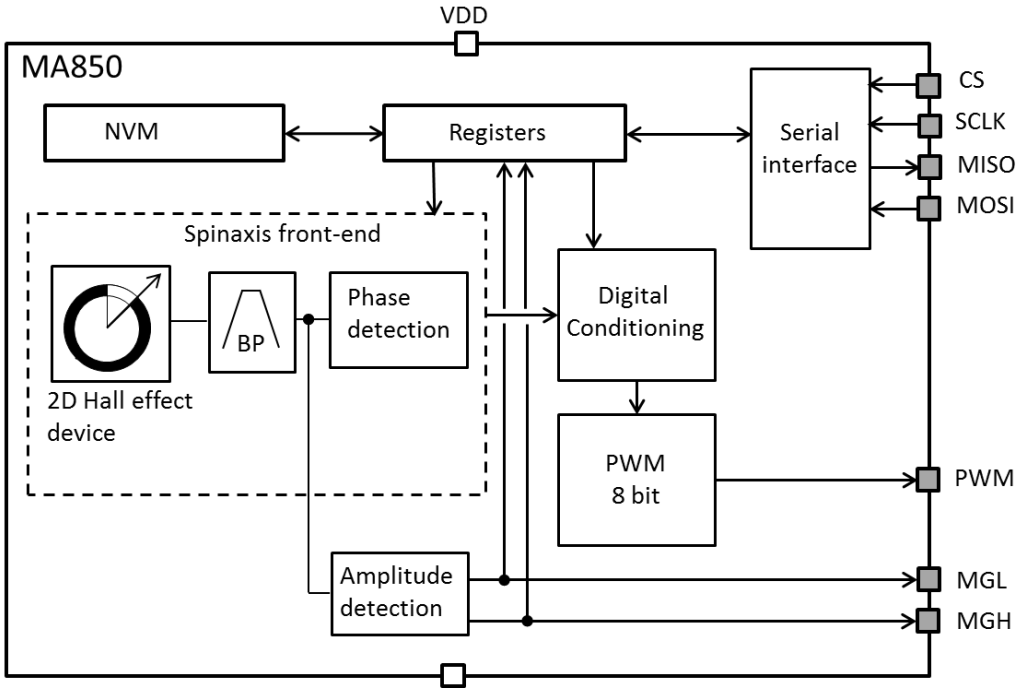

Figure 1: Functional Block Diagram

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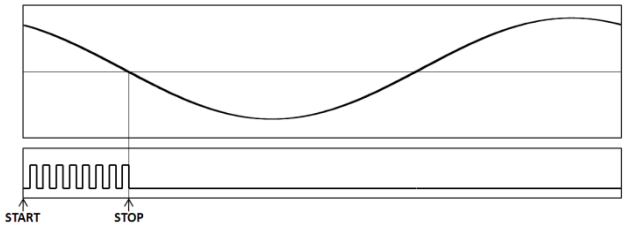
OPERATION

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 *Spin*axis™ method, which digitizes the direction of the field directly without complex arctangent computation or feedback loop-based circuits (interpolators).

The *Spin*axis™ 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 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 τ is the filter time constant related to the cutoff frequency by: τ = 0.38/*Fcutoff*. See the General Characteristics table on page 5 for the value of *Fcutoff*.

Sensor – Magnet Mounting

The sensitive volume of the MA850 is confined in a region less than 100µm wide and 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 unprogrammed sensor, where the cross indicates the sensitive point. Both the rotation direction and the zero angle can be programmed.

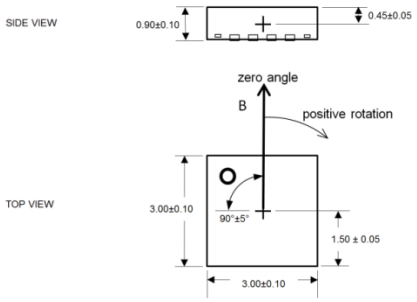


Figure 3: Detection Point and Default Positive Direction

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 MA850 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 MA850 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 Ø5x3mm 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.

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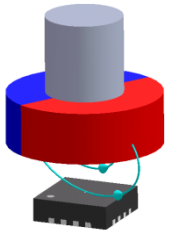

Figure 4: End-of-Shaft Mounting

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.

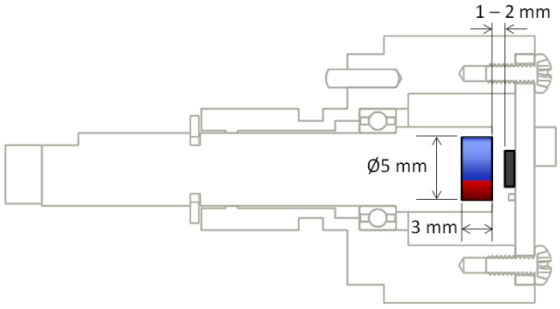

Figure 5: Example of Potentiometer-Like Assembly

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).

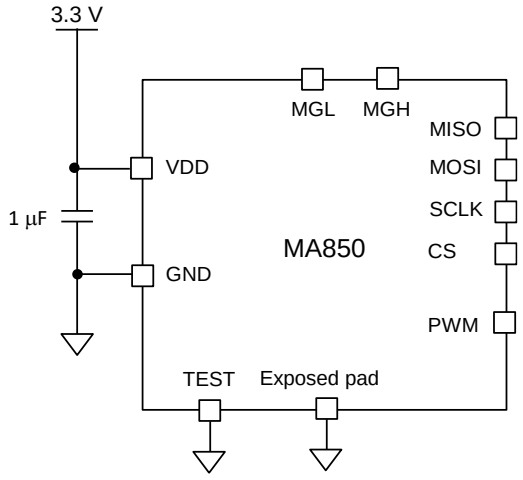

Figure 6: Connection for Supply Decoupling

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 register programming. 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 a 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)	

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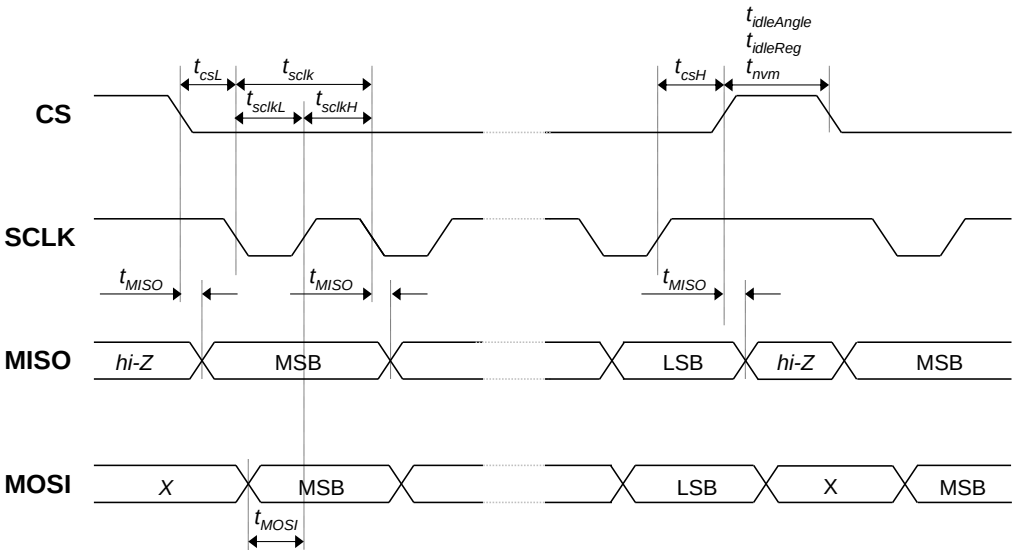

Figure 7: SPI Timing Diagram

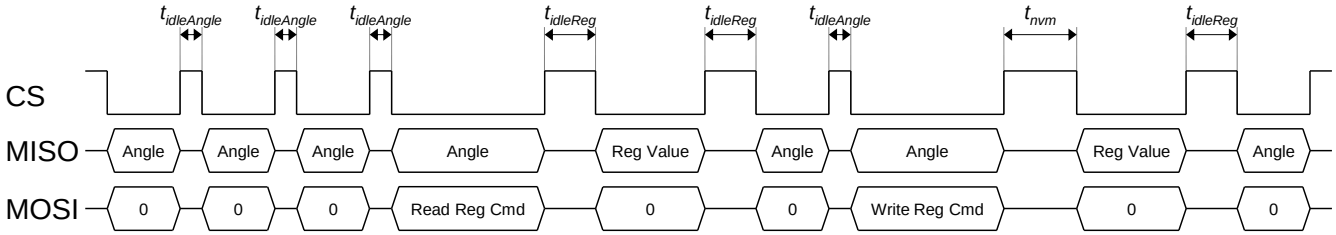

Figure 8: Minimum Idle Time

Table 3: SPI Timing

Parameter (6)	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_{sclk}	SCLK period	40		ns
t_{sclkL}	Low level of SCLK signal	20		ns
t_{sclkH}	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.

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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

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

	MSB															LSB
MISO	***Angle(15:0)***															
MOSI	***0***															

The MagAlpha family has sensors with different features and levels of resolution. See the data output length section 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.

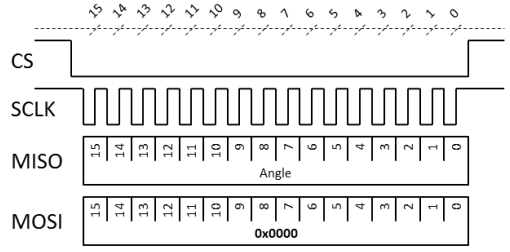

Figure 9: Full 16-Bit SPI Angle Reading

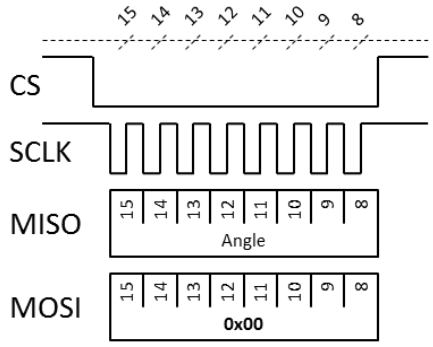

Figure 10: Partial 8-Bit SPI Angle Reading

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

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

	MSB															LSB
MISO	***Angle(15:0)***															

	command			*reg. address*												
MOSI	***0***	***1***	***0***	A_4	A_3	A_2	A_1	A_0	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

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

	reg. value															
MISO	V_7	V_6	V_5	V_4	V_3	V_2	V_1	V_0	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

	MSB															LSB
MOSI	***0***															

See Figure 11 for a complete transmission overview.

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

	MSB															LSB
MISO	***Angle(15:0)***															

	command			*reg. address*												
MOSI	***0***	***1***	***0***	***1***	***1***	***0***	***1***	***1***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

In the second frame, the MagAlpha replies:

	reg. value															
MISO	***MGH***	***MGL***	***X***	***X***	***X***	***X***	***X***	***X***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

	MSB															LSB
MOSI	***0***															

See Figure 12 for a complete example.

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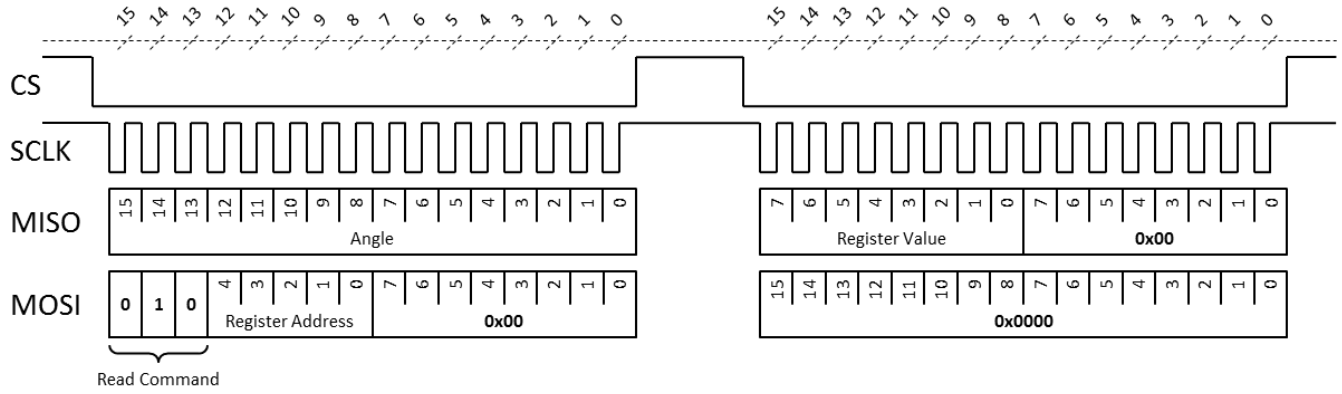

Figure 11: Two 16-Bit Frames Read Register Operation

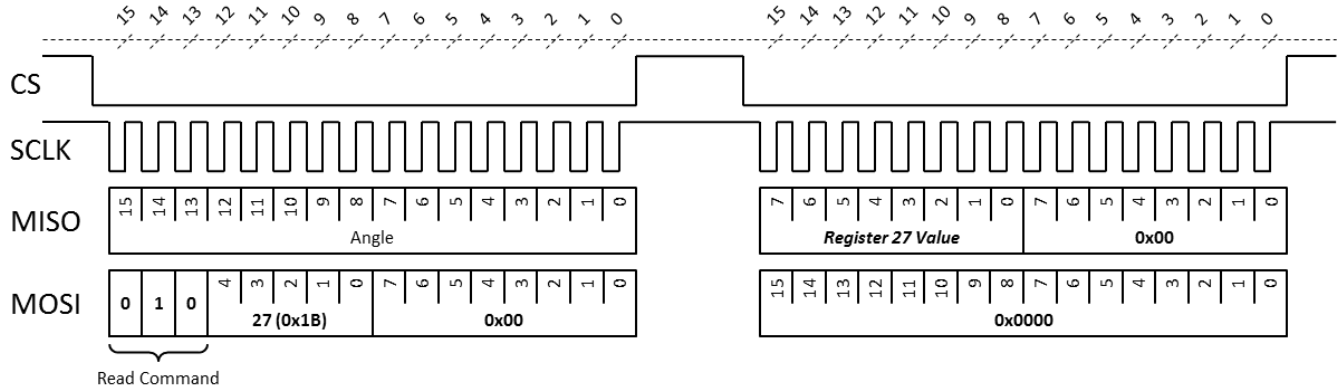

Figure 5: Example Read Magnetic Level Flags High and Low (MGH, MGH) on Register 27, Bit 7-6

SPI Write Register

Table 4 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 5.

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:

	MSB															*LSB*
MISO	***Angle(15:0)***															

	command			*reg. address*					*reg. value*							
MOSI	*1*	*0*	*0*	A_4	A_3	A_2	A_1	A_0	V_7	V_6	V_5	V_4	V_3	V_2	V_1	V_0

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

	reg. value															
MISO	V_7	V_6	V_5	V_4	V_3	V_2	V_1	V_0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

	MSB															*LSB*
MOSI	*0*															

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

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

	MSB															LSB
MISO	Angle(15:0)															

	command			reg. address					reg. value							
MOSI	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0

Send the second frame after a 20ms wait time. If the register is written correctly, the reply is:

	reg. value															
MISO	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	MSB															LSB
MOSI	0															

See Figure 14 for a complete example.

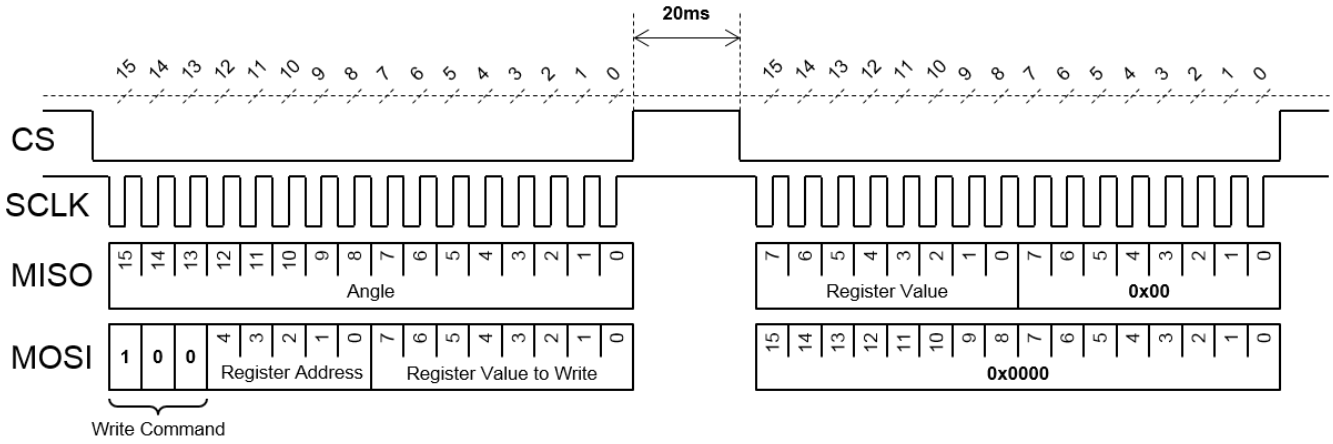

Figure 13: Overview of Two 16-Bit Frames Write Register Operation

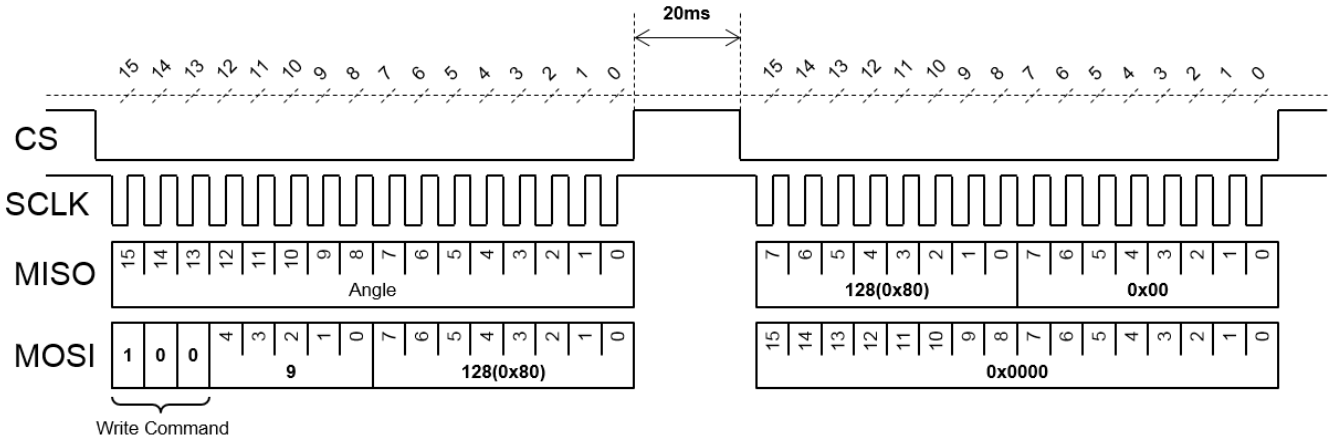

Figure 14: Example Write Output Rotation Direction (RD) to Counterclockwise (High), on Register 9, Bit 7

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REGISTER MAP

Table 4: 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 5: 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 6: Programming Parameters

Parameters	Symbol	Number of Bits	Description	See Table
Zero setting	Z	16	Set the zero position	7
Magnetic field high threshold	MGHT	3	Sets the field strength high threshold.	11
Magnetic field low threshold	MGLT	3	Sets the field strength low threshold.	11
Rotation direction	RD	1	Determines the sensor positive direction	9

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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. In decimals, it can be written as shown in Equation (3):

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

Table 7 shows the zero setting parameter.

Table 7: 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, it is written as 1111 0001 1100 0111.

Table 8 shows the content of registers 0 and 1.

Table 8: 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 15 and Table 9).

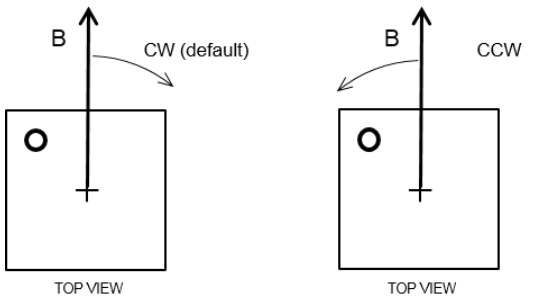

Figure 15: Positive Rotation Direction of the Magnetic Field

Table 9: Rotation Direction Parameter

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

PWM Absolute Output

This output provides a logic signal with a duty cycle proportional to the angle of the magnetic field. The PWM frequency is close to 50kHz (the nominal period is 20µs). The duty cycle is bounded by a minimum value (1/10 of the period) and a maximum value (9/10 of the period) (see Figure 16). This means that the duty cycle varies from approximately 10% to 90% with a resolution of eight bits. The angle can be retrieved by measuring the on time. Since the absolute PWM frequency can vary from chip to chip or with the temperature, accurate angle detection requires the measurement of the duty cycle (i.e.: the measurement of both the on time (t_{ON}) and the off time (t_{OFF})). The angle can be calculated with Equation (5):

$$angle(in\,\text{deg}) = 360\frac{1}{8}\left(10\frac{t_{ON}}{t_{ON}+t_{OFF}} - 1\right) \quad (5)$$

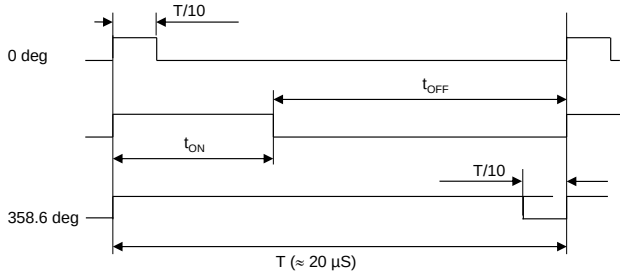

Figure 16: Timing Diagram of the PWM Output

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Filtering the PWM Output

The PWM output can be used to obtain a low-frequency analog output emulating a traditional potentiometer. For this purpose, the PWM signal must be low-pass filtered, either with a simple R-C network if the desired output range is 3.3V or with a buffered op-amp circuit for a larger range. Note that close to the zero angle transition, the PWM duty cycle changes from its maximum to its minimum value (or vice-versa depending on the rotation direction). Consequently, during the filter time constant, the filter output is an average between the small and the large duty cycle.

Figure 17 shows an example of a circuit with a ratio-metric output in a range larger than 3.3V, between 10% and 90% of the circuit supply voltage (V). V must be sufficiently more than 3.3V to supply the MagAlpha correctly via the linear regulator.

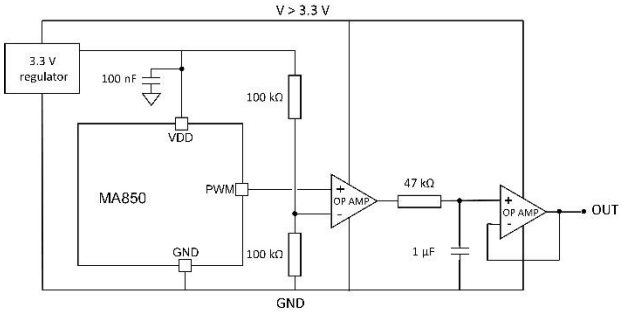

Figure 17: Typical Circuit for Replacement of an Analog Potentiometer

Magnetic Field Thresholds

Push Button Detection

The MA850 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 18).

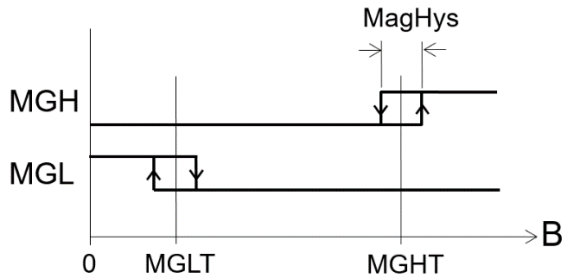

Figure 18: MGH and MGL Signals as a Function of the Field Strength

The MGL/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 air gap is smaller than 1.0mm (see Figure 19).

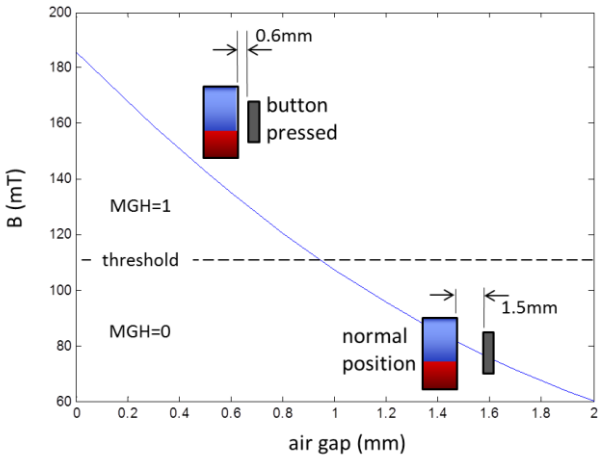

Figure 19: Magnetic Field Produced by a 5mmx3mm N35 Magnet as a Function of the Air Gap with Threshold Set to 110mT

In this way, it is possible to implement both 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 10).

Table 10: 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 11).

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Table 11: MGLT and MGHT Binary to mT Relation

MGLT or MGHT (8)	Field threshold in mT (7)	
	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*

The MA850 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 11). 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 12 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 12: MGL Multiple Reading 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

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TYPICAL APPLICATION CIRCUITS

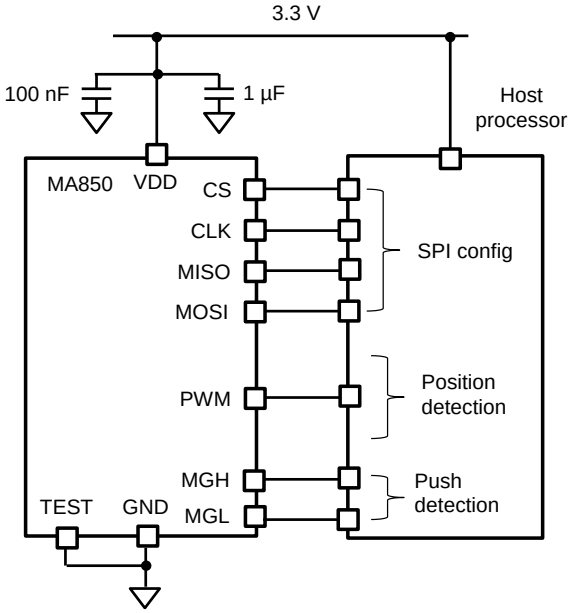

Figure 20: Typical Configurations to a Host Microprocessor

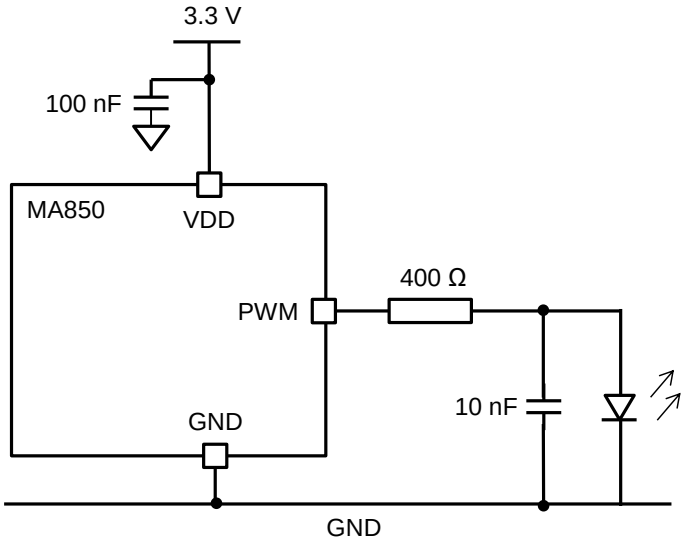

Figure 21: LED Intensity Driven by a Shaft Angle

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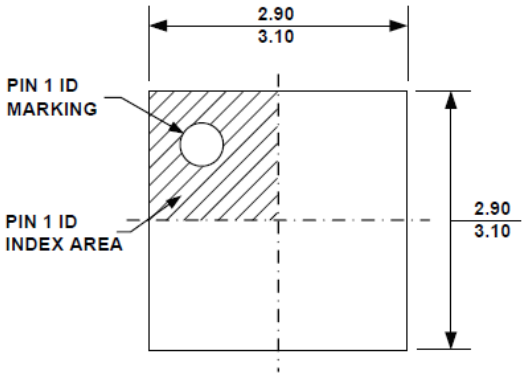
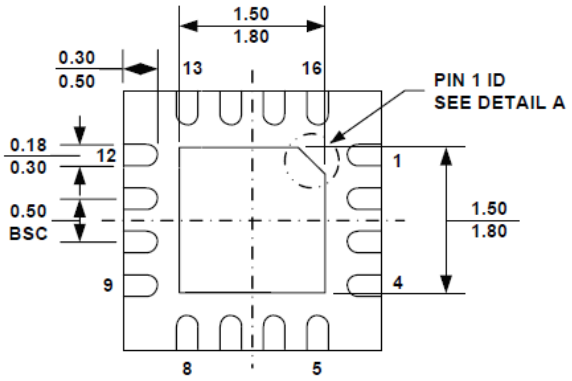
PACKAGE INFORMATION

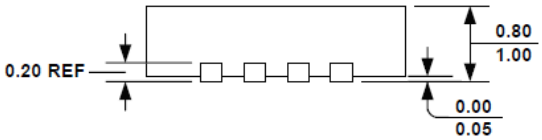
QFN-16 (3mmx3mm)



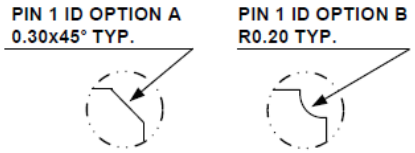
TOP VIEW



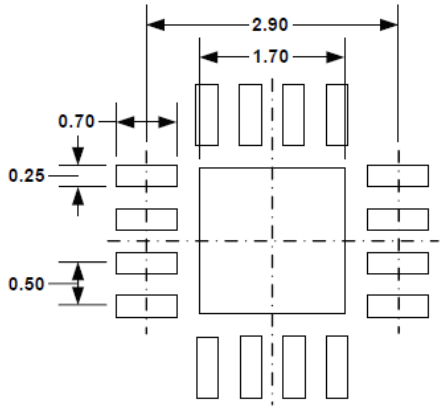
BOTTOM VIEW



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.

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APPENDIX A: DEFINITIONS

Resolution (3σ 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 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.

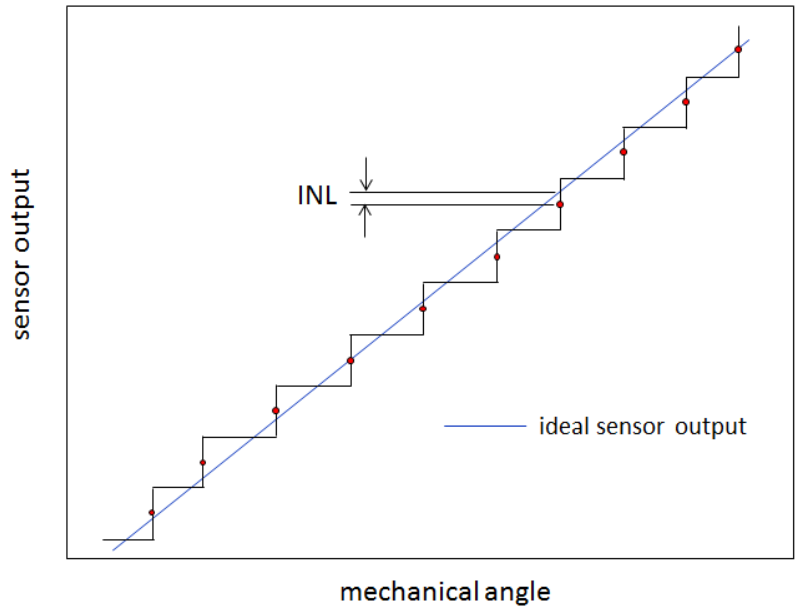

Figure A1: Integral Non-linearity

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

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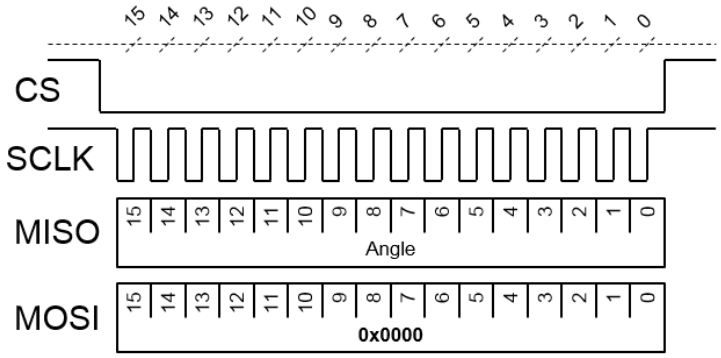
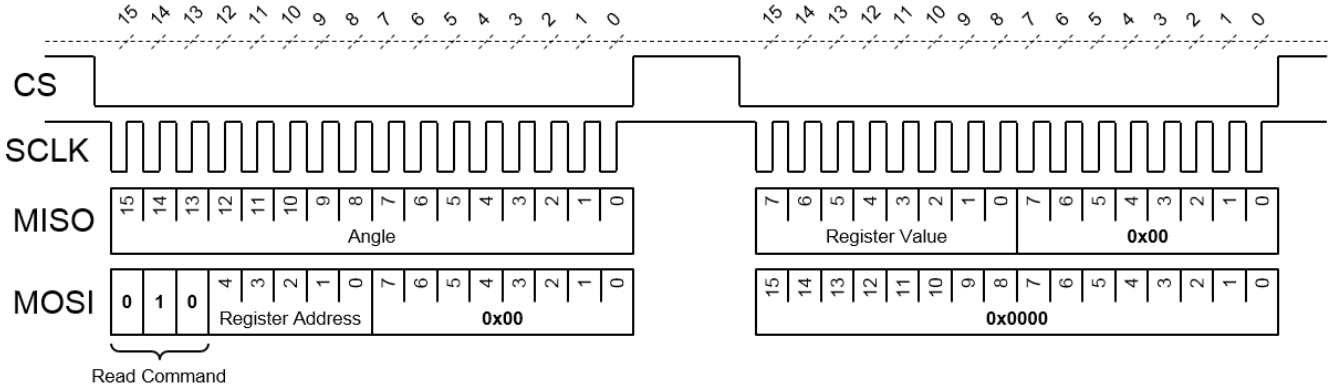
APPENDIX B: SPI COMMUNICATION CHEATSHEET

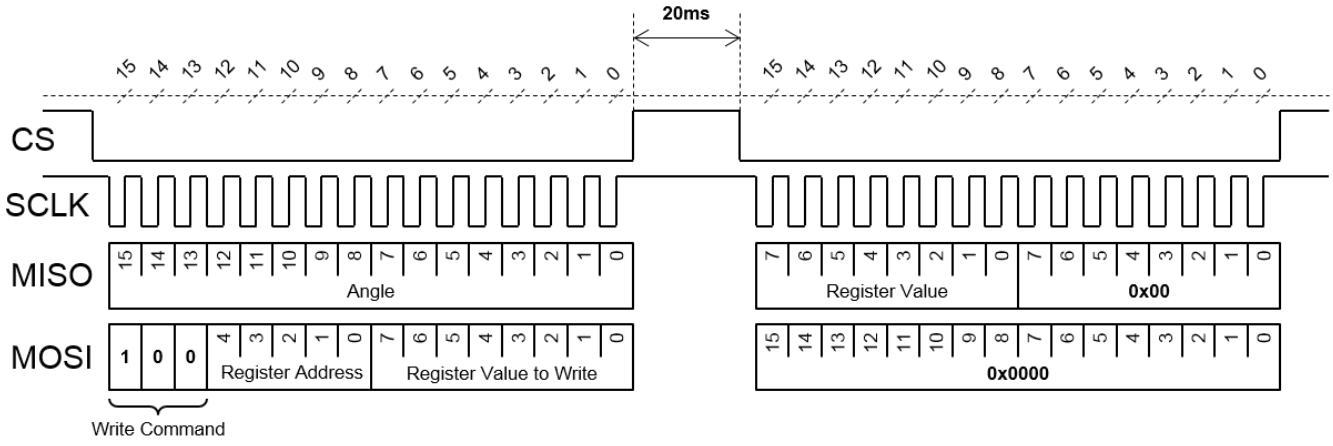
Read Angle



Read Register



Write Register



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REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	9/21/2017	Initial Release	-
1.01	6/15/2018	Update the description.	1
		Updated parameters in EC table.	5
1.1	8/11/2022	Updated legal notice.	1
		Updated orderable suffix from “–Z” to “-Z”.	2
		Added effective resolution parameter in General Characteristics table.	5
		Update Non-Linearity plots.	6
		Updated Figure 17 and Figure 18.	17
		Added MGL Application Note and MGL Workarounds sections and Table 15.	18
		Minor formatting updates.	All

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