MagAlpha MAQ850

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

DESCRIPTION

The MAQ850 is an automotive-grade, easy-to-use, magnetic angle encoder with a digital output designed to replace analogic potentiometers or rotary switches. The MAQ850 is designed 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 and outputs a pulse-width modulation (PWM) waveform with 8-bit resolution.

Magnet shapes and configurations are very flexible. Typically, the MAQ850 is used with a diametrically magnetized cylinder with a 2mm to 8mm diameter.

The MAQ850 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.

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

The MAQ850 is available in a QFN-16 (3mmx3mm) package.

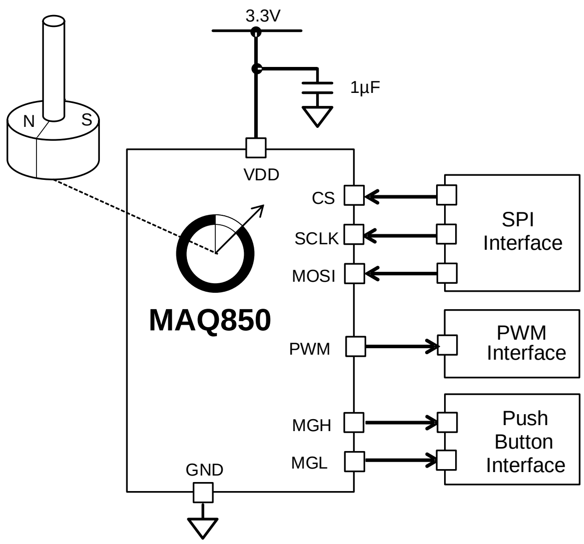
FEATURES

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

APPLICATIONS

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

TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MAQ850GQE-AEC1	QFN-16 (3mmx3mm)	*See Below*	1

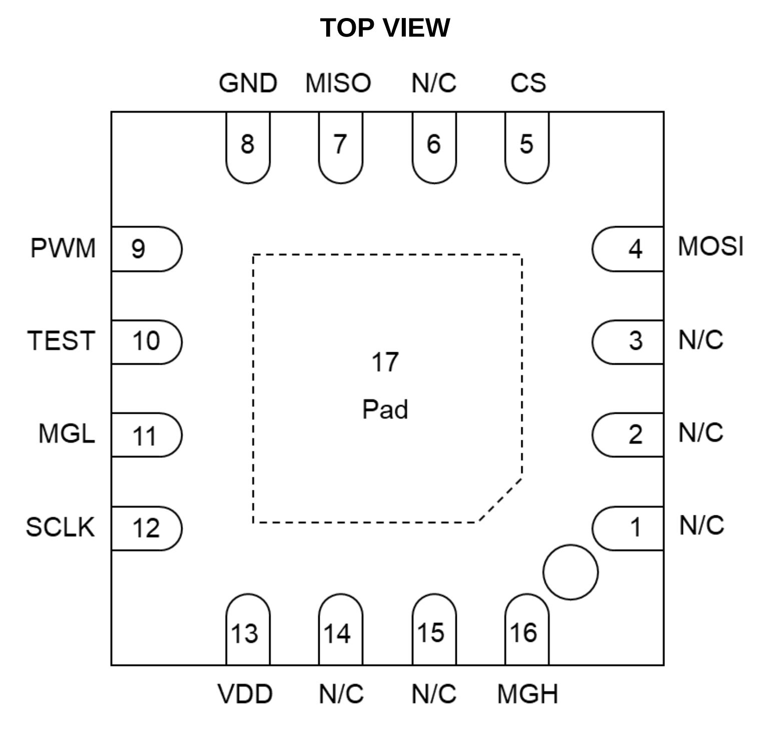
* For Tape & Reel, add suffix -Z (e.g. MAQ850GQE-AEC1-Z).

TOP MARKING

CALY
LLLL

CAL: Product code of MAQ850GQE-AEC1
Y: Year code
LLLL: Lot number

PACKAGE REFERENCE



QFN-16 (3mmx3mm)

PIN FUNCTIONS

Pin #	Name	Description
1, 2, 3, 6, 14, 15	N/C	**No connection.** Leave the N/C pin disconnected.
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 (Hi-Z) state.
8	GND	**Supply ground.**
9	PWM	**PWM output.**
10	TEST	**Connect to ground.**
11	MGL	**Digital output indicating whether the field strength below the MGLT level.**
12	SCLK	**Clock (SPI).** The SCLK pin has an internal pull-down resistor.
13	VDD	**3.3V supply.**
16	MGH	**Digital output indicating whether the field strength exceeds the MGHT level.**

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°C) (2)
.... 2W
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	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°C to +125°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Resolution						
Effective resolution		3σ 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 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
Pulse-Width Modulation (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

GENERAL CHARACTERISTICS *(continued)*

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

Parameter	Symbol	Condition	Min	Typ	Max	Units
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	kΩ
Pull-down resistor	R_{PD}		43	55	97	kΩ
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

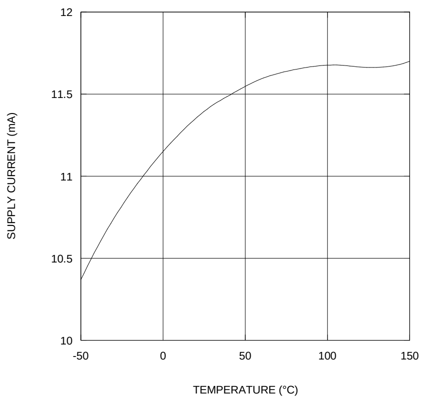
Notes:

4) Guaranteed by design.
5) Guaranteed by characteristization testing.

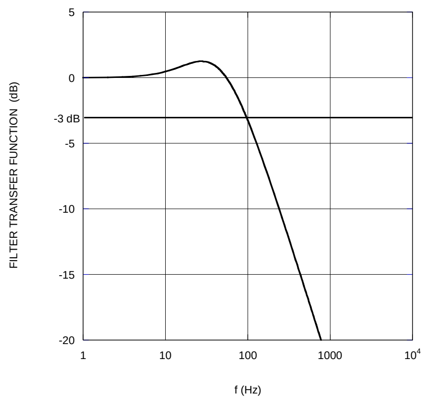
TYPICAL CHARACTERISTICS

V_{DD} = 3.3V, T_A = 25°C, unless otherwise noted.

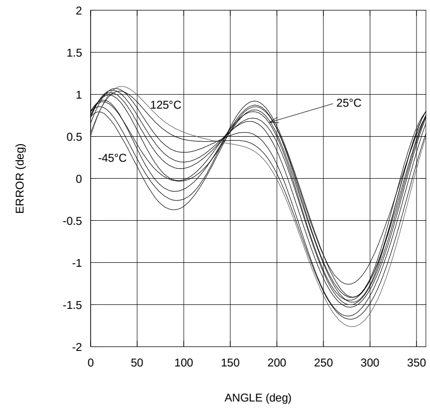
Current Consumption at V_{DD} = 3.3V



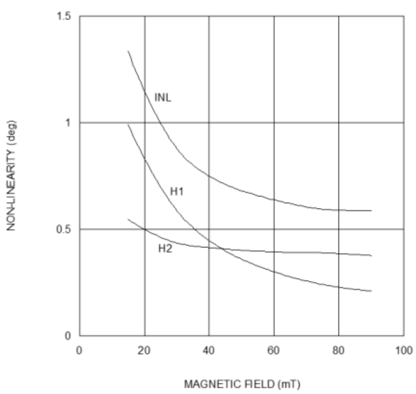
Filter Transfer Function



Error Curves at 50mT



Nonlinearity (INL and Harmonics)



FUNCTIONAL BLOCK DIAGRAM

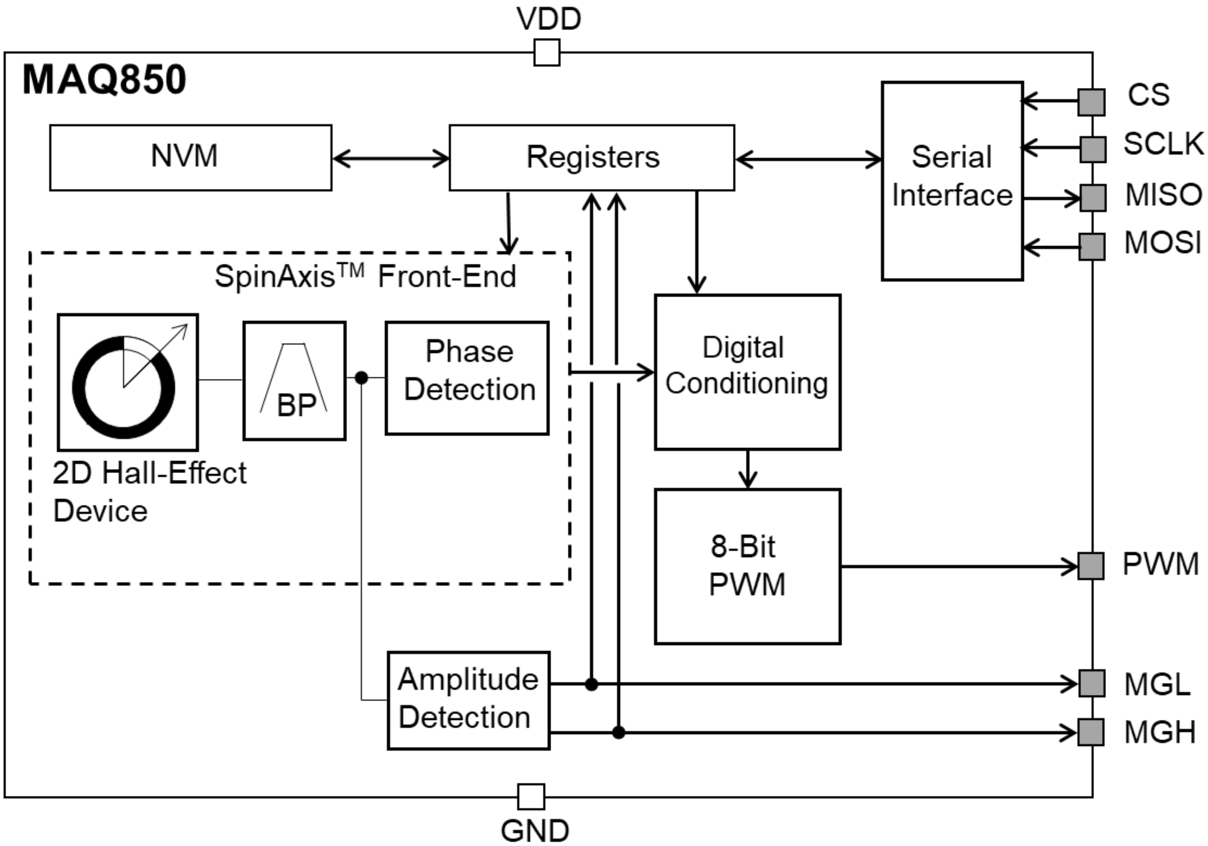


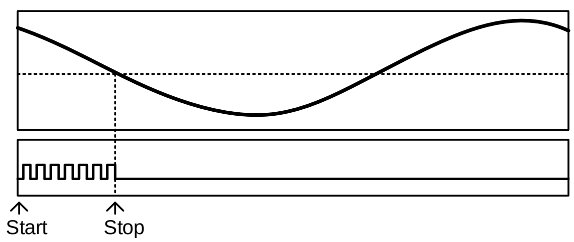
Figure 1: Functional Block Diagram

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):

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

See the General Characteristics section on page 5 for the value of f_{CUTOFF}.

Sensor — Magnet Mounting

The MAQ850'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.

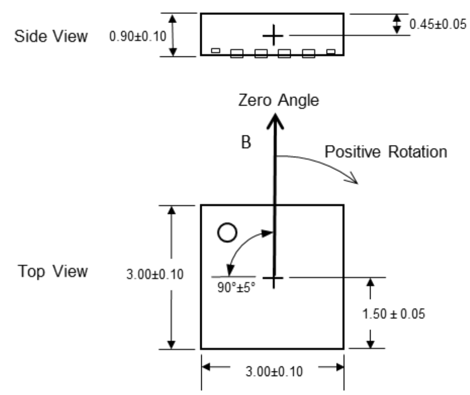


Figure 3: Detection Point and Default Positive Direction

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 MAQ850 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 MAQ850 sensor on the rotation axis of a permanent magnet (e.g. a diametrically magnetized cylinder) (see Figure 4 on page 10). 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 good linearity, the sensor is positioned with a precision of 0.5mm.

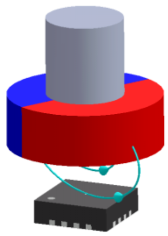


Figure 4: End-of-Shaft Mounting

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 1mm, and the sensor is positioned on the rotation axis with a precision of 0.5mm.

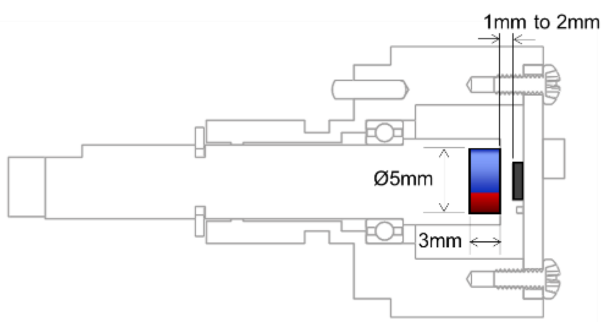


Figure 5: Potentiometer-Like Assembly

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).

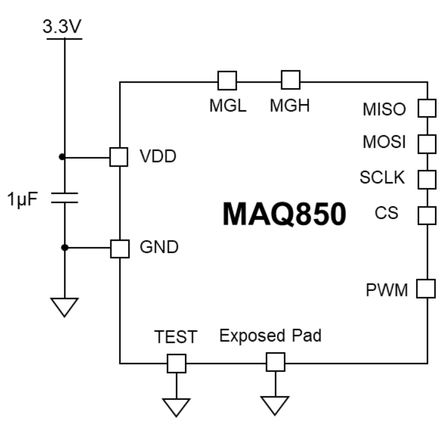


Figure 6: Supply Decoupling Connection

In general, the MAQ850 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 register configurations.

The SPI is a four-wire, synchronous, serial communication interface. The MAQ850 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. The SPI's maximum supported clock rate is 25MHz. There is no minimum clock rate. Note that real-life data rates depend on the PCB layout quality and signal trace length.

Table 1: SPI Specifications

	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 Standards

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

All commands to the MAQ850 (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.

Figure 7 on page 11 shows the SPI timing diagram.

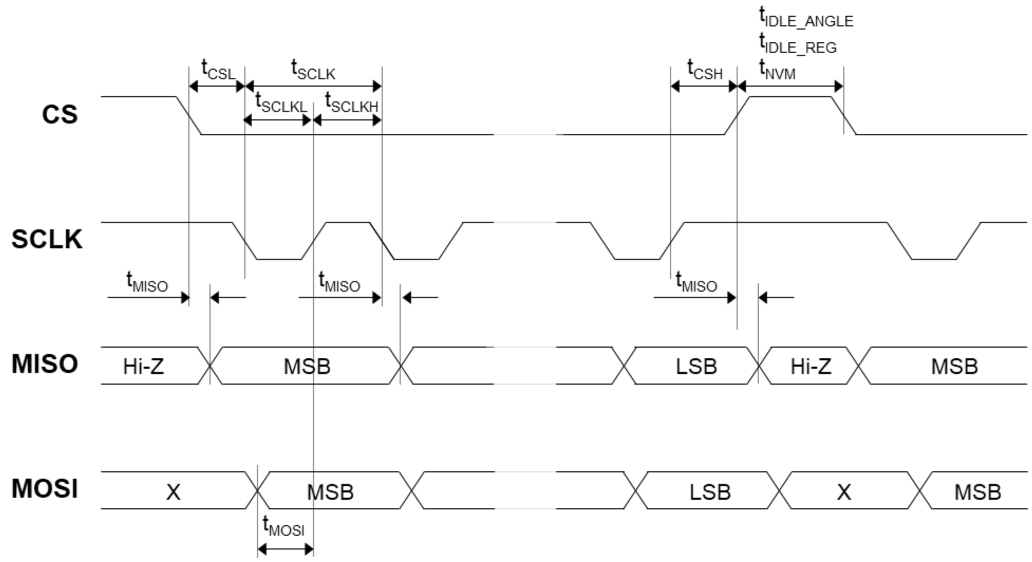


Figure 7: SPI Timing Diagram

Table 3 shows the SPI timing.

Table 3: SPI Timing

Parameter [6]	Description	Min	Max	Unit
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 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.

Table 8 shows the minimum idle time.

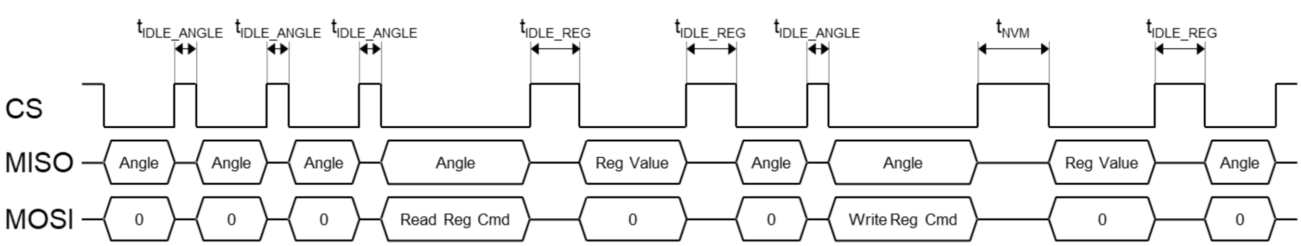


Figure 8: Minimum Idle Time

SPI Communication

The MAQ850 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

Figure 9 shows a full SPI angle reading.

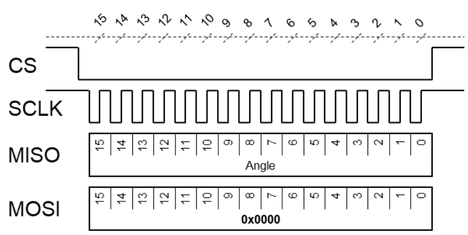


Figure 9: Full 16-Bit SPI Angle Reading

Figure 10 shows a partial SPI angle reading.

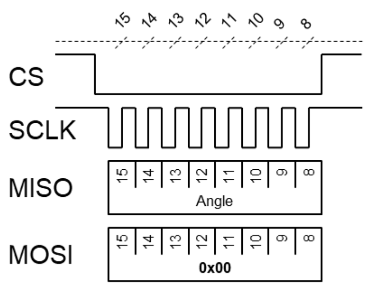


Figure 10: Partial 8-Bit SPI Angle Reading

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 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 5. If the data length is below 16 bits, the rest of the bits sent are zeros.

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 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*

Figure 11 on page 13 shows a complete transmission overview.

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

Figure 12 on page 13 shows a complete example.

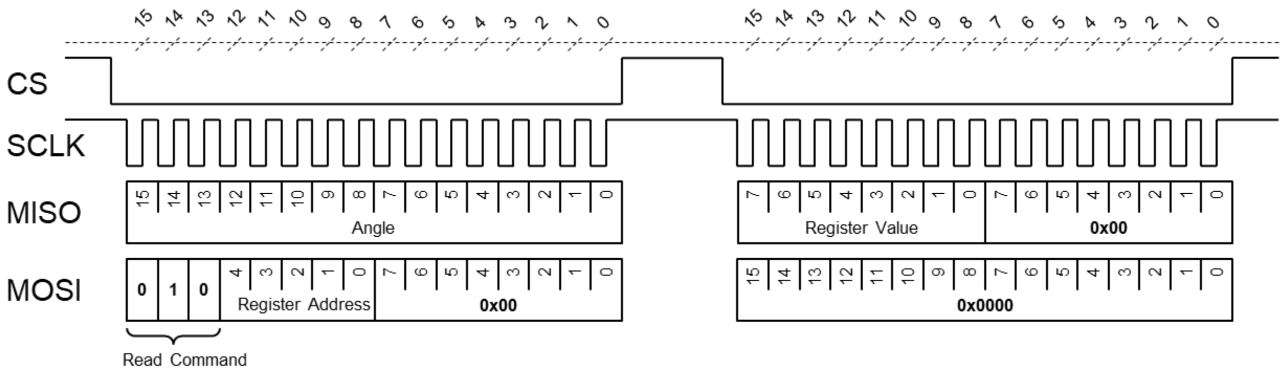


Figure 11: Two 16-Bit Frames Read Register Operation

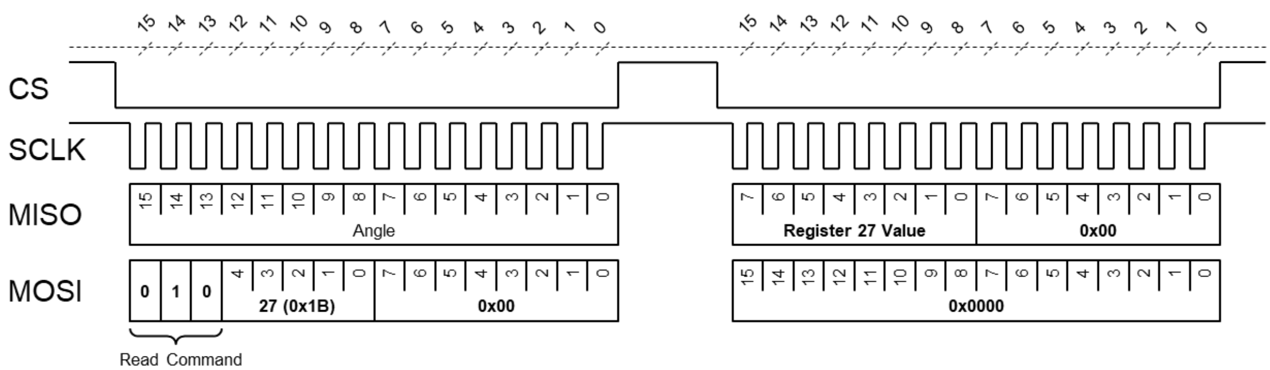


Figure 12: Example (Read Magnetic Level Flags High and Low (MGH, MGH) on Register 27, Bits[7:6])

SPI Write Register

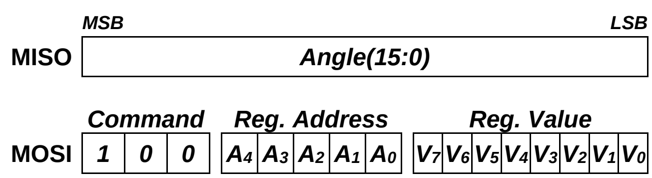
Table 4 on page 15 shows the configurable 8-bit registers. Data written to these registers are stored to the on-chip NVM and are automatically reloaded during start-up. Table 5 on page 15 shows the factory default register values.

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).

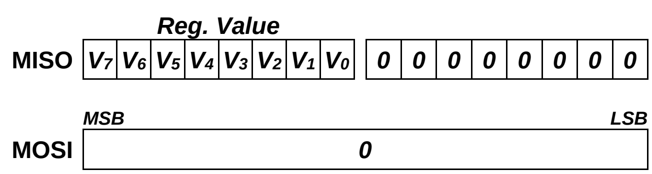
The on-chip memory is guaranteed to endure 1,000 write cycles at 25°C.

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 configurations.

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:

	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:

MISO	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

	MSB … *LSB*
MOSI	***0***

Figure 13 shows a complete transmission overview.

Figure 14 shows a complete example.

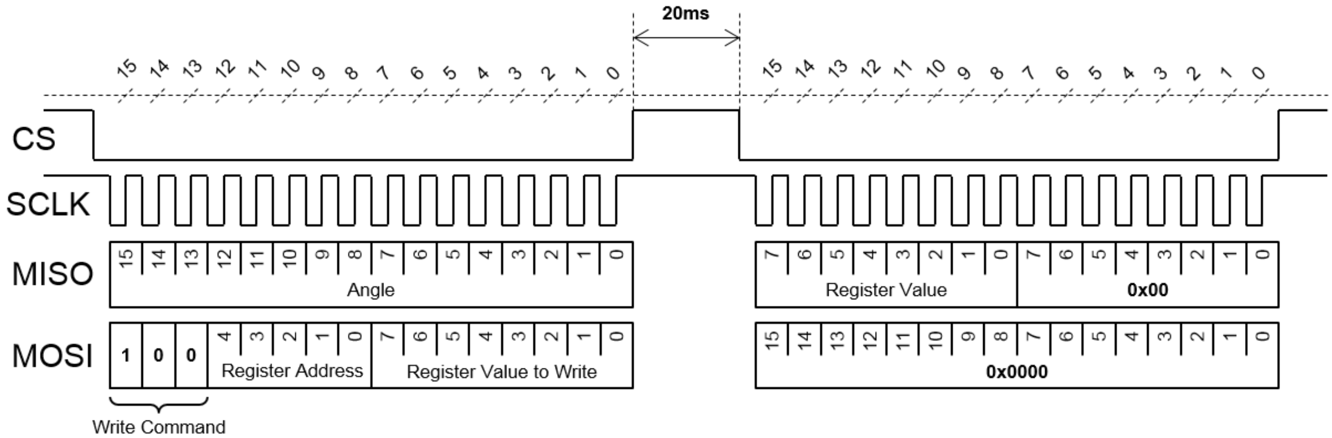


Figure 13: Overview of Two 16-Bit Frames Write Register Operation

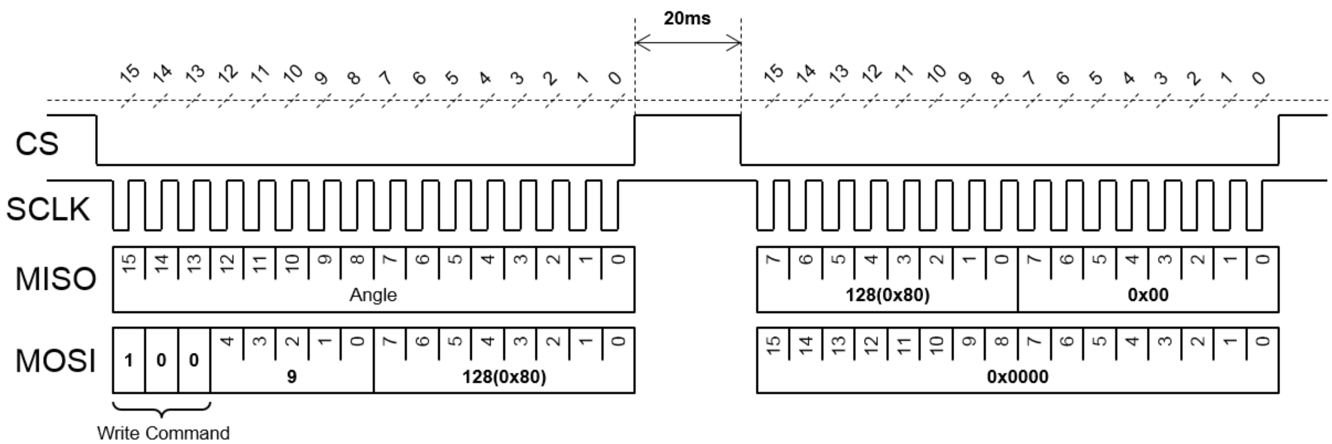


Figure 14: Example (Write Output Rotation Direction (RD) to Counterclockwise (High), on Register 9, Bit[7])

REGISTER MAP

Table 4: 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 5: 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 6: Configuration Parameters

Parameters	Symbol	Number of Bits	Description	See Table
Zero setting	Z	16	Sets 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's positive direction.	9

REGISTER SETTINGS

Zero Setting

The MAQ850's zero position (a_0) can be configured with 16 bits of resolution. The angle streamed out by the MAQ850 (a_{OUT}) can be calculated with Equation (3):

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

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):

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

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 degrees, the Z(15:0) parameter must be equal to the complementary angle, calculated with Equation (5):

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

In binary format, this value is written as 1111 0001 1100 0111. Table 8 shows the contents of register 0 and register 1 for this example.

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 shows the positive rotation direction of the magnetic field.

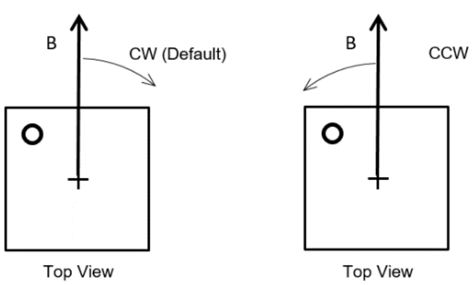


Figure 15: Positive Rotation Direction of the Magnetic Field

Table 9 shows the rotation direction parameter.

Table 9: Rotation Direction Parameter

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

Pulse-Width Modulation (PWM) Absolute Output

The PWM output provides a logic signal with a duty cycle that is proportional to the magnetic field's angle. The PWM frequency is close to 50kHz (the nominal period is 20µs). The duty cycle has a minimum value (1/10 of the period) and a maximum value (9/10 of the period) (see Figure 16 on page 17). This means that the duty cycle varies is generally between 10% and 90% of the period, with a resolution of 8 bits.

The angle can be retrieved by measuring the on time. Since the absolute PWM frequency can vary from chip to chip or with temperature fluctuations, accurate angle detection requires measuring the duty cycle, which is the measurement of both the on time (t_{ON}) and the off time (t_{OFF})). The angle can be calculated with Equation (6):

$$\text{Angle (in deg)} = 360\text{x}\frac{1}{8}\left(10\frac{t_{ON}}{t_{ON}+t_{OFF}}-1\right) \quad (6)$$

Figure 16 shows the PWM output timing diagram.

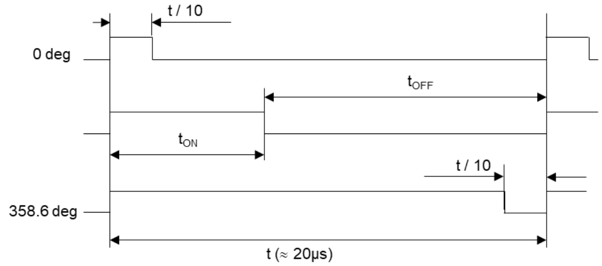


Figure 16: Timing Diagram of the PWM Output

Filtering the Pulse-Width Modulation (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 resistor-capacitor (RC) network if the output is 3.3V, or with a buffered operational amplifier circuit for a wider 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 minimum and maximum duty cycles.

Figure 17 shows a circuit with a ratiometric output between 10% and 90% of the circuit supply voltage (in V). V must exceed 3.3V to supply the MAQ850 via the linear regulator.

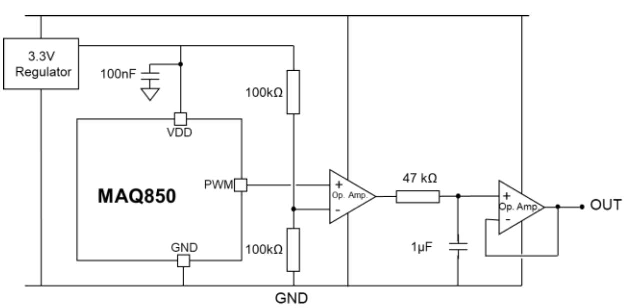


Figure 17: Typical Circuit for Replacement of an Analog Potentiometer

Magnetic Field Thresholds

Push Button Detection

The MAQ850 has two threshold options (MGHT or MGLT), which are complementary in their operation. The MGH flag becomes true (logic 1) if the magnetic field exceeds MGHT. The MGL flag becomes true (logic 1) if the magnetic field falls below MGLT (see Figure 18).

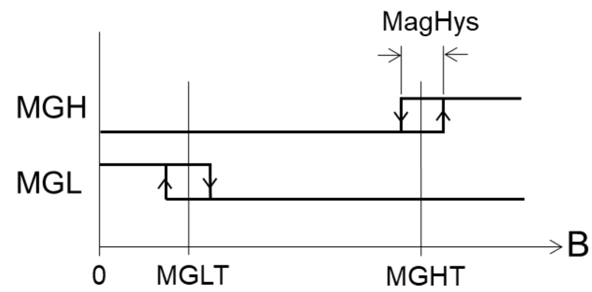


Figure 18: MGH and MGL Signals as a Function of the Field Strength

The MGL/MGH flags can be used 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 19).

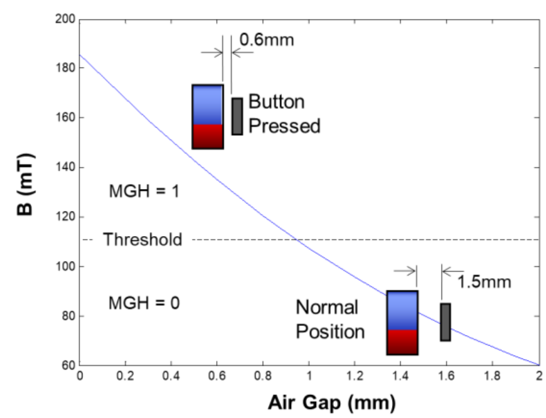


Figure 19: Magnetic Field as a Function of the Air Gap (Threshold Set to 110mT)

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

MagHys is the hysteresis on the MGH and MGL signals (see the General Characteristics section on page 5). The MGLT and MGHT thresholds are coded on 3 bits and stored in register 6 (see Table 10 on page 18).

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 for MGLT and MGHT correspond to the magnetic field (see Table 11).

Table 11: 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 the 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*

The MAQ850 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 in 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 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 that are between 2µs and 100µs apart allows the user to distinguish erroneous transitions from real transitions. Table 12 shows examples of these different cases.

Table 12: MGL Multiple Reading Workaround

	MGL First Reading	MGL Second Reading (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

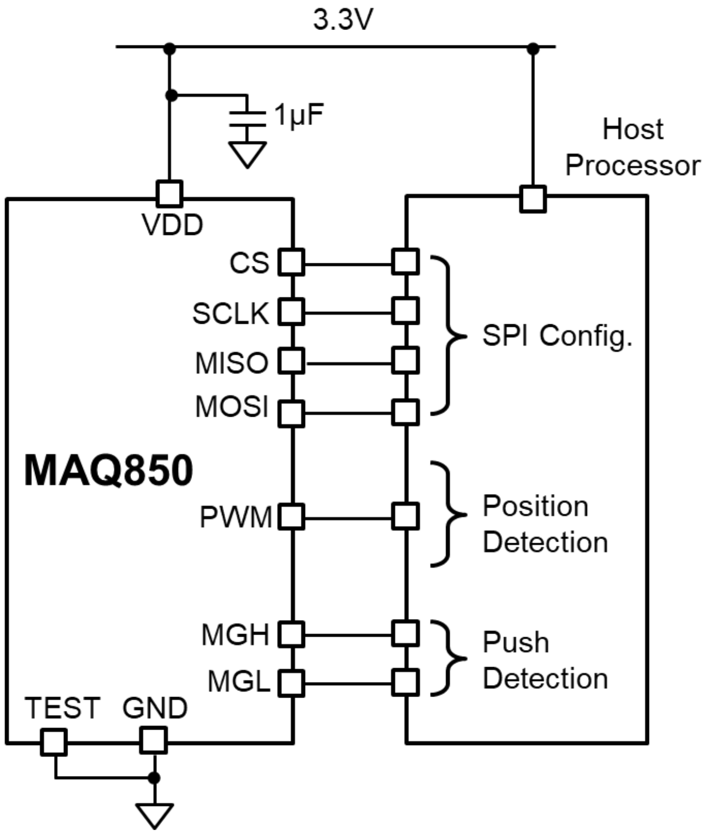


Figure 20: Typical Application Circuit (Configurations to a Host Microprocessor)

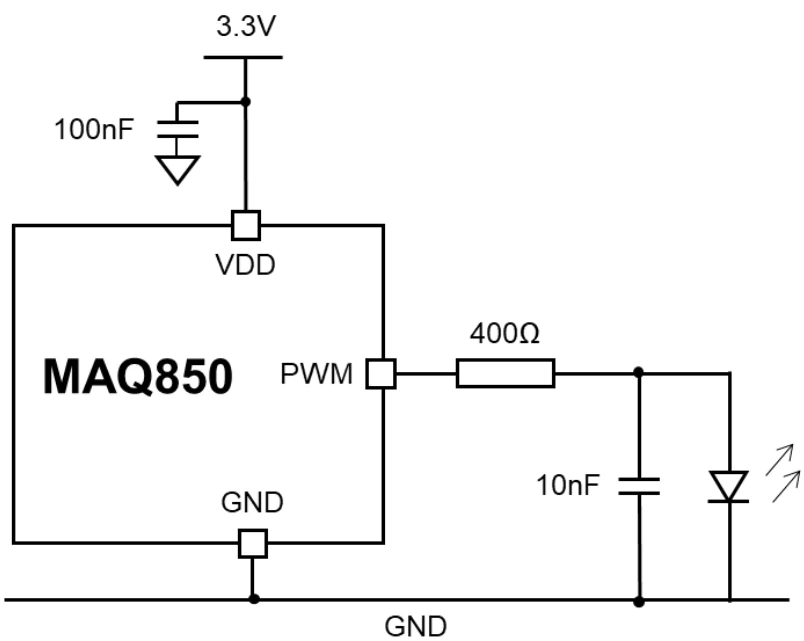
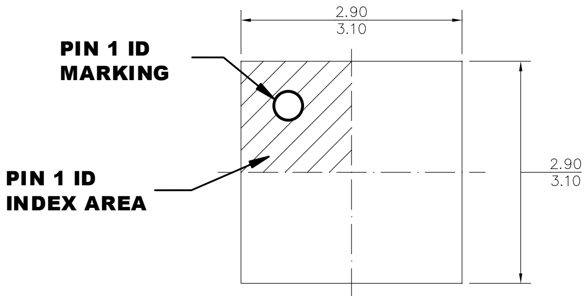


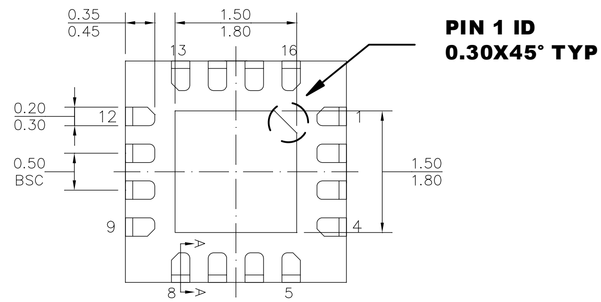
Figure 21: Typical Application Circuit (LED Intensity Driven by a Shaft Angle)

PACKAGE INFORMATION

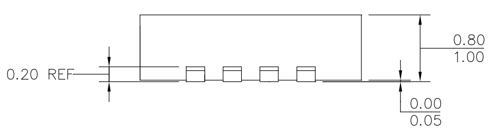
QFN-16 (3mmx3mm)



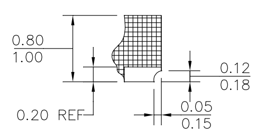
TOP VIEW



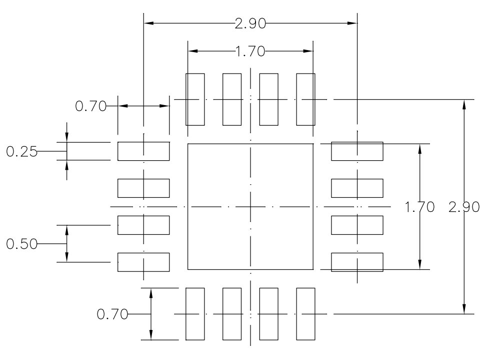
BOTTOM VIEW



SIDE VIEW



SECTION A-A



RECOMMENDED LAND PATTERN

NOTE:

1) THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
3) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
4) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
5) JEDEC REFERENCE IS MO-220.
6) DRAWING IS NOT TO SCALE.

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 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.

Integral Nonlinearity (INL)

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

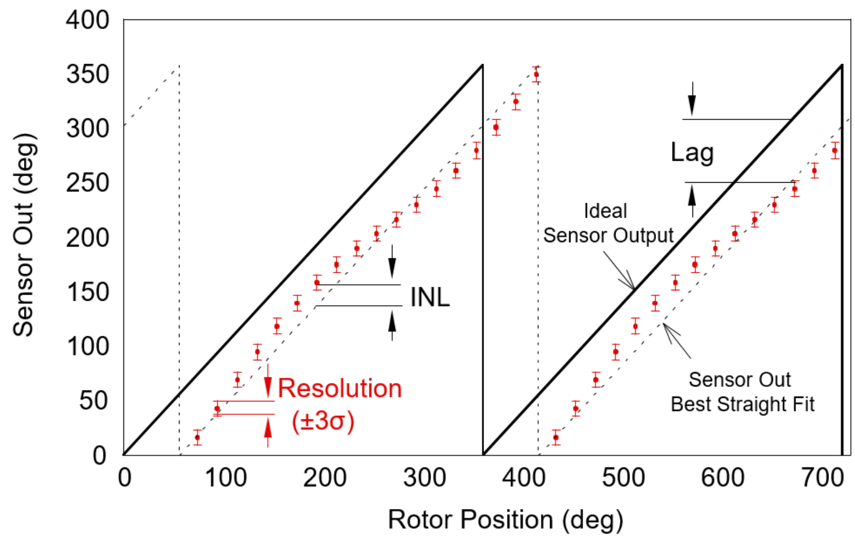


Figure A1: Resolution, INL, Lag

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°). INL is then calculated with Equation (A1):

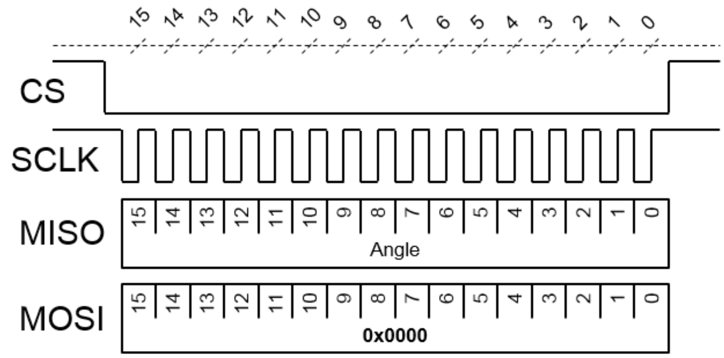
$$\text{INL} = \frac{\max(\text{err}(a)) - \min(\text{err}(a))}{2} \tag{A1}$$

Drift

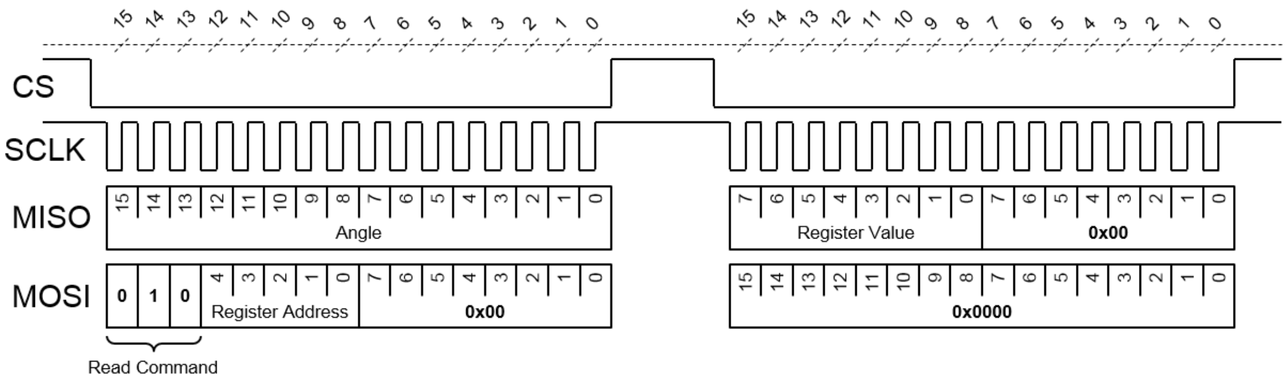
Angle variation rate when one parameter changes (e.g. temperature and V_{DD}) and all the other parameters (including the shaft angle) stay constant.

APPENDIX B: SPI COMMUNICATION CHEATSHEET

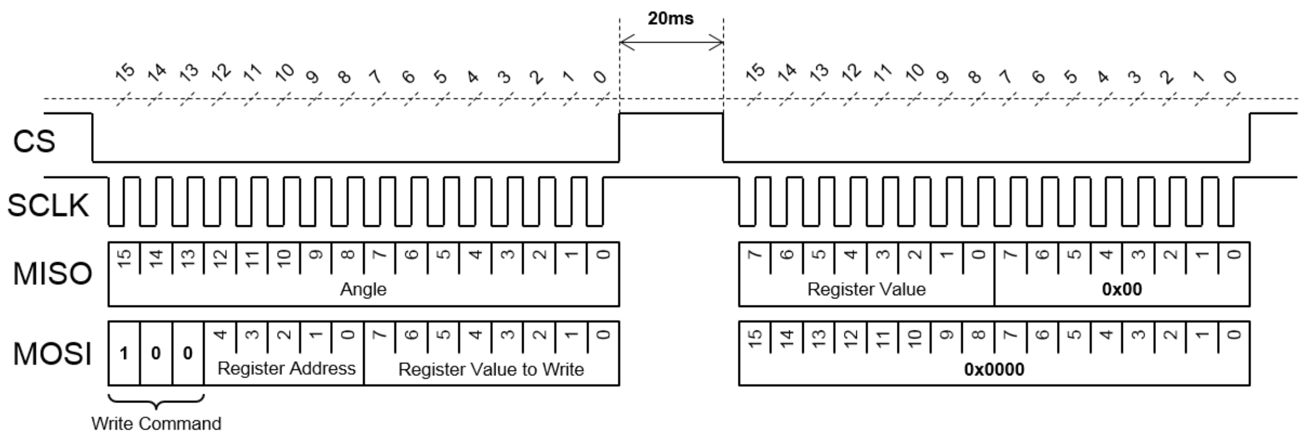
Read Angle



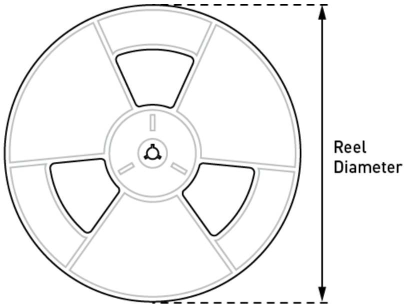
Read Register

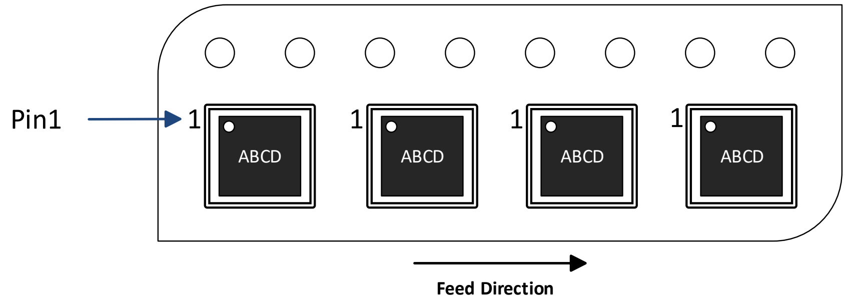


Write Register



CARRIER INFORMATION





Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MAQ850GQE-AEC1-Z	QFN-16 (3mmx3mm)	5000	N/A	N/A	13in	12mm	8mm

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	8/23/2023	Initial Release	-