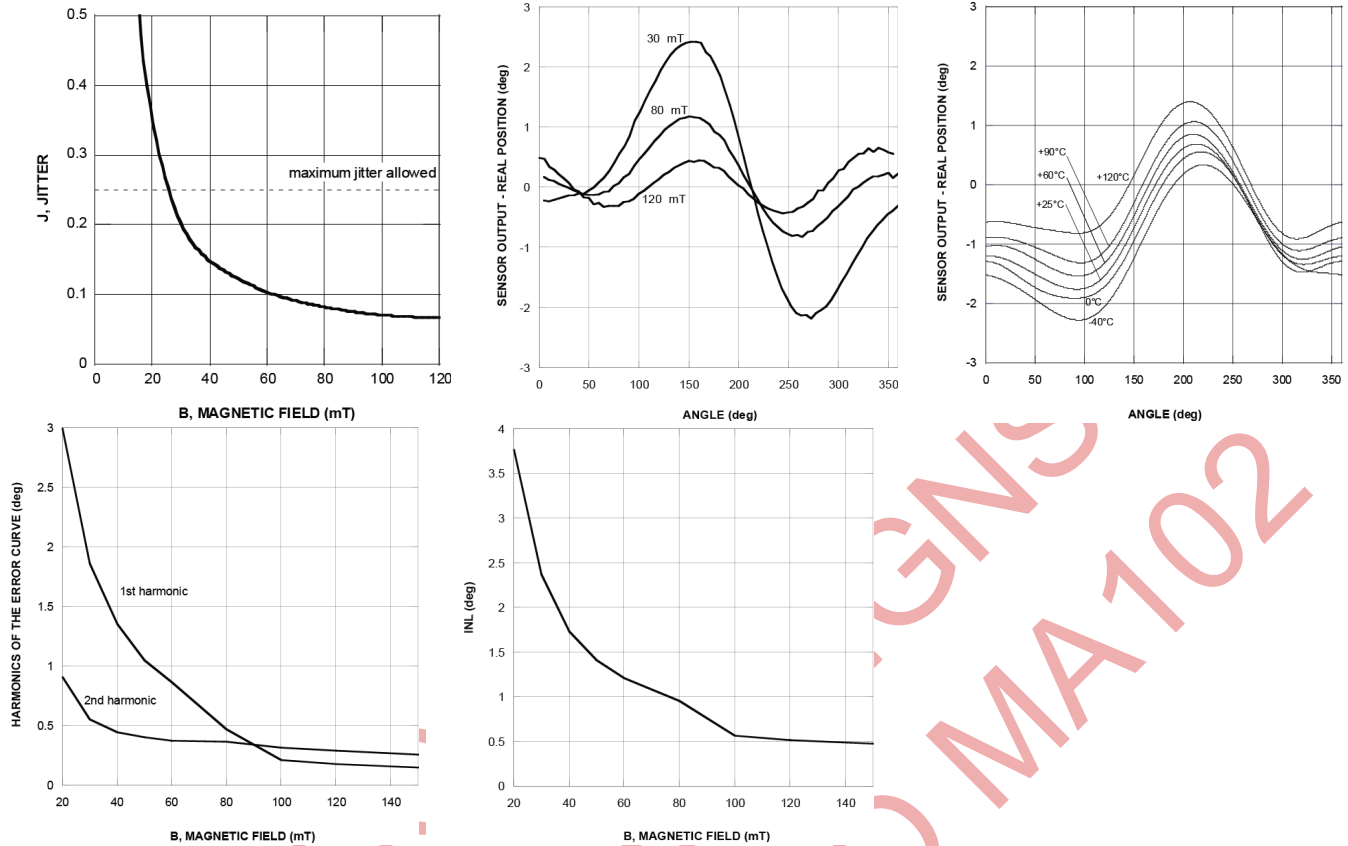


TYPICAL CHARACTERISTICS

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



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PIN FUNCTIONS

Package Pin #	Name	Description
1	V	Incremental output.
2, 3, 6, 10, 11, 14	NC	No connection. Leave unconnected.
4	MOSI	Data in. Serial.
5	CS	Chip select. Serial.
7	MISO	Data out. Serial.
8	GND	Ground.
9	W	Incremental output.
12	SCLK	Clock. Serial.
13	VDD	3.3V supply.
15	U	Incremental output.
16	VFLASH	Voltage supply for OTP flash. Leave unconnected if not used

NOT RECOMMENDED FOR NEW DESIGNS REFER TO MA102

BLOCK DIAGRAM

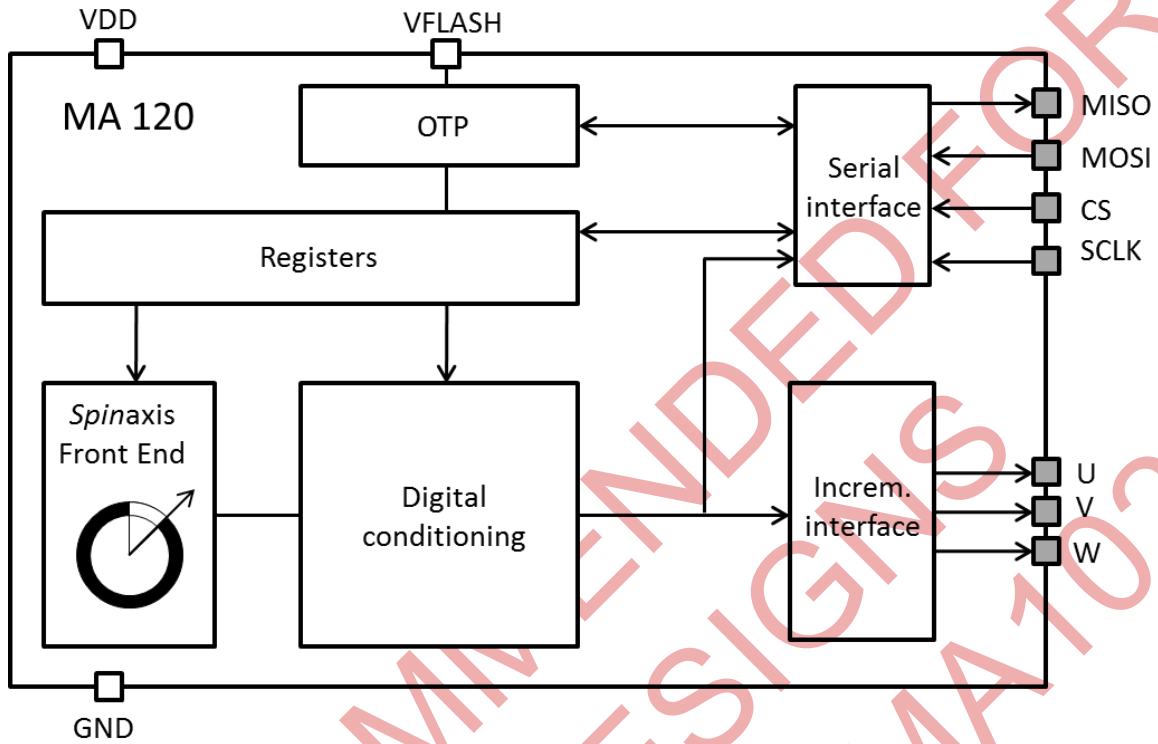


Figure 1: Functional Block Diagram

OPERATION

Timing of the Serial Interface

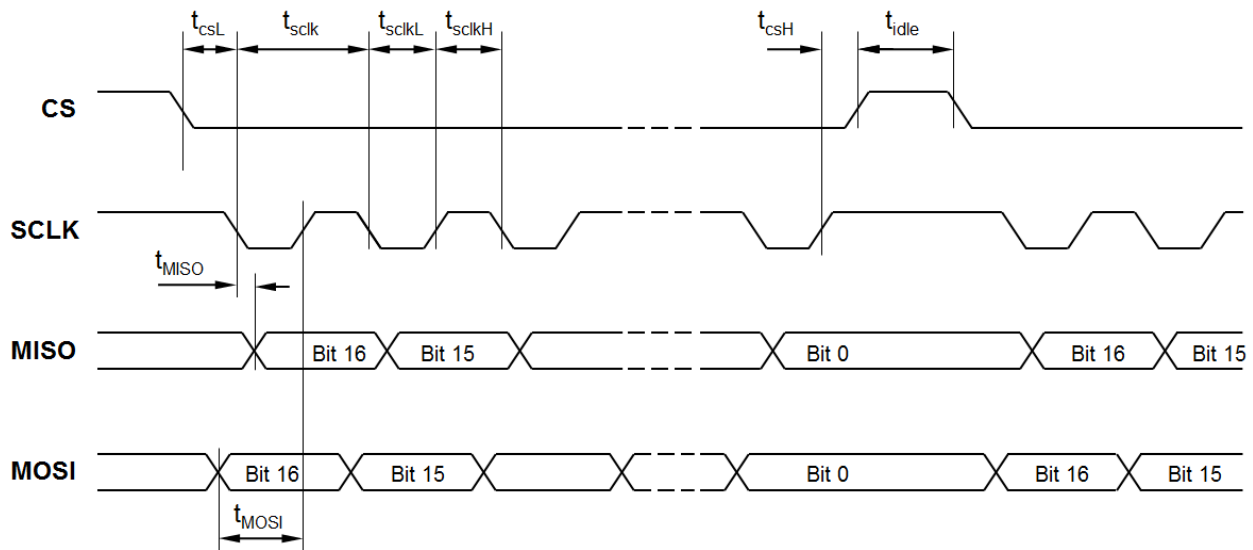
The data link is a 4-wire serial bus complying with the serial peripheral interface (SPI) usual convention (see Table 1 and Table 2). The MagAlpha sensor operates as a slave. During one transmission, a 16-bit word can be sent to the sensor MOSI and received from the sensor MISO simultaneously (see Figure 2).

Table 1: SPI Specification

SCLK idle state	High
SCLK readout edge	Rising
CS idle state	High
Data order	MSB first

Table 2: SPI Standard

CPOL	1
CPHA	1
MODE	3
DORD	0


Figure 2: SPI Timing Diagram
Table 3: SPI Timing

Parameter	Description	Min	Max	Unit
t_{idle}	Time between two subsequent transmissions	50		ns
t_{csL}	Time between CS falling edge and SCLK falling edge	50		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_{MOSI}	Data input valid to SCLK reading edge	15		ns
t_{MISO}	SCLK setting edge to data output valid		15	ns

Registers
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
4	0x4	0100	Z(7:0)							
9	0x9	1001	-	-	-	F4	-	-	-	-

Table 5: Programming Parameters

Parameters	Symbol	Number of Bits	Description	See Table
Zero setting	Z	8	Sets the zero position with resolution of 360/256 deg per bit ~ 1.41 deg.	6
Flash register <i>n</i>	<i>F_n</i>	1	Flash the content of register number <i>n</i>	

NOT RECOMMENDED FOR NEW DESIGNS REFER TO MA102

Sensor – Magnet Mounting

The sensitive volume of the MA120 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.

Rotation Direction

Looking at the MagAlpha top, the angle increases when the magnetic field rotates clockwise. Figure 3 shows the zero angle of the unprogrammed MA120, where the cross indicates the sensitive point.

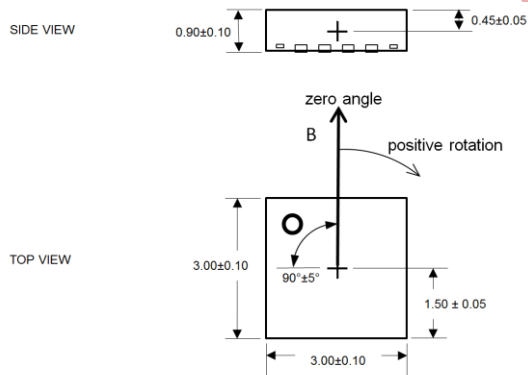


Figure 3: Zero Angle of Unprogrammed MA120

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 an amplitude of at least 30mT. Note that the MA120 can work with fields smaller than 30mT, but the linearity and resolution performance may deviate from the specifications. The straightforward solution is to place the MA120 sensor on the rotation axis of a permanent magnet (i.e.: a diametrically magnetized cylinder) (see Figure 4).

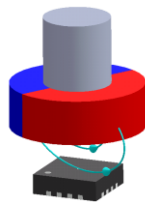


Figure 4: End-of-Shaft Mounting

Mounting and Power Supply Decoupling

For most applications, a single 100nF bypass capacitor placed close to the supply pins decouples the MA120 from power supply noise. If better decoupling is required, a larger capacitor (i.e.: 1µF to 10µF) can be added in parallel with the 100nF capacitor, and/or a serial resistor (i.e.: 10Ω) can be added on the supply line. Ensure that the capacitor is connected with low impedance paths.

VFLASH needs to be supplied only when flashing the memory. Otherwise, VFLASH can remain unconnected (see Figure 5).

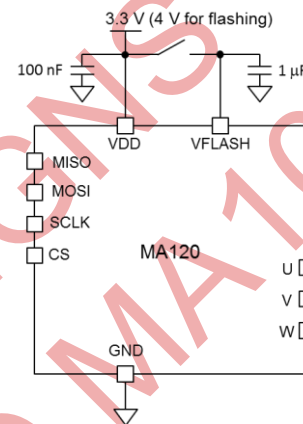


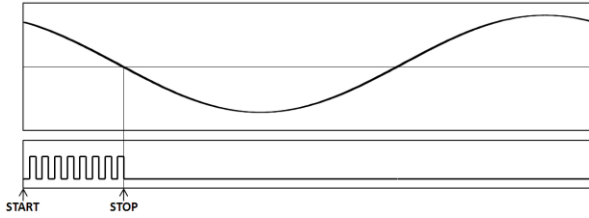
Figure 5: Connection for Supply Decoupling

The package's exposed pad can be soldered to the PCB to ensure optimal electrical, thermal, and mechanical conditions. In case the exposed pad is soldered, it is recommended to connect the pad to ground electrically.

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 any arctangent computation or feedback loop-based circuit (interpolators, etc.).

The *spinaxis* method is based on phase detection. It requires sensitive circuitry that generates a sinusoidal signal with a phase that represents the angle of the magnetic field. The angle is then retrieved by a time-to-digital converter, which counts the time between the zero crossing of the sinusoidal signal and the edge of a constant waveform (see Figure 6). The digitized time is the front-end output.



Top: Sine Waveform
Bottom: Clock of Time-to-Digital Converter
Figure 6: Phase Detection Method

At the output, the front-end delivers a digital number proportional to the angle of the magnetic field at the rate of 500kHz in a straightforward and open-loop manner.

Zero Setting

The zero position of the MagAlpha (a_0) can be programmed with 8 bits of resolution (1.40625 deg per bit). The angle streamed out (a_{out}) can be calculated with Equation (1):

$$a_{out} = a_{fe} - a_0 \quad (1)$$

Where a_{fe} is the raw angle out of the front end.

The parameter Z(7:0), which is 0 by default, determines a_0 (see Table 6). This setting is valid for all output formats (i.e.: SPI and UVW).

Table 6: Zero Position

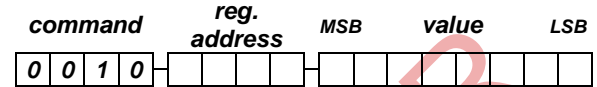
Z(7:0)	Zero Position a_0 (deg)
0	0
1	1.41
...	...
255	358.59

Programming the MA120

The MA120 incorporates three programmable registers. Each register has 8 bits of memory. When the MA120 is powered up, each of these three 8 bits of memory are set to zero, unless the register was previously stored in the one-time programmable (OTP) memory. This means that during start-up, the content of the OTP memory is copied to the registers. Once flashed, the register content can no longer be modified.

To set the content of a register, a digital stream must be sent to the register consisting of the 4-bit register/write command (0010), a 4-bit register address, and the 8-bit value.

The data stream, sent through the MOSI wire is a total of 16 bits long:



Once the command is sent, it is effective immediately and affects the next data sent from the MagAlpha.

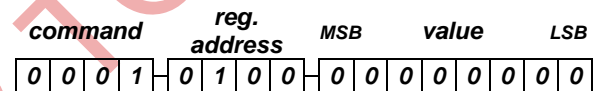
Reading Back the Register Content

To check the content of a register to verify that the programming was successful, first send the register/read command (0001) and the 4-bit address of the register being tested. The last 8 bits of the stream are irrelevant. For instance, the value 0000 0000 can be sent:

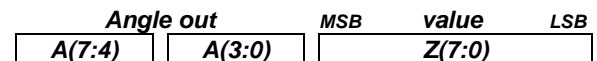


The MagAlpha response is within the same transmission. In the first byte (simultaneous to the 4-bit read command and the 4-bit address), the MagAlpha sends the 8 bits of the measured angle A(7:0). The second byte is the content of the register being tested. After this transmission, the MagAlpha continues delivering 8-bit angles A(7:0).

For example, to check the content of the register 4 (0100), which contains the zero setting, send the data:

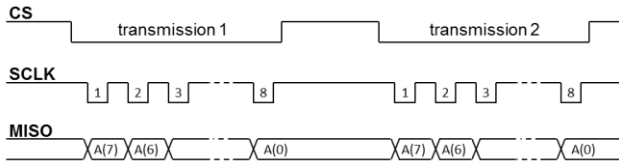


Simultaneously, the MagAlpha replies:

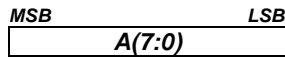


Output Signals

The bit order of the transmitted data is MSB first and LSB last. Every 2μs, new data is transferred into the output buffer. The master device connected to the MagAlpha triggers the reading by pulling CS down. When a CS signal falling edge occurs, the data remains in the output buffer until the CS signal returns to logic 1. When CS is low, the master can read the data by sending clock pulses with a maximum frequency of 25MHz. There is no minimum frequency or timeout. See Figure 7 for a simple reading of the 8-bit data.


Figure 7: Timing Diagram for Simple SPI Readout

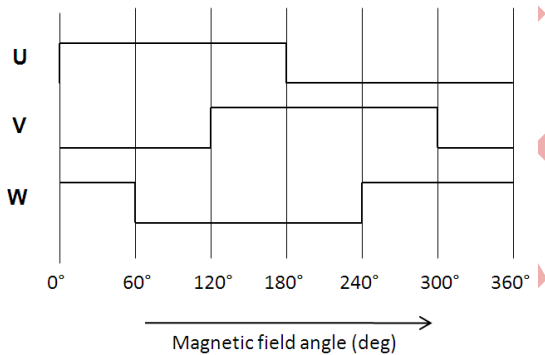
A full reading requires 8 clock pulses. The MA120 delivers:



If the master triggers the reading faster than the refresh rate, the MagAlpha may send the same sample several times.

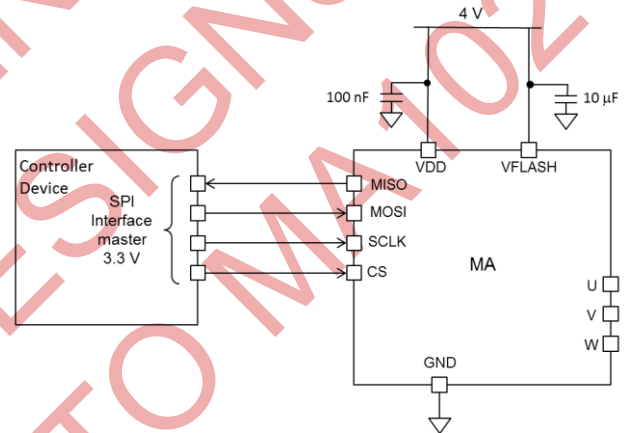
Block Commutation - UVW

The UVW output emulates the three Hall switches usually used for the block commutation of the 3-phase electric motor. The three logic signals have a duty cycle of 1/2 and are shifted by 60 deg relative to each other (see Figure 8).


Figure 8: UVW Output during Rotation

One-Time Programmable (OTP) Programming

The one-time programmable (OTP) memory can permanently store the content of the programmable registers. The OTP memory is made of poly-silicon fuses. By activating the flash command, the content of an entire register can be stored in the OTP memory. The flash command consists of setting some bits (F_n , where n is the register number) in register 9. For flashing the register, when the bit F_n is set, the register n is stored permanently. It is important to note that only one register can be flashed at a time. It is possible to operate the MagAlpha without flashing the registers (see Figure 9).


Figure 9: Circuit for Flashing

Burning the fuses during the flash process is irreversible. Once a register is flashed, the default values at power-up are always the same. After flashing, the content of the registers can no longer be modified.

Flashing Procedure

Prior to flashing, it is recommended to test the MagAlpha with the new settings and verify the performance of the sensor. Then, proceed with the flashing using the below steps:

1. Send the parameter to the register.
2. Read back for verification.
3. Connect VFLASH to VDD.
4. Raise VDD to 4V.
5. Set the bit corresponding to the register to be flashed in register 9.
6. Untie VFLASH.
7. Return VDD to 3.3V.
8. Switch the MagAlpha off and on.
9. Check by reading back the register content.

Permanently Storing the Zero Position

The following example shows how to set and flash the zero position at 50 deg. Note that permanently storing the zero position requires burning the register 4.

1. Convert into binary within a resolution of 8 bits. $50/360 * 256 = 35.56$. The closest 8-bit binary value is 00100100 (~50.63 deg).
2. Store the 8 MSB (00120120) of the zero position in register 4:

command	reg. address	MSB	value	LSB
0 0 1 0	0 1 0 0	0 0 1 0 0 1 0 0		

3. Read back register 4:

command	reg. address	MSB	value	LSB
0 0 0 1	0 1 0 0	0 0 0 0 0 0 0 0		

If the programming was correct, the MagAlpha replies with the register 4 content:

Angle out	MSB	value	LSB
A(15:12) A(11:8)	0 0 1	0 0 1 0 0 1 0 0	

Completing Flashing

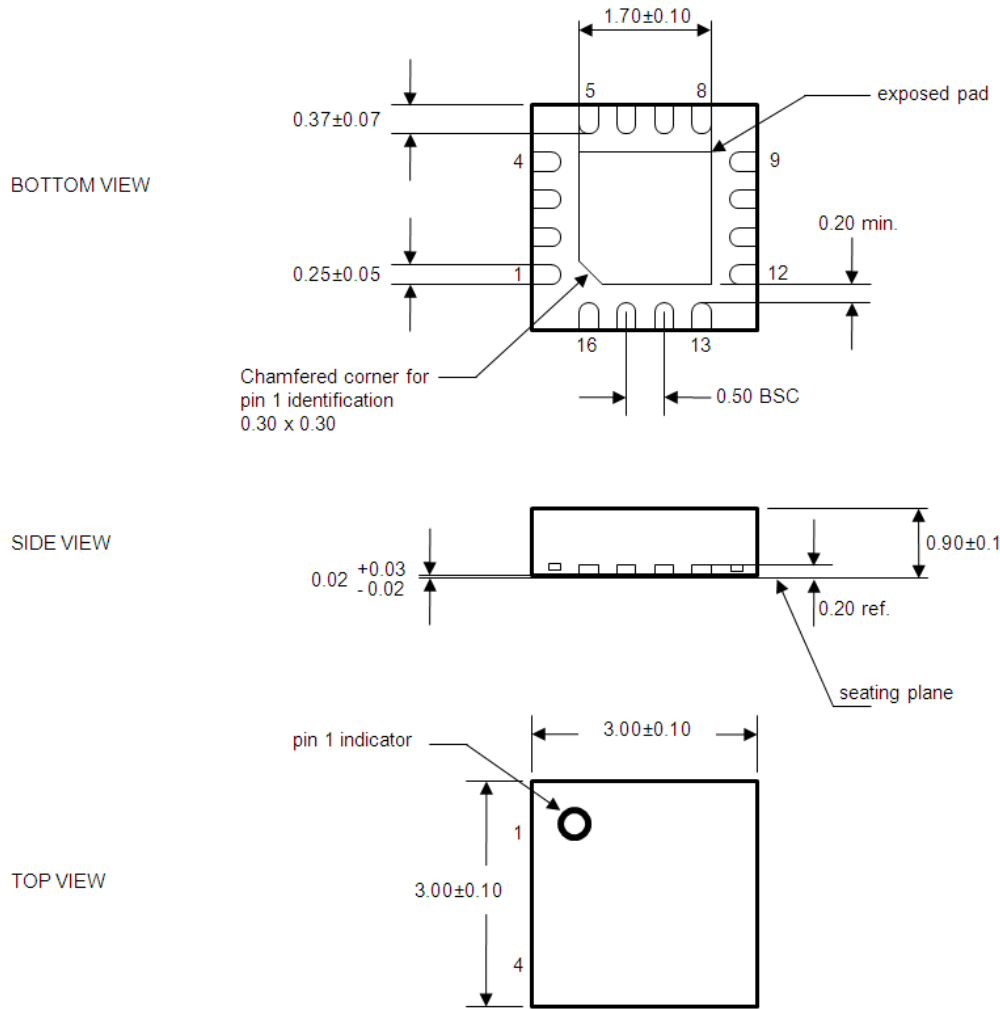
1. Connect VFLASH to VDD (4V).
 2. Flash register 4:
- | command | reg. address | MSB | value | LSB |
|---------|--------------|-----------------|-------|-----|
| 0 0 1 0 | 1 0 0 1 | 0 0 0 1 0 0 0 0 | | |
3. Disconnect VFLASH from VDD.
 4. Turn the MagAlpha off and on (with VDD back to the normal 3.3V value).
 5. Read back registers 4 to verify that the flashing was successfully accomplished.

For flashing multiple registers, send the flash command one by one. The flashing rate is specified in Sensor Output Specifications in the EC table.

Note: Flashing of the OTP registers requires raising both 3.3V VDD and VFlash to 4V. Isolate other devices sharing the 3.3V VDD rail if they are not tolerant to 4V.

PACKAGE INFORMATION

QFN-16 (3mmx3mm)



NOTES:

1. All dimensions are in mm.
2. Package dimensions do not include mold flash, protrusions, burrs, or metal smearing.
3. Coplanarity shall be 0.08.
4. Compliant with JEDEC MO-220.

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APPENDIX A: DEFINITIONS

- Resolution (3σ noise level)** The smallest angle increment distinguishable from the noise. Here, the resolution is defined as 3 times σ (the standard deviation in degrees) taken over 1200 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 between the data-ready at the output 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 noiseless sensor output and the shaft angle if the shaft zero angle coincides with the sensor zero angle.
- Drift** Angle variation rate when one parameter is changed (e.g.: temperature, VDD) and all the others, including the shaft angle, are maintained constant.

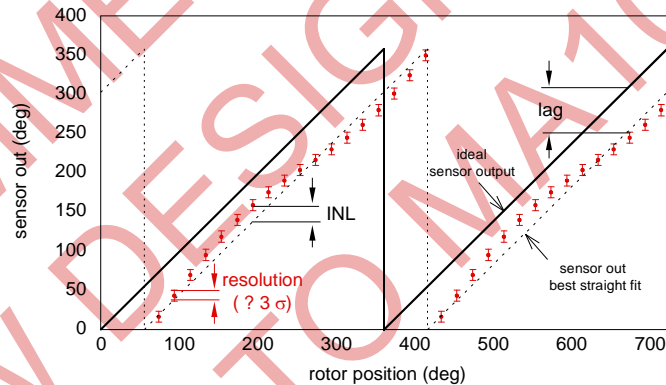


Figure A1: Absolute Angle Errors

- Overall Reproducibility** Maximum variation between two readings, successive or not, of the same shaft position at a fixed magnetic field over the complete temperature range.