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## AS5215

### Programmable 360° Magnetic Angle Encoder with Buffered SINE & COSINE Output Signals

#### 1 General Description

The AS5215 is a redundant, contactless rotary encoder sensor for accurate angular measurement over a full turn of 360° and over an extended ambient temperature range of -40°C to +150°C.

Based on an integrated Hall element array, the angular position of a simple two-pole magnet is translated into analog output voltages. The angle information is provided by means of buffered sine and cosine voltages. This approach gives maximum flexibility in system design, as it can be directly integrated into existing architectures and optimized for various applications in terms of speed and accuracy.

With two independent dies in one package, the device offers true redundancy. Usually the bottom die, which is exposed to slightly less magnetic field is employed for plausibility check.

An SSI Interface is implemented for signal path configuration as well as a one time programmable register block (OTP), which allows the customer to adjust the signal path gain to adjust for different mechanical constraints and magnetic field.

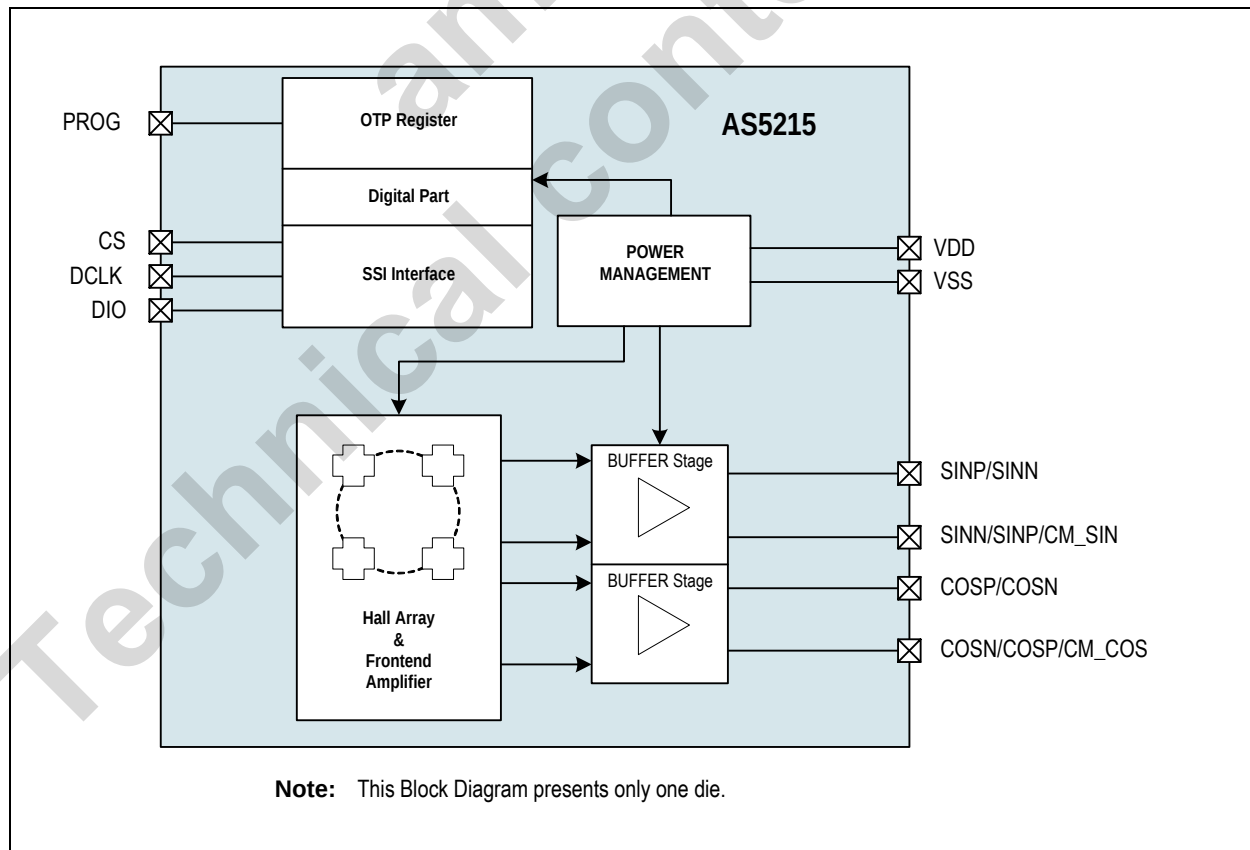
#### 2 Key Features

- Contactless angular position encoding
- High precision analog output
- Buffered Sine and Cosine signals
- SSI Interface
- Low power mode
- Two programmable output modes: Differential or Single ended
- Wide magnetic field input range: 20 – 80 mT
- Wide temperature range: -40°C to +150°C
- Fully automotive qualified to AEC-Q100, grade 0
- Thin punched 32-pin QFN (7x7mm) package

#### 3 Applications

The AS5215 is ideal for Electronic Power Steering systems and general purpose for automotive or industrial applications in microcontroller-based systems.

Figure 1. AS5215 Block Diagram

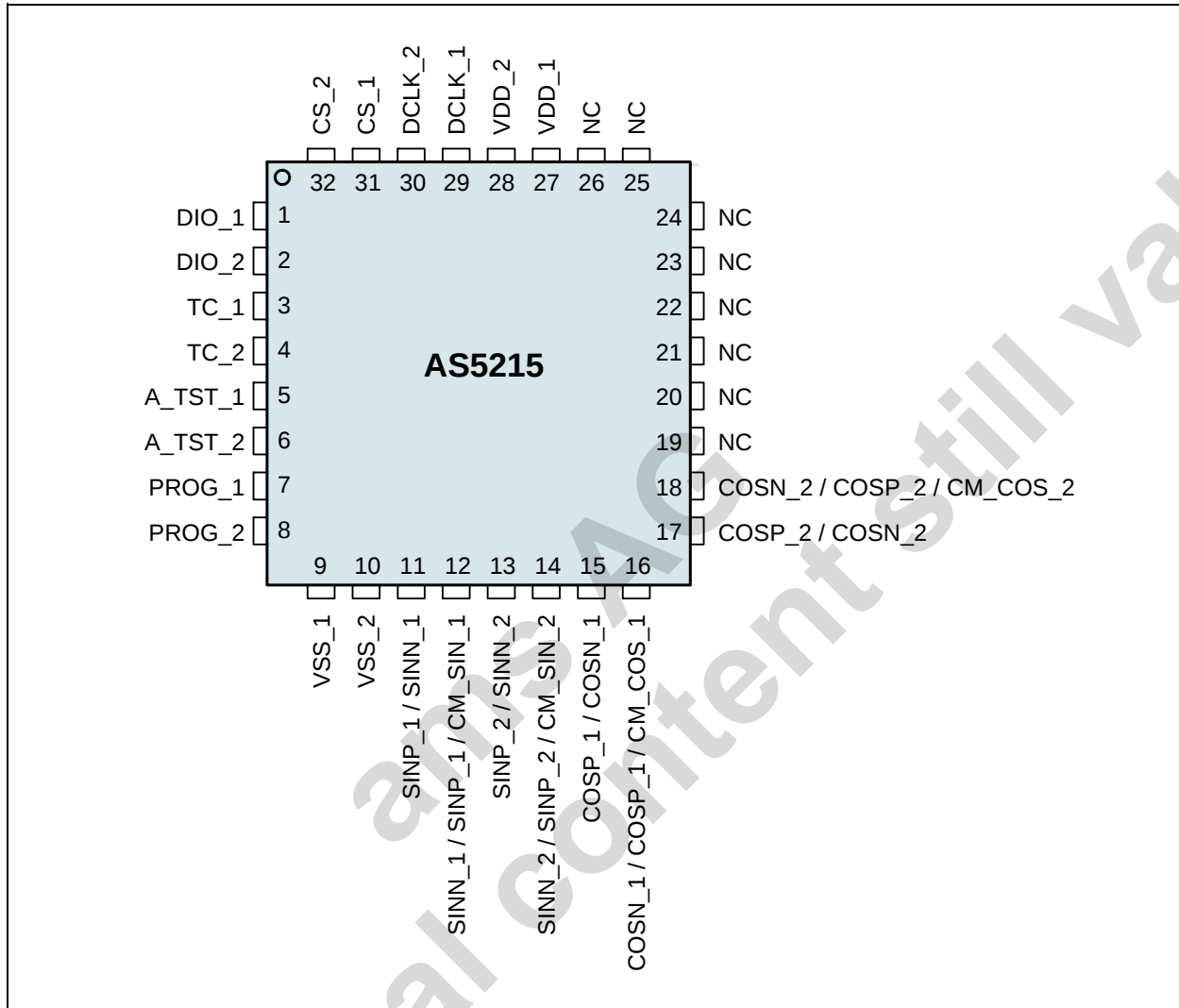


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## 4 Pin Assignments

Figure 2. Pin Assignments (Top View)



### 4.1 Pin Descriptions

Table 1. Pin Descriptions

| Pin Name | Pin Number | Description                    |
|----------|------------|--------------------------------|
| DIO_1    | 1          | Data I/O for digital interface |
| DIO_2    | 2          |                                |
| TC_1     | 3          | Test coil                      |
| TC_2     | 4          |                                |
| A_TST_1  | 5          | Analog test pin                |
| A_TST_2  | 6          |                                |
| PROG_1   | 7          | OTP Programming Pad            |
| PROG_2   | 8          |                                |

Table 1. Pin Descriptions

| Pin Name                   | Pin Number | Description                                      |
|----------------------------|------------|--------------------------------------------------|
| VSS_1                      | 9          | Supply ground                                    |
| VSS_2                      | 10         |                                                  |
| SINP_1 / SINN_1            | 11         | Switchable buffered analog output                |
| SINN_1 / SINP_1 / CM_SIN_1 | 12         | Switchable buffered analog or common mode output |
| SINP_2 / SINN_2            | 13         | Switchable buffered analog output                |
| SINN_2 / SINP_2 / CM_SIN_2 | 14         | Switchable buffered analog or common mode output |
| COSP_1 / COSN_1            | 15         | Switchable buffered analog output                |
| COSN_1 / COSP_1 / CM_COS_1 | 16         | Switchable buffered analog or common mode output |
| COSP_2 / COSN_2            | 17         | Switchable buffered analog output                |
| COSN_2 / COSP_2 / CM_COS_2 | 18         | Switchable buffered analog or common mode output |
| NC                         | 19         |                                                  |
| NC                         | 20         |                                                  |
| NC                         | 21         |                                                  |
| NC                         | 22         |                                                  |
| NC                         | 23         |                                                  |
| NC                         | 24         |                                                  |
| NC                         | 25         |                                                  |
| NC                         | 26         |                                                  |
| VDD_1                      | 27         | Digital + analog supply                          |
| VDD_2                      | 28         |                                                  |
| DCLK_1                     | 29         | Clock input for digital interface                |
| DCLK_2                     | 30         |                                                  |
| CS_1                       | 31         | Clock input for digital interface                |
| CS_2                       | 32         |                                                  |

## 5 Absolute Maximum Ratings

Stresses beyond those listed in [Table 2](#) may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in [Electrical Characteristics on page 6](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 2. Absolute Maximum Ratings

| Parameter                                          | Min  | Max                  | Units | Comments                                                                                                                                                                                                                                                                                                           |
|----------------------------------------------------|------|----------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Electrical Parameters</b>                       |      |                      |       |                                                                                                                                                                                                                                                                                                                    |
| Supply voltage (V <sub>DD</sub> )                  | -0.3 | 7                    | V     |                                                                                                                                                                                                                                                                                                                    |
| Input pin voltage (V <sub>in</sub> )               | -0.3 | V <sub>DD</sub> +0.3 | V     |                                                                                                                                                                                                                                                                                                                    |
| Input current (latchup immunity), I <sub>scr</sub> | -100 | 100                  | mA    | Norm: EIA/JESD78 Class II Level A                                                                                                                                                                                                                                                                                  |
| <b>Electrostatic Discharge</b>                     |      |                      |       |                                                                                                                                                                                                                                                                                                                    |
| Electrostatic discharge (ESD)                      |      | ±2                   | kV    | Norm: JESD22-A114E                                                                                                                                                                                                                                                                                                 |
| <b>Continuous Power Dissipation</b>                |      |                      |       |                                                                                                                                                                                                                                                                                                                    |
| Total power dissipation (P <sub>tot</sub> )        |      | 275                  | mW    |                                                                                                                                                                                                                                                                                                                    |
| Package thermal resistance (Θ <sub>JA</sub> )      |      | 27                   | °C/W  | Velocity =0; Multi Layer PCB; Jedec Standard Testboard                                                                                                                                                                                                                                                             |
| <b>Temperature Ranges and Storage Conditions</b>   |      |                      |       |                                                                                                                                                                                                                                                                                                                    |
| Storage temperature (T <sub>strg</sub> )           | -65  | 150                  | °C    |                                                                                                                                                                                                                                                                                                                    |
| Package body temperature (T <sub>body</sub> )      |      | 260                  | °C    | Norm: IPC/JEDEC J-STD-020.<br>The reflow peak soldering temperature (body temperature) specified is in accordance with IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices".<br>The lead finish for Pb-free leaded packages is matte tin (100% Sn). |
| Humidity non-condensing                            | 5    | 85                   | %     |                                                                                                                                                                                                                                                                                                                    |
| Moisture Sensitive Level (MSL)                     |      | 3                    |       | Represents a maximum floor time of 168h                                                                                                                                                                                                                                                                            |

## 6 Electrical Characteristics

Unless otherwise noted all in this specification defined tolerances of parameters are assured over the whole operation conditions range and also over lifetime.

Table 3. Operating Conditions

| Symbol           | Parameter               | Condition | Min | Typ | Max | Unit |
|------------------|-------------------------|-----------|-----|-----|-----|------|
| V <sub>DD</sub>  | Positive Supply Voltage |           | 4.5 |     | 5.5 | V    |
| V <sub>SS</sub>  | Negative Supply Voltage |           | 0.0 |     | 0.0 | V    |
| T <sub>amb</sub> | Ambient temperature     |           | -40 |     | 150 | °C   |

Table 4. DC/AC Characteristics for Digital Inputs and Outputs

| Symbol                      | Parameter                 | Condition | Min                   | Typ | Max                   | Unit |
|-----------------------------|---------------------------|-----------|-----------------------|-----|-----------------------|------|
| <b>CMOS Input</b>           |                           |           |                       |     |                       |      |
| V <sub>IH</sub>             | High level Input voltage  |           | 0.7 * V <sub>DD</sub> |     |                       | V    |
| V <sub>IL</sub>             | Low level Input Voltage   |           |                       |     | 0.3 * V <sub>DD</sub> | V    |
| I <sub>LEAK</sub>           | Input Leakage Current     |           |                       |     | 1                     | μA   |
| <b>CMOS Output</b>          |                           |           |                       |     |                       |      |
| V <sub>OH</sub>             | High level Output voltage | 4 mA      | V <sub>DD</sub> - 0.5 |     |                       | V    |
| V <sub>OL</sub>             | Low level Output Voltage  | 4 mA      |                       |     | V <sub>SS</sub> + 0.4 | V    |
| C <sub>L</sub>              | Capacitive Load           |           |                       |     | 35                    | pF   |
| t <sub>slew</sub>           | Slew Rate                 |           |                       |     | 30                    | ns   |
| t <sub>delay</sub>          | Time Rise Fall            |           |                       |     | 15                    | ns   |
| <b>CMOS Output Tristate</b> |                           |           |                       |     |                       |      |
| I <sub>OZ</sub>             | Tristate Leakage Current  |           |                       |     | 1                     | μA   |

Table 5. Magnetic Input Specification

| Symbol                                                 | Parameter                      | Condition       | Min | Typ | Max | Unit |
|--------------------------------------------------------|--------------------------------|-----------------|-----|-----|-----|------|
| Two pole cylindrical magnet, diametrically magnetized: |                                |                 |     |     |     |      |
| d <sub>MAG</sub>                                       | Diameter                       |                 | 4   | 6   |     | mm   |
| B <sub>pp</sub>                                        | Magnetic input field amplitude | 200 – 800 Gauss | 20  | 50  | 80  | mt   |
| f <sub>rot</sub>                                       | Rotational speed               | Max 30000 RPM   | 0   |     | 500 | Hz   |

Table 6. Electrical System Specifications

| Symbol                                      | Parameter                                          | Condition                                                                                            | Min                   | Typ | Max                  | Unit |
|---------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------|-----|----------------------|------|
| IDD                                         | Current Consumption                                | Max value derived at maximum I <sub>H</sub> (Hall Bias Current)<br><b>Note:</b> For single die only. | 20                    |     | 28                   | mA   |
| t <sub>power_on</sub>                       | Power up time                                      |                                                                                                      |                       |     | 1.275                | ms   |
| t <sub>prop</sub>                           | Propagation delay                                  | -40 to 150°C                                                                                         | 18                    | 22  | 30                   | μs   |
| M                                           | Magnetic Sensitivity                               | 1G = 0.1 mT                                                                                          | 1                     |     | 6                    | mV/G |
| V <sub>out</sub>                            | Analog output range                                |                                                                                                      | V <sub>SS</sub> +0.25 |     | V <sub>DD</sub> -0.5 | V    |
| SF=S <sub>F25C</sub><br>- (AP1_1/<br>AP2_1) | Amplitude ratio tracking accuracy over temperature | -40 to 150°C                                                                                         | -1                    |     | +1                   | %    |

Table 6. Electrical System Specifications

| Symbol                    | Parameter                                    | Condition                      | Min   | Typ | Max   | Unit                |
|---------------------------|----------------------------------------------|--------------------------------|-------|-----|-------|---------------------|
| SF=AP1_1/AP2_1            | Amplitude ratio mismatch at room temperature |                                | -2    |     | 2     | %                   |
| V <sub>offset1</sub>      | DC Offset                                    | Ratiometric to V <sub>DD</sub> | 0.294 | 0.3 | 0.306 | V / V <sub>DD</sub> |
| V <sub>offset2</sub>      |                                              |                                | 0.49  | 0.5 | 0.51  | V / V <sub>DD</sub> |
| DC <sub>offsetdrift</sub> | DC Offset Drift                              | -40 to 150°C                   | -50   |     | +50   | μV/°C               |
| THD                       | Total Harmonic Distortion                    |                                |       |     | 0.2   | %                   |
| SR                        | Slew Rate                                    |                                |       | 1   |       | V/μs                |
| C <sub>LOAD</sub>         | Capacitive Load                              |                                |       |     | 1000  | pF                  |

## 6.1 Timing Characteristics

Table 7. Timing Characteristics

| Symbol | Parameter                                                                    | Condition | Min          | Typ | Max           | Unit |
|--------|------------------------------------------------------------------------------|-----------|--------------|-----|---------------|------|
| t1_3   | Chip select to positive edge of DCLK                                         |           | 30           |     | -             | ns   |
| t2_3   | Chip select to drive bus externally                                          |           | 0            |     | -             | ns   |
| t3     | Setup time command bit<br>Data valid to positive edge of DCLK                |           | 30           |     | -             | ns   |
| t4     | Hold time command bit<br>Data valid after positive edge of DCLK              |           | 15           |     | -             | ns   |
| t5     | Float time<br>Positive edge of DCLK for last command bit to bus float        |           | -            |     | DCLK/<br>2+0  | ns   |
| t6     | Bus driving time<br>Positive edge of DCLK for last command bit to bus drive  |           | DCLK/<br>2+0 |     | -             | ns   |
| t7     | Data valid time<br>Positive edge of DCLK to bus valid                        |           | DCLK/<br>2+0 |     | DCLK/<br>2+30 | ns   |
| t8     | Hold time data bit<br>Data valid after positive edge of DCLK                 |           | DCLK/<br>2+0 |     | -             | ns   |
| t9_3   | Hold time chip select<br>Positive edge DCLK to negative edge of chip select  |           | DCLK/<br>2+0 |     | -             | ns   |
| t10_3  | Bus floating time<br>Negative edge of chip select to float bus               |           | -            |     | 30            | ns   |
| t11    | Setup time data bit at write access<br>Data valid to positive edge of DCLK   |           | 30           |     | -             | ns   |
| t12    | Hold time data bit at write access<br>Data valid after positive edge of DCLK |           | 15           |     | -             | ns   |
| t13_3  | Bus floating time<br>Negative edge of chip select to float bus               |           | -            |     | 30            | ns   |

**Remark:** The digital interface will be reset during the low phase of the CS signal.

## 7 Detailed Description

The AS5215 is a redundant rotary encoder sensor front end. Based on an integrated Hall element array, the angular position of a simple two-pole magnet is translated into analog output voltages. The angle information is provided by means of sine and cosine voltages. This approach gives maximum flexibility in system design, as it can be directly integrated into existing architectures and optimized for various applications in terms of speed and accuracy.

With two independent dies in one package, the device offers true redundancy. Usually the bottom die, which is exposed to slightly less magnetic field is employed for plausibility check.

An SSI (SPI standard) protocol is implemented for internal test access to the different circuit blocks and for signal path configuration.

A One Time Programmable register block (OTP) allows the customer to adjust the signal path gain to adjust for different mechanical constraints and magnetic field strengths. Furthermore, for internal use, the test mode can be enabled and the system oscillator is trimmable, DC offset of the output signal can be set to either 1.5V or 2.5V. A unique chip ID is stored to ensure traceability.

For operating point control, a band gap circuit is implemented together with a central bias block to distribute all reference bias currents for the analog signal conditioning. The digital signal part is based on a 2MHz system, CLK derived via divider from a 4MHz system oscillator.

Figure 3. Typical Arrangement of AS5215 and Magnet



### 7.1 Magnet Diameter and Vertical Distance

**Note:** Following is just an abstract taken from the elaborate application note on the Magnet.

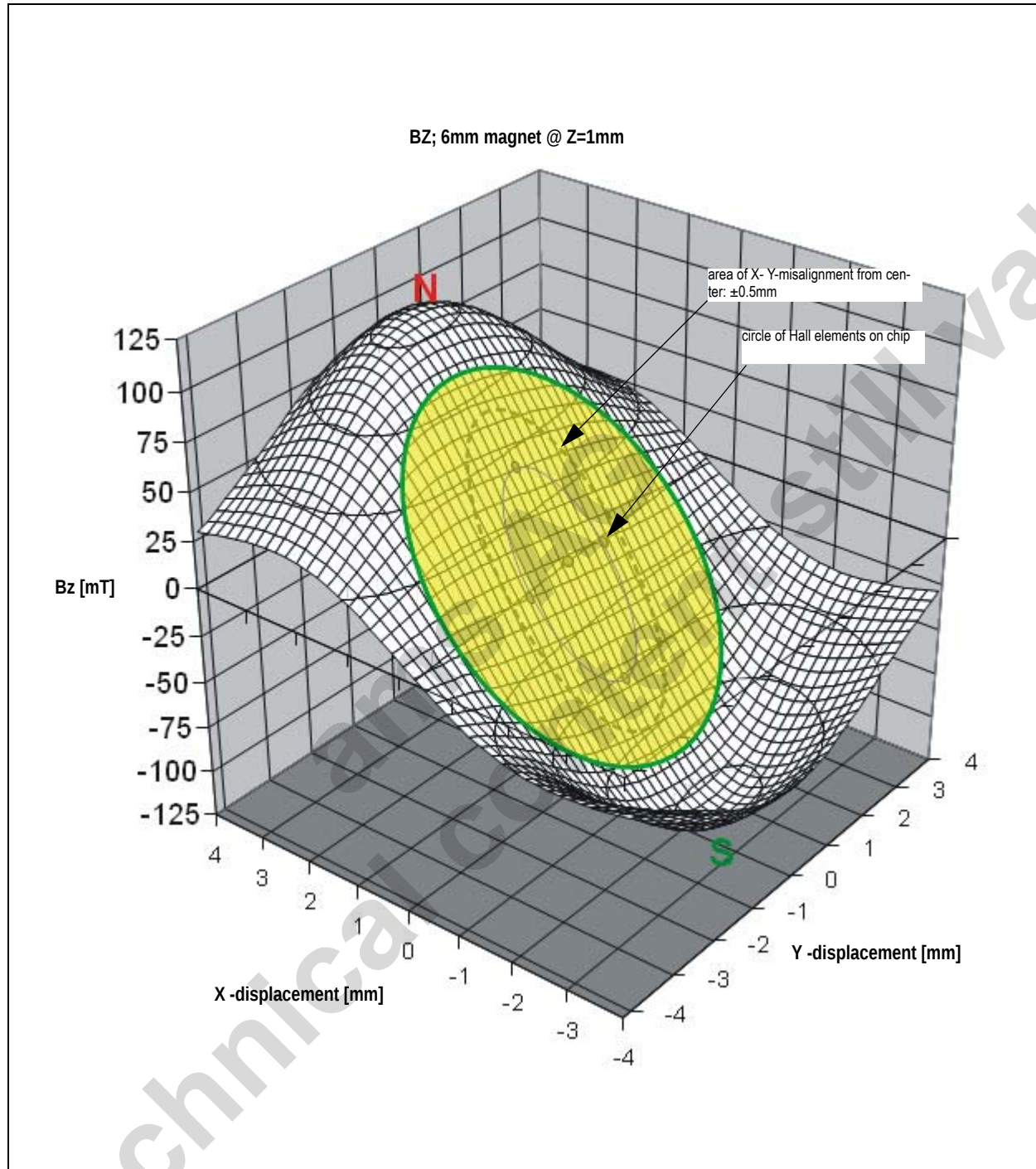
For more detailed information, please visit our homepage [www.austriamicrosystems.com](http://www.austriamicrosystems.com) → [Magnetic Rotary Encoders](#) → Magnet Application Notes

#### 7.1.1 The Linear Range

The Hall elements used in the AS5000-series sensor ICs are sensitive to the magnetic field component  $B_z$ , which is the magnetic field vertical to the chip surface. Figure 4 shows a 3-dimensional graph of the  $B_z$  field across the surface of a 6mm diameter, cylindrical NdFeB N35H magnet at an axial distance of 1mm between magnet and IC.

The highest magnetic field occurs at the north and south poles, which are located close to the edge of the magnet, at ~2.8mm radius (see Figure 5). Following the poles towards the center of the magnet, the  $B_z$  field decreases very linearly within a radius of ~1.6mm. This linear range is the operating range of the magnet with respect to the Hall sensor array on the chip. For best performance, the Hall elements should always be within this linear range.

Figure 4. 3D-Graph of Vertical Magnetic Field of a 6mm Cylindrical Magnet

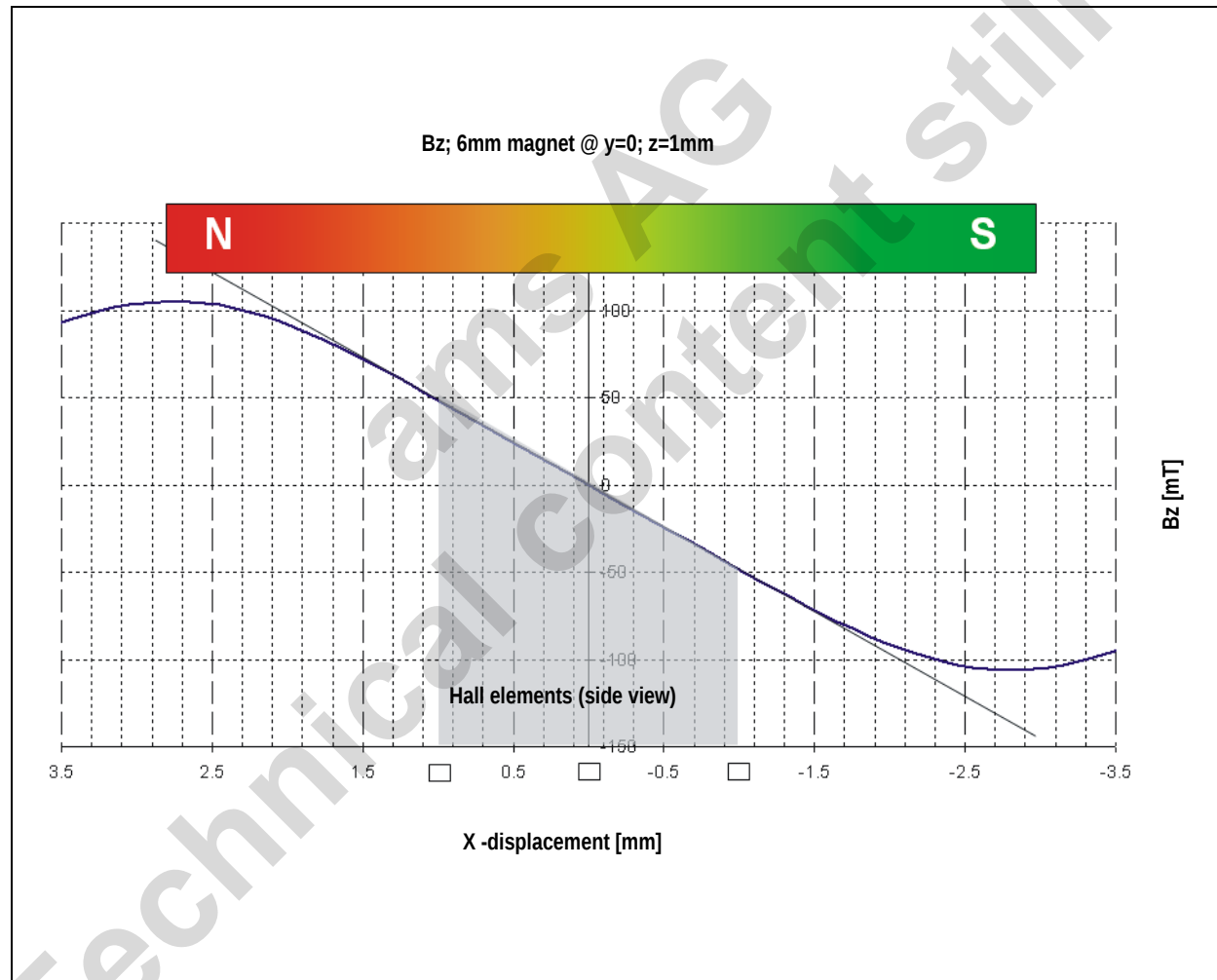


As shown in Figure 5 (grey zone), the Hall elements are located on the chip at a circle with a radius of 1mm. Since the difference between two opposite Hall sensors is measured, there will be no difference in signal amplitude when the magnet is perfectly centered or if the magnet is misaligned in any direction as long as all Hall elements stay within the linear range.

For the 6mm magnet (shown in Figure 5), the linear range has a radius of 1.6mm, hence this magnet allows a radial misalignment of 0.5mm (1.6mm linear range radius; 1mm Hall array radius). Consequently, the larger the linear range, the more radial misalignment can be tolerated. By contrast, the slope of the linear range decreases with increasing magnet diameter, as the poles are further apart. A smaller slope results in a smaller differential signal, which means that the magnet must be moved closer to the IC (smaller airgap) or the amplification gain must be increased, which leads to a poorer signal-to-noise ratio. More noise results in more jitter at the angle output. A good compromise is a magnet diameter in the range of 5...8mm.

| Small Diameter Magnet (<6mm)                                                     | Large Diameter Magnet (>6mm)                                                      |
|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| + stronger differential signal =<br>good signal / noise ratio,<br>larger airgaps | + wider linear range =<br>larger horizontal misalignment area                     |
| - shorter linear range =<br>smaller horizontal misalignment area                 | - weaker differential signal =<br>poorer signal / noise ratio,<br>smaller airgaps |

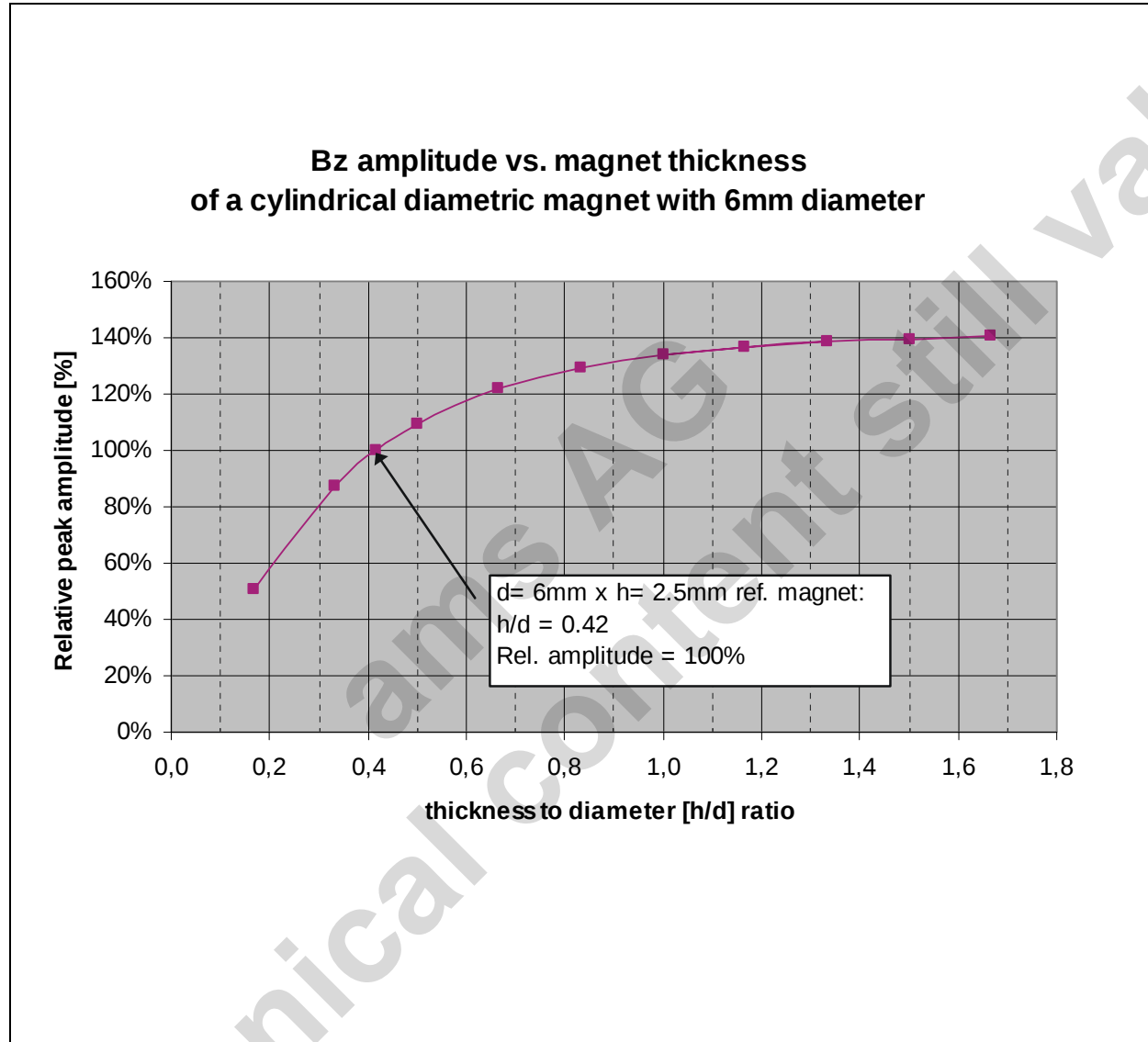
Figure 5. Vertical Magnetic Field Across the Center of a Cylindrical Magnet



### 7.1.2 Magnet Thickness

Figure 6 shows the relationship of the peak amplitude in a rotating system (essentially the magnetic field strength of the Bz field component) in relation to the thickness of the magnet. The X-axis shows the ratio of magnet thickness (or height) [h] to magnet diameter [d] and the Y-axis shows the relative peak amplitude with reference to the recommended magnet ( $d=6\text{mm}$ ,  $h=2.5\text{mm}$ ). This results in an  $h/d$  ratio of 0.42.

Figure 6. Relationship of Peak Amplitude vs. Magnet Thickness



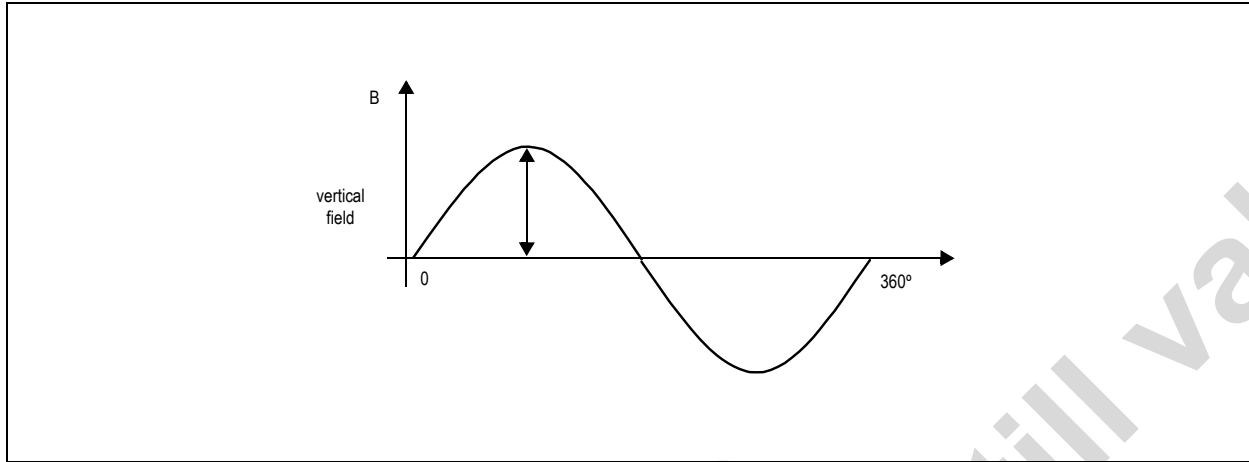
As the graph in Figure 6 shows, the amplitude drops significantly at  $h/d$  ratios below this value and remains relatively flat at ratios above 1.3.

Therefore, the recommended thickness of 2.5mm (at 6mm diameter) should be considered as the low limit with regards to magnet thickness.

It is possible to get 40% or more signal amplitude by using thicker magnets. However, the gain in signal amplitude becomes less significant for  $h/d$  ratios  $>1.3$ . Therefore, the recommended magnet thickness for a 6mm diameter magnet is between 2.5 and ~8 mm.

### 7.1.3 Axial Distance (Airgap)

Figure 7. Sinusoidal Magnetic Field Generated by the Rotating Magnet



The recommended magnetic field, measured at the chip surface on a radius equal to the Hall sensor array radius (typ 1mm) should be within a certain range. This range lies between 45 and 75mT or between 20 and 80mT, depending on the encoder product.

Linear position sensors are more sensitive as they use weaker magnets. The allowed magnetic range lies typically between 5 and 60mT.

#### 7.1.4 Angle Error vs. Radial and Axial Misalignment

The angle error is the deviation of the actual angle vs. the angle measured by the encoder. There are several factors in the chip itself that contribute to this error, mainly offset and gain matching of the amplifiers in the analog signal path. On the other hand, there is the nonlinearity of the signals coming from the Hall sensors, caused by misalignment of the magnet and imperfections in the magnetic material.

Ideally, the Hall sensor signals should be sinusoidal, with equal peak amplitude of each signal. This can be maintained, as long as all Hall elements are within the linear range of the magnetic field  $B_z$  (see Figure 5).

#### 7.1.5 Mounting the Magnet

Generally, for on-axis rotation angle measurement, the magnet must be mounted centered over the IC package. However, the material of the shaft into which the magnet is mounted, is also of big importance.

Magnetic materials in the vicinity of the magnet will distort or weaken the magnetic field being picked up by the Hall elements and cause additional errors in the angular output of the sensor.

Figure 8. Magnetic Field Lines in Air

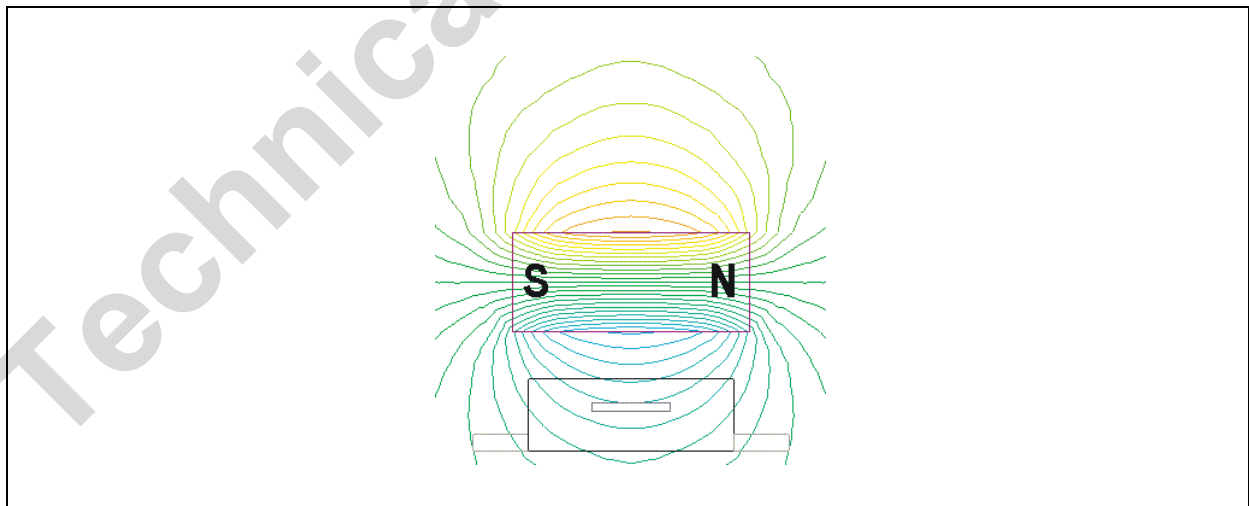
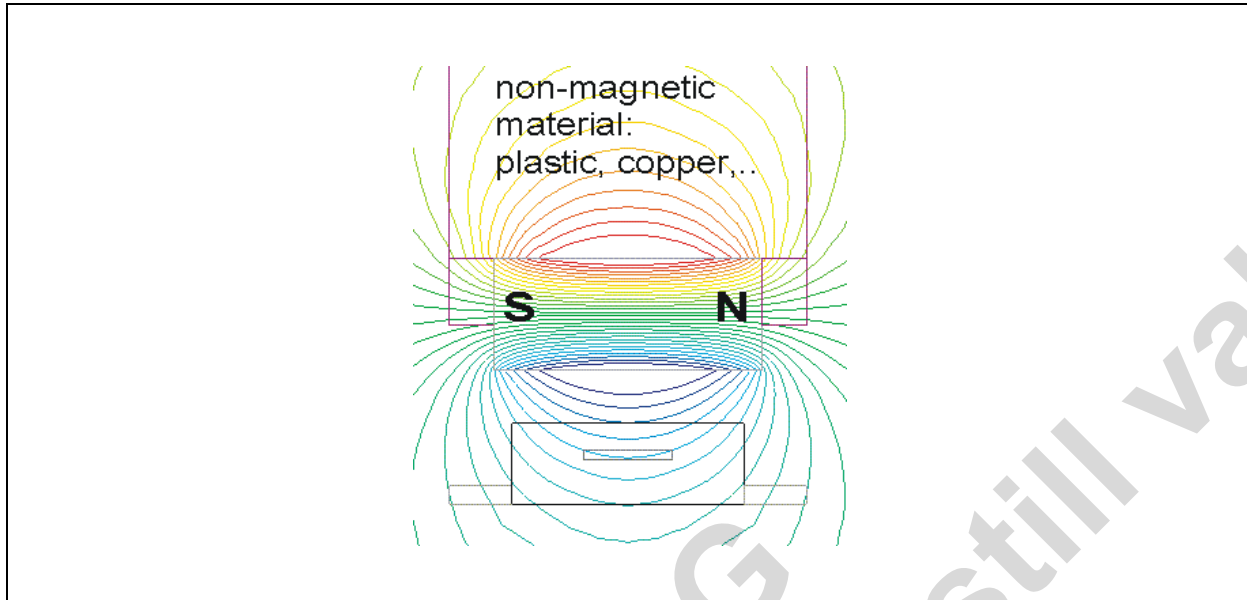


Figure 8 shows the ideal case with the magnet in air. No magnetic materials are anywhere nearby.

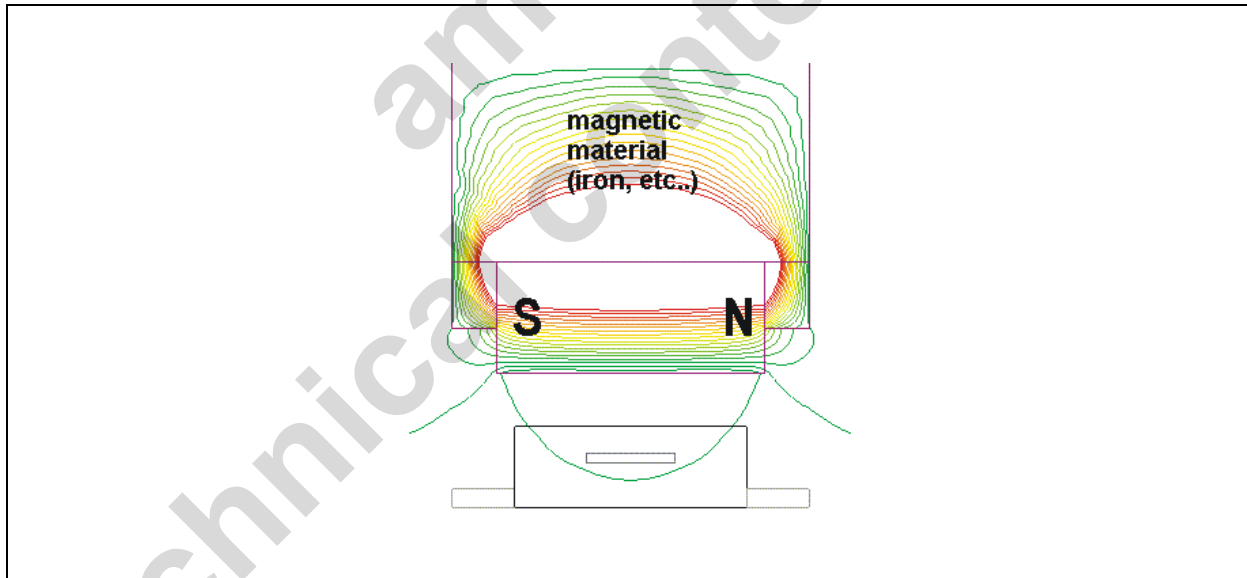
Figure 9. Magnetic Field Lines in Plastic or Copper Shaft



If the magnet is mounted in non-magnetic material, such as plastic or diamagnetic material, such as copper, the magnetic field distribution is not disturbed. Even paramagnetic material, such as aluminium may be used. The magnet may be mounted directly in the shaft (see Figure 9).

**Note:** Stainless steel may also be used, but some grades are magnetic. Therefore, steel with magnetic grades should be avoided.

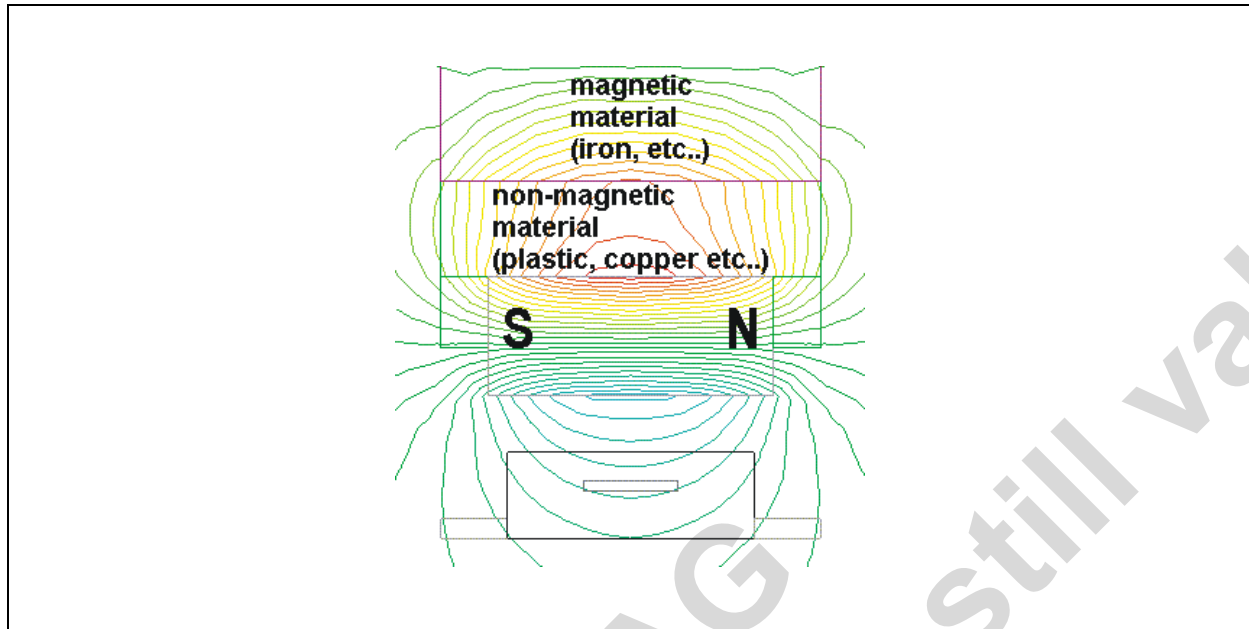
Figure 10. Magnetic Field Lines in Iron Shaft



If the magnet is mounted in a ferromagnetic material, such as iron, most of the field lines are attracted by the iron and flow inside the metal shaft (see Figure 10). The magnet is weakened substantially.

This configuration should be avoided!

Figure 11. Magnetic Field Lines with Spacer Between Magnet and Iron Shaft



If the magnet has to be mounted inside a magnetic shaft, a possible solution is to place a non-magnetic spacer between shaft and magnet, as shown in Figure 11. While the magnetic field is rather distorted towards the shaft, there are still adequate field lines available towards the sensor IC. The distortion remains reasonably low.

#### 7.1.6 Summary

- Small diameter magnets (<6mm Ø) have a shorter linear range and allow less lateral misalignment. The steeper slope allows larger axial distances.
- Large diameter magnets (>6 mm Ø) have a wider linear range and allow a wider lateral misalignment. The flatter slope requires shorter axial distances.
- The linear range decreases with airgap; Best performance is achieved at shorter airgaps.
- The ideal vertical distance range can be determined by using magnetic range indicators provided by the encoder ICs. These indicators are named MagInc, MagDec, MagRngn, or similar, depending on product.

## 8 Application Information

### 8.1 Sleep Mode

The target is to provide the possibility to reduce the total current consumption. No output signal will be provided when the IC is in sleep mode. Enabling or disabling sleep mode is done by sending the SLEEP or WAKEUP commands via the SSI interface. Analog blocks are powered down with respect to fast wake up time.

### 8.2 SSI Interface

The setup for the device is handled by the digital interface. Each communication starts with the rising edge of the chip select signal. The synchronization between the internal free running analog clock oscillator and the external used digital clock source for the digital interface is done in a way that the digital clock frequency can vary in a wide range.

Table 8. SSI Interface Pin Description

| Port                            | Symbol | Function                                                                                                         |
|---------------------------------|--------|------------------------------------------------------------------------------------------------------------------|
| Chip select                     | CS     | Indicates the start of a new access cycle to the device<br>CS = LO → reset of the digital interface              |
| DCLK                            | DCLK   | Clock source for the communication over the digital interface                                                    |
| Bidirectional data input output | DIO    | Command and data information over one single line<br>The first bit of the command defines a read or write access |

Table 9. SSI Interface Parameter Description

| Symbol                                         | Parameter                                      | Notes                                                                                                                                                                                                           | Min      | Typ   | Max   | Unit |
|------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------|-------|------|
| f_DCLK                                         | Clock frequency at normal operation            | The nominal value for the clock frequency can be derived from a 10MHz oscillator source.                                                                                                                        | no limit | 5     | 6     | MHz  |
| f_EZ_RW                                        | Clock frequency at easy zap read write access  |                                                                                                                                                                                                                 | no limit | 5     | 6     | kHz  |
| f_EZ_PROG                                      | Clock frequency at easy zap access program OTP | Correct access to the programmable zener diode block needs a strict timing – the zap pulse is exact one period.<br><br>The nominal value for the clock frequency can be derived from a 10MHz oscillator source. | 200      | -     | 650   | kHz  |
| f_EZ_ARB                                       | Clock frequency at easy zap analog readback    | 20pF external load allowed.<br><br>The nominal value for the clock frequency can be derived from a 10MHz oscillator source.                                                                                     | no limit | 156.3 | 162.5 | kHz  |
| Interface General at normal mode               |                                                |                                                                                                                                                                                                                 |          |       |       |      |
| Protocol: 5 command bit + 16 data input output |                                                |                                                                                                                                                                                                                 |          |       |       |      |
| Command                                        |                                                | 5 bit command: cmd<4:0> ← bit<21:16>                                                                                                                                                                            |          |       |       |      |
| Data                                           |                                                | 16 bit data: data<15:0> ← bit<15:0>                                                                                                                                                                             |          |       |       |      |
| Interface General at extended mode             |                                                |                                                                                                                                                                                                                 |          |       |       |      |
| Protocol: 5 command bit + 46 data input output |                                                |                                                                                                                                                                                                                 |          |       |       |      |
| Command                                        |                                                | 5 bit command: cmd<4:0> ← bit<50:46>                                                                                                                                                                            |          |       |       |      |
| Data                                           |                                                | 34 bit data: data<45:0> ← bit<45:0>                                                                                                                                                                             |          |       |       |      |
| Interface Modes                                |                                                |                                                                                                                                                                                                                 |          |       |       |      |
| Normal read operation mode                     |                                                | cmd<4:0> = <00xxx> → 1 DCLK per data bit                                                                                                                                                                        |          |       |       |      |
| Extended read operation mode                   |                                                | cmd<4:0> = <01xxx> → 4 DCLK per data bit                                                                                                                                                                        |          |       |       |      |
| Normal write operation mode                    |                                                | cmd<4:0> = <10xxx> → 1 DCLK per data bit                                                                                                                                                                        |          |       |       |      |
| Extended write operation mode                  |                                                | cmd<4:0> = <11xxx> → 4 DCLK per data bit                                                                                                                                                                        |          |       |       |      |

### 8.3 Device Communication / Programming

Table 10. Digital Interface at Normal Mode

| #  | command        | bin   | mode  | 15       | 14      | 13 | 12 | 11 | 10 | 9          | 8           | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----------------|-------|-------|----------|---------|----|----|----|----|------------|-------------|---|---|---|---|---|---|---|---|
| 23 | WRITE CONFIG 1 | 10111 | write | go2sleep | gen_rst |    |    |    |    | analog_sig | OB_bypassed |   |   |   |   |   |   |   |   |
| 16 | EN_PROG        | 10000 | write | 1        | 0       | 0  | 0  | 1  | 1  | 0          | 0           | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |

| Name        | Functionality                                        |
|-------------|------------------------------------------------------|
| go2sleep    | Enter/leave low power mode (no output signals)       |
| gen_rst     | Generates global reset                               |
| analog_sig  | Switches the channels to the test bus after the PGA  |
| OB_bypassed | Disable and bypass output buffer for testing purpose |

Table 11. Digital Interface at Extended Mode

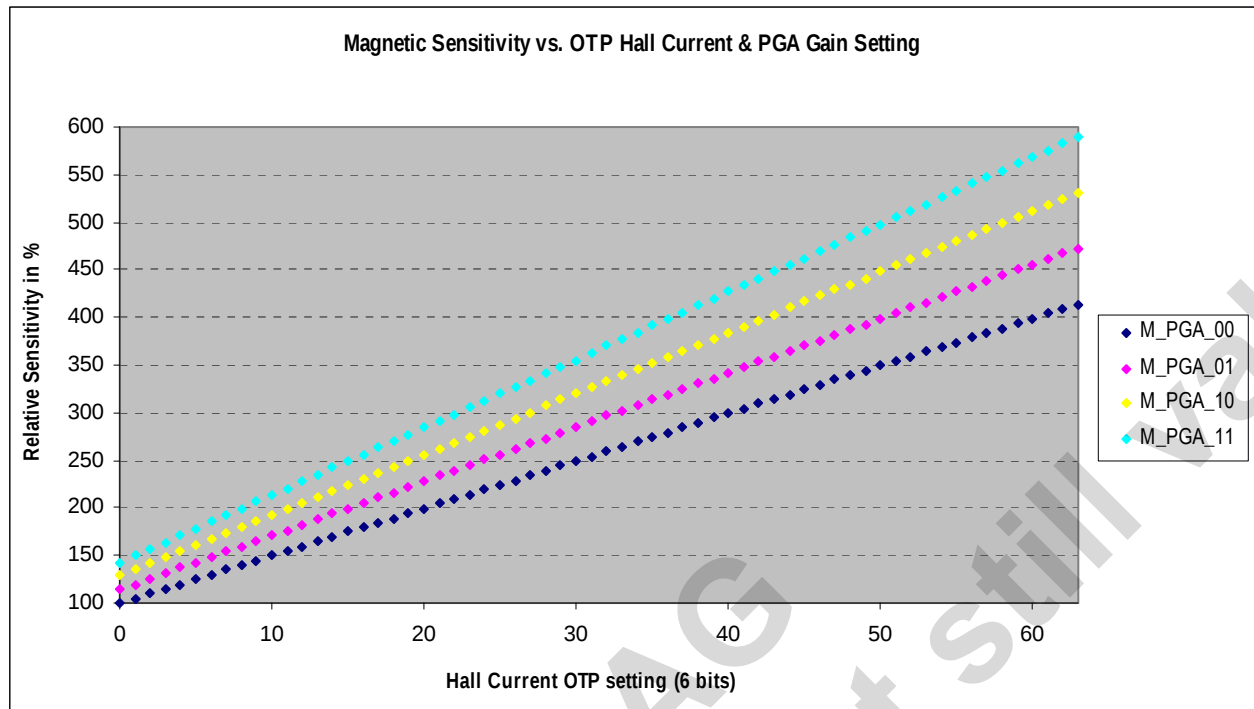
| #  | command    | bin   | mode     | Factory Settings |         |                   |         |         |         |          |      | User Settings  |        |        |       |           |           |
|----|------------|-------|----------|------------------|---------|-------------------|---------|---------|---------|----------|------|----------------|--------|--------|-------|-----------|-----------|
|    |            |       |          | <45:44>          | <43:26> | <25:23>           | <22:20> | <19:18> | <17:14> | <13>     | <12> | <11>           | <10>   | <9>    | <8:7> | <6>       | <5:0>     |
| 31 | WRITE OTP  | 11111 | xt write | otp test         | ID      | 10 $\mu$ biastrim |         | vref    | osc     | lock_OTP | n.c. | invert_channel | cm_sin | cm_cos | gain  | dc_offset | hall_bias |
| 25 | PROG_OTP   | 11001 | xt write | otp test         | ID      | 10 $\mu$ biastrim |         | vref    | osc     | lock_OTP | n.c. | invert_channel | cm_sin | cm_cos | gain  | dc_offset | hall_bias |
| 15 | RD_OTP     | 01111 | xt read  | otp test         | ID      | 10 $\mu$ biastrim |         | vref    | osc     | lock_OTP | n.c. | invert_channel | cm_sin | cm_cos | gain  | dc_offset | hall_bias |
| 9  | RD_OTP_ANA | 01001 | xt read  |                  |         |                   |         |         |         |          |      |                |        |        |       |           |           |

#### Remark:

1. Send EN PROG (command 16) in normal mode before accessing the OTP in extended mode.
2. OTP assignment will be defined/updated.

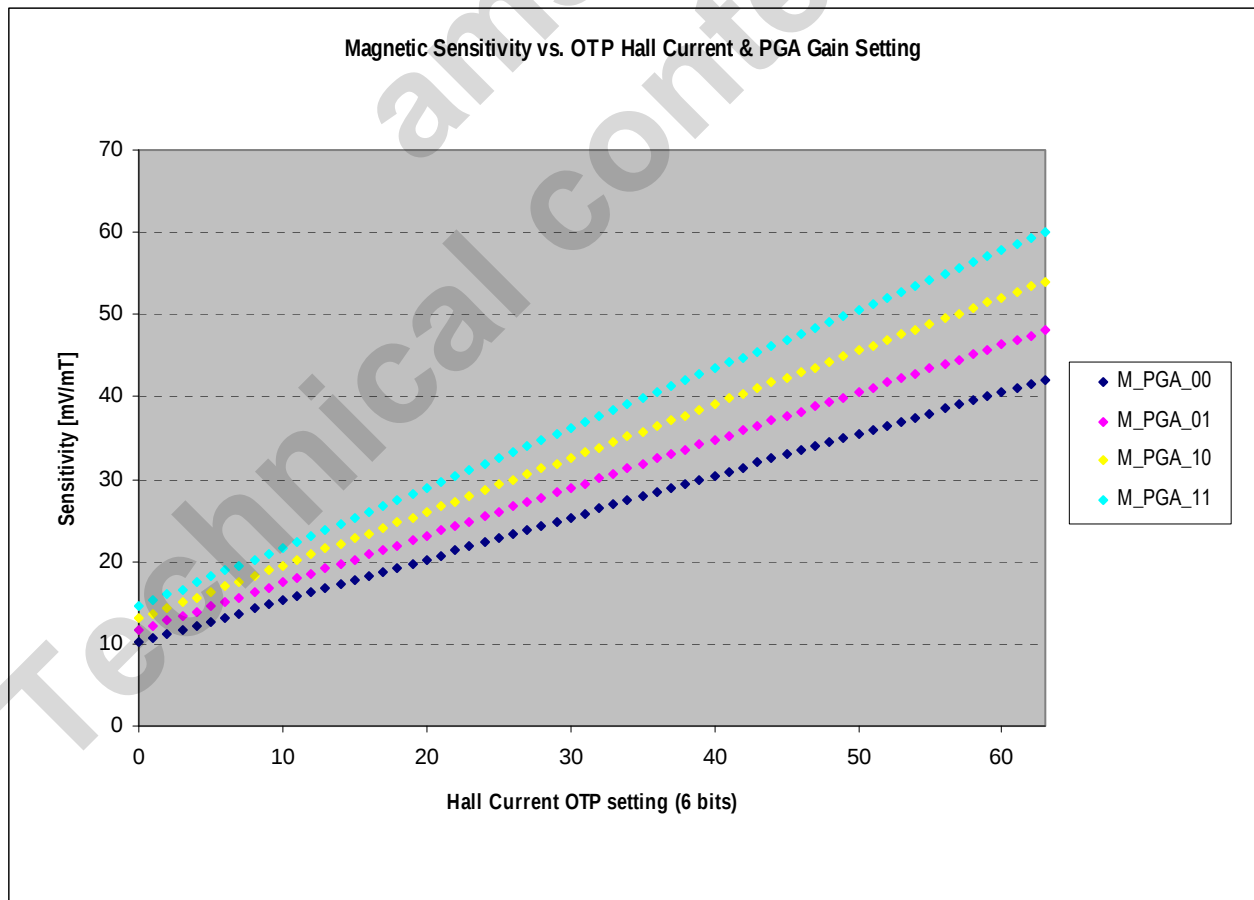
| Name              | Functionality                                                                                        |
|-------------------|------------------------------------------------------------------------------------------------------|
| Otp_test          | Dummy fuse bit used in production test                                                               |
| ID                | Part identification                                                                                  |
| n.c.              | Not connected                                                                                        |
| 10 $\mu$ biastrim | 10 $\mu$ bias current trim bits                                                                      |
| vref              | Bias Block reference voltage trim bits                                                               |
| osc               | Oscillator trimming bits                                                                             |
| lock_OTP          | To disable the programming of the factory bits <45...14>                                             |
| invert_channel    | Inverts SIN and COS channel before the PGA for inverted output function (0...SIN/COS, 1...SINN/COSN) |
| cm_sin            | Common mode voltage output enabled at SINN / CM pin (0...differential, 1...common)                   |
| cm_cos            | Common mode voltage output enabled at COSN / CM pin (0...differential, 1...common)                   |
| gain              | PGA gain setting (influences overall magnetic sensitivity), 2bit                                     |
| dc_offset         | Output DC offset (0...1.5V, 1...2.5V)                                                                |
| Hall_b            | Hall bias setting (influences overall magnetic sensitivity), 6bit                                    |

Figure 12. Sensitivity Gain Settings - Relative Sensitivity in %



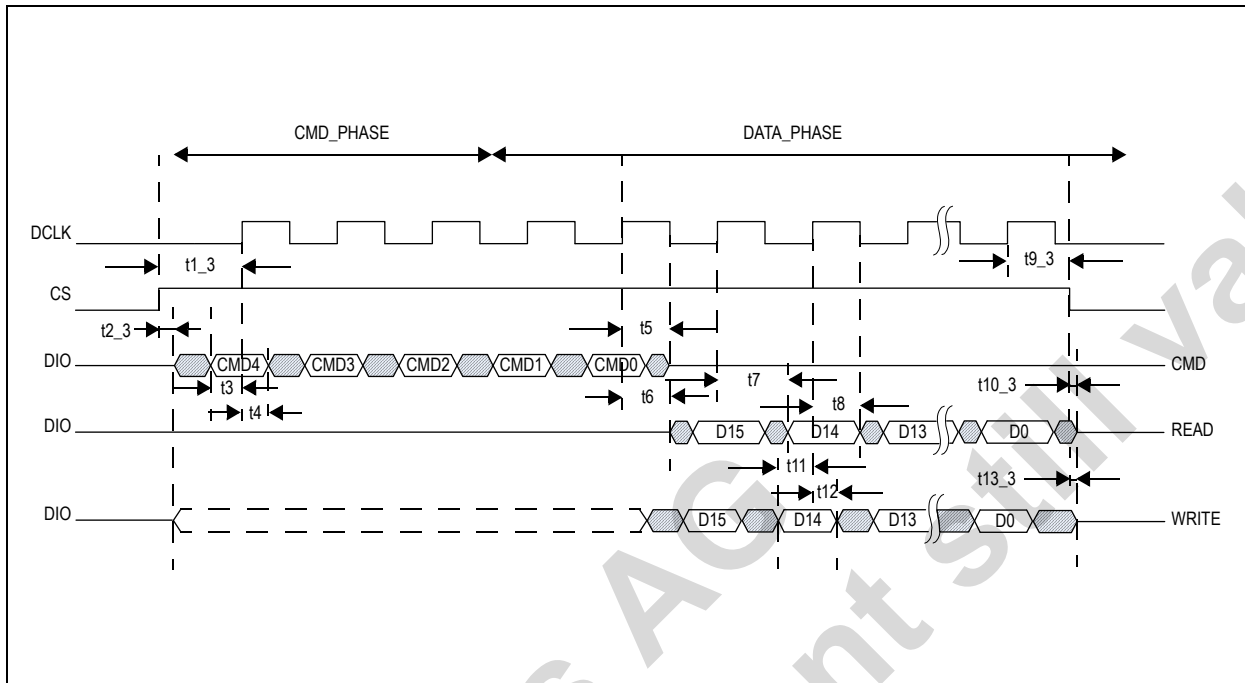
The amplitude of the output signal is programmable via sensitivity (6bit) and/or gain (2bit) settings (see Figure 12).

Figure 13. Sensitivity Gain Settings - Sensitivity [mV/mT]



## 8.4 Waveform – Digital Interface at Normal Operation Mode

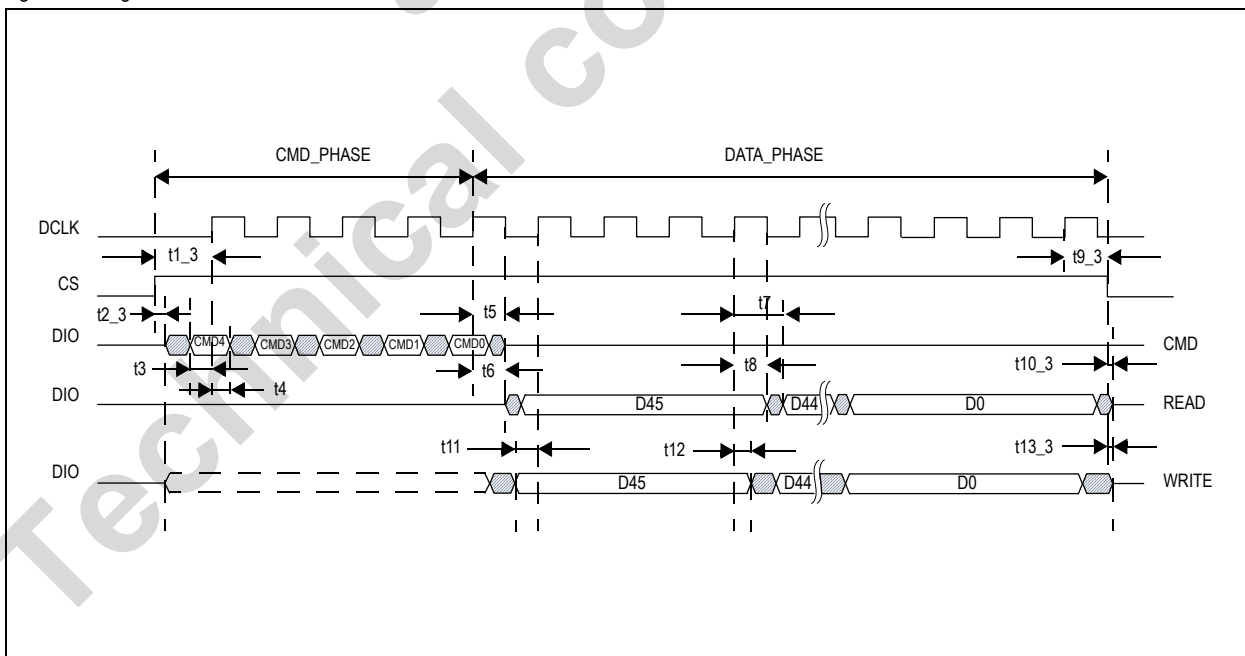
Figure 14. Digital Interface at Normal Operation Mode



## 8.5 Waveform – Digital Interface at Extended Mode

In the extended mode, the digital interface needs four clocks for one data bit. During this time, the device is able to handle internal signals for special access (e.g. the easy zap interface).

Figure 15. Digital Interface at Extended Mode



## 8.6 Waveform – Digital Interface at Analog Readback of the Zener Diodes

To be sure that all Zener-Diodes are correctly burned, an analog readback mechanism is defined. Perform the 'READ OTP ANA' sequence according to the command table and measure the value of the diode at the end of each phase.

Figure 16. Digital Interface at Analog Readback of Zener Diodes

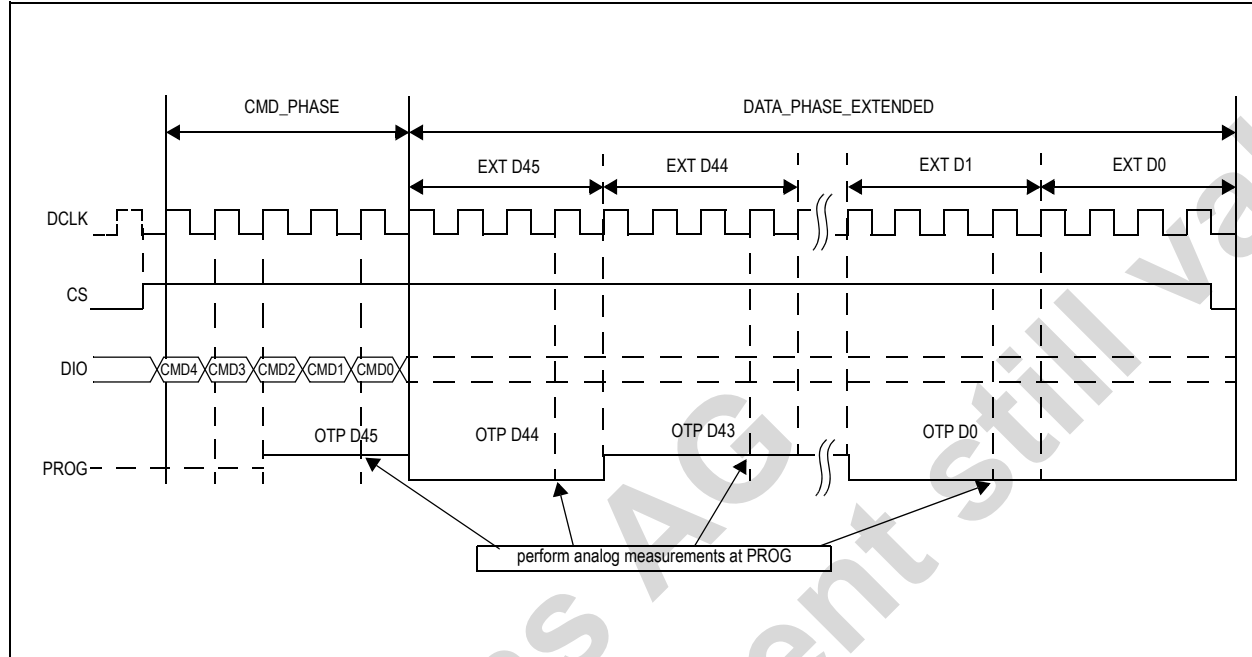


Table 12. Serial Bit Sequence (16-bit read / write)

| Write Command |    |    |    |    | Read / Write Data |     |     |     |     |     |    |    |    |    |    |    |    |    |    |    |
|---------------|----|----|----|----|-------------------|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| C4            | C3 | C2 | C1 | C0 | D15               | D14 | D13 | D12 | D11 | D10 | D9 | D8 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

## 8.7 EasyZapp OTP Content

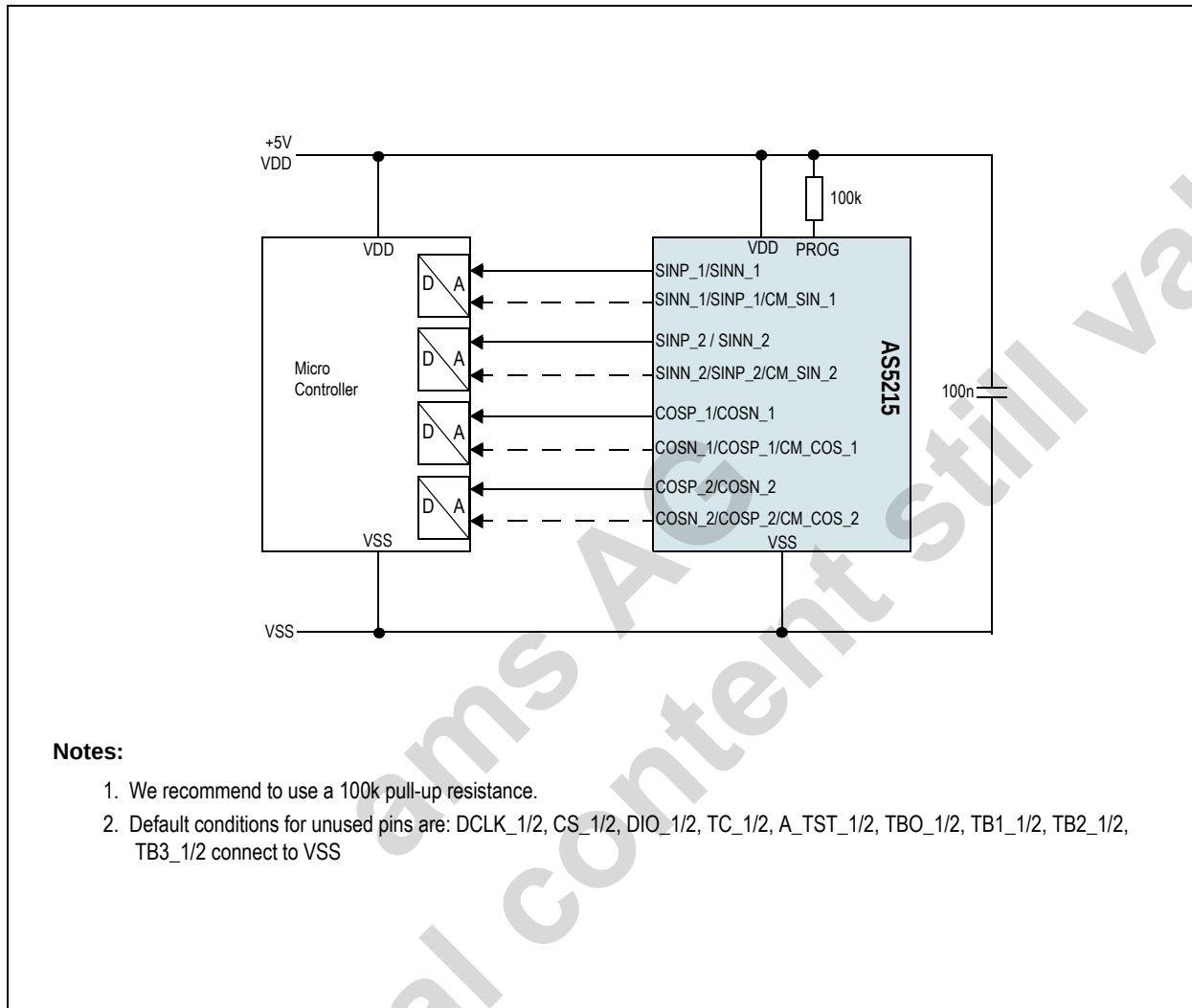
Each AS5215 die has an integrated 32-bit OTP ROM (EasyZapp) for trimming and configuration purposes. The PROM can be programmed via the serial interface. For irreversible programming, an external programming voltage at PROG pin is needed. For security reasons, the factory trim bits can be locked by a lock bit.

| Name           | Bit Count | OTP Start | OTP End | Access              | Comments                                                                |
|----------------|-----------|-----------|---------|---------------------|-------------------------------------------------------------------------|
| Hall Bias      | 6         | 0         | 5       | user                | Sets overall sensitivity                                                |
| DC offset      | 1         | 6         | 6       | user                | Output DC offset setting                                                |
| gain           | 2         | 7         | 8       | user                | Programmable gain amplifier setting                                     |
| Lock           | 1         | 13        | 13      | austriamicrosystems | Set in production test                                                  |
| invert_channel | 1         | 11        | 11      | user                | Inverts SIN and COS channel before the PGA for inverted output function |
| cm_sin         | 1         | 10        | 10      | user                | Common mode voltage output enabled at SINN / CM pin                     |
| cm_cos         | 1         | 9         | 9       | user                | Common mode voltage output enabled at COSN / CM pin                     |

**Remark:** OTP assignment will be defined/updated.

## 8.8 Analog Sin/Cos Outputs with External Interpolator

Figure 17. Sine and Cosine Outputs for External Angle Calculation



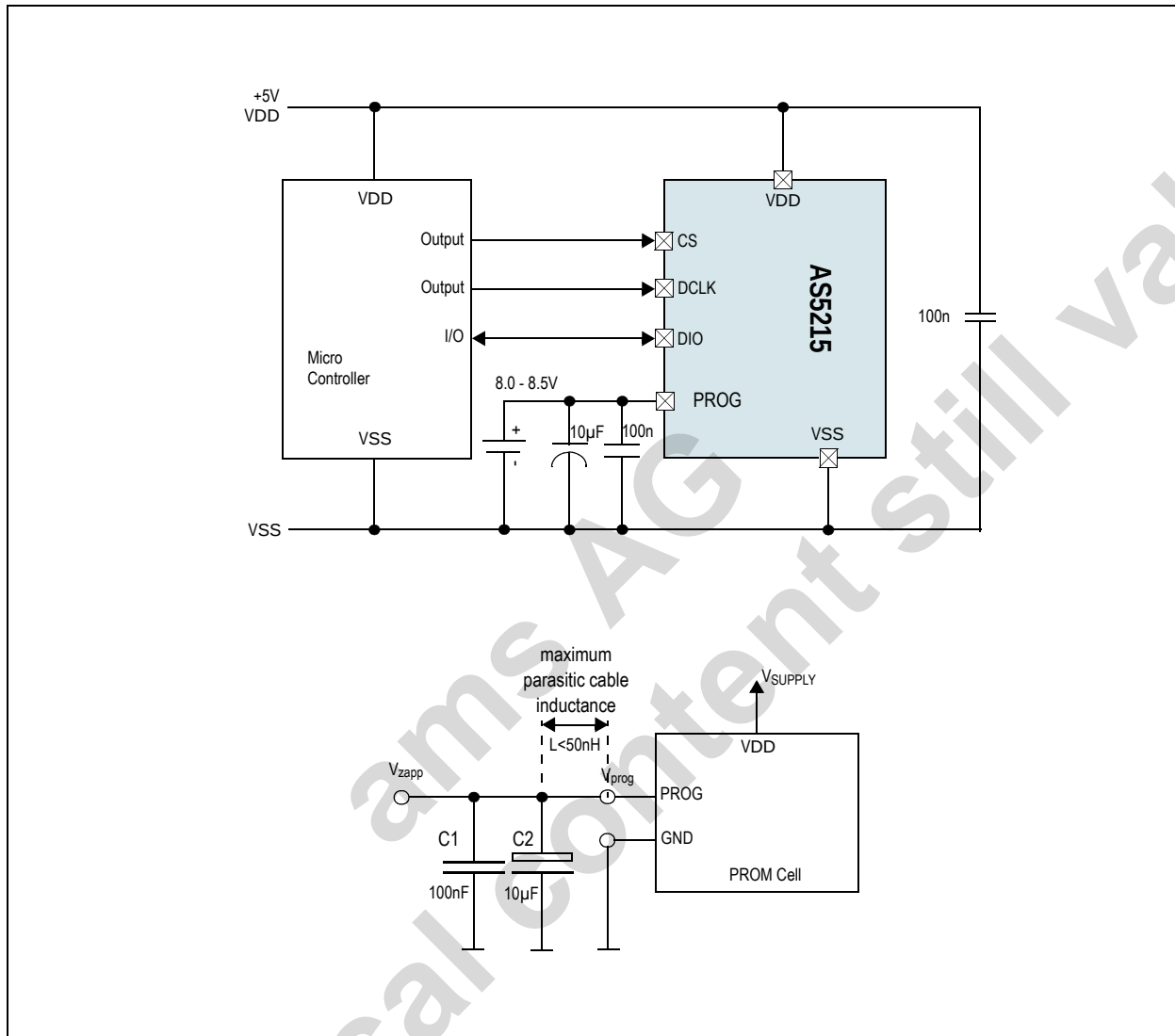
The AS5215 provides analog Sine and Cosine outputs (SINP, COSP) of the Hall array front-end for test purposes. These outputs allow the user to perform the angle calculation by an external ADC +  $\mu$ C, e.g. to compute the angle with a high resolution. The output driver capability is 1mA. The signal lines should be kept as short as possible, longer lines should be shielded in order to achieve best noise performance.

Through the programming of one bit, you have the possibility to choose between the analog Sine and Cosine outputs (SINP, COSP) and their inverted signals (SINN, COSN). Furthermore, by programming the bits <9:10> you can enable the common mode output signals of SIN and COS.

The DC bias voltage is 1.5 or 2.5 V.

## 8.9 OTP Programming and Verification

Figure 18. OTP Programming Connection



For programming of the OTP, an additional voltage has to be applied to the pin PROG. It has to be buffered by a fast 100nF capacitor (ceramic) and a 10µF capacitor. The information to be programmed is set by command 25. The OTP bits 16 until 45 are used for AMS factory trimming and cannot be overwritten.

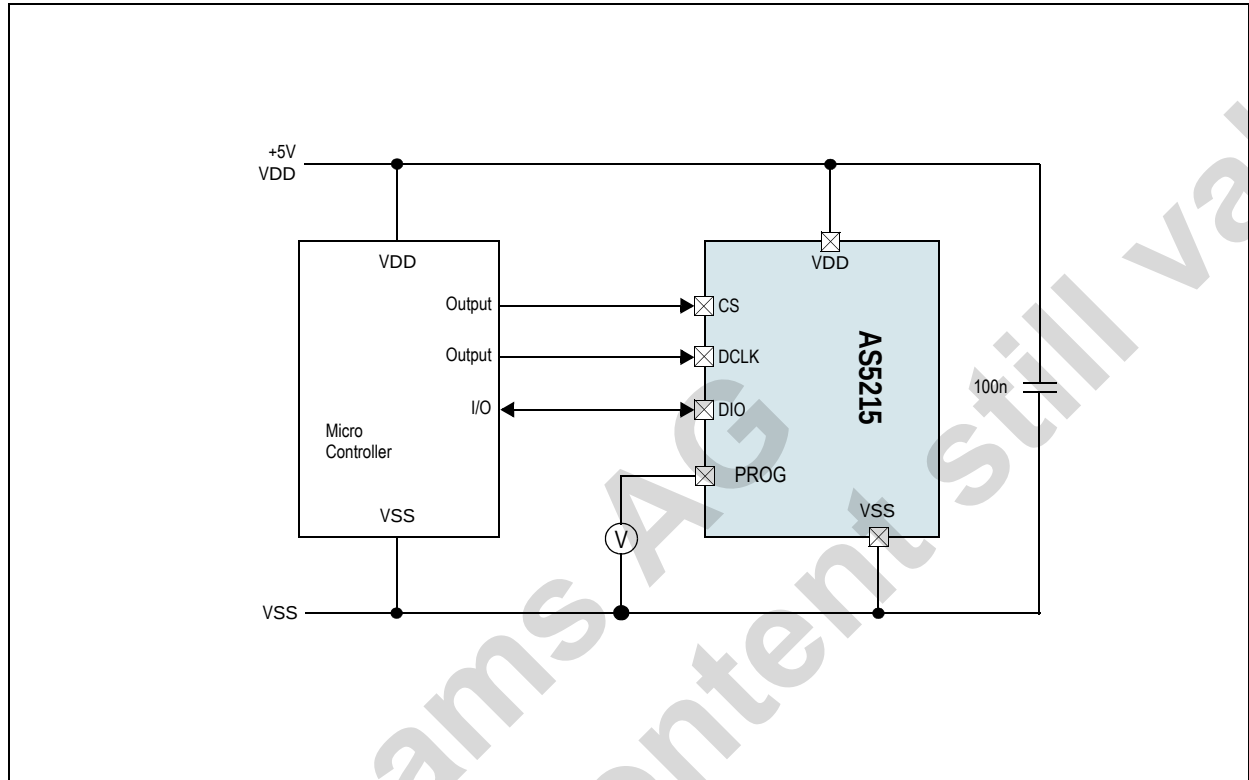
| Symbol            | Parameter           | Min | Max | Unit | Note        |
|-------------------|---------------------|-----|-----|------|-------------|
| V <sub>DD</sub>   | Supply Voltage      | 5   | 5.5 | V    |             |
| GND               | Ground level        | 0   | 0   | V    |             |
| V <sub>zapp</sub> | Programming Voltage | 8   | 8.5 | V    | At pin PROG |
| T <sub>zapp</sub> | Temperature         | 0   | 85  | °C   |             |
| f <sub>clk</sub>  | CLK Frequency       |     | 100 | kHz  | At pin DCLK |

After programming, the programmed OTP bits must be verified in two ways:

**By Digital Verification:** This is simply done by sending a READ OTP command (#15). The structure of this register is the same as for the OTP PROG or OTP WRITE commands.

**By Analog Verification:** By switching into Extended Mode and sending an ANALOG OTP READ command (#9), pin PROG becomes an output, sending an analog voltage with each clock representing a sequence of the bits in the OTP register (starting with D45). A voltage of <500mV indicates a correctly programmed bit ("1") while a voltage level between 2V and 3.5V indicates a correctly unprogrammed bit ("0"). Any voltage level in between indicates incorrect programming.

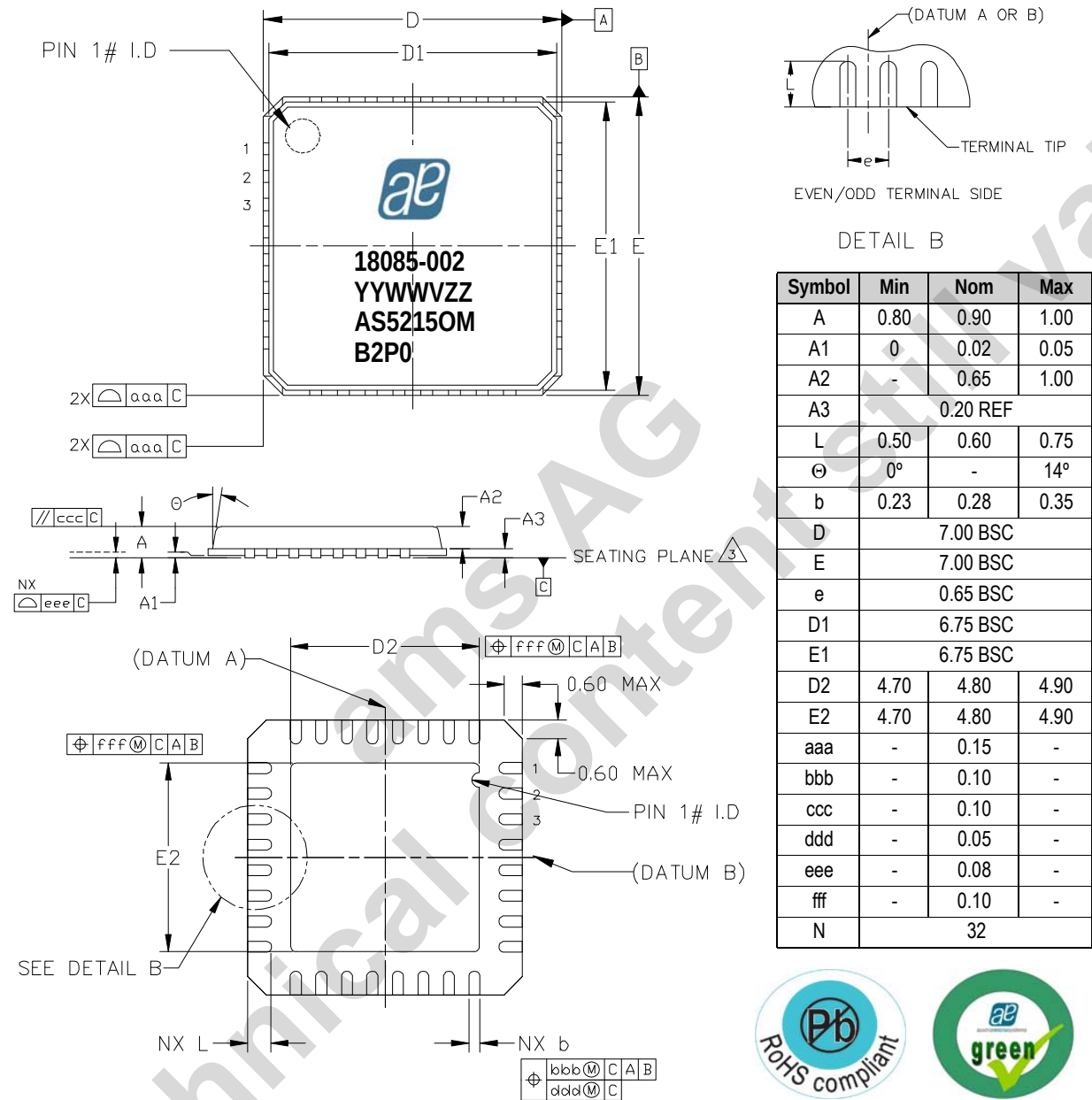
Figure 19. Analog OTP Verification



## 9 Package Drawings and Markings

The devices are available in a 32-pin QFN (7x7mm) package.

Figure 20. Package Drawings and Dimensions



### Notes:

1. Dimensions and tolerancing conform to ASME Y14.5M-1994.
2. All dimensions are in millimeters. Angles are in degrees.
3. Bilateral coplanarity zone applies to the exposed pad as well as the terminal.
4. Radius on terminal is optional.
5. N is the total number of terminals.

### Marking: YYWWVZZ.

| YY                                        | WW                 | V                | ZZ                         |
|-------------------------------------------|--------------------|------------------|----------------------------|
| Last two digits of the manufacturing year | Manufacturing week | Plant identifier | Assembly traceability code |

## Revision History

| Revision | Date           | Owner | Description                                                                                                                                                                                                                                                                                                                                                                                |
|----------|----------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.0      | April 29, 2008 | apg   | Initial revision                                                                                                                                                                                                                                                                                                                                                                           |
|          | July 03, 2008  |       | Redundancy Coding topic deleted.                                                                                                                                                                                                                                                                                                                                                           |
| 1.1      | July 15, 2008  |       | Updated Key Features, <a href="#">Table 1</a> - Pin Descriptions, <a href="#">Figure 1</a> and <a href="#">Figure 17</a> .                                                                                                                                                                                                                                                                 |
| 1.2      | July 14, 2009  |       | Updated min, typ, max values for 'Power up time' parameter in <a href="#">Table 6</a> .                                                                                                                                                                                                                                                                                                    |
| 1.3      | July 31, 2009  |       | Updated the following parameters in <a href="#">Table 6</a> :<br><ul style="list-style-type: none"> <li>- Values and conditions updated for <ol style="list-style-type: none"> <li>1. Propagation delay</li> <li>2. Amplitude ratio tracking accuracy over temperature</li> <li>3. DC Offset Drift</li> </ol> </li> <li>- Deleted the 'Output Offset' parameter from the table.</li> </ul> |
|          | Aug 24, 2009   |       | Updated following bits related information on page 16 - invert_channel, cm_sin, cm_cos, gain, dc_offset, Hall_b                                                                                                                                                                                                                                                                            |
| 1.4      | Aug 26, 2009   |       | Inserted <a href="#">Figure 12</a> and updated Applications and <a href="#">Figure 17</a> .                                                                                                                                                                                                                                                                                                |
| 1.5      | Sept 01, 2009  |       | Inserted <a href="#">Figure 13</a> , Added a note in Revision History.                                                                                                                                                                                                                                                                                                                     |
| 1.6      | Sept 02, 2009  |       | Deleted 'Displacement' parameter from <a href="#">Table 5</a> .                                                                                                                                                                                                                                                                                                                            |
| 1.7      | Nov 26, 2009   |       | Hall Array Radius value updated from 1.1mm to 1mm<br>Updated <a href="#">Figure 13</a>                                                                                                                                                                                                                                                                                                     |
| 1.8      | Dec 11, 2009   |       | Updated values for 'Magnetic Sensitivity' parameter in <a href="#">Table 6</a> .                                                                                                                                                                                                                                                                                                           |
|          | Dec 15, 2009   |       | Ordering code updated.                                                                                                                                                                                                                                                                                                                                                                     |
| 1.9      | Jan 27, 2010   |       | Updated 'Interface General at extended mode' (see <a href="#">Table 9</a> )                                                                                                                                                                                                                                                                                                                |
|          | Feb 10, 2010   |       | Updated values for 'Power up time' parameter in <a href="#">Table 6</a> .                                                                                                                                                                                                                                                                                                                  |
|          | Mar 19, 2010   |       | Added 'Current Consumption' parameter in <a href="#">Table 6</a> .                                                                                                                                                                                                                                                                                                                         |
| 1.10     | Sep 06, 2010   |       | Updated <a href="#">Package Drawings and Markings</a> (page 23) and <a href="#">Ordering Information</a> (page 25).                                                                                                                                                                                                                                                                        |
| 1.11     | Jun 27, 2011   | mub   | Updated <a href="#">Absolute Maximum Ratings</a> (page 5), <a href="#">Table 4</a> , <a href="#">OTP Programming and Verification</a> (page 21), <a href="#">Package Drawings and Markings</a> (page 23).                                                                                                                                                                                  |

**Note:** Typos may not be explicitly mentioned under revision history.

## 10 Ordering Information

The devices are available as the standard products shown in [Table 13](#).

Table 13. Ordering Information

| Ordering Code        | Description                                           | Delivery Form | Package            |
|----------------------|-------------------------------------------------------|---------------|--------------------|
| AS5215OM-HMFP, -HMFM | Sine and cosine analog output magnetic rotary encoder | Tape & Reel   | 32-pin QFN (7x7mm) |

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or find your local distributor at <http://www.austriamicrosystems.com/distributor>

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