# POS simulator

## Software Manual

Position sensors

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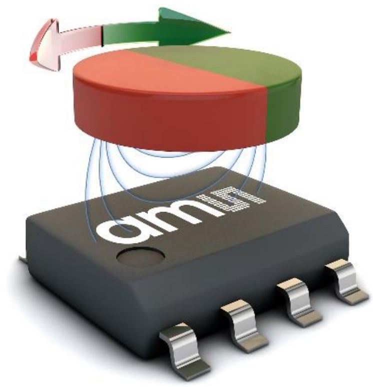
# Table of contents

# 1 Introduction

The design of a Magnetic Position Sensor System (POS System) requires at least 3 different engineering disciplines.

1. **Electronics:** To select proper sensor IC and integrate it into the electronic environment.
2. **Magnetics:** To equip the sensor IC with a suitable signal source.
3. **Mechanics:** To put the electronic and magnetic components together in a way to meet all requirements and to achieve a good performance to price ratio.

**Figure 1: Magnetic position sensor with magnet**



All of these three engineering disciplines are vital for the design of a magnetic position sensor system. The proper combination between Electronics, Magnetics and Mechanics is the main contributor for the price and performance of a magnetic position sensor system.

The knowledge base of most design engineers is focused on electronics and/or mechanics. Most do not have experience in Magnetics and even less have experience in all 3 disciplines. Additionally, the engineer has to consider that major semiconductor manufacturers use completely different technologies for the implementation of magnetic position sensors.

The optimization process usually requires extensive measurement with different sensor ICs, Magnets and mechanical arrangements. Although these measurements can be automated with robots, it remains a time-consuming task.

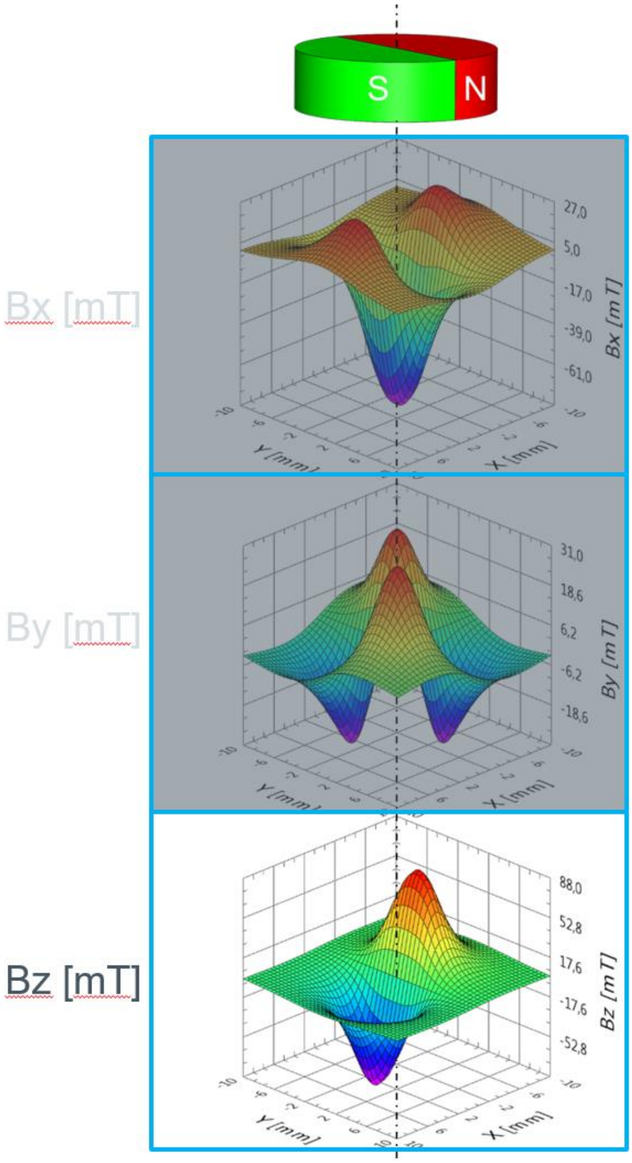
Some companies use tools to simulate the magnetics of position sensor systems to reduce the amount of measurements. The entrance hurdle for learning how to use them is high. Using them requires knowledge of the working principle of the sensors IC – Programming Skills are required. Furthermore, they are expensive. Therefore, ams OSRAM developed the POS-Simulator. It is an easy-to-use simulation tool developed to simulate all rotational magnetic positions sensors out of the ams OSRAM portfolio.

# 2 Information

## 2.1 Magnetic flux density Bz

ams OSRAM sensors measure the magnetic flux density in Z-direction, which is the vertical axis to the package surface. Figure 2 shows the magnetic flux density in all three directions (Bx, By and Bz).

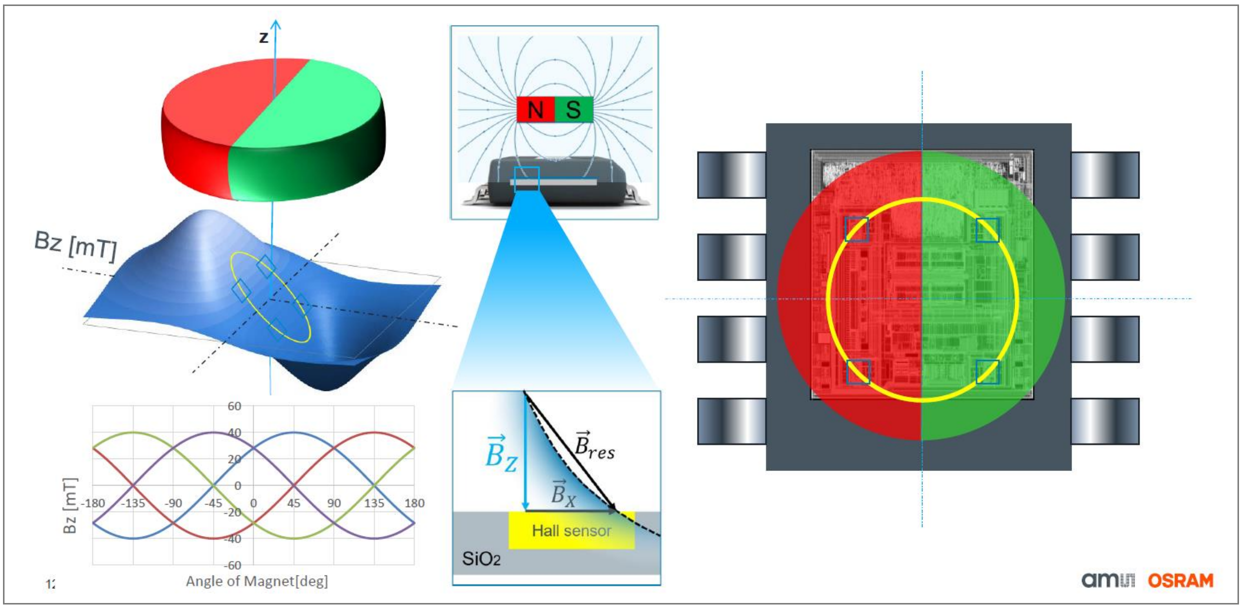
Figure 2: Magnetic flux density B



## 2.2 Sensor – hall element

The sensors have 4 hall elements. The magnet is placed above the sensor and the rotational axis is in the center of the hall elements (see Figure 3). Every hall element is detecting the Bz - field on different angles (every 90° on a circle) of the hall radius (see Figure 3: yellow circle).

Figure 3: Hall elements – principal function




The measured data of the sensor are 4 sinusoidal curves with a shift of 90°. Out of this information, the sensor calculates the angle of the magnet.

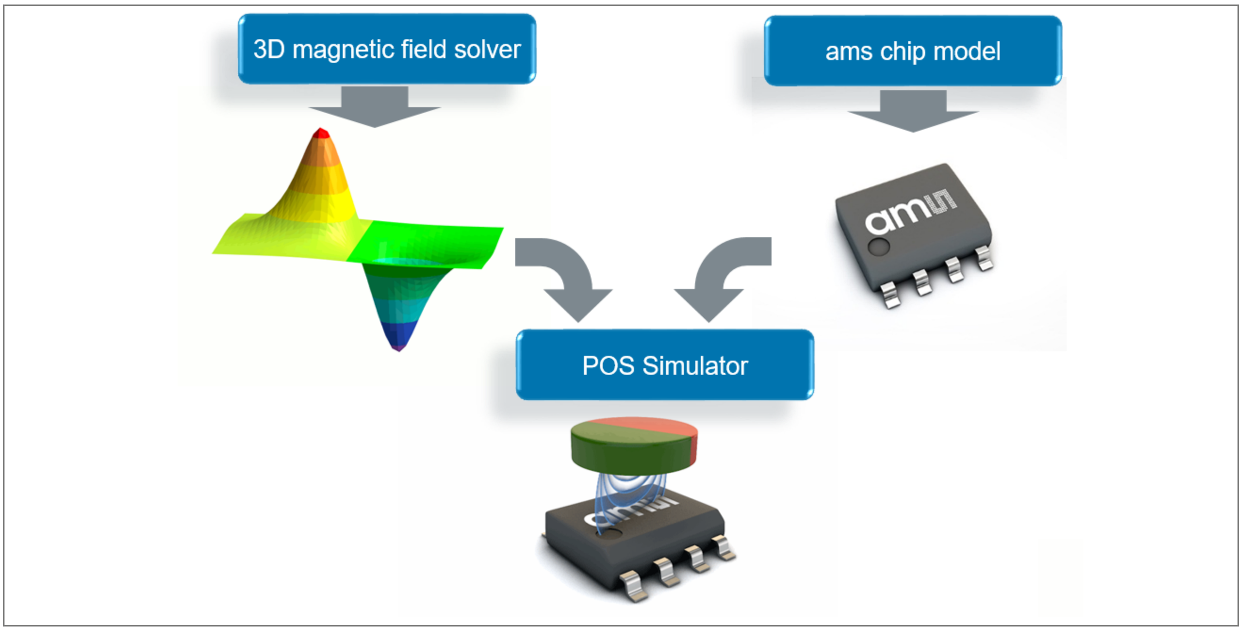
In reality, there are misalignments, caused by mechanical tolerances. Those misalignments and additional tolerances of sensor process will cause an angle error.

## 2.3 Simulation

The POS simulator is performing magnetic simulations on a server based on the parameters entered by the user and sends back the simulation results to the user's PC. The tool is free and the simulation on the server ensures high simulation speed with low requirements for the hardware on the user's side.

It combines a magnetic field solver and ams OSRAM chip models resulting in a very effective simulation outcome.

Figure 4: Simulator




The user has the possibility to adjust the parameters (e.g.: Mechanical misalignment) to analyze system functionality in advance.

# 3 SW description

## 3.1 Getting started

1. **Step 1**: Install LabVIEW Runtime Engine software from National Instruments website (LabVIEW Runtime Download - NI). Please select Windows Version 2016 32-bit (application bitrate).
2. **Step 2**: Download POS_Simulator_9. Alternatively, you can also download the link from Github (ams OSRAM-GitHub).
3. **Step 3**: Run POS_Simulator_9_preliminary.exe file
4. **Step 4**: Before step 3, make sure the internet is connected. Once the .exe file is run, you will see the GUI of the POS simulator as shown in Figure 5.

**Figure 5: POS simulator GUI**

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**Information:**

If internet connection is not available due to ID restrictions (firewall), it's also possible to run the program via mobile hotspot.

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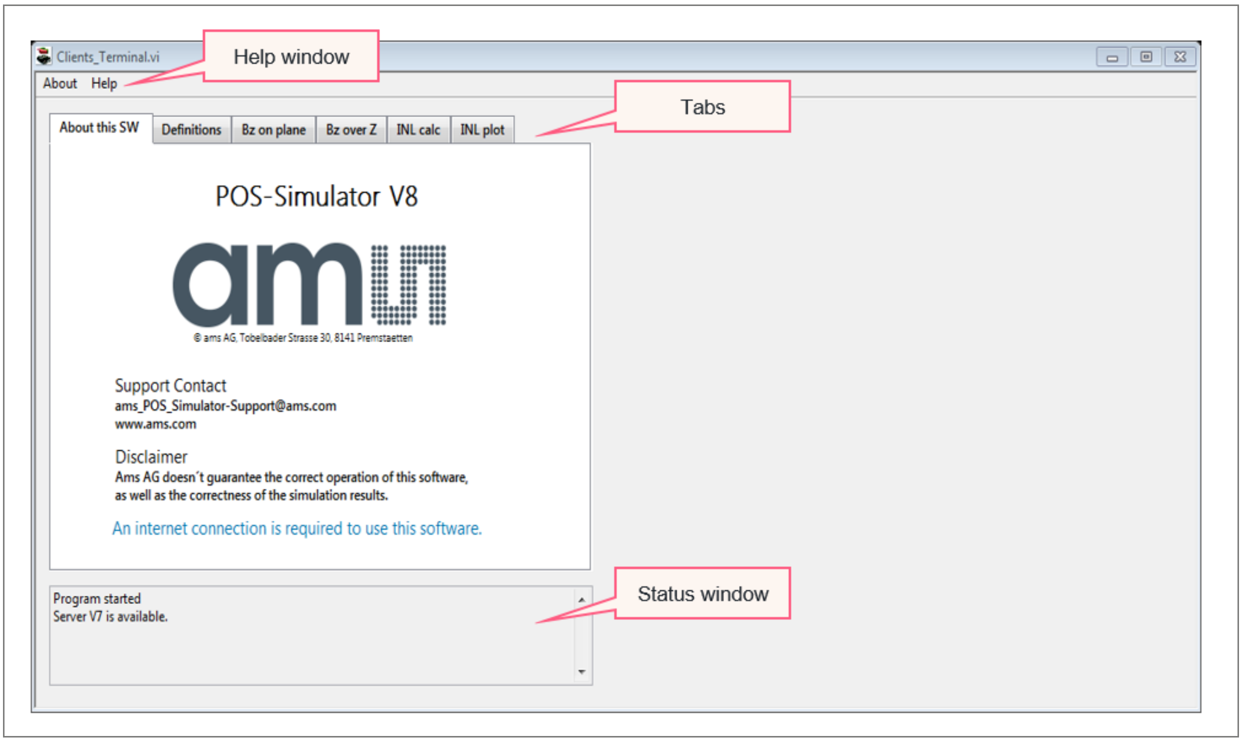
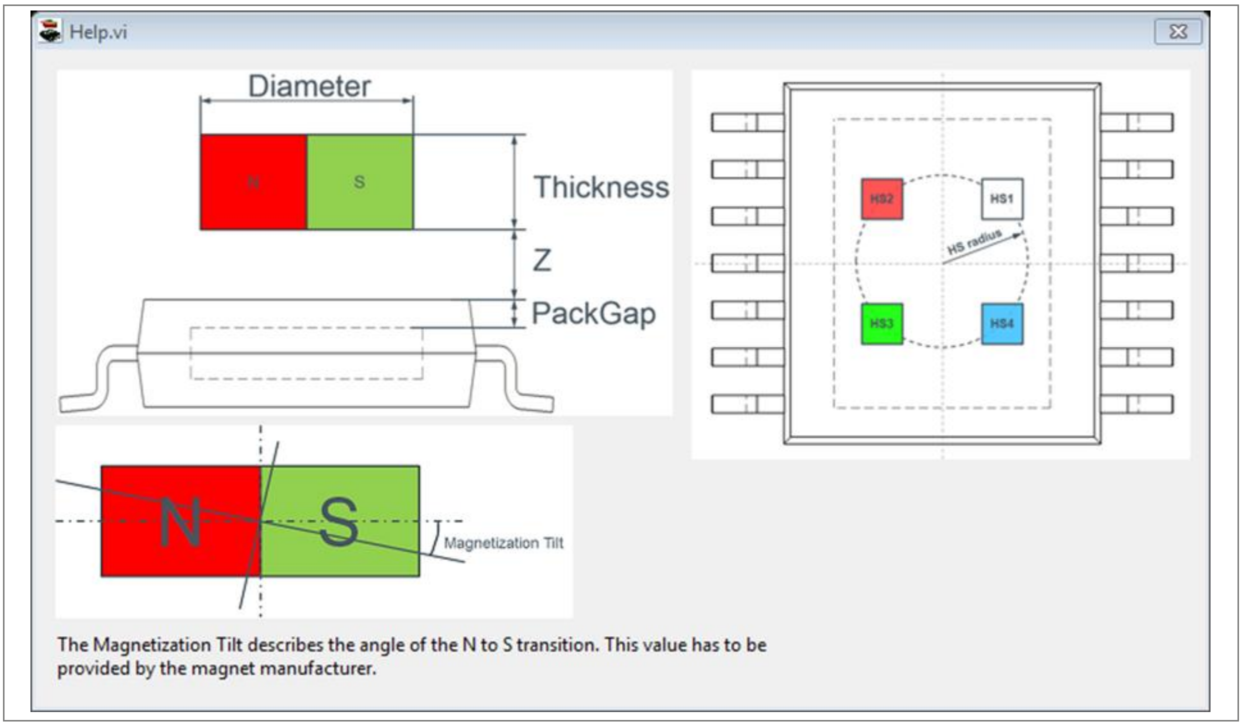
## 3.2 Usage of the POS simulator

**Figure 6: POS simulator GUI description**



### 3.2.1 Help

Figure 7: Help window




The help window (see Figure 7) provides information about various application parameters as explained in Table 1.

Table 1: Application parameters

| Parameter | Description |
|---|---|
| Diameter | Diameter of magnet |
| Thickness | Thickness of magnet |
| Z | Air gap between upper package surface to magnet lower |
| PackGap | Gap from die surface to package surface |
| Magnetization tilt | Magnetization tilt is in ideal case zero degree, but in reality, there can be tilt because of magnetization process. Some magnet manufacturers can guarantee a maximum tilt. |
| HS1, HS2, HS3, HS4 | Hall elements (coloring is the same as in the graphs) |
| HS radius | Radius of hall elements |

### 3.2.2 Status

The status window shows the connection status and the status of running simulations. After Startup it shows “Program started” in the first row followed by “Server Vx is available.” (x is a Placeholder for the version of the available Server). If no server can be found, then the internet connection of the PC has to be checked. If the problem persists then please contact support by using the email address. The POS-Simulator does not currently support proxy servers.

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**Attention:**

Make sure that you have an internet connection. Otherwise, the simulation will not work.

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### 3.2.3 Tabs

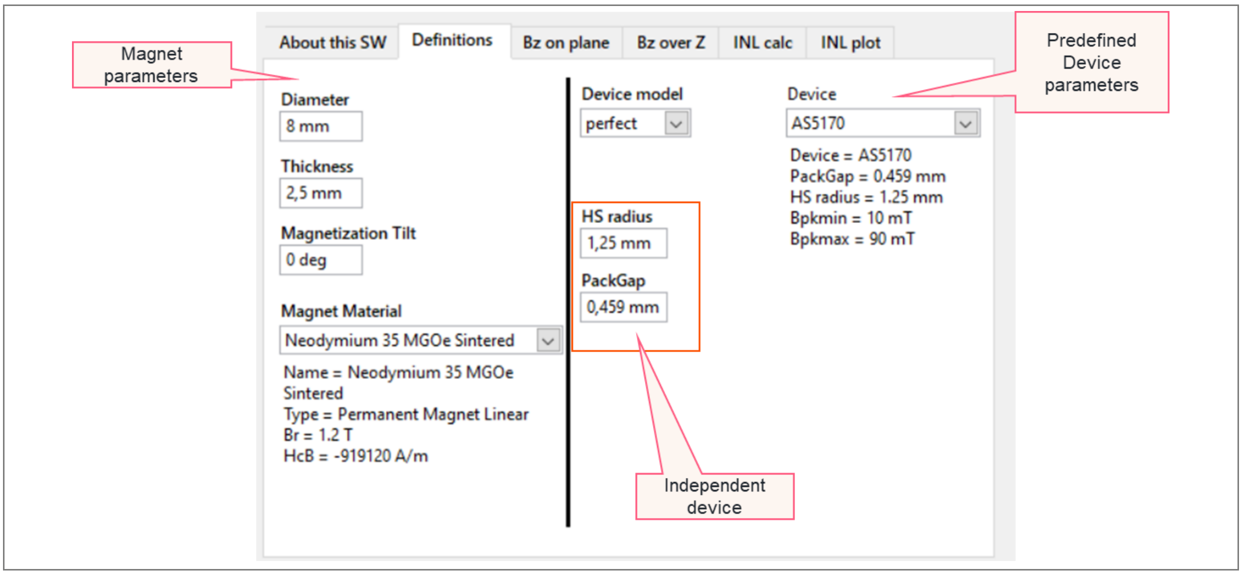
The GUI is separated into six different tabs:

- **About this SW:** Information about the Software (version, connection...).
- **Definitions:** Adjusting parameters.
- **Bz on plane:** Simulation of magnetic field.
- **Bz over Z:** Simulation of magnetic field over air gap.
- **INL calc:** Non-linearity simulation.
- **INL plot:** Non-linearity simulation in 3D plot.

# 4 Definitions

The Definitions tab allows the user to define the applications parameters. The Help Window (see Figure 7) explains most of the parameters.

**Figure 8: Definition**




Further parameters (not covered under 'Help') are explained below:

### 4.1.1 Magnet material

Two Neodymium and two Samarium-cobalt magnets are predefined in the library of the POS - Simulator. Selection of "Custom Magnet" allows to define a custom magnet based on the Br and HcB values that are defined in the datasheet of the magnet. Additionally, it allows to simulate a magnet at various temperatures by changing these parameters according to the recommendations of the magnet's datasheet.

### 4.1.2 Device model

Two selections are possible: "perfect" and "statistical". "Perfect" just considers the errors caused by the magnet and the mechanics. Errors caused by the device are not considered. "Statistical" considers the most important errors caused by the device too. Switching between "perfect" and "statistical" allows us to estimate the contribution of the errors caused by the device to the overall error.

### 4.1.3 Device

Allows the selection of the proper device.

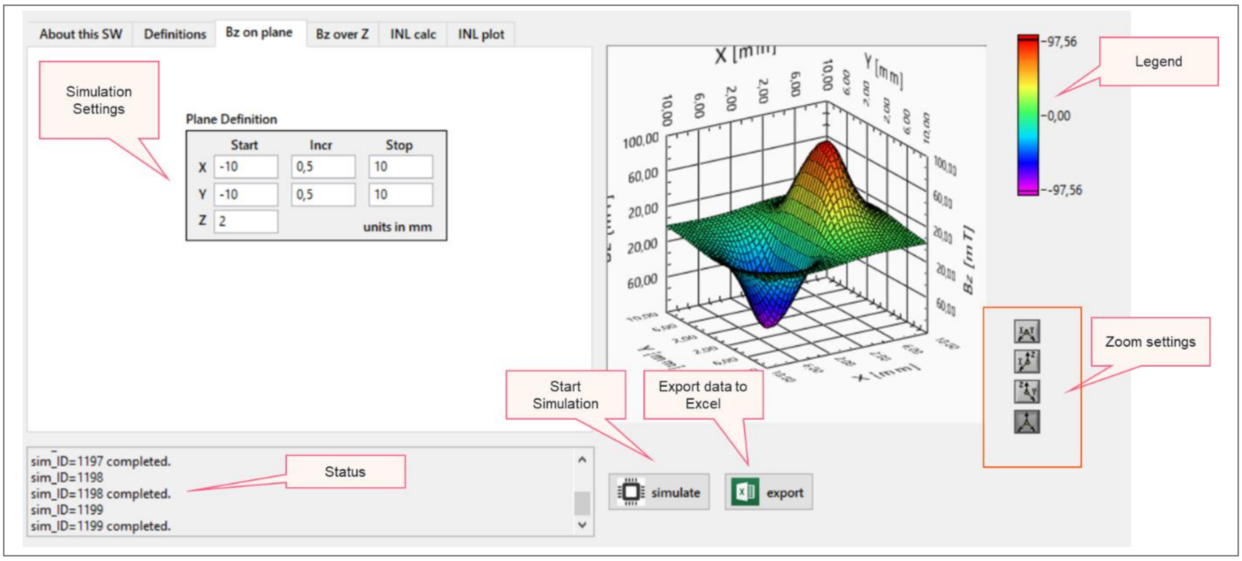
In case the device is not listed, you can choose a device with similar device parameters (e.g.: AS5047P <=> AS5147U). You can find those parameters in the datasheet of the sensors.

### 4.1.4 HS radius and pack gap

For customized device parameters, you choose “device independent” under “Device”. With this setting, you can manually set the ‘HS radius’ and the ‘PackGap’ parameters. This setting is useful for dual die simulations and for simulation of devices which don’t yet exist in the ams OSRAM products pool.

# 5 Bz on plane

Figure 9: Bz on plane

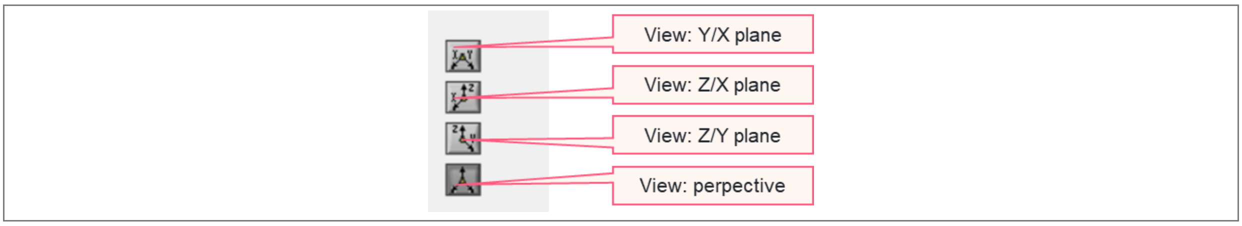



This tab allows the simulation of Bz component of the magnetic flux on a plane below the magnet. This plane is always parallel to the planar surface areas of the cylindrical magnet. The two axis “X” and “Y” build this plane. “Z” defines the gap between the lower planar surface area of the magnet and surface of the device package. The values for “Bz” that are shown in the 3D-Graph are simulated for the same gap as the surface of the sensitive spot of the device.

Table 2: Settings

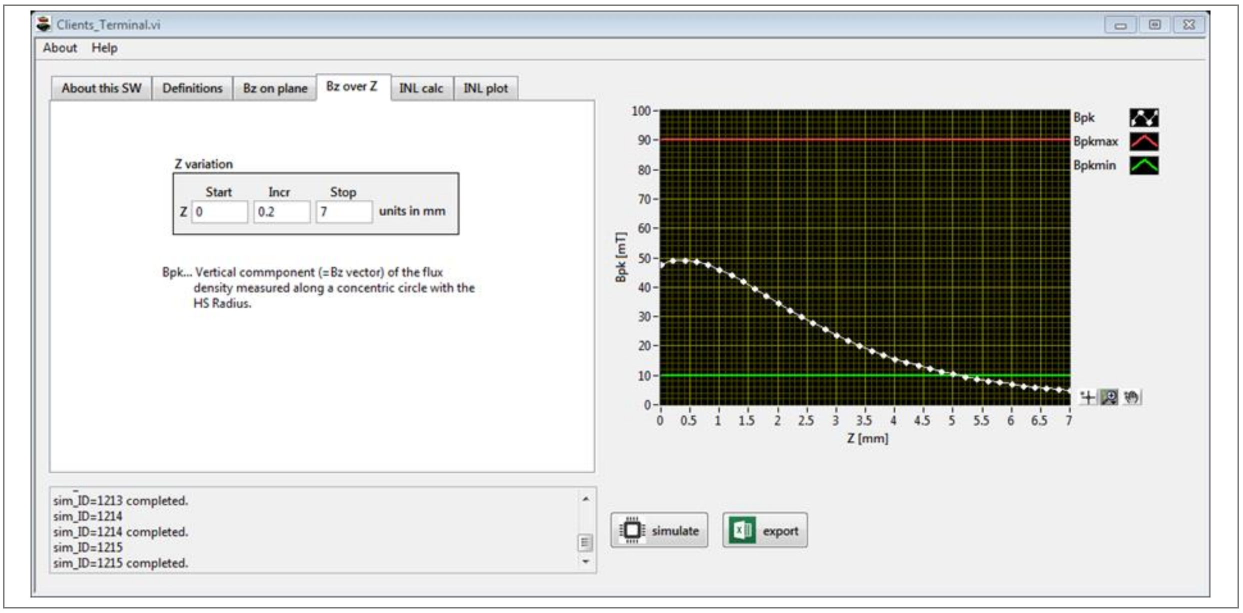
| Parameters | Description |
|---|---|
| X | Range of x- axis |
| Y | Range of y- axis |
| Z | Distance to the magnet |

Figure 10: Zoom/view



# 6 Bz over Z

Figure 11: Bz over Z



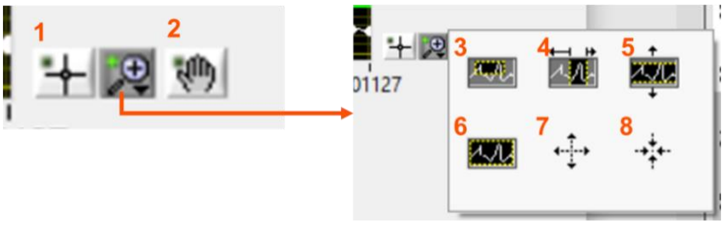

This tab allows the simulation of the maximum and minimum possible gap between the magnet and the device. The green line (Bpkmin) indicates the minimum gap, and the red line (Bpkmax) indicates the maximum airgap. The intersection points between the green and the white line indicate the maximum possible gap. And the intersection point between the white line and the red line would indicate the lowest possible airgap.

Equation 1:

$$Bpk\ (B\ peak)\ =\ Bzpp/2$$

Where Bzpp → Bz peak to peak

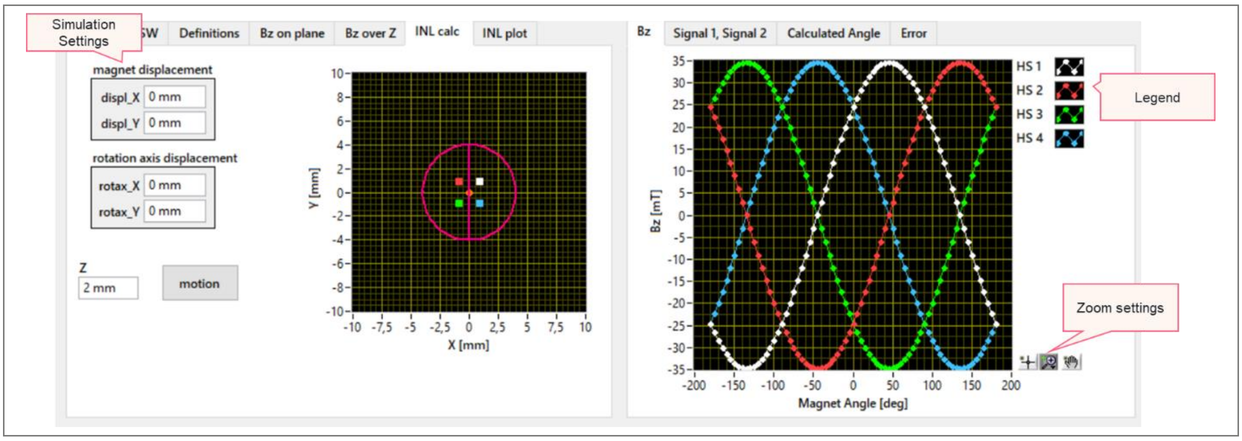
**Figure 12: Zoom/view settings**




**1** Cross tool
**2** Hand tool
**3** Zoom window
**4** Zoom in x-direction
**5** Zoom in x-direction
**6** Reset zoom
**7** Zoom in
**8** Zoom out

# 7 INL calc

Figure 13: INL CALC



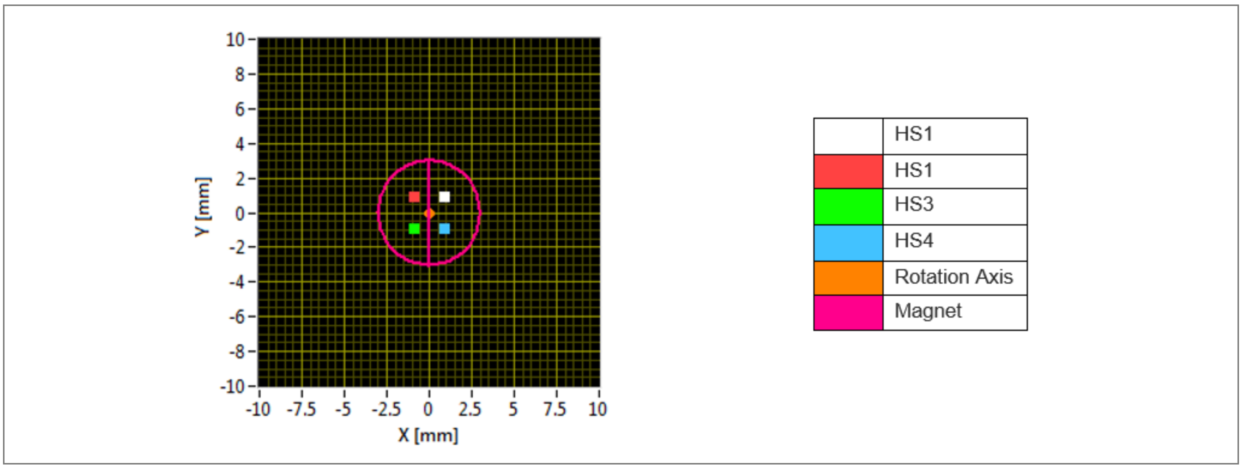

The displacement of the magnet and the rotation axis can be selected separately. After pressing the motion button, an animation is started. The animation visualizes the movement of the magnet above the hall sensors.

### 7.1.1 Magnet misalignment setting

#### 7.1.1.1 Physical magnet displacement in x and y direction and rotational axis displacement

When you click on motion, you get an illustration of the magnet rotating over the hall elements of the sensor.

Figure 14: Motion




### 7.1.2 Simulation results

Figure 15: Bz

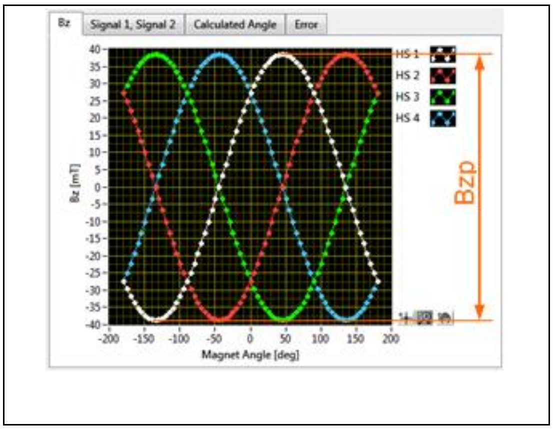



Figure 16: Signal 1, signal 2

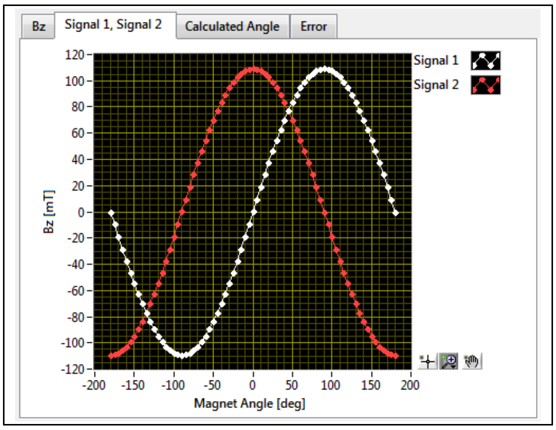


Figure 17: Calculated angle

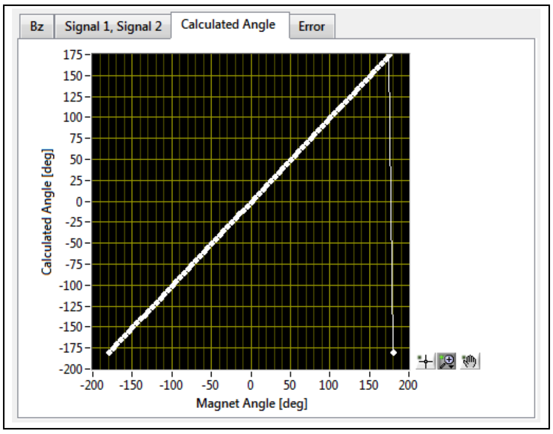
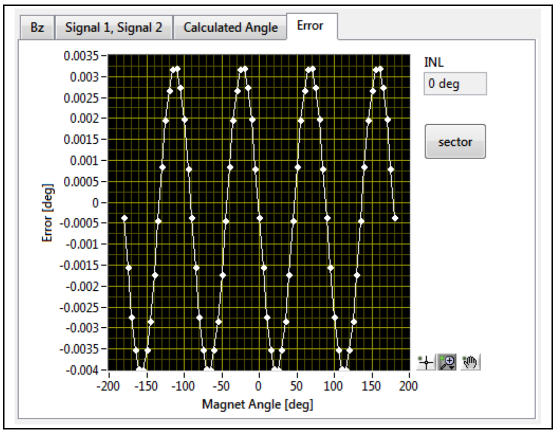



Figure 18: Error




### 7.1.2.1 Bz

Figure 15 shows the raw data measured by the 4 hall sensors. The curves in the graph have the same color coding than in the animation which is shown in Figure 15.

### 7.1.2.2 Signal 1, signal 2

Figure 16 shows the sine and cosine signal that is calculated from the raw data according to the following formulas:

Equation 2:

$$Signal_1 = +HS_1 + HS_2 - HS_3 - HS_4$$

$$Signal_2 = +HS_1 - HS_2 - HS_3 + HS_4$$

### 7.1.2.3 Calculated angle

Figure 17 shows the calculated angle according to the following formula:

Equation 3:

$$CalculatedAngle = ATAN2(Signal_2; Signal_1)$$

### 7.1.2.4 Error

Figure 18 shows the error over one rotation of the magnet. If the magnet is perfectly centered and if the device model is switched to perfect, then the error is almost zero. A negligible small error remains because of the finite accuracy of the 3D field solver.

### 7.1.2.5 Histogram

The histogram tab appears when the statically device model was chosen on “Definitions”. The simulation outcome is a deviation of linearity error, based on the statistical device model.

**Figure 19: Histogram**

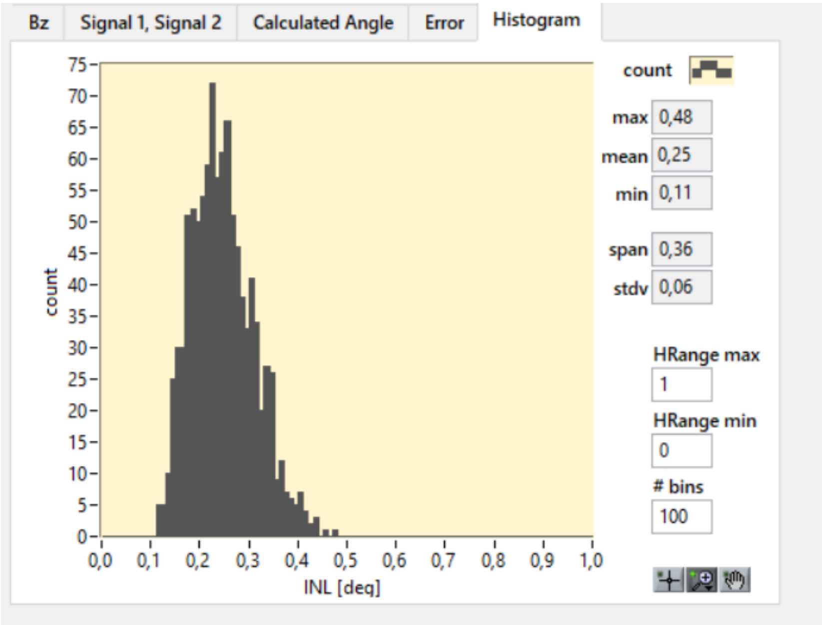
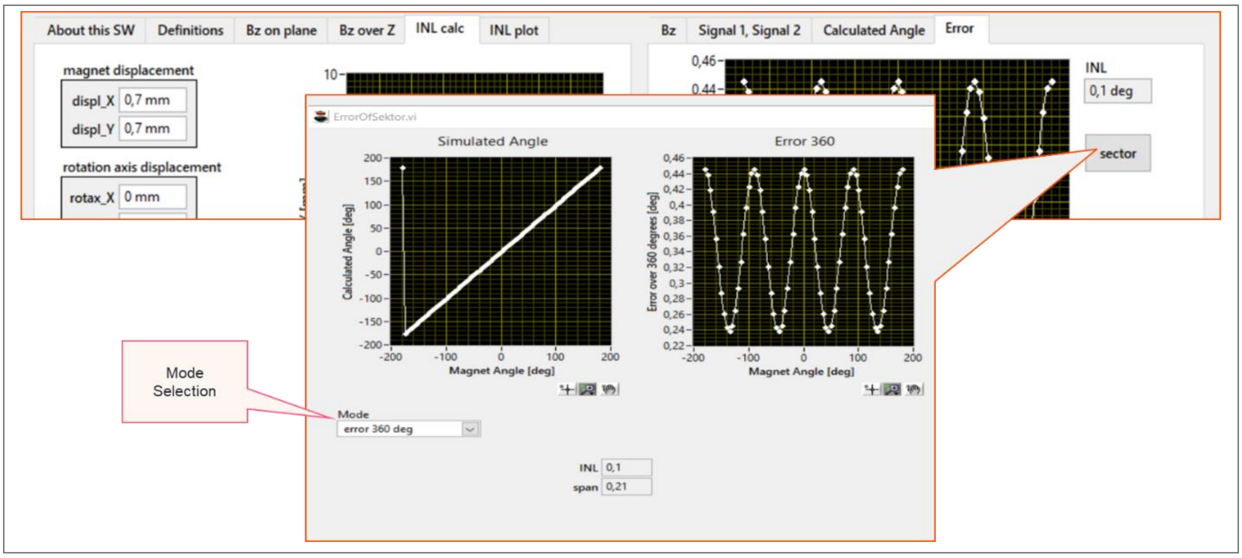


Table 3: Description

| Parameter | Description |
|---|---|
| Max | Maximum INL value |
| mean | Mean INL value |
| Min | Minimum INL value |
| Span | Span from minimum to maximum |
| Stdv | Standard deviation |
| HRange max | X-axis (INL) maximum shown value |
| HRange min | X-axis (INL) minimum shown value |
| # bins | Resolution on x-axis |

## 7.1.3 Sector angle mode

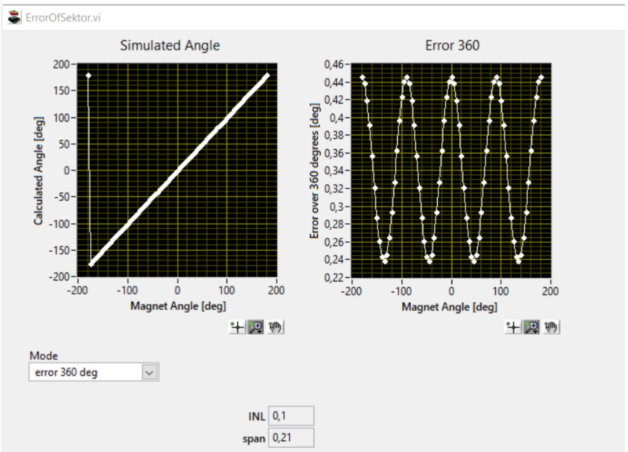
Figure 20: Sector




Usually, the error is simulated over one turn of the magnet. Some applications, however, require only a smaller sector out of the full turn. For these applications, just the error in this smaller sector is in the focus of interest. The sector angle mode can be started by clicking the sector button. Four different analysis modes are available: Error 360 deg, Custom curve, Start point end point, best fit line.

### 7.1.3.1 Error 360 deg

Figure 21: Error 360 deg

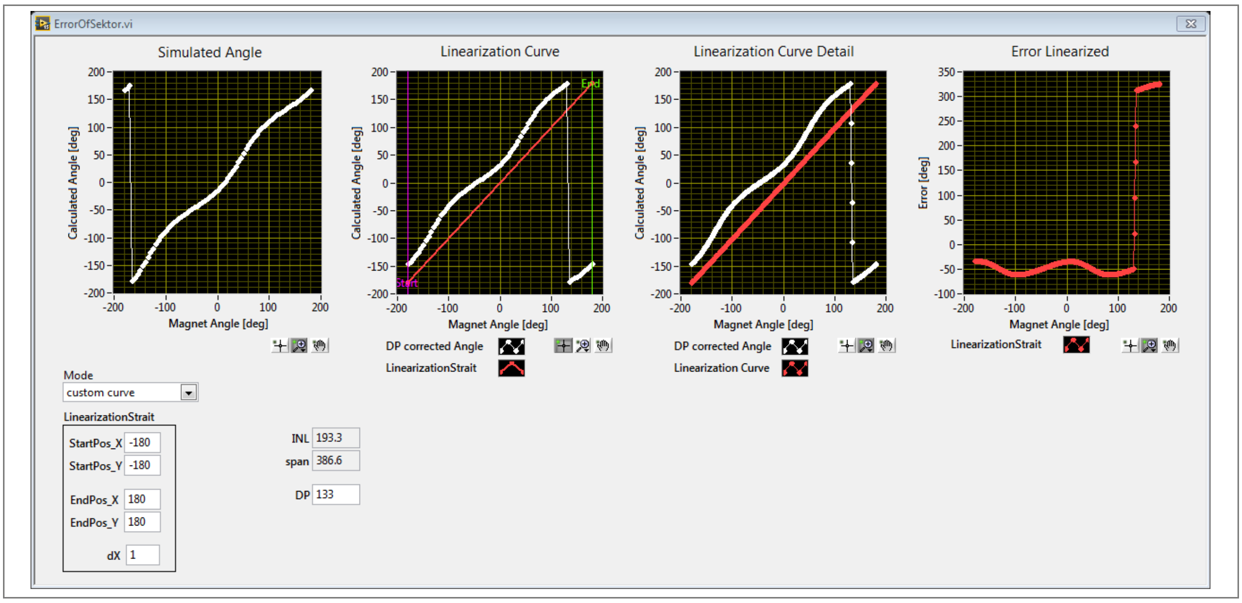



- **Simulated angle:** On the horizontal axis, it shows the reference angle of the magnet. On the vertical axis, it shows the angle as calculated in the simulation.
- **Error 360:** Error over 360 degrees is the deviation between the reference angle and the calculated angle.

The indicators INL and span give an overview of the total error. Where span is the value from minimum to maximum (peak to peak) and INL is half of span.

### 7.1.3.2 Custom curve

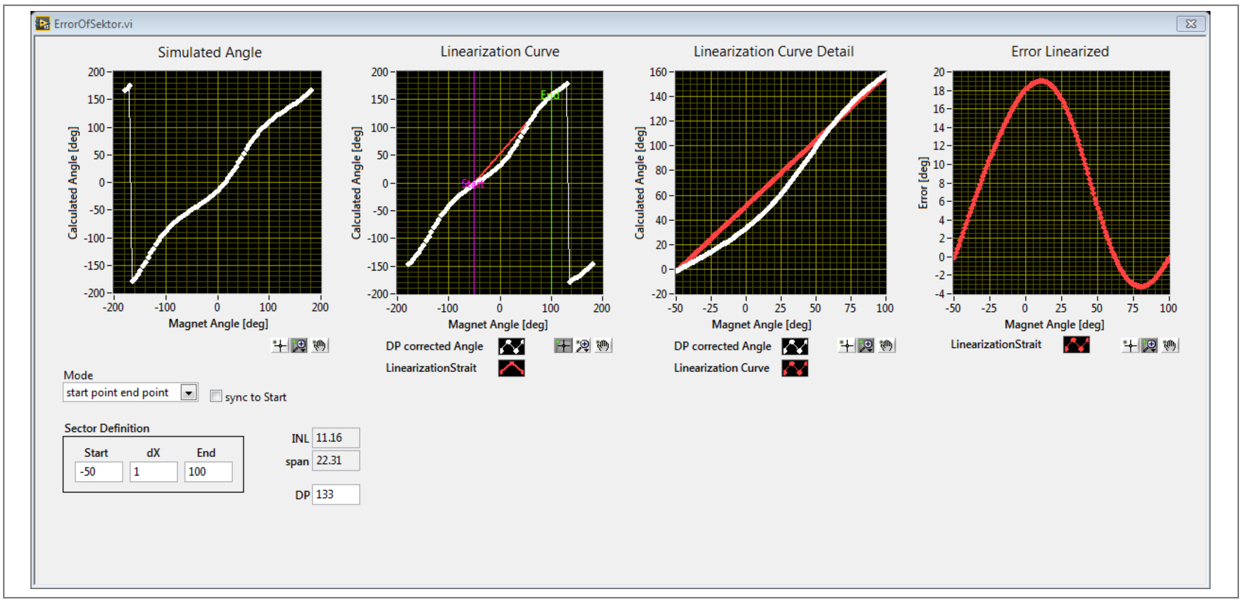
**Figure 22: Custom curve**




- **LinearizationStrait:** The Mode custom curve allows to define a user defined linearization curve for the linearization of the sector. The linearization curve is always a straight that can be defined by entering values into the LinearizationStrait controls.
- **DP (Discontinuity Point):** The Discontinuity Point is where the angle jumps between -180 and +180 degrees. It is applied to the calculated angle.

### 7.1.3.3 Start point end point

**Figure 23: Start point end point**

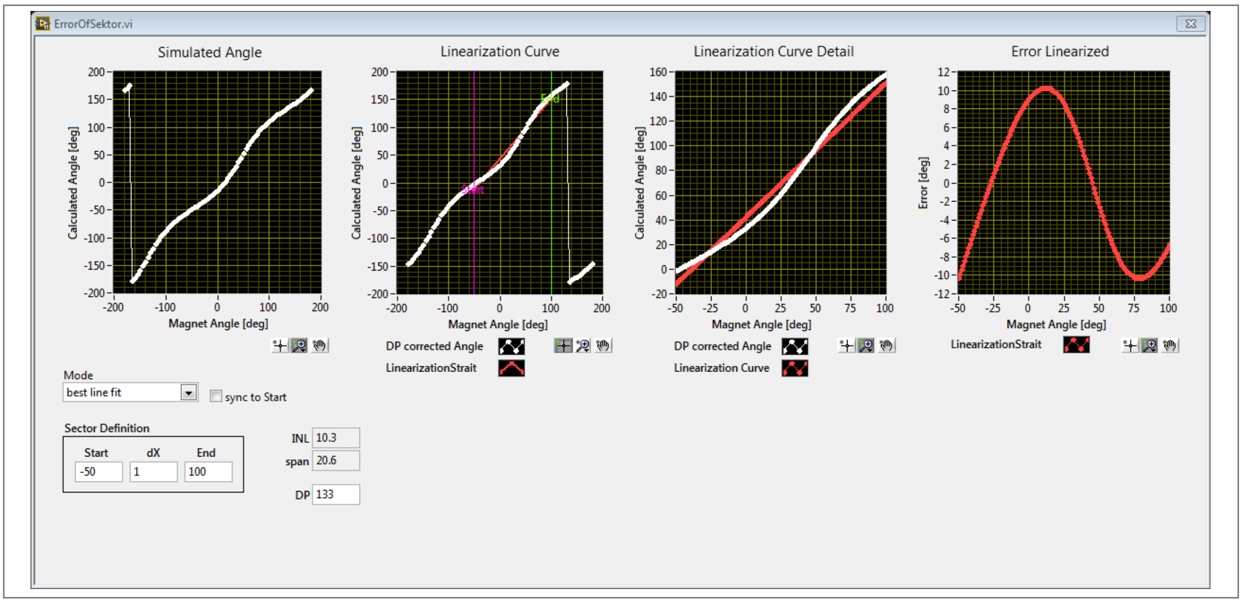



The POS-Simulator then automatically calculates a linearization strait that results a zero error for the start point and the end point of the sector.

After selection of the checkbox sync to Start, the end point of the sector definition automatically changes with the start point of the sector definition.

### 7.1.3.4 Best fit line

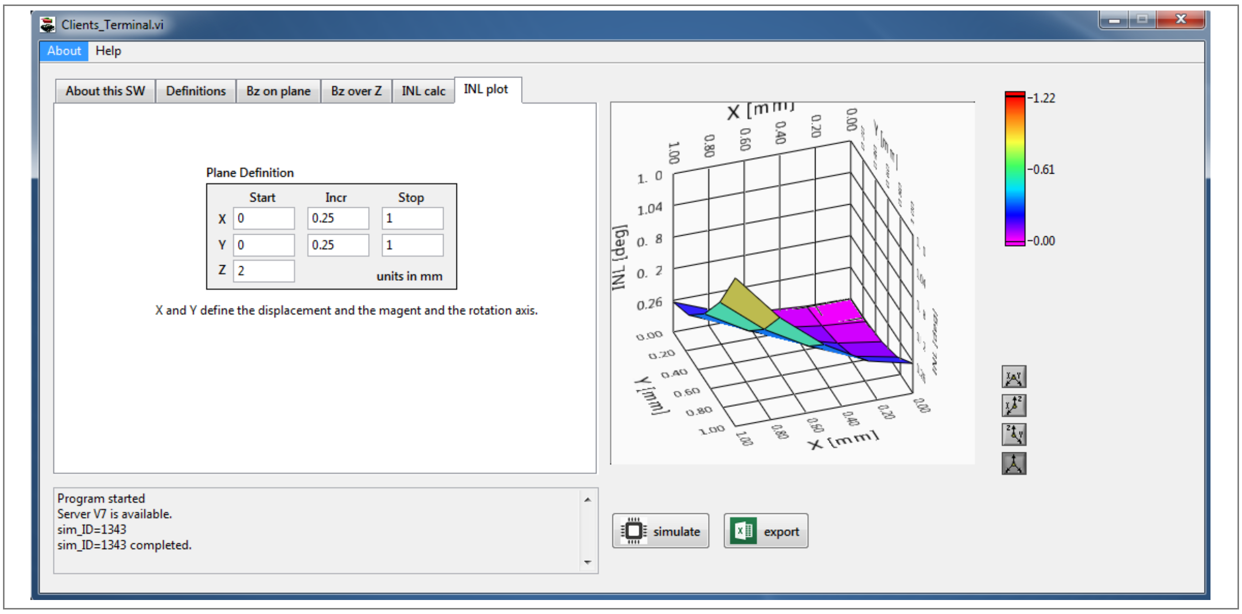
**Figure 24: Best fit line**




The POS-Simulator automatically calculates a linearization strait that results the lowest possible error over the whole sector.

# 8 INL plot

Figure 25: INL plot



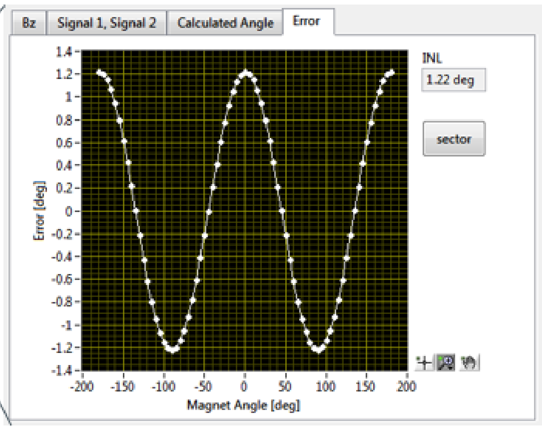

The purpose of the INL plot tab is to simulate the INL of the sensor on a plane below the magnet. There is a relation between the INL plot and the INL calc.

**Information:**

Table can be created by pressing the export button with the excel logo.

Figure 26: Relation between the INL plot and the INL calc tab

| INL [deg] | 0 | 0.25 | 0.5 | 0.75 | 1 | X [mm] |
|---|---|---|---|---|---|---|
| 0 | 0 | 0.01 | 0.04 | 0.1 | 0.25 | |
| 0.25 | 0.01 | 0.04 | 0.09 | 0.18 | 0.33 | |
| 0.5 | 0.04 | 0.09 | 0.19 | 0.33 | 0.54 | |
| 0.75 | 0.1 | 0.18 | 0.33 | 0.54 | 0.83 | |
| 1 | 0.25 | 0.33 | 0.54 | 0.83 | 1.22 | |
| Y [mm] | | | | | | |



# 9 Examples

## 9.1 Dual die

The sensors with dual die technology (2 sensors in one package) have different packaging gaps for each sensor (see Figure 27). This can only be simulated in V9 and more with “device independent” settings (Figure 28).

**Figure 27: PackGap of AS5247U**

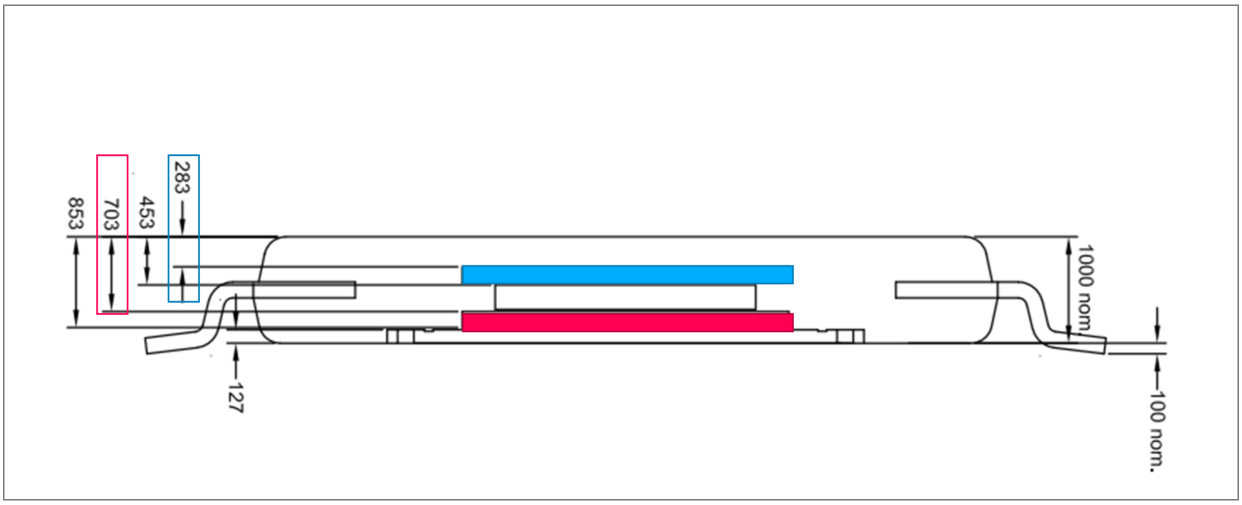



**Figure 28: Individual settings for top and bottom die**

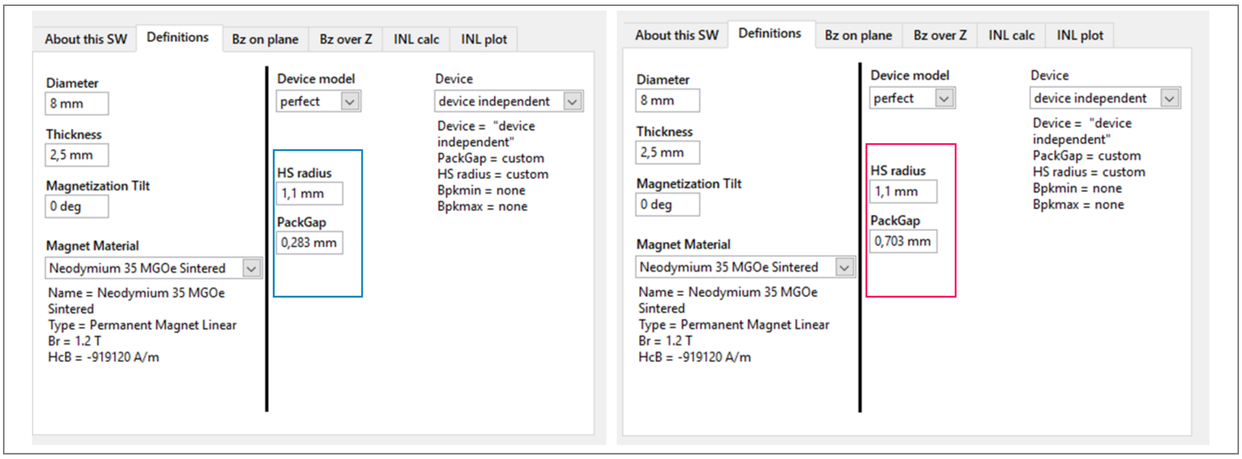
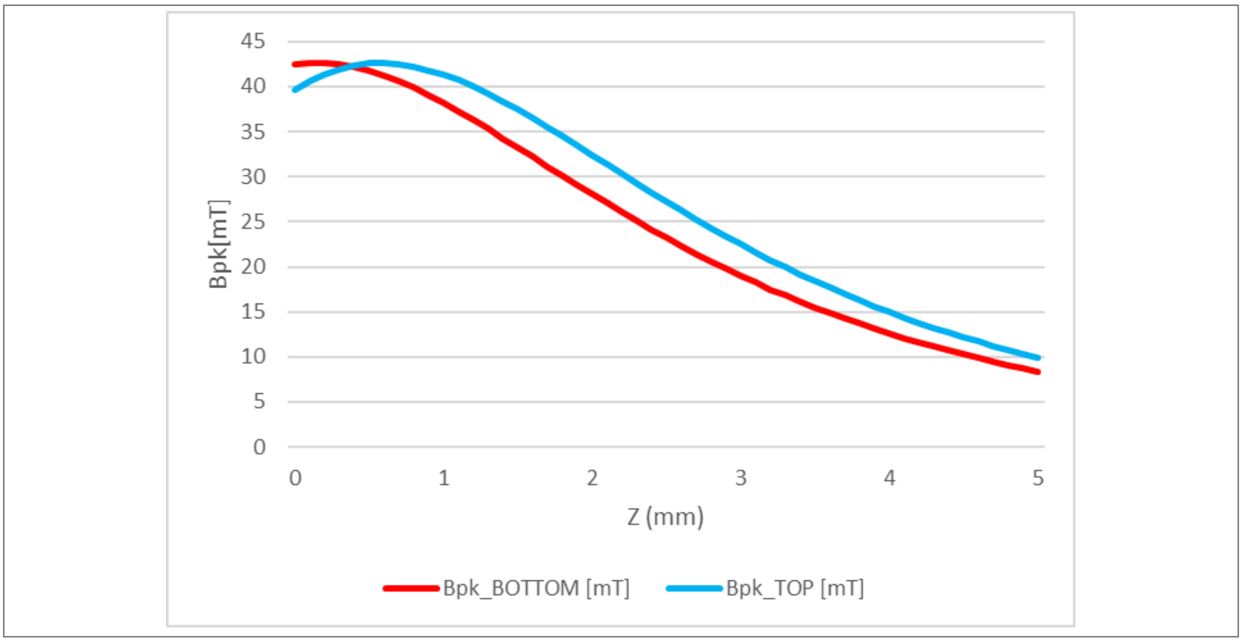


**Figure 29: Resulting Bz-curves over Z**



# 10 Revision information

**Definitions**

Draft / Preliminary:
The draft / preliminary status of a document indicates that the content is still under internal review and subject to change without notice. ams-OSRAM AG does not give any warranties as to the accuracy or completeness of information included in a draft / preliminary version of a document and shall have no liability for the consequences of use of such information.

| Changes from previous version to current revision v1-00 | Page |
|---|---|
| This Software Manual PD001065 replaces the user guide UG001042. | |
| Initial production version | |

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.

# 11 Legal information



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