User's Guide

Texas Instruments' Magnetic Sense Simulator User's Guide

TEXAS INSTRUMENTS

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Abstract

Magnetic sensors use technologies, such as the Hall-effect or magneto-resistive structures, to determine the magnitude or direction of an externally supplied magnetic field. These sensors detect the motion and position of key elements within a system by measuring the behavior of the field surrounding a permanent magnet. The device can track and define operating positions that help create user-friendly features, safety functions, and improve system monitoring and reliability.

The key challenge in designing with these sensors is that magnetic fields are invisible and not innately intuitive. As a result, designing many functions without the aid of a simulation tool can be difficult. Texas Instruments' Magnetic Sense Simulator (TIMSS) is available to use for free at Webench® on TI's website. This tool is a replacement to the *Magnetic Sense Enhanced Proximity Tool*. Related documentation and information is accessible at TI Magnetic Sense Simulator in the tool folder.

This software was built around Python libraries that enable quick approximations using an equation-based solver. This approach is somewhat limited because the tool only supports a single magnetic body and does not include the option to simulate the interaction with nearby ferromagnetic materials. More advanced tools that use a finite element method where systems are solved using complex 3D meshes are typically capable of supporting such efforts but these are often time consuming and require significant tools training to reach proficiency.

The purpose of TIMSS is to provide a platform which can parametize common types of motion to enable fast simulations and approximate device behavior under various conditions. The tool allows for control of temperature and parametric sweeps to evaluate system response across multiple tolerances. This evaluation is particularly helpful before attempting to prototype or run advanced simulations which involves significant computing time.

To aid the user with design development, TIMSS stores saved designs. Support of this functionality requires a myTI.com account. Please refer to the following links for help with setting up a my.TI™ on-line information services account.

- Register for a my.TI™ on-line information services account
- myTI™ on-line information services FAQs

The purpose of this guide is to explain the features and functions of Texas Instruments' Magnetic Sense Simulator (TIMSS) and to explain methods and approaches that aid in successful simulation configurations.

For questions about using TIMSS, please reach out on E2E™ support.
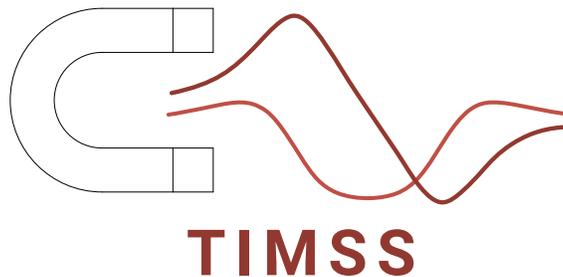
1 Introduction and Features Overview

There are four basic types of motion defined within Texas Instruments' Magnetic Sense Simulator (TIMSS). These definitions have a certain degree of flexibility in each that allows for quick customization of the simulation environment. The types of motion supported are:

- Hinge
- Linear
- Rotation
- Joystick

Up to six sensors can be placed simultaneously in each of these formats to evaluate relative placement and response as a system. The magnet and sensor can be rotated to match the user system configuration in all cases. Furthermore, plots relative to the sensor alignment provide the observed magnetic field and the sensor output.

A library of magnetic materials and predefined shapes are included in TIMSS and allows for a highly customizable magnetic source, which allows for both standard dipole magnets or more complex multipole structures.

Static position calculations are also available in TIMSS to quickly determine if the field produced by a magnetic structure is strong enough or in the correct direction to be useful in a given application.

1.1 Simulating Magnetic Fields Tool Introduction

This tool is intended for use as an electromechanical design aid for understanding the magnetic field produced by a single moving magnet and to predict device behavior by plotting simplified sensor outputs.

Temperature inputs for this tool evaluate only changes in the magnet strength on the assumption of a constant linear response. However, real magnets have temperature operating ranges that vary based on shape and material selection. The user is solely responsible for the operating range of their selected magnet and calibrating the magnet and sensor to always remain within their specified operating range. The modeled temperature compensation for device output behavior only considers intentional compensation of the device sensitivity but this does not impact any other device parameters.

TI recommends prototyping and evaluating mechanical systems using real components to verify typical operating tolerances and system behaviors. For instance, ferromagnetic materials which can be present in system construction can interact with magnetic fields and change the observable inputs to the magnetic sensor.

The tool provides functions matching several common types of motion and resulting typical device performance is modeled to demonstrate the relationship between the mechanical position of the magnet and the electrical response of the sensor.

2 Simulation Interface

The user can initiate a design simulation through a variety of functions upon logging into the simulation. These functions include:

- Creating a new design
- Opening a saved design within TIMSS
- Importing a saved design from a .json file
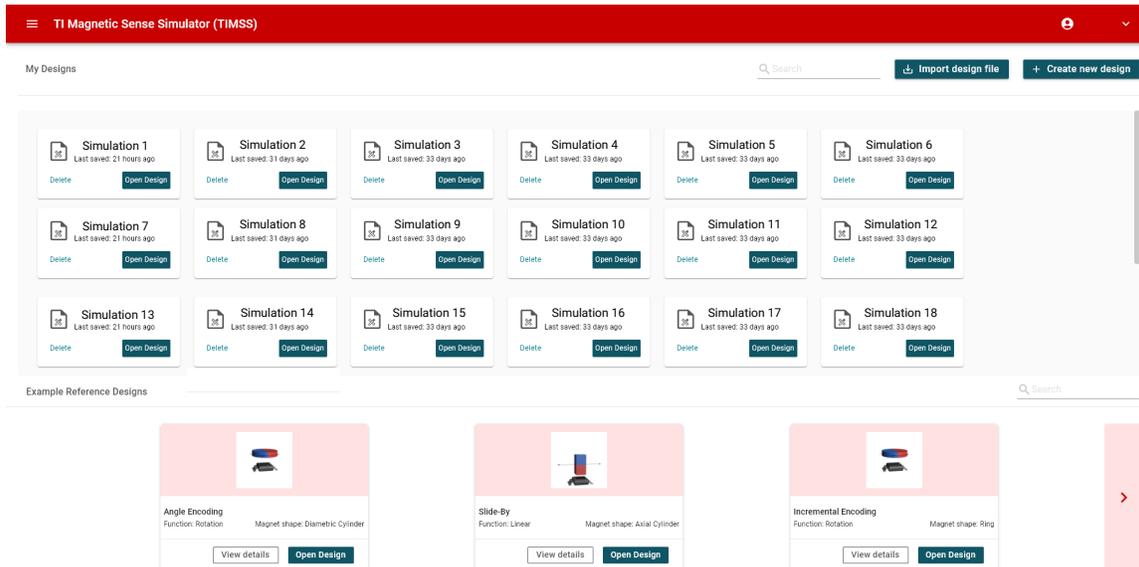- Loading a reference design

Figure 2-1. Homepage Screen

Several navigation options are available from the *Homepage* screen (Figure 2-1). The main navigation drop-down menu is represented by three parallel lines located at the top left of the *Homepage* screen (Figure 2-2). This menu is visible at any stage of simulation and allows quick navigation to several helpful links.
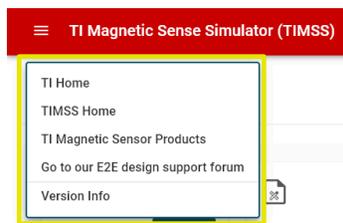

Figure 2-2. TIMSS Drop-Down Navigation Menu

The drop-down menu navigation is shown in Table 2-1 and external links open into new tabs.

Table 2-1. Home Drop-Down Menu Navigation

Menu Option	Destination	About
TI Home	www.ti.com	Return to the Texas Instruments home page
TIMSS Home	webench.ti.com/timss/	Abandon current simulation progress and return to top level menu
TI Magnetic Sensor Products	www.ti.com/halleffect	Explore Texas Instruments' magnetic sensing portfolio
Go to our E2E™ support forum	e2e.ti.com/support/sensors-group/sensors/f/sensors-forum	Get help from the *Engineer to Engineer* community
Version Info	Tool update history	See tool history and check for recent updates

2.1 Getting Started

There are a many options available for loading a design to get started. Three options exist in the top right of the window pane to help the user quickly launch a simulation (Figure 2-3).

Figure 2-3. My Designs

The *My Designs* pane has three function options.

1. **Search**: This field allows the user to type the name of a saved design and a tiled display of saved designs automatically filters to match the entered text (Figure 2-4).

Figure 2-4. Simulation Files

The *Open Design* button allows the user to open saved configurations from the tiled display list.
2. **Import design file**: This option allows a user to save the design to a local file once a simulation configuration is started. This file is saved in a .json format and read into the tool. A saved .json file is a preferred method for sharing design configurations.
3. **Create new design**: This option prompts the user to select a magnet shape, a type of motion, and up to six sensors to place in the simulation environment.

There are several reference designs available within the bottom pane of the GUI welcome page. These designs offer users a quick start configuration for several common functions (Figure 2-5).

Figure 2-5. Reference Designs

The reference designs include:

- Angle Encoding
- Slide-By
- Incremental Encoding
- Head-On
- Lid Closure

2.2 Creating a New Design

The *Create New Design* tool navigates to a selection window where the type of motion is selected (Figure 2-6). The options selected in this tool define the remainder of the simulation flow and constrain input parameters. Users must return to the TIMSS home screen and start again to change the motion function after starting the initial configuration.
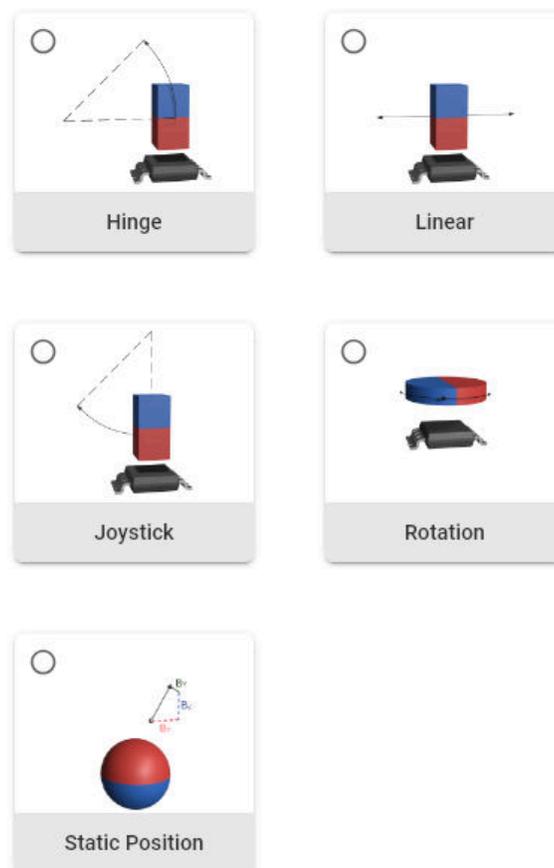

Figure 2-6. Motion Types

The five motion options are displayed in Table 2-2.

Table 2-2. Motion Type Descriptions

Function	Motion Description	Typical Applications
Hinge	The magnet pivots around the X-axis.	Lid closures, Lever positions, Door position
Linear	The magnet travels in a linear path from the start position (X_1,Y_1,Z_1) to a final position (X_2,Y_2,Z_2).	Linear Movers, Stroke Length Measurement, End of Travel, Liquid Level
Joystick	The magnet pivots around the origin by some tilt angle by any direction within the XY plane.	Joysticks, Levers
Rotation	The magnet rotates around the Z axis.	Angle Measurements, Liquid Level, Knobs, Motor commutation
Static Position	The field at a single point is calculated.	Magnet verification

Users can use the Hinge, Joystick, or Rotation option interchangeably where rotation is needed depending on system requirements. For instance, if rotating a magnet around the Y-axis is desired, set up a joystick simulation with the magnet centered at the origin. Similarly, rotating both the sensor (or sensors) and the magnet within the simulation space to use Z-axis rotation is possible. Regardless of the orientation chosen, the result produced in the simulation is in the sensor orientation.

Users can also select a starting magnet shape on the *Create New Design* page (Figure 2-7 and Table 2-3). This selection creates a simple dipole magnet of the specified shape in the simulation environment. This selection is the first step in updating and editing the magnet during the design process.
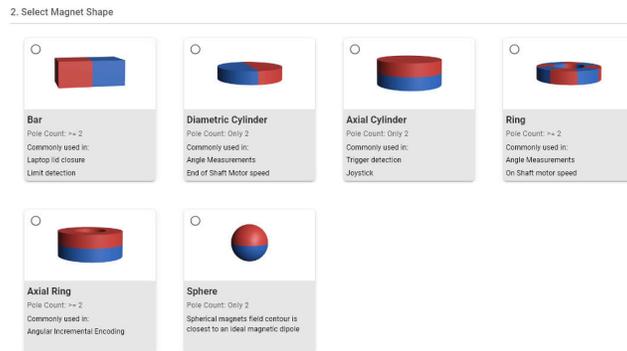

Figure 2-7. Magnet Shapes

Table 2-3. Magnet Shape Descriptions

Magnet Shape	Default Polarization	Pole Count Options
Bar Magnet	Z-axis	Even increments of poles cause the default magnet orientation to be subdivided along the X-axis length of the magnetD.
Diametric Cylinder	Y-axis with circular faces aligned in Z-direction	2
Axial Cylinder	Z-axis with circular faces aligned in Z-direction	2
Ring	Radially with circular faces aligned in Z-direction	Even increments of poles refer to number of poles observed when tracing the outer diameter
Axial Ring	Z-axis with circular faces aligned in Z-direction	For counts greater than 2, pole count is a multiple of 4. The count refers to the number of poles observed when tracing the outer diameter.
Sphere	Z-Axis	2

2.3 Selecting a Sensor

One key benefit of TIMSS is the ability to select a sensor and generate expected device outputs (Figure 2-8). Devices available for simulation are located at *Magnetic Sensors* on TI's website and up to 6 devices can be selected. This step can be skipped if only the magnetic field profile is needed.
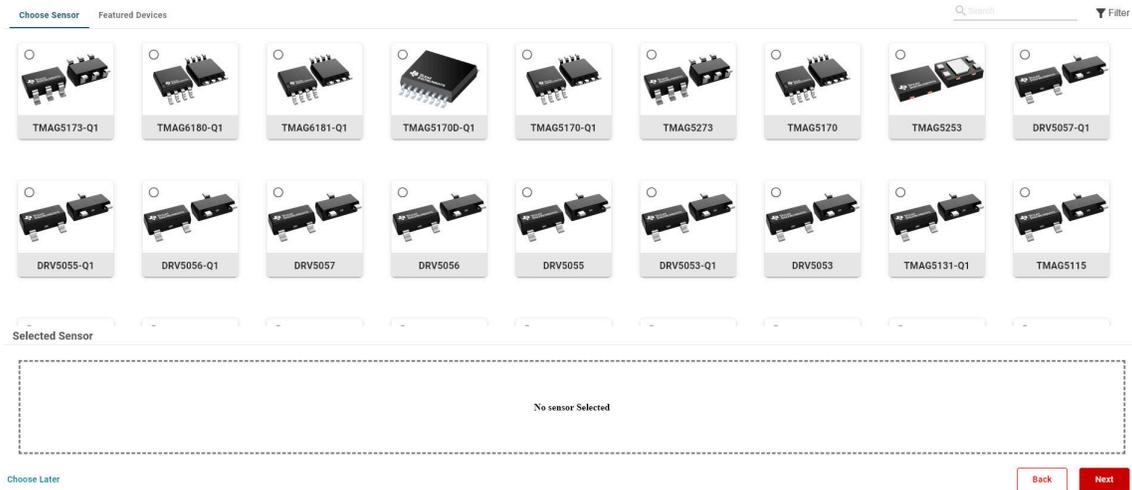

Figure 2-8. Sensor Selection

The full portfolio of products includes several different device package options and device families. The search function is available to assist with sensor selection by name. The filter menu is expandable to select options that only show devices that match the specified settings (Figure 2-9). Selecting the *Featured Devices* tab opens a list of commonly recommended devices for the appropriate motion type.
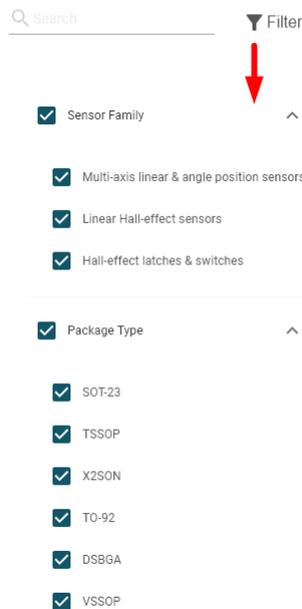
Figure 2-9. Sensor Selection Filter

Each tile expands when hovered over with a mouse to reveal a *More Info* button with more information about the devices. An info graphic showing the device block diagram is loaded and a link to the product page is available when *More Info* is selected. The *Product Page* link leads users to the device data sheet, application notes, and additional resources (Figure 2-10).
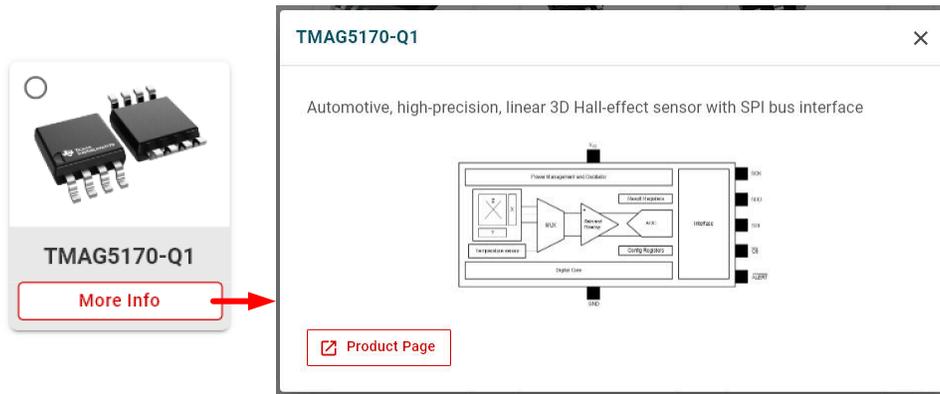
Figure 2-10. Sensor Information

Selecting a sensor tile adds the sensor to the *Selected Sensor* pane and up to six devices can be used in any simulation. The sensor quantity (Figure 2-11) can be increased in this pane if more than one sensor of a particular product is needed. Sensor selection can be skipped to produce a simulation that includes only the magnetic field input. The user is free to update the sensor selection and quantity after creating a new simulation.

Figure 2-11. Selected Sensors

2.4 Sensor Output Types

This section explains the common output modes available when using TIMSS.

- **Voltage Output Switch**: A switch device has two states that toggle when B_{OP} and B_{RP} thresholds are met. These two states are typically observed as a voltage on the output pin. Voltages in TIMSS switch between V_{OH} and V_{OL} for push-pull outputs or between V_{CC} and V_{OL} for open-drain devices.
- **Current Output Switch**: For switches with current mode output, there is no output pin to monitor voltage. Instead, the supply current, I_{cc}, increases or decreases depending on the output state.
- **Latch**: Latches operate similarly to switches with a voltage output but a key difference is that B_{OP} and B_{RP} are typically opposite values. For instance, if B_{OP} on a latch occurs at 2 mT, then the B_{RP} is set to -2 mT.
- **Voltage Output Linear**: Analog output linear devices vary the output voltage linearly with a changing input magnetic field. These devices typically have some sensitivity range specified to define the range of acceptable inputs. A wider input range corresponds to a higher sensitivity gain of the sensor. Outputs are typically set to a quiescent value, V_Q, with no magnetic input provided.
- **Digital Output Linear**: Many 3-axis sensors implement a digital output format to provide selectable access to specific magnetic field components. These devices often have built-in averaging functions to enable oversampling for reduced noise. The result of over-sampling is an increase in the effective number of bits (ENOB) of the sensor. Changes commonly occur in the output code range when averaging is enabled. For example, TMAG5170-Q1 changes from a 12-bit result to a 16-bit result whenever averaging is enabled.

3 Simulation Environment

Selecting the *Create Design* tool displays the simulation environment (Figure 3-1).
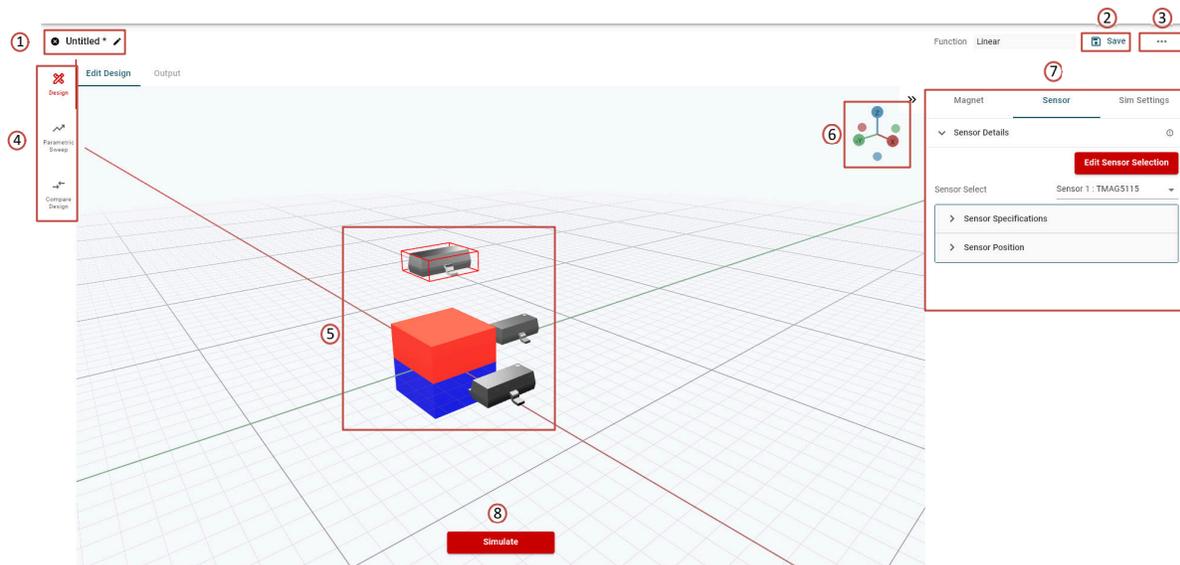

Figure 3-1. Simulation Environment

A 3D model of the system is displayed and updated as user entry fields are changed. The *Create Design* page contains several key interface selections.

1. **Simulation Name**: Selecting the pencil icon allows users to change the name of the simulation. This is the name displayed on the home screen tile under *My Designs*.
2. **Save**: Selecting this overwrites any existing configuration settings for the design. Any changes made to an existing design without selecting *Save* are lost when exiting the simulation environment.
3. **Import and Export Menu**: This menu includes options to externally save simulation information contained in the tool (Figure 3-2).
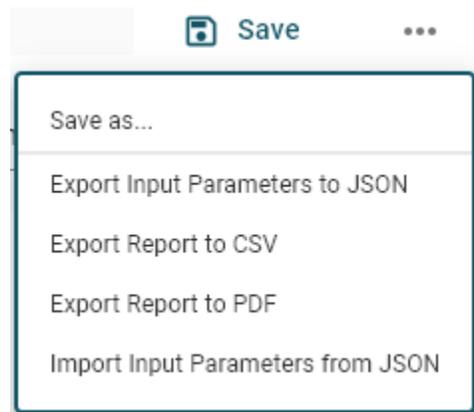
Figure 3-2. Import and Export Menu

a. **Save As**: This selection allows users to create a new saved design in *My Designs* after being prompted for a new design name.
b. **Export Input Parameters to JSON**: This creates a local file which can be imported by any user.
c. **Export Report to CSV**: This exports all data and settings into a single .csv file after running a simulation. This file is formatted for use with pivot tables and similar data processing tools after running a simulation. This is particularly powerful when analyzing data from parameterized sweeps.
d. **Export Report to PDF**: This generates a PDF report showing the simulation setup, input plots, output plots, and tabulated simulation data.

e. **Import Input Parameters from JSON**: This loads simulation local files exported with the *Export Input Parameters to JSON* function.
4. **Simulation Mode**: These tabs allow the user to change between three simulation modes.
   a. **Design**: This is the standard design format.
   b. **Parametric Sweep**: Parametric sweep allows for user input fields to be stepped through either ranges or discrete values to compare the impact of system tolerances on end behavior. This is discussed in detail in Section 6.
   c. **Compare Designs**: This runs a comparison between two simulations side by side after multiple designs of the same type have been saved. This is discussed in detail in Section 7.
5. **3D Render**: The 3D model of the system can be adjusted freely to observe the motion of the magnet relative to the sensors. The tool does not prevent collisions and the user is responsible for placing the devices appropriately. The following list of functions help users navigate in the tool.
   a. Click and Drag: This changes the camera perspective.
   b. Scroll Wheel: This zooms in or out from the design center of focus.
   c. Shift + Click and Drag: This pans the camera and adjusts the center of focus.
6. **Cartesian Coordinates**: The axes are colored following this convention.

   X = red

   Y = green

   Z = blue

   Selected on this marker quickly auto-aligns the view to the direction of the specific axis selected.
7. **Simulation Input Fields**: These menu feature allows users to customize the simulation settings. The various fields are explained in Section 4.2.

   For help understanding magnet and sensor rotation within the simulation environment please refer to Section A.3.
8. **Simulate**: Selecting this button runs the simulation and generates field data and output results.

4 Simulation Inputs

The simulation inputs are divided into three tabs: *Magnet*, *Sensor*, and *Sim Settings*. In both the Magnet and Sensor tabs, the user is asked to provide information about the starting position of both the sensor and the magnet.

4.1 Magnet Input Fields

4.1.1 Magnet Specifications

The key element in any simulation is the permanent magnet input source. The strength of any magnet varies based on the material of the magnet and the particular grade, size, and shape of the magnet, and the ambient temperature. A list of magnet materials and grades can be found in Section A.2.

Figure 4-1. Magnet Specification Entry

Changing the magnet shape from the initially selected design when first created is possible. Additionally, increasing the number of poles the magnet is subdivided into is possible if the selected magnet shape allows (Figure 4-1). Invalid pole counts display with a warning and the 3D view automatically updates to show the results of this setting.

A library of common industry standardized materials is built in and automatically loads. The tool relies primarily on the remanence value (B_R), which describes the closed loop magnetic field that remains after an external magnetizing field is applied.

The input parameters are manually entered to create a custom material in the event that the desired magnet grade is not available.

All magnetic materials typically exhibit a negative temperature coefficient. For example, as the temperature of the material increases the magnetization strength reduces. This behavior is mostly a linear characteristic near standard operating temperatures. Typical values are shown in Table 4-1. The temperature value provided in the magnet properties also applies to the Hall-effect sensor when the device includes temperature compensation.

Table 4-1. Common Magnet Temperature Coefficients

Material	Temperature Coefficient
NdFeB	-0.12 % / C°
SmCo	-0.03 % / C°
Ferrite	-0.2 % / C°
AlNiCo	-0.02 % / C°

4.1.2 Magnet Geometry

The *Magnet Geometry* section prompts for the size of the magnet after choosing the magnet shape and material. The displayed fields vary based on the selected shape. Figure 4-2 shows an example input field for a bar type magnet and Table 4-2 lists the various inputs required for each magnet shape.

Figure 4-2. Magnet Geometry

Table 4-2. Magnet Geometry Fields

Input Field	Magnet Type
Length (X)	Bar
Width (Y)	Bar
Height (Z)	Bar, Diametric Cylinder, Axial Cylinder, Ring, Axial Ring
Outer Diameter	Diametric Cylinder, Axial Cylinder, Ring, Axial Ring, Sphere
Inner Diameter	Ring, Axial Ring

4.1.3 Magnet Motion

The last requirement is to define the magnet travel. All motion types begin by defining the starting location of the magnet. Coordinates (X,Y,Z) of the magnet are defined at the center of the magnet. Re-orienting the magnet by performing rotations in XYZ order are possible at the start position. This orientation allows for any possible start orientation. The rotation steps are applied around the magnet center and not the origin.
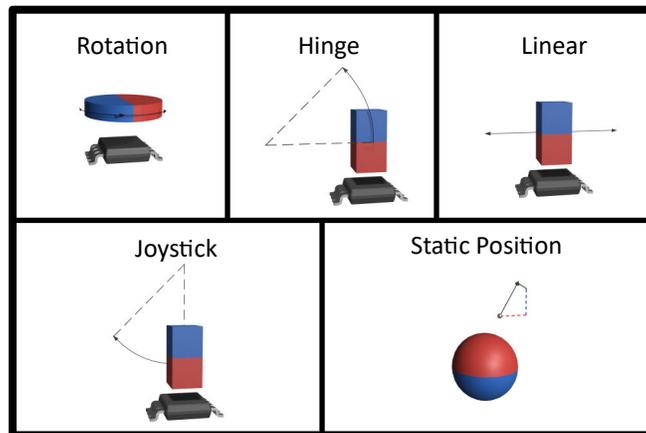

Figure 4-3. TIMSS Motion Types

The various fields for each type of motion are shown in subsections Section 4.1.4 through Section 4.1.7.

4.1.4 Magnet Rotation

Figure 4-4. Rotation Motion Fields

For help understanding magnet orientation and rotation within the simulation environment please refer to Section A.3.

The magnet moves by rotating around the Z-axis by the distance *Arc Length* which is measured in degrees for the rotation simulation format. The arc length resolution can be set using the step size as described in Section 4.3. Rotation begins (0 degrees) from the *Origin Position* angle shown in Figure 4-4. Either a positive (counter clockwise) or negative (clockwise) rotation can be used.

4.1.5 Hinge Magnet Motion

Figure 4-5. Hinged Motion Fields

For help understanding magnet orientation and rotation within the simulation environment please refer to Section A.3.

The magnet pivots around the X-axis by distance *Arc Length* which is measured in degrees for the Hinge rotation format. Normal lid-close simulations have a displacement in the Y-direction for both the magnet and sensor with each separated by some distance in the Z-direction. As the magnet pivots, the magnet typically arcs upward away from the sensor. The simulation resolution can be set using the step size as described in Section 4.3.

4.1.6 Linear Magnet Motion

Figure 4-6. Linear Motion Fields

For help understanding magnet orientation and rotation within the simulation environment please refer to Section A.3.

Linear travel requires that both the start and final coordinates are entered. Motion steps the position of the magnet evenly from the start to finish position. TI recommends choosing a value that is a factor of the total distance traveled when setting the step size. Step size can be set as described in Section 4.3.

4.1.7 Joystick Magnet Motion

Figure 4-7. Joystick Motion Fields

For help understanding magnet orientation and rotation within the simulation environment please refer to Section A.3.

Joystick motion has the fewest constraints when rotating the magnet. The magnet pivots around the origin by an arc length defined as *Tilt Angle* in this mode, as shown in Figure 4-8. The resolution of the tilt angle can be set using the step size as described in Section 4.3.

The direction of rotation is around the Y axis when *XY Angle* is set to 0. The *XY Angle* defines the direction of the tilt within the XY plane relative to this starting direction as shown in Figure 4-9.
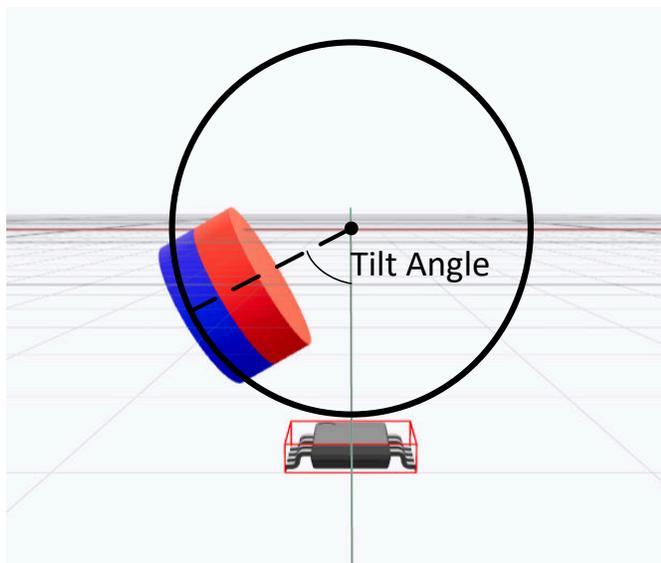
Figure 4-8. Joystick Tilt Parameter
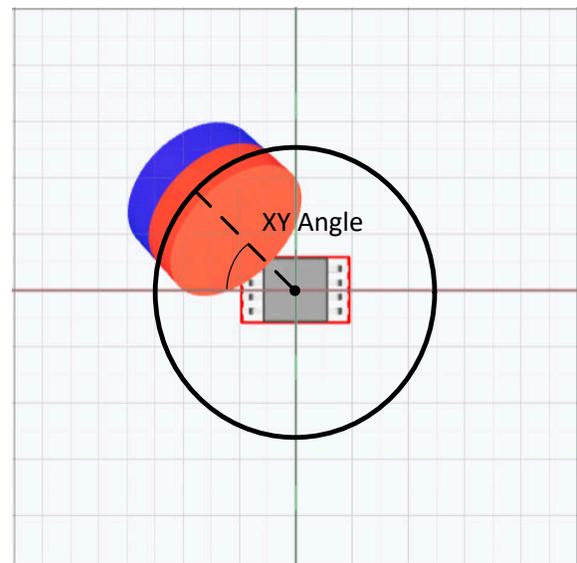
Figure 4-9. Joystick XY Angle Parameter

4.2 Sensor Input Fields

The specific sensor selected and the location of that sensor in the simulation directly influences the output behavior observed. The goal of TIMSS is to help evaluate what this output is. Placing the sensor anywhere to compare similar devices at the same location helps in selecting the correct sensor for any design, including overlapping with other sensors. Up to six sensors can be placed in any simulation (Figure 4-10).
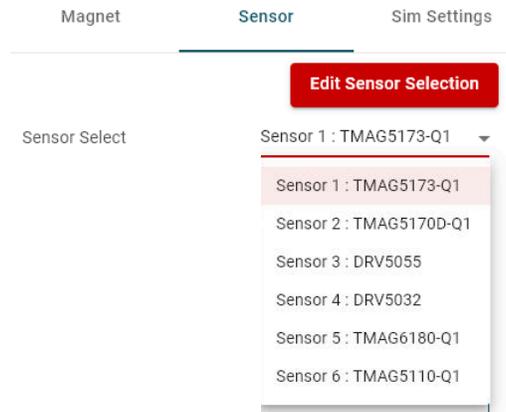
Figure 4-10. Sensor Selection Menu

Select sensors for use in the simulation at any time by clicking *Edit Sensor Selection*. All user inputs tied to the sensor are deleted once a sensor is removed.

Using different settings for each sensor is possible. Select the drop-down arrow to expand the list of sensors and switch between sensor settings (Figure 4-10).

Each device is set to a specific oderable part number and the fields of the form automatically update with all the relevant specifications that govern device response. There are generally two formats: one for linear devices and another for latches and switches.

4.2.1 Linear Sensor Format

Figure 4-11. Linear Sensor Input Parameters

1. **Oderable Part Number**: Within the product family there can exist a variety of sensitivity options and package variants. Each of these options can be selected from and used to run a simulation. **The location of the sensing element within the package is accounted for automatically**. TI recommends referring to the product data sheet for exact sensor locations when configuring simulations.
2. **Applied Vcc**: A value within this range must be selected. Setting this value is used to determine the linear output range of the device where appropriate. Shown adjacent to this field are the maximum and minimum operating values for this entry. This field also adjusts the sensitivity in the case of ratio metric devices.
3. **Max Input**: This field changes the sensitivity range of the sensor and updates any related fields accordingly. A programmable sensitivity range is common for sensors which utilize a digital interface. For example, TMAG5273A1 can be programmed to either a ±40 mT or a ±80 mT input range.
4. **Temperature Compensation**: Many digital interface devices also offer the ability to choose a temperature compensation scheme. Settings here often match the typical values provided in Table 4-1.
5. **Averaging**: Another feature of digital interface devices is the ability to use averaging to effectively reduce the observed noise from the sensor. This over-sampling function effectively multiplies the typical input referred noise by $1/\sqrt{n}$, where n is the number of averages. Oversampling is a helpful method to reduce the effect of random noise sources.

4.2.2 Latch and Switch Format

Figure 4-12. Latch and Switch Input Parameters

1. **Orderable Part Number**: Within the product family there exists a variety of sensitivity options and package variants. Each of these options is selected from and used to run a simulation. **The location of the sensing element within the package is accounted for automatically**. TI recommends referring to the product data sheet for exact sensor locations when configuring simulations. Please refer to Section A.1 for more details setting the sensor origin.
2. **Applied Vcc**: For latches and switches the output is binary and typically consists of either a push-pull type or requires a pull-up resistor. In cases where a pull-up is required (open-drain), the output is shown to toggle between the output logic low voltage, V_{OL} and V_{cc}. If the output format is push-pull then the upper limit is output logic high voltage V_{OH}.
3. **Select BOP**: B_{OP} is defined as the operating threshold field. The output switches to an active output state when the input field exceeds this value. TI recommends setting this field to the *High Value ($B_{OP\ Max}$ in the data sheet)* to verify that even the highest threshold setting is met during operating conditions.
4. **Select BRP**: BRP is defined as the release threshold field. The output is released from the active output state when the input field is below this value. TI recommends setting this field to *Low Value ($B_{RP\ Min}$ in the data sheet)*to verify that the lowest release threshold is met.

4.2.3 Sensor Position

The final sensor inputs relate to the orientation of the sensor package within the simulation and the physical placement. The sensor response corresponds to the sensitivity direction and rotating the package within the simulation environment to achieve the desired response.

Figure 4-13. Sensor Position Inputs

This rotation coordinates with the sensor reference and not the global origin, similar to the magnet. The sensor reference point is typically the center of the package footprint seen on the surface of the PCB. More details for each package are available in Section A.1.

For help understanding sensor orientation and rotation within the simulation environment please refer to Section A.3.

4.3 Simulation Settings

The last user field is set within *Sim Settings*. This field sets the step size for either the rotation or linear movement and directly impacts the simulation time and size of any export file.

5 Simulation Results

The user interface displays the results after simulating a particular setup. This page has several points for the user to interact with (Figure 5-1).
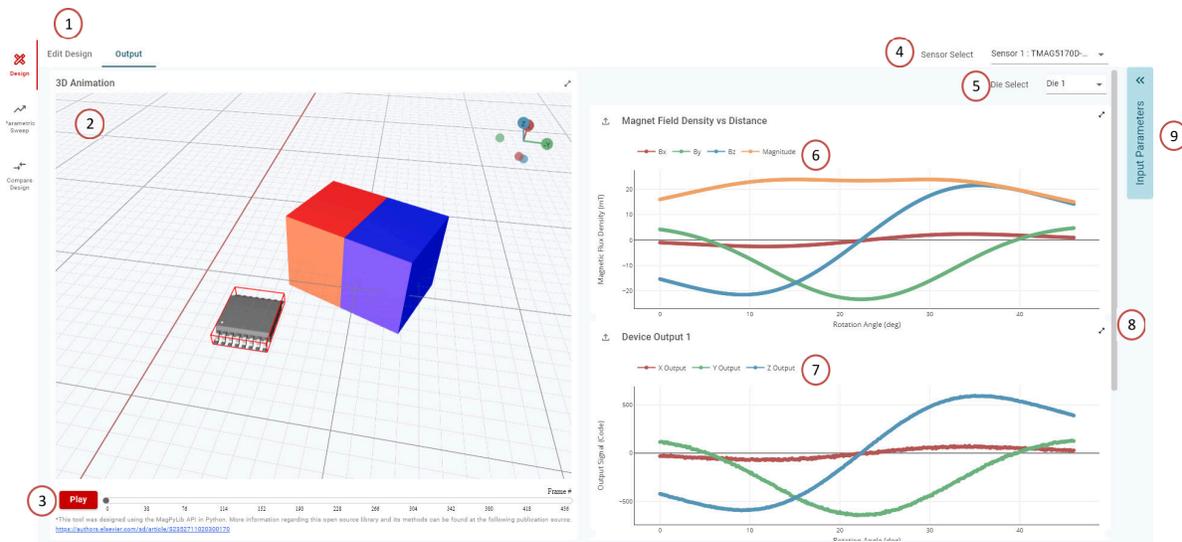
Figure 5-1. Simulation Outputs

1. **Edit Design**: Click the *Edit Design* tab to return to the simulation input panel.
2. **Simulation Environment**: Navigate this feature as described in Section 3.
3. **Play**: Select this button to play an animation of the magnet motion. The progress slider can be clicked and dragged to set the animation to a specific frame. Watching the full animation is helpful to verify the input parameters related to magnet motion are correct and match expectations. This is particularly useful in cases where the magnet is rotated.
4. **Sensor Select**: Select this option for simulations with more than one sensor to switch the field and output results to display the simulation results for the selected sensor.
5. **Die Select**: Select this feature to display the results for the selected die in devices with more than one die.
6. **Magnet Field Density Versus Distance**: This plot displays *Magnetic Flux Density* in millitesla versus the travel of the magnet. This plot demonstrates the sensor orientation and not the global coordinate space. The field is calculated based on the alignment shown in Appendix A if the sensor is rotated.
   a. Single click the trace in the legend to remove individual results in the plot from view.
   b. Double click the trace in the legend to keep all results from view in the plot except selected results.
   c. Hovering over any trace with the selection tool shows the value of the field at that point.
   d. Use the selection tool scroll wheel to zoom in on the plot.
   e. Select the home icon to return to the full view of the plot.
   f. Click the double arrow icon in the top right of the panel to create an enlarged pop-out of the graph.
7. **Device Output** - Emulated device outputs are overlaid in the device output plots. Outputs of the same type are overlaid on a single graph. This plot can be manipulated using the same controls as the input magnetic field plot.
8. **Scroll Bar** - Using the mouse scroll wheel over the plot zooms the plot instead of advancing to the next plot. Some devices have more than one output mode. When this scroll bar is present there is another plot available by scrolling down.
9. **Input Parameters** - This tab expands and collapses to show the parameters used for the simulation. This is helpful for allowing the user to remain on the simulation outputs page without needing to navigate to *Edit Design*, which removes the output results from view.

6 Parametric Sweeps

Parametric sweeps allow the user to run a series of simulations and to accumulate the resulting data across all variations. This function can be particularly useful when assessing the effect of system tolerances on device performance.

Parametric sweeps are available from the simulation environment during either the input or output stages by clicking the icon on the left side of the screen (Figure 6-1).

Parameters selected in this mode override those set in the main simulation page. All unmodified input parameters remain as entered.
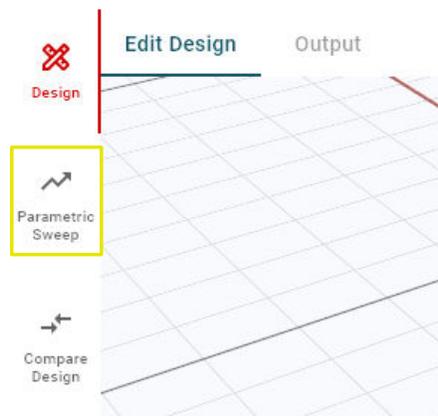

Figure 6-1. Parametric Sweeps

There are two selectable sweep options available through the toggle icon at the top of the page within parametric mode, *Individual Sweep* and *Combinational Sweep* (Figure 6-2).

| Individual Sweep | Combinational Sweep |

Figure 6-2. Sweep Type Select

- **Individual Sweep**: Simulates each added parameter individually and allows up to 250 parameterized simulation points. Any number of variables can be added as long as the final number of simulations remains below this limit.
- **Combinational Sweep**: This mode combines all selected sweep parameters in a nested fashion. This mode attempts all permutations of each sweep parameter to include in the output report. In this mode, a maximum of 125 simulation points are available using up to 3 variables.

The first parameter can be added from the *+ Add New Parameter* button in the center of the screen (Figure 6-3). After this entry is created the button moves to the top right.

Figure 6-3. Adding New Parameters

Selecting which sensor (or sensors) the sweeps apply to is possible if multiple sensors exist in the simulation space.

Simulation outputs appear in the format shown in Figure 6-4.
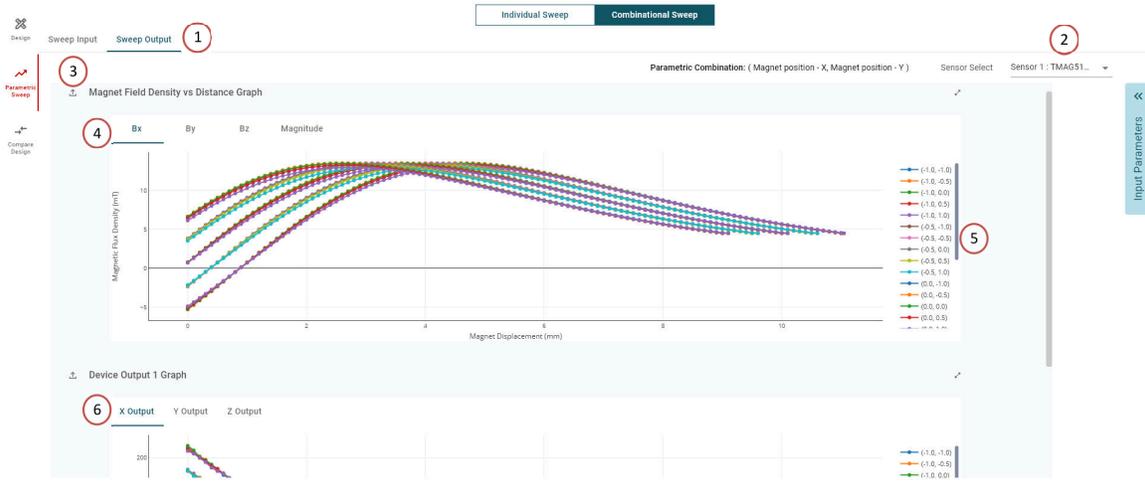
Figure 6-4. Parametric Sweep Outputs

1. **Input and Output Select**: Editing the parameters by selecting the *Sweep Input* title is possible. The tool automatically moves to the sweep output tab once the simulation is complete.
2. **Sensor Select**: Selecting which sensor is displayed when multiple sensors exist in the simulation is possible. Only one sensor is shown at a time since large sets of data exist in parametric sweeps.
3. **Plot Download**: Selecting the icon to the left of the title plot allows the specific data shown in the plot to be downloaded. Data is included for all tab selections in the plot. This selection downloads only the data from the plot. Please use the export options shown in Section 3 for a comprehensive collection of data from all plots and specific simulation settings.

4. **Magnetic Field Input Plot**: Selecting B_x, B_y, B_z, or *Magnitude* switches between the various plots of magnetic flux density available for the selected sensor.
5. **Plot Legend**: Double click on the legend entry to hide all other plots to isolate specific combinations. Single click on the legend entry to hide specific combinations. The various traces are notated based on the parameter values in the order that the parameters were defined.
6. **Device Output Plots**: Scroll with the bar on the right to navigate to any additional plots. The output related plots are appended below the magnetic field plots if a device is added to the simulation.

7 Comparing Designs

Another feature that can help functionally improve the design process is the *Compare Designs* mode. Using this mode compares the existing design to any other saved design of the same motion type (for example, comparing rotation and hinge is not permitted).

An example comparison is shown in Figure 7-1.
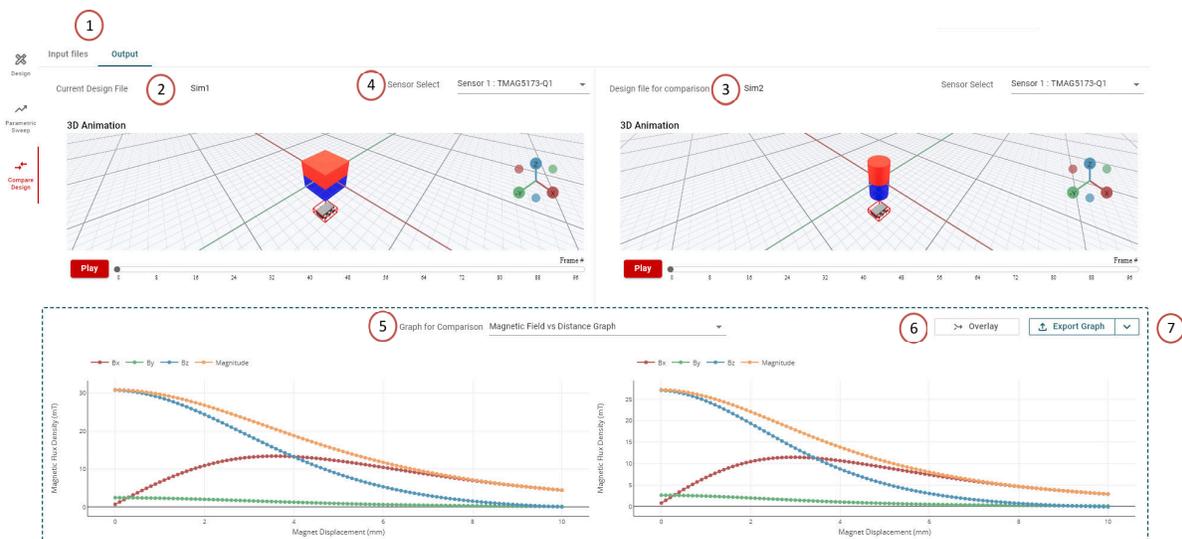
Figure 7-1. Compare Designs Example

1. **Input and Output Select**: The simulation results for both designs are shown side by side after selecting designs to compare. If needed, returning to the simulation selection page is possible by clicking on *Input Files*.
2. **Simulation 1**: The left side is the active simulation in use when *Compare Designs* is selected. The title of the primary simulation is displayed here.
3. **Simulation 2**: The right side is the simulation selected from either the user account simulations or from a locally saved .json file.
4. **Sensor Select**: The drop-down menu at this location allows the user to select the device response comparison of more than one sensor and is available in either simulation.
5. **Graph Selection**: This drop-down menu allows the user to select the input magnetic field and the device output (or outputs).
6. **Overlay**: Selecting this option combines the outputs into a single plot as shown in Figure 7-2. Some differences are not easily observed when comparing the two simulation results side-by-side. Conveniently, the individual components are plotted independently in this mode.
7. **Export Graph**: This option allows the user to export the graph data shown for both sensors in a single .csv file.
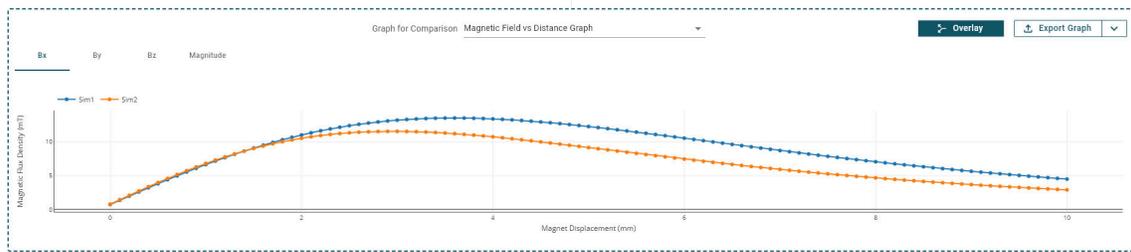
Figure 7-2. Overlaid Comparison Outputs

8 Summary

Texas Instruments' Magnetic Sense Simulator (TIMSS) is a powerful free resource that helps with magnetic sensing designs. The tool is meant to help expedite designs but TI recommends confirming these configurations through physical testing of outcomes.

Please refer any questions or concerns to Texas Instruments' E2E™ support forum.

9 References

1. Texas Instruments, TI.com™
2. Texas Instruments, E2E™ Support Forum, website
3. Texas Instruments, Magnetic Sense Simulator, tool
4. Texas Instruments, Webench®
5. Magnetic Library, *Amazing Magnets*, website
6. Texas Instruments, *TMAG5170-Q1 High-Precision 3D Linear Hall-Effect Sensor With SPI*, data sheet
7. Texas Instruments, *TMAG5273 Low-Power Linear 3D Hall-Effect Sensor With I2C Interface*, data sheet
8. Texas Instruments, *Magnetic Sensing Enhanced Proximity Tool*, user's guide

A Appendix

A.1 Sensor Placement

Understanding the reference origin of the device to properly position the device relative to the magnet is important for placing a sensor within a simulation. Placing the sensor at (0,0,0) results in the face of the package body located at the global origin, which touches the PCB. TIMSS assumes this location matches the appropriate package drawing from the device data sheet and calculates the actual sensing element position within the package.

For better understanding, see the following reference diagrams for Figure A-1, Figure A-3, and Figure A-5 packages. The red X in the diagram represents the package origin used in TIMSS.

✖ Package Reference Coordinate Location
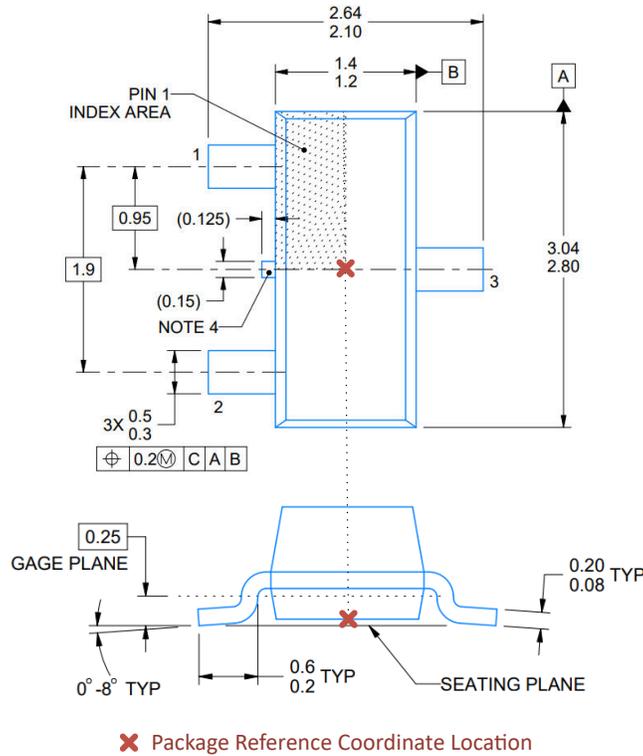
Figure A-1. SOT-23 Package Reference Location
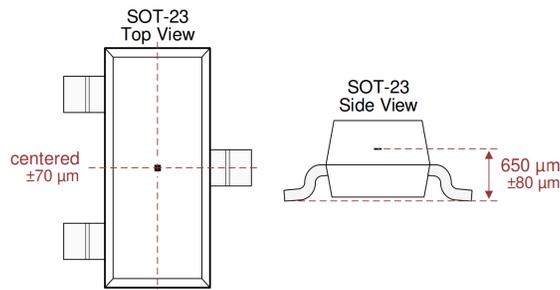
Figure A-2. DRV5032 SOT-23 Sensor Location in Package
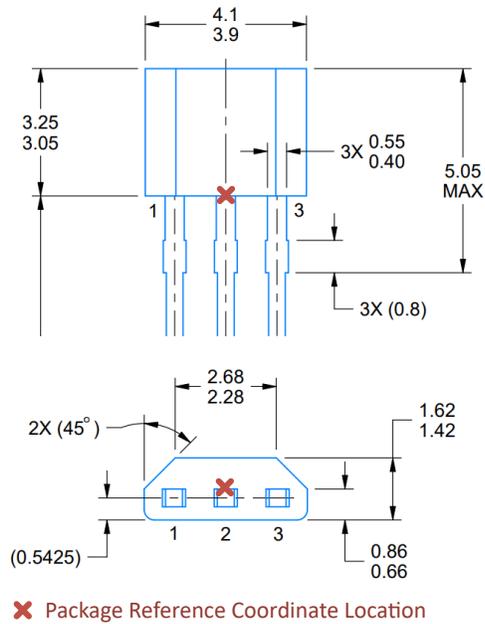
Figure A-3. T0-92 Package Reference Location
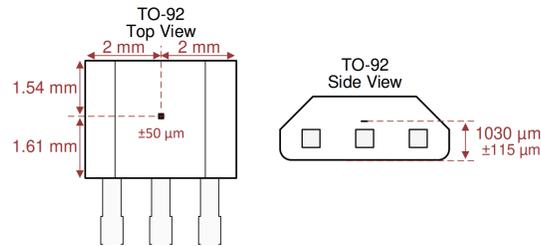
Figure A-4. DRV5032 T0-92 Sensor Location in Package

Notably, the through hole leads are not centered in the package. The package center shown in the top down view is roughly aligned to the start of the bevel edge.
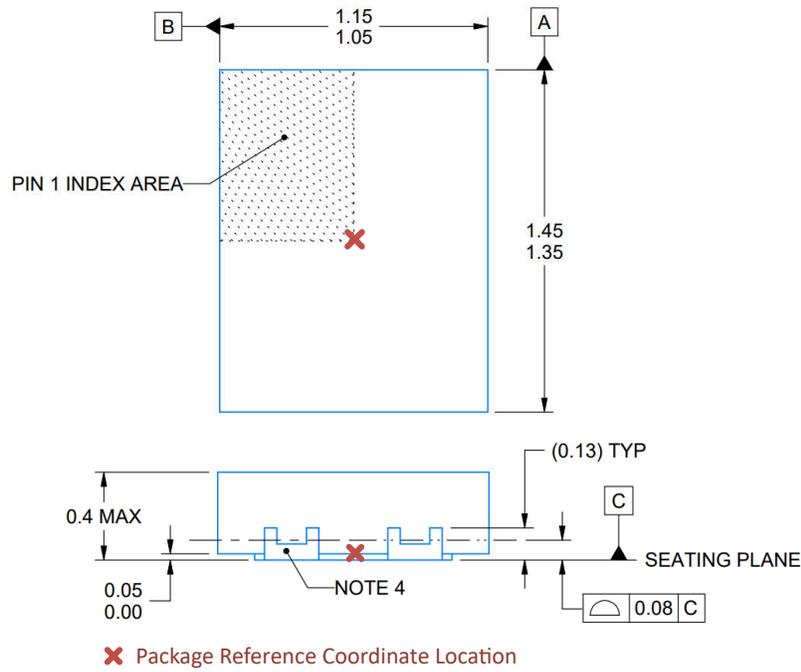
Figure A-5. X2SON Package Reference Location
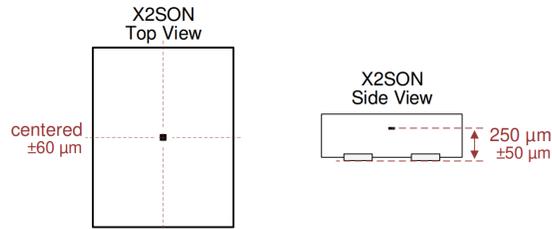
Figure A-6. DRV5032 X2SON Sensor Location in Package

The same method for locating the package center is followed on all other devices not shown.

A.2 Magnet Materials

The following materials are loaded into the tool:

Sintered Neodymium Iron Boron (NdFeB)

- N35
- N38
- N40
- N42
- N45
- N48
- N50
- N52
- N55

Samarium Cobalt (SmCo)

- YX18
- YX20
- YX24
- YXH24
- YXG26
- YXG28
- YXG28B
- YXG30
- YXG30B

Bonded Neodymium (NdFeB)

- BDM-4
- BDM-6
- BDM-8
- BDM-10
- BDM-12
- BDM-L

Aluminum Nickel Cobalt (AlNiCo)

- LN9
- LN10
- LN12
- LN13
- LNG34
- LNG37
- LNG40
- LNG44
- LNG52
- LNGT28
- LNGT36J
- LNGT32
- LNGT40
- LNGT60
- LNGT72

Ceramic Ferrite

- C1
- C5
- C7
- C8
- C8B
- C9
- C10
- C11

Rubberized Ferrite

- FRM-5
- FRM-6
- FRM-8
- FRM-11
- FRM-12

The magnet materials information in this section is gathered from *Amazing Magnets*.

A.3 Rotation Tips

Rotation is implemented by rotating the desired magnet or sensor around the specific axis. For instance, if rotating around X, the magnet rotates within the YZ plane. Consider a small ring magnet with 6 poles.
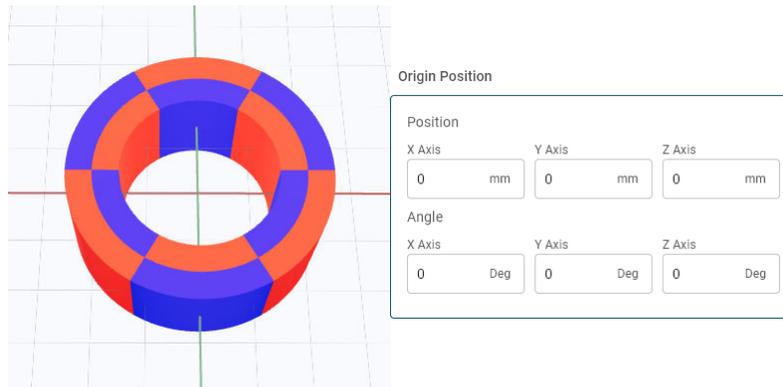
Figure A-7. Ring Magnet Without Rotation

Examples of simple 90 degree rotations are shown in Figure A-8 through Figure A-10.
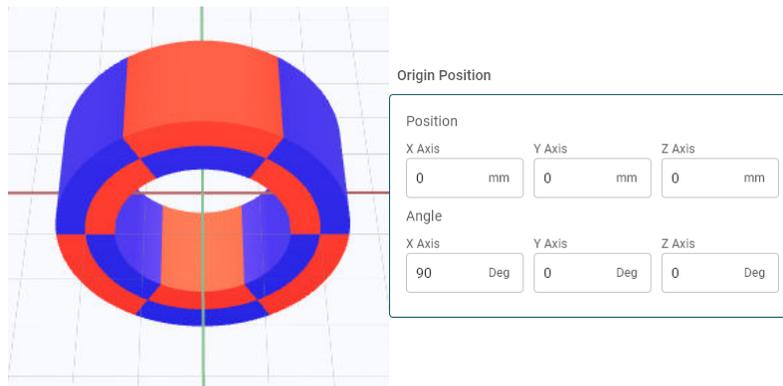
Figure A-8. Ring Magnet Rotated Around X
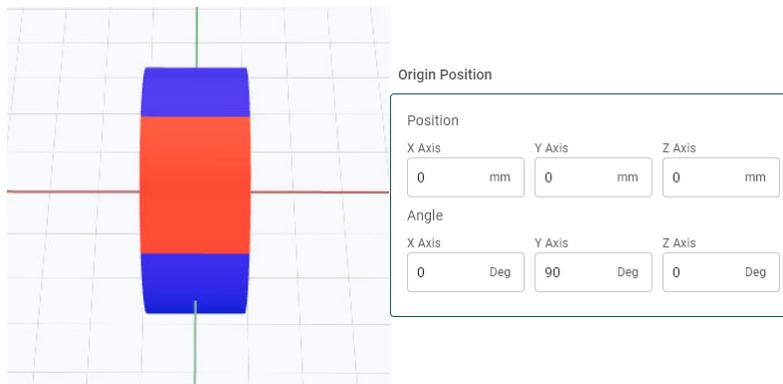
Figure A-9. Ring Magnet Rotated Around Y
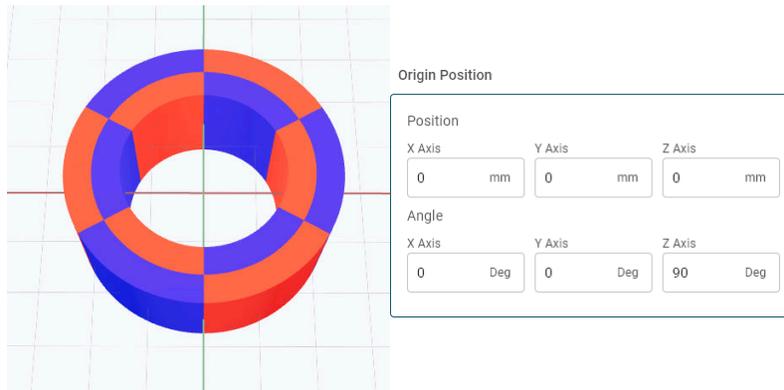
Figure A-10. Ring Magnet Rotated Around Z

The 3D rotation of any object follows the X to Y to Z order within TIMSS. There are many approaches to achieving the end orientation that can achieve the same result. In Figure A-11 the magnet is rotated by:

- X = 15 degrees
- Y = 15 degrees
- Z = 180 degrees
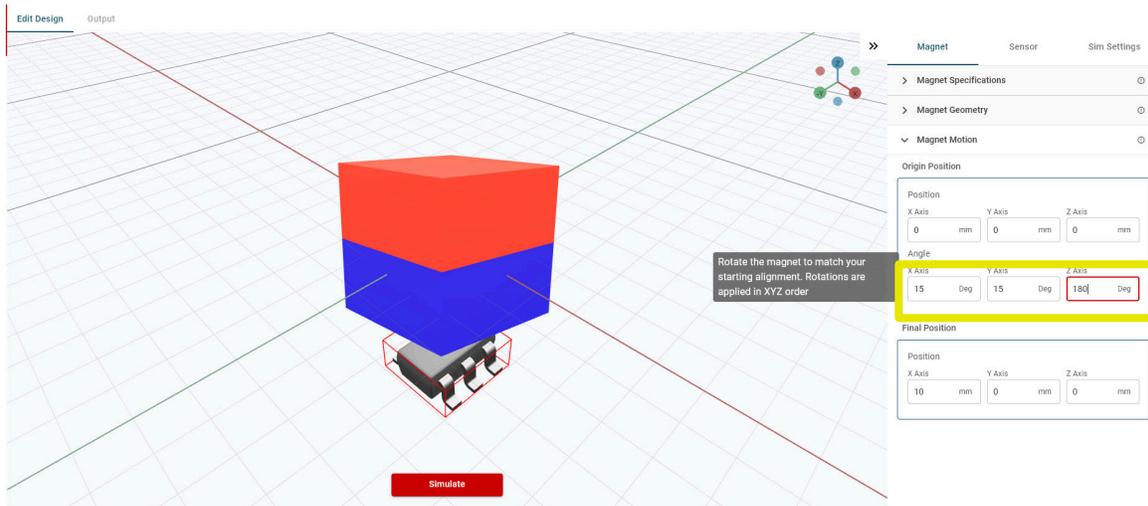
Figure A-11. Initial Rotation

Achieving the same final orientation is possible by using the following inputs:

- X = -15 degrees
- Y = -15 degrees
- Z = 0 degrees
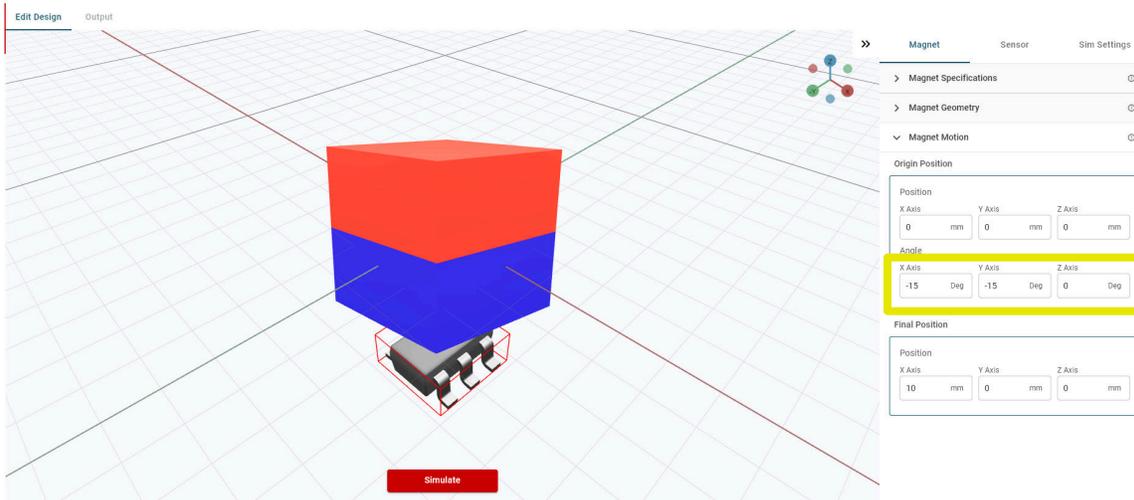
Figure A-12. Matching Rotation

Using the live, updated version of the system in TIMSS is advisable for verifying the resulting orientations match expectation before starting the simulation. Formatting the rotation to another orientation is important to meet the constraints within TIMSS. For instance, Hinge rotation is constrained around the X-axis. Rotating the sensor 90 degrees around X to create motion that models a pendulum above the sensor can be necessary.
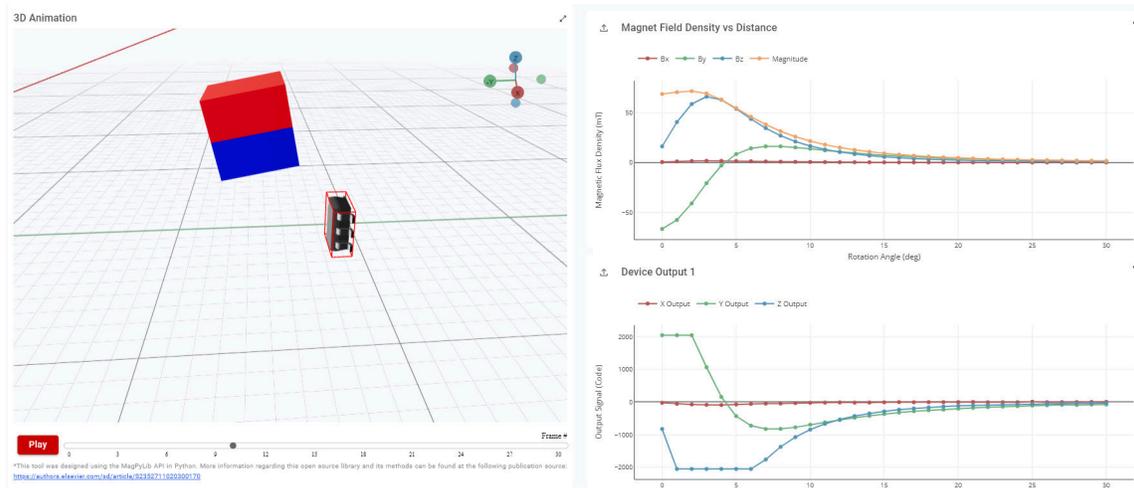
Figure A-13. Pendulum Motion With Hinge

The example in Figure A-13 shows the starting position to the left of the magnet aligned directly with the sensor seated on the Y-axis. To model a full arc which can swing both positive and negative directions, calculate the starting coordinates using Equation 1.

$$Y\ position\ =\ magnet\ center\ radius\ \times\ \cos\left(\frac{full\ rotation\ angle}{2}\right)$$

$$Z\ position\ =\ -magnet\ center\ radius\ \times\ \sin\left(\frac{full\ rotation\ angle}{2}\right)$$

(1)

In the example of the magnet swinging ±20 degrees at a radius of 35 mm, the new calculated starting points are Y = 32.889 mm and Z = -11.971 mm. Finally, tilting the magnet at X by -20 degrees is necessary. The resulting starting alignment is shown in Figure A-14.
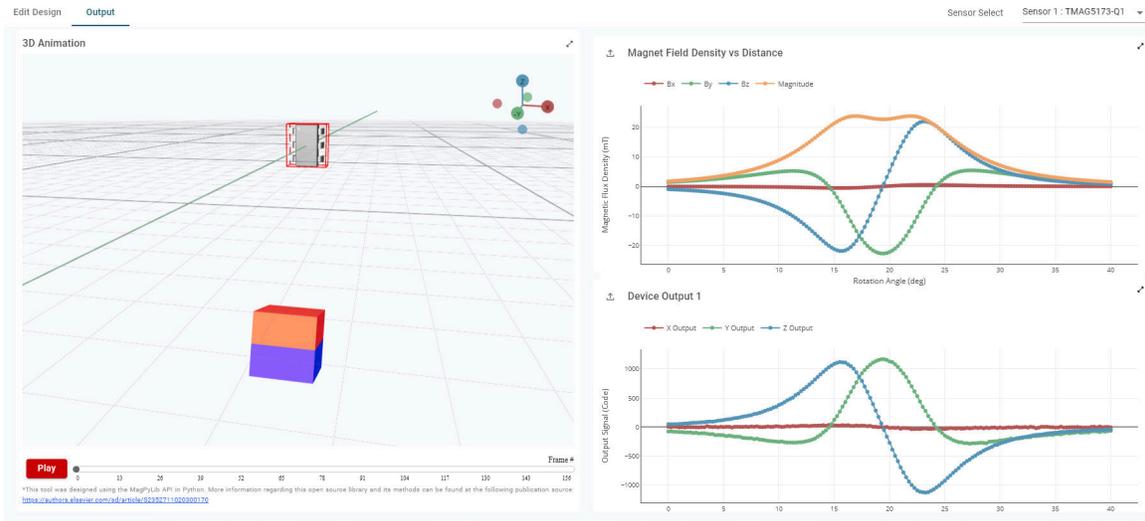
Figure A-14. Full Pendulum Sweep

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