Sensors Converge

Simplifying your design with Hall-effect sensors

June 20–22, 2023 | Santa Clara, CA

#SensorsConverge

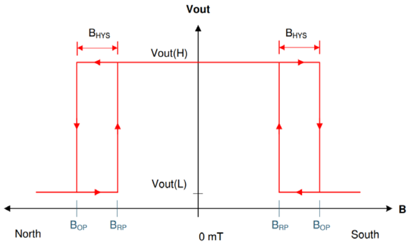
Agenda

- Hall-effect Sensor Types
- Design Options
  - Linear Displacement
  - Hinged Rotation
  - Axial Rotation
  - Joystick
- Free Tools
  - FEMM
  - MagPyLib
  - Magnetic Sense Enhanced Proximity Tool

Hall-effect sensor types

Switch

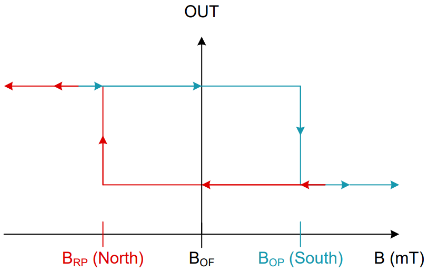
- Operate and Release thresholds
- Omni-polar or uni-polar



- Limit Detection

Latch

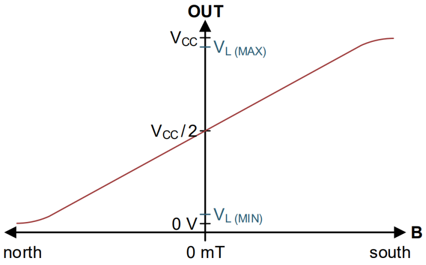
- Symmetric operate and release thresholds for alternating fields



- Speed and Direction
- Motor Commutation

Analog linear

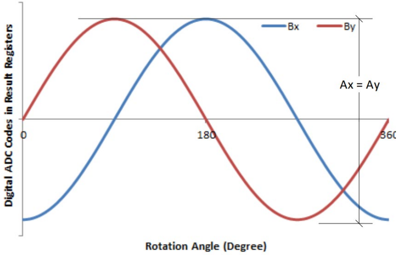
- Produce a linear output voltage with changing magnetic fields



- Linear Arrays
- Angle

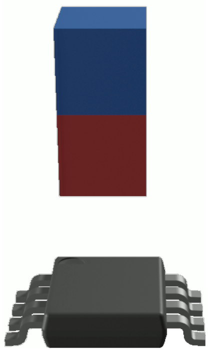
Digital linear

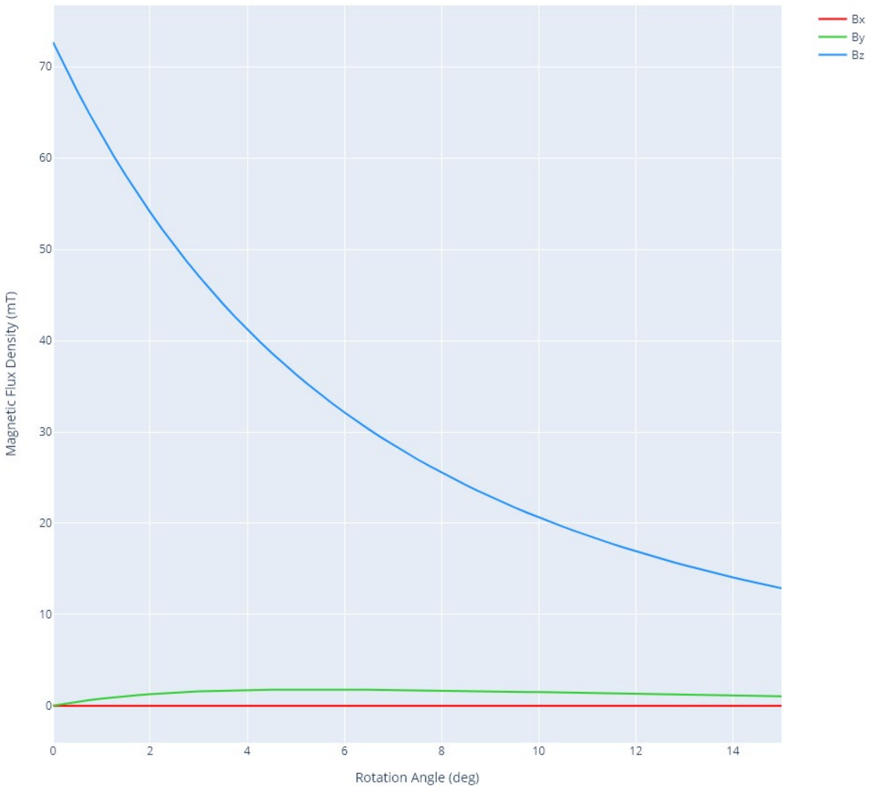
- Integrated ADC and digital interface for programable sensors
- Support 3D sensor configurations



- Absolute Field
- Tamper detect
- Angle

Hinged rotation





- Exponential decay closely resembling the head-on equation

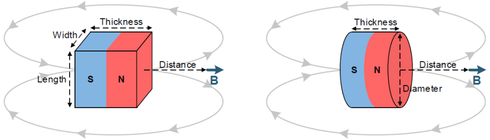


Figure 20. Rectangular Block and Cylinder Magnets

Use Equation 1 for the rectangular block shown in Figure 20:

$$\vec{B} = \frac{B_r}{\pi}\left(\arctan\left(\frac{WL}{2D\sqrt{4D^2+W^2+L^2}}\right) - \arctan\left(\frac{WL}{2(D+T)\sqrt{4(D+T)^2+W^2+L^2}}\right)\right) \quad (1)$$

Use Equation 2 for the cylinder shown in Figure 20:

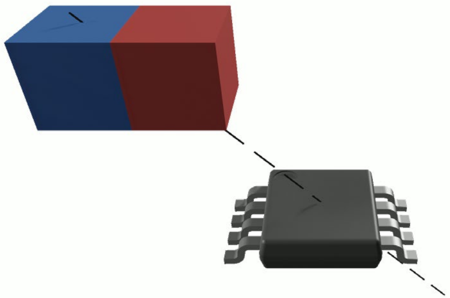
$$\vec{B} = \frac{B_r}{2}\left(\frac{D+T}{\sqrt{(0.5C)^2+(D+T)^2}} - \frac{D}{\sqrt{(0.5C)^2+D^2}}\right) \quad (2)$$

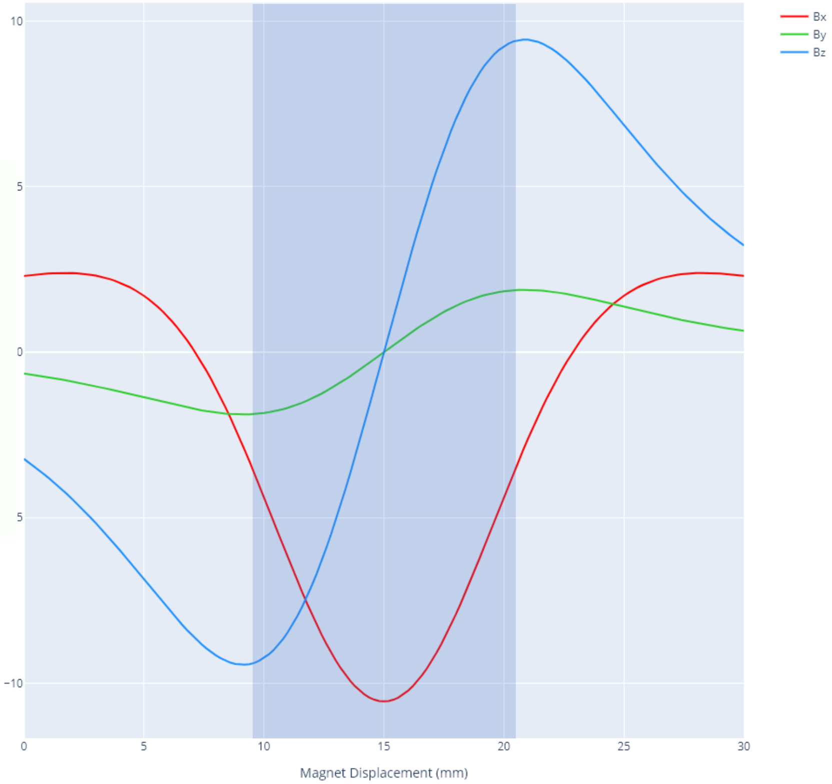
where

- W is width.
- L is length.
- T is thickness (the direction of magnetization).
- D is distance.
- C is diameter.

- Design for B_{OP} max and B_{RP} min for robust design

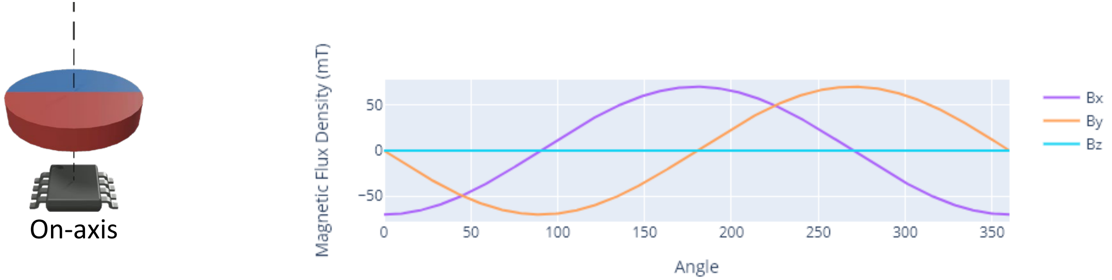
Linear displacement

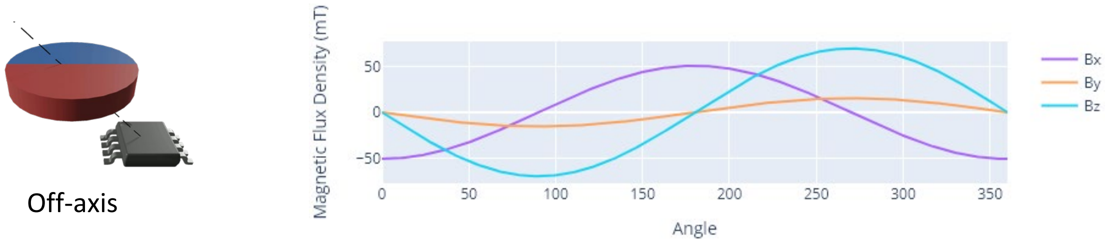


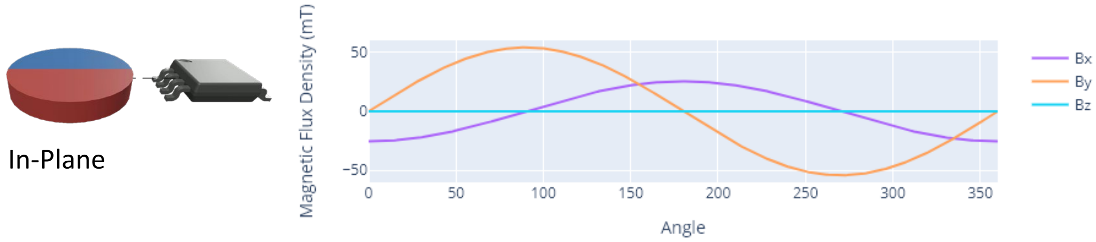


- Linear region ≈ magnet length
- 1D sensors can only be used for the linear region
- 3D sensors can expand range by using full vector

Axial rotation

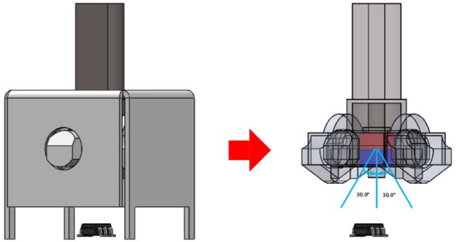


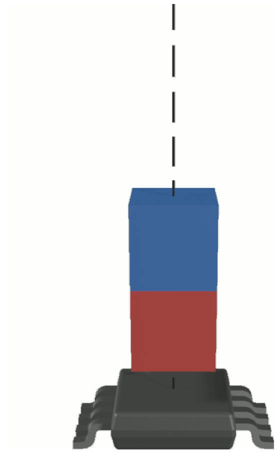


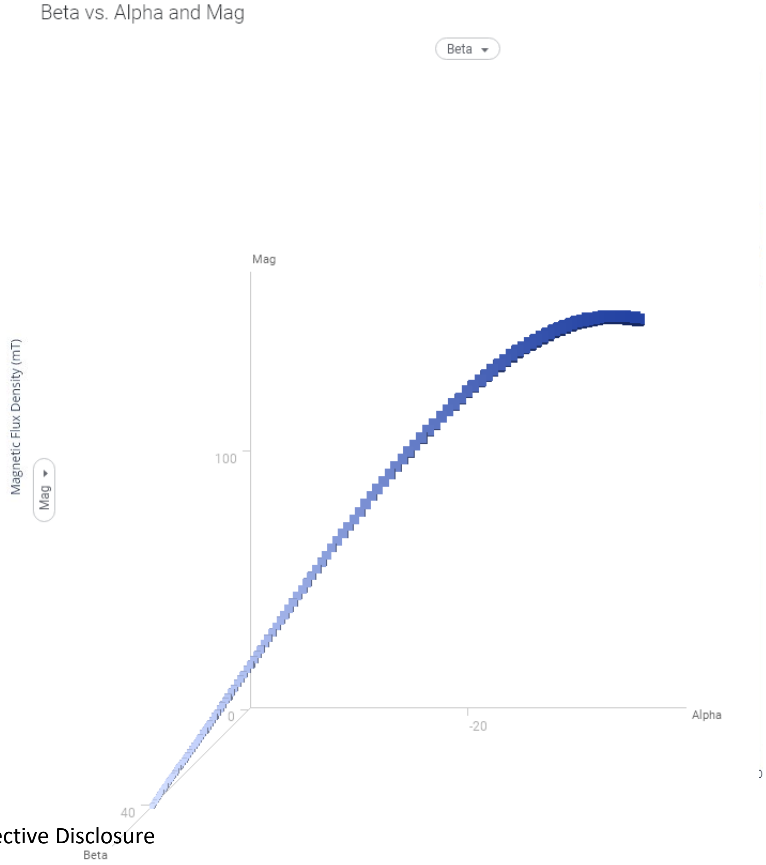


- Field components are naturally 90 degrees separated in phase
- Arctangent can be used to calculate absolute angle
- Amplitude mismatch will result in non-linearity.
  - This error can be corrected using scalar amplitude correction.

Joystick tilt







- Similar profile to slide-by example in linear displacement
- Commonly tracked using Alpha and Beta angles:

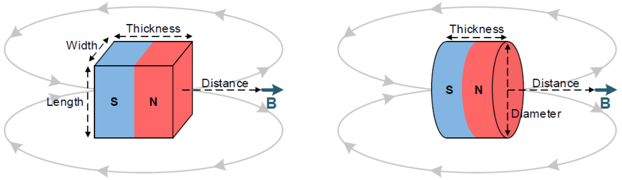
$$\alpha = \operatorname{atan}\left(\frac{\sqrt{{B_z}^2 + {B_x}^2}}{B_y}\right)$$

$$\beta = \operatorname{atan}\left(\frac{\sqrt{{B_z}^2 + {B_y}^2}}{B_x}\right)$$

$$magnitude = \sqrt{{B_x}^2 + {B_y}^2 + {B_z}^2}$$

Design options

Solve using Equations



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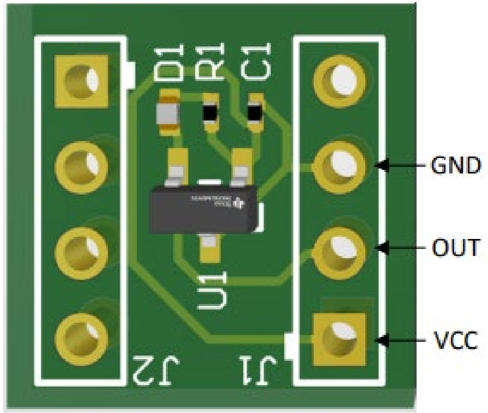
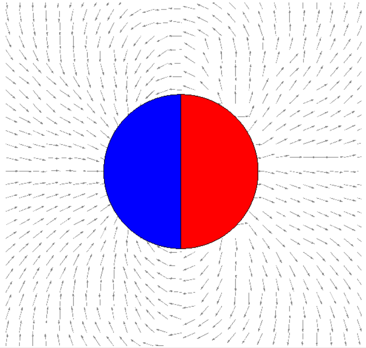
Time consuming and difficult

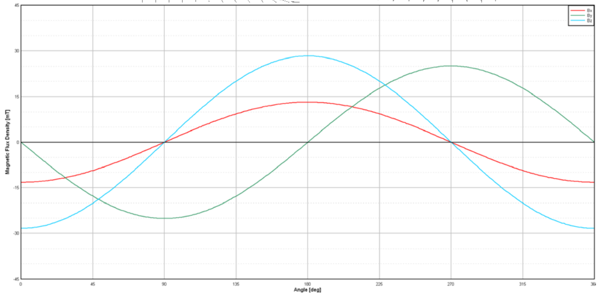
Iterate Prototypes



Immediate feedback on design, but expensive to iterate

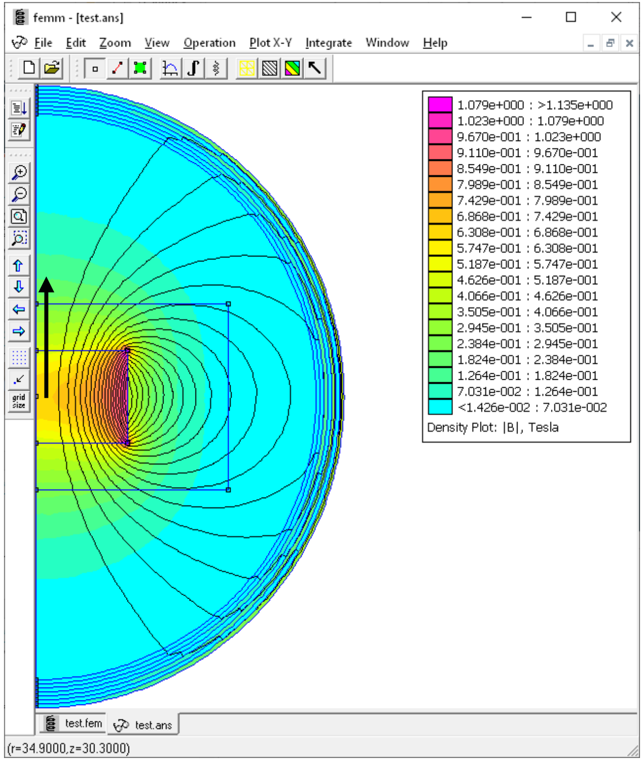
Simulations and Tools





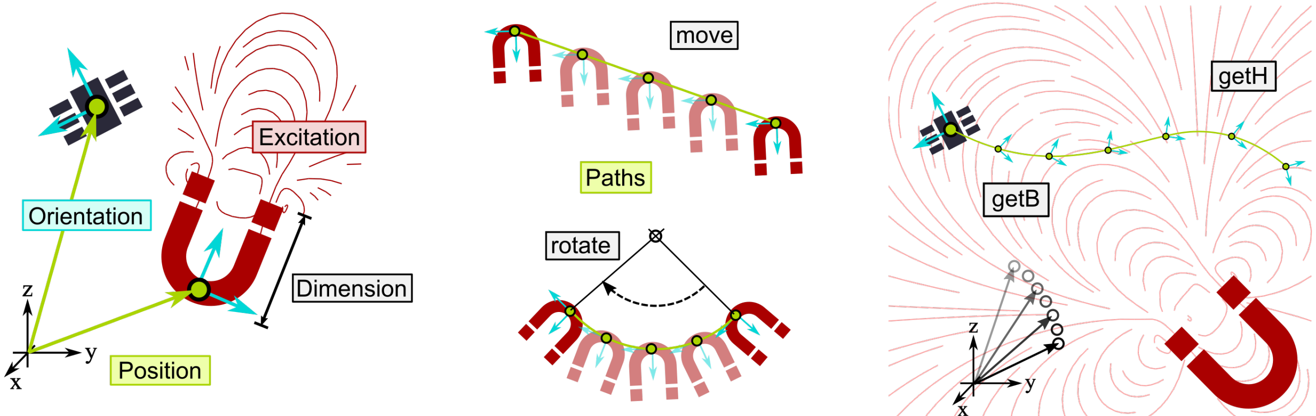
FEMM – Finite Element Method Magnetics

- Free to download and Open Source
- Simulates in 2D, either assuming radial symmetry or infinite length
- Doesn't support all magnet shapes, but runs quickly with a mesh based algorithm



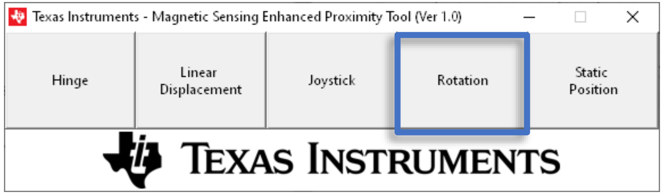
MagPy Lib

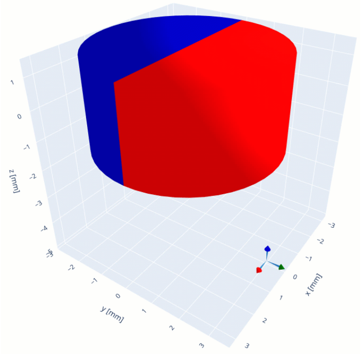
- Free to download and Open Source
- Equation based algorithm that supports a variety of magnet shapes and pole arrangements using superposition
- Full 3D Support
- Runs extremely fast and comparable to industry standard tools
- Does not support materials that interact with magnetic fields (i.e. Steel, Nickel, Chrome)

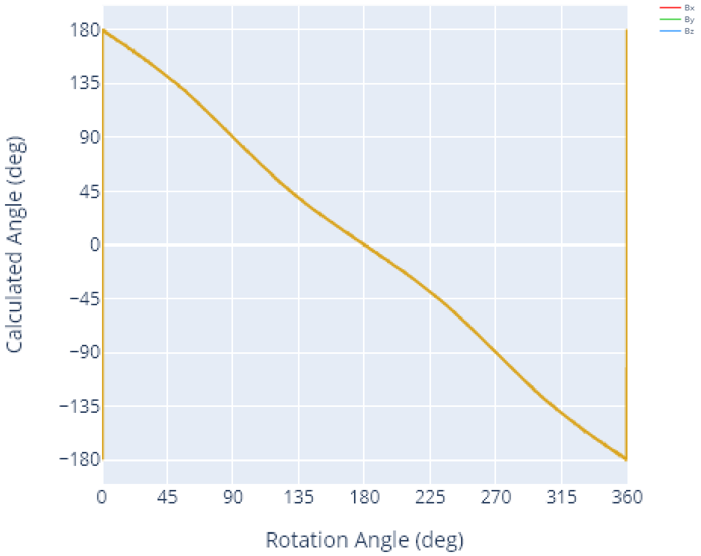


Magnetic Sense Enhanced Proximity Tool

- Free downloadable
  - Webtool format (TIMSS) deploying in June 2023
- Built using the MagPyLib tool
- Supports all the motion types discussed
- Includes device output emulation for rapid system verification
- Runs many times faster than mesh algorithms for quick evaluation







Resources

- FEMM: https://www.femm.info/wiki/HomePage
- MagPyLib: https://magpylib.readthedocs.io/en/latest/
- Magnetic Sense Enhanced Proximity Tool: https://www.ti.com/tool/download/MAGNETIC-SENSE-ENHANCED-PROXIMITY/1.0
- Equation Based Articles:
  - https://pubs.aip.org/aapt/ajp/article/78/3/229/1058297/Cylindrical-magnets-and-ideal-solenoids
  - https://www.jpier.org/issues/reader.html?pid=11112606
  - https://ieeexplore.ieee.org/abstract/document/6392436
  - https://hal.science/hal-01011497/

Questions?