TIMKEN

A Comparison of Performance Characteristics of On and Off Axis High Resolution Hall Effect Encoder ICs

Sensor Products

Mark LaCroix
A John Santos
Dr. Lei Wang

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Presentation Outline

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1. Description of On & Off axis sensors
2. Theory of operation
3. Calculations & Theoretical Modeling
4. Testing results
5. Selection guidelines

By Design.

Timken Overview

- Industrial components and specialty steels manufacturer, serving diversified markets, including:
  - Aerospace
  - Mining
  - Energy/Wind
  - Rail
  - Construction
  - Truck
  - Automotive
  - Distribution
- Established in 1899
- Headquartered in Canton, Ohio
- 2012 sales: US $5.0 billion
- Global footprint with operations in 30 countries
- 21,000 people




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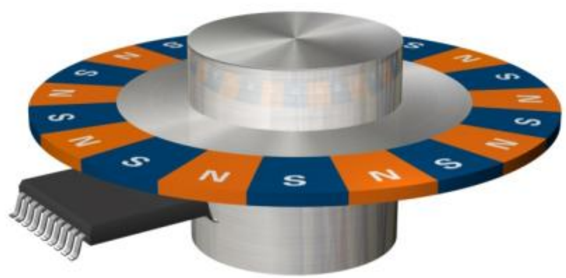
15 years in sensor business

Supplier in integrated Hall encoder market serving industrial customers & critical vehicle systems

Sensor Products

Magnetic Encoder Market

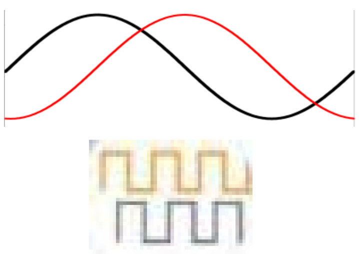
- The Magnetic Encoder Market is Growing
  - Reliability of magnetic technology
  - Environmental capabilities
  - Accurate feedback from system-on-a-chip designs
  - Excellent value
- Two primary sensor configurations



On Axis Designs --- Off Axis Designs

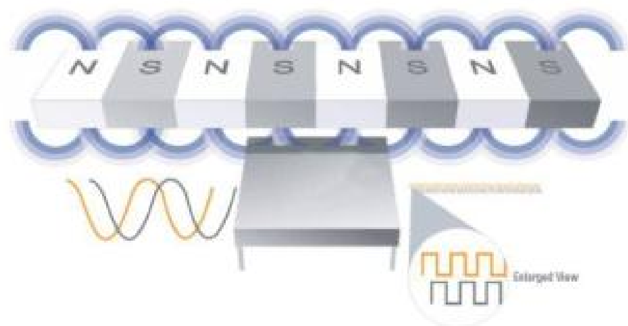
On Axis Sensors

- Aligned with the centerline of the rotating shaft
- Rare earth button magnet: 4 to 10 mm Dia. mounted off the end of the shaft
- Sensor IC has typically 4 to 8 Hall elements in a circular array
- Produces a once per turn Sine & Cosine signal that is converted to a quadrature or serial position signal

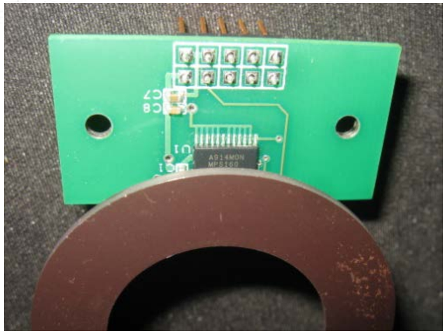


Off Axis Sensors

- Sensor is offset from the center of the rotating shaft
- Multi-pole magnet: Typically 20 to 300 mm diameter axial or radial

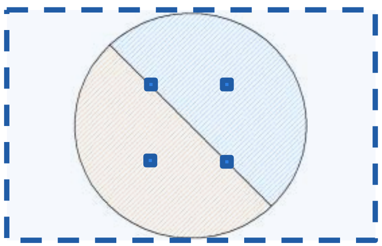


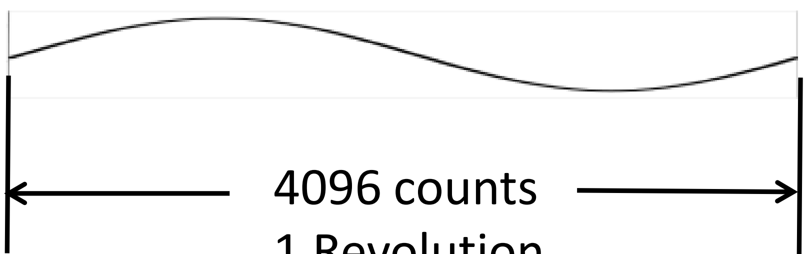
- Sensor IC has typically 8 to 16 Hall element array
- Produces a Sine & Cosine signal for each pole pair and signal is converted to a quadrature or serial position signal



THEORY OF OPERATION FOR BOTH SENSOR TYPES

On-Axis
1 pole pair

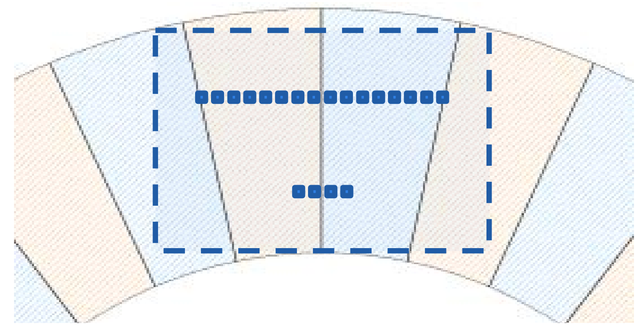


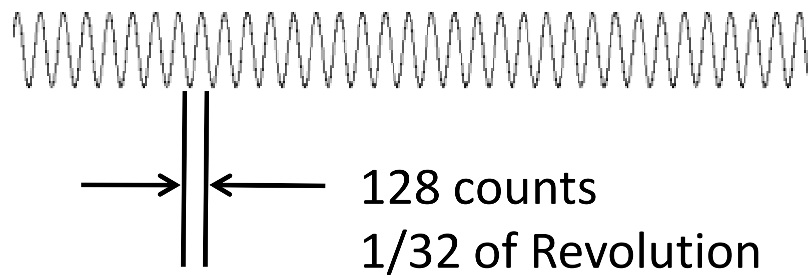


4096 counts
1 Revolution

Deep interpolator required to get full resolution from 1 revolution

Off-Axis
32 pole pairs





128 counts
1/32 of Revolution
4096 total / Rev

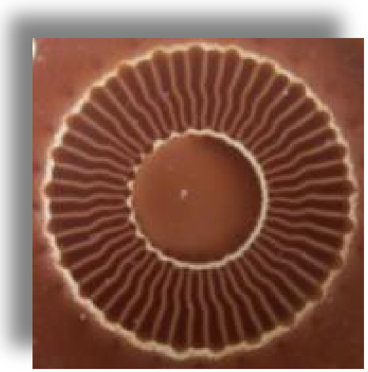
Shallow interpolator used to get 1/32 of the resolution from 1 pole pair

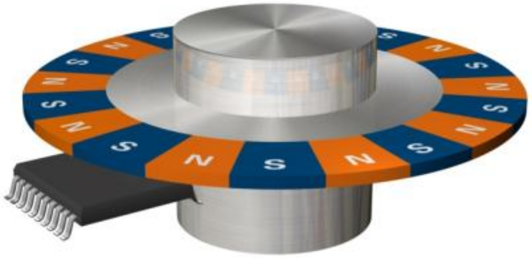
Typical On-Axis Sensor Characteristics

- Incremental (quadrature) and absolute position signals available
- U, V, W commutation
- Index/marker pulse
- Interpolator must extract full resolution from sine/cosine (1 Rev.)
- DSP/Digital Signal Processor interpolator (Deep but with slower response time than hardware interpolators)

Off-Axis performance characteristics

- Incremental (quadrature) position
- U, V, W commutation with external Halls.
- Hardware based interpolator is very fast (real-time)
- Shallow interpolator produces resolution for each pole pair
- Index/marker pulse - one per turn or once per pole pair
- One chip works with a wide range of pole sizes & diameters





Key characteristics affecting accuracy

- Diameter & mechanical leverage effect.
- Number of poles – leveraging interpolator accuracy

Detailed on the following two slides:

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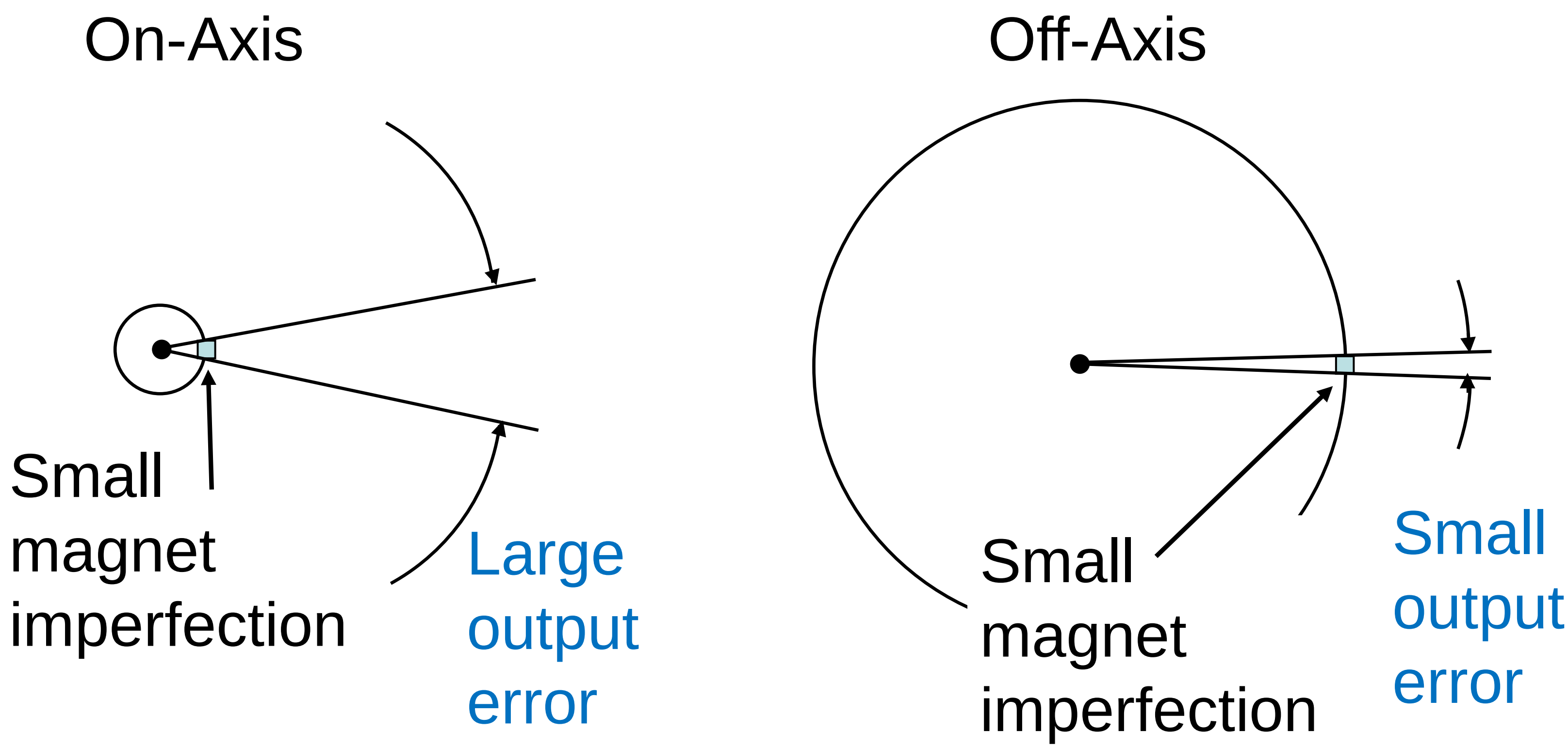
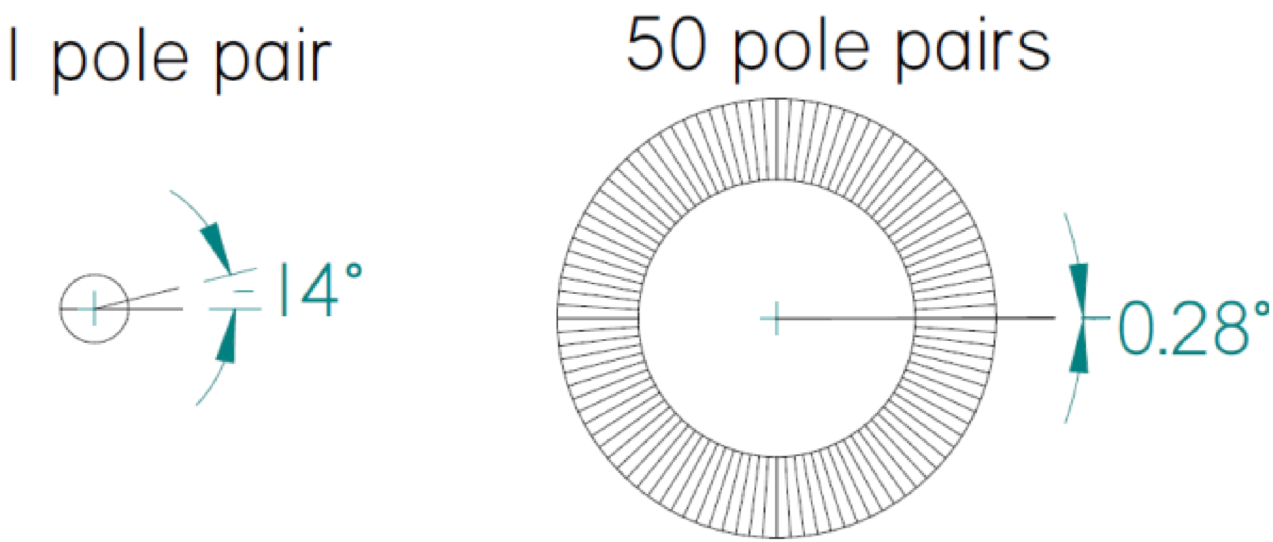
DIAMETER & MECHANICAL LEVERAGE EFFECT



Magnet errors:
Larger error for on-axis sensors - small diameter.
Smaller error for off-axis sensors - large diameter.

NUMBER OF POLES – LEVERAGING INTERPOLATOR ACCURACY



4% of I pole pair
= 14 degrees

4% of I pole pair
= 0.28 degrees

Example shows interpolator with 4% error
(From sine wave purity and interpolator errors)

The interpolator error shows up directly (1:1 ratio) for on-axis
The interpolator error is divided by the pole pair count for off-axis

Calculations & Theoretical Modeling

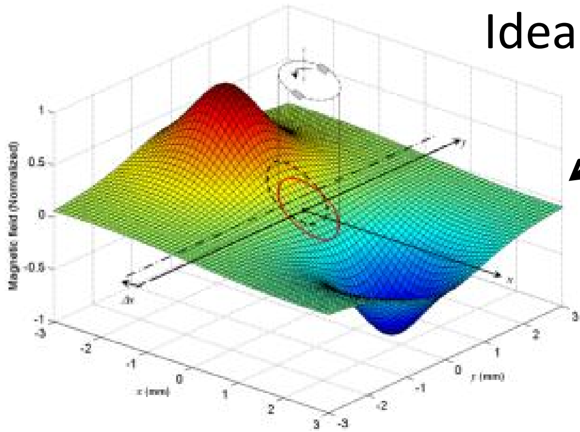
Magnetic Targets:
Magnetic field and resulting sine wave which affect the final accuracy

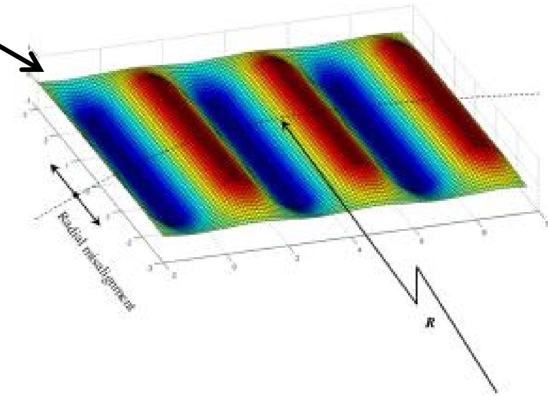
On Axis (4mm OD)

Off Axis (2mm pole pitch)

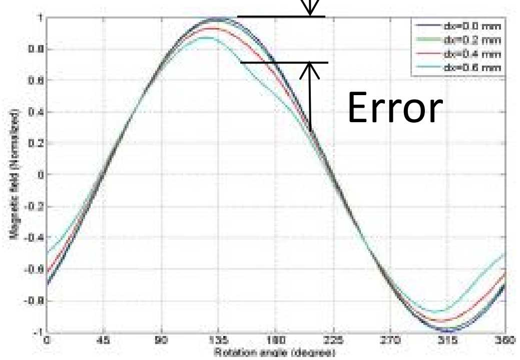
Ideal magnetic field

Magnetic field

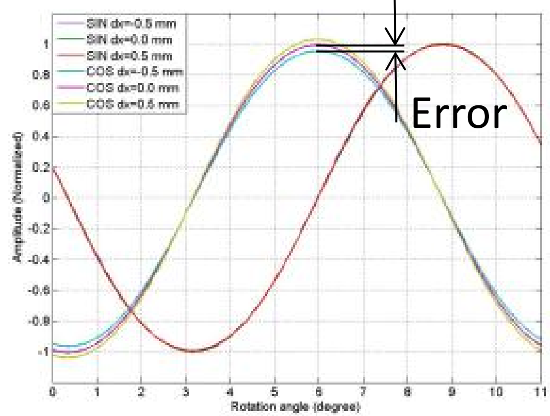




Resulting signal



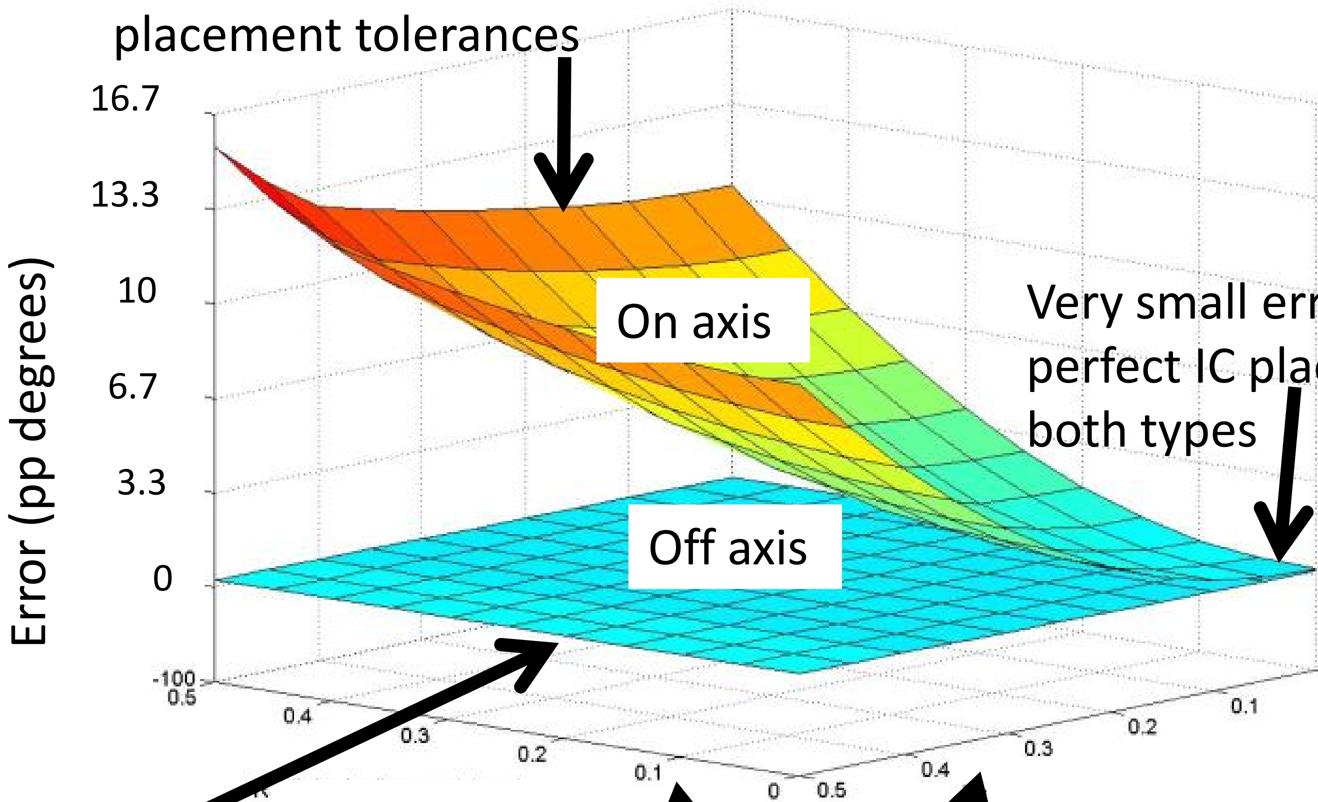
Error



Error

CHIP/SENSOR TOLERANCE PLACEMENT

Large error over sensor placement tolerances



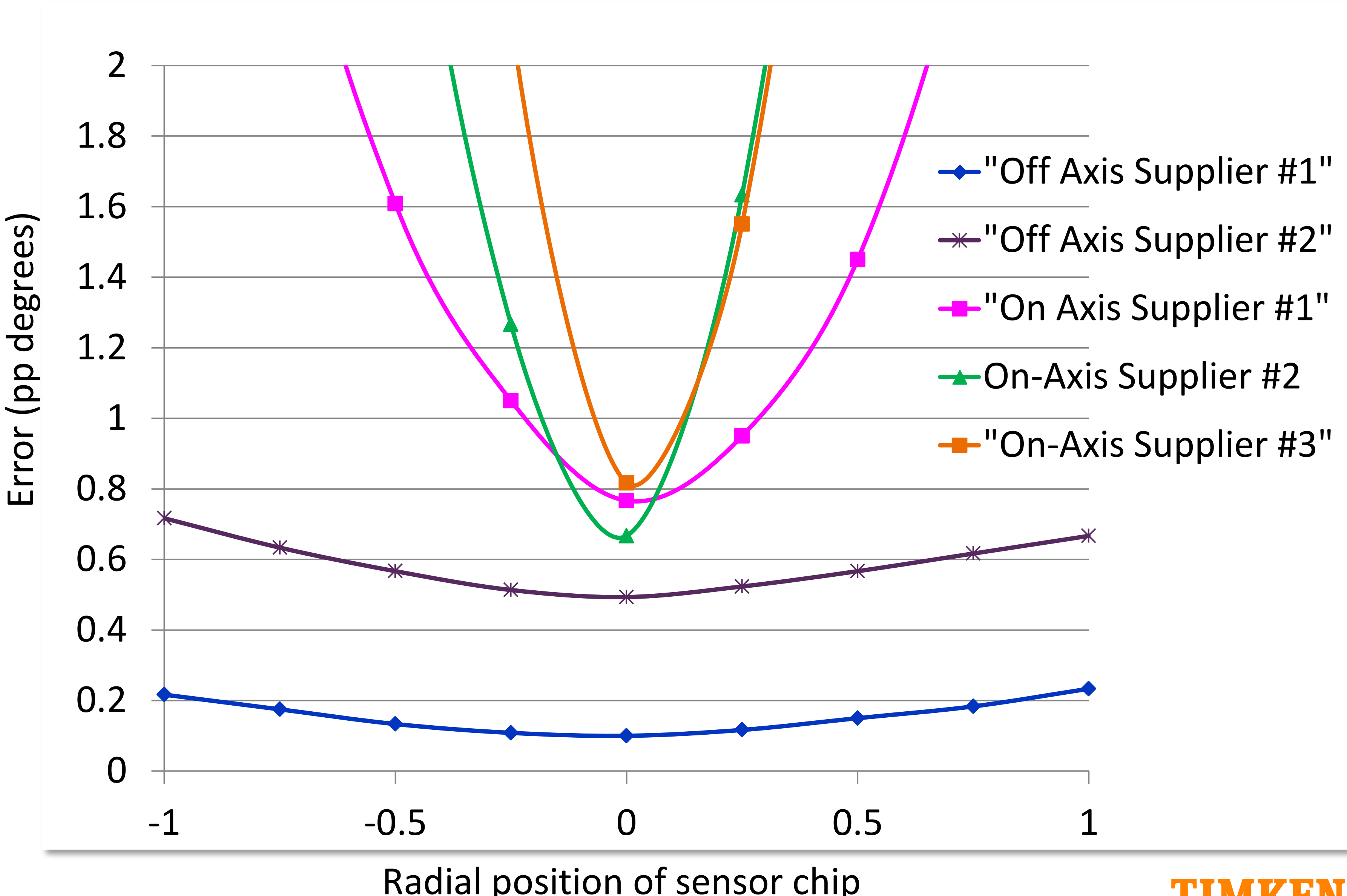
Very small error with perfect IC placement for both types

Small error over sensor placement tolerances

0.5mm X & Y Position error of sensor

Test Results

Accuracy versus radial position at 1mm gap



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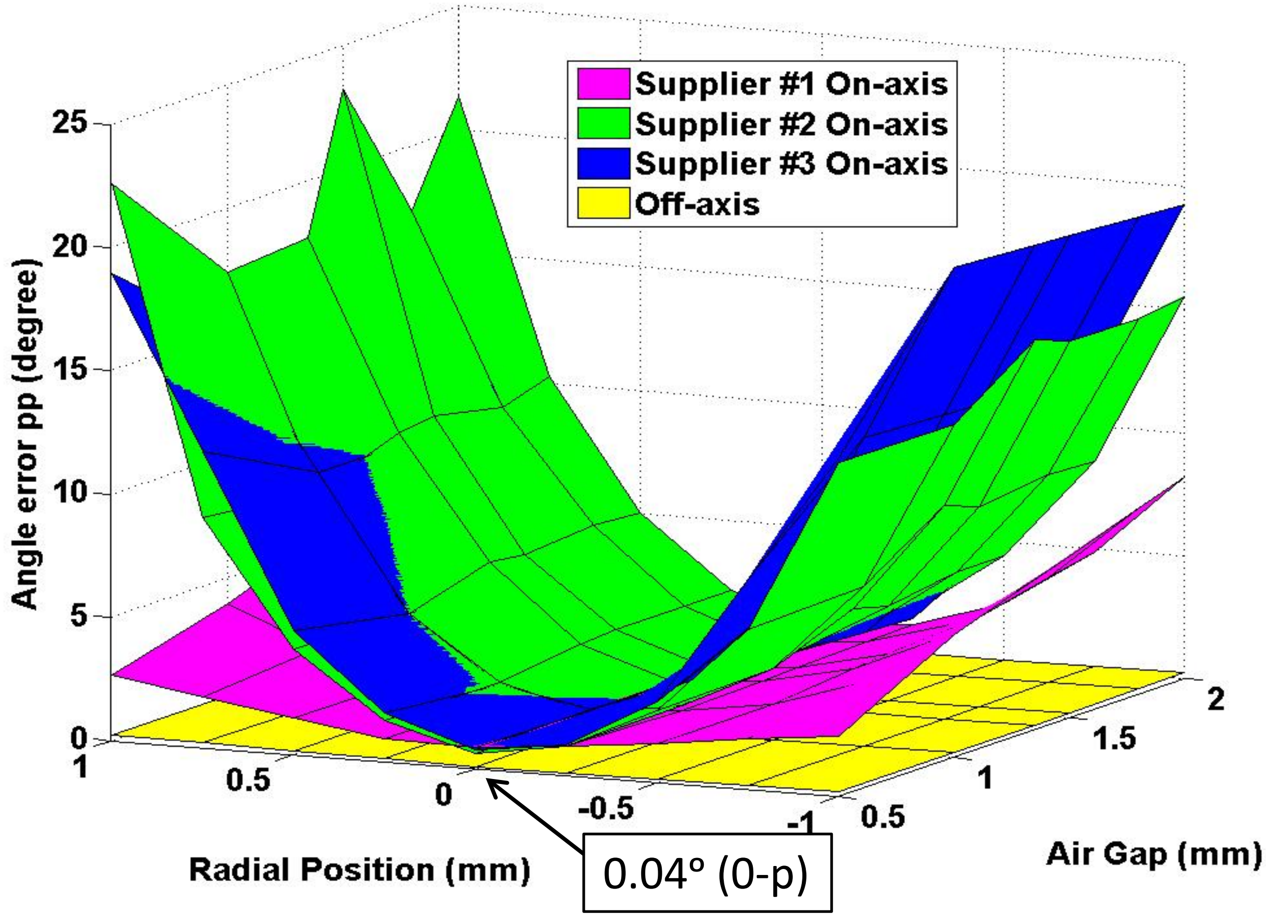
MEASURED ERRORS

OVER RADIAL POSITION AND AIR GAP



Real world testing correlated well with theoretical predictions

- Errors were larger over all conditions for on-axis sensors
- Errors were larger for non-ideal chip placement for on-axis sensors

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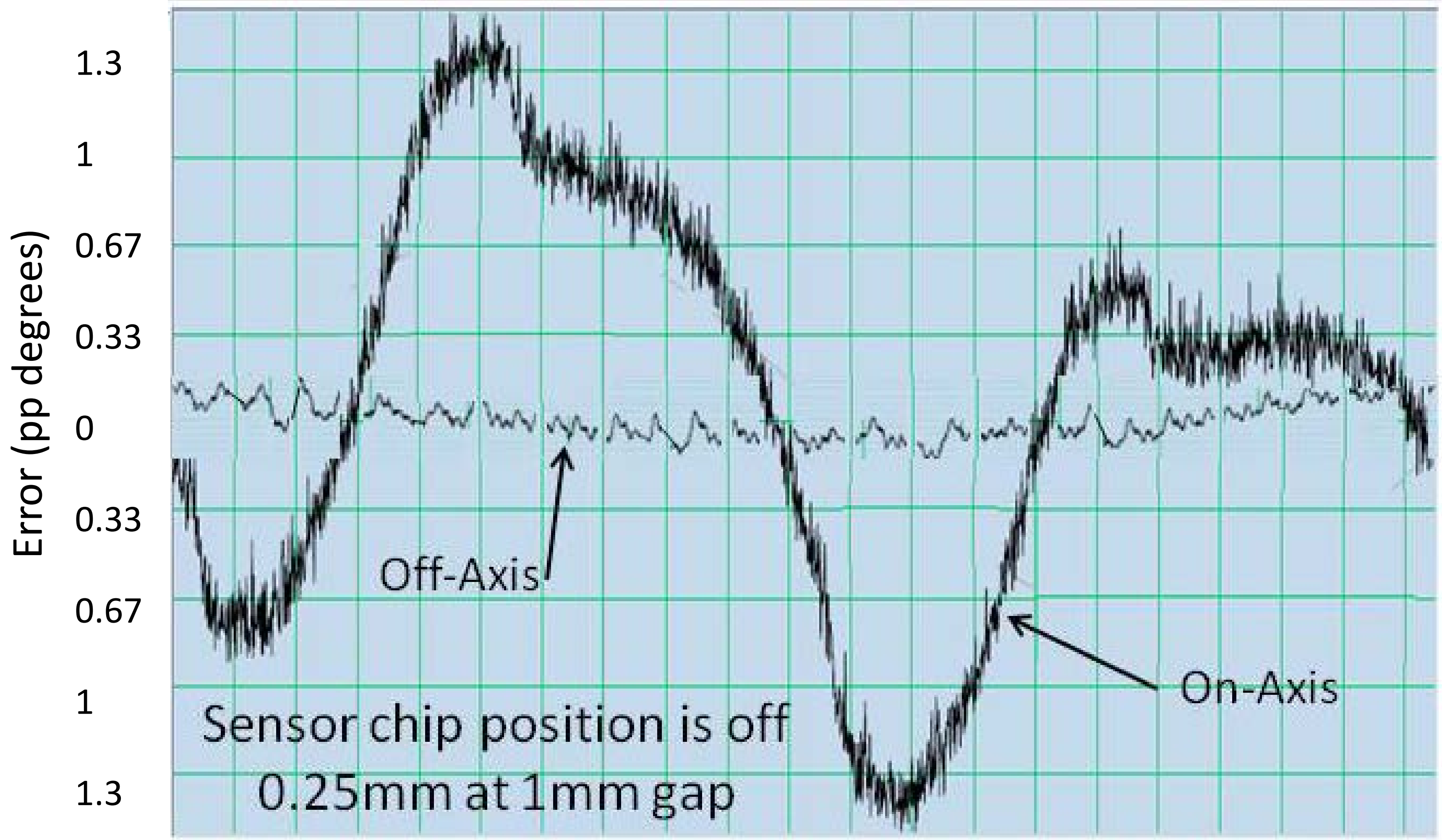
Example of Typical Error

over 1 Revolution



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Error frequency component effect on system performance

Errors on both sensors are linked to pole pair count

- Once/rev for on-axis
- 20-50/revolution for off axis

Low frequency errors generally cause more system problems such as vibration (Typical of on-axis sensors)

Higher frequency errors, system performance is generally tolerant

- Motor controllers are less sensitive to higher frequency errors on encoder feedback signals
- Mechanical system filters high frequency feedback errors

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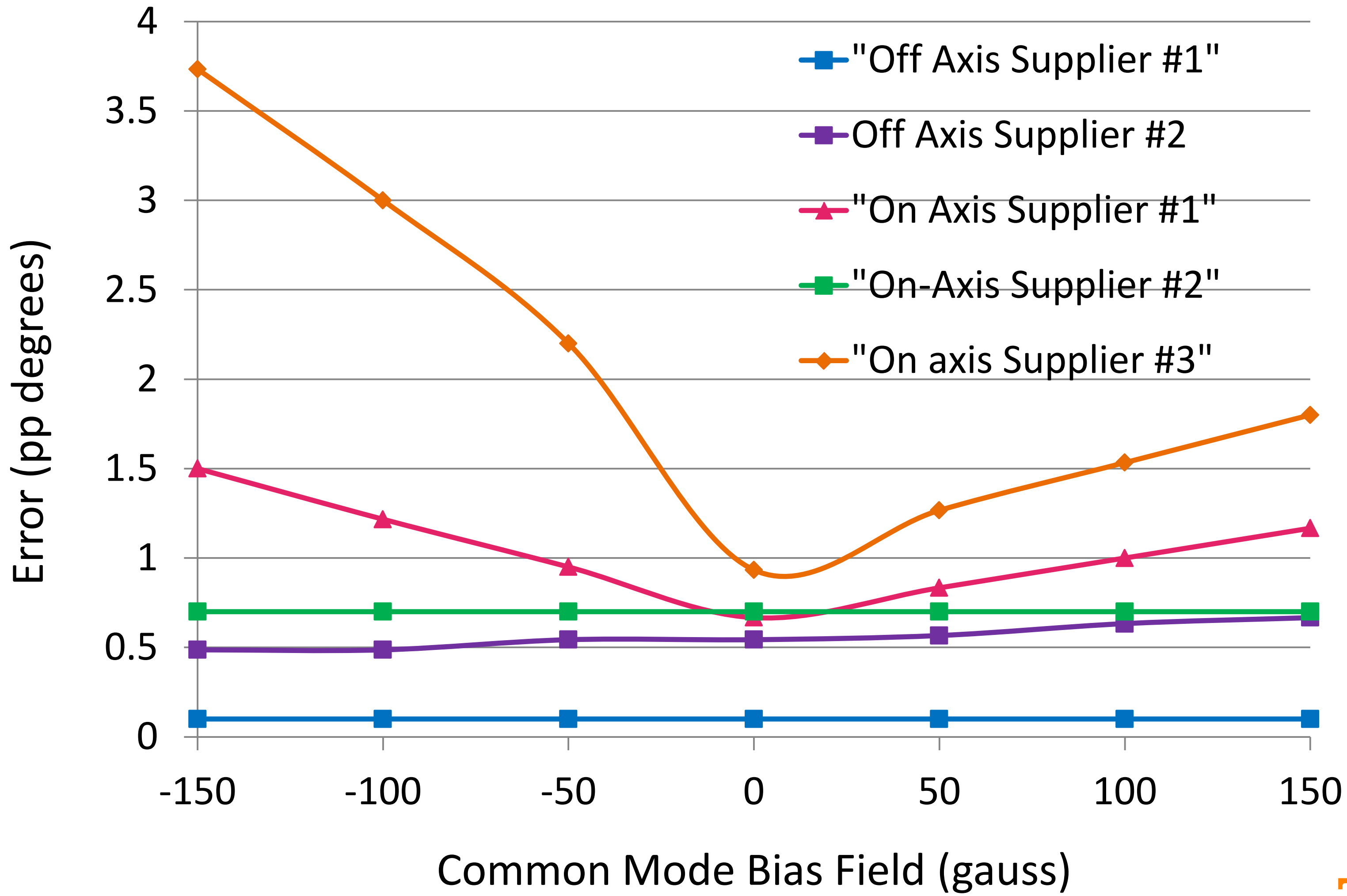
Error: external common-mode fields

From magnetized shafts, motor windings and motor magnets

(1mm gap)



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SELECTION GUIDELINES

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- Both on-axis and off-axis sensor continue to grow as viable alternatives to optical encoders
- Performance & physical constraints drive selection

Key Characteristics of on-axis and off-axis sensors

	Maximum Resolution	Position Accuracy	IC & PCB Mounting Tolerance	Absolute Position	Stray Field Rejection	Target Inertia	Propagation Delay / Real Time Sensing
On Axis	-	-	-	+	+/-	+	-
Off Axis	+	+	+	-	+	+/-	+

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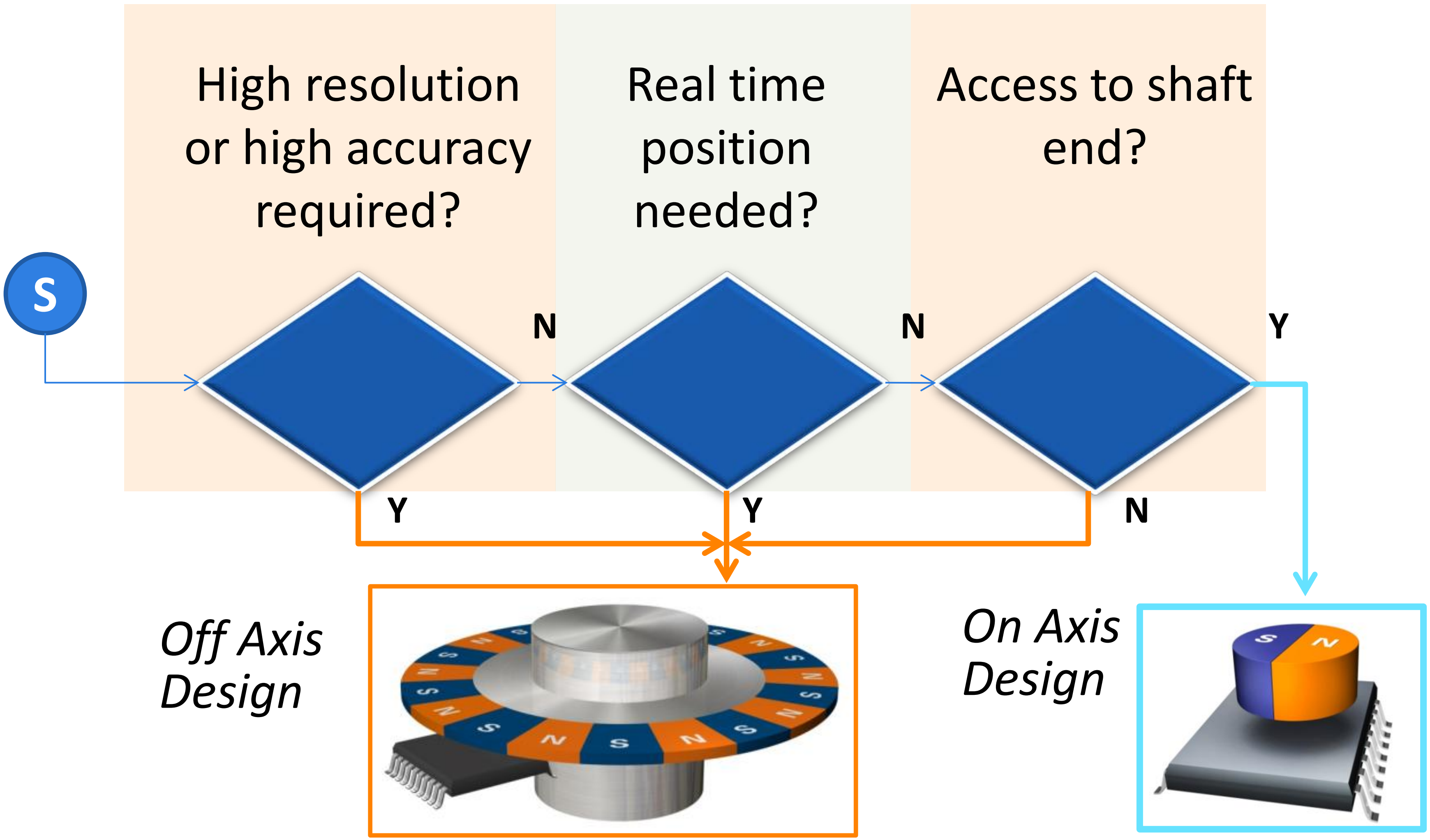
SELECTION GUIDELINES
SENSOR SELECTION PROCESS FLOW



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