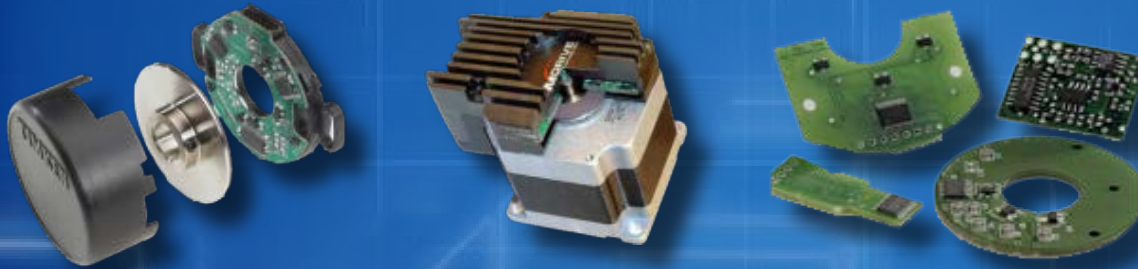


A Comparison of Performance Characteristics of On and Off Axis High Resolution Hall Effect Encoder ICs



Sensor Products

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8 FEB 13 • Orlando

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PRESENTATION OUTLINE

1. DESCRIPTION OF ON & OFF AXIS SENSORS
2. THEORY OF OPERATION
3. CALCULATIONS & THEORETICAL MODELING
4. TESTING RESULTS
5. SELECTION GUIDELINES

By Design.

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

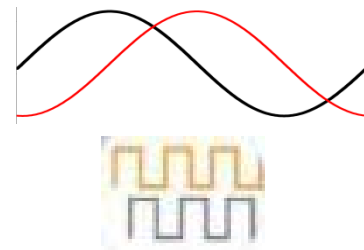


Off Axis Designs

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ON AXIS SENSORS

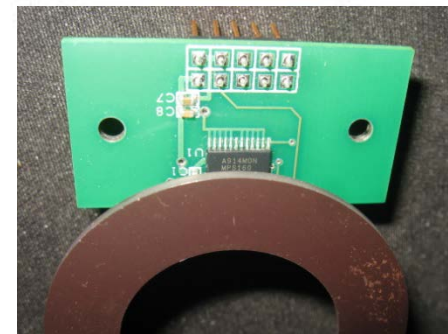
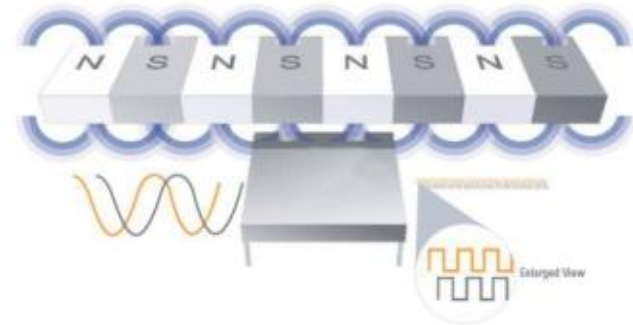
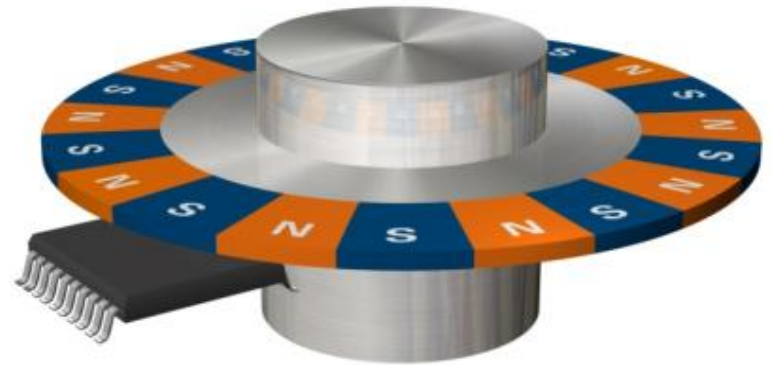
- Aligned with the centerline of the rotating shaft
- Rare earth button magnet: 4 to 10 mm Dia. mounted off the end of the shaft
- Sensor IC has typically 4 to 8 Hall elements in a circular array
- Produces a once per turn Sine & Cosine signal that is converted to a quadrature or serial position signal



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OFF AXIS SENSORS

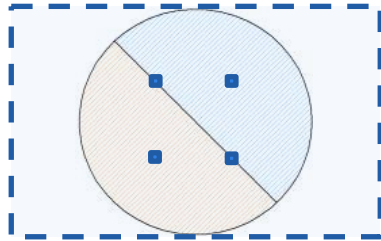
- Sensor is offset from the center of the rotating shaft
- Multi-pole magnet: Typically 20 to 300 mm diameter axial or radial
- Sensor IC has typically 8 to 16 Hall element array
- Produces a Sine & Cosine signal for each pole pair and signal is converted to a quadrature or serial position signal



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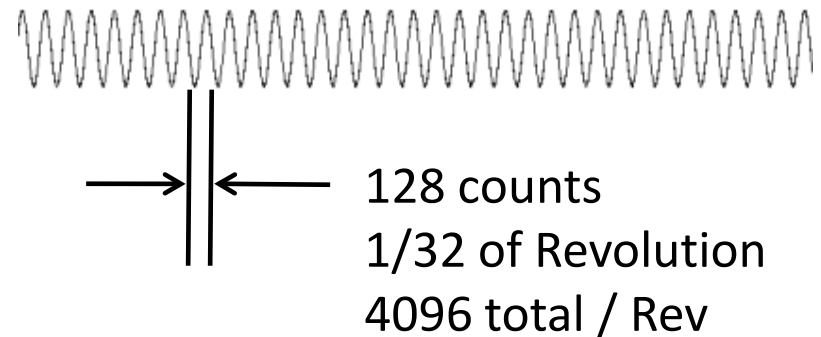
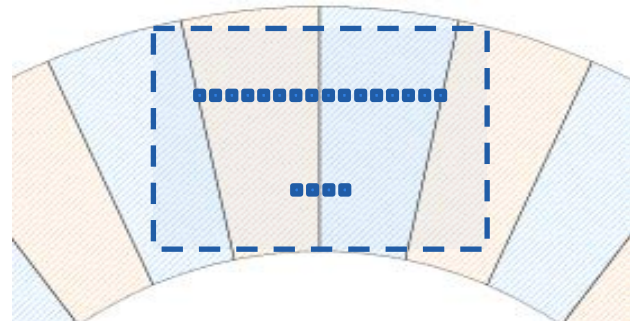
THEORY OF OPERATION FOR BOTH SENSOR TYPES

On-Axis
1 pole pair



Deep interpolator required to get full resolution from 1 revolution

Off-Axis
32 pole pairs



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

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TYPICAL ON-AXIS SENSOR CHARACTERISTICS

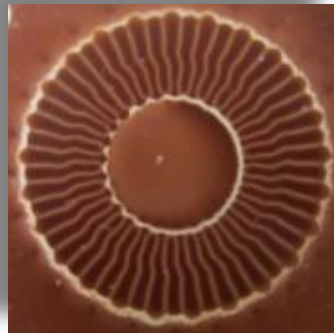
- Incremental (quadrature) and absolute position signals available
- U, V, W commutation
- Index/marker pulse
- Interpolator must extract full resolution from sine/cosine (1 Rev.)
- DSP/Digital Signal Processor interpolator (Deep but with slower response time than hardware interpolators)



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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



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KEY CHARACTERISTICS AFFECTING ACCURACY

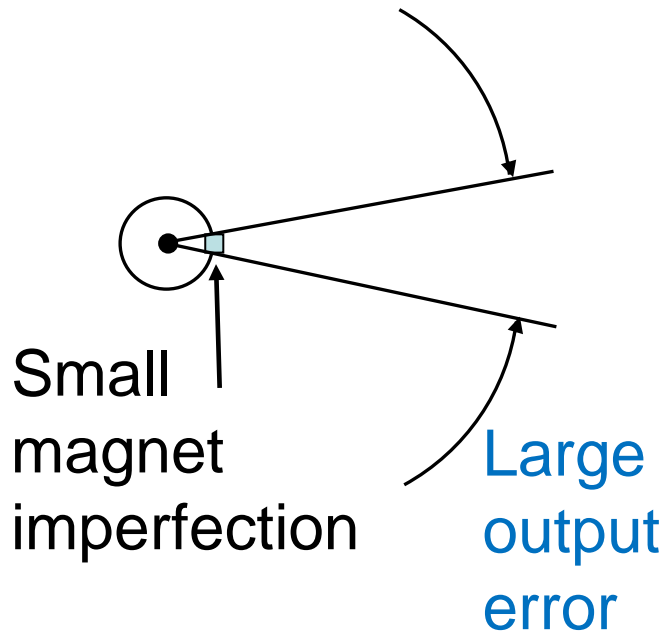
- Diameter & mechanical leverage effect.
- Number of poles – leveraging interpolator accuracy

Detailed on the following two slides:

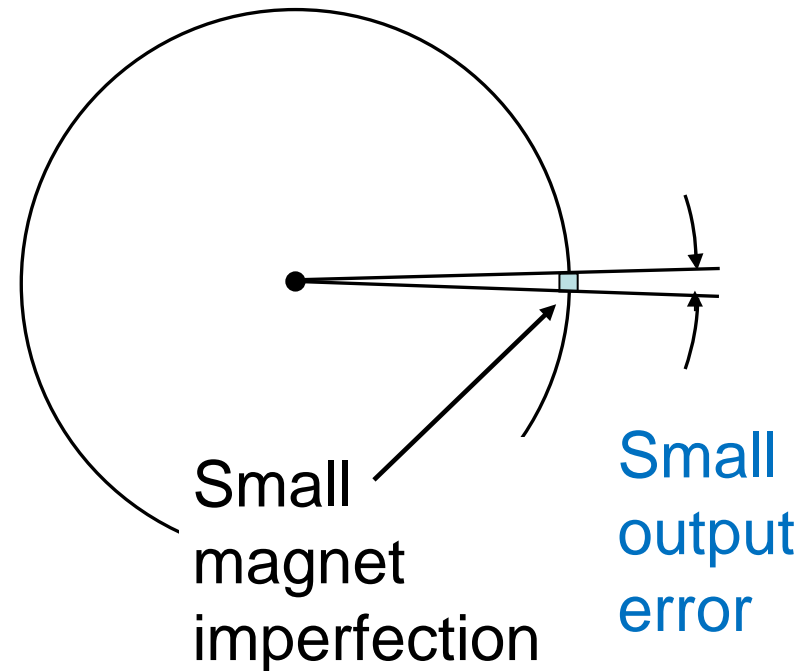
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DIAMETER & MECHANICAL LEVERAGE EFFECT

On-Axis



Off-Axis



Magnet errors:

Larger error for on-axis sensors - small diameter.

Smaller error for off-axis sensors - large diameter.

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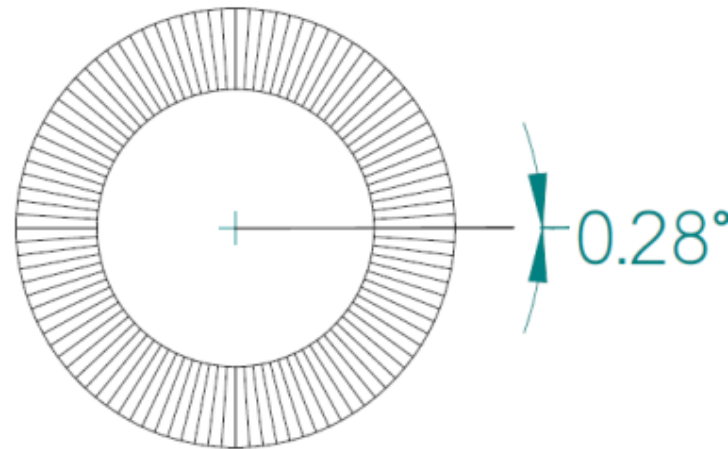
NUMBER OF POLES – LEVERAGING INTERPOLATOR ACCURACY

1 pole pair



4% of 1 pole pair
= 14 degrees

50 pole pairs



4% of 1 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

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CALCULATIONS & THEORETICAL MODELING

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MAGNETIC TARGETS:

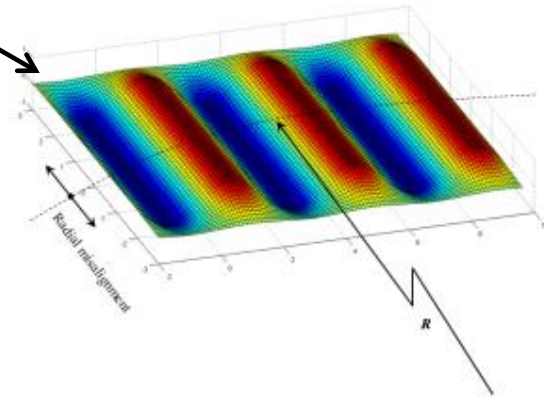
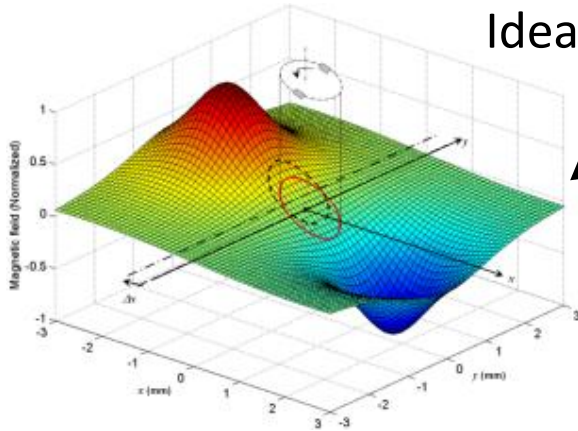
MAGNETIC FIELD AND RESULTING SINE WAVE WHICH AFFECT THE FINAL ACCURACY

On Axis (4mm OD)

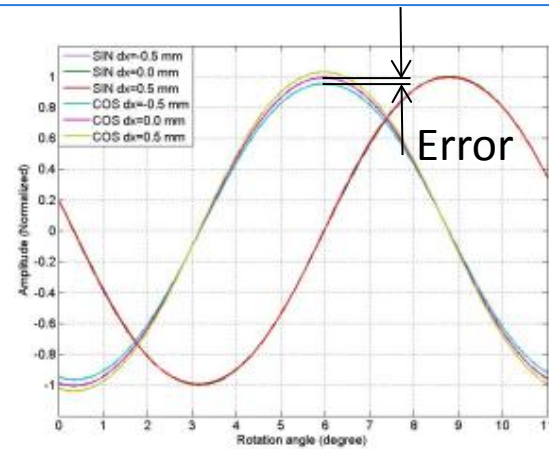
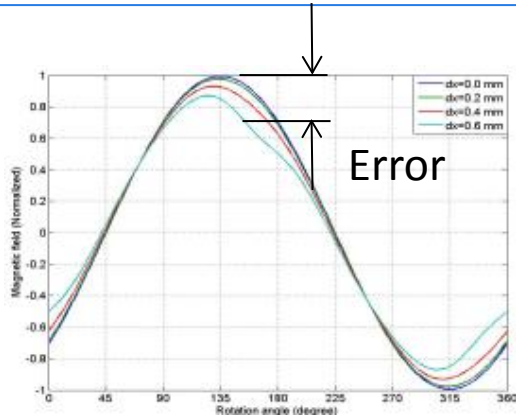
Off Axis (2mm pole pitch)

Ideal magnetic field

Magnetic field

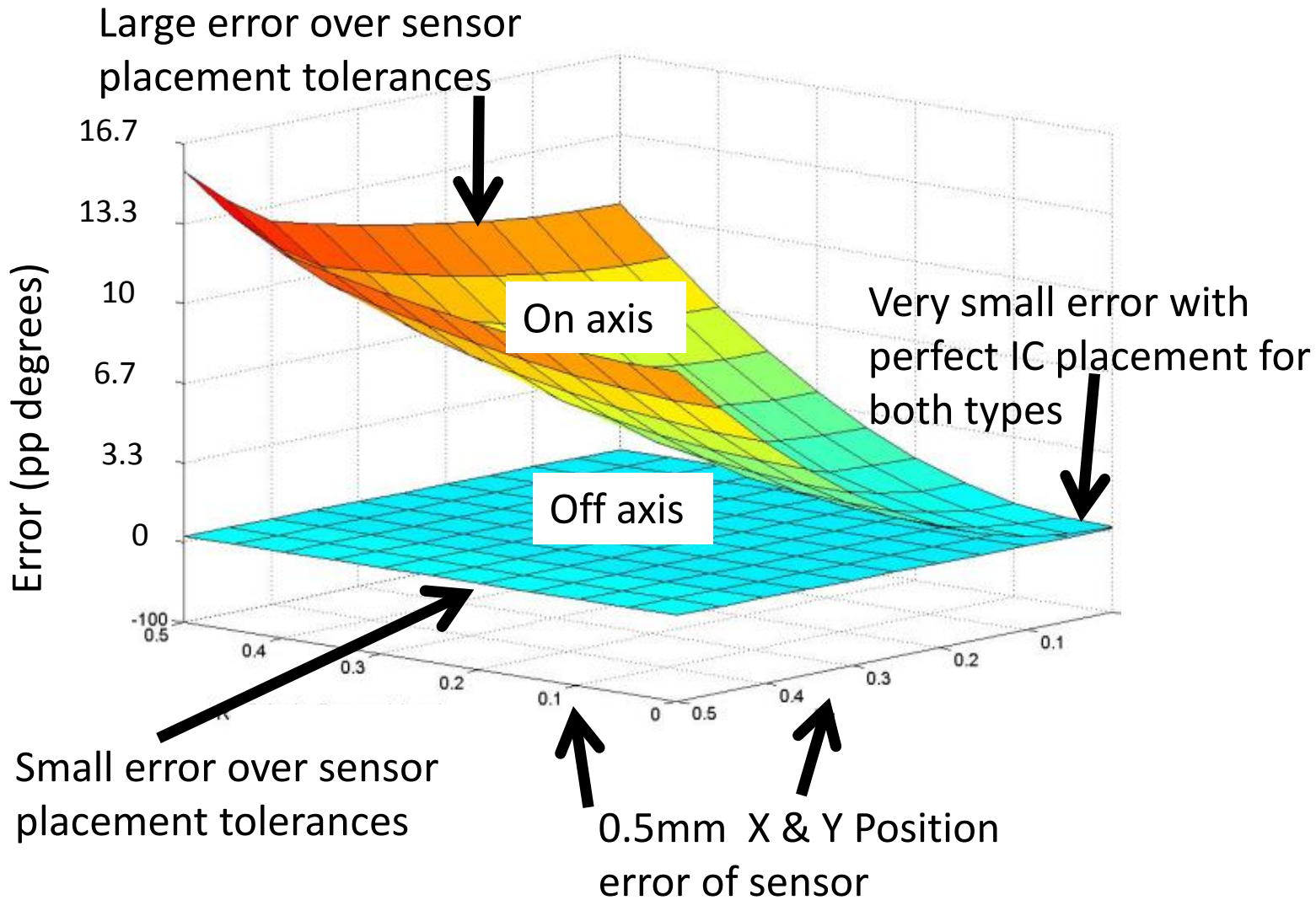


Resulting signal



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CHIP/SENSOR TOLERANCE PLACEMENT

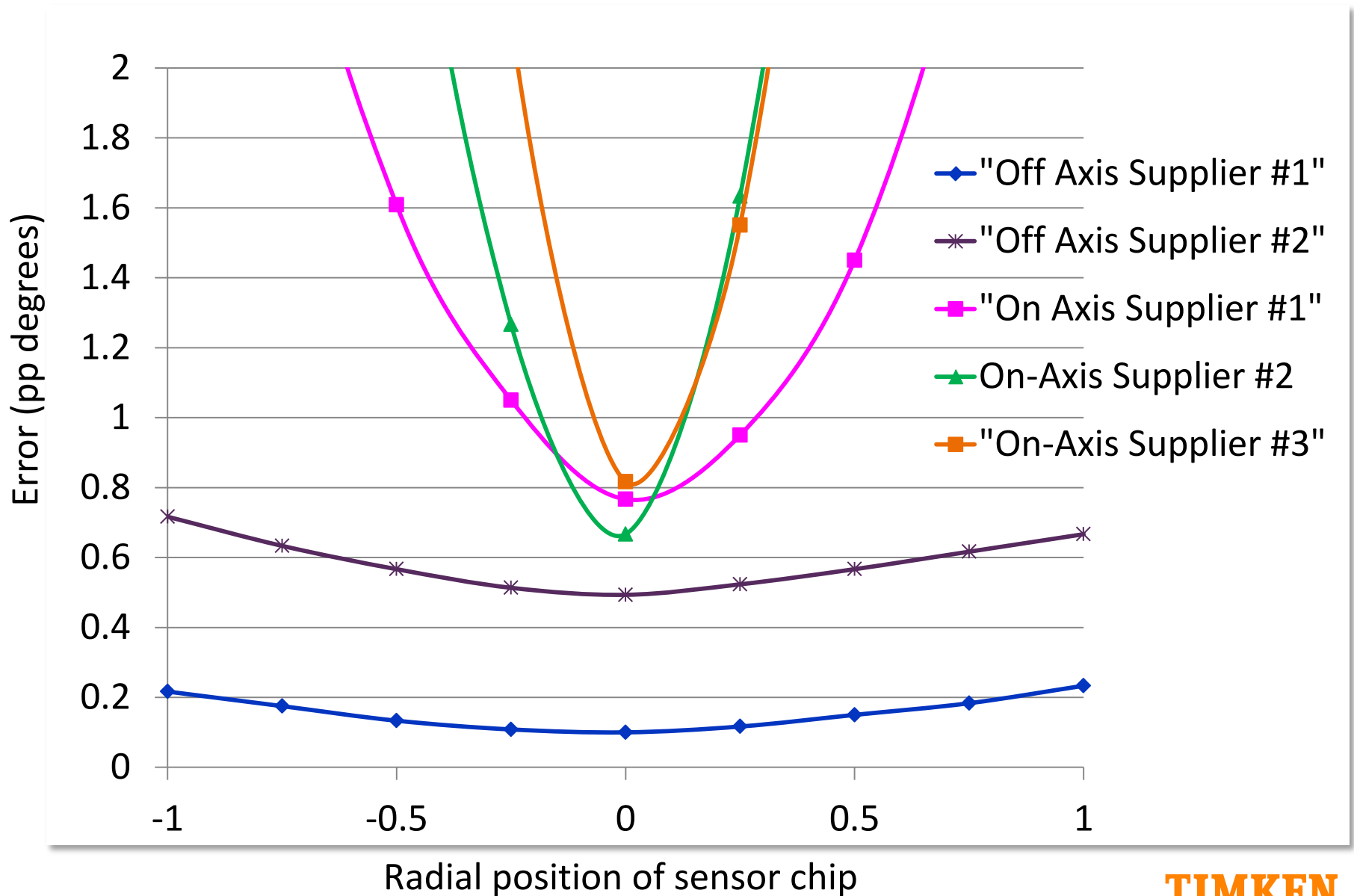


TEST RESULTS

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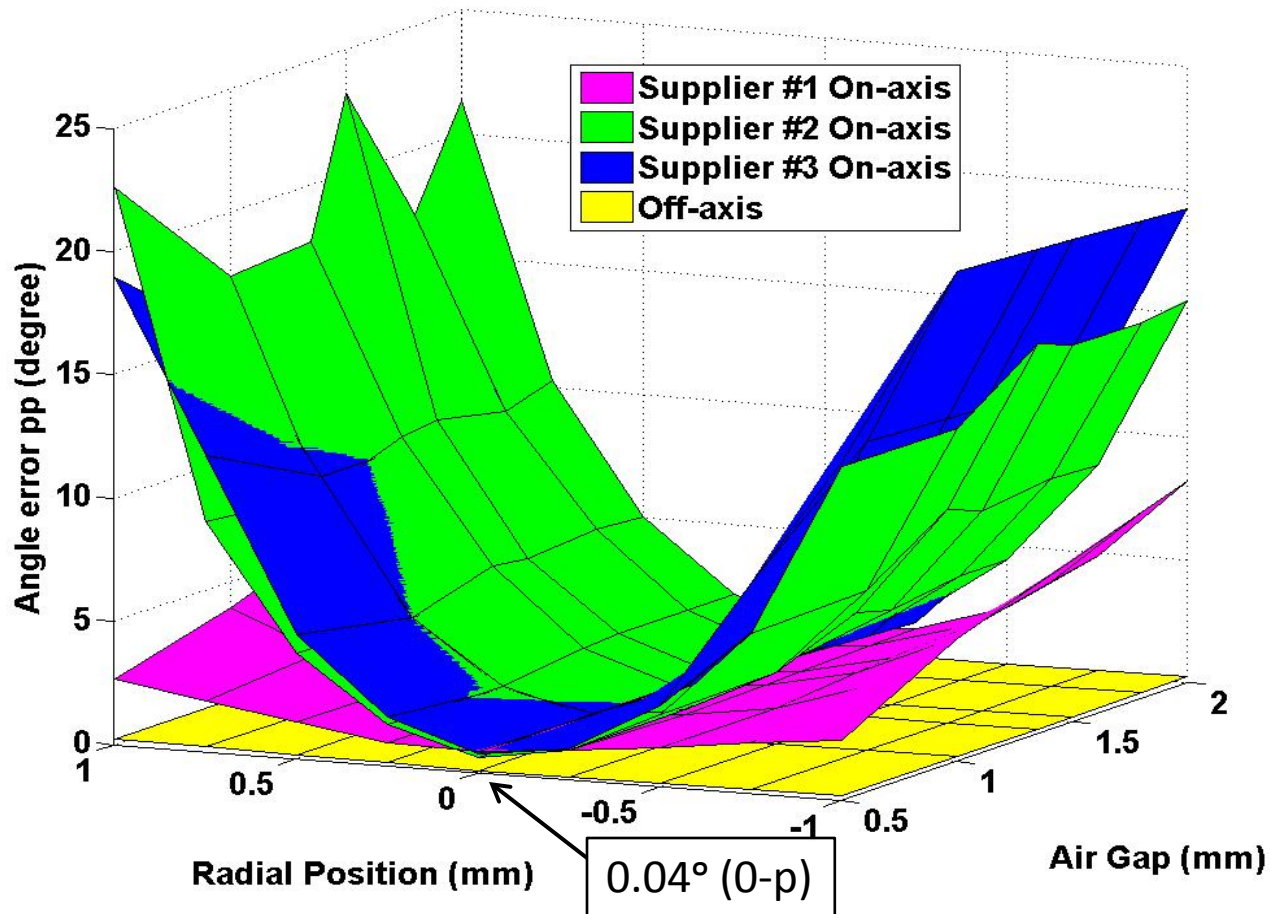
Accuracy versus radial position at 1mm gap



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MEASURED ERRORS

OVER RADIAL POSITION AND AIR GAP

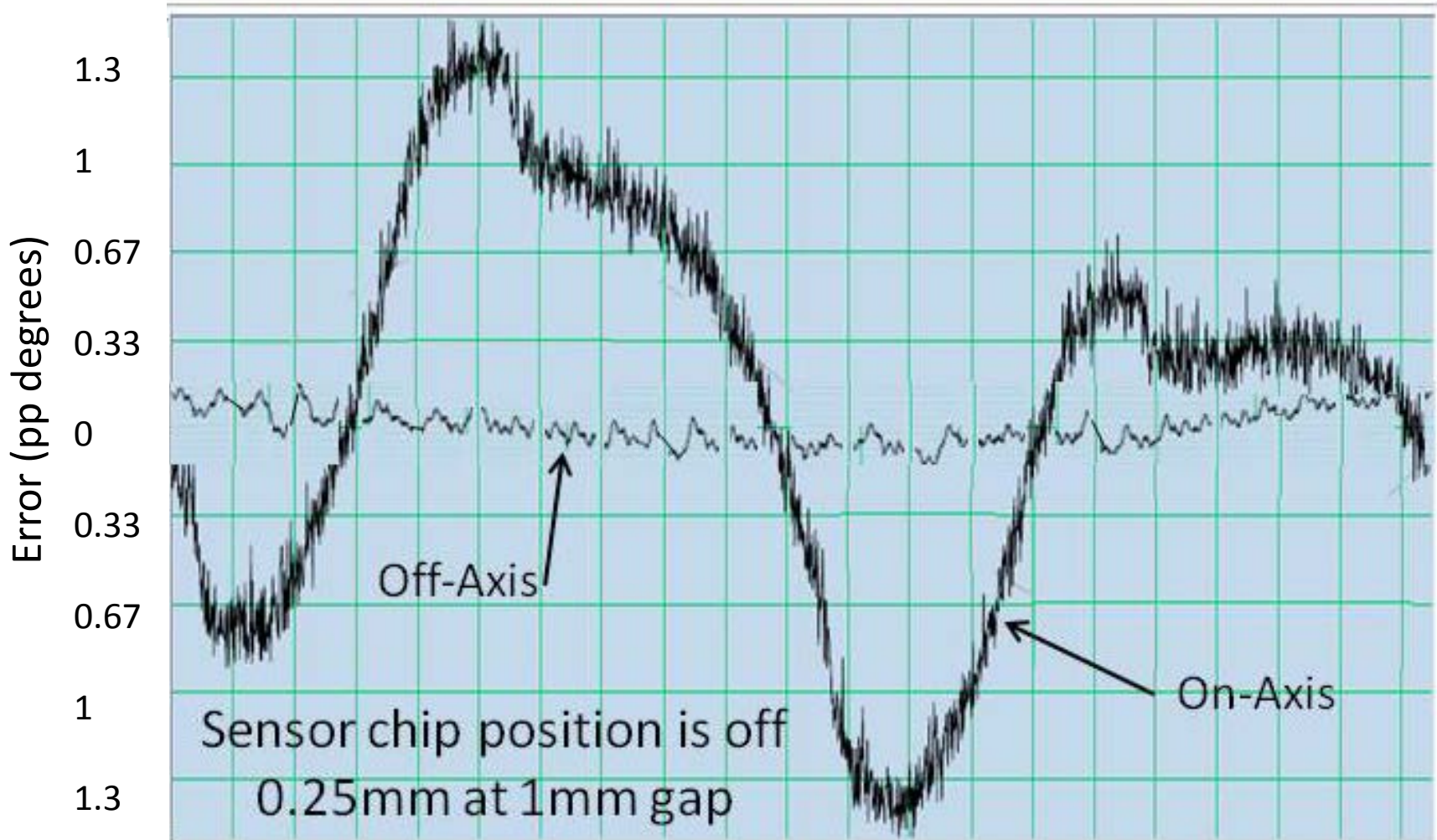


Real world testing correlated well with theoretical predictions

- 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



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)

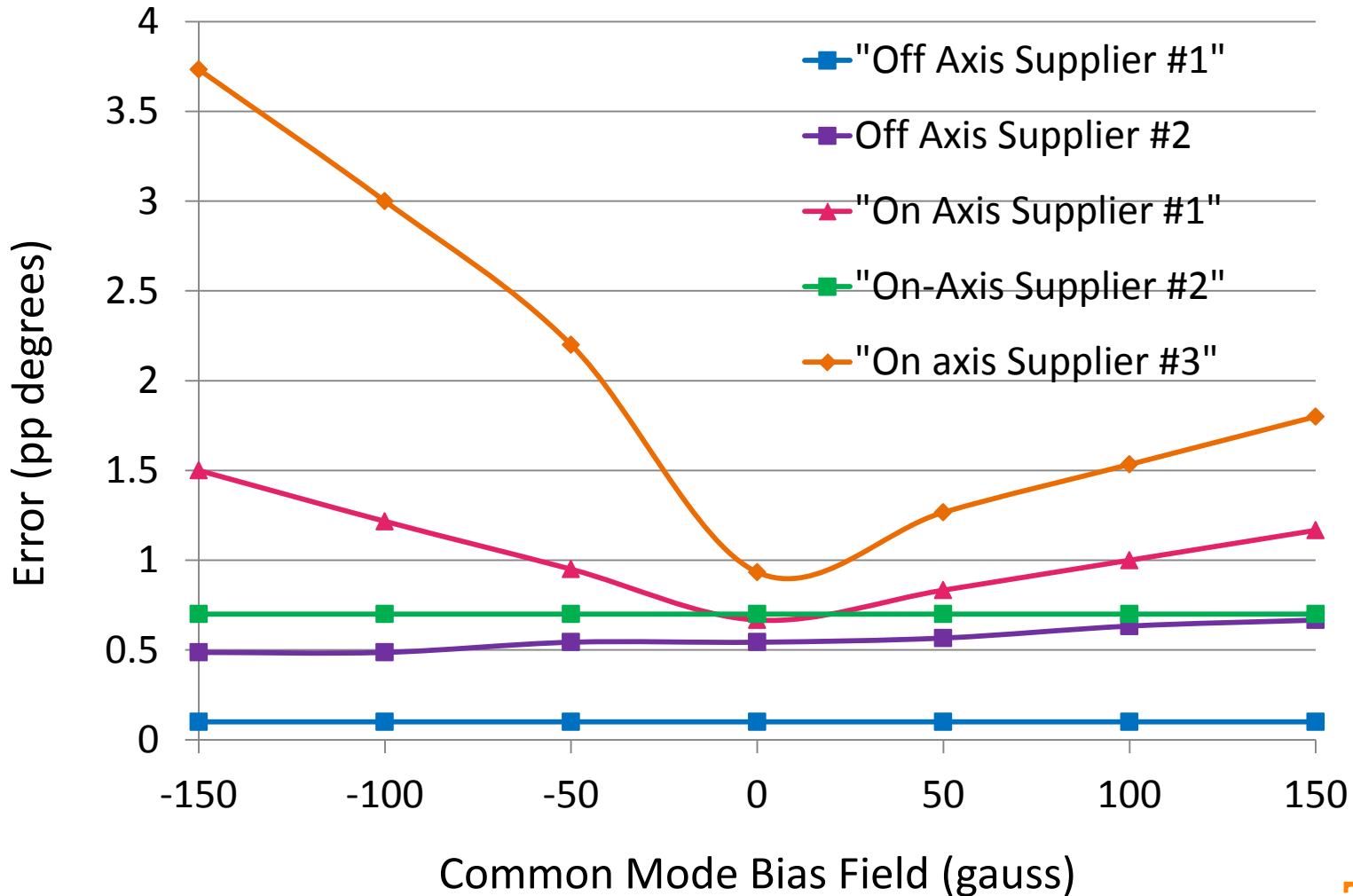
Higher frequency errors, system performance is generally tolerant

- 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)



SELECTION GUIDELINES

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SELECTION GUIDELINES

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

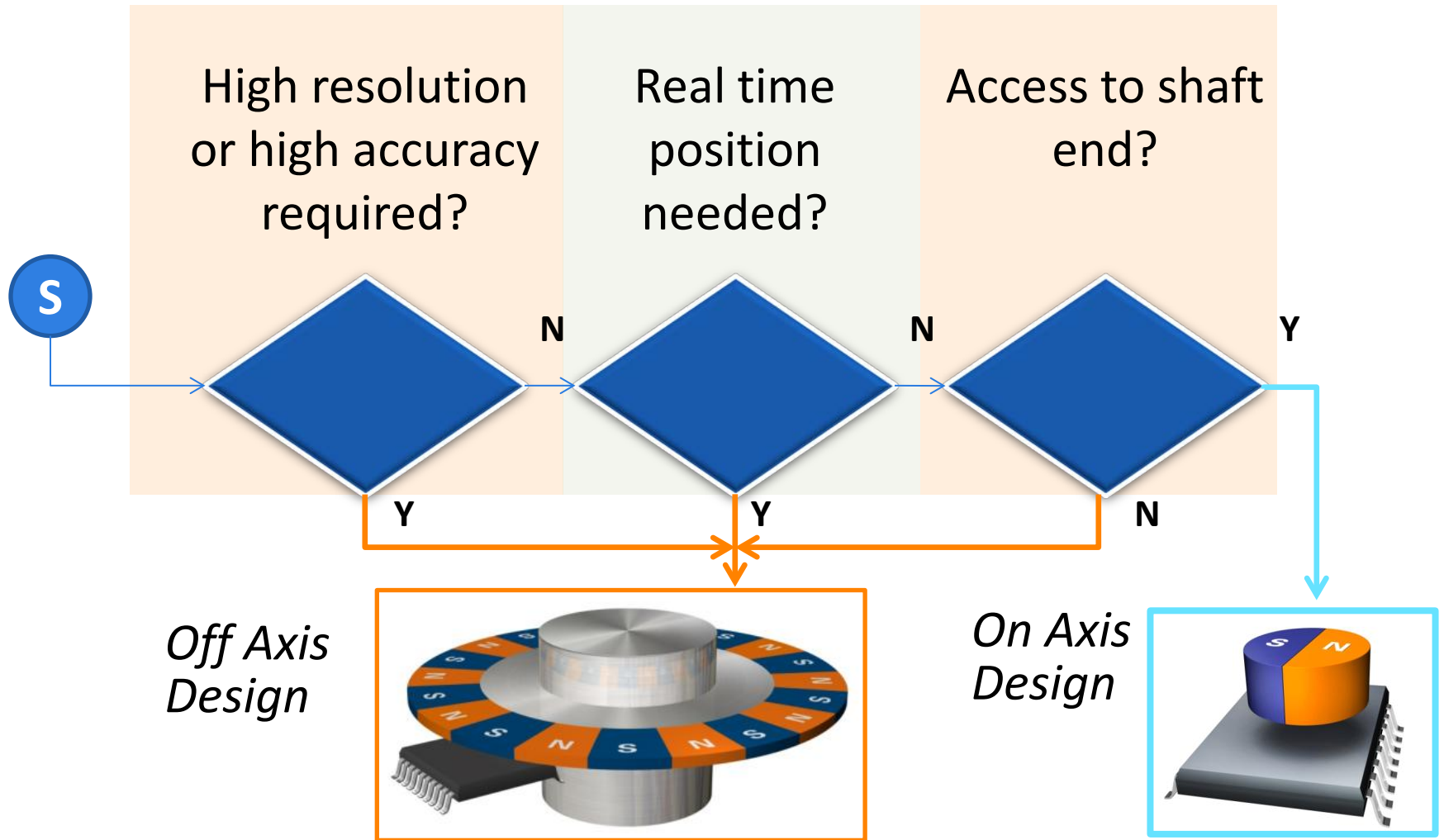
Key Characteristics of on-axis and off-axis sensors

	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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