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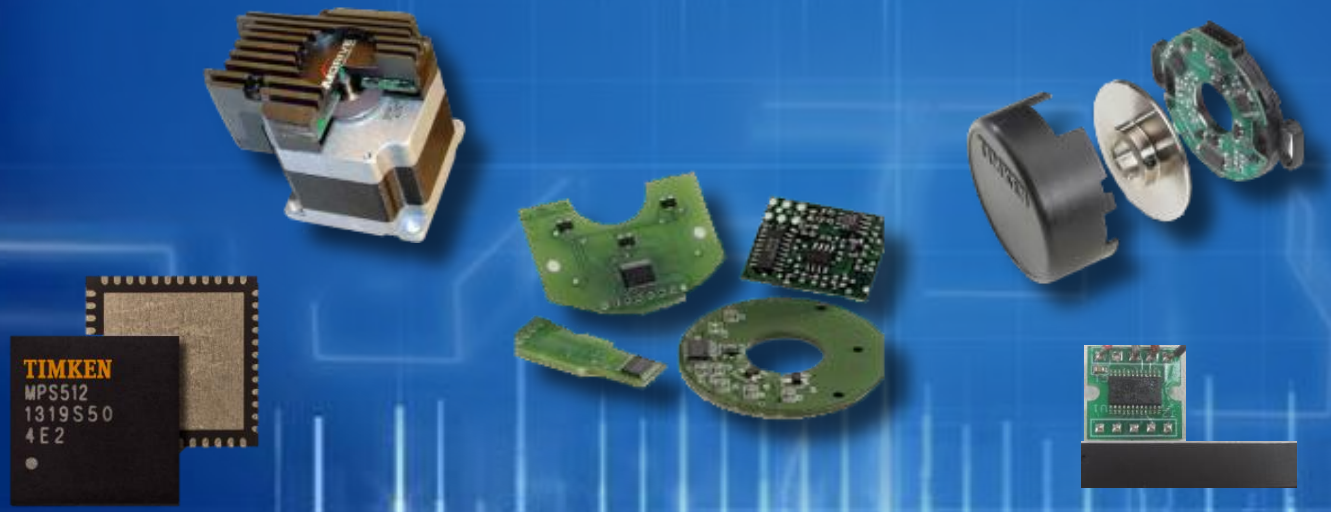
High resolution Hall effect encoders provide high accuracy signals in harsh environments including the presence of high external magnetic fields .



Mark LaCroix
A John Santos
Dr. Lei Wang

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Stronger.

Presentation Outline

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1. Timken introduction
2. Applications & market demand for high resolution off axis sensors
3. Off axis sensors – typical configurations
4. Theory of operation:
   - High resolution Hall array sensors
   - Cosine and sine signal generation
   - Rejection of external fields
5. Operation with varying in field strengths
6. Testing results
7. Conclusions

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: $5.0 B
- Global footprint with operations in 30 countries & 20,000 associates

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15 YEARS IN SENSOR BUSINESS

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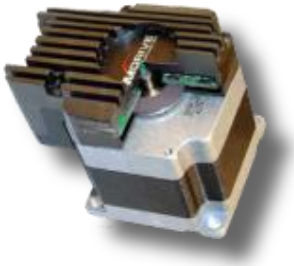
SUPPLIER OF INTEGRATED HALL ENCODER PRODUCTS SERVING INDUSTRIAL CUSTOMERS & CRITICAL VEHICLE SYSTEMS

SENSOR PRODUCTS & APPLICATIONS



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Off axis high resolution magnetic sensors are used on large & small motors

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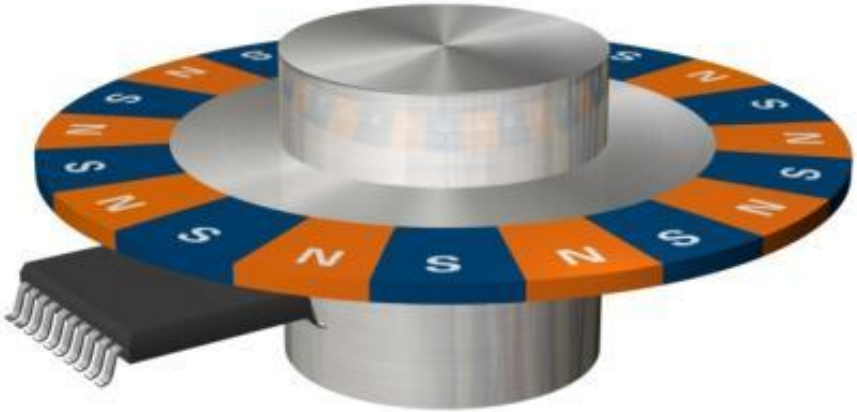
Magnetic Encoder Market

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



Off Axis Magnetic Sensor Configuration

Off Axis Sensors

- Sensor is offset from the center of the rotating shaft
- Direct replacement for optical encoders.
- Can be used inside packaged encoders or integrated into AC or permanent magnet DC motor

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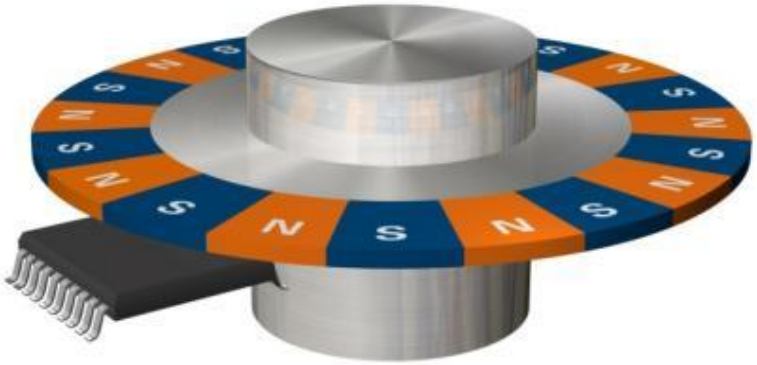
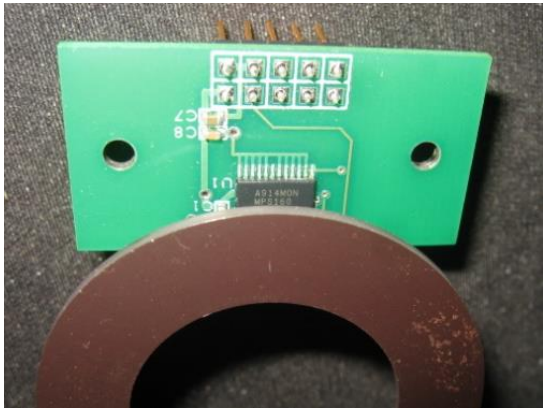
Off Axis Sensors

- Multi-pole magnet: Typically 17 to 300 mm diameter axial or radial
- Sensor IC typically has a 8 to 16 Hall element array
- Produces a Sine & Cosine signal for each pole pair and signal is converted into a quadrature or serial position signal





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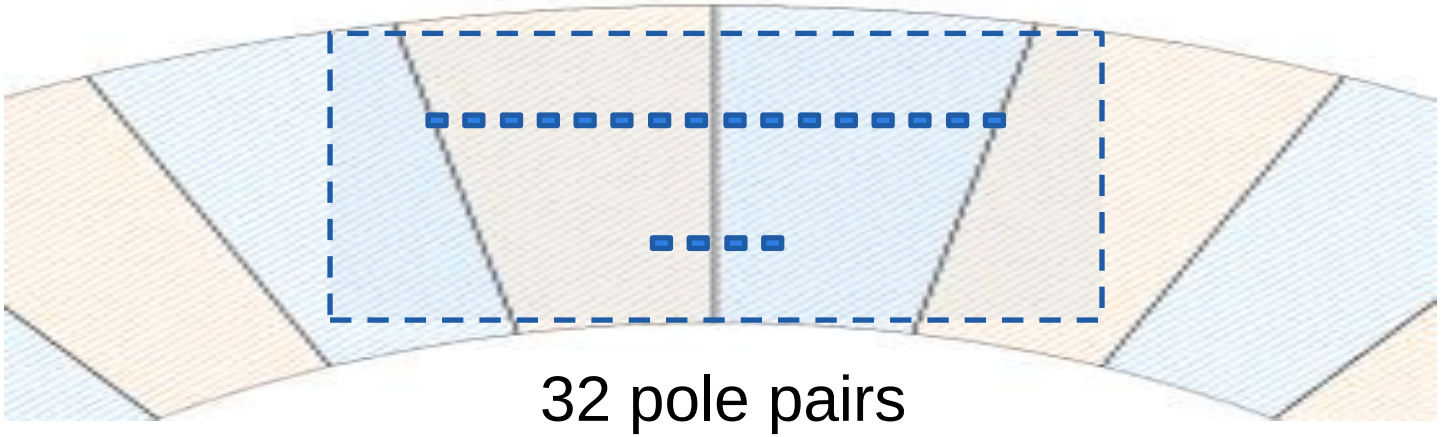
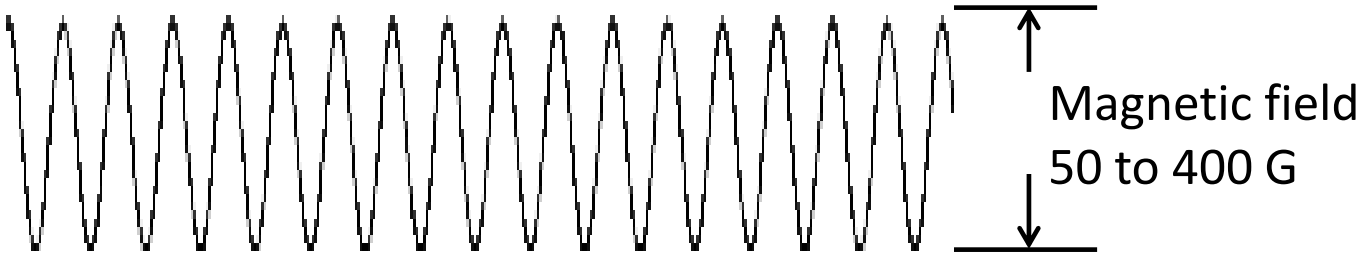
Theory of operation for off axis sensors



32 pole pairs

512 counts for each N-S yields 16,384 counts per turn



Objective: Produce an optical quality high resolution signal from a low resolution magnetic target.

- ✓ Immune to external fields
- ✓ Immune to changes in field strength

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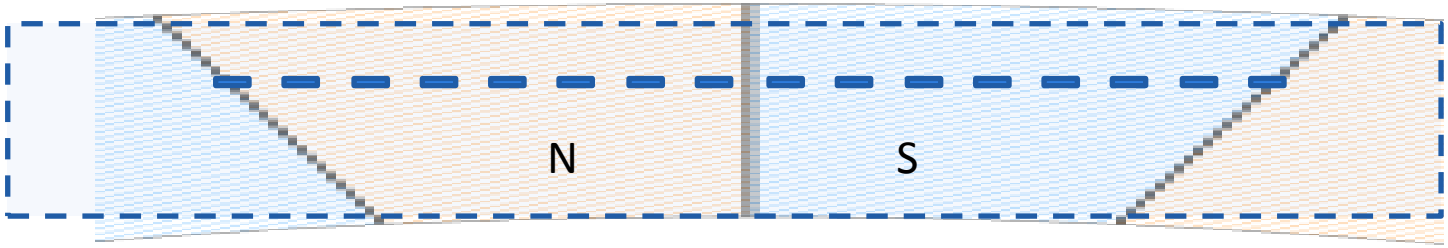
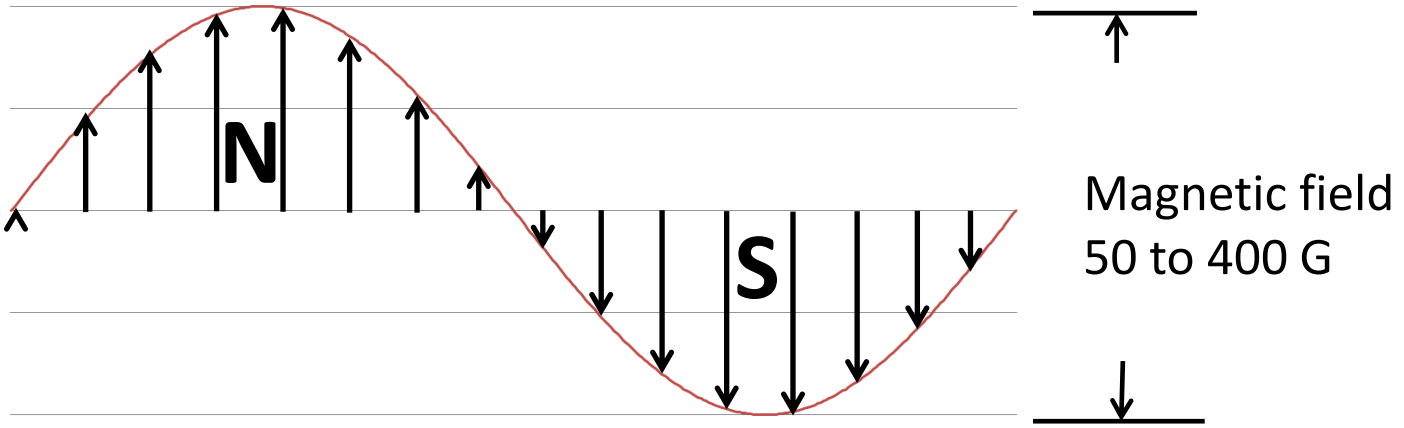
Theory of operation Hall arrays





16 Hall Elements Measure Field Strength

Summing 16 Hall outputs together to produce a robust signal

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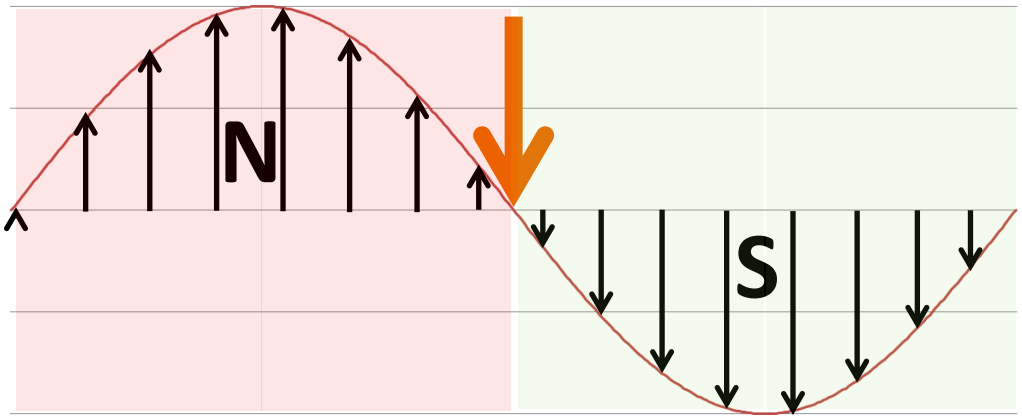
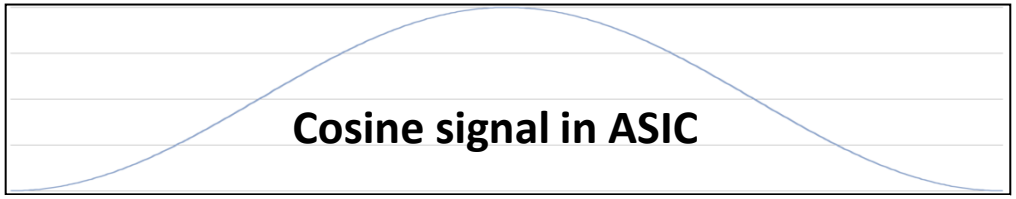
Theory of operation: Cosine signal



Magnetic field from target magnet

H1 +H2 +H3 +H4 +H5 +H6 +H7 +H8 -H9-H10-H11-H12-H13-H14-H15-H16 = Cosine

- **We add the signal from 8 green Halls and subtract the signal from red 8 Halls**
- **Combined signal is 16X stronger & sampled 16 time across a N-S pole pair**



HR Hall Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SIN	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-
COS	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-

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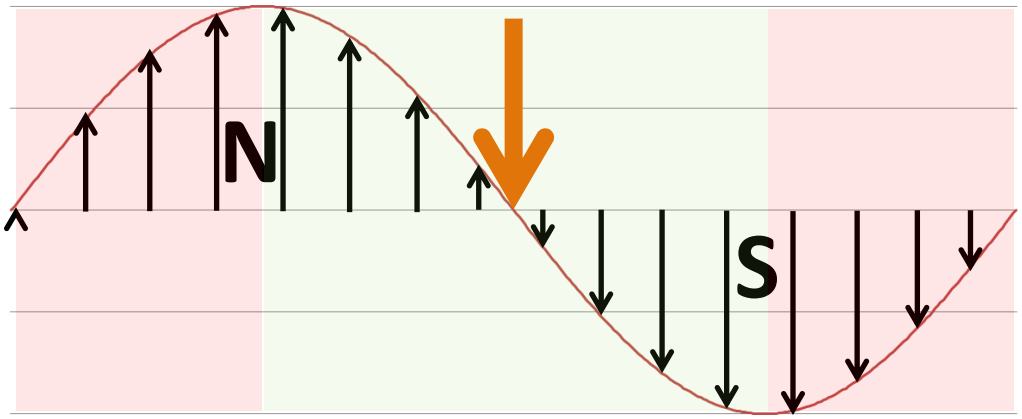
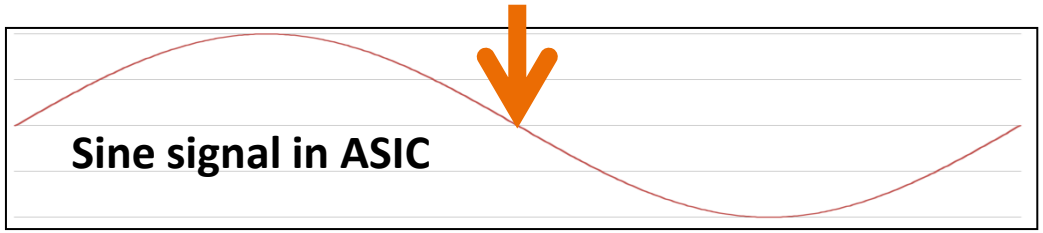
Theory of operation: Sine signal



Magnetic field from target magnet

-H1 -H2 -H3 -H4 +H5 +H6 +H7 +H8 +H9+H10+H11+H12-H13-H14-H15-H16 = Sine

- We add the signal from 8 green Halls and subtract the signal from red 8 Halls
- Combined signal is 16X stronger & sampled 16 time across a N-S pole pair



HR Hall Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SIN	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-
COS	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-

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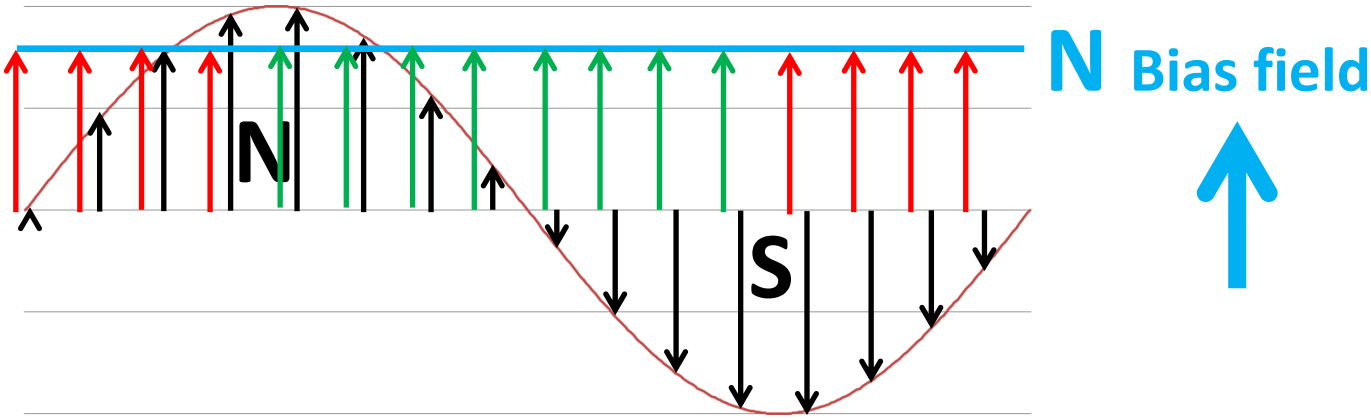
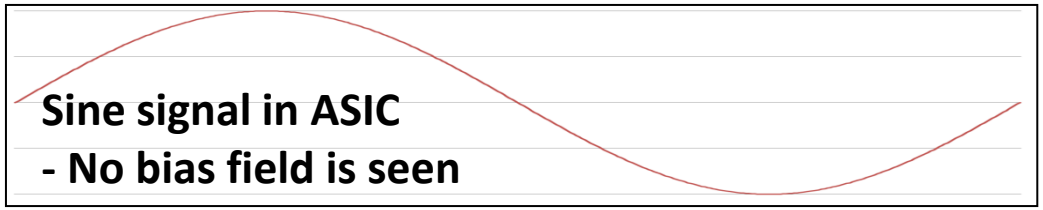
Theory of operation: Bias Field rejection



-H1 -H2 -H3 -H4 +H5 +H6 +H7 +H8 +H9+H10+H11+H12-H13-H14-H15-H16 = Sine

- We add the signal from 8 Halls and subtract the signal from 8 Halls
- Produces a Sine wave that is not affected by common mode fields on the array



HR Hall Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SIN	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-
COS	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-

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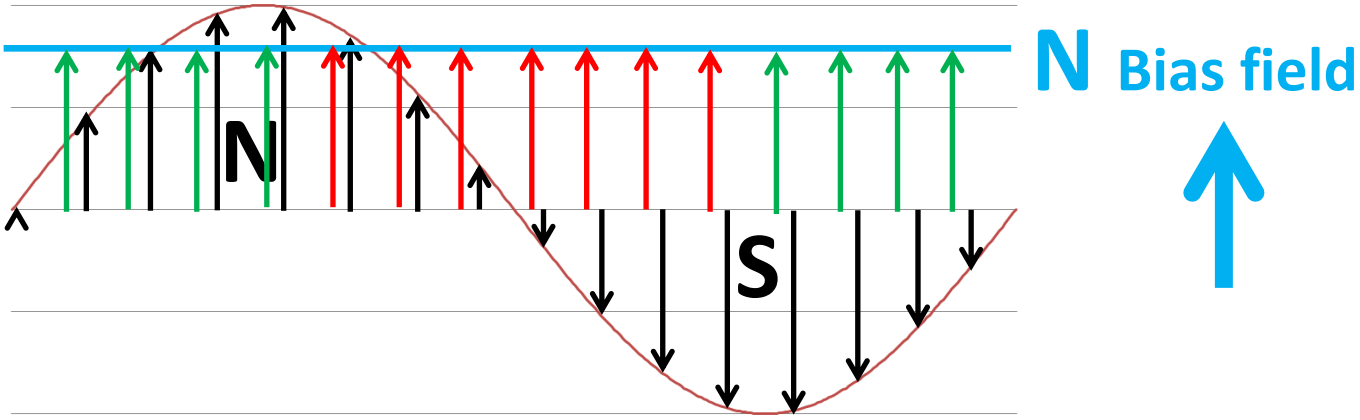
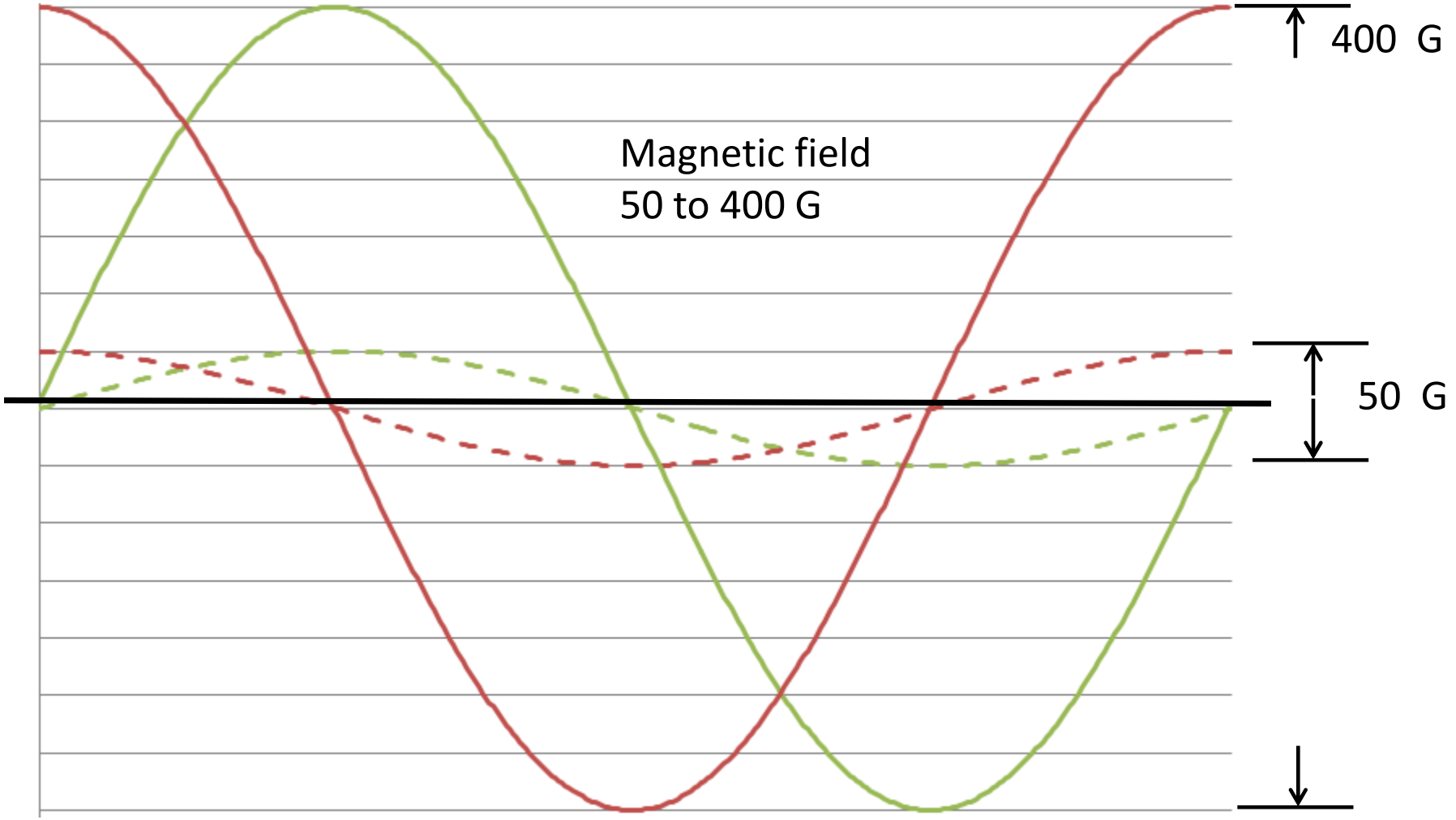
Theory of operation: Bias Field rejection



- Earths field is +/- 0.43 Gauss ~1% of a +/- 50 G working field. This alone would cause a 3 count error with fixed magnetic thresholds.
- New sensors can reject over 98% of external fields even when external field is stronger than the magnetic field from the target magnet

Magnetic amplitude and air gap



Sine & Cosine amplitudes track each other since both are derived from the same 16 Hall signals

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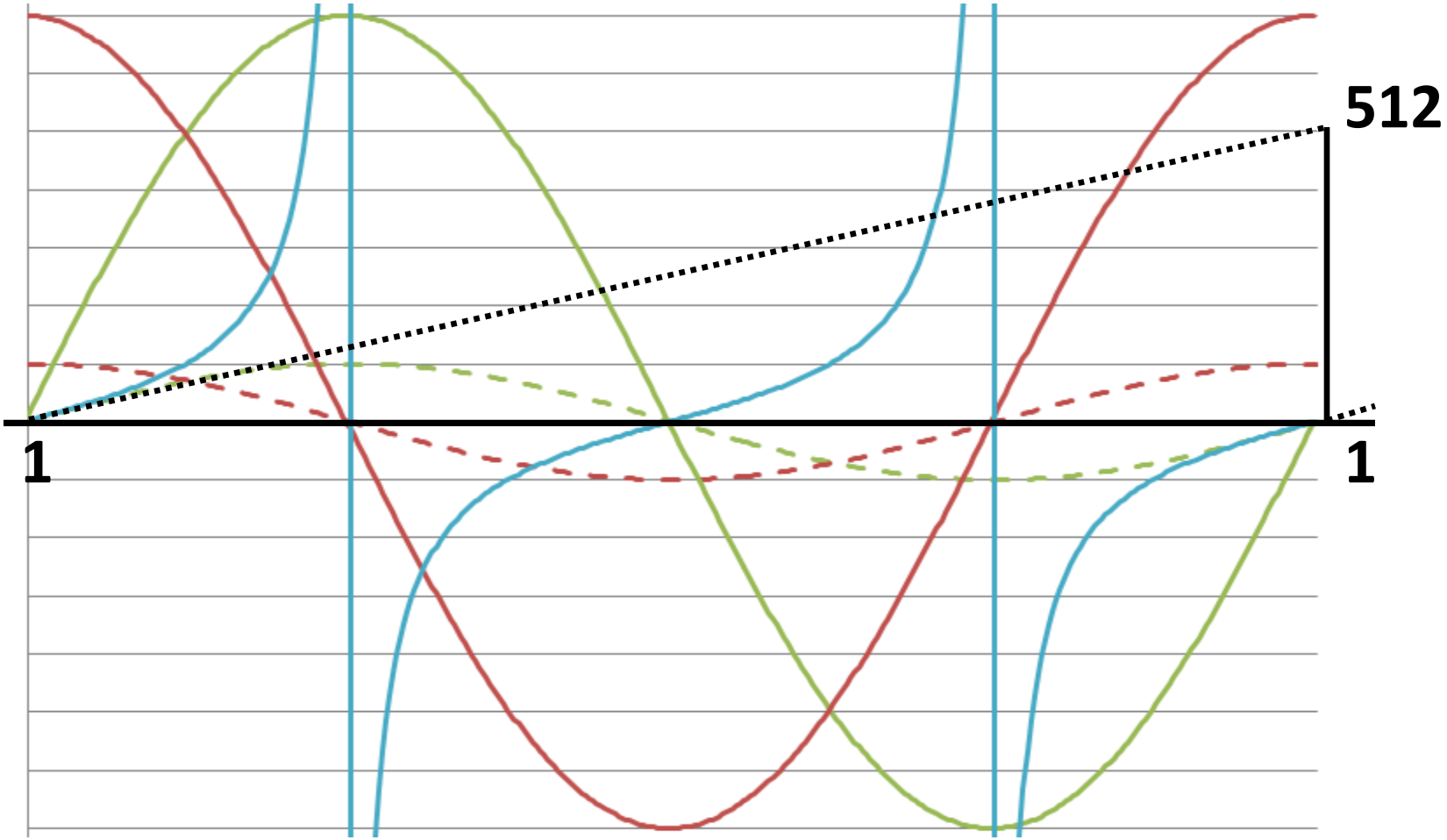
ARCTANGENT WEIGHTED CONVERTER



Sensor chips typically use an ARCTAN weighted converter that detects the RATIO of the SIN & COS signals which makes the circuit independent of Sin & COS amplitude.

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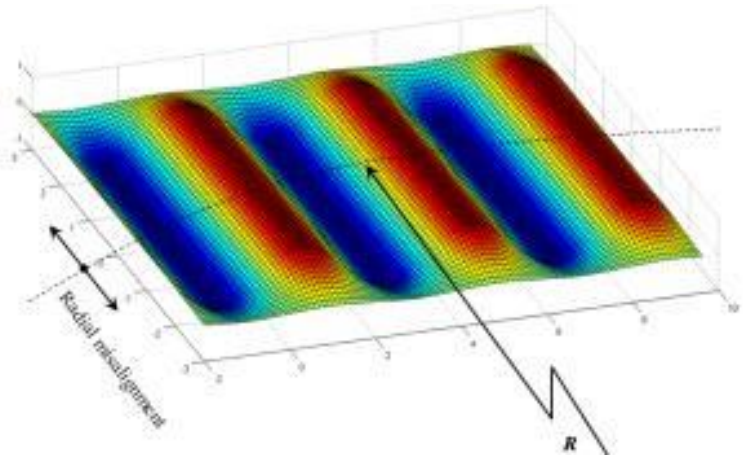
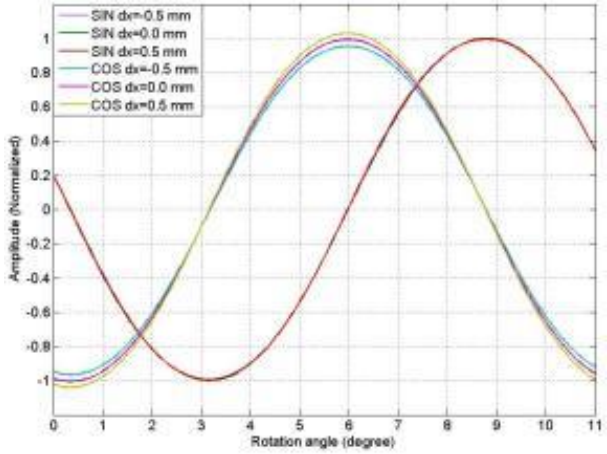
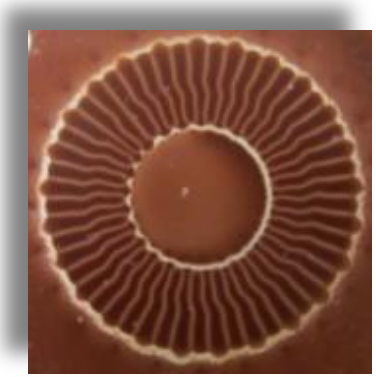
Results of testing and modeling

MAGNETIC TARGETS:





Models of multi pole target magnets



Sample target and image of actual magnetic fields

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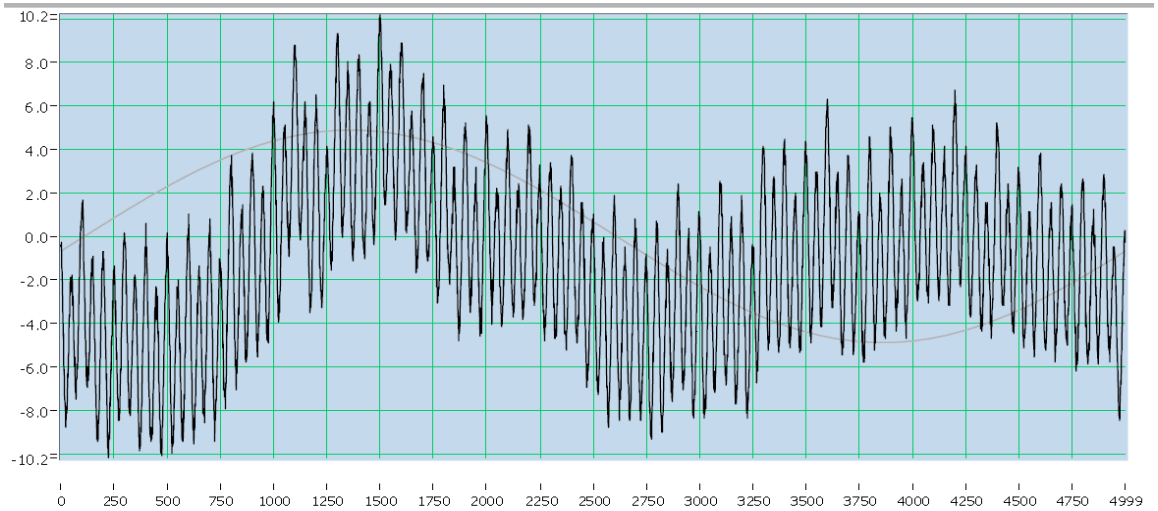
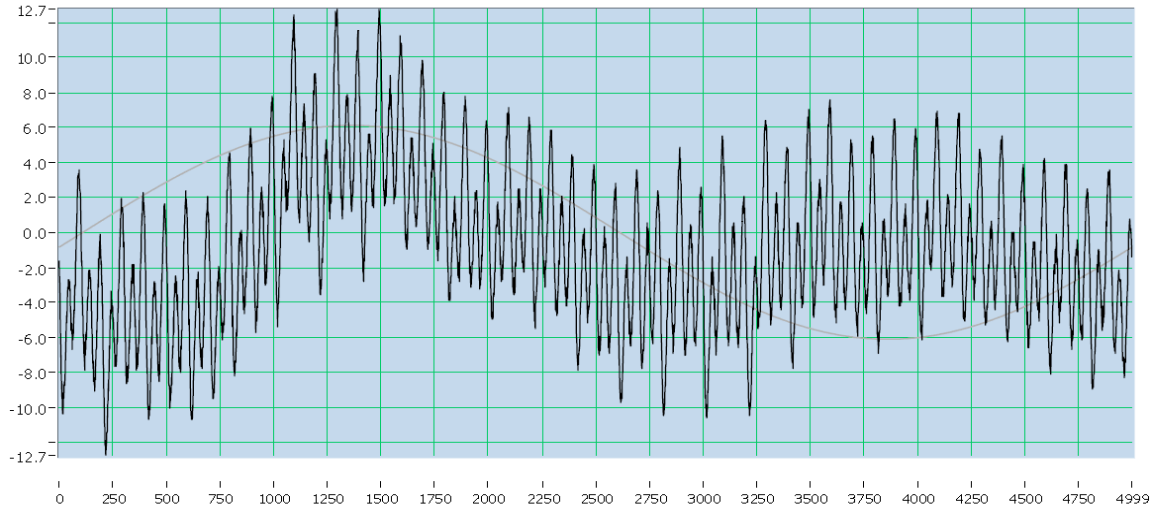
AFFECT OF A MAGNETIC BIAS FIELD ON ACCURACY



Accuracy is +/- .17° over a full turn with a 0 G bias field



Accuracy is +/- .21° over a full turn with a 500 G bias field

Sensor: Timken MPS512. Target: 21 mm Dia. 25 Pole pair polymer bonded ferrite

Plot shows accumulated accuracy at 10,000 edges per revolution

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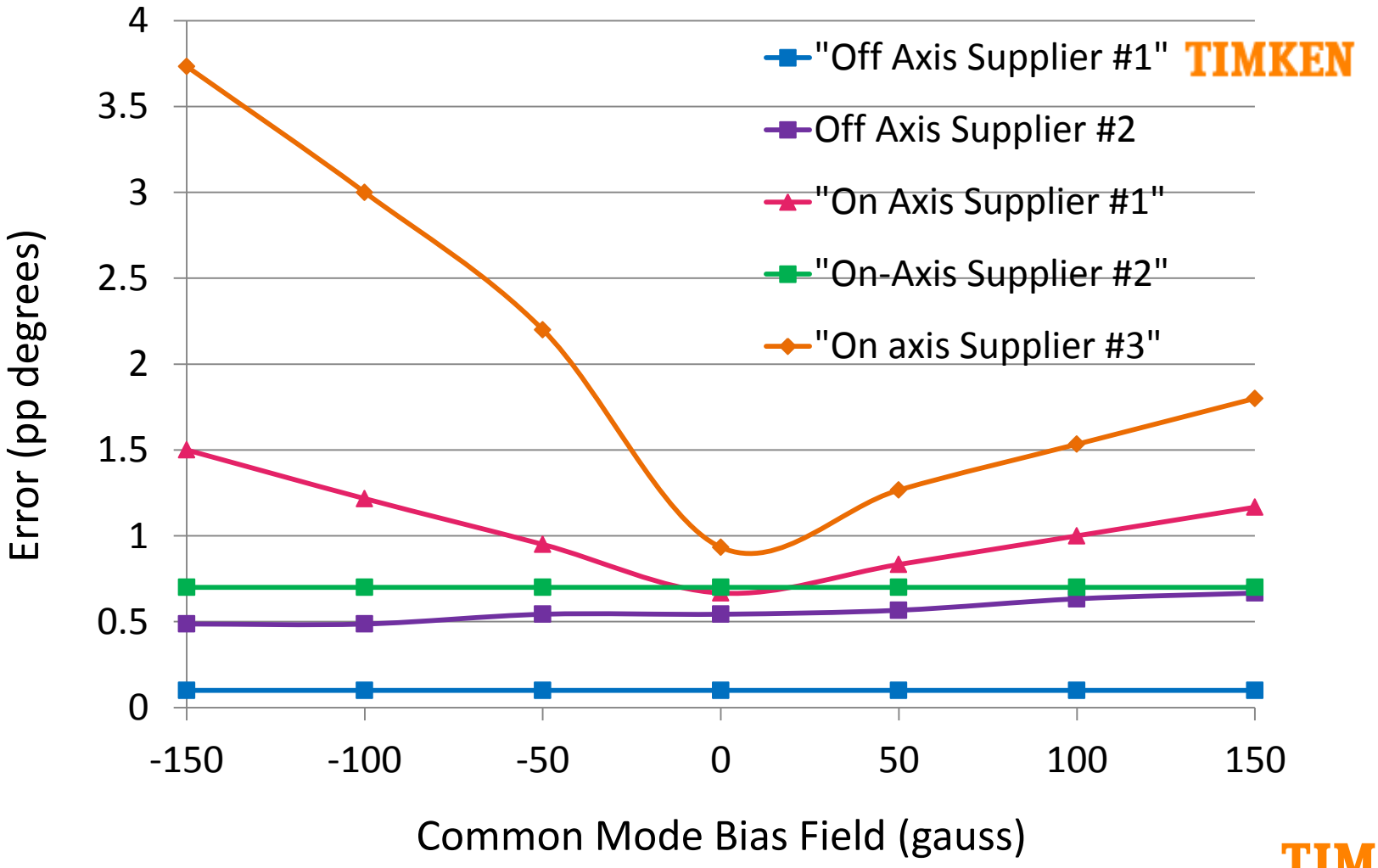
Error: external common-mode fields

From magnetized shafts, motor windings and motor magnets



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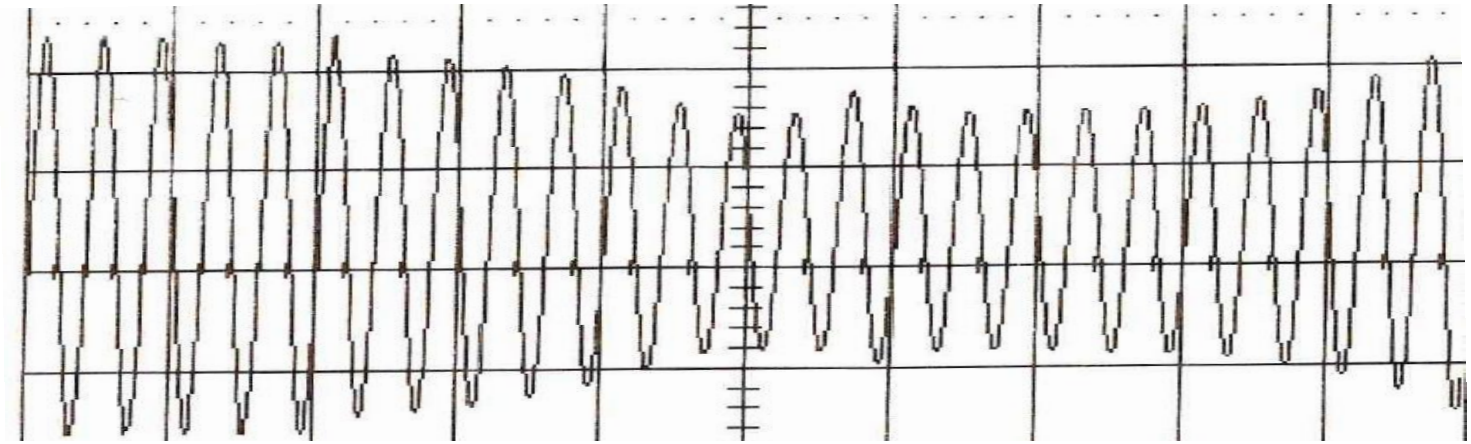
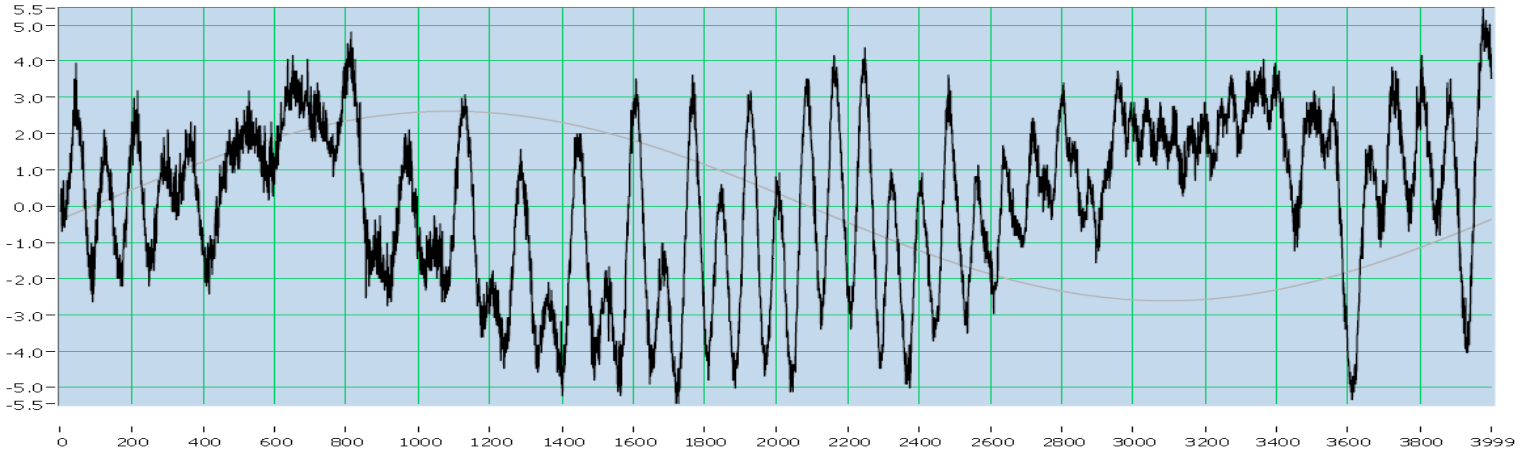
Tolerance to air gap variation:



Accuracy is better then 1/10° over a full turn with a 40% variation in field strength



Sensor: Timken MPS512. Target: 36 mm Dia. 25 Pole pair polymer bonded ferrite

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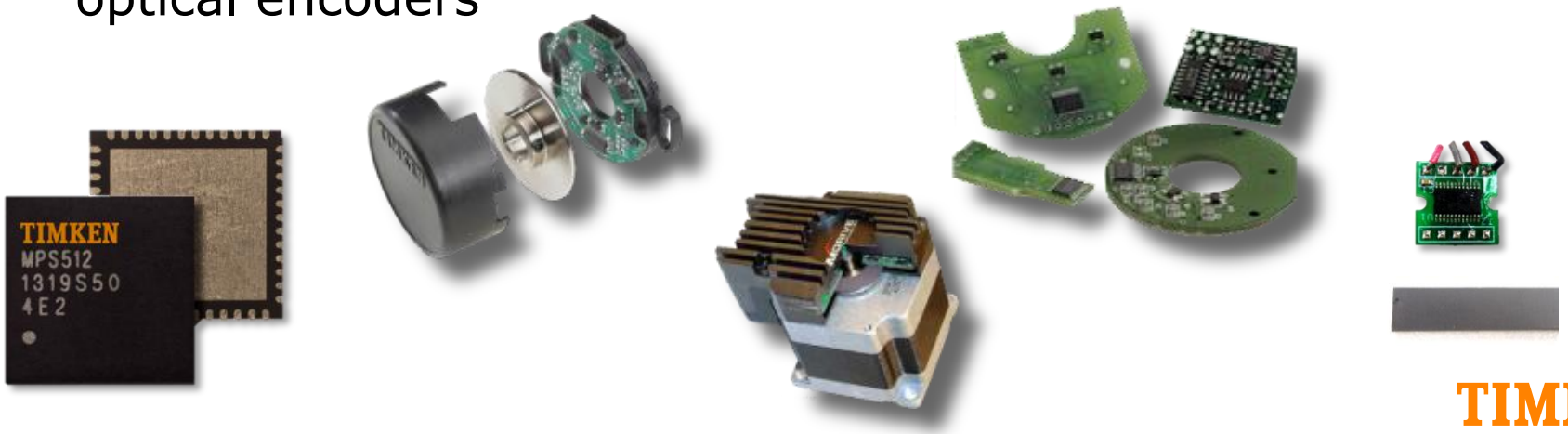
CONCLUSIONS

- It is possible to use modern magnetic sensors in applications where traditional magnetic sensors could not be used
- Modern off axis magnetic sensors incorporate innovative circuitry to reject external magnetic fields
- Modern off axis magnetic sensors incorporate innovative circuitry that permit accurate high resolution sensing with changing air gaps
- Off axis high resolution magnetic sensors offer advantages in applications that exceed the environmental capabilities of optical encoders



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