Description

A resonant inductive position sensor for measuring over a full 360° of rotation. Works with CambridgeIC's Central Tracking Unit (CTU) family of single chip processors to provide high-quality position data to a host device.

The 75mm rotary sensor is available as a blueprint in Gerber format, to enable integration with a customer's own PCB. It is also available as assembled sensors for evaluation, customer prototyping and low-volume production.

This datasheet describes the sensor's performance used with two different targets. The standard target is a packaged resonator comprising wound ferrite rod and capacitor. This is available as a standard part. An air cored target design is also described as an alternative, and yields a more compact system with no magnetic materials.

The sensor measures the angle of the target relative to the *Sensor Axis*. If the target is mounted onto a rotating shaft, there will be an error in the measurement of shaft angle proportional to the amount of radial misalignment between Sensor Axis and shaft axis. This can be avoided by using a different, smaller sensor in End Shaft configuration.

Features

- Simple non-contact target
- Large gaps – up to 7mm
- Full absolute sensing over 360°
- Standard 4-layer PCB process
- 45mm hole, e.g. for through shaft
- 75mm diameter copper coil pattern
- Highly repeatable

Performance (Standard Target)

- ±0.5° (±0.14%) Absolute Error at gap 1…5mm
- Add ±1.7° error per mm of radial misalignment

Performance (Air Cored Target)

- ±0.7° (±0.2%) Absolute Error at gap 2…5mm
- Add ±2° error per mm of radial misalignment

Applications

- Motion control
- Actuator position feedback
- Precision front panel controls
- Contactless dial reading
- Valve position sensing
- Absolute Optical Encoder replacement

Product identification	
Part no.	**Description**
013-0015	Assembled sensor
013-6001	300mm ribbon connector
013-1005	Compatible target
010-0035	Sensor Blueprint

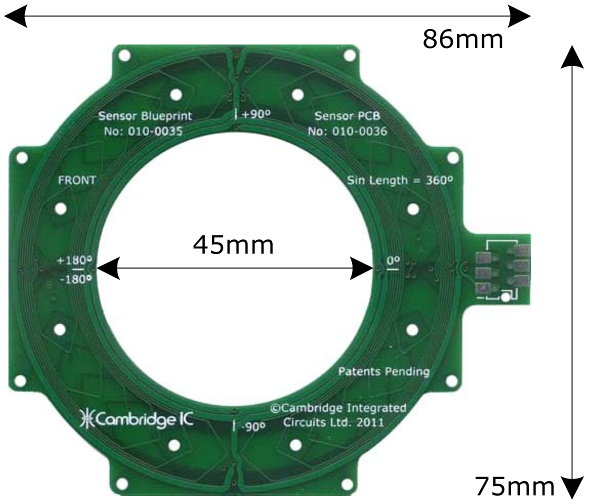

Figure 1 sensor 013-0015 (without connector)

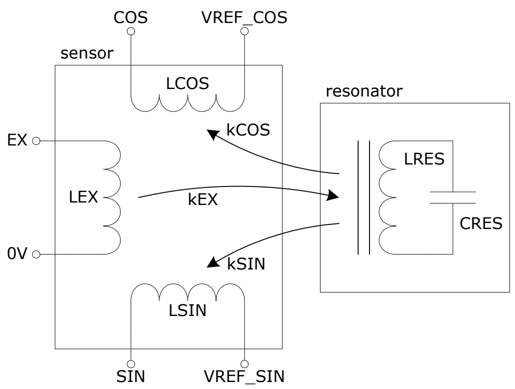

Figure 2 equivalent circuit

1 Assembled Sensor 013-0012

Figure 3 is a dimensioned drawing of the assembled sensor. Dimensions are in mm.

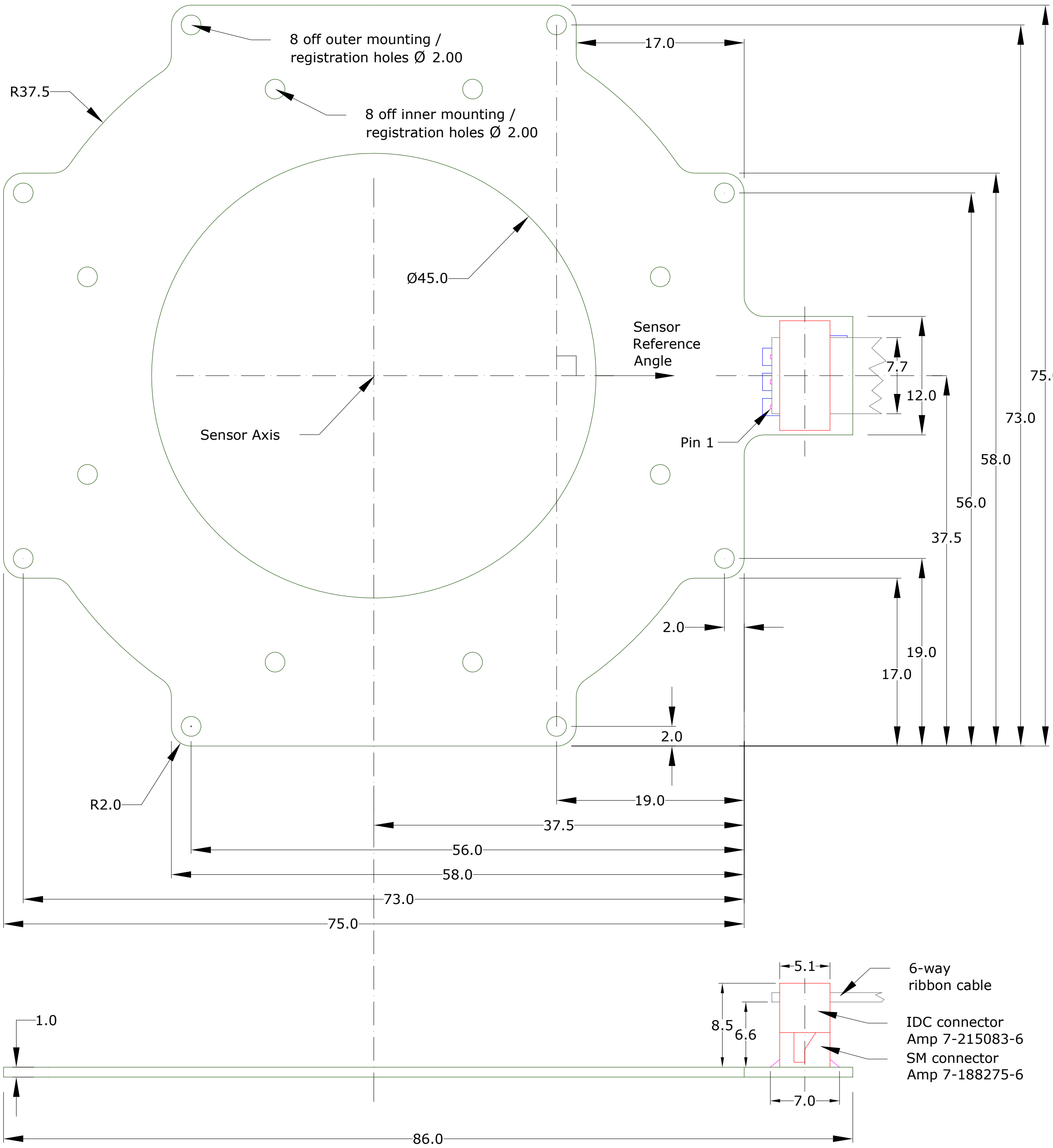

Figure 3 sensor board part number 013-0015 mated with connector 013-6001

2 Definitions

2.1 Transfer Function and Performance Metrics

The sensor is connected to a CTU chip which reports position as a 16-bit signed integer, here denoted *CtuReportedPositionI16*. The sensor's *Sin Length* parameter is 360°, so the reported position may be converted to degrees using:

$$ReportedDegrees = \frac{CtuReportedPositionI16}{65536} \times 360°$$

Equation 1

The actual angle is defined as the angle formed by the target and the Sensor Reference Angle illustrated in Figure 3, so that:

$$ActualDegrees = TargetReferenceAngle - SensorReferenceAngle$$

Equation 2

Actual Degrees is zero when the Target Reference Angle and Sensor Reference Angle are equal. Its direction is positive for anticlockwise target rotation when viewing the front of the sensor.

Absolute Error is the difference between these two:

$$AbsoluteError = ReportedDegrees - ActualDegrees$$

Equation 3

3 Operation with Standard Target

Figures below are representative of assembled sensors available from CambridgeIC (as described in section 1) and of sensors built according to CambridgeIC's blueprint to the recommended specifications (section 6). Measurements are taken with a typical target (part number 013-1005) and CTU Development Board (part number 013-5006 using CambridgeIC's CAM204BE chip).

3.1 Alignment of Sensor and Standard Target

The standard target (part number 013-1005) contains an inductively coupled resonator including a wound ferrite rod along its long axis (*Target X Axis*). When used as an angle marker with the 75mm rotary sensor, this long axis points towards the Sensor Axis, and the sensor measures the angle that this makes with the Sensor Reference Angle. The centre point of the target (the *Target Origin*) should be positioned 21mm from the Sensor Axis as illustrated in Figure 4.

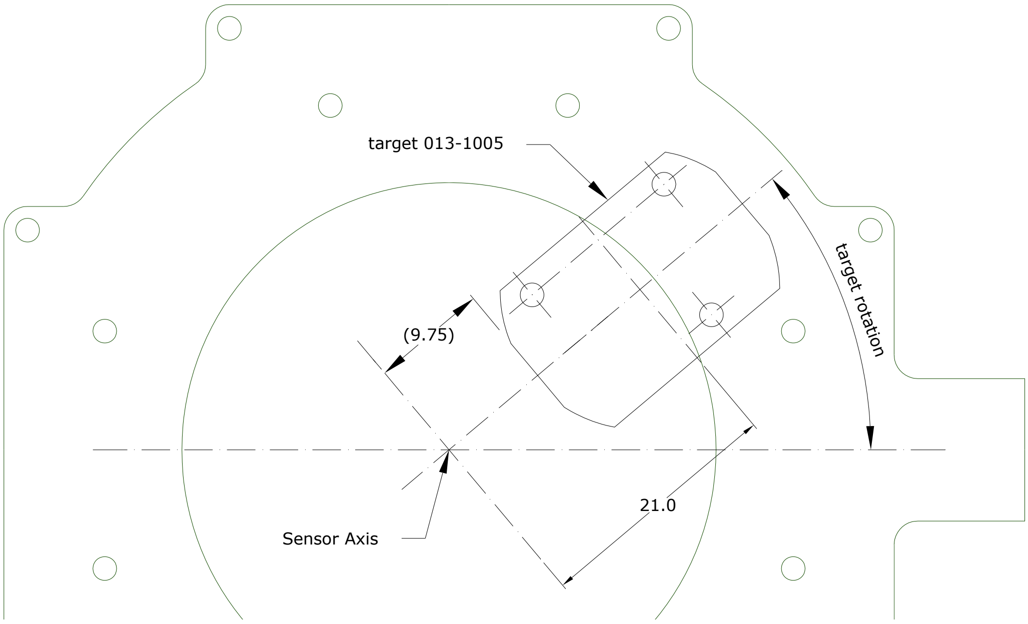

Figure 4 sensor alignment with standard target (shown at +40°)

The sensor measures the position of the ferrite rod inside the target. The target is designed to minimise the location tolerance of the ferrite rod inside, so that its contribution to the overall system error budget is small. When aligned as in Figure 4, its main contribution to overall angle error is due to linear magnetic axis alignment. A value of ±0.1mm yields an angle offset error of ±0.17°.

The target may be located either at the front or rear of the sensor. It may be used either way up (it is free to rotate about the Target X Axis as defined in the target's datasheet).

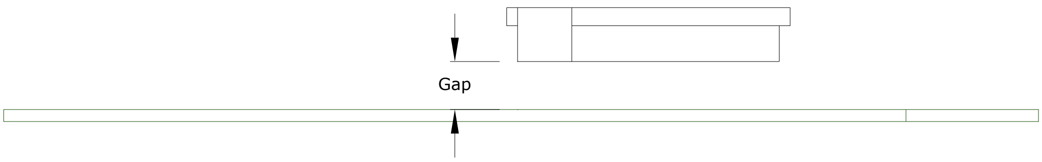

Figure 5 Definition of Gap for standard target

3.2 Absolute Error, Standard Target

Figure 6 illustrates how Absolute Error depends on Gap for a typical sensor in free space.

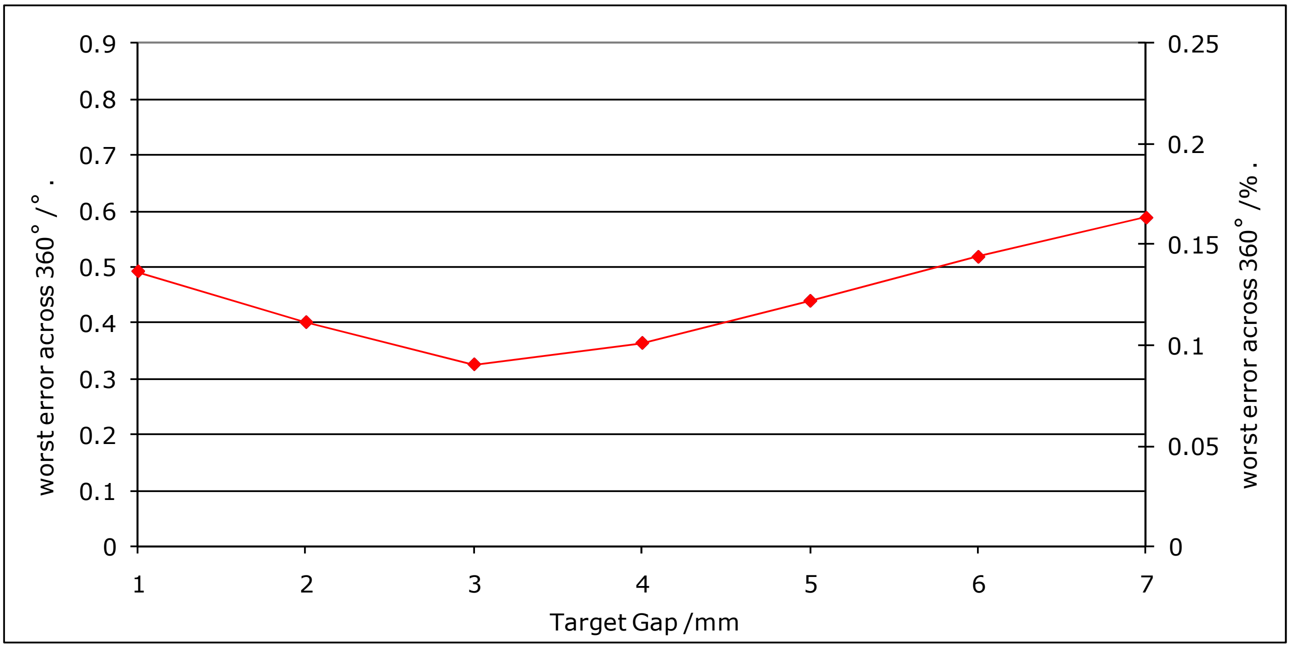

Figure 6 Absolute Error against Gap, standard target

3.3 Amplitude, Standard Target

Amplitude is a measure of inductive signal coupling between the sensor and target. Higher values are preferable since they result in better resolution when the sensor is used with a CTU chip. Figure 7 illustrates how Amplitude changes with Gap for a typical sensor.

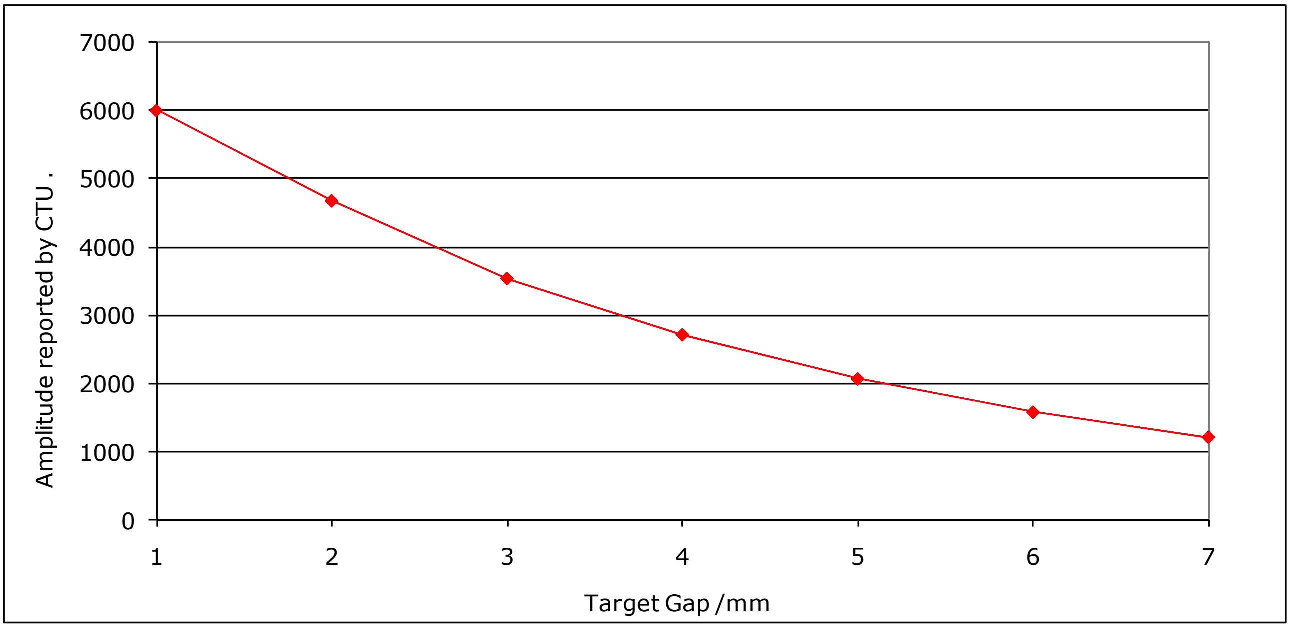

Figure 7 Amplitude reported by CTU against Target Gap, standard target

4 Operation with Air Cored Target

An air cored target design is presented below as an alternative to the standard target. This achieves a more compact assembly. It allows operation with larger shafts than the standard target. It also tolerates large magnetic fields without saturation, due to the absence of magnetic materials.

Figures below are representative of assembled sensors available from CambridgeIC (as described in section 1) and of sensors built according to CambridgeIC's blueprint to the recommended specifications (section 6). Measurements are taken with a typical target according to the design below, and typical CTU Development Board (part number 013-5006 using CambridgeIC's CAM204BE chip).

4.1 Air Cored Target Design

The air cored target comprises a wound coil connected to a capacitor. The coil is built from self bonding wire. This is wound onto on oval former and heated to yield a self-supporting coil illustrated in Figure 8.

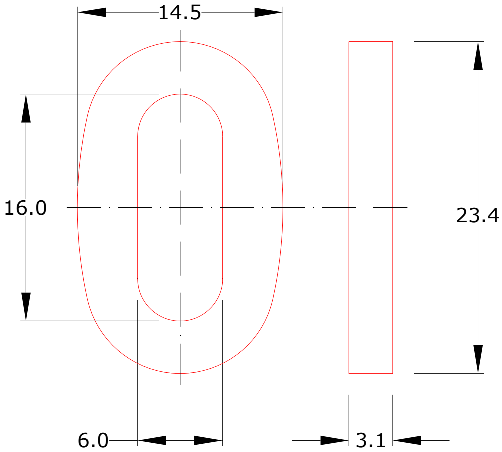

Figure 8 coil dimensions

Table 1 specifies the coil winding and capacitor.

Table 1 target specifications

Parameter	Specification
Coil winding wire	7 strands self bonding 0.1mm enameled copper wire, twisted
Coil inductance	153µH ±3%
Number of turns	100, approx
Resonating capacitor value	4.7nF ±5%
Resonating capacitor type	NPO (COG)
Peak capacitor voltage in operation	50V
Recommended capacitor voltage rating	≥200V DC
Target resonant frequency	187.5kHz ±4kHz

4.2 Alignment of Sensor and Air Cored Target

The air cored target described above should be positioned as shown in Figure 9. The coil's centre is positioned 30mm from the Sensor Axis.

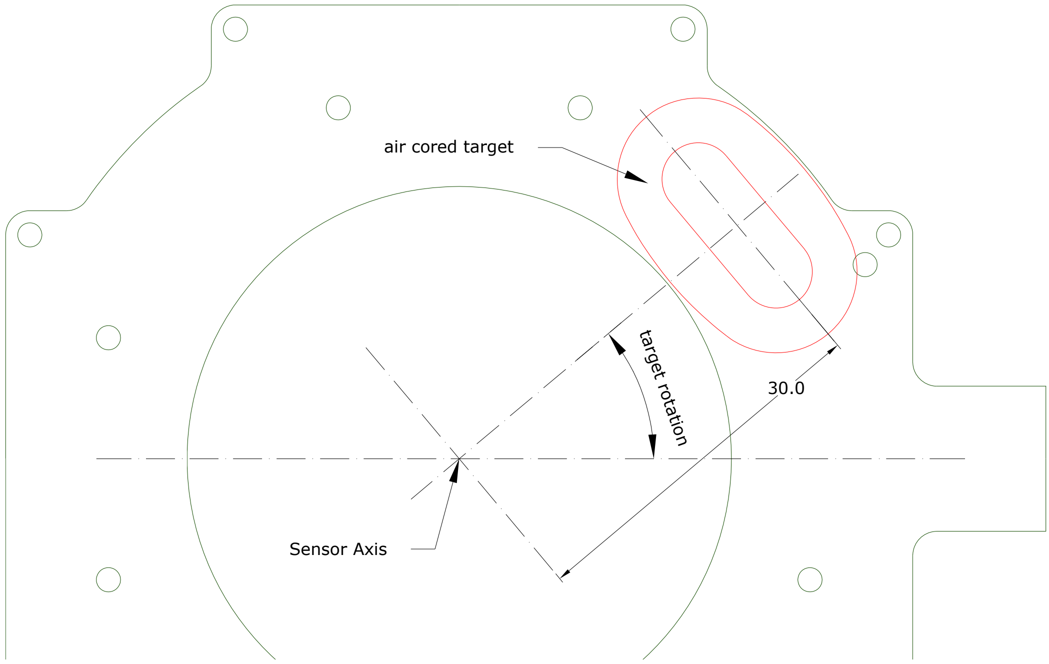

Figure 9 sensor alignment with air cored target (shown at +40°)

The target may be located either at the front or rear of the sensor.

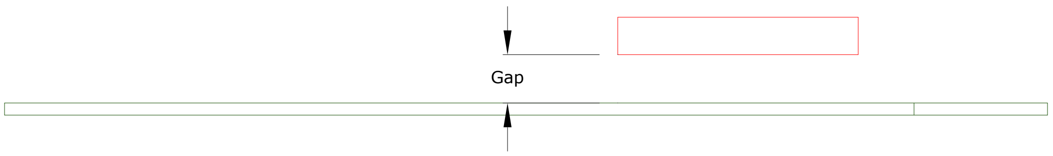

Figure 10 Definition of Gap for air cored target

4.3 Absolute Error, Air Cored Target

Figure 11 illustrates how Absolute Error depends on Gap for a typical sensor in free space.

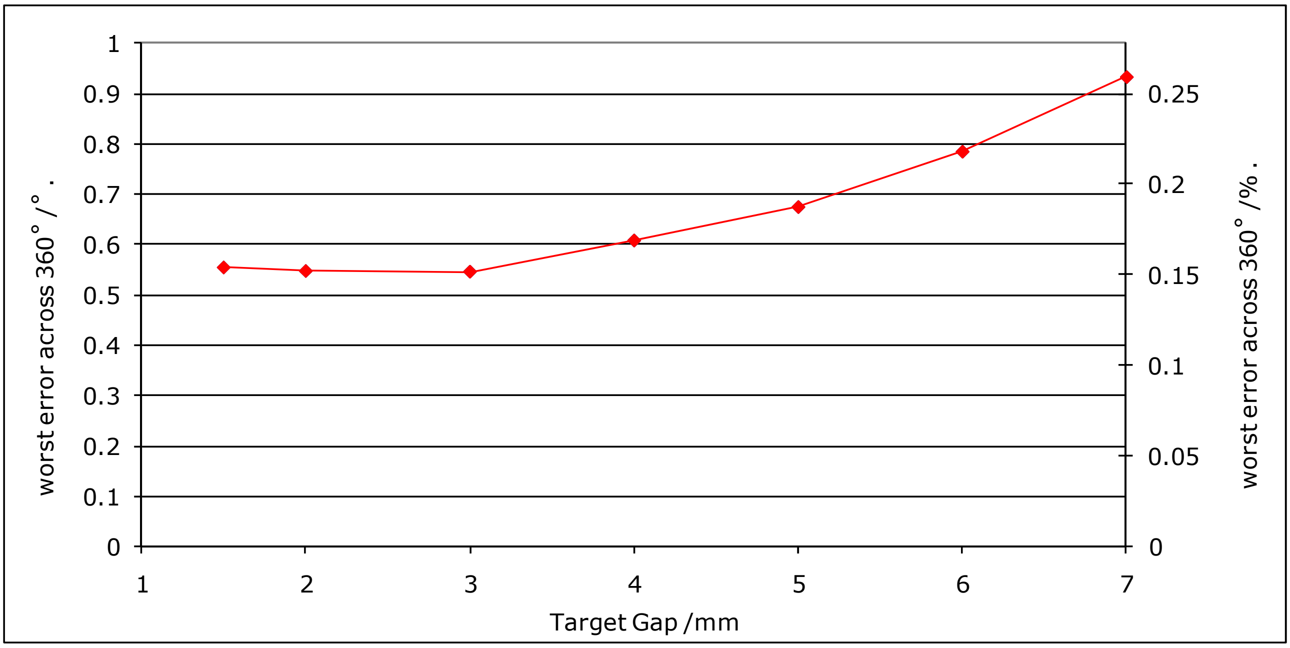

Figure 11 Absolute Error against Gap, air cored target

4.4 Amplitude, Air Cored Target

Amplitude is a measure of inductive signal coupling between the sensor and target. Higher values are preferable since they result in better resolution when the sensor is used with a CTU chip. Figure 12 illustrates how Amplitude changes with Gap for a typical sensor.

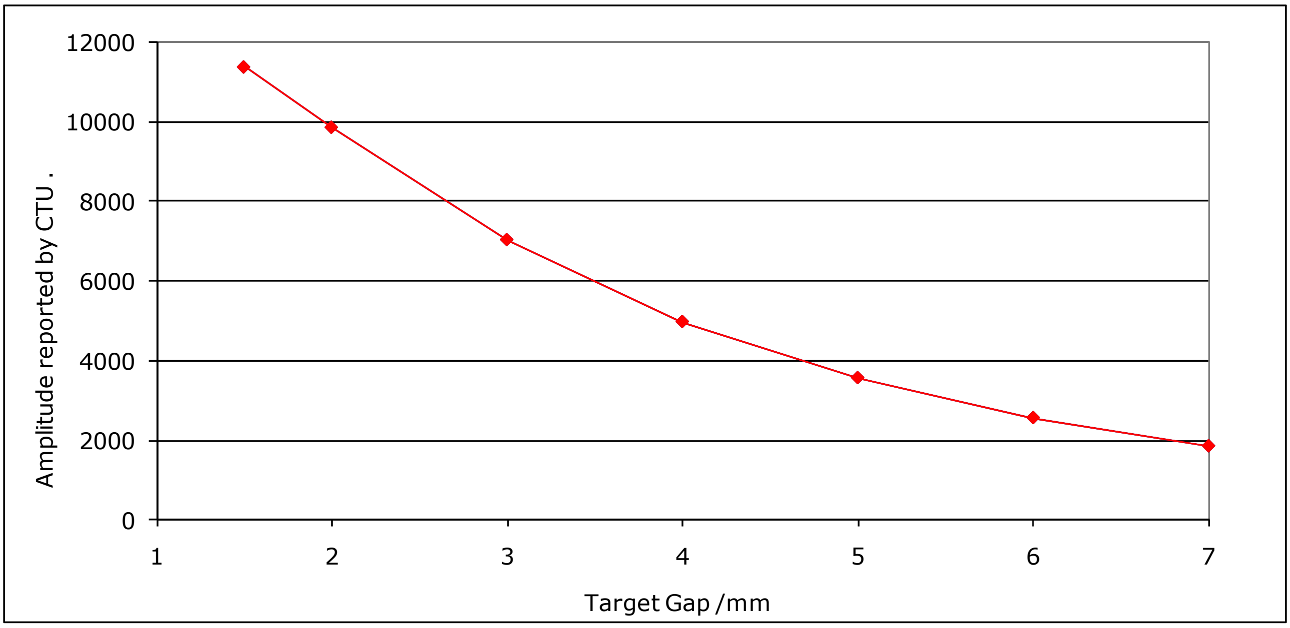

Figure 12 Amplitude reported by CTU against Target Gap, air cored target

Amplitudes of greater than 10,000 should be avoided due to possible CTU saturation, which may cause additional errors. The air cored target is therefore recommended for use with Gap greater than or equal to 2mm.

4.5 Effect of Metal Shaft, Air Cored Target

When used together with an air cored target illustrated in Figure 9, the sensor can accommodate shafts through the centre up to 45mm diameter. If the shaft is made from a metal, it is recommended that the diameter is kept less than 40mm. Larger diameter metal shafts generally yield lower amplitudes and hence slightly worse resolution. As illustrated in Figure 13, the reduction is worse with mild steel than aluminium. If a large diameter steel shaft is required while maintaining the highest amplitudes, it is recommended to use a thin sleeve around the shaft in the immediate vicinity of the target.

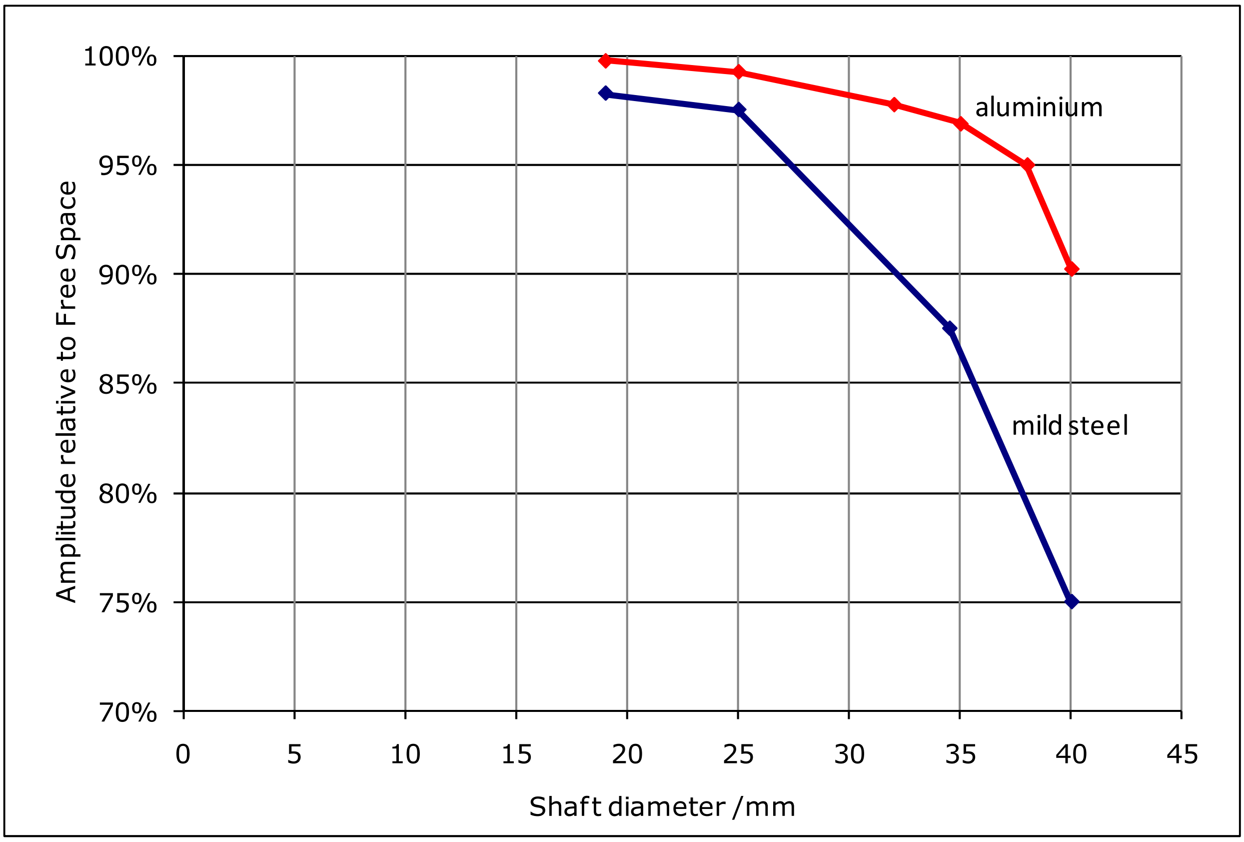

Figure 13 effect of a metal shaft through the centre of the sensor at 3mm Gap

5 Effect of Radial Misalignment

The sensor measures the angle formed by the target's magnetic centroid with its reference direction. If the target is attached to a rotating shaft whose axis coincides with the Sensor Axis then the system will measure the shaft angle accurately, with the performance specified above. However if the two are misaligned as shown in Figure 14, the measured angle will no longer match the shaft angle. The radial misalignment causes a displacement of the target's centroid which appears as a change in angle.

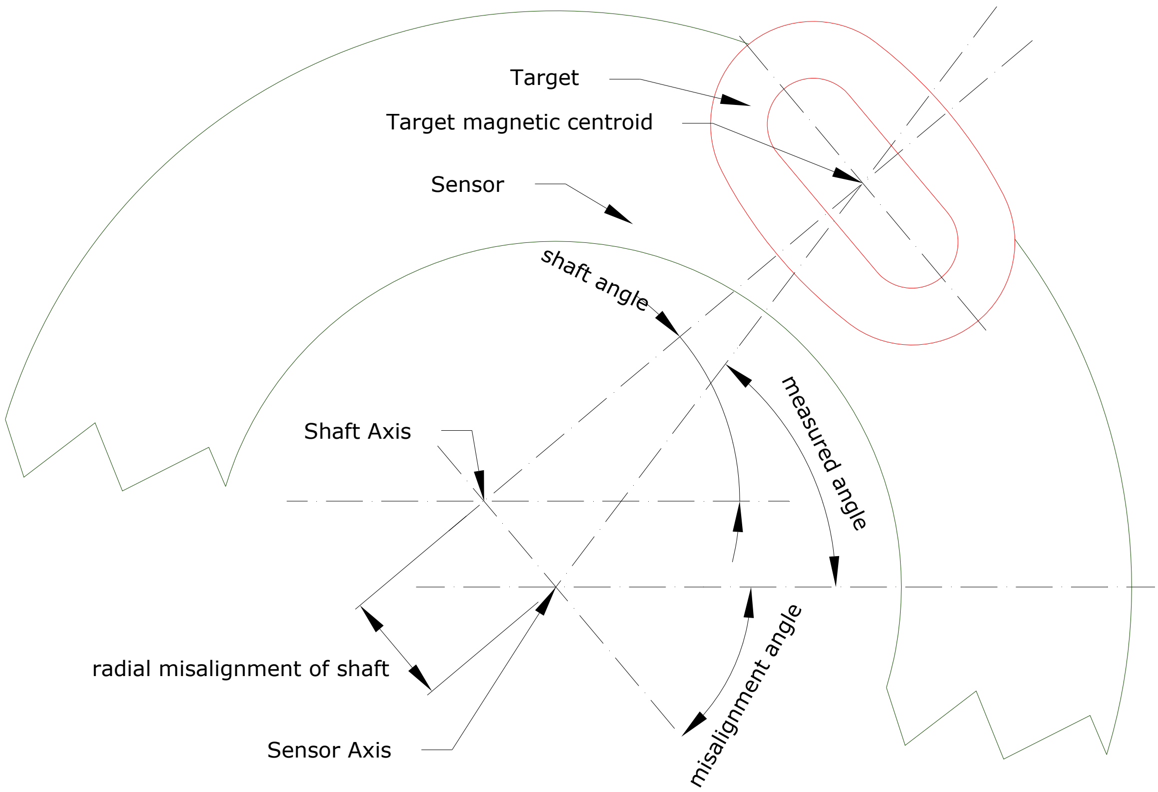

Figure 14 misalignment between shaft carrying target and sensor (exaggerated for clarity)

The peak angle error due to misalignment is proportional to the amount of radial misalignment, at a rate of ±2° error per mm for the air cored target and ±1.7° error per mm for the standard target. (These figures depend on the distance of the target's magnetic centroid from the Sensor Axis).

The error varies sinusoidally with angle as illustrated in Figure 15. The error is zero when the shaft angle matches the misalignment angle, and repeats once per revolution.

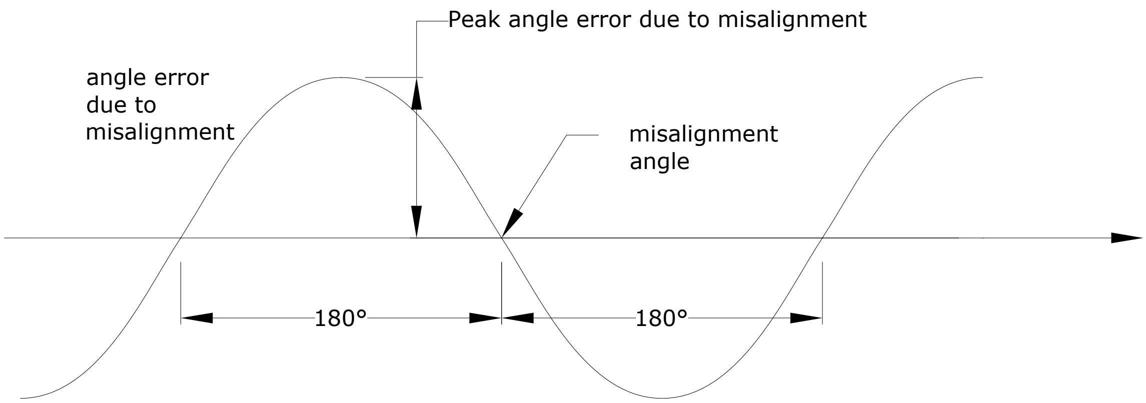

Figure 15 effect of radial misalignment

6 Sensor Blueprint 010-0035

6.1 Purpose

A Sensor Blueprint is data defining the pattern of conductors for building the sensor onto a PCB. A customer may build their own sensors for use with CambridgeIC's CTU chips, either as stand-alone sensors or combined with their own circuitry.

6.2 Fabrication Technology

The Sensor Blueprint is fabricated on a 4-layer PCB. Recommended copper thickness is shown in Table 2.

Table 2

Copper thickness	oz	µm
Minimum	0.8	28
Recommended	1	35

6.3 PCB Design Parameters

Table 3

PCB Design Rules	Minimum values used	
	mm	inches
Track width	0.2	0.0079
Gap between tracks	0.2	0.0079
Via land outer diameter	0.8	0.031
Drill hole diameter	0.4	0.016

6.4 Data Format

Sensor Blueprint is supplied as Gerber data is in RS-274-X format with the following settings: imperial, 2.4 precision and leading zero suppression.

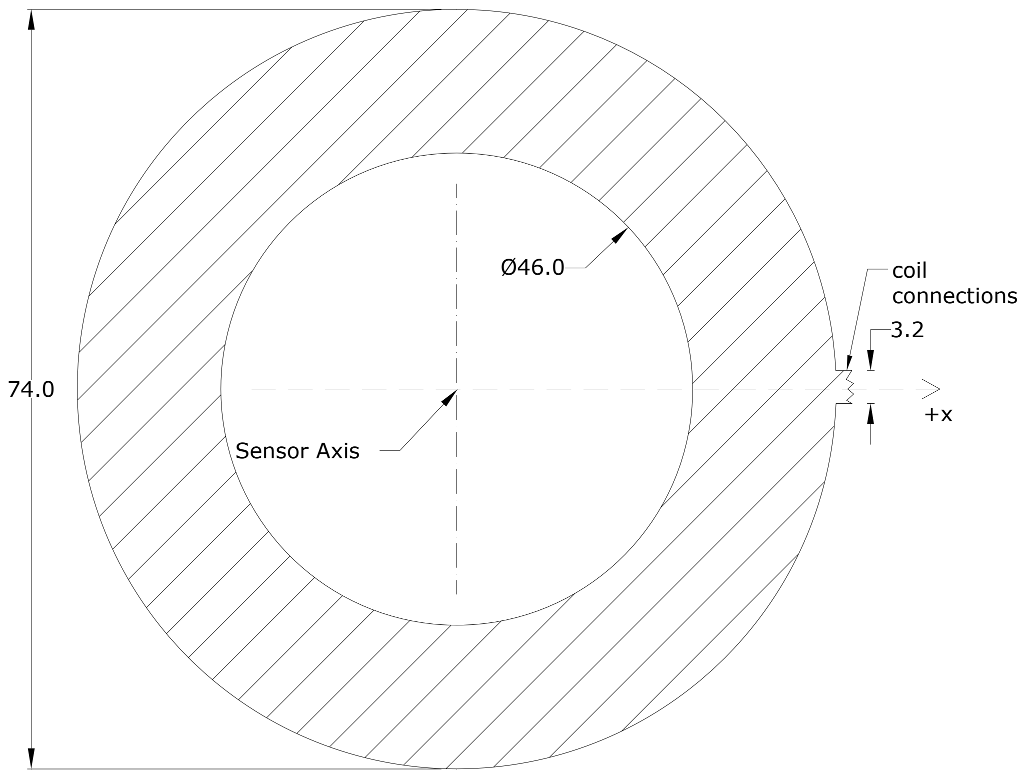

Figure 16 copper extents

6.5 PCB Integration

Figure 16 illustrates the extent of the copper pattern required to build the sensor on a PCB. The circular area is the sensor itself, with coil connections shown to the right. The coil pattern may be rotated or flipped to fit a customer's assembly, in which case the position reported by the CTU will be transformed accordingly.

When integrating with other electronic circuitry, a keep-out of 2mm is recommended all round the sensor's conductors.

6.6 Trace Connections

There are three pairs of tracks, which should be connected to the respective CTU circuit connections with the minimum practical trace lengths.

Please refer to the CAM204 datasheet for recommendations on track design for connecting sensors to CTU circuitry.

7 Environmental

Assembled sensor part number 013-0006 conforms to the following environmental specifications:

Item	Value	Comments
Minimum operating temperature	-40°C	Limited by specification of connector
Maximum operating temperature	105°C	
Maximum operating humidity	95%	Non-condensing

Sensors built to Sensor Blueprints can operate in more extreme conditions by choice of materials and encapsulation.

8 Document History

Revision	Date	Comments
0001	2 February 2011	First draft

9 Contact Information

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