21mm Through-Hole Rotary Sensor

Description

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

The sensor is connected to a CambridgeIC CTU chip such as the CAM204, which performs processing and delivers precise angle data to a host system over an SPI interface.

Features

Sensor

- Full absolute sensing over 360°
- 5.8mm hole, e.g. for through shaft
- 20.4mm diameter copper coil pattern
- Target can be sensed from front or rear of PCB
- 6-layer PCB process
- Connect to Type 4 circuitry

Target

- Simple design using SMD PCB assembly
- Balanced for immunity to misalignment
- Buy from CambridgeIC or build from components

Product identification	
Part no.	**Description**
013-0040	21mm Rotary Sensor Assembly
013-0041	21mm Rotary Sensor with Screen
013-1019	21mm Rotary Target, 195.4kHz
013-6011	6-way PicoBlade sensor cable
010-0107	Sensor Blueprint
012-5048	NEMA8 Motor 21mm Sensor Mount

Applications

- NEMA8 stepper motor angle feedback
- Actuator position feedback
- Motion control
- Valve position sensing
- Absolute Optical Encoder replacement

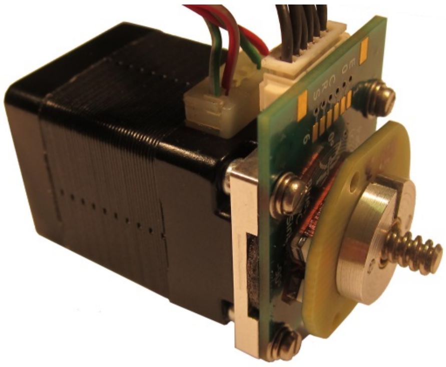

Figure 1 NEMA8 stepper motor integration

Performance

Table 1 Performance

	Condition	
	Best	**Realistic installation tolerances**
Gap Sensor to Target Coils	0.5mm	0 to 1mm
Radial Misalignment	0mm	0.4mm
Angular Misalignment	0°	±0.5°
	Result	
Max Linearity Error	±0.9°	±1.5°
Noise Free Resolution	11.2 bits	11 bits

Figure 2 sensor 013-0040

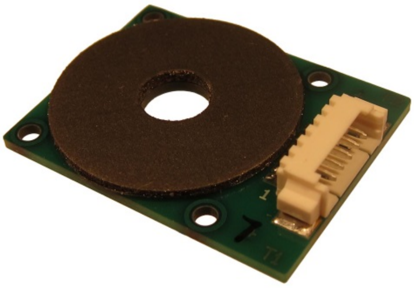

Figure 3 screened sensor 013-0041

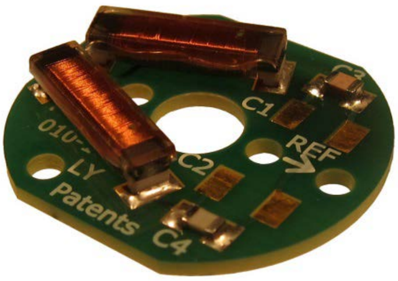

Figure 4 Target 013-1025

1 Assembled Sensors

21mm Through-Hole Rotary Sensors are available as assemblies from CambridgeIC. There are two variants. Part number 013-0040 is the 21mm Rotary Sensor Assembly without screen. Part number 013-0041 is similar but also includes a ferrite loaded rubber screen.

Figure 5 is a dimensioned drawing of the assembled sensor PCB part number 013-0040.

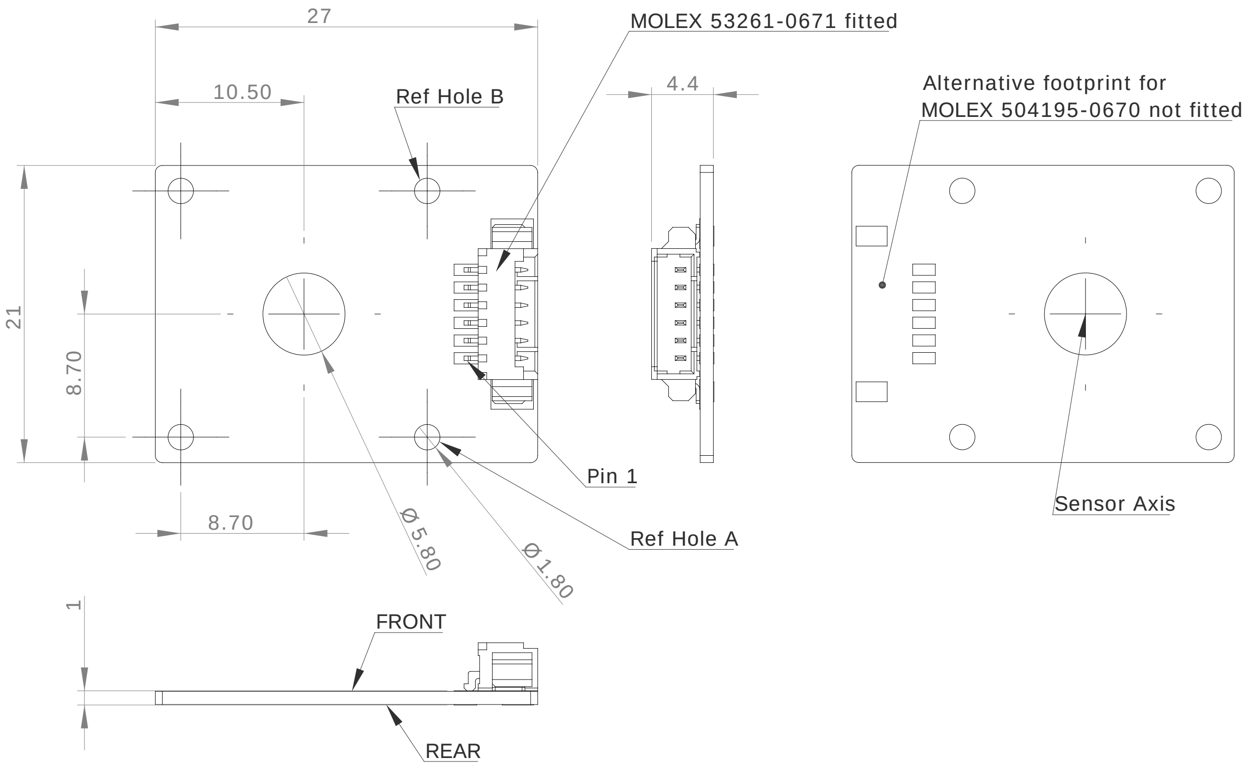

Figure 5 21mm Rotary Sensor Assembly 013-0040

The nominal location of the Sensor Axis is defined as 8.7mm to the left of mid way between Ref Hole A and Ref Hole B. The Reference Direction is perpendicular to the line joining the centres of these two holes, to the right as drawn in the top left view. The target may be positioned either side of the sensor PCB, either its FRONT or REAR.

The actual location of the Sensor Axis may be up to 0.1mm from the Nominal Sensor Axis due to hole location tolerances relative to the copper sensing pattern inherent in the PCB production process. When performance is quoted at a Radial Misalignment of 0.4mm, for example in Table 1, this 0.4mm is *in addition to* the 0.1mm misalignment between actual and Nominal Sensor Axis. In this case an allowance of 0.5mm has been made for the radial misalignment between the centroid of the copper pattern and the Target Axis.

The assembled sensor includes a connector, MOLEX 53261-0671, mounted on the FRONT and located as shown in Figure 5. Table 2 shows signal names and their pin allocations.

Table 2 Sensor Assembly electrical connections

Pin no	**Signal name**
1	SIN
2	SENSOR_REF
3	COS
4	N/C
5	EX_REF
6	EX

Figure 6 is a drawing of the 21mm Rotary Sensor with Screen, part number 013-0041. In this case the FRONT side of the sensor PCB is screened, so the target may only be positioned next to the REAR.

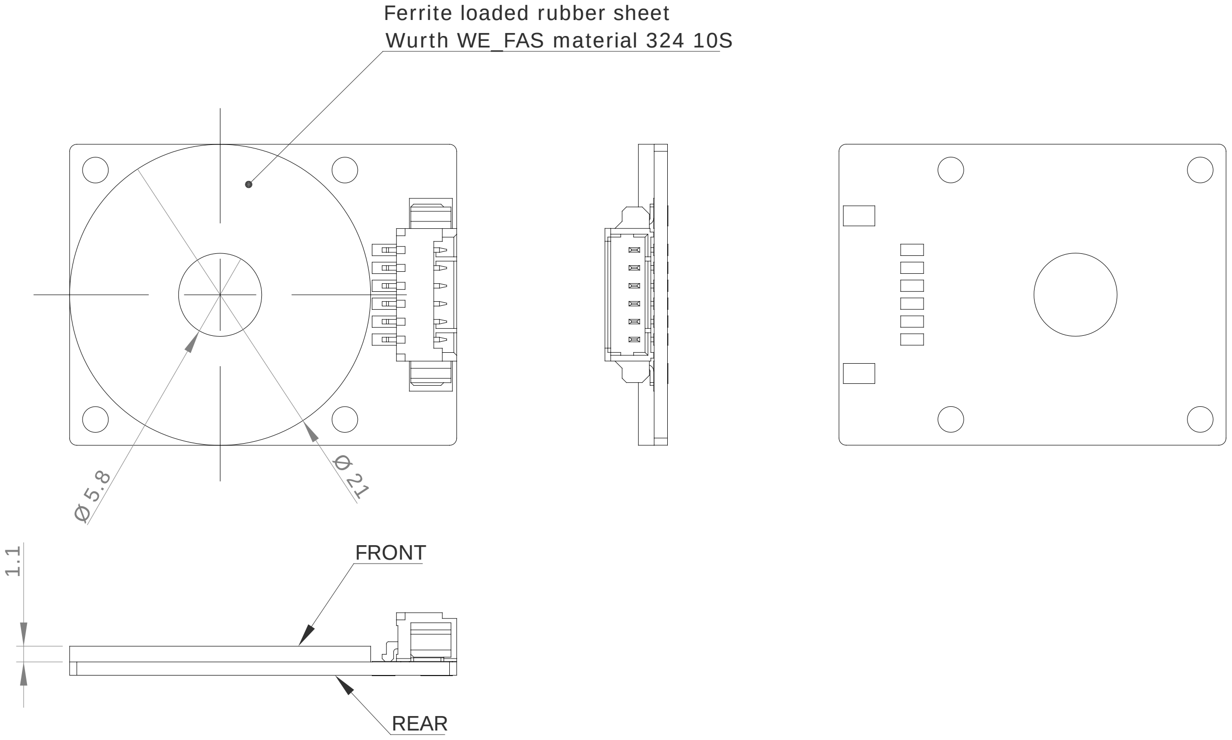

Figure 6 21mm Rotary Sensor with Screen 013-0041

2 Target Design

2.1 Electrical

The 21mm Through-Hole Rotary Sensor is designed to work with an inductively coupled resonant target comprising 2 off RFID transponder coils LX and LY connected to capacitance CRES as illustrated in Figure 7.

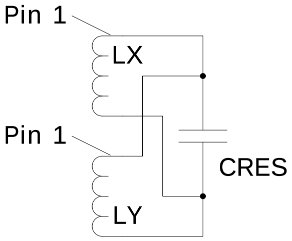

Figure 7 Schematic for target

Resonant frequency, Fres, should usually match the Nominal Operating Frequency of the CTU chip processing the sensor. Fres given by Equation 1.

$$Fres = \frac{1}{2\pi\sqrt{CRES \times LRES}}$$

Equation 1

CRES is the total resonating capacitance (the sum of the parallel connected resonating capacitors if more than one capacitor is used).

LRES is the combined inductance of the parallel connected RFID transponder coils. These each have nominal inductance LX=LY in free space. When connected together according to Figure 7 and located as in Figure 8 the combined inductance is given by…

$$Lres = \frac{LX}{2} \times 0.909$$

Equation 2

LX is divided by 2 because the inductors LX and LY are connected in parallel. The factor 0.909 accounts for the mutual coupling between inductors LX and LY, which tends to reduce the value of their combined inductance.

When the target is integrated with metal parts, LRES should be the inductance in the presence of metal.

CRES may comprise two or more capacitors connected in parallel. CRES should be formed with a stable, high Q-factor dielectric capacitor(s) such as NPO or COG, and have an operating voltage of at least 100V. The combined capacitance and inductance tolerance, including temperature effects, must yield values of Fres within Tuning Range of the CTU chip. Please refer to the CambridgeIC white paper “Resonant Frequency Centering” for more details.

2.2 RFID Transponder Coil Locations

To function correctly with the 21mm Through-Hole Rotary Sensor and deliver the specified performance, locations and angles of the RFID transponder coils must be as illustrated in Figure 8, and they must be mounted flush with the target PCB.

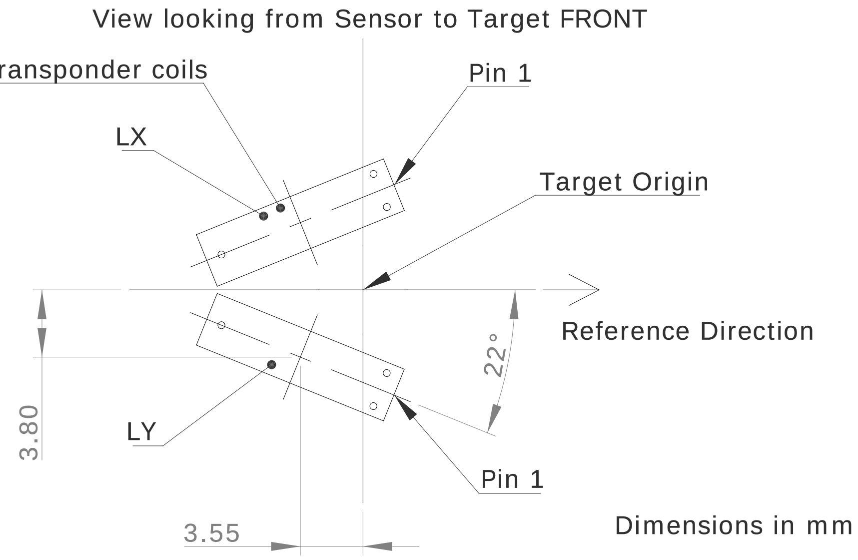

Figure 8 Transponder Coil Locations

The electrical winding direction of the two RFID transponder coils is shown in Figure 7, with pin 1 of each part's PCB pad connected together. The mechanical orientation of the RFID transponder coils is illustrated in Figure 8, with the pin 1 pad ends once again marked. It is essential that the pads are connected this way round for the target to work.

The RFID transponder coils themselves may be placed either way round, because a 180° rotation reverses both the direction of current and the direction of the field relative to the RFID transponder coil. The field therefore ends up in the same direction relative to the Target PCB. However for best symmetry it is recommended that the two transponder coils be fed from their reel with the same end positioned on pin 1.

2.3 Assembled Target

Assembled targets are also available from CambridgeIC, as illustrated in Figure 4. The mechanical design of assembled targets is shown in Figure 9. The nominal position of the Target Origin is defined as mid-way between the centre of Ref Hole A and Ref Hole B. The Reference Direction is along a line joining their centres. There are a total of 5 holes that may be used for mounting and/or alignment.

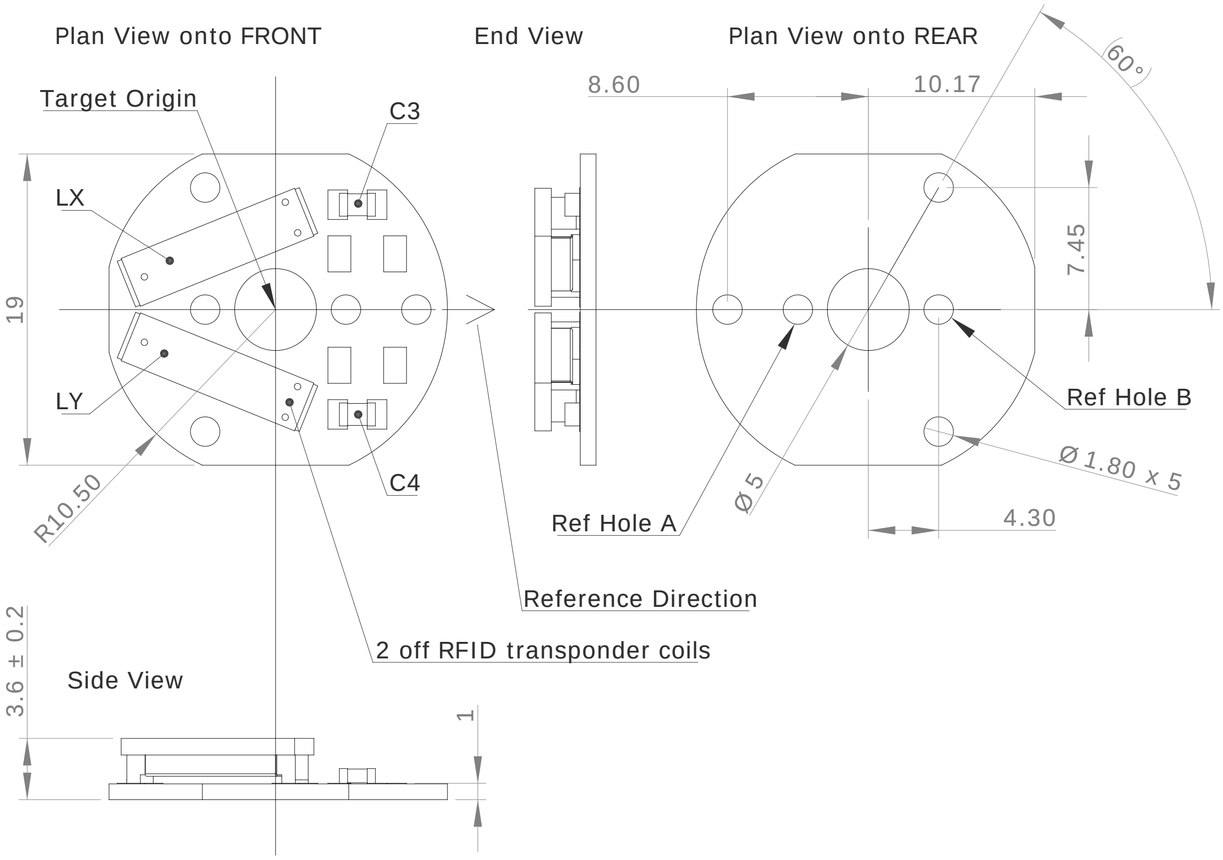

Figure 9 Assembled Target 013-1025 mechanical design

Assembled targets may be fitted with different values of capacitors, for different free space resonant frequency and hence compatibility with different metal environments. Their corresponding part numbers are shown in Table 3.

Table 3 Transponder Coil Based Assembled Targets

Part Number	**013-1025**
Fres, free space	195.4kHz (1)
Fres tolerance, 20°C	±2%
Fres tolerance, -40°C to +85°C	±4%
LX, LY RFID transponder coils	Coilcraft 4308RV-115XGLB
C1 capacitor	Not fitted
C2 capacitor	Not fitted
C3 capacitor	1.2nF COG/NPO 100V ±1%
C4 capacitor	150pF COG/NPO 100V ±1%

Note (1) For operation with the CAM204 across -40°C to +85°C in proximity with screened sensor, brass shaft and aluminium target mount illustrated in Figure 1 and section 6, reducing resonator frequency by 4.5% at 0.5mm gap.

Please contact CambridgeIC to enquire about assembled targets with different nominal values of Fres.

3 Definitions

3.1 Coordinate System

The system measures the angle of a target relative to a sensor. The Target Reference Direction is defined in Figure 8. For assembled sensors, the Sensor Reference Direction is defined relative to REF Hole A and Ref Hole B shown in Figure 5. The Actual Angle is the angle between the two. Strictly, since the target may be slightly tilted relative to the sensor, Actual Angle is the angle between the projection of the Target Reference Direction onto the sensor's XY plane and the Sensor Reference Angle. This is denoted Actual Angle below.

The sensor's X Axis coincides with the Sensor Reference Direction, and its Y-Axis is orthogonal and in the plane of the sensor, as shown in Figure 10. The Z-Axis is orthogonal to X and Y Axes.

The target's X-Axis is denoted Xr and coincides with the Target Reference Direction. The target's Y-Axis, Yr, is orthogonal to Xr and also in the plane of the Target PCB. Tilt of the target relative to the sensor is defined about Xr and Yr. References to Angular Misalignment below are either AXr or AYr, whichever has the worst effect on linearity.

Radial Misalignment is the distance between the Target Origin and Nominal Sensor Axis.

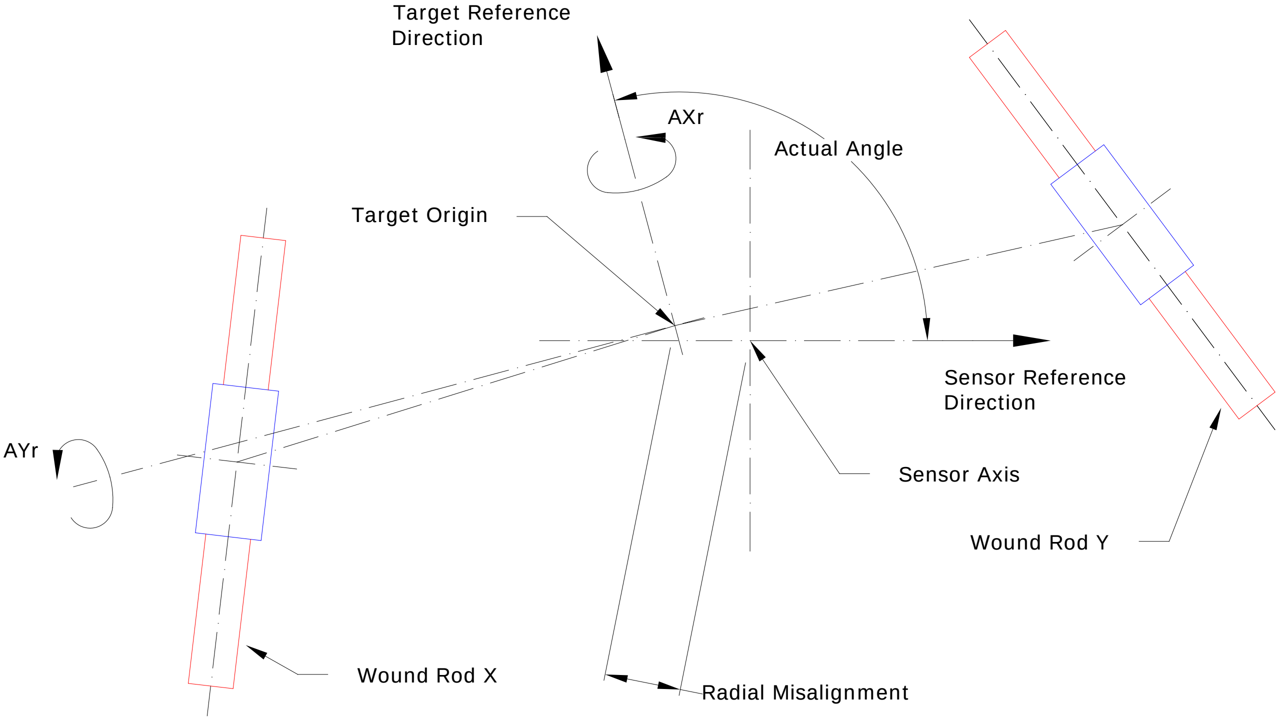

Figure 10 Coordinate System

3.2 Gap Definition

Figure 11 shows how Gap is defined. It is the distance between sensor PCB and Target PCB FRONT surfaces minus 2.6mm. That way, Gap equals the physical gap when the transponder coils are their nominal height of 2.6mm.

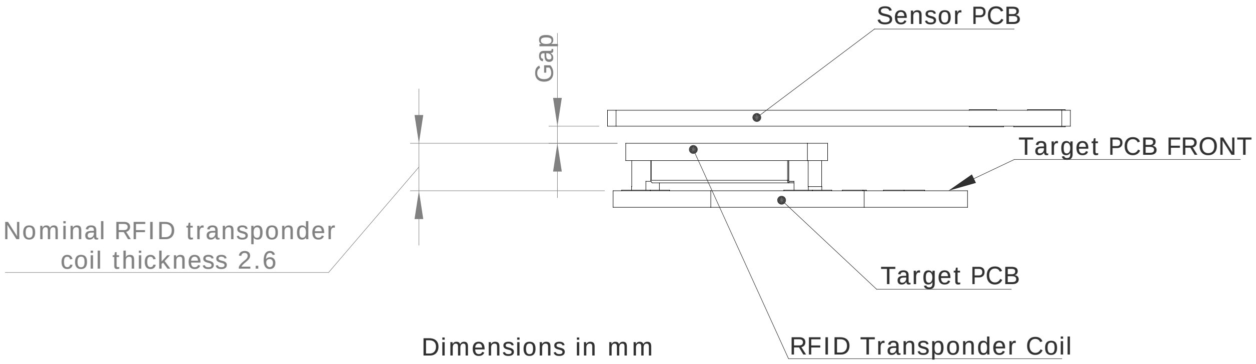

Figure 11 Definition of Gap

3.3 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°. The reported position may be converted to degrees using:

$$Reported\ Angle\ in\ Degrees = \frac{CtuReportedPositionI16}{65536} \times 360°$$

Equation 3

This figure is nominally equal to the Actual Angle defined in section 3.1. The figures differ due to random noise, Linearity Error and Offset Error:

$$Reported\ Angle - ActualAngle = RandomNoise + LinearityError + OffsetError$$

Equation 4

3.4 Random Noise and Resolution

Random noise is inherent in any analog measurement. The random noise present in the CTU's reported measurements can be considered Gaussian (*well behaved noise*). There are two general measures of Random Noise, Peak to Peak Noise and Standard Deviation. Defining Peak to Peak Noise such that it encompasses 99.9% of samples (100% is physically impossible due to the statistical nature of noise) yields the following relationship:

$$Peak\ to\ Peak\ Noise = 6.6\ \times Standard\ Deviation$$

Equation 5

Another common measure of noise used in encoders is Noise Free Resolution, which is related to Peak to Peak Noise as follows:

$$Noise\ Free\ Resolution = \log_2 \frac{360°}{Peak\ to\ Peak\ Noise\ in\ °}$$

Equation 6

Noise Free Resolution can be improved by averaging raw samples from a CTU, or applying some other digital filter to the samples. Averaging 2^N samples increases Noise Free Resolution by N/2 bits. So averaging 4 samples (N=2) improves Noise Free Resolution by 1 bit, and averaging 16 (N=4) samples improves Noise Free Resolution by 2 bits. Measurements of Linearity Error, Offset Error and DNL are all based on averaged measurements to separate their results.

3.5 Linearity Error, Offset Error and DNL

Linearity Error is the deviation of the transfer function from a straight line. In this case the slope of the straight line is fixed at 360° per 360° because of the continuous rotary nature of the sensor. So Linearity Error simply measures deviations relative to an Offset Error.

There are two main contributions to Offset Error: one from the sensor and one from the target.

The target's contribution to Offset Error is mainly due to the location and symmetry of its transponder coils relative to the Target Reference Direction.

The sensor's contribution to Offset Error is mainly due to the PCB manufacturing process, in particular angular misregistration of layers 2, 3, 4 and 5 relative to the holes defining the Sensor Reference Angle.

Differential Non-Linearity (DNL) is a measure of how smoothly reported position changes relative to actual position…

Equation 7

$$DNL = 100\% \times \left(\frac{Change\ in\ Reported\ Angle}{Change\ in\ Actual\ Angle} - 1\right)$$

DNL is a useful measure of performance when the system's measurement of angular velocity is important, or any time small angle changes need measuring accurately.

3.6 Sensitivity to Radial Misalignment

Sensitivity to Radial Misalignment is measured by comparing Reported Position values with and without Radial Misalignment, and expressing the result in "angle per distance" units using…

$$Measured\ Sensitivity\ to\ Radial\ Misalignment = \frac{Reported\ Position(with\ Radial\ Misalignment) - Reported\ Position\ (no\ Radial\ Misalignment)}{Radial\ Misalignment}$$

Equation 8

This depends on Actual Angle, Angular Misalignment, Gap and so on, so typically a worst case value is presented.

When applied to an optical or magnetic encoder without the benefit of a balanced design, the worst case sensitivity is given by...

$$Imbalanced\ Sensitivity\ to\ Radial\ Misalignment = \frac{180°}{\pi} \times \frac{1}{Code\ Radius}$$

Equation 9

…where Code radius is the working radius of the code disc's optical or magnetic patterning. When comparing performance between the 21mm Through-Hole Rotary Sensor and an optical or magnetic encoder of similar size, the Code Radius is taken to be the average of the outer and inner radii of the sensor…

$$Imbalanced\ Reference\ Sensitivity\ to\ Radial\ Misalignment = \frac{180°}{\pi} \times \frac{2}{(Outer\ Radius + Inner\ Radius\ )}$$

Equation 10

The Radial Misalignment Rejection Ratio can then be defined, comparing measured performance to expected performance for an alternative encoder system that does not benefit from balance…

$$Radial\ Misalignment\ Rejection\ Ratio = \frac{Imbalanced\ Reference\ Sensitivity\ to\ Radial\ Misalignment}{Measured\ Sensitivity\ to\ Radial\ Misalignment}$$

Equation 11

4 Performance

Figures below are representative of assembled sensors available from CambridgeIC (part number 013-0040 without screen as described in section 1) and of sensors built to the same specification. Measurements are taken with a typical target (built according to section 2) and Type 4 CAM204 CTU Circuitry (see CAM204 datasheet, grade A components), at room temperature and in free space unless otherwise stated. Sensors are mounted flush against a flat surface for test purposes.

Measurements are presented as a function of Gap, which is defined in section 3.2.

4.1 Linearity Error

Linearity Error is defined in section 3.5. It is minimised when there is no Radial or Angular Misalignment. Figure 12 shows how Linearity Error changes with Gap and when misalignments are introduced. The quoted misalignment is *in addition* to ±0.1mm of misalignment between copper and REF Holes.

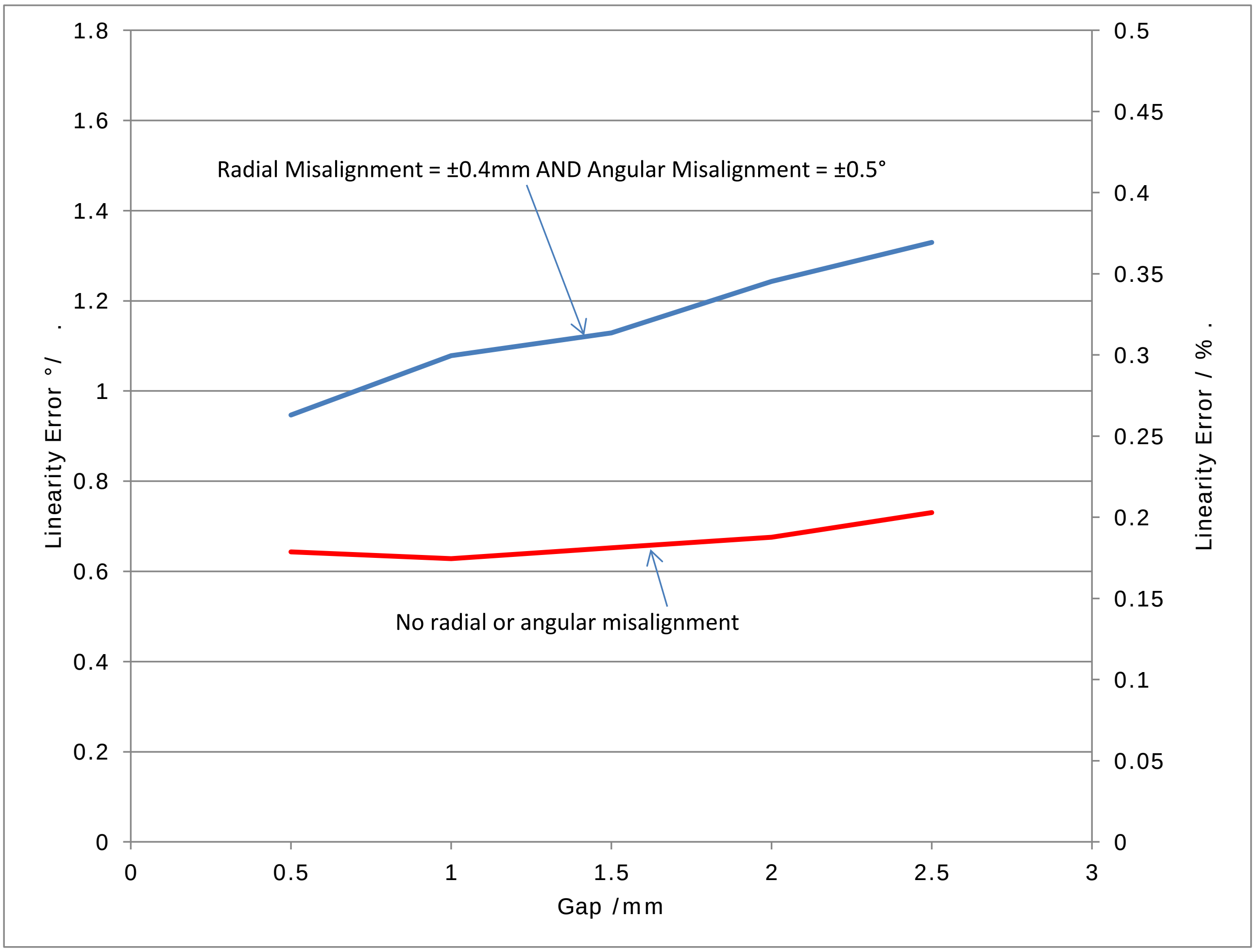

Figure 12 Linearity Error as a function of Gap and misalignment

4.2 Amplitude

In addition to reporting position, the CTU chip also reports Amplitude. Amplitude is a useful measure of system health, and reduces with gap as shown in Figure 13.

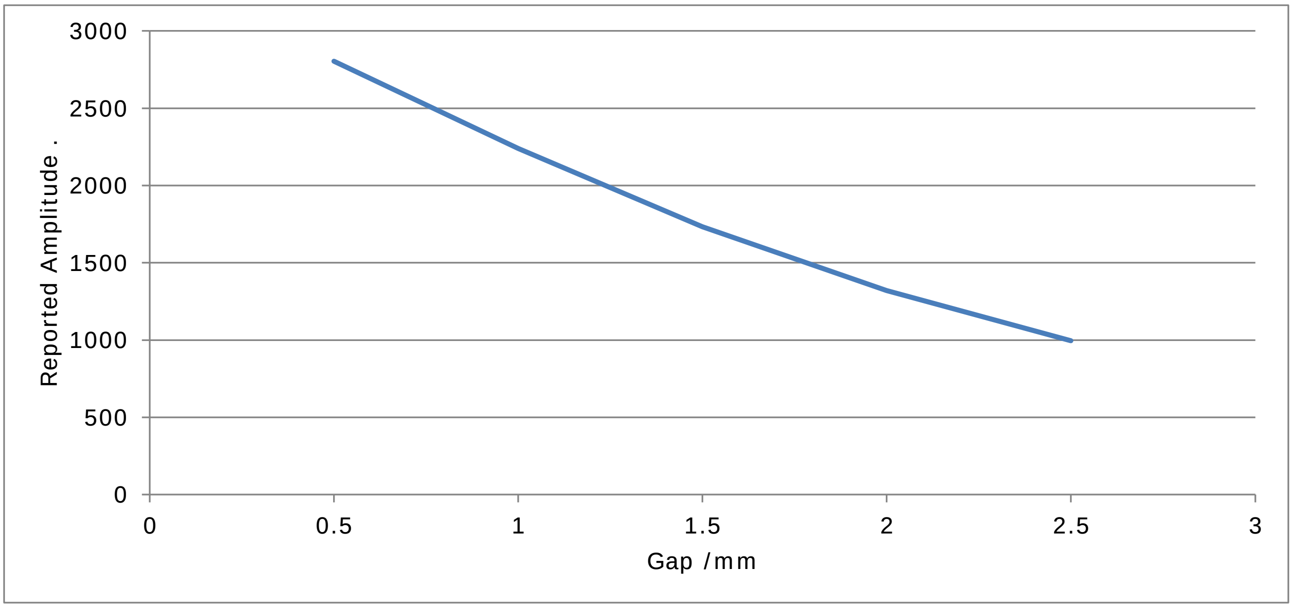

Figure 13 Minimum Reported Amplitude as a function of Gap, free space

4.3 Noise Free Resolution

Noise Free Resolution is defined in section 3.4. It is a function of the signal level detected by the CTU chip. It therefore reduces with gap in a similar way to Reported Amplitude as illustrated in Figure 14.

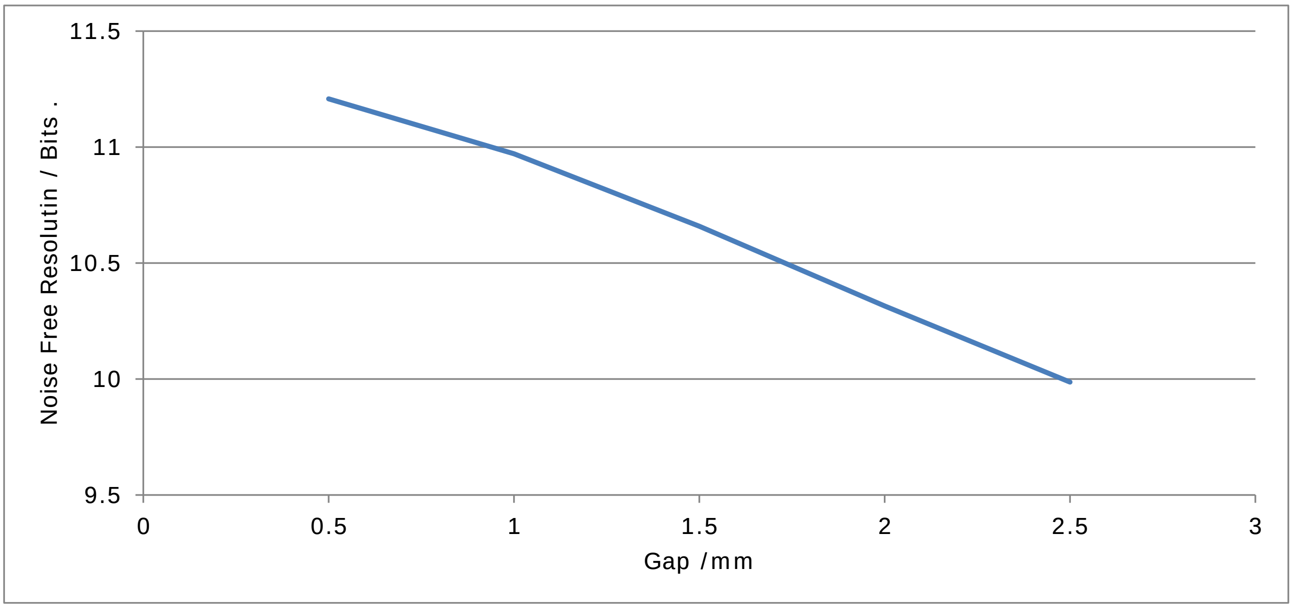

Figure 14 Noise Free Resolution as a function of Gap, free space

Quoted Noise Free Resolution is based on single measurements from a CTU chip. The host may average (or otherwise digitally filter) measurements to yield a higher resolution than shown above, at the expense of greater latency.

4.4 Differential Non-Linearity (DNL)

DNL is a measure of how well the sensor system measures small changes in angle, and is defined in section 3.5. Figure 15 shows typical DNL as a function of Gap and when misalignments are introduced. Measurements are based on 5° changes in actual position.

Figure 15 DNL, free space

4.5 Immunity to Misalignment

Section 3.6 defines how immunity to radial misalignment between target and sensor axes can be quantified, and results for the 35mm Type 6.3 Rotary Sensor are presented in Table 4.

Table 4 Immunity to Misalignment

Parameter	Value
Measured Sensitivity to Radial Misalignment, worst case across Actual Angle, misalignment direction, Gap up to 1.5mm and Angular Misalignment up to 0.5°	1.6°/mm
Radial Misalignment Rejection Ratio	9

5 Metal Integration

As with all resonant inductive sensors, the 21mm Through-Hole Rotary Sensor and its target can be integrated near metal providing the metal's influence is not excessive.

Nearby metal can cause additional linearity error, although the effect is usually small, especially when the metal is placed symmetrically around the sensor.

The metal must not dampen the resonator's Q-factor excessively, and distort fields such that coupling factor is reduced excessively, otherwise Amplitude will be significantly reduced. Low Amplitude causes low Noise Free Resolution. When Amplitude is reduced to 50% of its original value, Noise Free Resolution will reduce by approximately 1 bit. In extreme cases Amplitude may fall below the CTU chip's minimum Amplitude for reporting VALID.

The target's resonant frequency Fres when integrated with the customer's product must also remain within the tuning limits of the CTU it will be used with, typically 187.5kHz ±7% for the CAM204. Fres is a function of the metal environment inside the product. When there is very little metal nearby, Fres will equal the target's free space resonant frequency. When there is metal nearby, Fres will shift. For non-ferrous, highly conductive materials such as aluminium and brass, Fres increases as metal approaches. If the shift is substantial, it may be necessary to alter the nominal free space resonant frequency so that when integrated with the product Fres remains within the CTU's tuning range. The free space resonant frequency may be lowered by increasing the target's resonating capacitance CRES of Figure 7.

Small metal objects such as fixing screws have less effect than larger objects and metal surfaces. The sensors 013-0040 and 013-0041 can be mounted using steel M1.6 screws with barely noticeable effect on Amplitude, for example.

The effect of a product's fixed metal environment is highly reproducible and can be established by experiment, for example using CambridgeIC's CTU Demo application and appropriate sensor, target and CTU Development Board.

Large areas of aluminium, brass or copper near the sensor and target can be tolerated. However these materials must be at least 0.2mm thick, otherwise their conductivity is insufficient to repel magnetic fields efficiently and Amplitude is reduced more than the values illustrated.

The sensor and its target tolerate aluminium and brass nearby much better than steel, iron, titanium or stainless steel. It is recommended to cover any large areas of iron, titanium or stainless steel near the sensor and target with an aluminium screen at least 0.2mm thick. For example if there is a steel shaft passing through the middle of the sensor and target, it should preferably be shrouded in an aluminium tube with wall thickness 0.2mm or more.

In applications requiring close proximity between the rear of the sensor and metal, screening material may be used between that metal and the sensor, for example as provided in screened sensor 013-0041. An example is illustrated in section 6. When screening is used it will tend to decrease the resonant frequency of the target, so care must again be taken to ensure the target's resonant frequency remains sufficiently close to the operating frequency of the CTU chip.

Please refer to the CambridgeIC white paper "Resonant Frequency Centering" for more details, including practical approaches for testing and analysis.

6 NEMA 8 Motor Integration

This section illustrates a way to integrate the 21mm Through-Hole Rotary Sensor with a NEMA8 stepper motor. In this case, the NEMA8 motor is configured as a non-captive linear actuator. The rotating armature includes a nut which drives a central screw back and forth.

6.1 Mechanical Assembly

The 21mm Through-Hole Rotary Sensor is mounted to the rear cover of the motor and measures the angle of a target attached to the rotating armature. The assembly is illustrated in Figure 16, with a prototype shown in Figure 1.

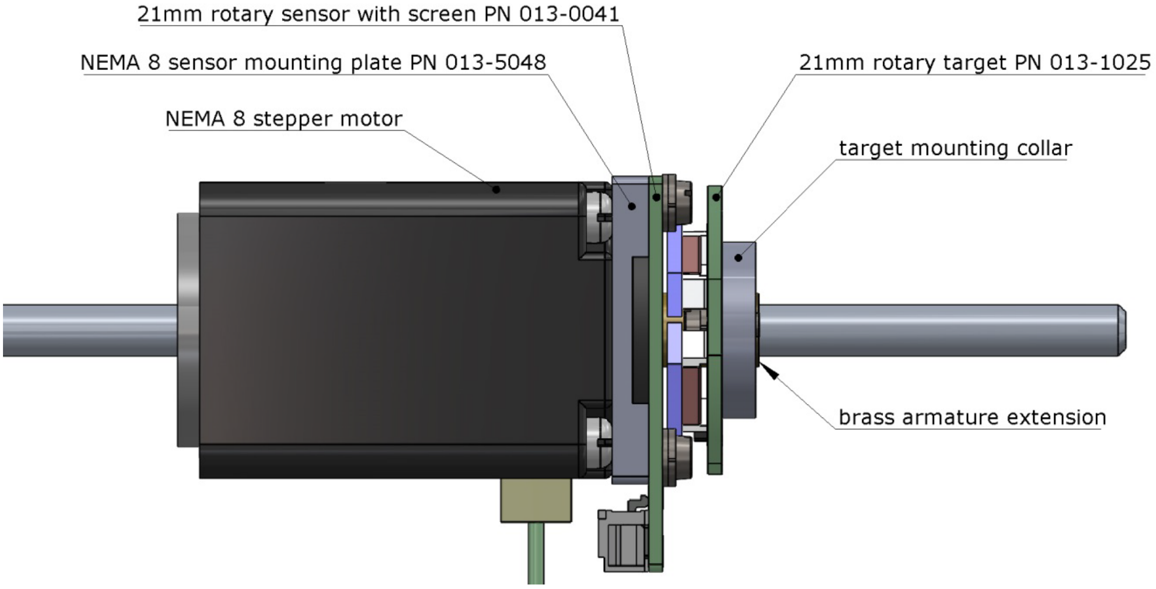

Figure 16 NEMA8 motor mechanical integration

The sensor can not screw directly to the motor’s rear cover because its screws are too far from the central axis. Instead, an aluminium NEMA8 mounting plate is first screwed to the rear of the motor. Then the sensor is screwed to the NEMA8 mounting plate. The screened version is used, to allow it to operate in close proximity to the aluminium of the mounting plate, sensor part number 013-0041.

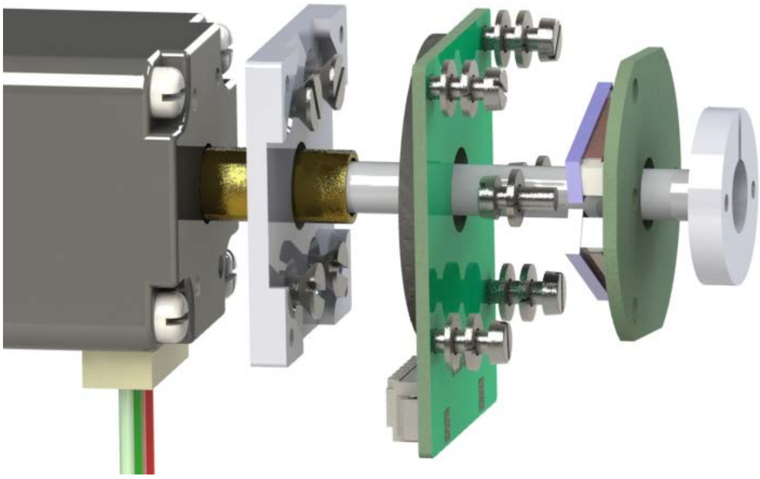

Figure 17 NEMA8 motor mechanical integration, exploded view

Figure 17 shows an exploded view of the assembly, which illustrates the individual components more clearly.

The NEMA8 motor is modified from standard in two ways. First, the rear cover of the motor includes 4 tapped mounting holes, to allow the NEMA8 mounting plate to be screwed to the rear of the motor. Second, the armature inside the motor is extended to the rear to allow the target to be mounted. These modifications are illustrated in Figure 18.

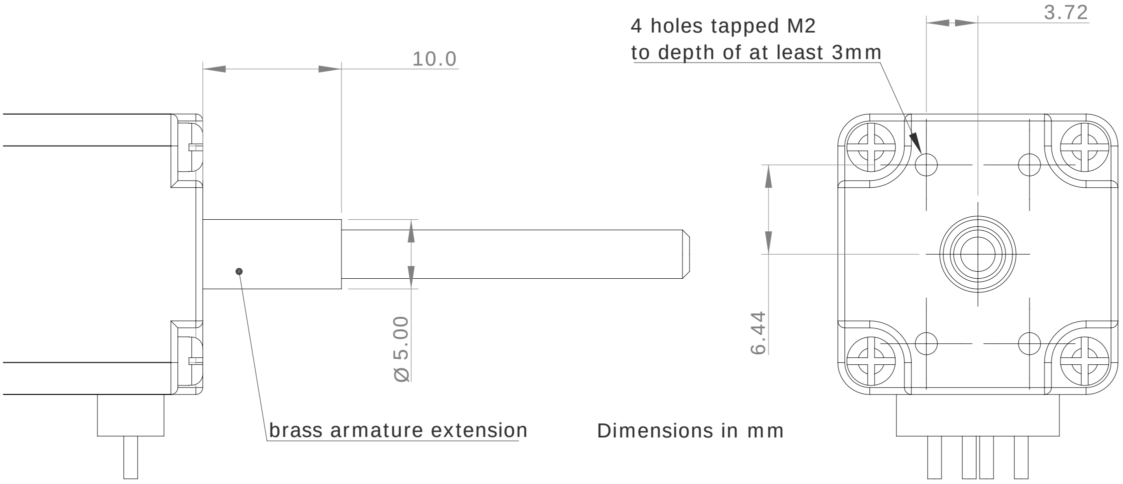

Figure 18 NEMA8 motor modifications for sensor and target mounting

The target is mounted to the armature extension with a 0.5mm nominal Gap to the sensor as defined in Figure 11. To attach the target, it is first screwed to a target mounting collar. The target mounting collar is made from aluminium so that it does not significantly reduce signal Amplitude. Its diameter is limited to 12.0mm, again to limit its Amplitude effect and also to prevent excessive resonant frequency change of the target. Once the target and target mounting collar are screwed together, they are pressed onto the armature extension. The design of the target mounting collar is shown as a split collar for simplicity, although it would be preferable to avoid this type of split because it stresses the target PCB.

6.2 Change in Resonant Frequency

The resonant frequency of the target is significantly reduced by the presence of the sensor screen. The amount of reduction increases as the Gap reduces. At a nominal 0.5mm Gap the reduction is 4.5% relative to the target in free space. The free space resonant frequency of target 013-1025 is deliberately set 4.5% above the CAM204 nominal operating frequency to compensate, with the aim of centralizing its frequency at nominal Gap. See section 2.3

6.3 Performance

The performance of the sensor when integrated with a NEMA8 motor as illustrated above is substantially the same as its free space performance documented in section 4 and Table 1.

The addition of the ferrite loaded screen to the sensor board tends to increase signal Amplitude, while their integration with the aluminium NEMA8 mounting plate tends to reduce Amplitude. The net effect is that Amplitude, and hence Noise Free Resolution, is hardly changed.

Stepper motors typically have step angles of 1.8°. There are therefore 200 full steps per revolution. These full steps refer to the angle detents when the motor is unpowered. Each step is also the angle change when current switches from the A to B motor windings, or from -B to -A, -A to -B or -B to A.

If the sensor is used to check the motor has not lost step, its job is to ensure that the armature angle is reliably following the applied current. There are two main aspects to this job. One is to check that the armature is actually moving at all when the driver current steps. If the armature is moving, the question is then whether it has “lost step”. Note that the smallest “lost step” is NOT 1.8°, because losing step while still moving and not stalled means that the armature is still roughly following the applied phase currents. Losing step therefore means a minimum armature angle error of 7.2°, equivalent to missing a full cycle of motor currents A to B, -B to -A, -A to -B and –B back to A.

The 21mm rotary sensor has more than enough accuracy for the job of detecting a lost step of 7.2° like this. Given any start angle and end angle, the maximum error in the angle change between the two is 3°, because each measurement is subject to a maximum linearity error of ±1.5° (Table 1) plus a small amount of positon noise.

If angle measurements are taken frequently so that each difference in actual angle is small, the sensor’s DNL is a better measure of performance. DNL is less than 10% (section 4.4). So, for example, if the actual angle changes by 7.2°, the error in the change in reported position will be less than 10% of 7.2° which is 0.72°.

7 Sensor Blueprint 010-0107

7.1 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.

7.2 Fabrication Technology

The Sensor Blueprint is fabricated on a 6-layer PCB. Recommended copper thickness is shown in Table 5.

Table 5

Copper thickness	oz	µm
Minimum	0.8	28
Recommended	1	35

7.3 PCB Design Parameters

Table 6

PCB Design Rules	Minimum values used	
	mm	inches
Track width	0.12	0.0047
Gap between tracks	0.12	0.0047
Via land outer diameter	0.64	0.025
Drill hole diameter	0.3	0.012

7.4 PCB Integration

Figure 19 illustrates the extent of the copper pattern required to build the sensor on a PCB. The shaded area is the sensor itself, with coil connections shown to the upper 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 3mm is recommended all round the sensor's conductors.

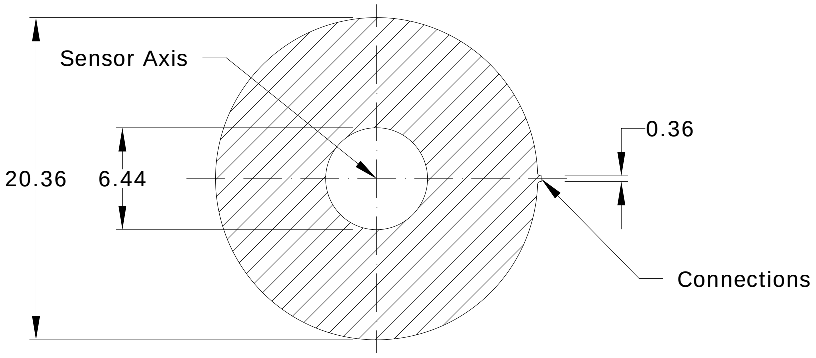

Figure 19 Copper extent

7.5 Data Format

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

7.6 Trace Connections

There are 5 pairs of tracks (EX, COSA, SINA, COSB, SINB and their respective VREF connections), 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.

8 Environmental

Assembled sensor part number 013-0024 conforms to the following environmental specifications:

Item	**Value**	**Comments**
Minimum operating temperature	-40°C	Limited by the wire used for connections
Maximum operating temperature	85°C	
Maximum operating humidity	85%	Non-condensing

The maximum operating temperature may be increased if a customer manufactures their own sensor PCB to CambridgeIC's design, and uses an alternative, higher temperature, connecting method.

9 RoHS Compliance

CambridgeIC certifies, to the best of its knowledge and understanding that part numbers 013-0040, 013-0041 and 013-1025 are in compliance with EU RoHS directive 2011/65/EU, China RoHS and Korea RoHS.

10 Document History

Revision	**Date**	**Comments**
0001	22 September 2016	First draft

11 Contact Information

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12 Legal

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The design of the sensor, comprising each of the patterned copper layers, drill locations, silk screens, assembly layers and board outline are protected by copyright.

The parts described in this datasheet are subject to the following patents: US8570028, GB2461448, GB2488389 and GB2500522. Other patents are pending.