BROADCOM®

Design Guide

# AEDR-8300/8400/8500/8700

## Achieving Low CPR Options through a Spiral Codewheel Design

## Description

The Broadcom® reflective encoders offering cover a wide range of resolutions and are available in different package sizes.

In this document, a method is described on how to use a higher-resolution incremental reflective encoder to achieve a lower-resolution output codewheel or codestrip.

Due to the tooling investment involved, it is relatively easier and more cost-effective to vary the codewheel/codestrip resolution instead of the resolution of the photodetector ASIC.

The CPR reduction is achieved by using the concept of angular scanning of the bar-window patterns in the codewheel/codestrip by the reflective encoder photo-detector ASIC.

## Applications

- Portable or handheld consumer devices
- Lens control in photography equipment
- Outdoor surveillance cameras
- Direct linear measurement system
- Human interface input devices
- Miniature and piezo motors feedback
- Robotic arms
- Drone
- Automated guided vehicles

## Reflective Encoder Advantages

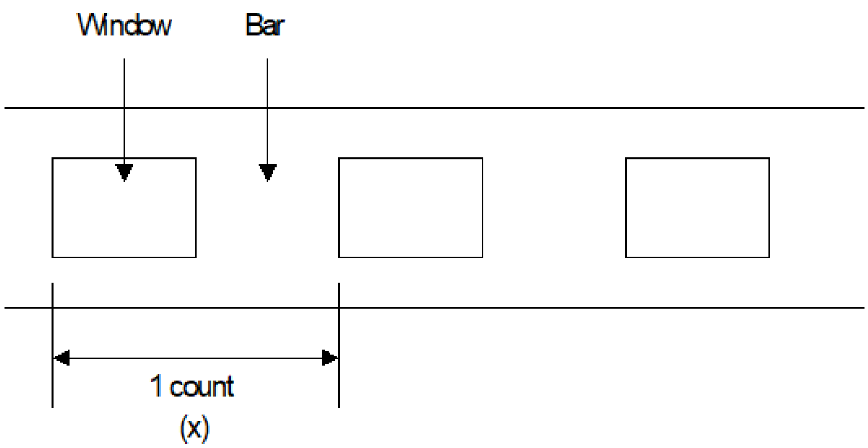
- Direct monitoring of position information with a feedback sensor
- Increase of accuracy due to actual position measurement
- Reduced effects of mechanical slippage and gearing backlash
- Smooth motion with real-time velocity feedback
- Small size encoders enable flexible and easy integration with motors
- High line per inch density, LPI rating to achieve a high cycles per revolution, CPR with a very small optical radius, Rop
- Quasi absolute positioning possible with single or multiple index slots

# Background Information of Encoder Resolution

## Linear Count Density

For linear encoders, the line count density is defined in Figure 1. The count density is expressed as lines per mm (LPmm), or lines per inch (LPin or LPI).

**Figure 1: Linear Count Density of an Incremental Encoder**




$$Count\ Density = Number\ of\ Window\ and\ Bar\ Pairs = \frac{1}{x}$$

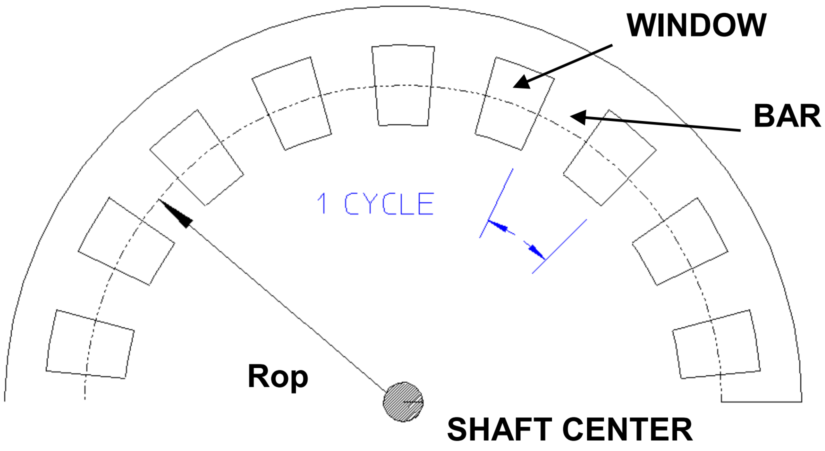
$$LPmm = \frac{1}{x(mm)}$$

$$LPI = \frac{1}{x(in)} = 25.4 \cdot LPmm$$

# Rotary Count Density and Resolution

As for rotary incremental encoders, the resolution is typically referred to as the cycles per revolution (CPR). As illustrated in Figure 2, the rotary encoder CPR can be calculated by knowing the optical radius (Rop) and the LPI of the encoder photodetector.

**Figure 2: Resolution of a Rotary Incremental Encoder**




$$Cycle = Mechanical\ rotation\ corresponding\ to\ 1\ Window\ and\ Bar\ pair$$

$$N = CPR = Number\ of\ Window\ and\ Bar\ pairs\ per\ revolution$$

$$Count\ Density = \frac{Number\ of\ Window\ and\ Bar\ pairs}{Arc\ Length} = \frac{CPR}{2\pi Rop}$$

$$LPmm = \frac{CPR}{2\pi Rop(mm)}\ or\ LPI = \frac{CPR}{2\pi Rop(inch)}$$

# Bar-Window Scanning in an Angular Manner

Figure 3 illustrates the examples of the resolution reduction design for a codestrip. In this example, an arbitrary LPI of codestrip is varied from a ratio of 1.0 to 1.04, 1.15, and 1.41. The resultant angle of rotations are 15°, 30°, and 45°, respectively.

Similarly, for a codewheel, the effects or the angle rotation to the CPR are illustrated in the example in Figure 4 to Figure 6. From a base CPR of 64 with 5-mm optical radius, a 48 CPR and 32 CPR can be generated when used in combination with a 51.74-LPI encoder.

**Figure 3: Angular Scanning at Different Angle Using a Codestrip to Achieve Different Resolutions**

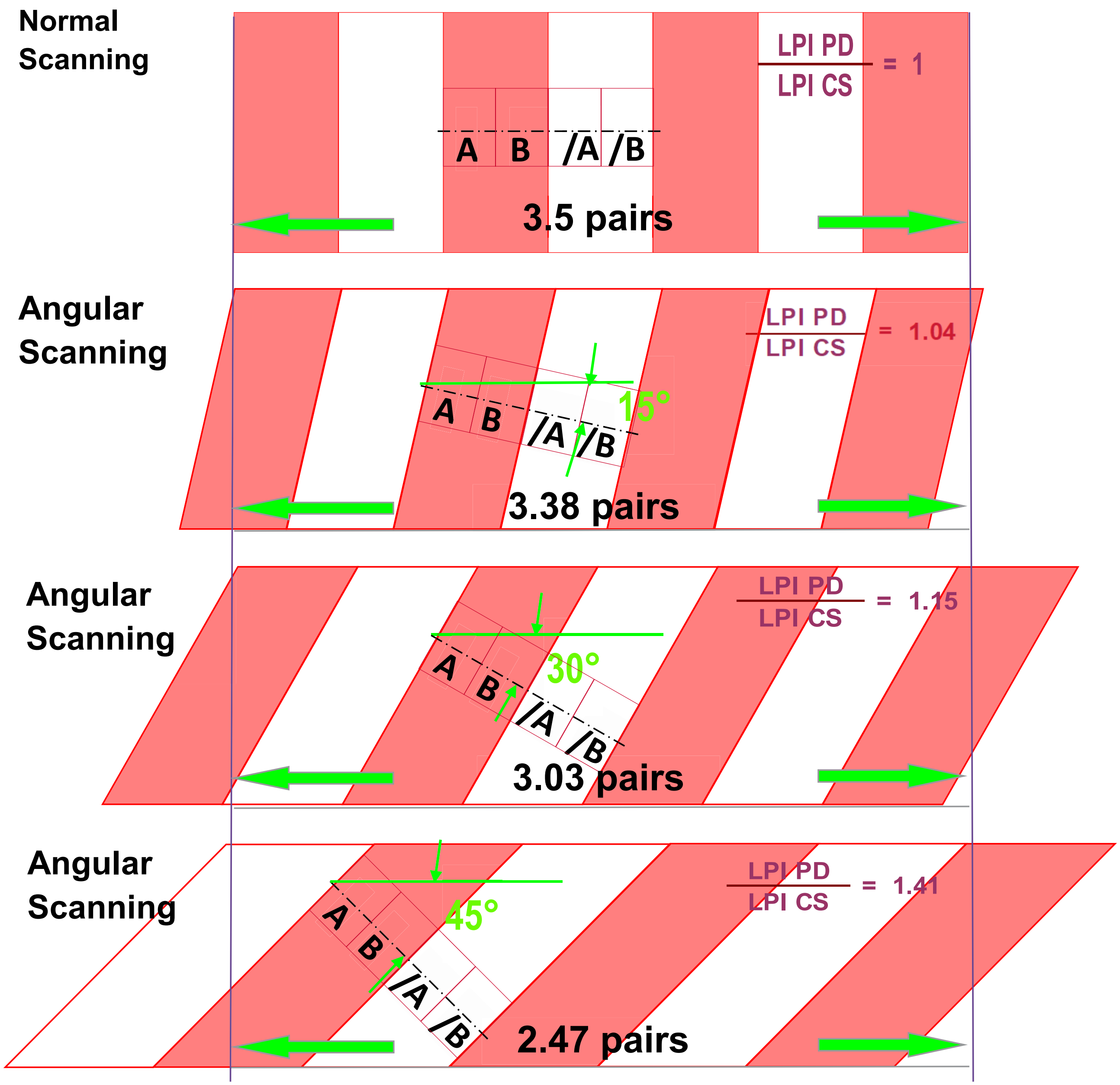
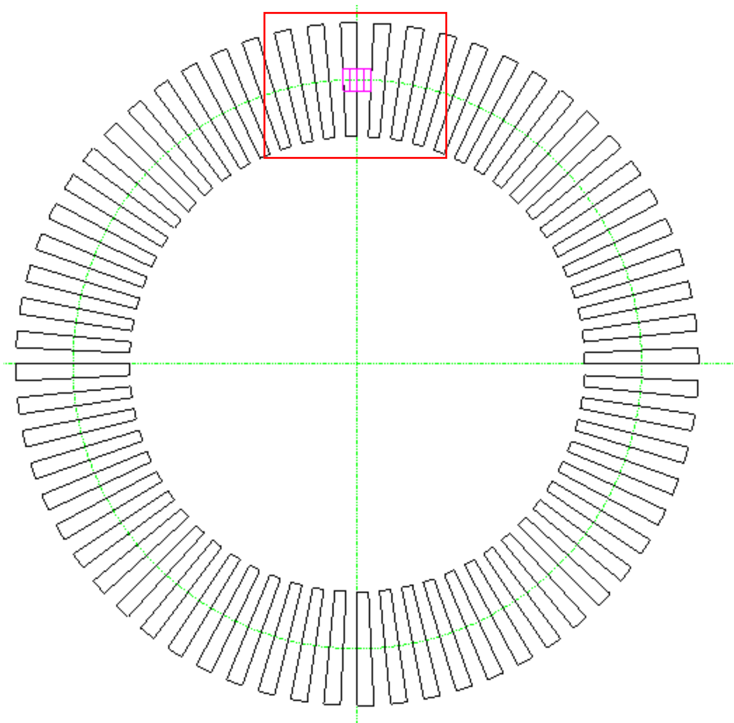
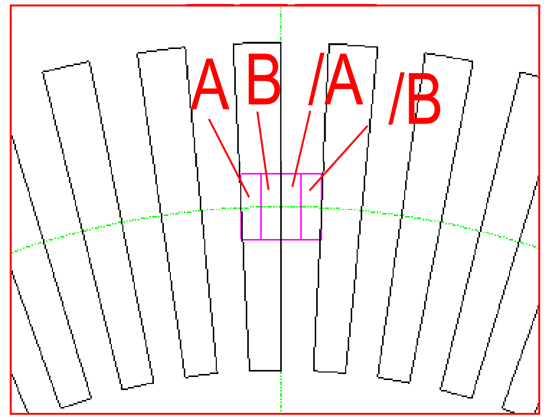


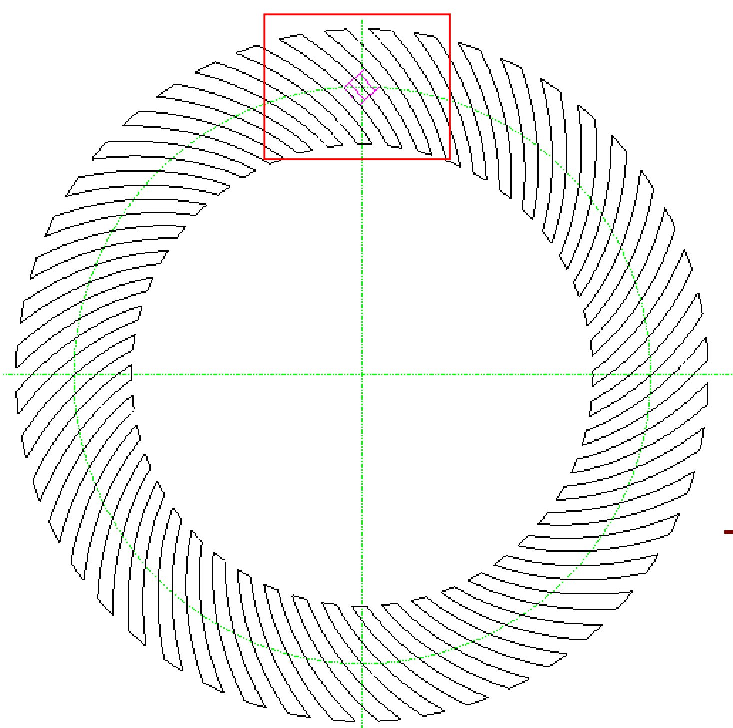
**Figure 4: Rotary: CW at 64 CPR at 5-mm Rop**

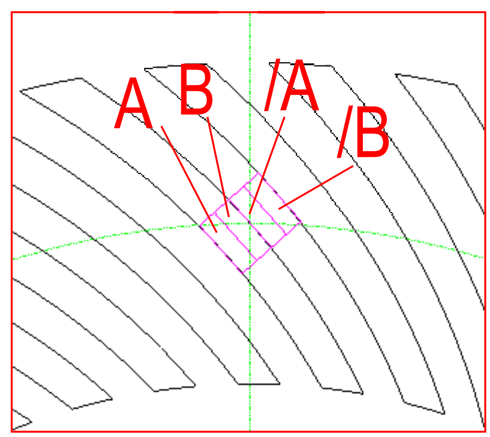





$$\frac{\text{LPI PD}}{\text{LPI CW}} = \frac{51.74}{51.74} = 1$$

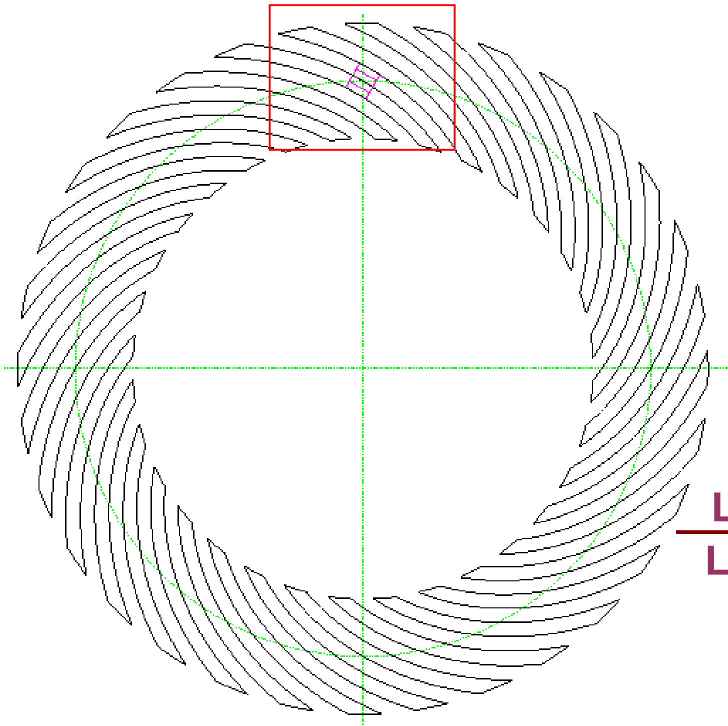
**Figure 5: Rotary: CW at 48 CPR at 5-mm Rop**

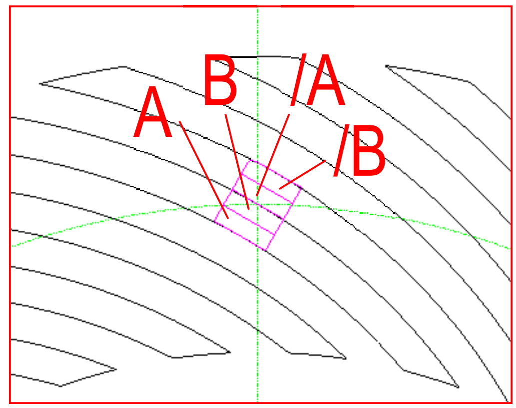





$$\frac{\text{LPI PD}}{\text{LPI CW}} = \frac{51.74}{38.81} = 1.33$$

**Figure 6: Rotary: CW at 32 CPR at 5-mm Rop**



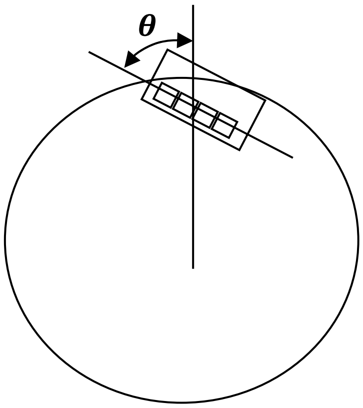



$$\frac{\text{LPI PD}}{\text{LPI CW}} = \frac{51.74}{25.87} = 2.00$$

# Relationship between a Spiral Image and the Photodetector (PD)

To find the angle of the rotation to generate a new codewheel with a reduced CPR, the formulas given in Figure 7 are applied.

**Figure 7: Relationship between a Spiral Image and the Photodetector**




$$\theta = \sin^{-1}\left(\frac{NW}{2\pi R}\right)$$

$$K = 360\frac{\cos\theta}{NW}$$

*θ*: Angle formed between a line parallel to the long side of PD and a radial line, which passes through the optical center of the PD

N: Number of counts per revolution or CPR of the code wheel

W: Width of the PD (1 pitch) with a unit of mm

R: Optical radius of the PD with a unit of mm

K: spiral constant, change in angle/change in radius, with a unit of (°/mm).

## How to Draw the Spline Line for a Spiral Codewheel

For a 75-LPI encoder, the width of the photodetector,

$$W = \frac{25.4}{LPI}mm = \frac{25.4}{75}mm = 0.338667\text{mm}$$

The typical CPR with normal codewheel at 11-mm Rop will be 204CPR.

To get a N = 100-CPR resolution, the following calculation steps are required to generate a design for the spiral codewheel.

$$\theta = \sin^{-1}\left(\frac{100 \cdot 0.338667}{2\pi \cdot 11}\right) = 29.341°$$

$$K = 360 \frac{\cos(29.341)}{100 \cdot 0.338667} = 9.2663\ °/mm$$

When the K constant is determined, then the radial transition is fixed to calculate the angle per radial transition. In the example shown in Table 1, the value is set as 0.1 mm.

Rotation angle per radial transition is derived by multiplying K to the radial transition, that is:

$$Rotation\ angle\ per\ radial\ transition\ = K \cdot Radial\ Transition = 0.92663\ °$$

**Table 1: Example of a Calculation to Determine the Spiral Constant and Rotation Angle**

| N (CPR) | R (mm) | LPI | W(mm) | PD Rotation, θ (°) | Spiral constant, K (°/mm) | Radial transition (mm) | Rotation angle per radial transition (°) |
|---|---|---|---|---|---|---|---|
| 100 | 11.00 | 75 | 0.338667 | 29.341 | 9.2663 | 0.1 | 0.92663 |

**NOTE:** Input parameters are marked in blue cells.

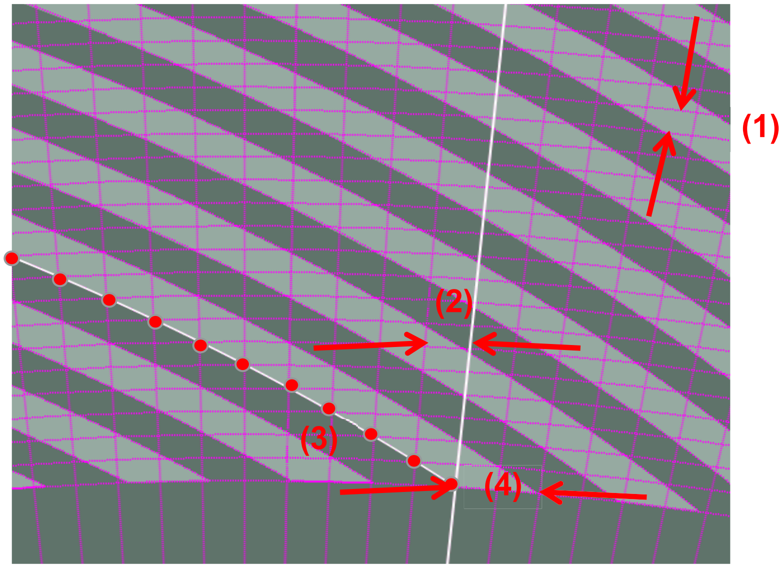
Referring to Figure 8, the following steps generate the spline line in a computer aided design (CAD) tool.:

1. Draw the construction radius with a radian transaction. In this example, the radial transaction = 0.1 mm.

**NOTE:** The smaller the radial transaction, the smoother the spline line.

2. Draw a construction line with a calculated angle per radian.
3. By using the spline line function in CAD, join the intersection of the radius and the line to form the spline transaction = 0.92663°.
4. Rotate the spline line from CW center per CW CPR, to form the adjacent window/bar line. In this example, rotate 180°/N = 180°/100 =1.8° to form the adjacent window/bar line.

**Figure 8: Example of Spline Line of a Spiral Codewheel**




## Performance of Spiral Codewheel

**Figure 9: Effect of the Rotation Angle to Different CPR Codewheels**

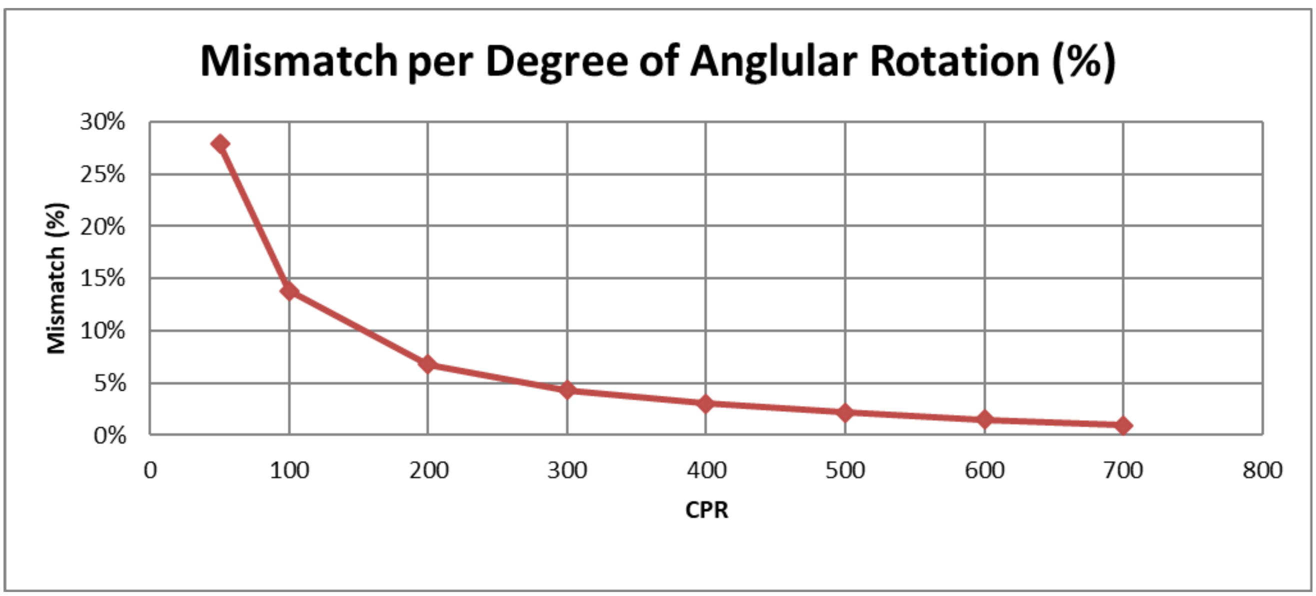


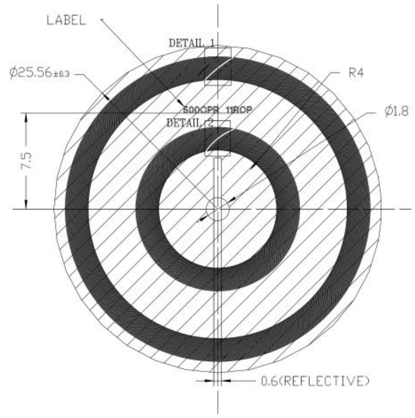
**Table 2: Selected Spiral Codewheel CPR vs. the Rotation Angle with the AEDR-85xx eEncoder**

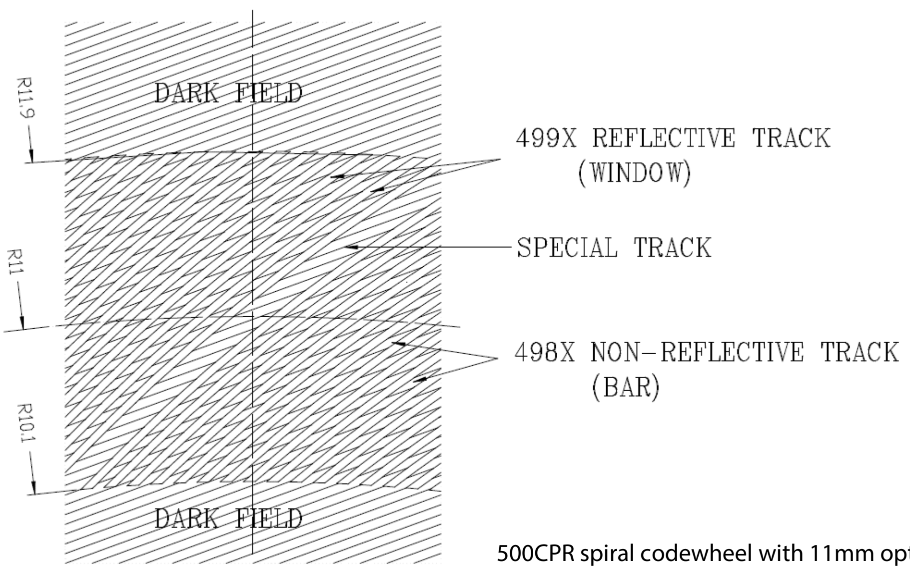
| N (CPR) | Encoder Rotation, θ (°) |
|---|---|
| 50 | 3.6 |
| 100 | 7.2 |
| 200 | 14.5 |
| 300 | 22.0 |
| 400 | 30.0 |
| 500 | 38.7 |
| 600 | 48.6 |
| 700 | 61.0 |

**NOTE:**

1. Figure 9 depicts the dynamic performance for the spiral codewheel with different CPRs based on the AEDR-85xx with nominal 294-LPI resolution. The optical radius is 11 mm.
2. For a CPR of 300 to less than 800 CPR using spiral codewheel, good encoder performance is expected with within a 5% of mismatch.
3. The performance is degraded for a lower resolution codewheel of 200 CPR and 100 CPR as compared to normal codewheel because of the tilted encoder has a larger mismatch with the same spatial as compared to non-tilted encoder with normal CW.
4. The 500-CPR spiral codewheel design with index track is shown in Figure 10.

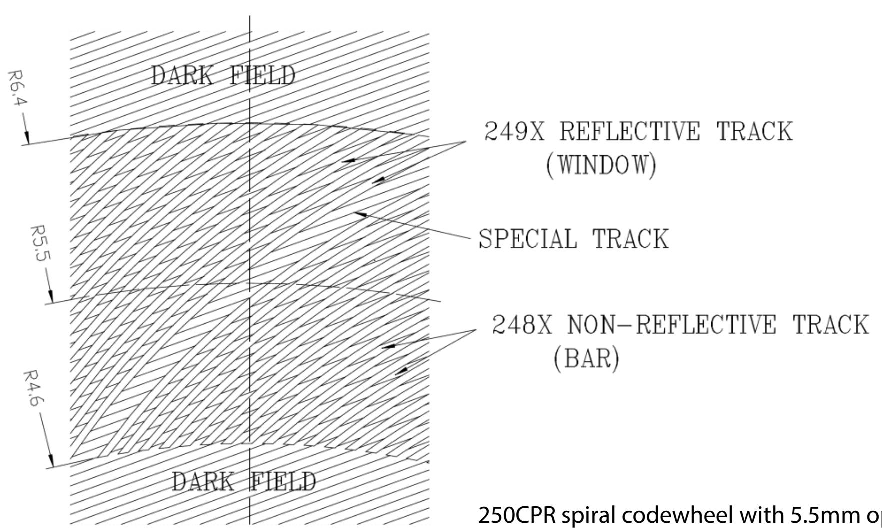
**Figure 10: Example Drawing of the AEDR-8500 with 500CPR/250CPR Spiral Codewheel**




Detail-1

500CPR spiral codewheel with 11mm optical radius.




Detail-2

250CPR spiral codewheel with 5.5mm optical radius.

# Reflective Encoders Resolution

Table 3 lists the current encoder offering from Broadcom that is suitable to apply the spiral codewheel design.

**Table 3: Reflective Encoders Resolution Range At A Glance**

| | Encoder LPI | Number of Channels | Output | CPR at 11-mm Rop |
|---|---|---|---|---|
| AEDR-8300-1Kx | 75 | 2 | Digital | 204 |
| AEDR-8300-1Px | 150 | 2 | Digital | 408 |
| AEDR-8300-1Qx | 180 | 2 | Digital | 490 |
| AEDR-8300-1Wx | 212 | 2 | Digital | 577 |
| AEDR-8310-1Kx | 75 | 1 | Digital | 204 |
| AEDR-8310-1Vx | 36 | 1 | Digital | 98 |
| AEDR-8311-1Kx | 75 | 1 | Digital | 204 |
| AEDR-8400-13x | 254 | 2 | Digital | 691 |
| AEDR-850x-1xx | 294 | 3 | Digital | 800 |
| AEDR-8600-1xx | 294 | 2 | Digital | 800 |
| AEDR-871x-1xx | 318 | 3 | Digital | 865 |
| AEDR-872x-1xx | 318 | 3 | Analog | 865 |

**NOTE:**

1. Possible base CPR solution up to a maximum of ~865 CPR with a 1-in. codewheel.
2. AEDR-8311-1Kx is suitable for index applications