Three Channel Codewheel Design Guide

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1.0 OVERVIEW

This document is meant to be a guide for designing codewheels to be used with HEDS-9040/9140 Encoder Modules. It contains information for an engineering group to create a detailed drawing for use by a codewheel vendor.

2.0 DISCLAIMER

This document is intended for use by you as a single end user. Distribution of this information to other users is not granted except under explicit written permission from Avago Technologies.

In accepting the information in this document, please realize that it is your responsibility to both qualify a vendor for codewheels and to certify that those codewheels meet the specifications of the original design. In addition, please be advised of the following:

- Avago is under no obligation to provide design assistance to any vendor for your codewheels.
- Avago will not accept responsibility for, nor will we test non-Avago codewheels.
- The codewheels designed with this package are intended for use with encoder modules which match the exact resolution and optical radius. No warranty is implied on our encoder modules if non-Avago codewheels which do not match in resolution and optical radius are used.
- Functionality of the encoder module is dependent on the quality of the codewheel with which it is being used. Together, the encoder module and codewheel constitute a full encoding system. Should a problem occur with this system, the possibility exists that the problem lies not with the encoder module, but with the codewheel. In the case of a product return for Avago's encoder module, Avago will test the functionality of the encoder module with Avago-certified codewheels only. As part of the product return analysis performed by Avago, no non-Avago codewheels will be used to determine the functionality of encoder modules.

3.0 References

The user of this document should refer to the following two documents for definitions of encoder terminology.

- Three Channel Optical Incremental Encoder Modules Technical Data HEDS-9040/HEDS-9140.
- Application Brief M-101, Encoder Questions and Answers.

4.0 General Codewheel Considerations

4.1 Error Sources

The codewheel is a major contributor towards the success or failure of any encoder system. Once a codewheel has been properly designed to match a specific resolution, the two most significant sources of errors are:

- The slot to slot inconsistency in size and location.

Slot to slot errors lead to pulse width and quadrature (state) errors.

- The eccentricity of the codewheel.

Eccentricity affects the accuracy (position error).

Accuracy refers to correctly reporting a position.

For a more detailed discussion of encoder errors see above referenced application note.

4.2 Role of Codewheel

The role of the codewheel is to cast a series of shadows over an encoder detector. The codewheel slot spacing should match the detector resolution.

Since the codewheel’s function is to cast a shadow, anything that affects the quality of the shadow needs to be considered and controlled. Consistency of the slot pattern needs to be maintained around the codewheel. The codewheel and its mounting system need to have the proper codewheel track always positioned over the corresponding detector array.

4.3 Codewheel Flatness

The codewheel gap should follow the specifications as shown in the data sheet for the HEDS-9040/9140. Variations in codewheel gap could introduce additional encoding errors. Codewheel flatness should be considered when implementing a codewheel assembly design. A good codewheel design should be flat within ±.13 mm.

4.4 Codewheel Maximum Outline Dimensions

In order to avoid a mechanical crash with the internal back wall of the encoder, the codewheel must not exceed the maximum outer diameter shown in Table 1.

TABLE 1.

Product	Maximum Outer Diameter	Units
HEDS-9140	25.64	mm
HEDS-9040	50.56	mm

4.5 Codewheel Tracks

Three channel codewheels have three distinct codewheel tracks.

Starting from the outer diameter and proceeding inward they are:

- Outer Index Track
- Middle Channel A/B (data) Track
- Inner Index Track

The outer and inner index tracks work in conjunction to produce the index channel output.

The middle track generates the channel A/B output.

4.6 Codewheel Orientation

The Index photodiode area on the HEDS-9040 Option T00, 2000 CPR Encoder Module has a non-symmetrical index pattern. The codewheel used with this devices has inner and outer Index track patterns that match the photodetectors. The encoder module produces a functional index signal when these patterns are aligned. When the encoder module is placed with “Side A” of the Module (side with the connecting pins) face-down, the codewheel (seen in Figure 4) will match the detector pattern. All other Encoder Modules have symmetric index patterns and will work with the codewheel facing or pointing away from “Side A”

5.0 Channel A/B Design Rules

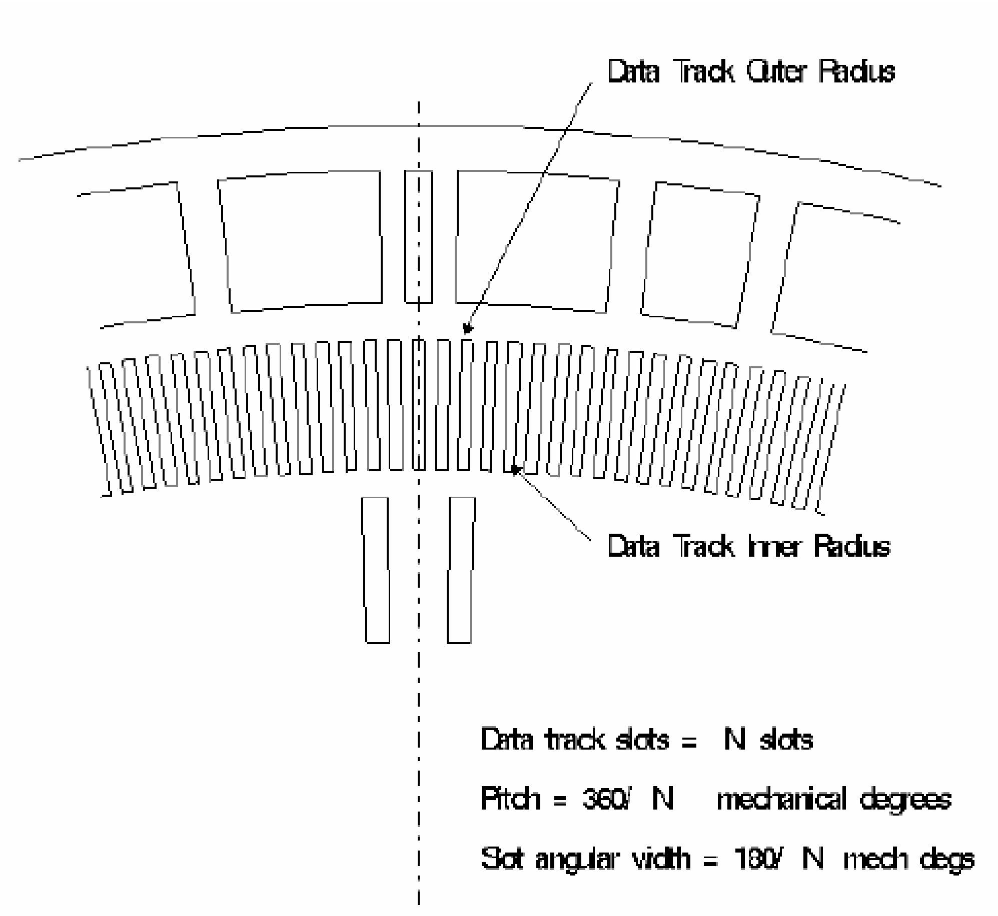


Figure 1

5.1 A/B Slot/Bar Inner & Outer Radii

Data track inner and outer radii are chosen so that the slot lengths match the corresponding detectors.

Each slot is a four-sided figure, bounded on the top and bottom by appropriate arc lengths and bounded on the left and right by radii segments.

• The appropriate radii & tolerances are shown in Table2.

TABLE 2. A/B Track Inner and Outer Radii

	Optical Radius	Inner Radius	Outer Radius	Radius Tolerance	Units
HEDS-9140	11.00	10.61	11.43	± 0.025	mm
HEDS-9040*	23.36	22.97	23.79	± 0.025	mm
HEDS-9040 option T00	23.36	22.92	23.79	± 0.015	mm

* except option T00

The optical radius should be concentric with the codewheel inner diameter. Concentricity requirements vary with end applications. A good design goal would be .038 mm max TIR (Total Indicated Runout).

For Non-standard optical radii, the line density of the codewheel and the line density of the detector should match. The optical radius should always be greater than 10.00 mm. The optical radius of HEDS-9040 option #T00 should always be greater than 20.00 mm

5.2 A/B Slot to Bar Width Ratios

The slot to bar ratios should be held as close to 1:1 as possible. The ratio should in all cases be between 0.7 and 1.4.

6.0 Index Tracks Design Rules

6.1 Index Inner & Outer Tracks

There are two index tracks. The outer track is normally lit. The inner track is normally dark. At the location of the index pulse, this is reversed and the outer track is momentarily dark and the inner track is momentarily lit.

The details for the index tracks around the index pulse zone are shown in sections 6.5 and 6.6.

6.2 Index Track Architecture

The HEDS-9040/9140 encoders use three index design architectures. The architectures are either double slot (see Figure 2), single slot (see Figure 3), or quadruple slot (see Figure 4). This means that either one, two, or four slots on the inner index track are used to generate an index pulse. Table 3 shows the existing three channel encoders and their corresponding index architecture. Check with the factory for the appropriate architecture for other CPR's (counts per revolution).

TABLE 3. Index Architectures

Product	Option	CPR	Optical Radius	Index Architecture
HEDS-9140	K00	96	11.00	Single Slot
HEDS-9140	C00	100	11.00	Single Slot
HEDS-9140	E00	200	11.00	Single Slot
HEDS-9140	F00	256	11.00	Double Slot
HEDS-9140	G00	360	11.00	Double Slot
HEDS-9140	H00	400	11.00	Double Slot
HEDS-9140	A00	500	11.00	Double Slot
HEDS-9140	I00	512	11.00	Double Slot
HEDS-9040	B00	1000	23.36	Double Slot
HEDS-9040	J00	1024	23.36	Double Slot
HEDS-9040	T00	2000	23.36	Quadruple Slot

6.3 Inner and Outer Index Track Radii

This section defines the index slot length, position and width for both the 23.36 mm optical radius (HEDS-9040) and 11.00 mm optical radius (HEDS-9140) encoders.

Index tracks inner and outer radii are chosen so that the slot lengths match the corresponding detectors.

Each slot is a four-sided figure, bounded on the top and bottom by appropriate arc lengths and bounded on the left and right by radii segments.

The appropriate radii & tolerances are shown in Table 4:

TABLE 4. Index Tracks Inner and Outer Radii

		Inner Index		Outer Index			
	Optical Radius	Inner Radius	Outer Radius	Inner Radius	Outer Radius	Radius Tolerance	Units
HEDS-9140	11.00	9.52	10.44	11.66	12.50	± 0.025	mm
HEDS-9040*	23.36	21.80	22.80	24.02	24.86	± 0.025	mm
HEDS-9040 opt T00	23.36	21.88	22.70	23.84	24.86	± 0.015	mm

*except opt T00

6.4 Inner and Outer Index Track Slot Widths

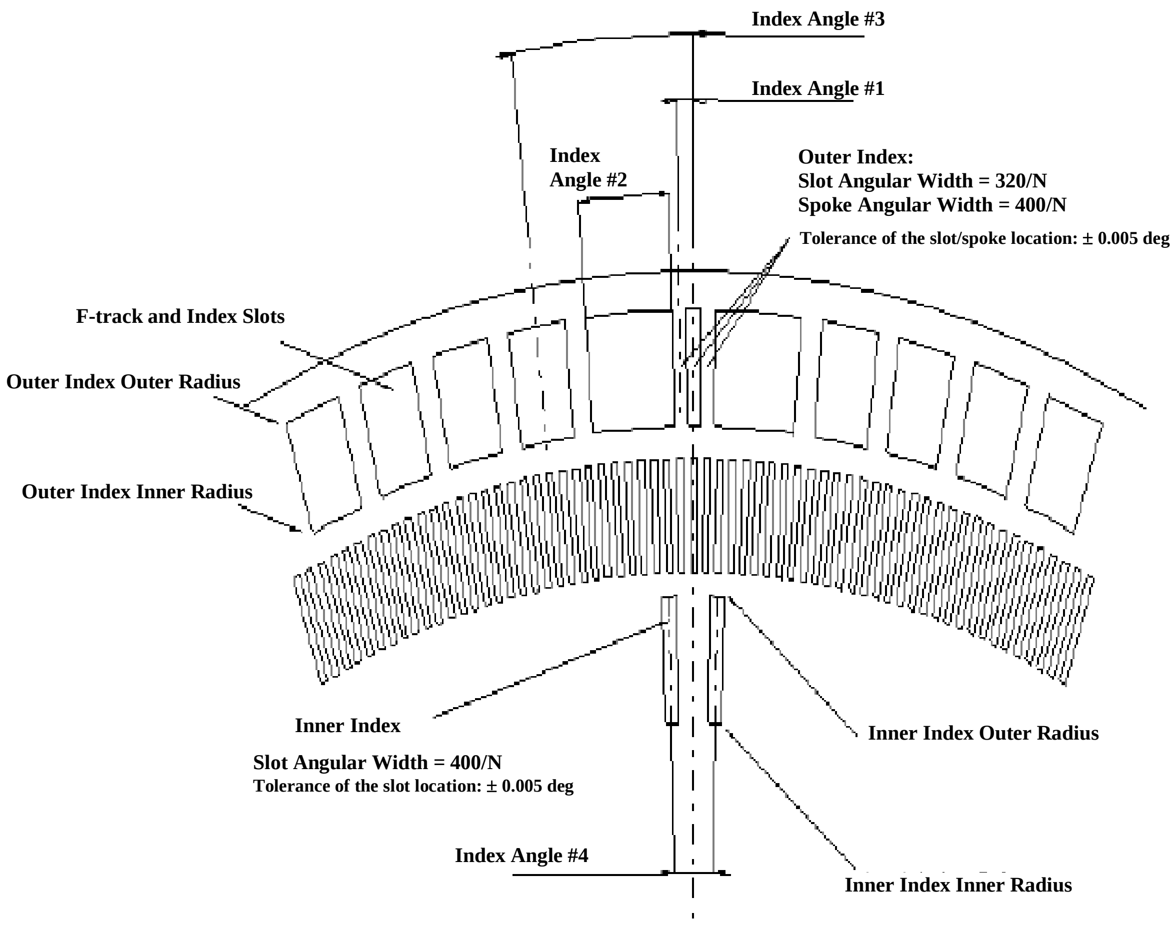
The index angular slot width is nominally 400 electrical degrees. In mechanical degrees, this is expressed as 400/N, where N is the number of A/B cycles per revolution. Tolerance on the slot width is ±20 electrical degrees.

6.5 Index Slot Locations for Double Slot Index Architecture

The double slot architecture consists of two index slots at the index pulse location. See Figure 2. The centerline of the inner index angle #4 is coincident to an A/B datatrack slot centerline. Index track features are symmetrical about this centerline. Table 5 refers to features annotated in Figure 2.

TABLE 5. Double Slot Index

Feature		Units
Index Angle #1	360/N	Mechanical Degrees
Index Angle #2	6*(360/N)	Mechanical Degrees
Index Angle #3	See section 6.8	Mechanical Degrees
Index Angle #4	4 * (360/N)	Mechanical Degrees



6.6 Index Slot Locations for Single Slot Index Architecture

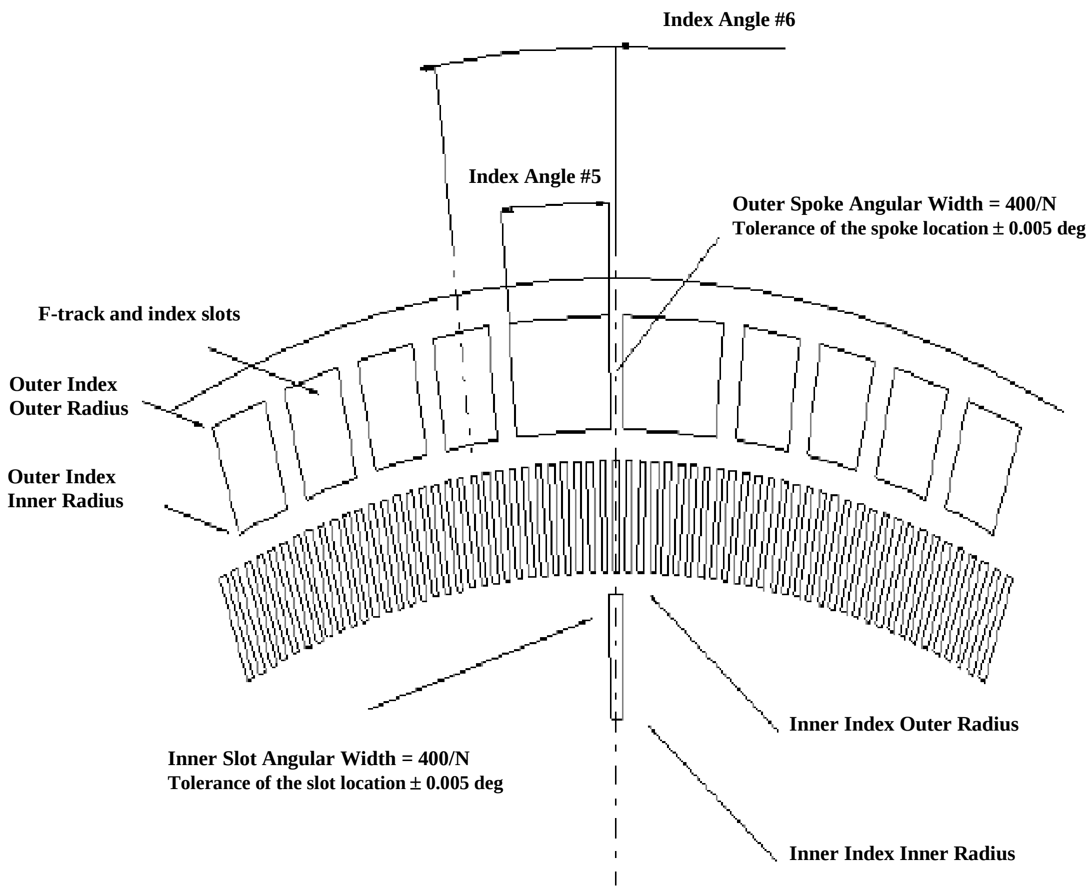


Figure 3

The single slot architecture consists of one index slot at the index pulse location. See Figure. The centerline of the inner index track slot is coincident to an A/B datatrack slot centerline. Index track features are symmetrical about this centerline. Table 6 refers to features annotated in above Figure 3.

TABLE 6. Single Slot Index

Feature		Units
Index Angle #5	6*(360/N)	Mechanical Degrees
Index Angle #6	See section 6.8	Mechanical Degrees

6.7 Index Slot Locations for Quadruple Slot Index Architecture

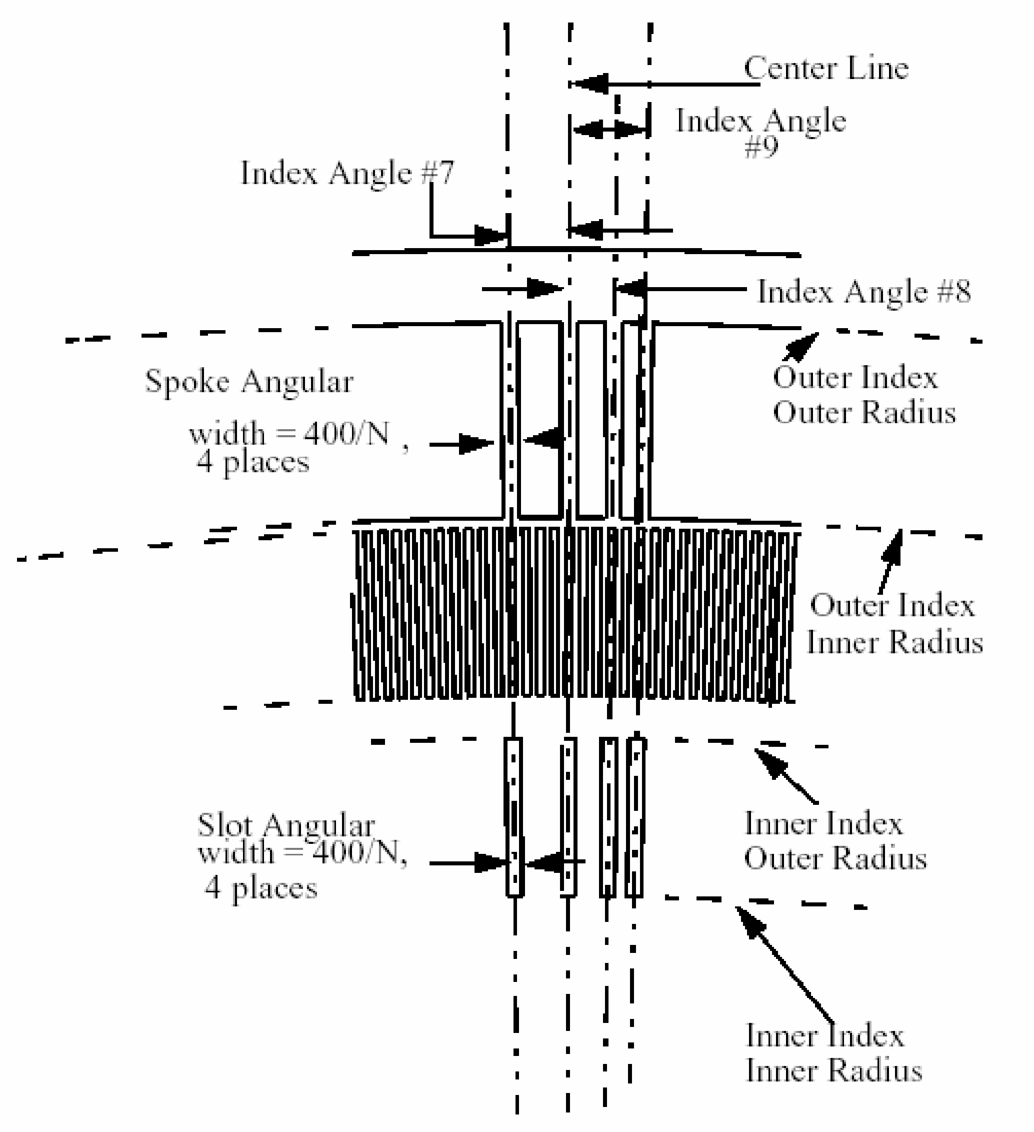


Figure 4

The quadruple slot architecture consists of four slot/bar pairs at the index pulse location. Table 7 refers to features annotated above in Figure 4.

TABLE 7. Quadruple Slot Index

Feature		Units
Index Angle # 7	4*(360/N)	Mechanical Degrees
Index Angle # 8	-3*(360/N)	Mechanical Degrees
Index Angle # 9	-5*(360/N)	Mechanical Degrees

6.8 The balance of the outer index track (F-track)

The index slots at the index pulse zone are determined by angles #1, #2 and #4 for the double index architecture, angle #5 for the single index architecture, and angles #7, #8, and #9 for the quadruple index architecture. Reference Figures 2, 3, and 4 and Tables 5,6 and 7.

At angles when the index pulse is not active, the inner index track is always blocking light. The corresponding outer index track should be normally transparent. Depending on the codewheel material, this may not be possible. If connecting bars are needed in this area for structural support, the design should strive for wide slots with narrow bars. The intent is to keep the outer index track as fully transparent as possible.

When using a metal codewheel with connecting bars in the outer index track, the maximum width of the connecting bars is one half of a cycle (for single slot architecture) or one full cycle (for double slot architecture).

If outer index bars are needed, the slots should be evenly spaced around the remainder of the outer index track. The center of the first of these slots is given by angle #3 or angle #6. The number of outer index slots and spacing is determined by the optical radius of the encoder and the widths of angle #2 or angle #4.

HEDS-9040 option#T00 has a density that exceeds present metal codewheel technology. Film or Glass can be used in this situation. These codewheel materials need no connecting bars for support, so the nonactive part of the F-track can be made transparent.