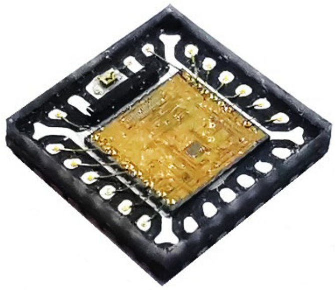
Preliminary Data Sheet

AEDR-9830DP

Three-Channel Reflective Incremental Encoder with Analog or Digital Differential Output (318 LPI)



Description

The Broadcom® AEDR-9830DP is a three-channel reflective optical encoder. It can be configured to analog or digital outputs employing reflective technology for motion control purposes. The selectable options available are two channels differential analog with a third channel differential digital or analog index output or three-channel digital differential A, B, and I output.

The AEDR-9830DP in analog encoder modes with two-channel differential analog outputs (Sin, /Sin, Cos, /Cos), can be interfaced directly, with external interpolators available.

The AEDR-9830DP in digital encoder mode offers two-channel (AB) quadrature digital outputs and a third channel digital index output. Being TTL compatible, the outputs of the AEDR-9830DP encoder can be interfaced with most signal processing circuitries. Therefore, the encoder provides easy integration and flexible design into existing systems.

The AEDR-9830DP encoder is designed to operate over a –40°C to +115°C temperature range and is suitable for commercial, industrial, and automotive end applications.

The encoder houses an infrared LED light source and photodetecting circuitry in a single package. The small size of 4.00 mm (L) × 4.00 mm (W) × 0.73 mm (H) allows it to be used in a wide range of miniature commercial applications, where size and space are primary concerns.

Features

- Analog output option: two-channel differential analog output and differential digital or analog index output.
- Digital output option: three-channel differential or TTL compatible; two-channel quadrature (AB) digital outputs for direction sensing and a third channel, index digital output.
- Built in interpolator for 1x, 2x, 4x, 8x, and 16x interpolation.
- Surface-mount leadless package: 4.0 mm (L) × 4.0 mm (W) × 0.73 mm (H)
- Operating voltage of 3.3V and 5.0V supply
- Built-in LED current regulation
- Wide operating temperature range from –40°C to +115°C
- High encoding resolution: 318 LPI (lines per in.) or 12.52 LPmm (lines per mm)
- Translucent protection compound

Applications

- Closed-loop stepper motors
- Small motors, actuators
- Industrial printers
- Robotics
- Card readers
- Pan-tilt-zoom (PTZ) cameras
- Portable medical equipment
- Optometric equipment
- Linear stages

Output Waveform

Analog Output Option

Figure 1: Analog Output Option

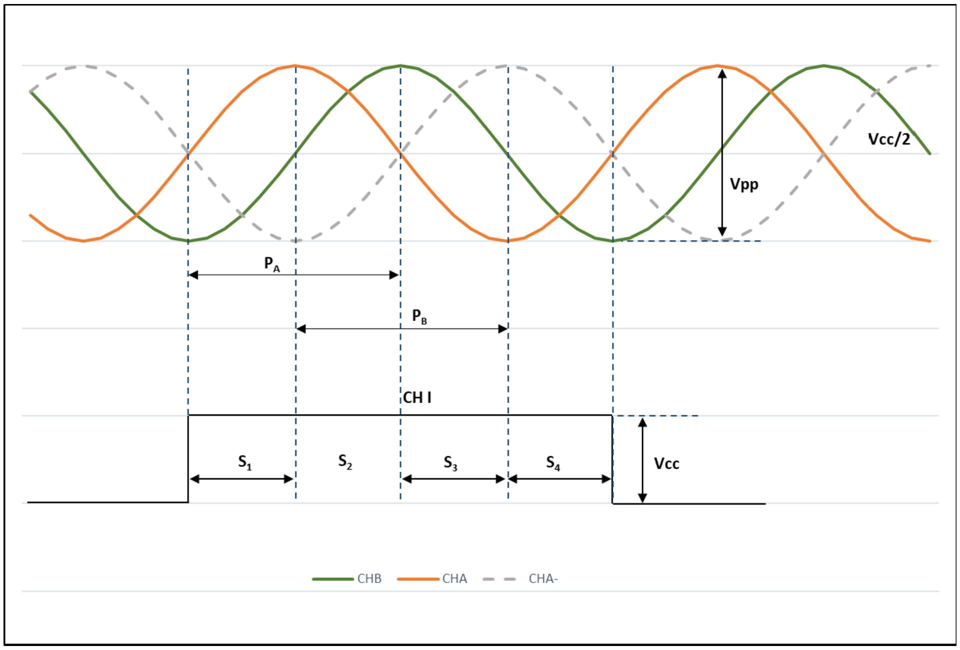
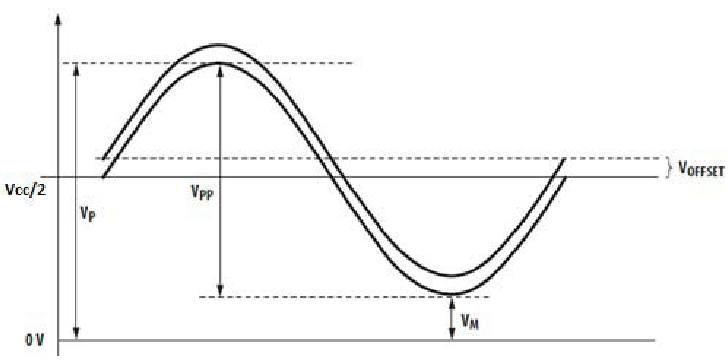


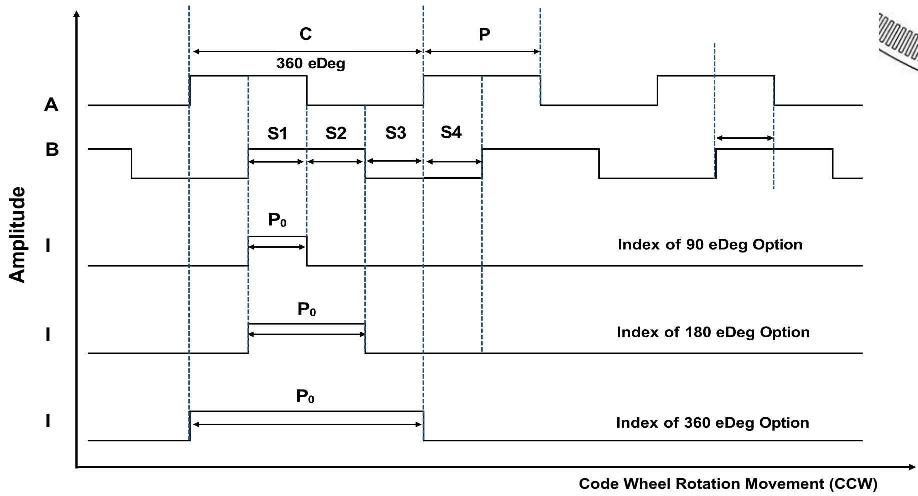
Figure 2: Code Wheel Rotation Movement (Counter-Clockwise)

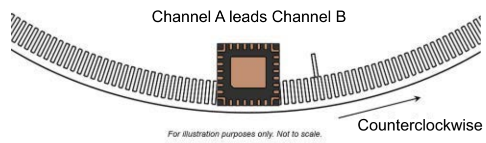


Test Parameter Definitions

Term	Symbol	Definition
Analog Peak-to-Peak	V_{pp}	The peak-to-peak signal magnitude in V of the analog signal.
Analog Offset	V_{OFFSET}	The offset in mV from the mid-point of the analog peak-to-peak signal to the zero voltage point.
Analog Peak/Valley Voltage	V_{PA}, V_{PB}, V_{MA}, V_{MB}	The value in V of the peak/valley of the analog signal (that is, one-sided reading).
Analog Peak-to-Peak Voltage	V_{PPA}, V_{PPB}	The absolute difference between V_P and V_M of channel A or B.

Figure 3: Sample of Output Waveforms





Quadrature Signals A,B and I

Digital Parameter Definitions

Term	Parameter	Definition
Count	N	The number of bar and window pairs or counts per revolution (CPR) of the code wheel.
Cycle	C	360 electrical degrees (°e), 1 bar and window pair. One Shaft Rotation: 360 mechanical degrees, N cycles.
Cycle Error	ΔC	An indication of cycle uniformity. The difference between an observed shaft angle that gives rise to one electrical cycle, and the nominal angular increment of 1/N of a revolution.
Pulse Width (Duty) Error	ΔP	The deviation, in electrical degrees, of the pulse width from its ideal value of 180°e.
State	S	The number of electrical degrees between a transition in the output of channel A and the neighboring transition in the output of channel B. There are 4 states per cycle, each nominally 90°e.
Phase	φ	The number of electrical degrees between the center of the high state of channel A and the center of the high state of channel B. This value is nominally 90°e for quadrature output.
Optical Radius	R_{OP}	The distance from the code wheel's center of rotation to the optical center (O.C.) of the encoder module.
Index Pulse Width	P_0	The number of electrical degrees that an index is high during one full shaft rotation.

Absolute Maximum Ratings

Parameter	Symbol	Value
Storage Temperature	T_S	–40°C to 125°C
Operating Temperature	T_A	–40°C to 115°C
Supply Voltage	V_{CC}	7V

NOTE:

1. Proper operation of the encoder cannot be guaranteed if the maximum ratings are exceeded.
2. If necessary, clean the encoder surface after the SMT reflow process and just before final assembly. Take precautions to keep the encoder ASIC clean at all times.
3. Some particles might be present on the surface of the encoder ASIC surface. The presence of these particles does not degrade the performance of the encoder.

CAUTION! Take anti-static discharge precautions when handling the encoder in order to avoid damage, degradation, or both, induced by ESD.

Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit	Notes
Operating Temperature	T_A	–40	25	115	°C	
Supply Voltage	V_{CC}	2.97	3.3	3.63	V	Ripple < 100 mV_{p-p}
		4.5	5	5.5		
Current	I_{CC}	—	30	65	mA	
Pin Current (All I/O Outputs)	I	–20	—	20	mA	
Maximum Output Frequency (External Pin Selectable)	F	—	—	200	kHz	At 1x Interpolation
		—	—	400	kHz	At 2x Interpolation
		—	—	800	kHz	At 4x Interpolation
		—	—	1.6	MHz	At 8x Interpolation
		—	—	2.0	MHz	At 16x Interpolation
Radial Misalignment	E_R	—	—	±0.2	mm	
Tangential Misalignment	E_T	—	—	±0.2	mm	
Tilt Misalignment	E_θ	—	—	±2.0	°	
Code Wheel Gap	G	0.82	1.32	1.82	mm	

Power-Up Behavior

When AEDR-9830DP is powered on, the A, B, and I digital outputs are invalid until after the initial first toggle state of either the Channel A or Channel B signal.

Encoder Pinout

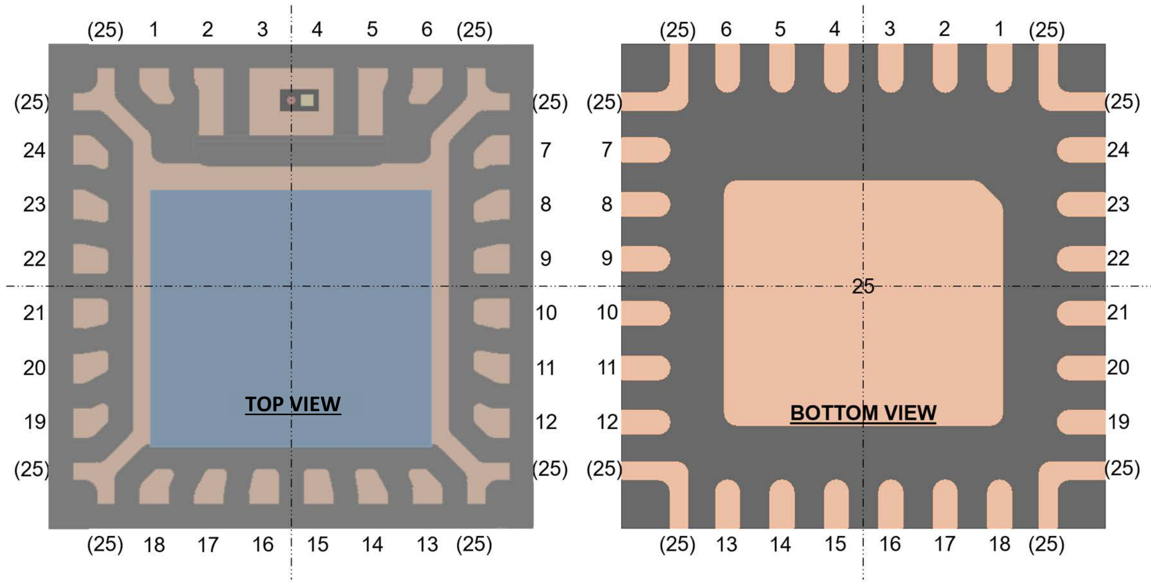


Table 1: AEDR-9830DP Pinout

Pin	Name	Function
1	CH_A / A+	Digital A+/Analog Sin+
2	N.C.[a]	—
3	LED ANODE	LED Anode
4	LED ANODE	LED Anode
5	LED CATHODE	LED Cathode
6	LED REG	LED Regulation
7	VDDA/VCC	Analog Supply Voltage
8	VSSA/AGND	Analog Ground
9	SEL2	Mode Selection 2
10	SEL1	Mode Selection 1
11	INDEX_N/I-	Index Output Z- (Digital/Analog)
12	INDEX_P/I+	Index Output Z+ (Digital/Analog)
13	N.C.	—

Pin	Name	Function
14	N.C.	—
15	N.C.	—
16	N.C.	—
17	N.C.	—
18	N.C.	—
19	INDEX_SEL	Index Control
20	CH_BB/B-	Digital B-/Analog Cos-
21	CH_B/B+	Digital B+/Analog Cos+
22	VSSD/DGND	Digital Ground
23	VDD	Digital Supply Voltage
24	CH_AB/A-	Digital A-/Analog Sin-
25	VSSA	Analog Ground
(25)	N.C.	—

a. N.C. = No connect.

NOTE:

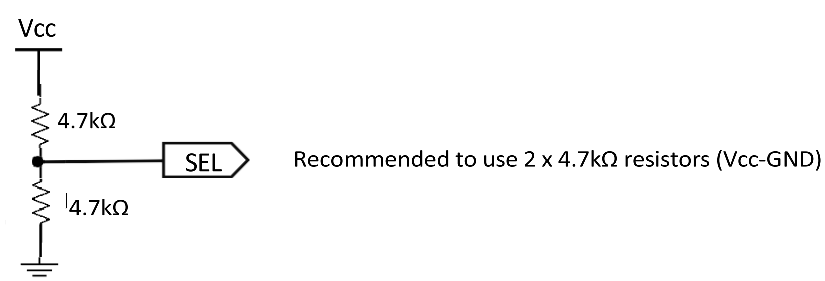
1. No connection to all corner pads indicated as (25).
2. Connect pin 8, pin 22, and pin 25 to common ground for all digital or analog mode applications. Pin 25 is the center pad of the package.
3. Both pin 7 and pin 23 must be powered during operation.
4. Both pin 5 and pin 6 must be connected together.

Select Options: Encoder Built-In Interpolation

SEL 1	SEL 2	IND SEL	Interpolation Factor	Index	Maximum Output Frequency	CPR at ROP 7.95 mm	CPR at ROP 11 mm
Open	Open	Low	1X	Gated 90°	200 kHz	625	865
		High		Gated 180°			
		Open		Ungated raw			
Open	Low	Low	2X	Gated 90°	400 kHz	1250	1730
		High		Gated 180°			
		Open		Gated 360°			
High	High	Low	4X	Gated 90°	800 kHz	2500	3460
		High		Gated 180°			
		Open		Gated 360°			
Low	Low	Low	8X	Gated 90°	1.6 MHz	5000	6920
		High		Gated 180°			
		Open		Gated 360°			
High	Low	Low	16X	Gated 90°	2.0 MHz	10,000	13,840
		High		Gated 180°			
		Open		Gated 360°			
Open	High	N/A	Analog (500 mV_{pp})	Analog	200 kHz	N/A	N/A
Low	High	N/A	Analog 1 V_{pp}	Ungated Digital			
High/Low	Open	N/A	Analog 1 V_{pp}	Analog			

NOTE: Open selection must be connected to the middle of a voltage divider circuit.

Figure 4: Example of Voltage Divider Circuit



The digital interpolation factor above is used with the following equations to cater to various rotational speed (RPM) and count per revolution (CPR).

RPM = (Count Frequency × 60) / CPR

The CPR (at 1X interpolation) is based on the following equation, which is dependent on radius of operation (R_{OP}).

CPR = LPI × 2π × R_{OP} (in.) or CPR = LPmm × 2π × R_{OP} (mm)

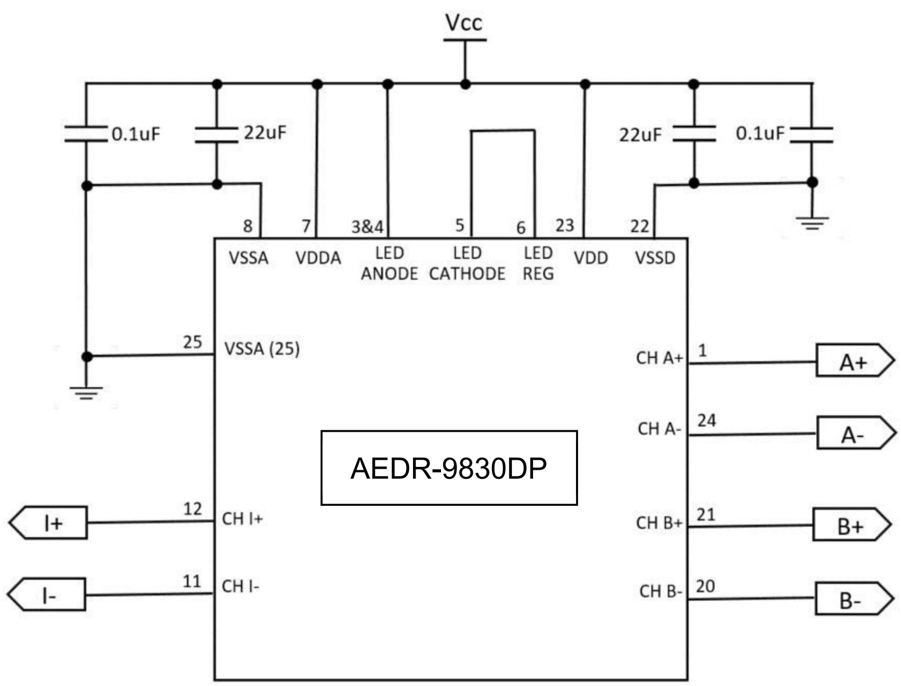
NOTE: LPmm = LPI / 25.4

Recommended Setup for the Power Supply Pins and General Routing

Both VDDA, VDD, and the respective grounds (VSSA and VSSD) are to be connected separately as shown in Figure 5. Follow these schematic design rules:

- Use a pair of 22-µF and 0.1-µF capacitors as bypass on VDD and VDDA. Place them in parallel as close as possible to the encoder ASIC package, in between the power and ground pins.
- Avoid routing the INDEX trace in parallel and close to the analog signals to reduce the INDEX signal switching noise from coupling into the analog signal.
- Design separate VDD and VDDA traces.
- Minimize trace or cable length where possible.
- For single-ended applications, do not ground the Output- from the encoder. Allow the output to float.

Figure 5: Reference Schematic Diagram



NOTE:

1. Pin 25 is the center pad of the package and is labeled AGND.
2. See the table in Select Options: Encoder Built-In Interpolation for SEL1X, SEL2X, and IND_SEL configurations.

Analog Encoder Characteristics

Parameter	Symbol	Min.	Typ.[a]	Max.	Units
Peak-to-Peak Voltage (Average)	V_{PPA}, V_{PPB}	0.9	1.0	1.1	V
		0.45	0.50	0.55	V
Analog Offset Voltage	$V_{OFFSETA}$, $V_{OFFSETB}$	0.45 V_{CC}	0.5 V_{CC}	0.55 V_{CC}	V
Voltage Reference (Midpoint of Signal V_{pp})	V_{ref}	—	$V_{CC}/2$	—	V

a. Typical values represent the average value of encoder performance in Broadcom factory-based setup conditions.

NOTE: The optimal performance of encoder depends on the motor/system setup condition of the individual customer.

Digital Encoder Characteristics (Code Wheel of R_{OP} at 7.95 mm)

Parameter	Symbol	Dynamic Performance Typical[a]					Units
Interpolation Factor		1X	2X	4X	8X	16X	
Cycle Error	ΔC	± 7	± 12	± 21	± 28	± 35	°e
Pulse Width (Duty) Error	ΔP	± 6	± 13	± 14	± 18	± 25	°e
Phase Error	Δϕ	± 3	± 7	± 7	± 9	± 9	°e
State Error	ΔS	± 6	± 8	± 11	± 12	± 14	°e
Index Pulse Width (Gated 90°)	P_O	90	90	90	90	90	°e
Index Pulse Width (Gated 180°)	P_O	180	180	180	180	180	°e
Index Pulse Width (Gated 360°)	P_O	N/A	360	360	360	360	°e
Index Pulse Width (Raw Ungated)	P_O	330	N/A	N/A	N/A	N/A	°e

a. Typical values represent the average value of encoder performance based on factory setup conditions at 12k RPM with a metal code wheel.

NOTE: The optimal performance of encoder depends on the motor/system setup condition of the individual customer.

Electrical Characteristics

Characteristics over recommended operating conditions at 25°C.

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
High Level Output Voltage	V_{OH}	2.4	—	—	V	I_{OH} = –20 mA
Low Level Output Voltage	V_{OL}	—	—	0.4	V	I_{OH} = +20 mA
Output Current per Channel, I_{out}	I_O	—	—	20	mA	
Rise Time[a]	t_r	—	< 50	—	ns	CL ≤ 50 pF
Fall Time[a]	t_f	—	< 50	—	ns	

a. Applicable for all digital modes except Index in Analog mode.

Code Wheel Design Guidelines

- The window tracks are reflective surfaces, and the bar tracks are opaque surfaces; all window and bar tracks are trapezoid.
- The number of Incremental window/bar tracks depend on the CPR; the Incremental windows/bars have the same width value.
- There is an offset between the Incremental window tracks and the Index window track.
- There is only one Index window track, and its width is constant.
- The center point to form the Incremental Optical Radius (R_{OP}) and the Index R_{OP} are two different points, except for 625 CPR.

Figure 6: Code Wheel Design (A)

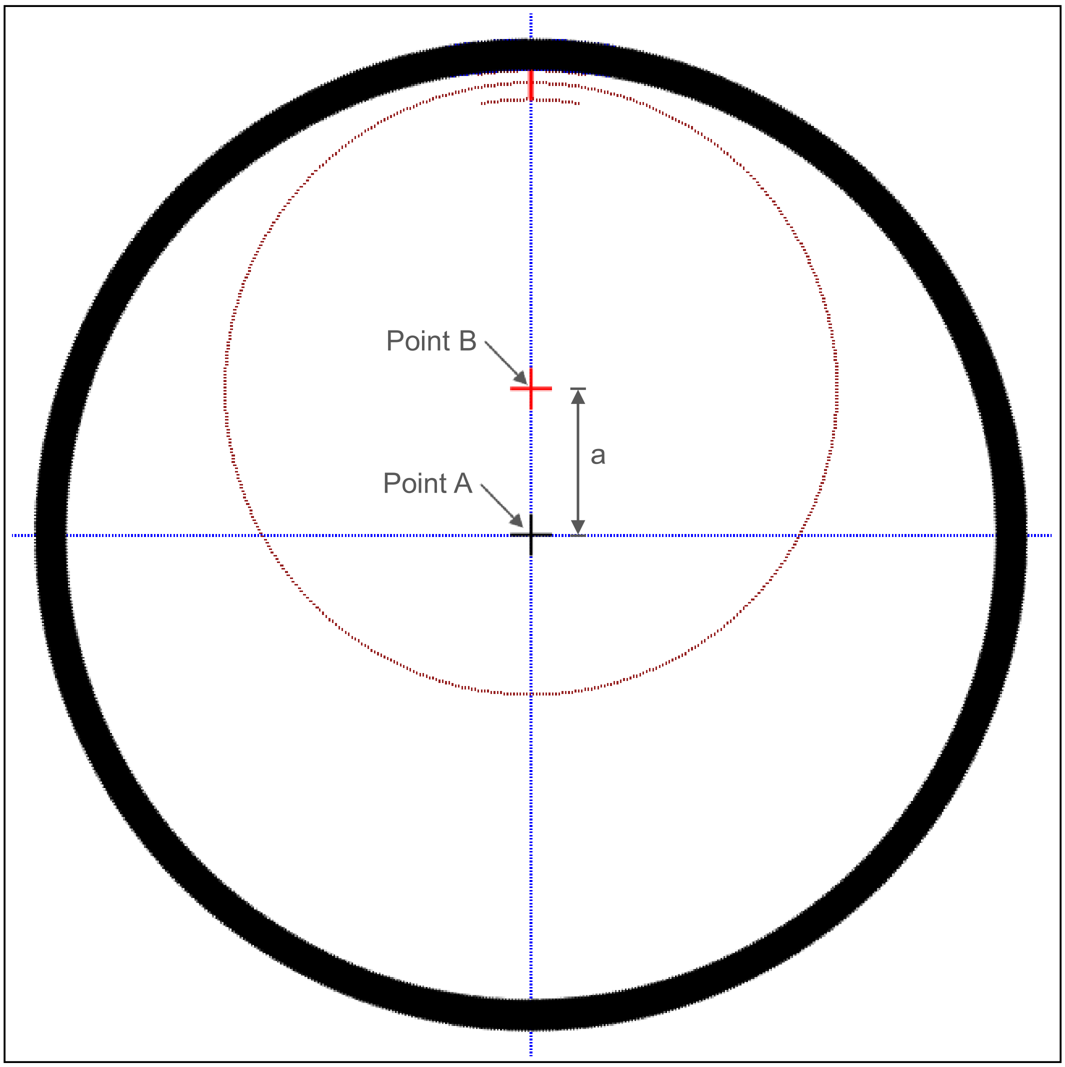
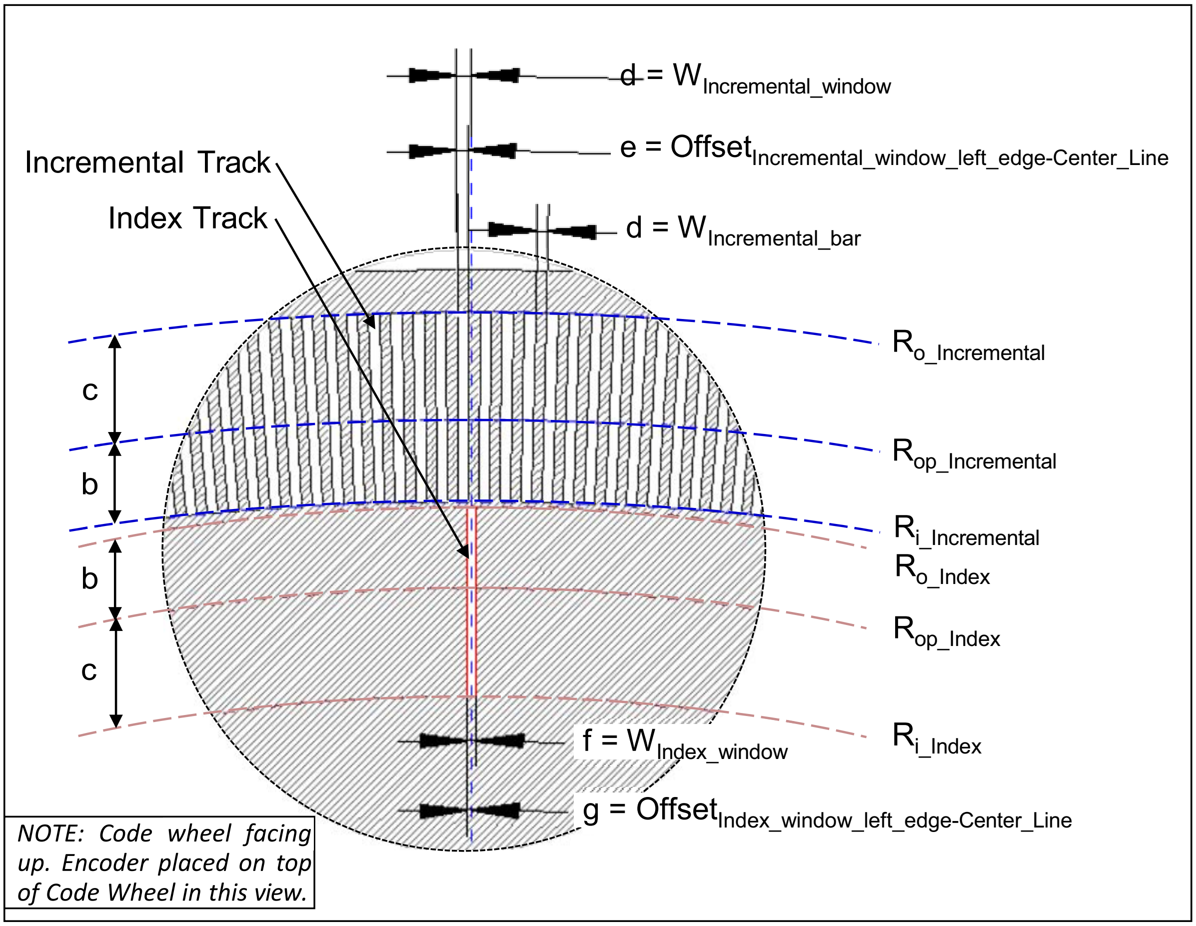


Figure 7: Code Wheel Design (B)



Dimension	Formula	Constant for AEDR-9830DP
$R_{op\_Incremental}$ (mm)	(25.4 / 318) × (CPR / 2π)	—
R_{op_Index} (mm)	—	R7.3198 from Point B
$R_{o\_Incremental}$	$R_{op\_Incremental}$ + c	—
$R_{i\_Incremental}$	$R_{op\_Incremental}$ – b	—
R_{o_Index}	R_{op_Index} + b	—
R_{i_Index}	R_{op_Index} – c	—
a (mm)	$R_{op\_Incremental}$ – 7.9452	—
b (mm)	(0.625 – h) / 2	—
c (mm)	$R_{o\_Incremental}$ – $R_{op\_Incremental}$ or R_{op_Index} – R_{i_Index}	≥ 0.35
d (°)	(Pitch / 2) or ((360 / CPR) / 2)	—
e (°)	1.25d	—
f (°)	—	0.288
g(°)	f / 2	0.144
h (mm)	R_{o_Index} – $R_{i\_Incremental}$ at Y-axis	0 ≥ h ≥ 0.05

Code Wheel Design Example

The following demonstrates a code wheel design for the AEDR-9830DP at 625 CPR.

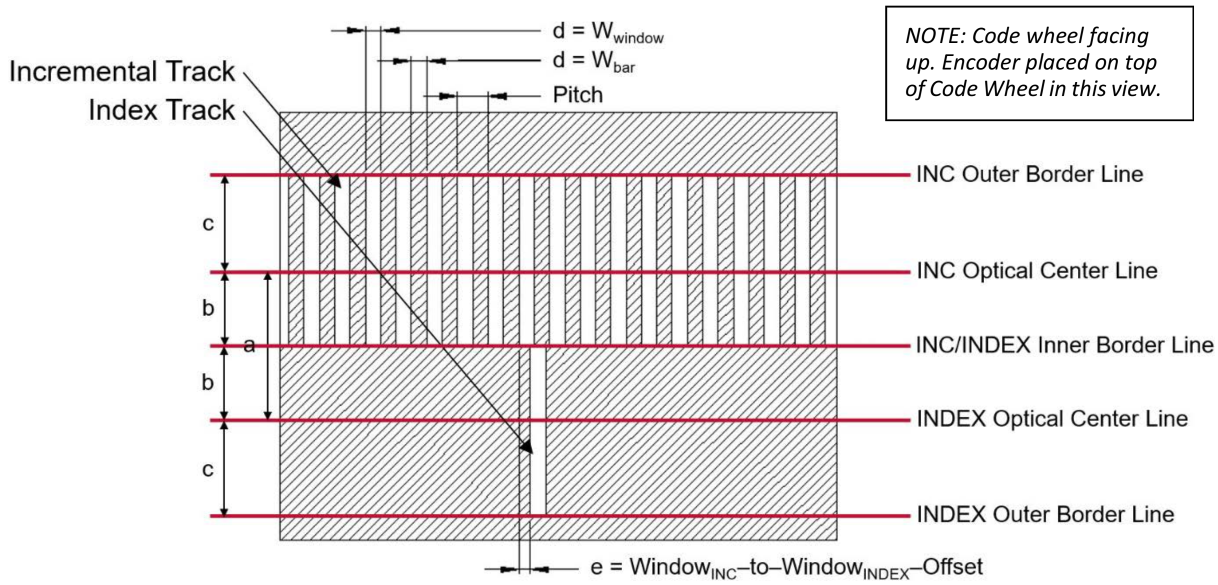
Determine $R_{op\_Incremental}$	(25.4 / 318) × (625 / 2π)	≈ 7.9452 mm
Determine $R_{o\_Incremental}$	7.9452 + 0.35	= 8.2952 mm
Determine $R_{i\_Incremental}$	7.9452 – (0.625 / 2)	= 7.6327 mm
Determine Pitch	360 / 625	= 0.576°
Determine d	0.576 / 2	= 0.288°
Determine e	1.25 × 0.288	= 0.360°
With the preceding information, draw a trapezoid based on Point A (0, 0), populate 625x at pitch = 0.576°		
Determine a	7.9452 – 7.9452	= 0 mm
R_{op_Index}		= 7.3198 mm
R_{o_Index}	7.3198 + (0.625 / 2)	= 7.6323 mm
R_{i_Index}	7.3198 – 0.35	= 6.9698 mm
f		= 0.288°
g	f / 2	= 0.144°
With the preceding information, draw a trapezoid based on Point B (0, 0)		

The following demonstrates a code wheel design for the AEDR-9830DP at 1200 CPR.

Determine $R_{op\_Incremental}$	(25.4 / 318) × (1200 / 2π)	≈ 15.2549 mm
Determine $R_{o\_Incremental}$	15.2549 + 0.35	= 15.6049 mm
Determine $R_{i\_Incremental}$	15.2549 – (0.625 / 2)	= 14.9424 mm
Determine Pitch	360 / 1200	= 0.300°
Determine d	0.300 / 2	= 0.150°
Determine e	1.25 × 0.150	= 0.1875°
With the preceding information, draw a trapezoid based on Point A (0, 0), populate 1200x at pitch = 0.300°		
Determine a	15.2549 – 7.9452	= 7.3097 mm
R_{op_Index}		= 7.3198 mm
R_{o_Index}	7.3198 + (0.625 / 2)	= 7.6323 mm
R_{i_Index}	7.3198 – 0.35	= 6.9698 mm
f		= 0.288°
g	f / 2	= 0.144°
With the preceding information, draw a trapezoid based on Point B (0, 7.3097)		

Code Strip Design Guideline

- The Incremental/Index window track is a reflective surface and the Incremental bar track is opaque.
- The window width is denoted by W_{window} and the bar width is denoted by W_{bar}.
- All windows and bars have the same width value, d.
- There is an offset between Incremental window track and Index window track, denoted by e.

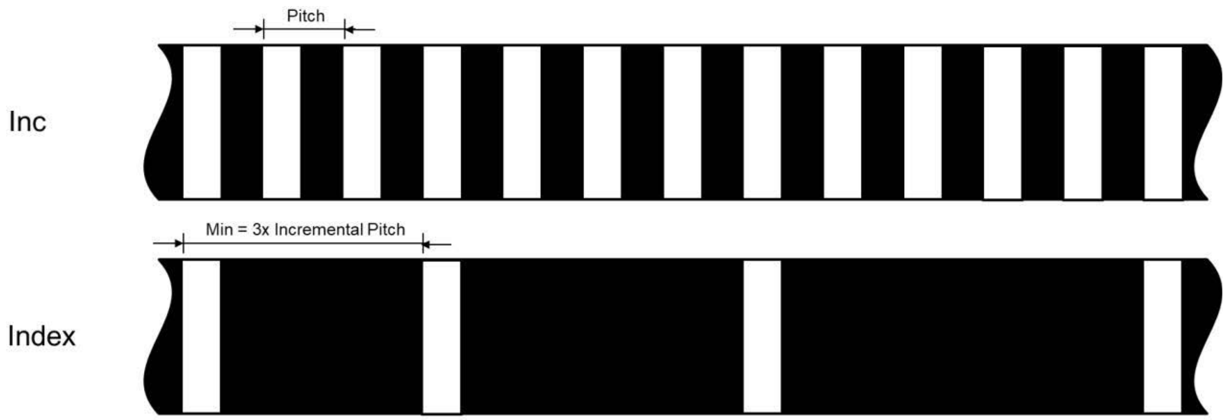


Dimension	Formula	318 LPI
Pitch (mm)	25.4 / LPI	0.080
a (mm)	$R_{OP\_INC} - R_{OP\_INDEX}$	0.625
b (mm)	$R_{OP\_INC} - R_{I\_INC}$ or $R_{O\_INDEX} - R_{OP\_INDEX}$	a / 2
c (mm)	$R_{O\_INC} - R_{OP\_IN}C$ or $R_{OP\_INDEX} - R_{I\_INDEX}$	0.35
d (mm)	Pitch / 2	0.040
e (mm)	(3 / 4) × d	0.030

Multiple Index Pulse Code Wheel or Strip Design Guideline

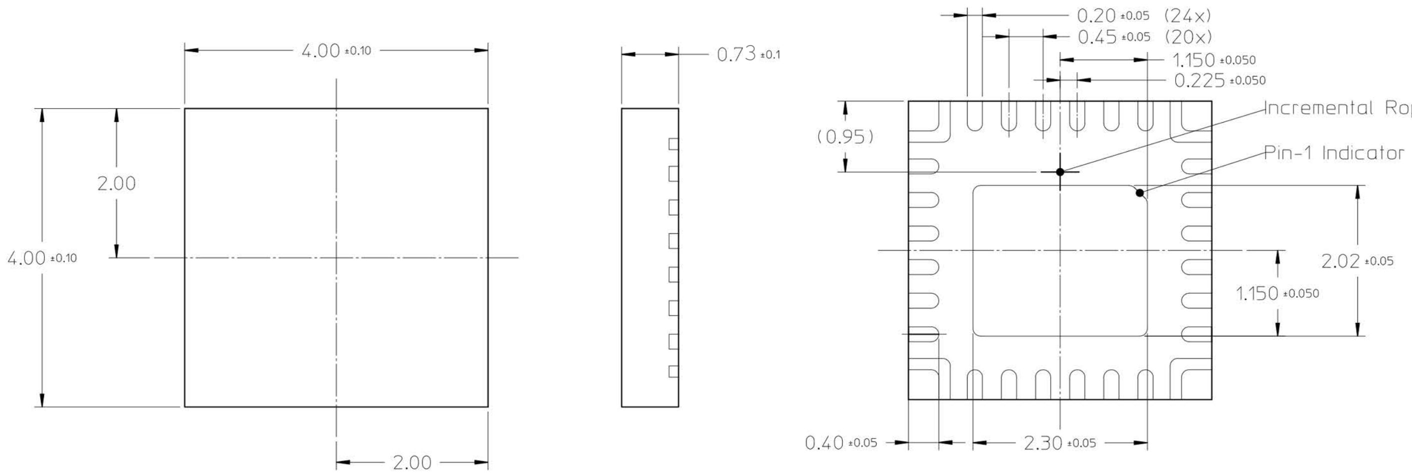
For a pseudo absolute encoder application, the multiple Index pulse can be designed into the code wheel or the code strip. The minimum index bar width is 3x the incremental pitch.

The recommended multiple Index pulse design guideline is shown in the following figure.



Example 1		**Example 2**	
LPI	= 318	CPR	= 900
Pitch	= 1inch / 318	Pitch	= 360° / 900
	≈ 80um		= 0.40°
Min Index Pitch	= 3 * 80	Min Index Pitch	= 3 * 0.40
	= 240um		= 1.20°

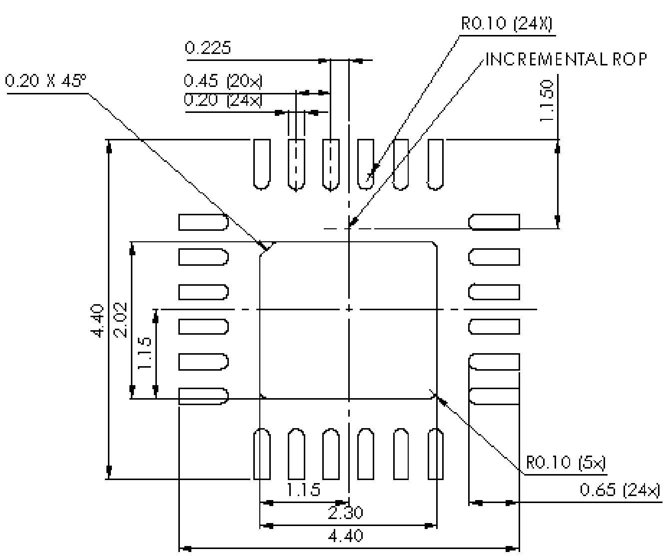
Package Outline Drawing



NOTE:

1. All dimensions are in millimeters (mm).

Recommended PCB Land Pattern



NOTE:

1. All dimensions are in millimeters (mm).
2. Tolerance is x.xx ± 0.05 mm.

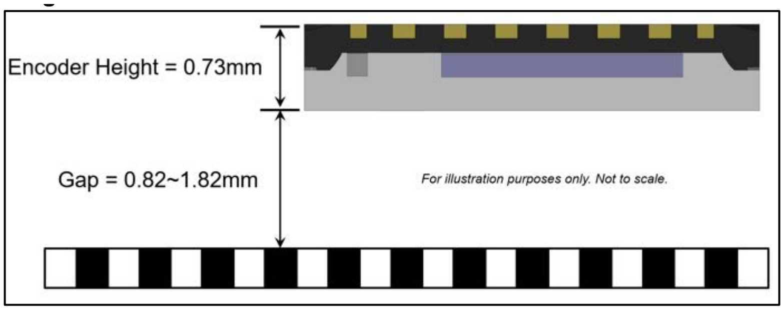
Encoder Placement Orientation, Position, and Direction of Movement

The AEDR-9830DP is designed with both the emitter and detector die placed in parallel to the code wheel window/bar orientation. The encoder package is mounted on top facing down onto the code wheel. When properly aligned, the detector side will be closer to the center of the code wheel than the emitter.

The optical center of the encoder package must be aligned tangential to the code wheel's R_{OP}. The optimal gap setting recommended is 1.32 mm, with the range of 0.82 mm to 1.82 mm.

Channel A leads Channel B when the code wheel rotates counterclockwise, and Channel B leads Channel A when the code wheel rotates clockwise.

Figure 8: Encoder Placement Orientation



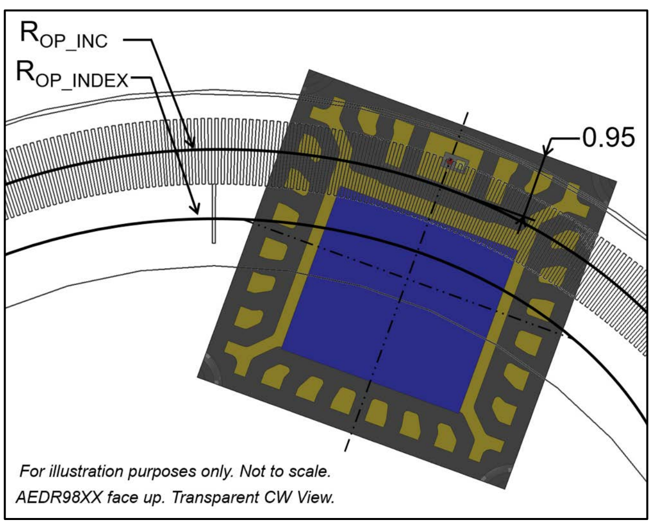
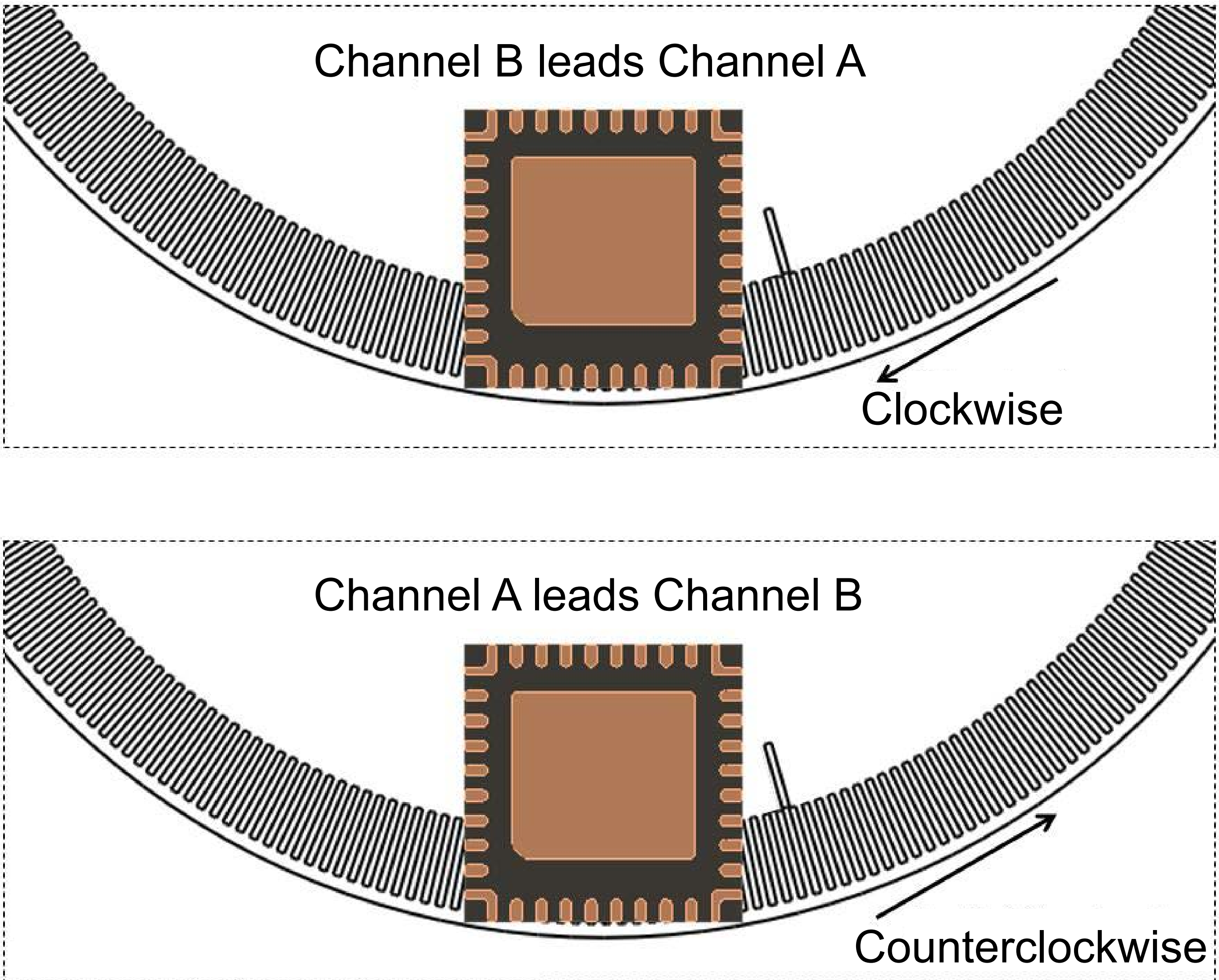


Figure 9: Channel A and Channel B Signal Output Sequence with Respect to Code Wheel Rotational Direction



NOTE: Drawings are for illustration purposes only and are not to scale.

Moisture Sensitivity Level

The AEDR-9830DP package is qualified to moisture sensitive level 3 (MSL 3). Take precautions when handling this moisture-sensitive product to ensure the reliability of the product.

Storage before use:

- Unopened moisture barrier bag (MBB) can be stored at <40°C/90% RH for 12 months.
- Open the MBB just prior to assembly.

Control after opening the MBB:

- The encoder that will be subjected to reflow solder must be mounted within 168 hours of exposure to factory conditions of <30°C/60% RH.

Control for unfinished reel:

- Store a sealed MBB with desiccant or desiccators at <5% RH.

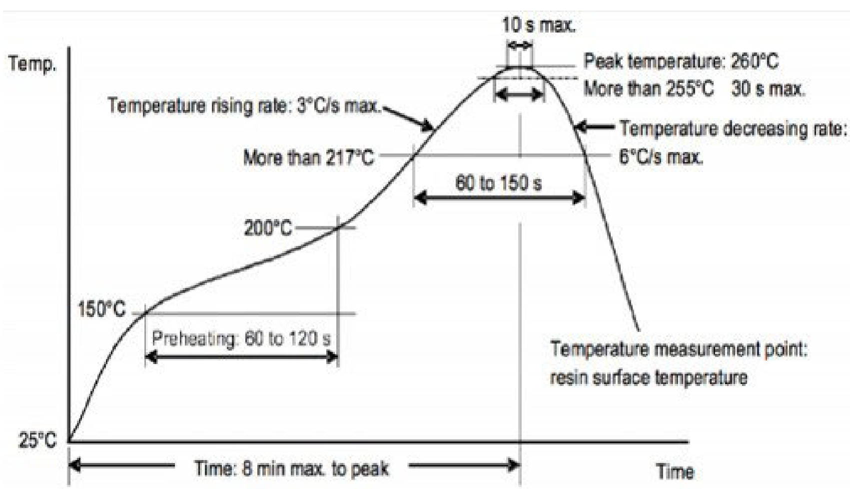
Baking is required if the following conditions exist:

- The humidity indicator card (HIC) is >10% when read at 23°C ± 5°C.
- The encoder floor life exceeded 168 hours after opening the moisture barrier bag.

Recommended baking condition:

- 40°C ± 5°C for 22 hours (tape and reel) or 125°C ± 10°C for 1hour (loose units).

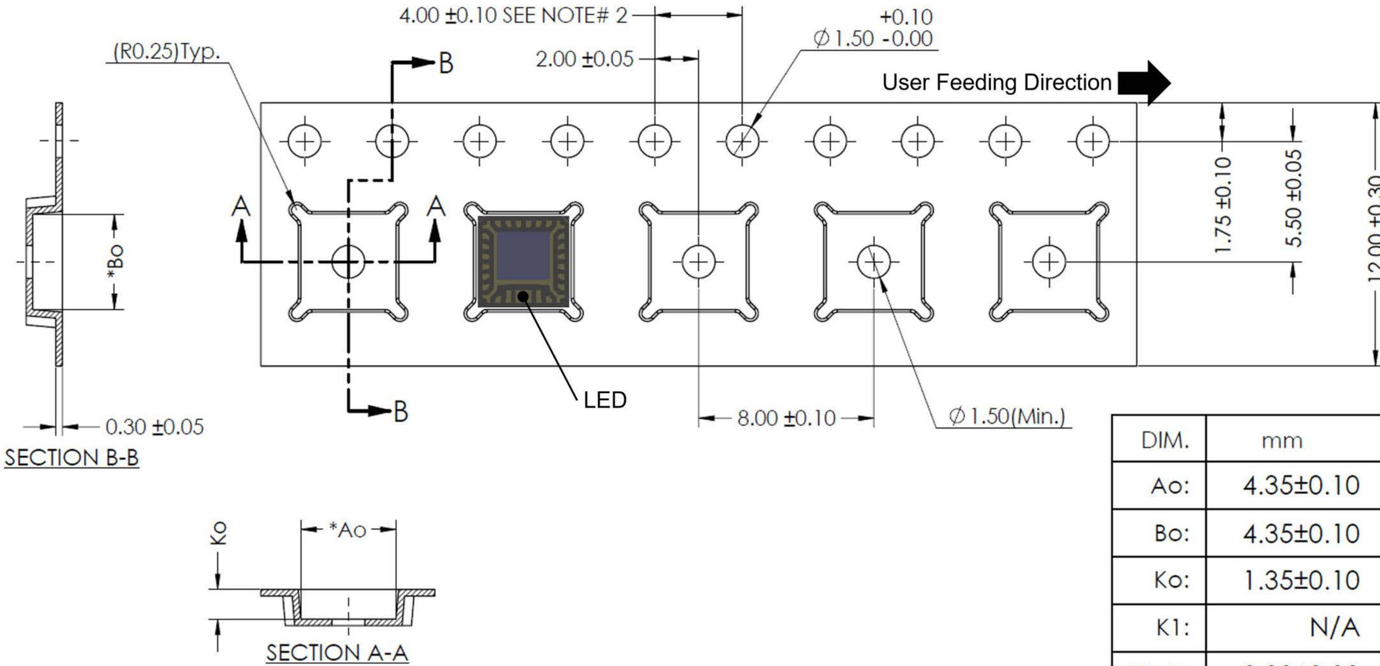
Figure 10: Typical Lead-Free Solder Reflow Profile



CAUTION! Use care when handling the encoder ASIC because it is a sensitive optical device. Gently clean the optical surface with a soft lint-free swab aided with lab grade IPA (if needed) after the reflow process and just before final assembly.

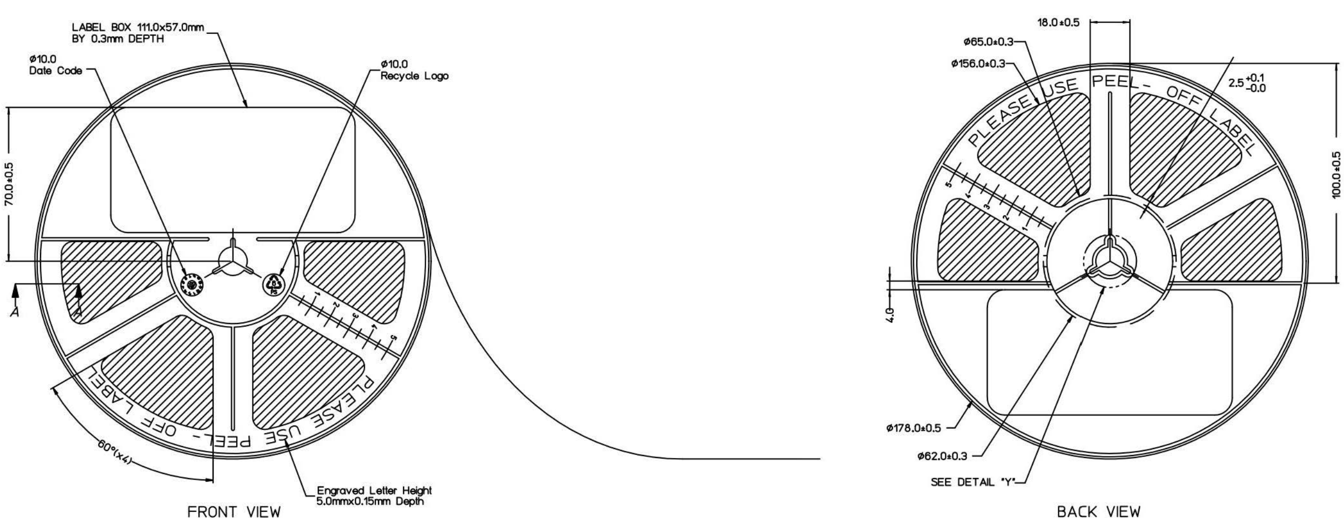
Tape and Reel Information

Figure 11: Carrier Tape Dimensions



DIM.	mm
Ao:	4.35±0.10
Bo:	4.35±0.10
Ko:	1.35±0.10
K1:	N/A
Pitch:	8.00±0.10
Width:	12.00±0.30

Figure 12: Reel Dimensions and Orientation



Ordering Information

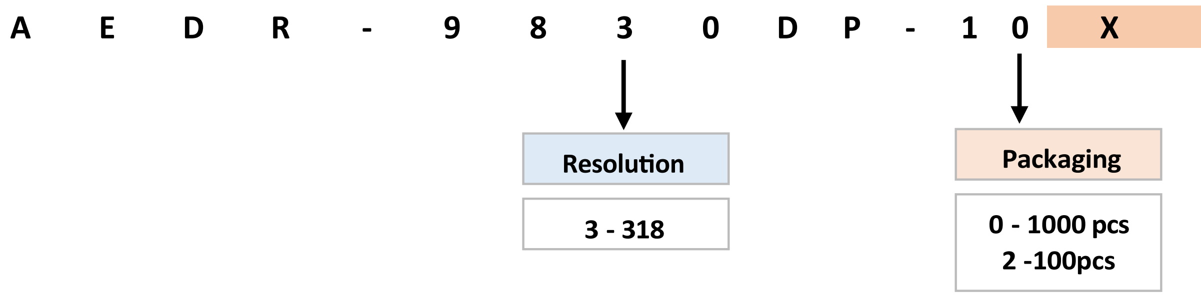


Table 2: Relevant Part Numbers and Ordering Information

Ordering Information	Type
HEDS-9830DPEVB	AEDR-9830DP Evaluation Board 318 LPI Evaluation Board and Code Wheel