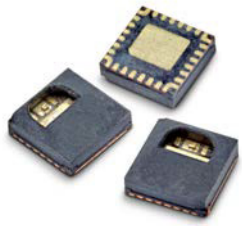
Data Sheet

AEDR-9920

Three-Channel Reflective Incremental Encoder with Programmable Interpolator Digital Output (225 LPI)



Description

The Broadcom® AEDR-9920 is a three-channel reflective optical encoder. The selectable and programmable options available are three-channel digital differential A, B, and I outputs.

The AEDR-9920 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-9920 encoder can be interfaced with most of the signal processing circuitries. Therefore, the encoder provides easy integration and flexible design-in into existing systems.

The AEDR-9920 encoder is designed to operate over –40°C to 115°C temperature range and is suitable for commercial, industrial, and automotive end applications.

The encoder houses an LED light source and a photo-detecting circuitry in a single package. The small size of 4.00 mm (L) × 4.00 mm (W) × 1.05 mm (H) allows it to be used in a wide range of miniature commercial applications, where size and space are primary concerns.

Features

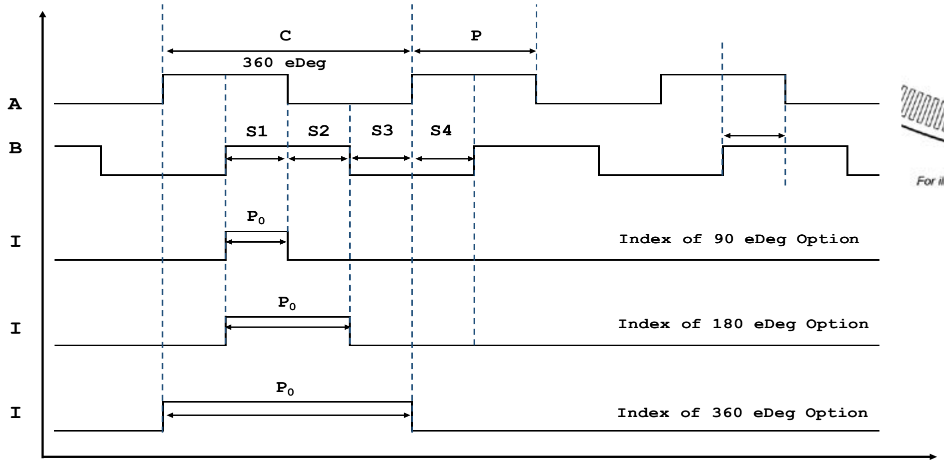
- Digital output option: three-channel differential or TTL compatible; two-channel quadrature (AB) digital outputs for direction sensing and a third channel, index digital output
- Built-in pin-selectable interpolator for 1x, 2x, 4x, 8x, 16x, 32x, 64x, 128x, and 256x interpolation
- SPI programmable interpolator from 1x to 512x
- Surface mount leadless package: 4.0 mm (L) × 4.0 mm (W) × 1.05 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: 225 LPI (lines/inch) or 8.86 LPmm (lines/mm)

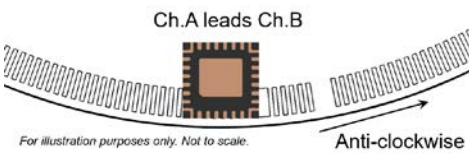
Applications

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

Output Waveform

Figure 1: Sample of Output Waveforms





Digital Parameter Definitions

Test	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 in one cycle.

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. Remove kapton tape only after 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.

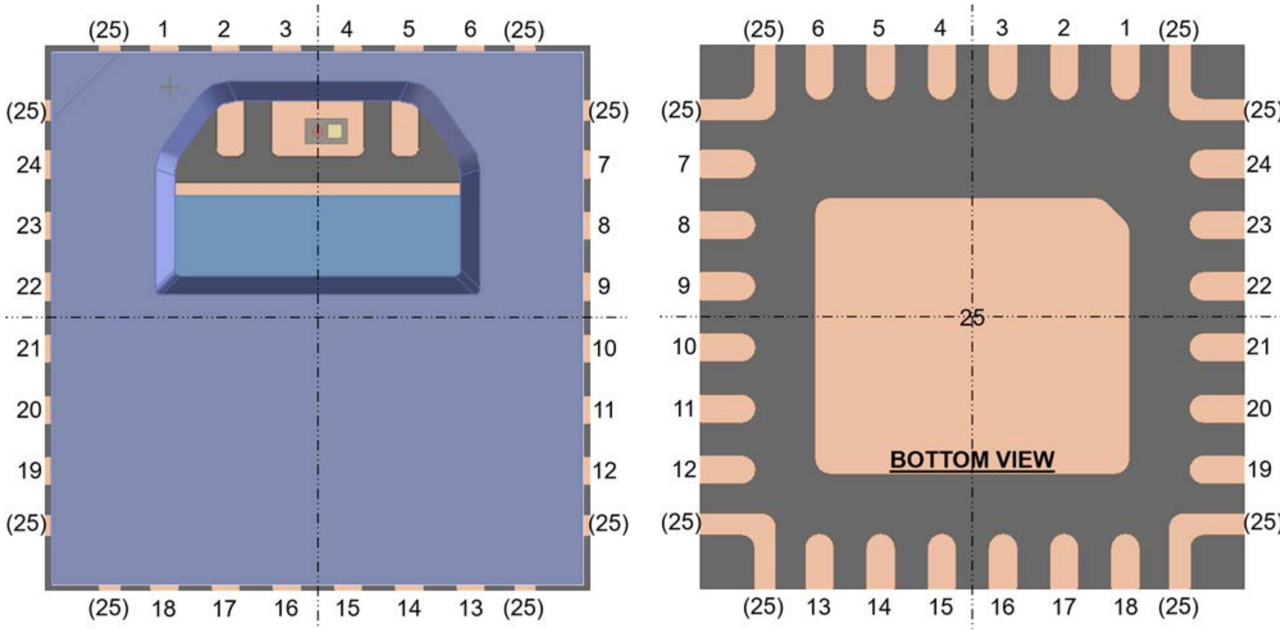
Recommended Operating Conditions

Parameter	Sym.	Min.	Typ.	Max.	Unit	Notes
Operating Temperature	T_A	–40	25	115	°C	
Supply Voltage	V_{CC}	3.0	3.3	3.6	V	Ripple < 100 mVp-p
		4.5	5	5.5		
Current	I_{CC}	—	48	85	mA	No load
Pin Current (All I/O Outputs)	I	–20	—	20	mA	
Max Output Frequency (External Pin Selectable)	F	—	—	0.2	MHz	At 1x Interpolation
		—	—	0.4	MHz	At 2x Interpolation
		—	—	0.8	MHz	At 4x Interpolation
		—	—	1.6	MHz	At 8x Interpolation
		—	—	2.0	MHz	At 16x Interpolation
		—	—	2.0	MHz	At 32x Interpolation
		—	—	2.0	MHz	At 64x Interpolation
		—	—	2.0	MHz	At 128x Interpolation
		—	—	2.0	MHz	At 256x Interpolation
Max Output Frequency (SPI Programmable)	F	—	—	2.0	MHz	At >16x Interpolation
Radial Misalignment	E_R	—	—	± 0.5	mm	
Tangential Misalignment	E_T	—	—	± 0.5	mm	
Code Wheel Gap	G	0.5	1.00	1.5	mm	

Power-Up Behavior

When AEDR-9920 is powered on, the A+, A–, B+, and B– digital outputs will be low and I+ and I– will be high until the encoder is ready.

Encoder Pinout



Pin	Name[a]	Function
1	N.C.	—
2	N.C.	—
3	LED ANODE	LED Anode
4	LED ANODE	LED Anode
5	LED CATHODE	LED Cathode
6	N.C.	—
7	LED REG	LED Regulation
8	VDDA[b]	Supply Voltage
9	VSSA[c]	Ground
10	SEL2	Mode Selection 2
11	SEL1	Mode Selection 1
12	CH_I–	Digital I-
13	N.C.	—

Pin	Name	Function
14	CH_I+ / SPI_DOUT	Digital I+ / SPI Dout
15	N.C.	—
16	N.C.	—
17	INDEX_SEL	Index Selection
18	N.C.	—
19	CH_B–/SPI_CLK	Digital B–/SPI Clk
20	CH_B+	Digital B+
21	CH_A–/SPI_DIN	Digital A–/SPI Din
22	CH_A+	Digital A+
23	VSSD[c]	Ground
24	VDD[b]	Supply Voltage
25	VSSA[c]	Ground
(25)[d]	N.C.	—

a. N.C. = No connect.

b. VDD and VDDA can be connected to the same voltage supply.

c. VSSA and VSSD ***must*** be connected together.

d. No connection to all corner pads indicated as (25).

Select Options – Encoder Built-in Interpolation

SEL 1[a]	SEL 2[a]	IND SEL	Interpolation Factor	Index	Max Output Frequency	CPR at R_{OP} 4.6 mm	CPR at R_{OP} 11.23 mm
Open	Open	Low	1X	Gated 90°e	0.2 MHz	256	625
		High		Gated 180°e			
		Open		Ungated raw			
Open	Low	Low	2X	Gated 90°e	0.4 MHz	512	1250
		High		Gated 180°e			
		Open		Gated 360°e			
High	High	Low	4X	Gated 90°e	0.8 MHz	1024	2500
		High		Gated 180°e			
		Open		Gated 360°e			
Low	Low	Low	8X	Gated 90°e	1.6 MHz	2048	5000
		High		Gated 180°e			
		Open		Gated 360°e			
High	Low	Low	16X	Gated 90°e	2.0 MHz	4096	10000
		High		Gated 180°e			
		Open		Gated 360°e			
Open	High	Low	32X	Gated 90°e	2.0 MHz	8192	20000
		High		Gated 180°e			
		Open		Gated 360°e			
Low	High	Low	64X	Gated 90°e	2.0 MHz	16384	40000
		High		Gated 180°e			
		Open		Gated 360°e			
High	Open	Low	128X	Gated 90°e	2.0 MHz	32768	80000
		High		Gated 180°e			
		Open		Gated 360°e			
Low	Open	High	256x or SPI Mode Output[b]	Gated 90°e or SPI Mode Output[c]	2.0 MHz	65536	160000
		Low	SPI Mode[d]	SPI Mode: Program Selection	NA	NA	NA

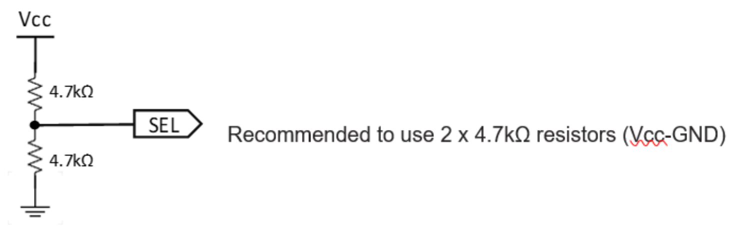
a. Open selection must be connected to middle of a voltage divider circuit.

b. Factory default = 256x ABI output; SPI Mode Output = AB interpolation based on Interpolation, Index (90°e, 180°e, and 360°e) Setting and Programming settings.

c. Factory default = 90°e output; SPI Mode Output = Index width based on Interpolation, Index (90°e, 180°e, and 360°e) Setting and Programming settings.

d. SPI Mode = Enable SPI communication.

Figure 2: Example of Voltage Divider Circuit



The digital interpolation factor above can be 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 = LP mm × 2π × R_{OP} (mm)

NOTE: LPmm (lines per mm) = LPI / 25.4

Programmable Select Options

The AEDR-9920 digital encoder features an SPI programmable interpolator with a factor from 1x to 512x.

1. Configure external selection to SPI Mode: Program Selection.
2. For signals output after configuration, set external selection to SPI Mode: Output Enabled.

SPI Communication Pinout (for Programming Interpolation Settings)

Table 1: SPI Protocol Pinout

Pin	Name	Function
14	SPI DOUT	SPI Data Output
21	SPI DIN	SPI Data Input
19	SPI CLK	SPI Clock

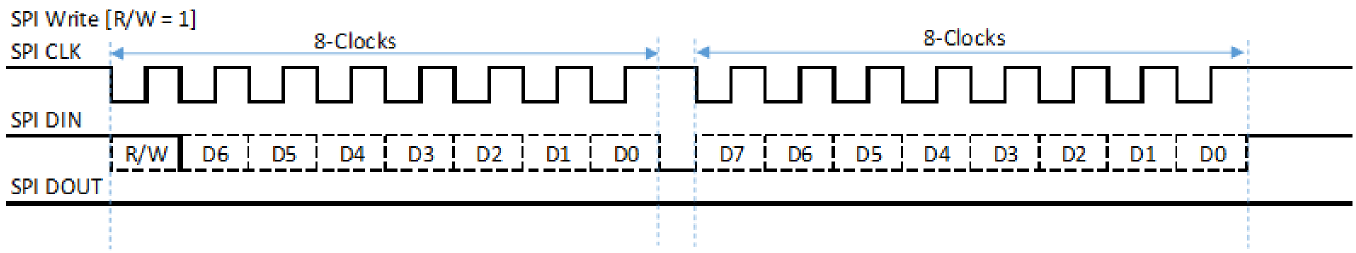
SPI Read and Write Timing Diagram (Maximum Clock Frequency 1 MHz)

Table 2: SPI Read and Write Memory Map

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	Address[6:0]							Data[7:0]							
Write	1	Address[6:0]							Data[7:0]							

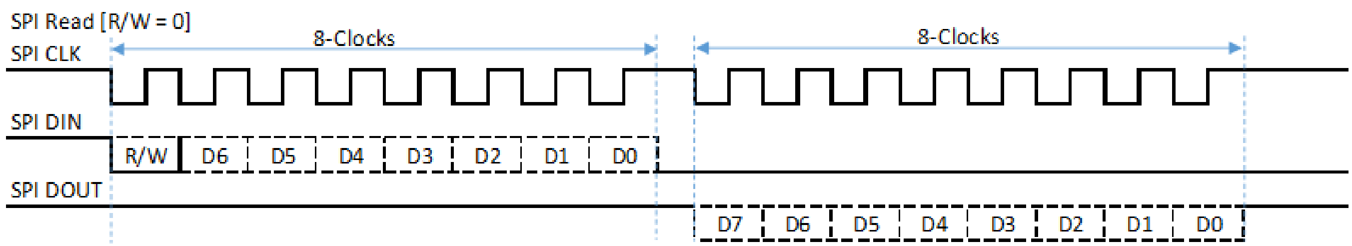
SPI Write: <Write Command = 1><7bits address><8bits data>

Figure 3: SPI Write Timing Diagram



SPI Read: <Read Command = 0><7bits address>

Figure 4: SPI Read Timing Diagram



Unlock Sequence

1. Write to SPI Address 0x10 with value AB (Hex) to unlock Level 1.
2. Write to SPI Address 0x14 with value 00 (Hex) to go to Page 0.

Interpolation, Index (90°e, 180°e, and 360°e) Setting and Programming

1. Write to SPI Address 0x0B and 0x0C with the value shown in the following tables.
2. After finalizing the CPR settings in the following tables, write to SPI Address 0x11 (Hex) with a value A1 (Hex) to program EEPROM.

Byte Address	Page	Bit								Note
[hex]		7	6	5	4	3	2	1	0	
0x0B	0			Index [1:0]				INT [9:8]		INT: 0-512
0x0C		INT [7:0]								

Interpolation Index, 90°e	0x0B (HEX)	0x0C (HEX)
1x	00	01
2x	00	02
.	.	.
.	.	.
10x	00	0A
11x	00	0B
.	.	.
.	.	.
256x	01	00
.	.	.
.	.	.
512x	02	0

Interpolation Index, 180°e	0x0B (HEX)	0x0C (HEX)
1x	10	1
2x	10	2
.	.	.
.	.	.
10x	10	0A
11x	10	0B
.	.	.
.	.	.
256x	11	0
.	.	.
.	.	.
512x	12	0

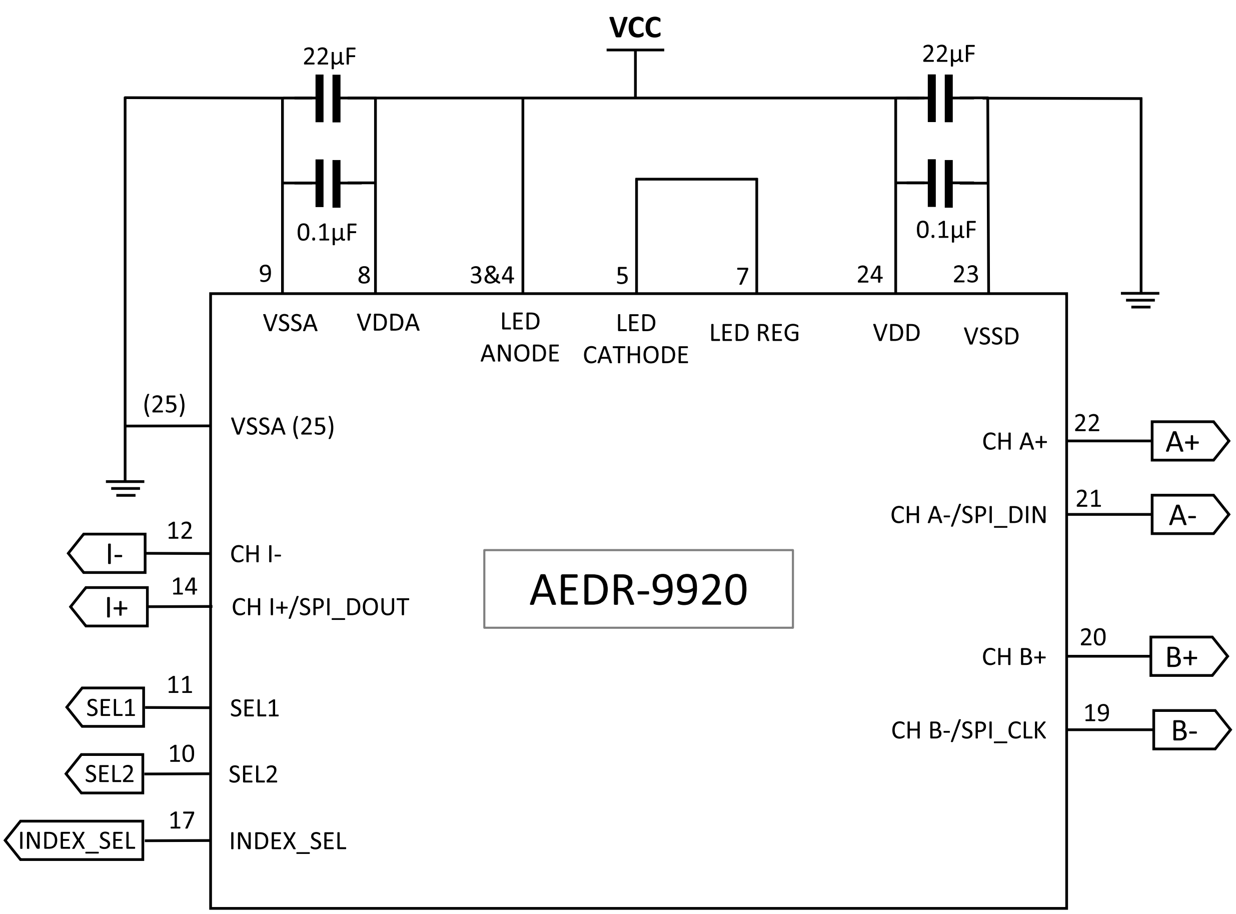
Interpolation Index, 360°e	0x0B (HEX)	0x0C (HEX)
1x	30	1
2x	30	2
.	.	.
.	.	.
10x	30	0A
11x	30	0B
.	.	.
.	.	.
256x	31	0
.	.	.
.	.	.
512x	32	0

Recommended Setup for the Power Supply Pins and General Routing

Both VDDA, VDD, and the respective grounds (VSSA and VSSD) are to be connected as shown in Figure 5. Be sure to 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.
- Design separate VDD and VDDA traces from a common input.
- Design separate VSSD and VSSA traces from a common input.
- Minimize trace or cable length where possible.

Figure 5: Reference Schematic Diagram for AEDR-9920



NOTE:

1. Pin 25 is the center pad of the package and is designated as AGND.
2. See the table in Select Options – Encoder Built-in Interpolation for SEL1X, SEL2X, and IND SEL configuration.
3. VDDA and VDD ***must*** be the same voltage level.
4. VSSA and VSSD ***must*** be connected together.

Digital Encoder Characteristics (Code Wheel of R_{OP} at 4.6 mm)

Parameter		Dynamic Performance[a]									Unit
		Typical[b]									
Interpolation Factor	Symbol	1X	2X	4X	8X	16X	32X	64X	128X	256X	
Cycle Error	ΔC	±5	±15	±20	±25	±30	±35	±40	±57	±60	°e
Pulse Width (Duty) Error	ΔP	±5	±10	±15	±15	±20	±25	±38	±45	±45	°e
Phase Error	Δϕ	±2	±7	±9	±11	±15	±28	±30	±33	±35	°e
State Error	ΔS	±3	±7	±9	±11	±25	±28	±40	±43	±45	°e
Index Pulse Width (Gated 90°)	P_O	90									°e
Index Pulse Width (Gated 180°)	P_O	180									°e
Index Pulse Width (Gated 360°)	P_O	NA	360								°e
Index Pulse Width (Raw Ungated)	P_O	330	NA								°e

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

b. Typical values represent the average value of the encoder performance based on the factory setup conditions at 2-MHz frequency.

Electrical Characteristics

Characteristics over recommended operating conditions at 25°C.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Notes
High Level Output Voltage	V_{OH}	2.4	—	—	V	IOH = –20mA
Low Level Output Voltage	V_{OL}	—	—	0.4	V	IOH = +20 mA
Output Current Per Channel	I_O	—	—	20	mA	
Rise Time	t_r	—	<50	—	ns	CL ≤ 50 pF
Fall Time	t_f	—	<50	—	ns	

Code Wheel Characteristics

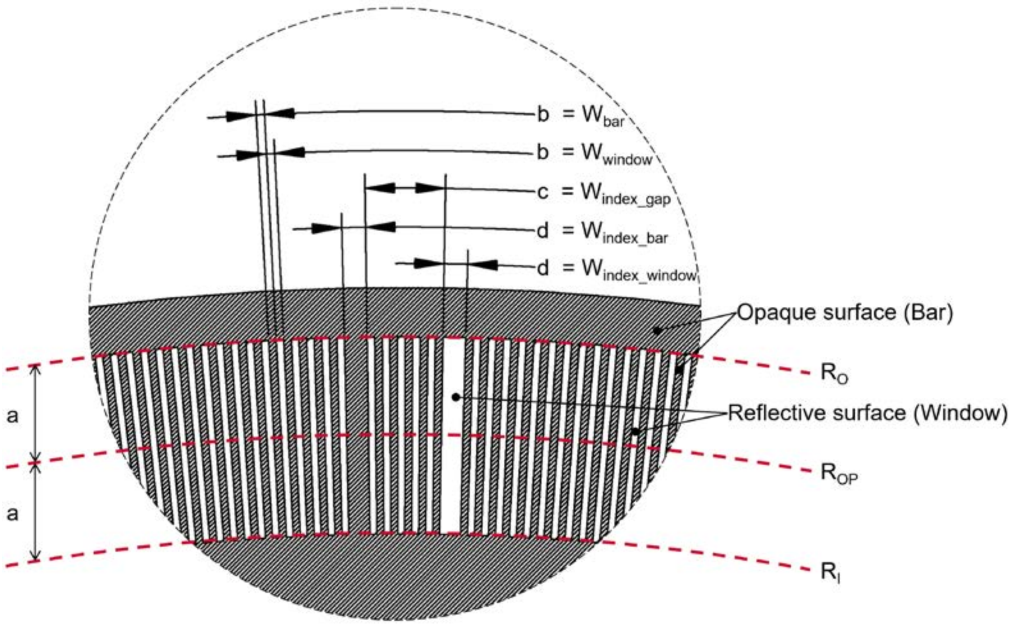
Characteristics are based on a Broadcom-qualified code wheel supplier. Contact Broadcom for information regarding qualified reflective code wheel suppliers.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Notes
Specular Reflectance	R_f	60%	—	—	—	Reflective area
		—	—	5%	—	Non-reflective area
LED Peak Wavelength	λ_p	—	853	—	nm	

Code Wheel Design Guidelines

- The incremental and index window tracks are reflective surfaces and the window width is denoted by W_{window} and W_{index_window} respectively.
- The incremental and index bar tracks are opaque surfaces and the bar width is denoted by W_{bar} and W_{index_bar} respectively.
- There is only one index window track and one index bar track; while the number of incremental window and bar tracks depend on the CPR.
- All incremental window and bar tracks have the same width value, b°.
- Both index window and bar tracks have the same width value, d°.
- There are five pairs of incremental tracks (1 pair = 1 W_{window} and 1 W_{bar}) between index window and bar track, which denoted by c°.
- The W_{window}/W_{bar} ratio is recommended to be within a range of 0.95 to 1.05.
- Reflectance of window and bar surface is 60% and 5%, respectively.

Figure 6: Code Wheel Design



NOTE: Code wheel facing up. Encoder placed on top of Code Wheel in this view.

Dimension	Formula	225LPI
a (mm)	$R_O - R_{OP}$ or $R_{OP} - R_i$	0.550
b (°)	(360/CPR)/2	—
c (°)	10 × b	—
d (°)	3 × b	—

Code Wheel Design Example

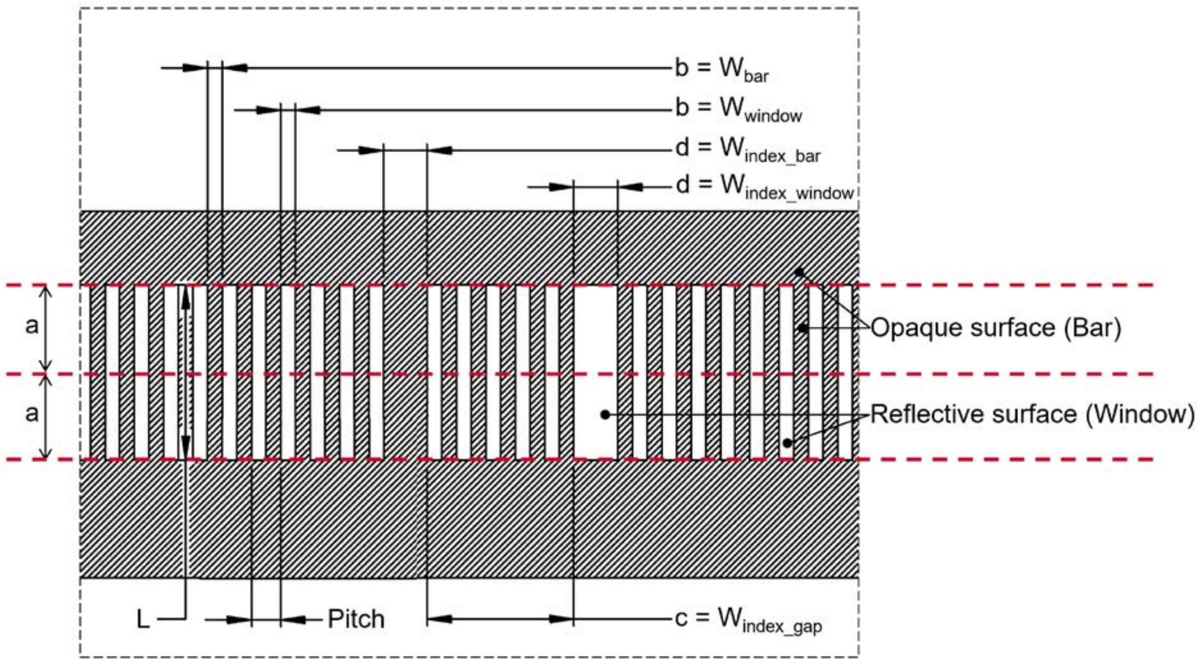
The following demonstrates a code wheel design for 225LPI at 256 CPR.

Determine R_{OP}:	(25.4/225) × (256/2π)	= 4.600 mm
Determine R_O:	4.600 + 0.550	= 5.150 mm
Determine R_I:	4.600 – 0.550	= 4.050 mm
Determine W_{window} and W_{bar}:	(360 / 256) / 2	= 0.703°
Determine W_{index_gap}:	10 × b	= 7.030°
Determine W_{index_window} and W_{index_bar}:	3 × b	= 2.109°

Code Strip Design Guideline

- The incremental and index window tracks are reflective surfaces and the window width is denoted by W_{window} and W_{index_window} respectively.
- The incremental and index bar tracks are opaque surfaces and the bar width is denoted by W_{bar} and W_{index_bar} respectively.
- All incremental window and bar tracks have the same width value, b.
- Both index window and bar tracks have the same width value, d.
- There are 5 pairs of incremental tracks (1 pair = 1 W_{window} and 1 W_{bar}) between index window and bar track, which denoted by c.

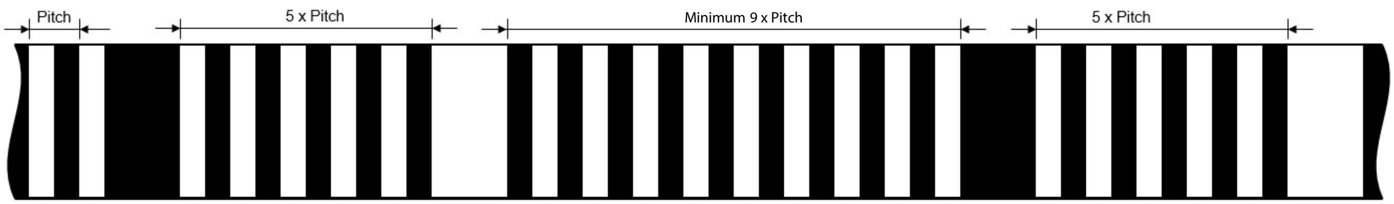
Figure 7: Code Strip Design



NOTE: Code wheel facing up. Encoder placed on top of Code Wheel in this view.

Dimension	Formula	225LPI
Pitch (mm)	25.4/LPI	0.113
a (mm)	L/2	0.550
b (mm)	Pitch/2	0.056
c (mm)	5 × Pitch	0.564
d (mm)	Pitch × 3/2	0.169

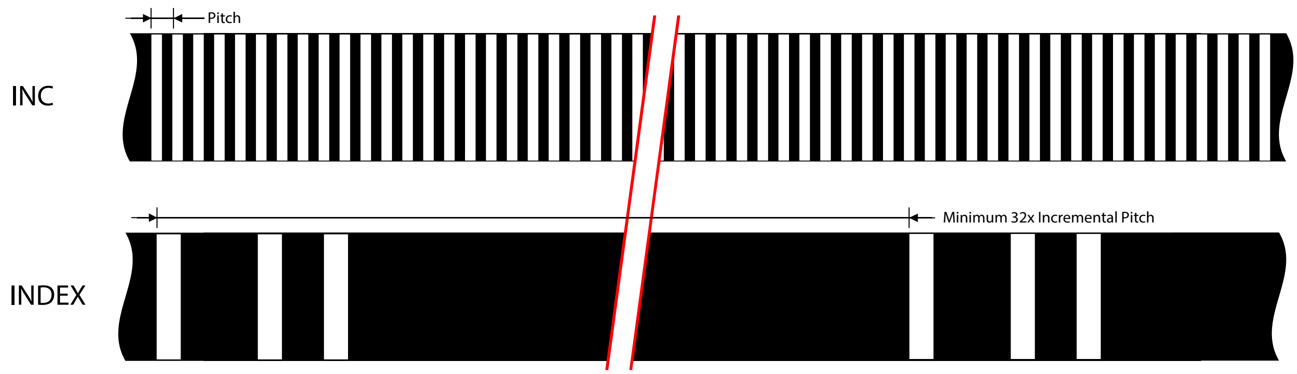
AEDR-9920 Pseudo ABS Recommendation



NOTE:
1. Code wheel facing up. Encoder placed on top of Code Wheel in this view.
2. Sketch is for illustration purposes only. Not to scale.

Example 1		Example 2	
LPI	= 225	CPR	= 400
Pitch	= 1 in. / 225	Pitch	= 360° / 400
	≈ 113 µm		= 0.90°
Min Index Pitch	= 9 × 113	Min Index Pitch	= 9 × 0.90
	= 1017 µm		= 8.10°

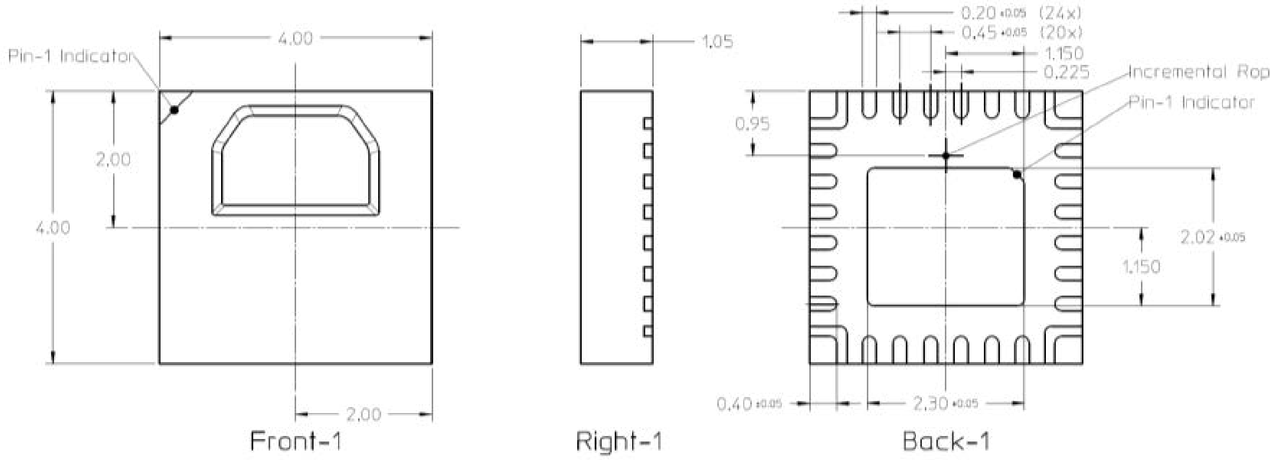
AEDR-9930 Pseudo ABS Recommendation



NOTE:
1. Code wheel facing up. Encoder placed on top of Code Wheel in this view.
2. Sketch is for illustration purposes only. Not to scale.

Example 1		Example 2	
LPI	= 397	CPR	= 400
Pitch	= 1 in. / 397	Pitch	= 360° / 400
	≈ 64 µm		= 0.90°
Min Index Pitch	= 32 × 64	Min Index Pitch	= 32 × 0.90
	= 2048 µm		= 28.80°

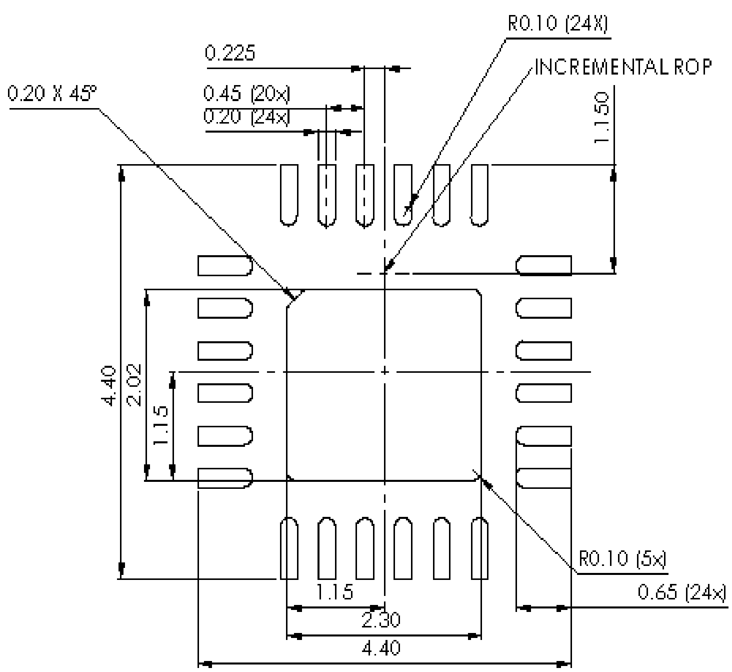
Package Outline Drawing



NOTE:

1. All dimensions are in millimeters (mm).
2. Unless otherwise specified, tolerance is x.xx ± 0.15 mm.
3. Package tolerances are not a factor in mechanical misalignment (radial and tangential) stack up.

Recommended Land Pattern



NOTE:

1. All dimensions are in millimeters (mm).
2. Unless otherwise specified, tolerance is x.xx ± 0.05 mm.

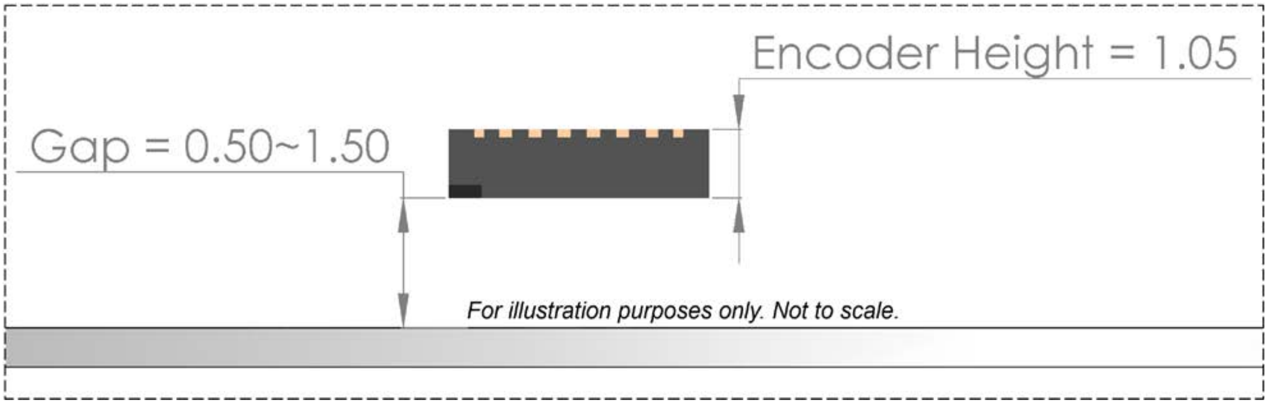
Encoder Placement Orientation, Position, and Direction of Movement

The AEDR-9920 is designed with both the emitter and detector dice placed in parallel to code wheel window/bar orientation. The encoder package mounted on top facing down onto code wheel. When properly aligned, the detector side will be closer to the center of 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 1.00 mm, with the range of 0.50 mm to 1.50 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



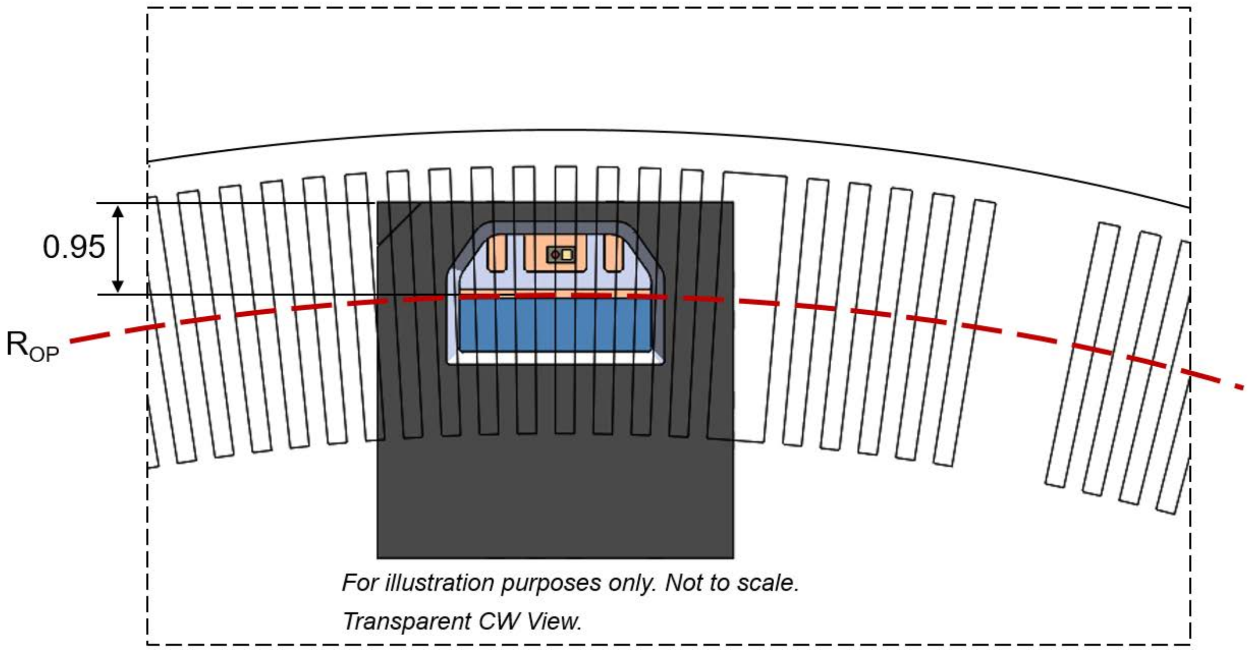
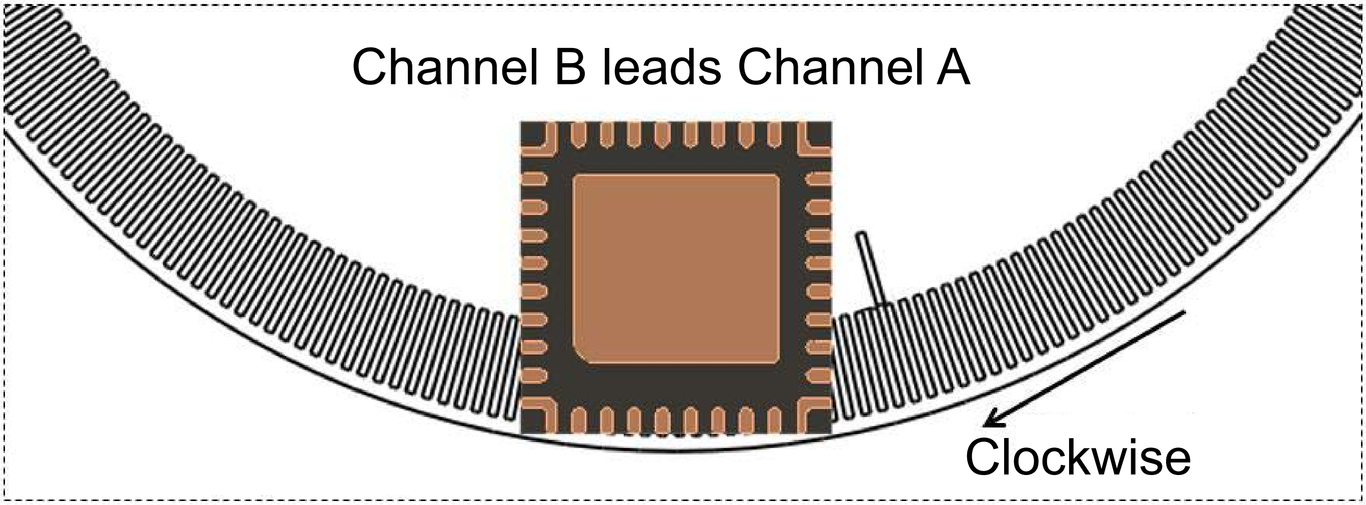
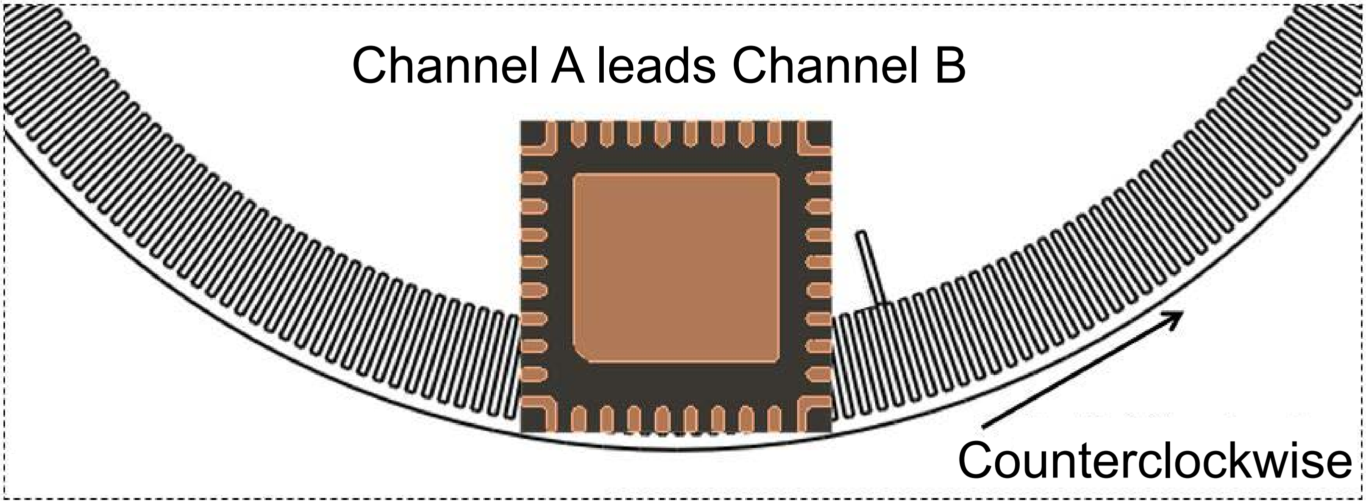


Figure 9: Channel A and Channel B Signal Output Sequence with Respect to Code Wheel Rotational Direction





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

Moisture Sensitivity Level

The AEDR-9920 package is specified to moisture sensitive level 3 (MSL 3). Precaution is required to handle 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 soldering 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.

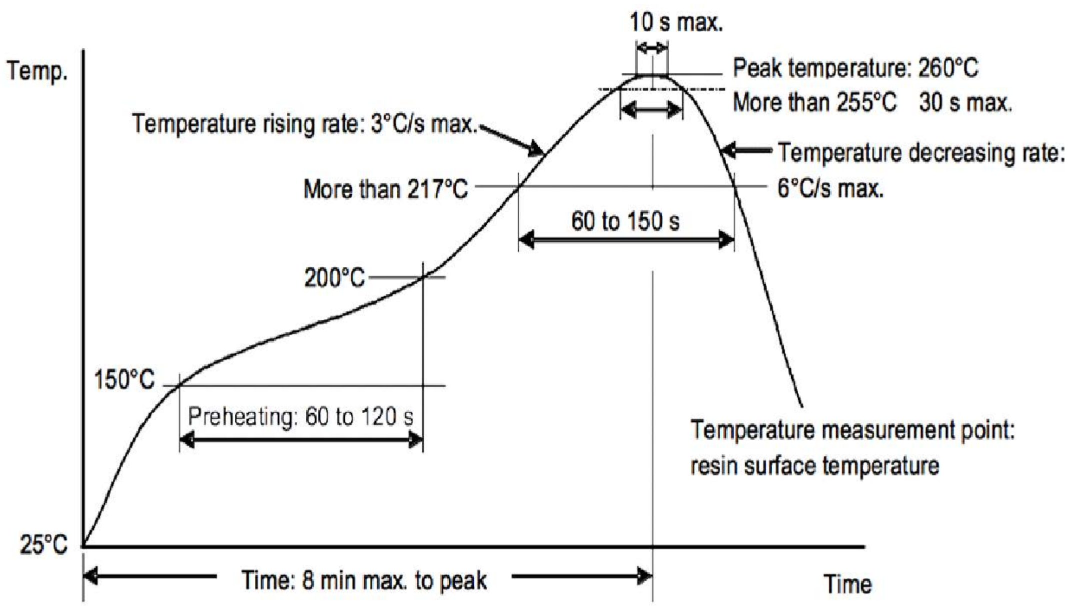
Baking is required if the following conditions exist:

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

Recommended baking condition:

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

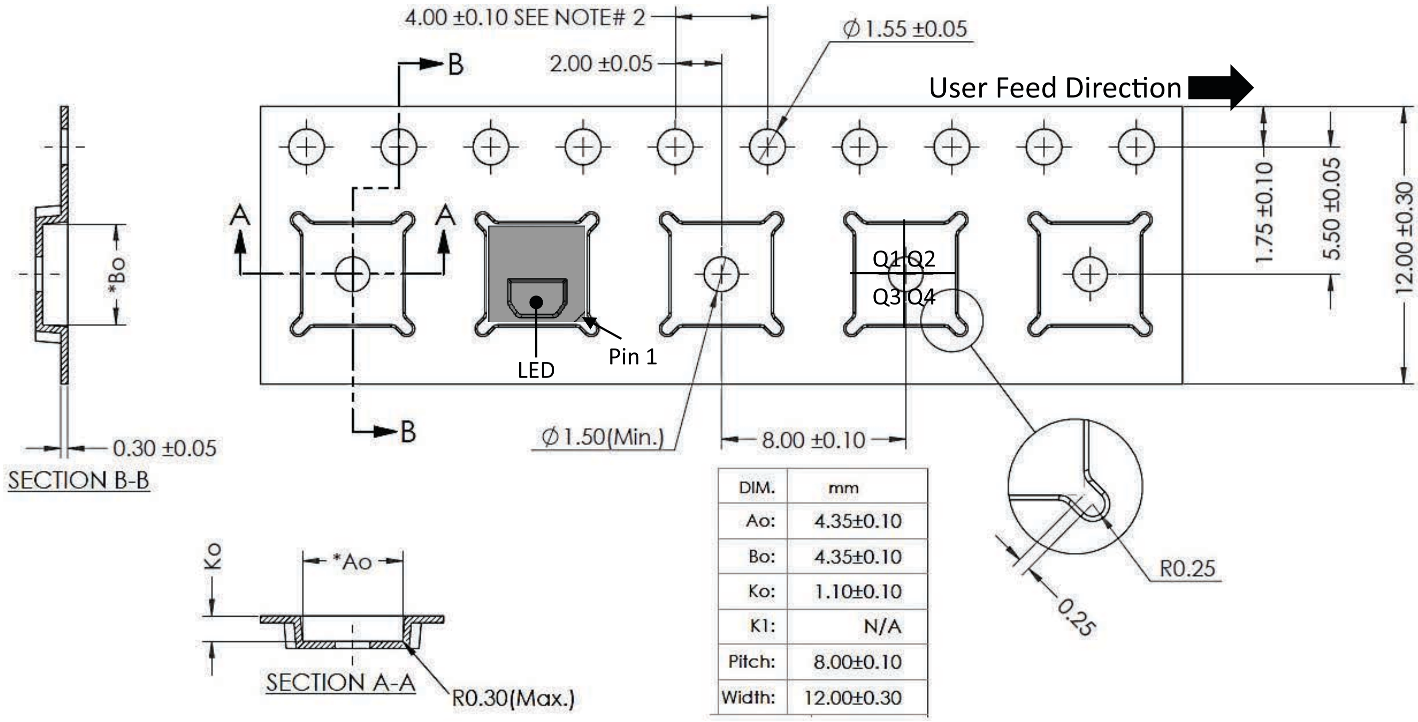
Figure 10: Typical Lead-Free Solder Reflow Soldering Temperature Profile



CAUTION! Use care when handling the encoder ASIC because it is a sensitive optical device. Remove the protective kapton tape only after the reflow process and just before final assembly.

Tape and Reel Information

Figure 11: Tape and Reel



DIM.	mm
Ao:	4.35±0.10
Bo:	4.35±0.10
Ko:	1.10±0.10
K1:	N/A
Pitch:	8.00±0.10
Width:	12.00±0.30

Figure 12: Tape Dimensions

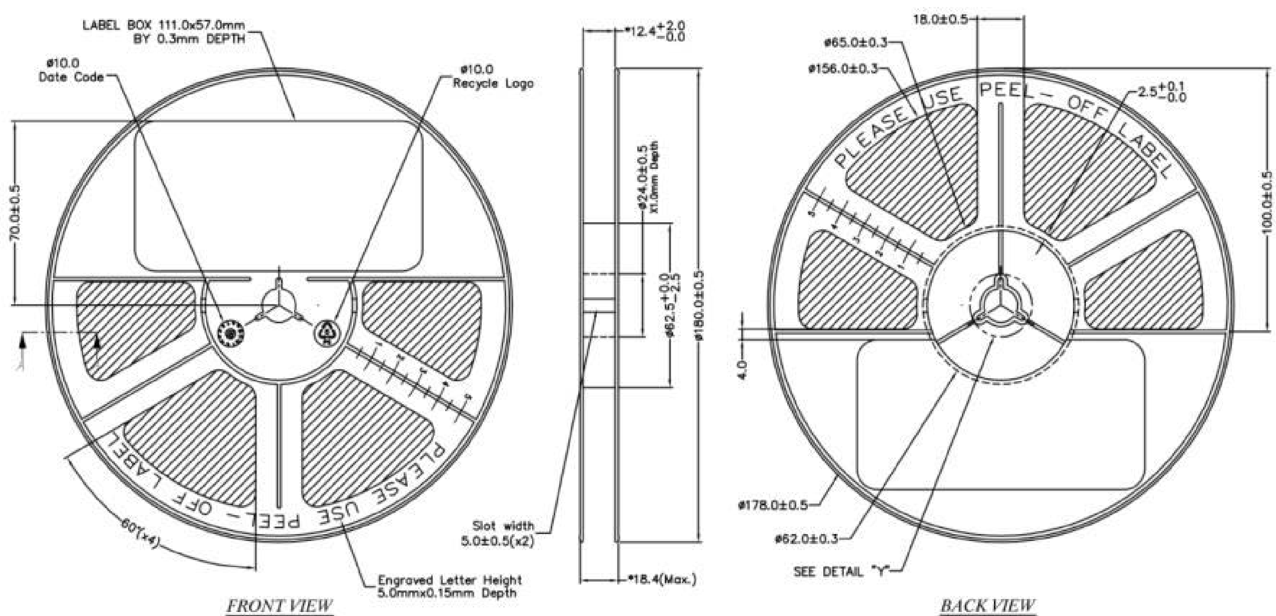
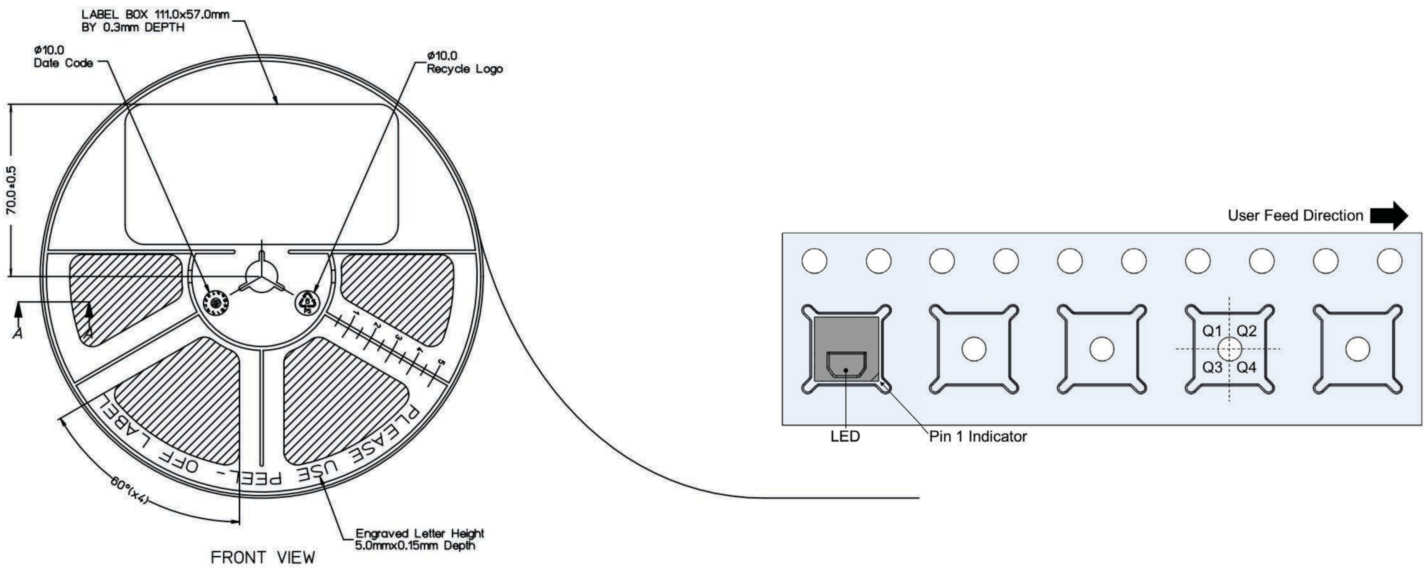


Figure 13: Reel Orientation



Ordering Information

A E D R - 9 9 2 0 - 1 0 X

Resolution

2 - 225

Packaging

0 - 1000 pcs
2 - 100 pcs