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BROADCOM®

Data Sheet

# AEDR-9820A

## Three-Channel Reflective Incremental Encoders with Analog and Digital Output (225 LPI)



## Description

The Broadcom® AEDR-9820A is a three-channel reflective optical encoder. It can be configured to analog or digital outputs using reflective technology for motion control purposes. The selectable options available are two-channel differential analog with a third channel differential digital or analog index output or three-channel digital differential A, B, and I output.

The AEDR-9820A in analog encoder mode with two-channel differential analog outputs (Sin, /Sin, Cos, /Cos) can be interfaced directly with external interpolators.

The AEDR-9820A 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-9820A encoder can be interfaced with most of the signal processing circuitries. Therefore, the encoder provides easy integration into, and flexible design for, existing systems.

The AEDR-9820A encoder is designed to operate over a –40°C to 125°C temperature range and is suitable for commercial, industrial, and automotive end applications.

The encoder houses an infrared LED light source and 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

- 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) × 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 125°C
- High encoding resolution: 225 LPI (lines/in.) or 8.86 LPmm (lines/mm)
- Qualified automotive standard AEC-Q100 Grade 1

## Applications

- Closed-loop stepper motors
- Small motors, actuators
- Industrial printers
- Robotics
- Light detection and ranging (LiDAR)
- Pan-tilt-zoom camera
- Automated guided vehicles (AGVs)
- Optometric equipment
- Linear stages

**Disclaimer:** Except as expressly indicated in writing, the component is not designed or warranted to be suitable for use in safety-related applications where its failure or malfunction can reasonably be expected to result in injury, death, or severe equipment damage. Customers are solely responsible for determining the suitability of this product for its intended application and solely liable for all loss, damage, expense or liability in connection with such use.

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# Output Waveform

**Figure 1: Analog Output Option**

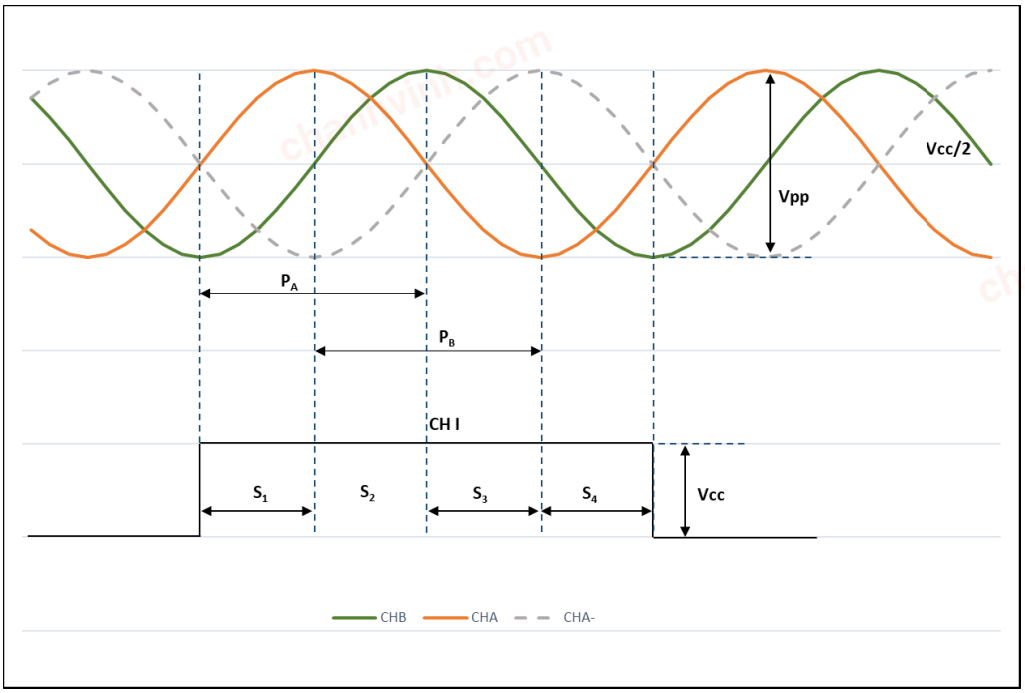
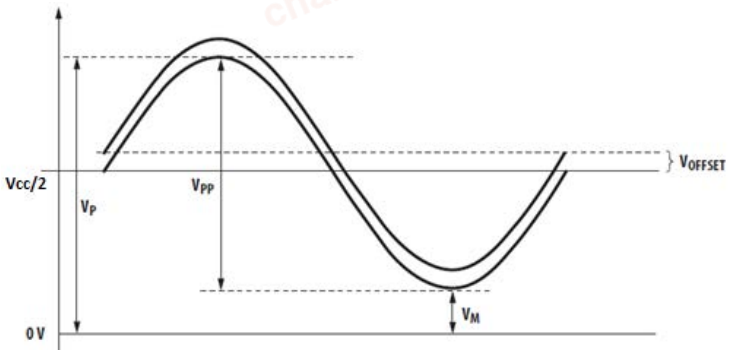



**Figure 2: Code Wheel Rotation Movement (Counterclockwise)**




# Analog Parameter Definitions

| Test | Parameter | Definition |
|---|---|---|
| Analog Peak-to-Peak | Vpp | 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 | $V_{PA}$, $V_{PB}$<br>$V_{MA}$, $V_{MB}$ | 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 |

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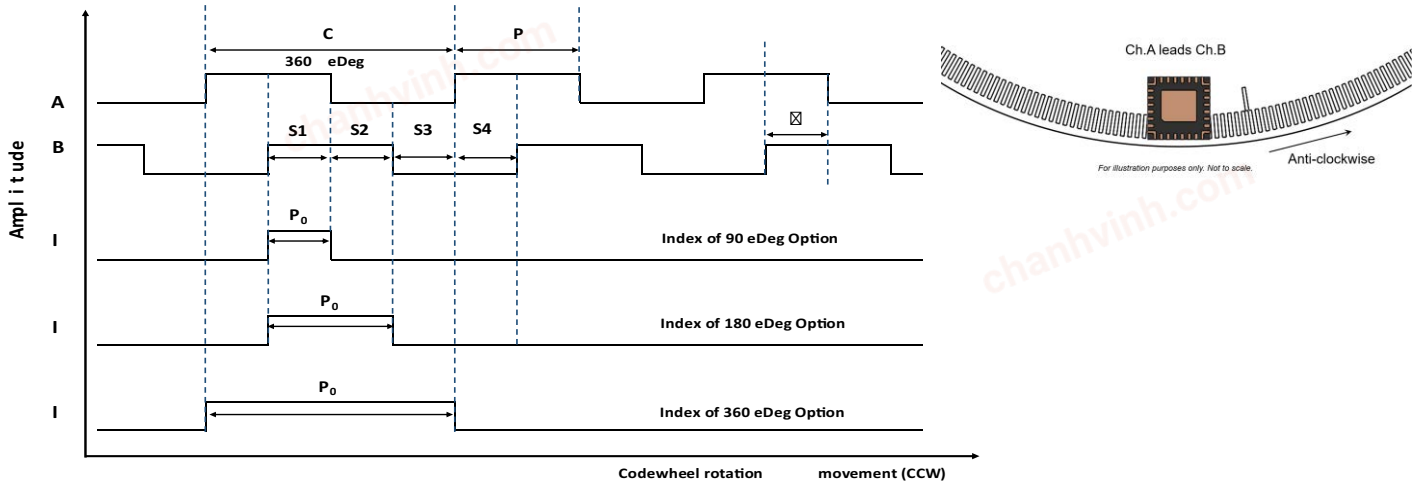
# Digital Output Option

**Figure 3: Sample of Output Waveforms**




**Quadrature Signals A, B, and I**

# 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.<br>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 four 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. |

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# Absolute Maximum Ratings

| Parameter | Symbol | Value |
|---|---|---|
| Storage Temperature | $T_S$ | –40°C to 150°C |
| Operating Temperature | $T_A$ | –40°C to 125°C |
| Supply Voltage | $V_{CC}$ | 7V |
| ESD Human Body Model | — | 4000V |
| ESD Charge Device Model | — | 1000V |

**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 may be present on the surface of the encoder ASIC surface. The presence of these particles do not degrade the performance of the encoder.

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

# Recommended Operating Conditions

| Parameter | Symbol | Min. | Typ. | Max. | Units | Notes |
|---|---|---|---|---|---|---|
| Operating Temperature | $T_A$ | –40 | 25 | 125 | °C | |
| Supply Voltage | $V_{CC}$ | 2.97 | 3.3 | 3.63 | V | Ripple < 100 mVp-p |
| | | 4.5 | 5 | 5.5 | | |
| Current | $I_{CC}$ | — | 30 | 65 | mA | No load |
| Pin Current (All I/O Outputs) | I | –20 | — | 20 | mA | |
| Maximum Output Frequency | F | — | — | 200 | kHz | At 1x interpolation |
| | | — | — | 400 | kHz | At 2x interpolation |
| | | — | — | 800 | kHz | At 4x interpolation |
| | | — | — | 1.6 | MHz | At 8x interpolation |
| | | — | — | 2 | MHz | At 16x interpolation |
| Radial Misalignment | $E_R$ | — | — | ± 0.2 | mm | |
| Tangential Misalignment | $E_T$ | — | — | ± 0.2 | mm | |
| Tilt Misalignment | $E_\theta$ | — | — | ± 2.0 | ° | |
| Code Wheel Gap | G | 0.5 | 1.00 | 1.5 | mm | |

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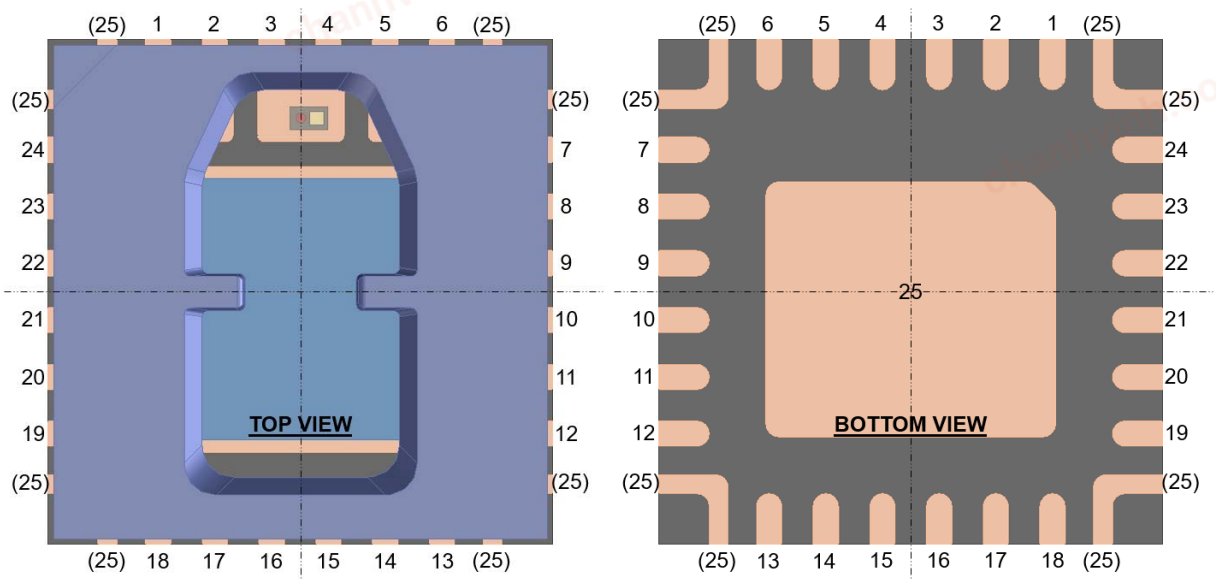
# Power-Up Behavior

When the AEDR-9820A is powered on, the A, B, and I digital outputs are invalid until after the initial first state of either Ch A or Ch B signal.

# Encoder 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 | — |
| 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.

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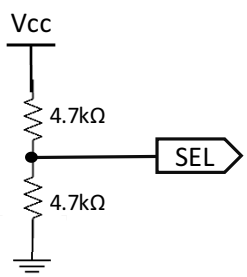
# Select Options – Encoder Built-In Interpolation

| SEL 1[a] | SEL 2[a] | IND SEL | Interpolation Factor | Index | Maximum Output Frequency | CPR at ROP 4.6 mm | CPR at ROP 11 mm |
|---|---|---|---|---|---|---|---|
| Open | Open | Low | 1X | Gated 90°e | 200 kHz | 256 | 612 |
| | | High | | Gated 180°e | | | |
| | | Open | | Ungated raw | | | |
| Open | Low | Low | 2X | Gated 90°e | 400 kHz | 512 | 1224 |
| | | High | | Gated 180°e | | | |
| | | Open | | Gated 360°e | | | |
| High | High | Low | 4X | Gated 90°e | 800 kHz | 1024 | 2448 |
| | | High | | Gated 180°e | | | |
| | | Open | | Gated 360°e | | | |
| Low | Low | Low | 8X | Gated 90°e | 1.6 MHz | 2048 | 4896 |
| | | High | | Gated 180°e | | | |
| | | Open | | Gated 360°e | | | |
| High | Low | Low | 16X | Gated 90°e | 2.0 MHz | 4096 | 9792 |
| | | High | | Gated 180°e | | | |
| | | Open | | Gated 360°e | | | |
| Open | High | N/A | Analog (500 mVpp) | Analog | 200 kHz | N/A | N/A |
| Low | High | N/A | Analog 1 Vpp | Ungated Digital | | | |
| High / Low | Open | N/A | Analog 1 Vpp | Analog | | | |

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

**Figure 4: Example of Voltage Divider Circuit**




**NOTE:** Recommended to use 2 × 4.7-kΩ resistors ($V_{CC}$-GND).

The digital interpolation factor above may 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.

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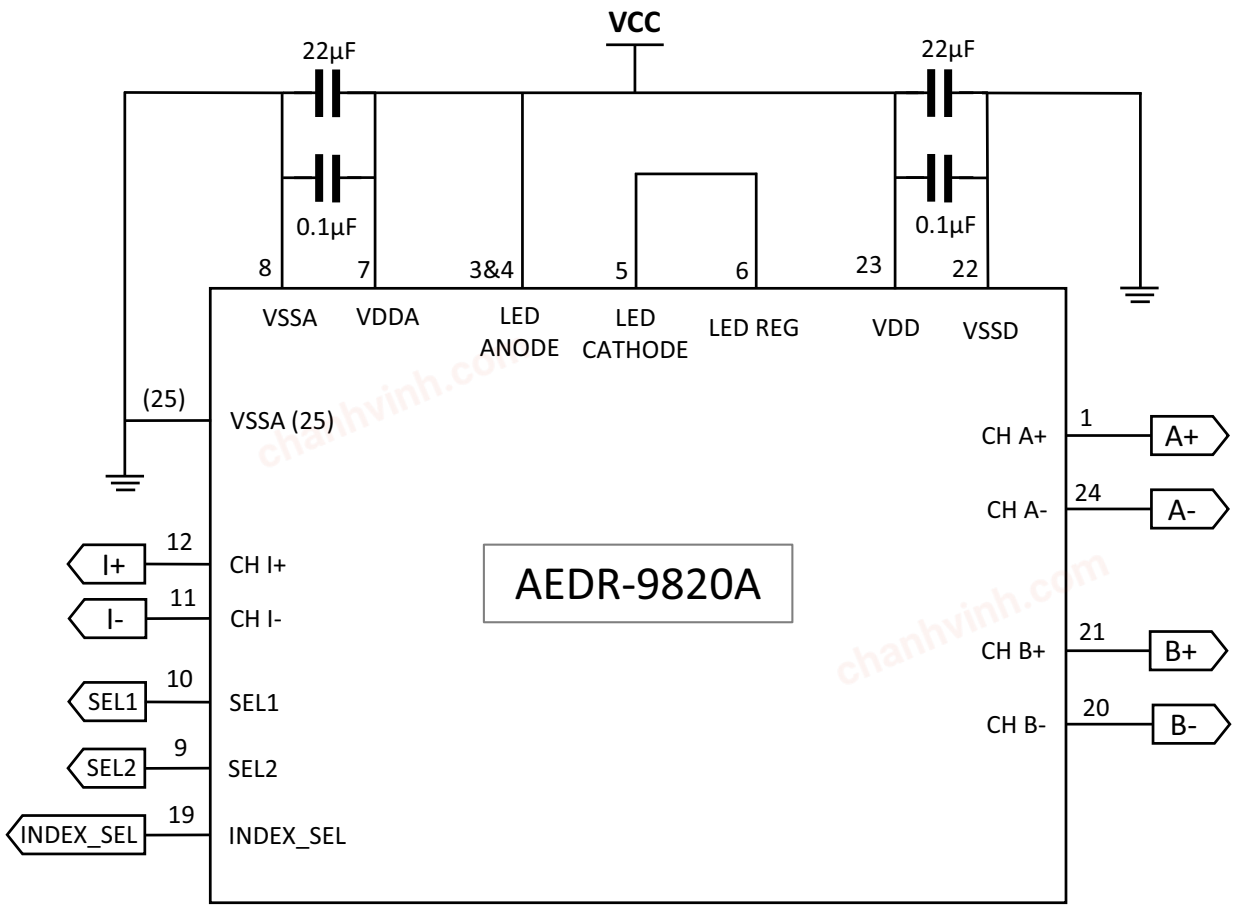
# Recommended Setup for the Power Supply Pins and General Routing

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.
- 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 a single-ended application, do not ground the Output- from the encoder. Allow the output to float.

**Figure 5: Reference Schematic Diagram for AEDR-9820A**




**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 configurations.

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# Analog Encoder Characteristics

| Parameter | Symbol | Min. | Typical[a, b] | Max. | Units |
|---|---|---|---|---|---|
| Peak-to-Peak Voltage (Average) | $V_{PPA}$, $V_{PPB}$ | 0.9 | 1 | 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 Vpp) | Vref | — | $V_{CC}$ / 2 | — | V |

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

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

# Digital Signals Characteristics (Code Wheel of $R_{OP}$ at 4.6 mm)

| Parameter | | Dynamic Performance[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Typical[b] | | | | | |
| Interpolation Factor | Symbol | 1X | 2X | 4X | 8X | 16X | Units |
| 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. The optimal performance of the encoder depending on the motor/system setup and code wheel type and condition.

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

# 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

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# 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 | $\lambda_p$ | — | 853 | — | nm | |

# 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; and 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 256 CPR.

**Figure 6: Code Wheel Design (A)**

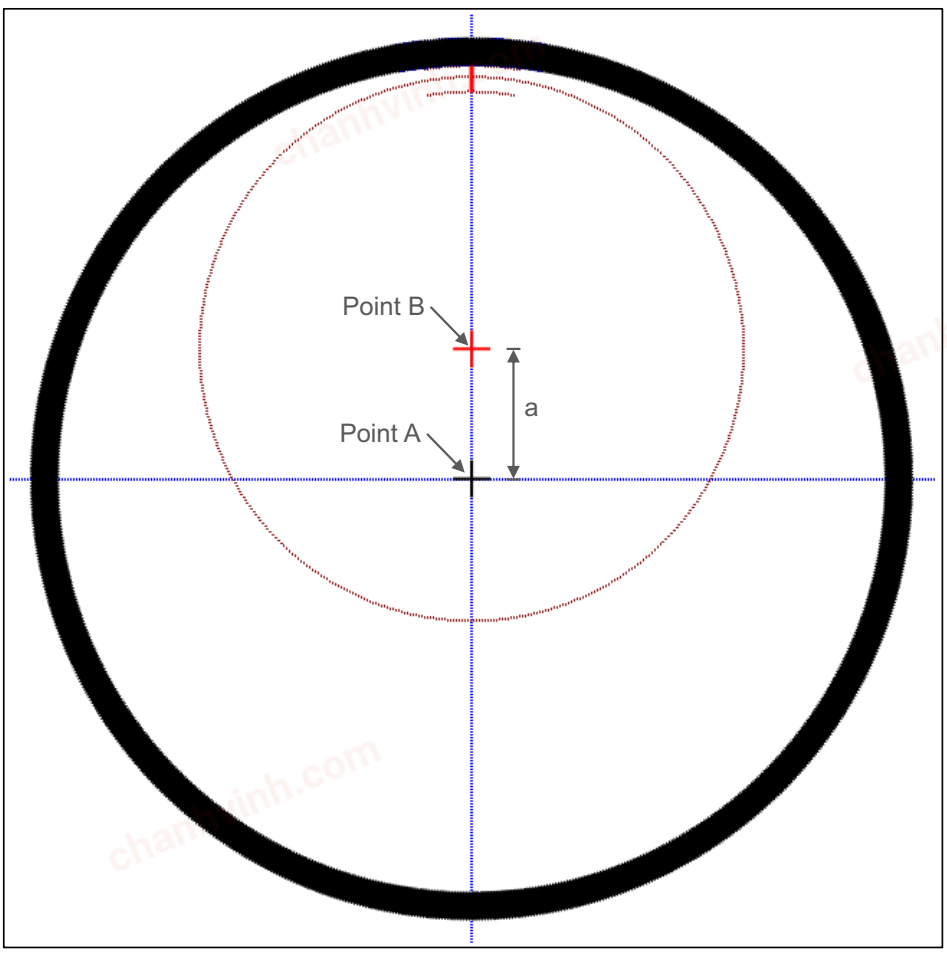

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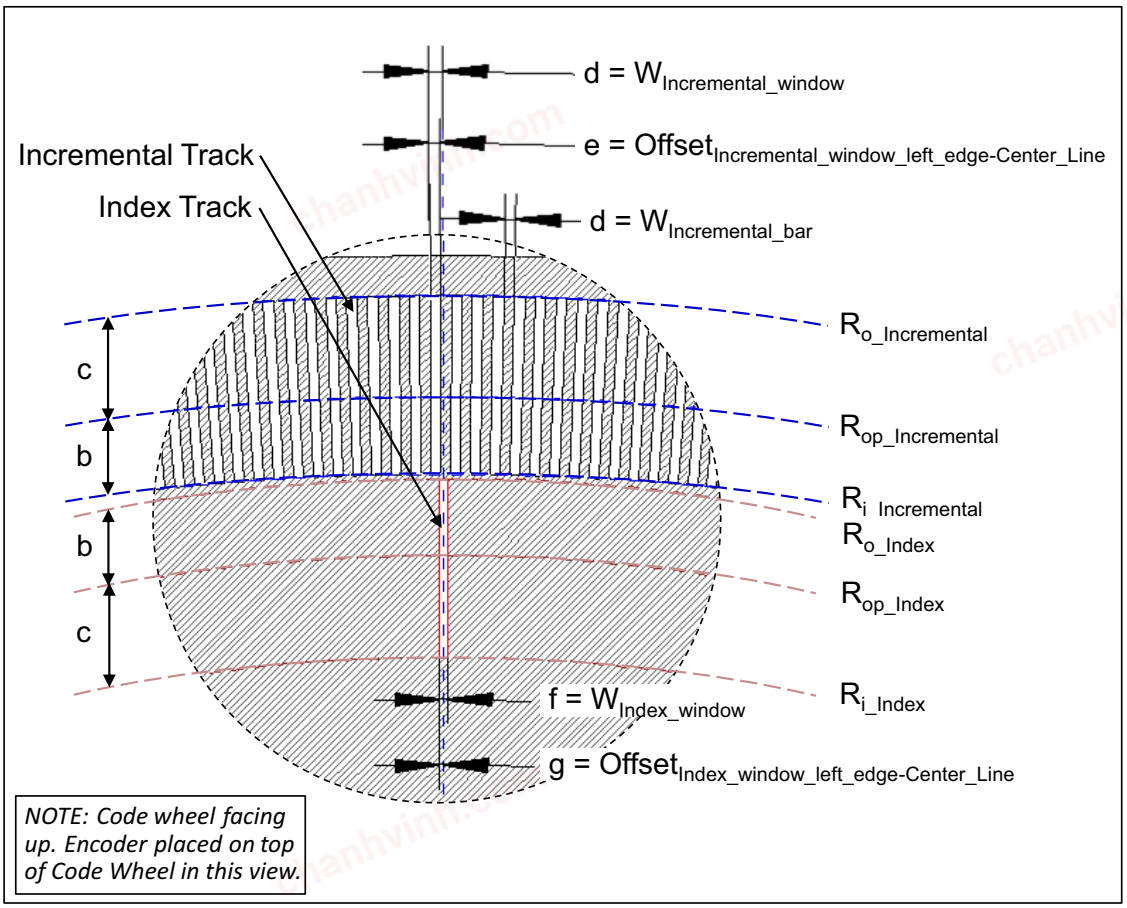
**Figure 7: Code Wheel Design (B)**




| Dimension | Formula | Constant for AEDR-9820A |
|---|---|---|
| $R_{op_Incremental}$ (mm) | (25.4 / 225) × (CPR / 2π) | — |
| $R_{op_Index}$ (mm) | — | R4.0485 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) | $R_{op_Incremental}$ – 4.5995 | — |
| b (mm) | (0.551 – 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 (°) | — | 0.7031 |
| g(°) | f / 2 | 0.3516 |
| h (mm) | $R_{o_Index}$ – $R_{i_Incremental}$ at Y-axis | 0 ≥ h ≥ 0.05 |

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# Code Wheel Design Example

The following demonstrates a code wheel design for the AEDR-9820A at 256 CPR.

| | | |
|---|---|---|
| Determine $R_{op_Incremental}$ | (25.4 / 225) × (256 / 2π) | ≈ 4.5995 mm |
| Determine $R_{o_Incremental}$ | 4.5995 + 0.35 | = 4.9495 mm |
| Determine $R_{i_Incremental}$ | 4.5995 – (0.551 / 2) | = 4.3240 mm |
| Determine Pitch | 360 / 256 | = 1.4062° |
| Determine d | 1.406 / 2 | = 0.7031° |
| Determine e | 1.25 × 0.703 | = 0.8789° |
| With the preceding information, draw a trapezoid based on Point A (0, 0), populate 256x at pitch = 1.4062° | | |
| Determine a | 4.5995 – 4.5995 | = 0 mm |
| $R_{op_Index}$ | | = 4.0485 mm |
| $R_{o_Index}$ | 4.0485 + (0.551 / 2) | = 4.3240 mm |
| $R_{i_Index}$ | 4.0485 – 0.35 | = 3.6985 mm |
| f | | = 0.7031° |
| g | f / 2 | = 0.3516° |
| With the preceding information, draw a trapezoid based on Point B (0, 0) | | |

The following demonstrates a code wheel design for the AEDR-9820A at 1024 CPR.

| | | |
|---|---|---|
| Determine $R_{op_Incremental}$ | (25.4 / 225) × (1024 / 2π) | ≈ 18.3980 mm |
| Determine $R_{o_Incremental}$ | 18.3980 + 0.35 | = 18.7480 mm |
| Determine $R_{i_Incremental}$ | 18.3980 – (0.551 / 2) | = 18.1225 mm |
| Determine Pitch | 360 / 1024 | = 0.3516° |
| Determine d | 0.3516 / 2 | = 0.1758° |
| Determine e | 1.25 × 0.1758 | = 0.2197° |
| With the preceding information, draw a trapezoid based on Point A (0, 0), populate 1024x at pitch = 0.3516° | | |
| Determine a | 18.3980 – 4.5995 | = 13.7985 mm |
| $R_{op_Index}$ | | = 4.0485 mm |
| $R_{o_Index}$ | 4.0485 + (0.551 / 2) | = 4.3240 mm |
| $R_{i_Index}$ | 4.0485 – 0.35 | = 3.6985 mm |
| f | | = 0.7031° |
| g | f / 2 | = 0.3515° |
| With the preceding information, draw a trapezoid based on Point B (0, 13.7985) | | |

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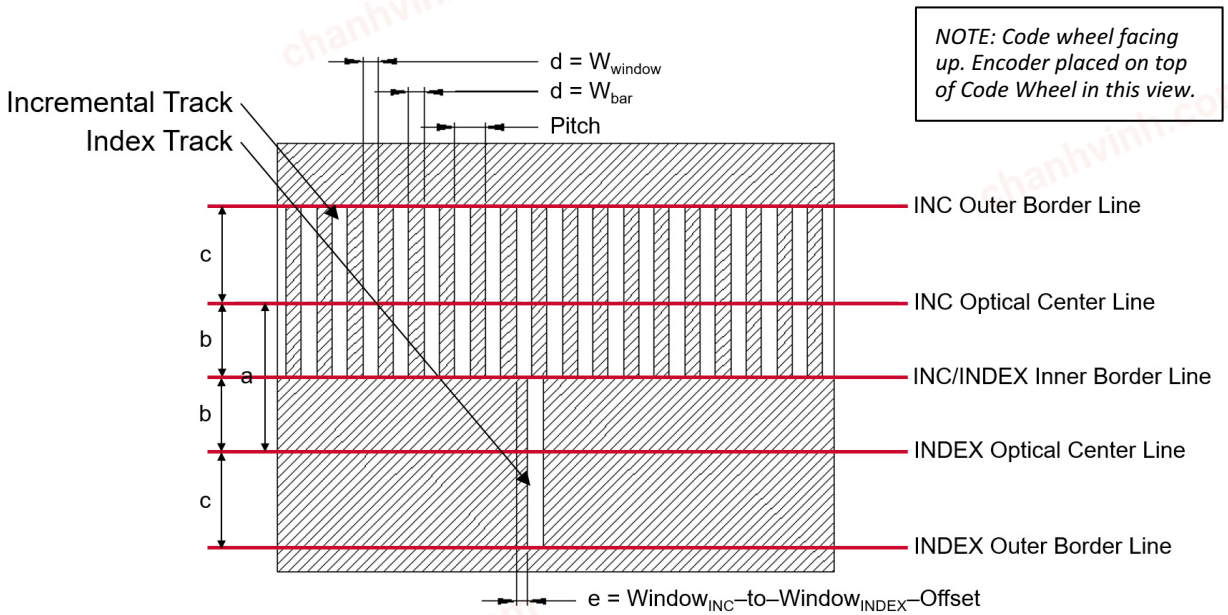
# Code Strip Design Guideline

- 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 has the same width value, d.
- There is an offset between Incremental window track and Index window track, denoted by e.




| Dimension | Formula | 225 LPI |
|---|---|---|
| Pitch (mm) | 25.4 / LPI | 0.113 |
| a (mm) | $R_{OP_INC} - R_{OP_INDE}X$ | 0.551 |
| b (mm) | $R_{OP_INC} - R_{I_INC}$ OR $R_{O_INDEX} - R_{OP_INDEX}$ | a / 2 |
| c (mm) | $R_{O_INC} - R_{OP_INC}$ OR $R_{OP_INDEX} - R_{I_INDEX}$ | 0.35 |
| d (mm) | Pitch / 2 | 0.057 |
| e (mm) | (3 / 4) × d | 0.042 |

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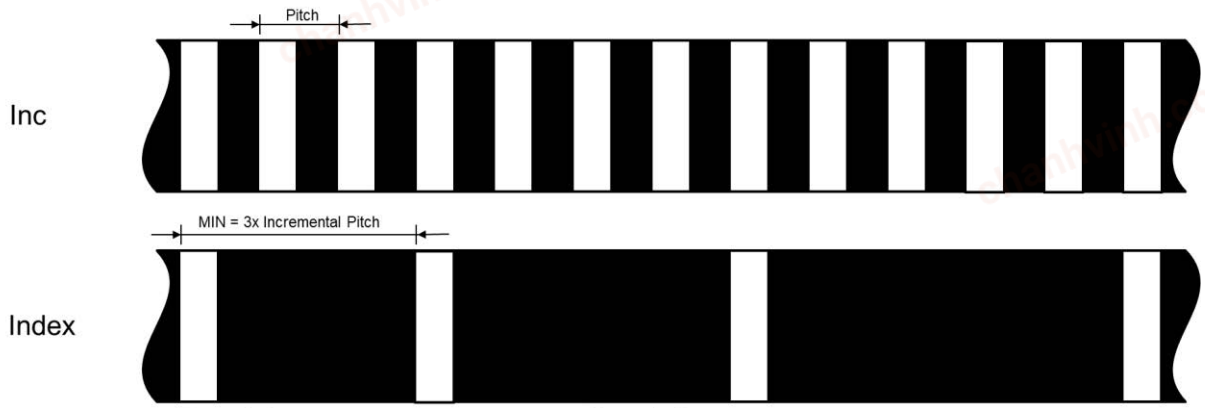
# Multiple Index Pulse Code Wheel or Strip Design Guideline

For pseudo absolute encoder applications, the multiple Index pulse can be designed into the code wheel or 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 | = 225 | CPR | = 612 |
| Pitch | = 1inch / 225 | Pitch | = 360° / 612 |
| | ≈ 113um | | = 0.59° |
| Min Index Pitch | = 3 * 113 | Min Index Pitch | = 3 * 0.59 |
| | = 339um | | = 1.76° |

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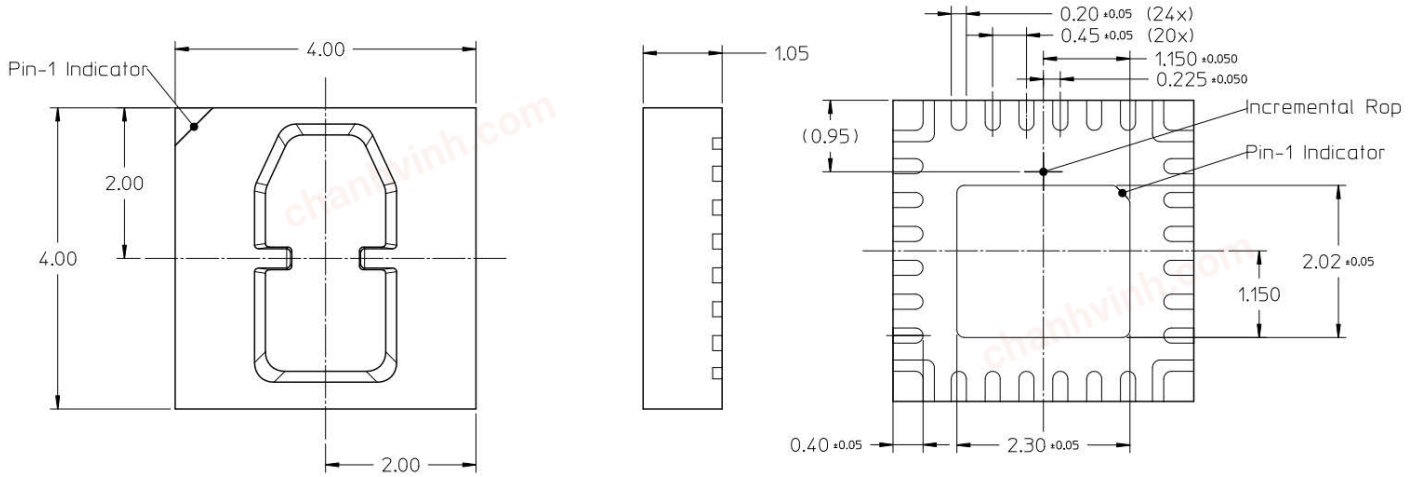
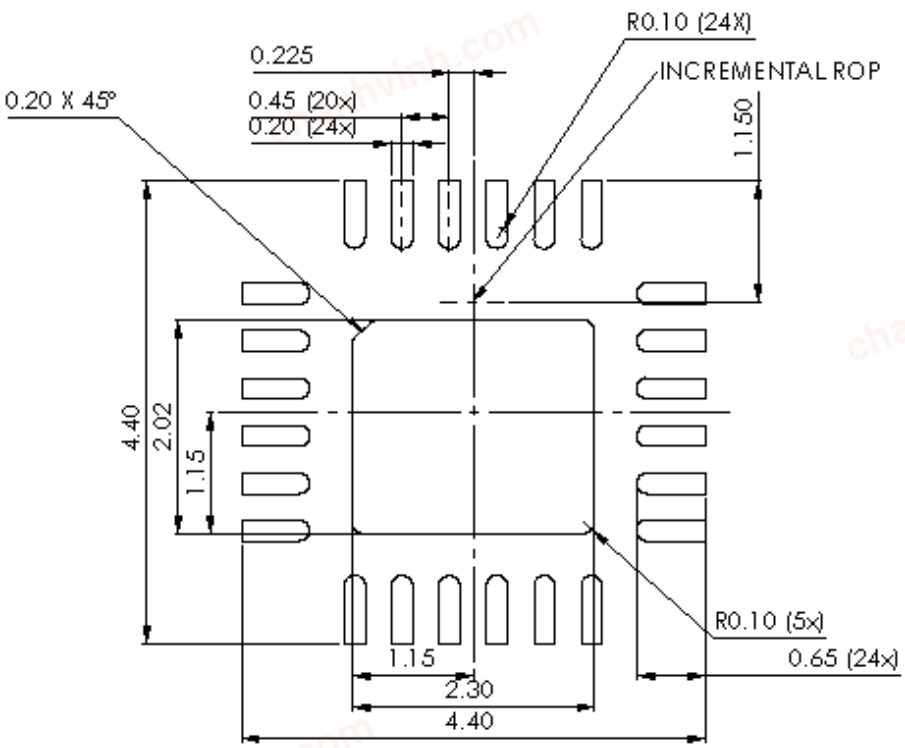
# Package Outline Drawing




**NOTE:**

1. All dimensions are in mm.
2. Tolerance is x.xx ± 0.15 mm.

# Recommended Land Pattern




**NOTE:**

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

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# Encoder Placement Orientation, Position, and Direction of Movement

The AEDR-9820A is designed with both the emitter and detector dice 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 1.00 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 Orientation**

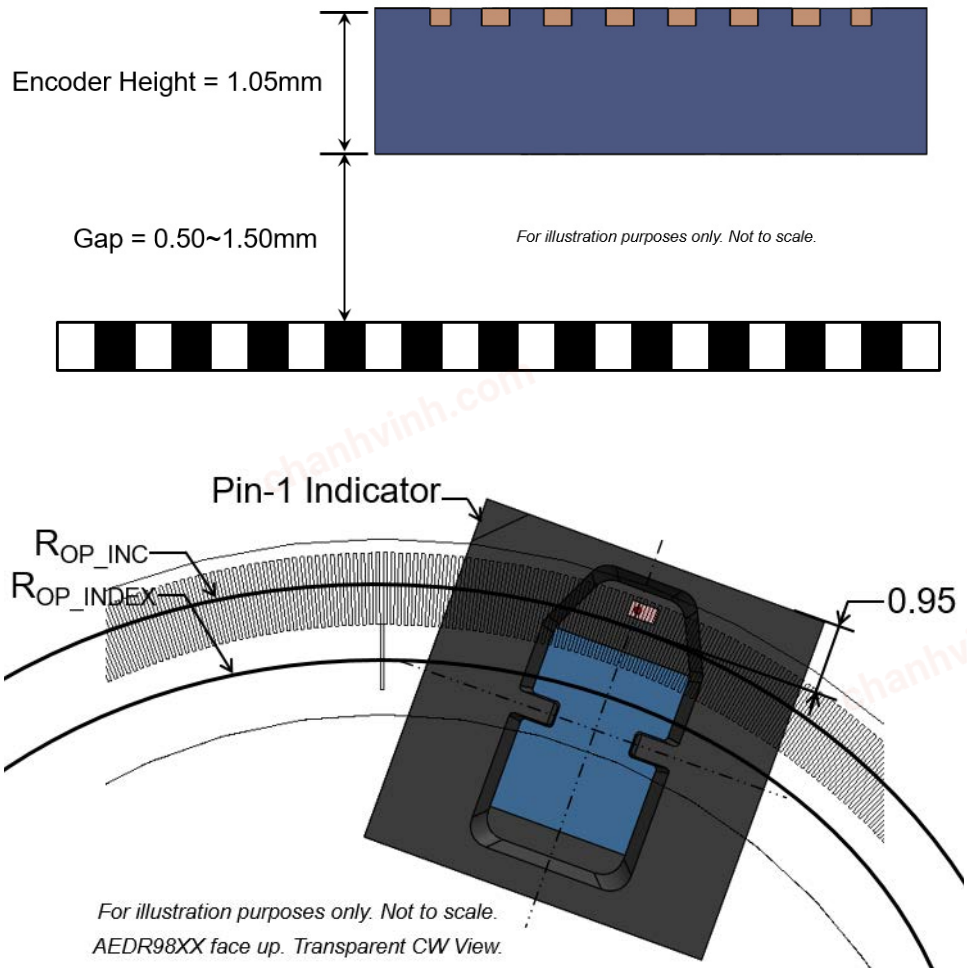

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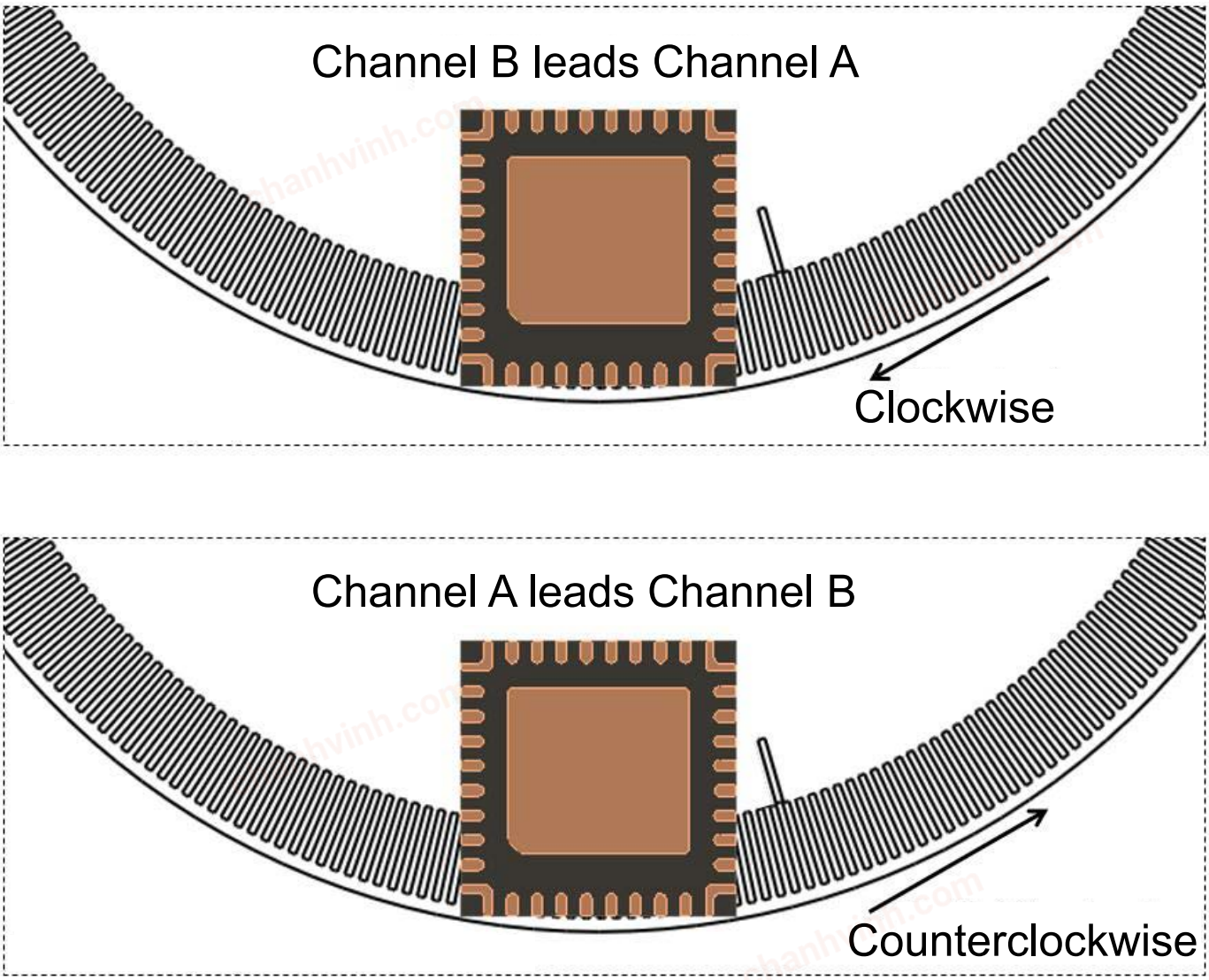
**Figure 9: Channel A and Channel B Signal Output Sequence with Respect to Code Wheel Rotational Direction**




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

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# Moisture Sensitivity Level

The AEDR-9820A package is specified 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:**

- An 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 a < 5% RH.

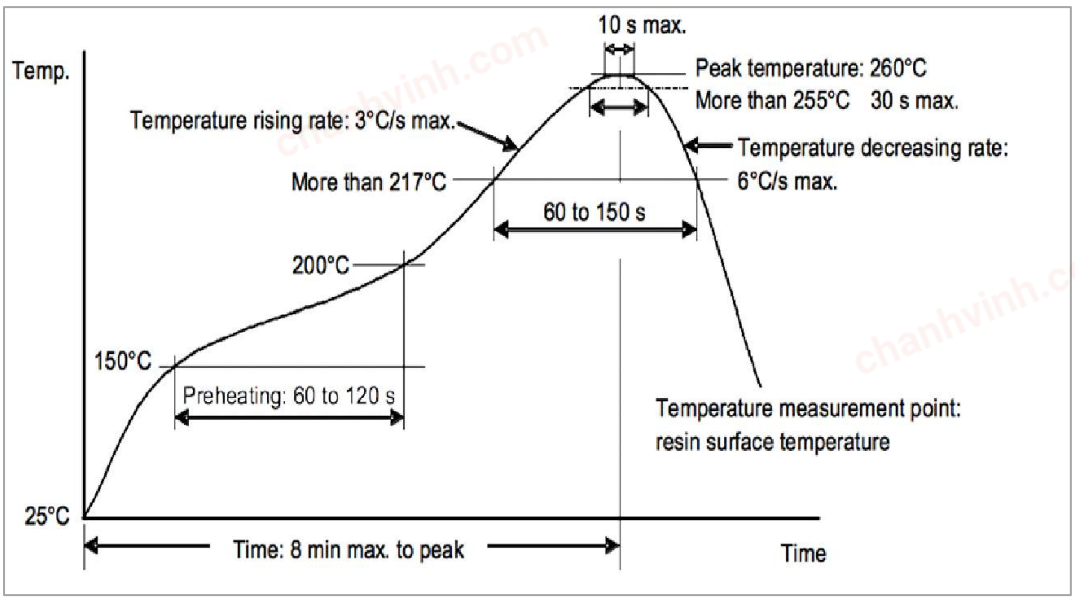
**Baking is required if the following conditions exist:**

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

**Recommended baking condition:**

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

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




**CAUTION!** Exercise 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.

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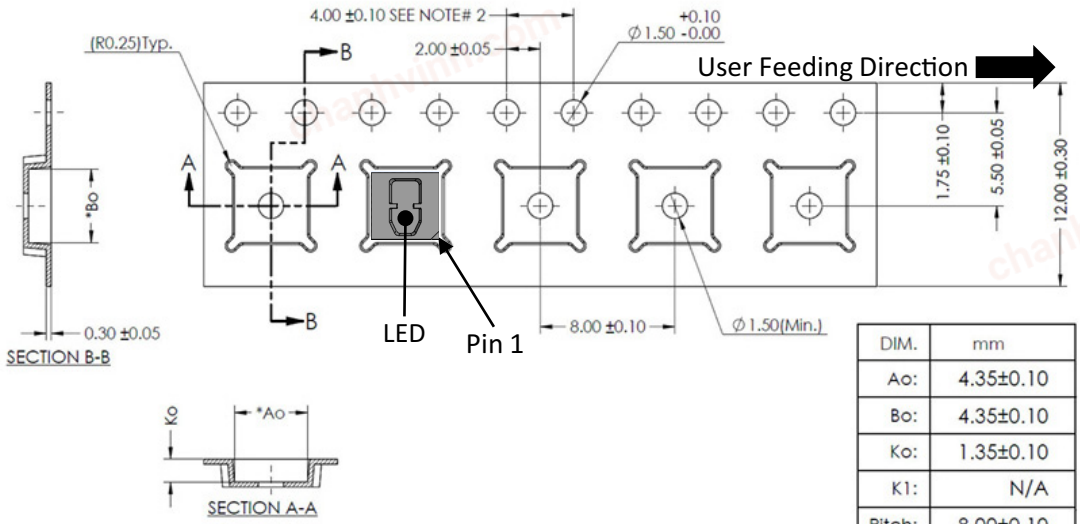
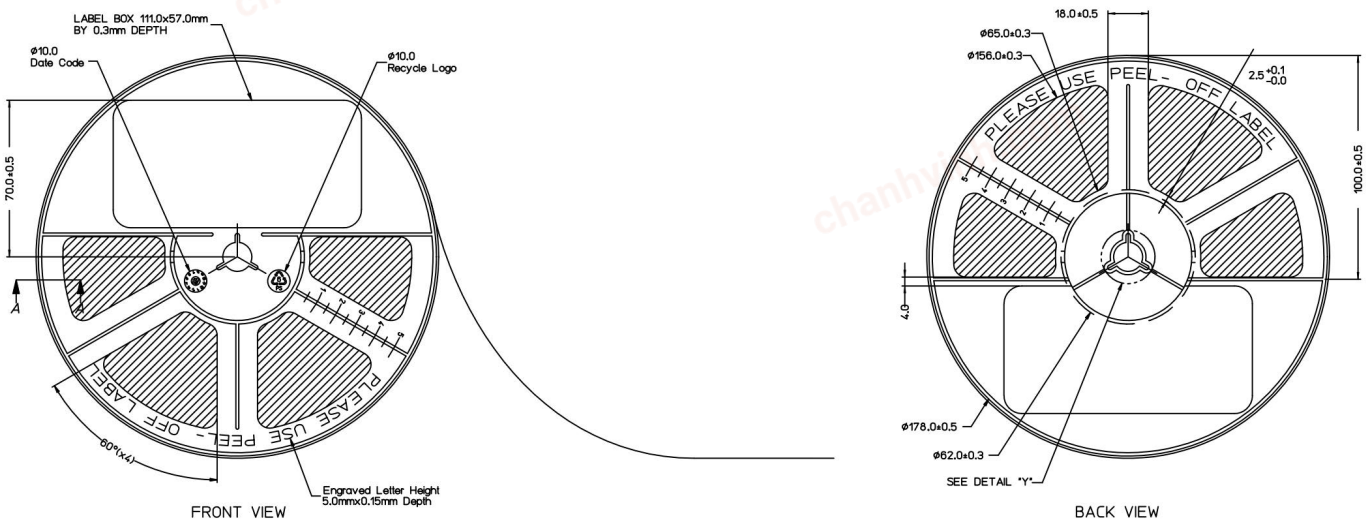
# Tape and Reel Information

**Figure 11: Tape and Reel**




| 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**



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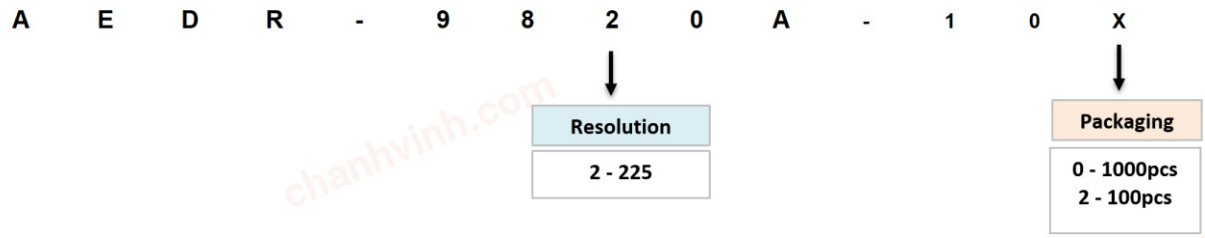
# Ordering Information




# Accessories Ordering Information

| Part Number | Description |
|---|---|
| HEDS-9820EVB | AEDR-9820 Evaluation Board 225 LPI Evaluation Board and Code Wheel |

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