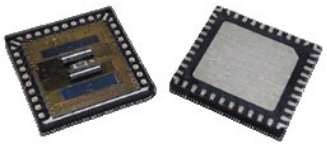
BROADCOM®

Data Sheet

# AR55 Series

## Smart Programmable 32-Bit Hollow-Shaft and Linear Absolute Encoder



## Description

The Broadcom® AR55 series is an absolute encoder ASIC designed to meet the growing demand for large-diameter rotary and linear motion applications. Utilizing advanced reflective optical encoding technology, the AR55 series delivers high positional accuracy through a correction algorithm that magnetic encoders cannot achieve.

The AR55 encoder is a one-chip solution that supports a wide range of overall diameters, from code wheels with an outer diameter (OD) of 53 mm to linear code strips up to 8.33m in length. With larger code wheels, the AR55 supports not only blind-hollow shaft configurations but also through-hole and linear applications. User-programmable resolutions range from 1-bit to 32-bit single-turn absolute outputs. Additionally, the AR55 provides differential analog sine/cosine or digital incremental ABIUVW signals with configurable counts per revolution (CPR) and pole-pair settings. Its state-of-the-art auto-calibration feature simplifies integration into end-user systems.

The AR55 series is compatible with the Broadcom proprietary batteryless energy-harvesting multi-turn (EHMT) solution. It also supports alternative multi-turn (MT) mechanisms, such as gear-based systems and battery-backed counters, via a dedicated multi-turn interface port.

For power, the ASIC supports dual-mode operation at either 3.3V or 5V, making it suitable for versatile integration with a wide range of industrial applications. It operates reliably across a wide temperature range of –40°C to 125°C, ideal for most industrial environments. To enhance design flexibility, the AR55 offers a variety of user-selectable communication protocols. Supported protocols include encoder serial link (ESL), RS-485 half duplex, SSI, BiSS-C, and SPI 4-wire.

## Features and Benefits

- Miniature surface-mount QFN package: 6 mm (L) × 6 mm (W) × 0.7 mm (H)
- User-programmable resolution:
  - Absolute output: 1 bit to 32 bits
  - Incremental (ABI) output: 1 CPR to $2^{26}$ CPR
  - Commutation signals (UVW): 1 to 32 pole pairs
- High temperature range: –40°C to 125°C
- Dual-mode operating voltage: 3.3V and 5V
- Multi-turn integration: EHMT, gear, or battery backup
- Optical radius (ROP) flexibility: blind-hollow, through-hole, or linear application
  - ROP range: 25 mm to 1335 mm
- Linear code strip pattern length: 10.2 mm to 8.33m
- Built-in line transceiver for protocol with selectable driveability strength
- Built-in calibration
  - Full-code or partial-code signal calibration
  - Accuracy calibration with constant speed rotation or with a reference encoder
- Selectable communication protocols:
  - RS-485 2.5/5/10 Mb/s
  - ESL 2.5/5/10 Mb/s
  - SSI 2-wire up to 10 MHz
  - SPI 4-wire up to 10 MHz
  - BiSS-C up to 10 MHz
- Up to 128 Kb of external user-accessible EEPROM memory
- Built-in temperature sensor
- RoHS compliant

# Applications

- Robotics automation and engineering
- Industrial servo motors and linear actuators
- Through-shaft motor, gear motor, and speed reducer
- Factory automation and drones
- Medical and laboratory equipment

**NOTE:** The AR55 series encoders are not halogen-free products.

**CAUTION!** Except as expressly indicated in writing, this product 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.

# Functional Description

**Figure 1: AR55 Block Diagram**

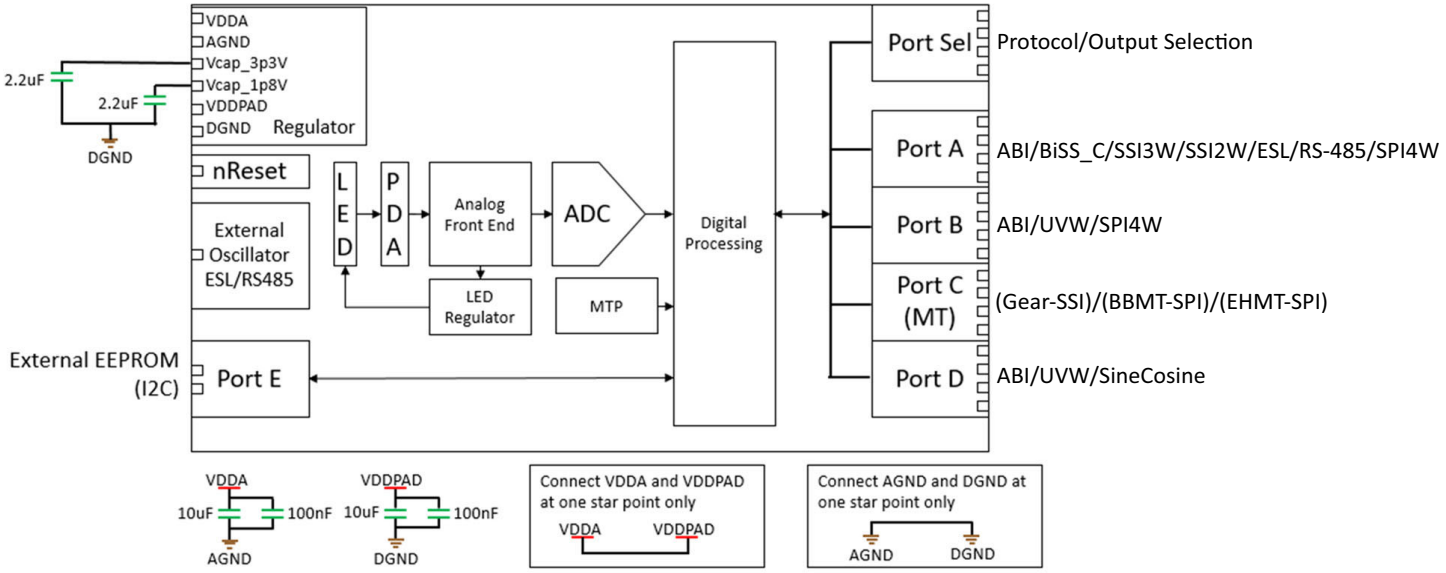
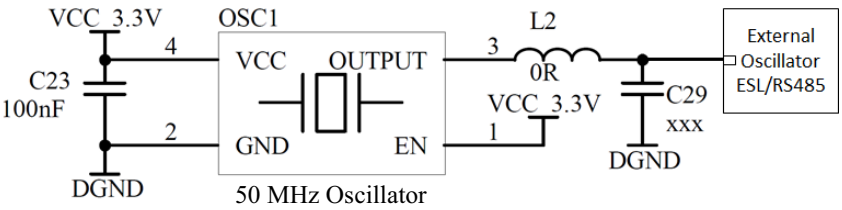



**Figure 2: AR55 External Oscillator Connection Diagram**




**NOTE:**

- For a 5V application, OSC1 Vcc 3.3V can be supplied from the Vcap_3p3V pin.
- The external oscillator is supplying only the clock signal for RS485 50-MHz communication. The internal ASIC clock is not supplied by this external oscillator.

**Figure 3: AR55 External EEPROM Connection Diagram**

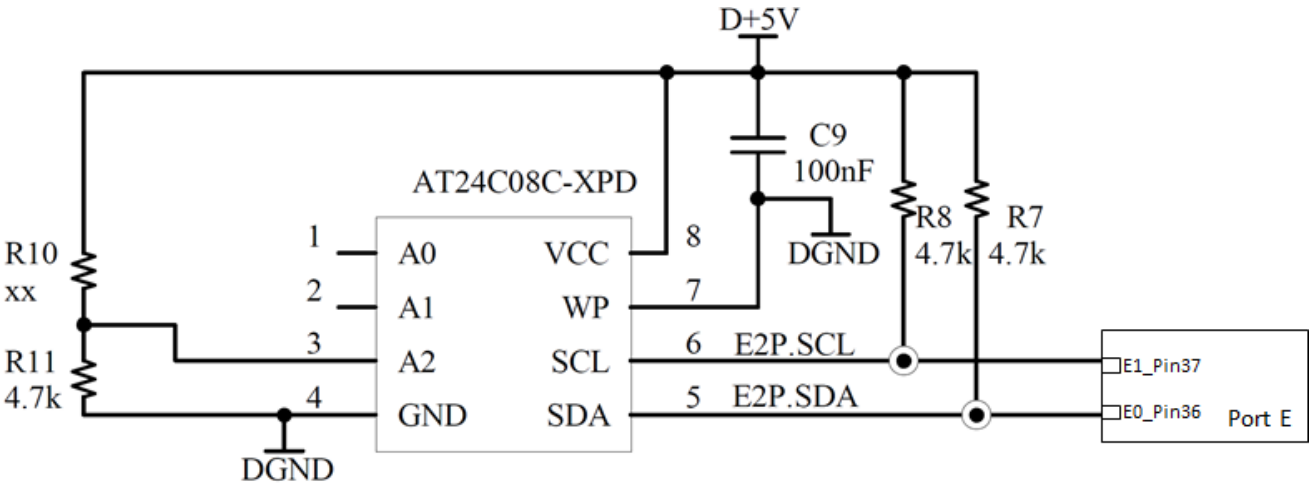
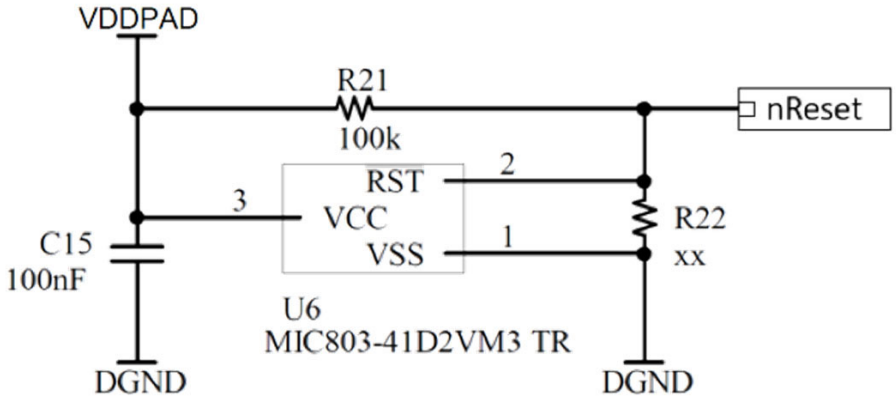



**Figure 4: AR55 External nReset Connection Diagram**

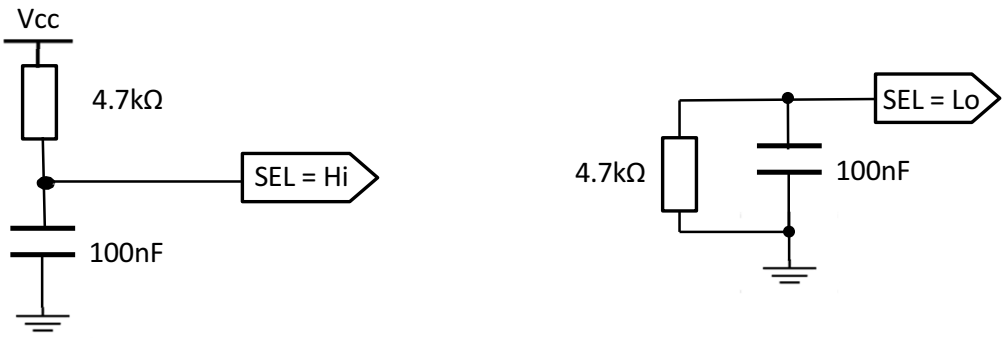



**NOTE:** For additional design details, refer to the AR55 series application note.

# Selection Pins

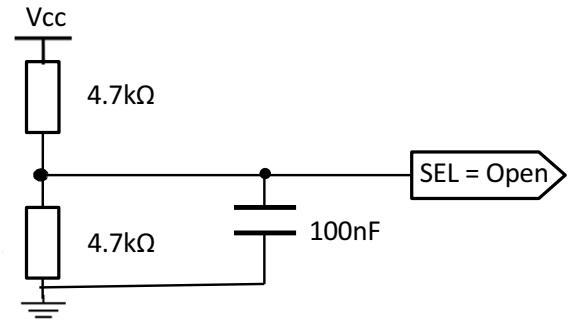
Include capacitors at the SEL pins to prevent or eliminate any unwanted disturbance or signal coupling that could impact the operating mode selection of the AR55 encoders and lead to unwanted behavior of the encoder device.

**Figure 5: Examples of High and Low Selection Circuits**



# Voltage Divider Circuit

**Figure 6: Example of a Voltage Divider Circuit**




**NOTE:** Use two 4.7-kΩ resistors (VDDA-GND).

# I/O Pins

## I/O Contention

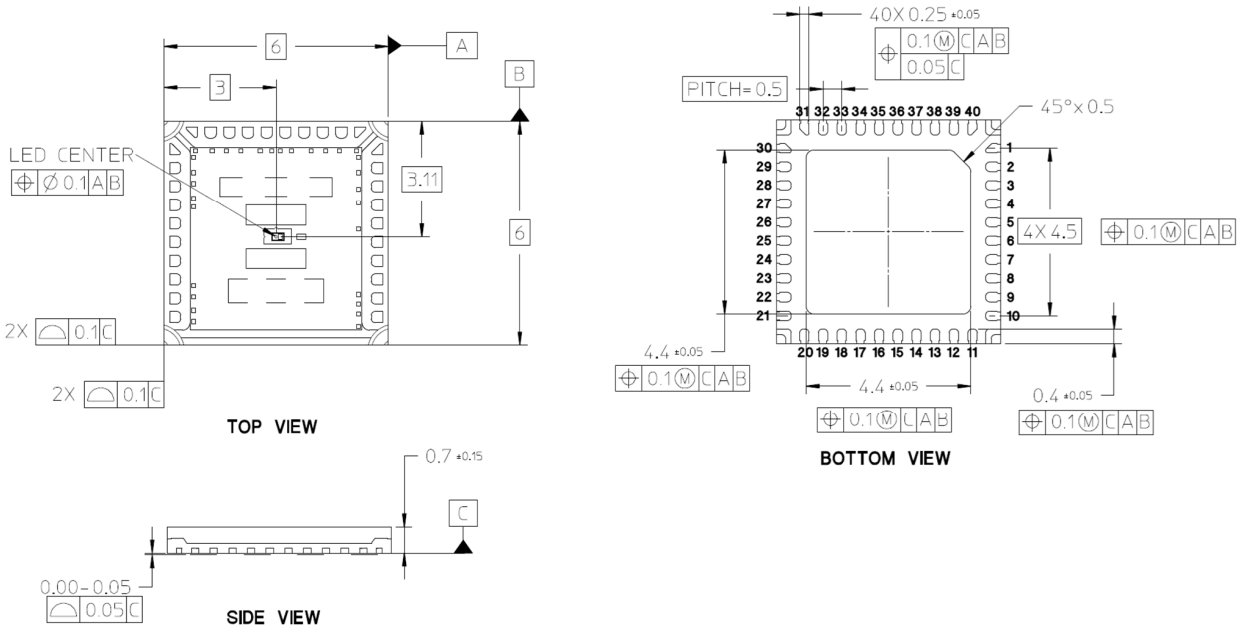
Do not apply voltage or current to the I/O pins before the AR55 encoder is powered up. There are ESD diodes and I/O multiplexing in the ASIC device pads, and any undue voltage or current going into the device can partially power up the device and bring it to an unknown state or cause an undue collection of charges prior to a proper power-up. Proper power sequencing is required to ensure proper operation of the encoder device.

## Output Load

The AR55 encoder is designed for a wide range of applications and as such, provides different modes of functional selections. Careful consideration of external load is required to prevent unwanted overshoot, ringing, and even instability of the device. Select a proper RC load at the output for the mode selected in the application. Do not directly drive a capacitive or inductive load.

# Mechanical Specifications

**Figure 7: Package Dimensions and Pinouts**




**NOTE:** All dimensions are in millimeters (mm).

**Table 1: Pinout Descriptions**

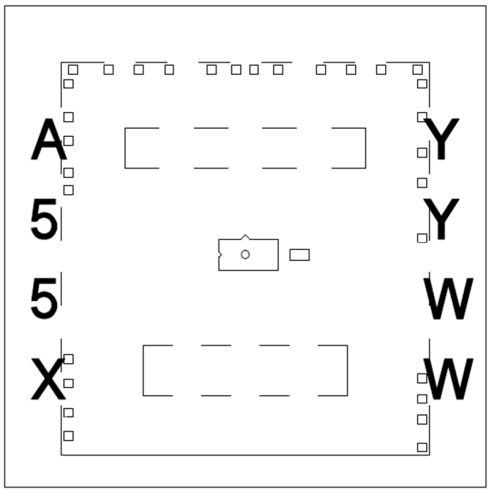
| Pin | Name | Function |
|---|---|---|
| 1 | Port_B3 | I/O protocol depends on Port_SEL[3:0] or internal register selection |
| 2 | Port_B2 | |
| 3 | Port_B1 | |
| 4 | Port_B0 | |
| 5 | VDDPAD | Digital power 3.3V/5V |
| 6 | DGND | Digital ground |
| 7 | Port_A3 | I/O protocol depends on Port_SEL[3:0] or internal register selection |
| 8 | Port_A2 | |
| 9 | Port_A1 | |
| 10 | Port_A0 | |
| 11 | No Connection | Open/No connection |
| 12 | No Connection | |
| 13 | No Connection | |
| 14 | No Connection | |
| 15 | No Connection | |
| 16 | No Connection | |
| 17 | No Connection | |
| 18 | No Connection | |
| 19 | No Connection | |
| 20 | No Connection | |

| Pin | Name | Function |
|---|---|---|
| 21 | Port_C0 | Multi-turn I/O protocol depends on Port_SEL[3:0] or internal register selection |
| 22 | Port_C1 | |
| 23 | Port_C2 | |
| 24 | Port_C3 | |
| 25 | AGND | Analog ground |
| 26 | VDDA | Analog power 3.3V/5V |
| 27 | Port_D0 | Incremental and analog output depend on Port_SEL[3:0] or internal register selection |
| 28 | Port_D1 | |
| 29 | Port_D2 | |
| 30 | Port_D3 | |
| 31 | nRESET | Power-up delay or ASIC reset pin |
| 32 | Port_SEL0 | Protocol selection or output selection pin. Refer to the AR55 series application note for selection details. |
| 33 | Port_SEL1 | |
| 34 | Port_SEL2 | |
| 35 | Port_SEL3 | |
| 36 | Port_E0 | $I^2C$ SDA External EEPROM |
| 37 | Port_E1 | $I^2C$ SCL External EEPROM |
| 38 | VDDcap_1p8V | Buffer capacitor, 1.8V |
| 39 | VDDcap_3p3V | Buffer capacitor, 3.3V |
| 40 | External Oscillator | 50-MHz external oscillator input |

**NOTE:** For additional PORT_SEL[3:0] selection information, refer to the AR55 series application note.

# Package Marking

**Figure 8: Product Marking Information**



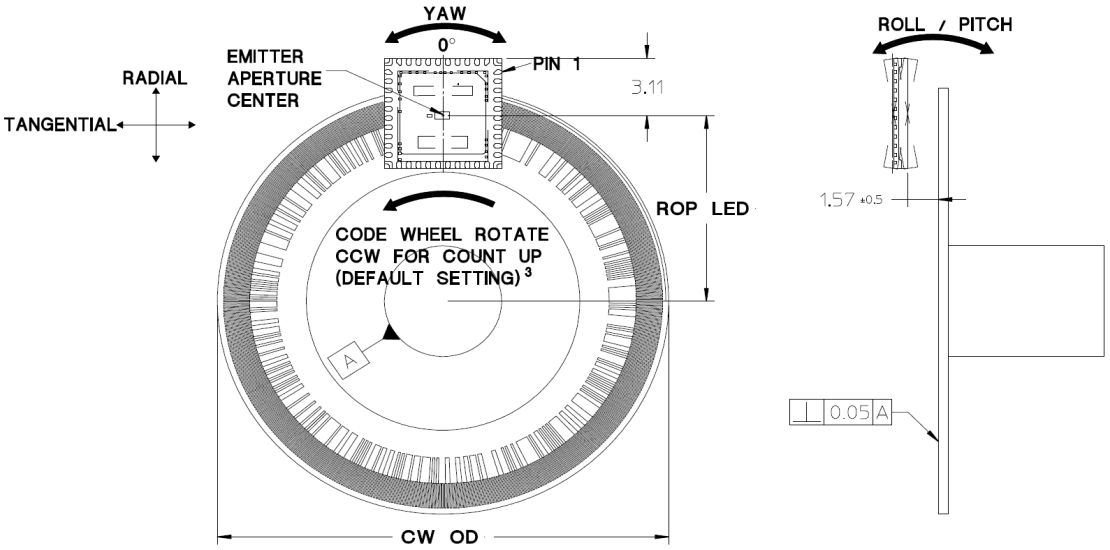

MARKING CONFIGURATION

| PART NUMBER | PROTOCOL | MARKING |
|---|---|---|
| AR55-AS0x | STANDARD | A55S |
| AR55-AB0x | BiSS | A55B |

YYWW: YEAR, WORK WEEK

# Encoder Mounting

**Figure 9: Encoder Mounting Orientation for Rotary Applications**

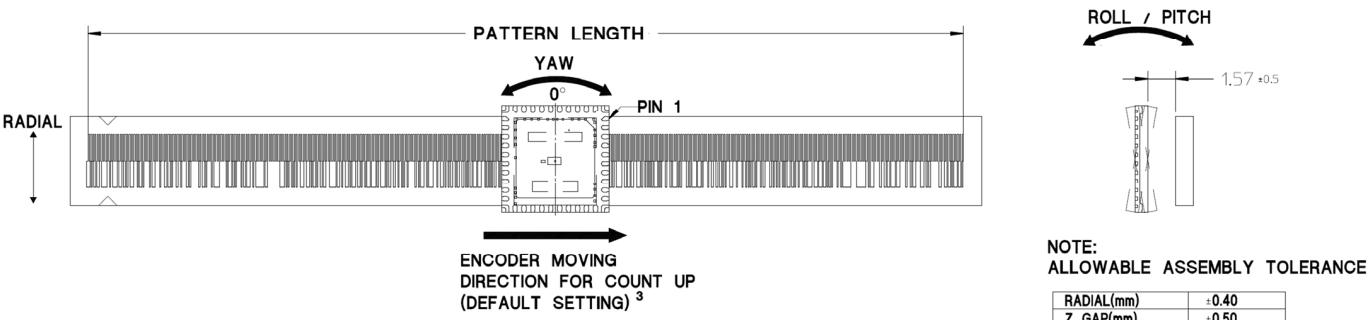



| CPR | ROP LED (mm) | CW OD (mm) |
|---|---|---|
| N | 0.020372xN–0.6285 | 2x (ROP_LED+1.7) |
| 1250 | 24.837 | 53.1 |
| 1500 | 29.930 | 63.3 |
| 3200 | 64.562 | 132.5 |
| 65535 | 1334.451 | 2672.3 |

NOTE:
ALLOWABLE ASSEMBLY TOLERANCE

| | |
|---|---|
| RADIAL(mm) | ±0.40 |
| TANGENTIAL(mm) | ±0.50 |
| Z GAP(mm) | ±0.50 |
| YAW(°) | ±2.0 |
| ROLL/PITCH (°) | ±2.0 |

**Figure 10: Encoder Mounting Orientation for Linear Applications**




| SCAN PITCH LENGTH | PATTERN LENGTH (mm) | REMARK |
|---|---|---|
| P | 0.128xP + 10 | |
| 64 | 18.192 | MIN LENGTH |
| 65535 | 8398.48 | MAX LENGTH |

NOTE:
ALLOWABLE ASSEMBLY TOLERANCE

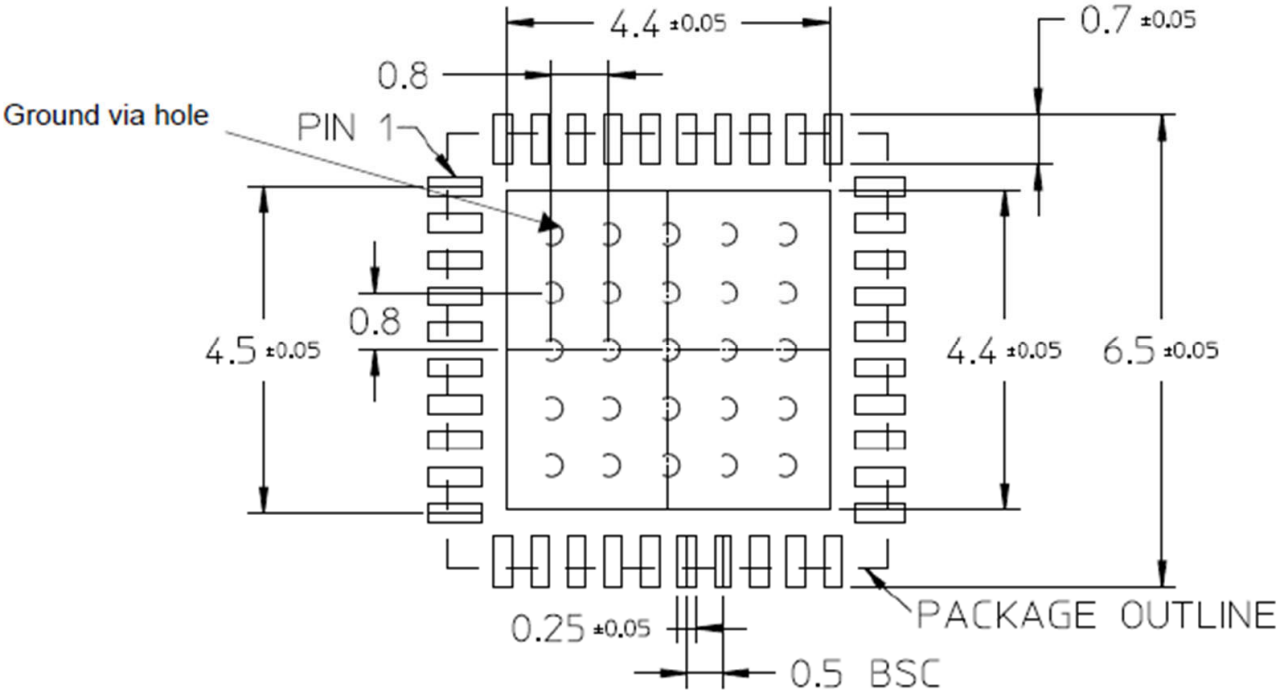
| | |
|---|---|
| RADIAL(mm) | ±0.40 |
| Z GAP(mm) | ±0.50 |
| YAW(°) | ±2.0 |
| ROLL/PITCH (°) | ±2.0 |

**NOTE:**

- The assembly of the encoder requires a clean room condition, Class 100k or better.
- The encoder requires an IP50 or higher rated enclosure for optimal protection against external contamination.
- For more mechanical design requirements, refer to the AR55 series application note.
- Contact your Broadcom sales representative for nonstandard code wheel or code strip designs.

# Recommended PCB Land Pattern

**Figure 11: Recommended PCB Land Pattern Details**




**NOTE:**

- Apply solder mask to areas that are not soldered.
- Use a 4-layer PCB with 25 × ø0.3mm, pitch = 0.8 mm via hole at the center pad as shown in the land pattern above.
- The center pad must be connected to GND.

For additional mechanical design requirements, refer to the AR55 series application note.

# Moisture Sensitivity Level

The AR55 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 moisture barrier bag (MBB):**

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

**Control for unfinished reel:**

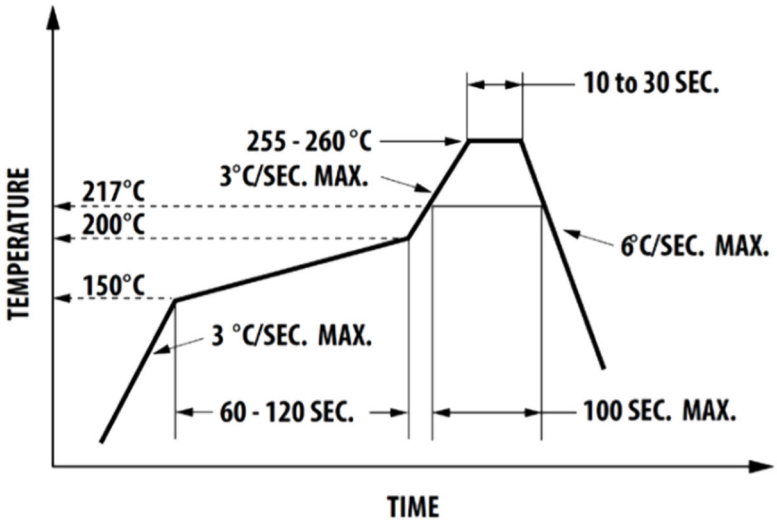
Store a sealed MBB with desiccant or desiccators at <5% RH condition.

**Baking is required if any of 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.

The recommended baking condition is 40°C ±5°C for 22 hours (tape and reel) or 125°C ±10°C for 1 hour (loose units).

**Figure 12: Recommended SMT Reflow Soldering Profile**




**NOTE:**

- Pb-free SMT reflow soldering profile (according to JEDEC Pb-Free [J-STD-020D]).
- Infrared reflow and no cleaning process to prevent contamination.

# Product Specifications

## Absolute Maximum Rating

**Table 2: Absolute Maximum Ratings**

| Parameter | Symbol | Value |
|---|---|---|
| Storage Temperature | $T_S$ | –40°C to 125°C |
| Operating Temperature | $T_A$ | –40°C to 125°C |
| Supply Voltage | $V_{dd}$ | –0.3V to +6.5V |
| ESD (HBM), JS-001-2014 | — | ±2 kV |
| Moisture Sensitive Level | MSL | 3 (Maximum floor life = 168 hours) |

**NOTE:**

- Proper encoder operation cannot be guaranteed if the maximum ratings are exceeded.
- Take precautions to keep the encoder ASIC clean at all times: clean room condition, Class 100k or better.
- Some particles may be present on the surface of the encoder ASIC surface. The presence of these particles may degrade the performance of the encoder.

**CAUTION!** Anti-static discharge precautions should be taken when handling the encoder in order to avoid damage and/or degradation induced by ESD.

Subjecting the product to stresses beyond those listed in this section may cause permanent damage to the devices. These are stress ratings only and do not imply that the device will function beyond these ratings. Exposure to the extremes of these conditions for extended periods may affect product reliability.

# Electrical Specifications

**Table 3: Recommended Operating Conditions**

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Notes |
|---|---|---|---|---|---|---|
| DC Supply Voltage, 5V | $V_{dd}$ | +4.5 | +5.0 | +5.5 | V | |
| DC Supply Voltage, 3.3V | $V_{dd}$ | +3.0 | +3.3 | +3.6 | V | |
| Ripple of Supply Voltage | — | — | — | 100 | mVpp | 100 kHz |
| Output Current per Channel | — | — | — | ±5 | mA | Single-ended digital output |
| Rise Time | $t_r$ | — | 30 | — | ns | $C_L$ = 50 pF<br>$R_L$ = 1.2 kΩ |
| Fall Time | $t_f$ | — | 30 | — | ns | |
| Ambient Temperature | $T_{amb}$ | — | +25 | — | °C | |
| Operational Temperature | $T_{PCB}$ | –40 | +25 | +125 | °C | PCB (FR4, 4 layers) temperature |
| Storage Temperature | $T_S$ | –40 | +25 | +125 | °C | |
| Humidity | RH | — | — | 85 | % | Temperature = 40°C |
| INC Operating Frequency | — | — | — | 156 | kHz | Velocity (rpm) × CPR/60 |
| Linear Speed | — | — | — | 20 | m/s | |
| Radial Misalignment | — | –500 | Nominal | +500 | µm | |
| Tangential Misalignment | — | –400 | Nominal | +400 | µm | |
| Gap | — | –500 | Nominal | +500 | µm | |
| Temperature Sensor Accuracy | — | — | ±3 | — | °C | At 125°C |

**Table 4: Recommended Code Wheel or Code Strip Characteristics**

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Notes |
|---|---|---|---|---|---|---|
| Specular Reflectance | $R_f$ | 80% | — | — | — | Reflective area |
| | | — | — | 5% | V | Non-reflective area |

**NOTE:** Characteristics are based on Broadcom-qualified code wheel and code strip suppliers. Contact Broadcom for qualified reflective code wheel and code strip suppliers.

**Figure 13: Metal (Stainless Steel or Aluminum) Code Wheel and Code Strip Structure**

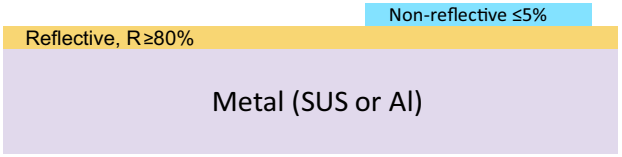
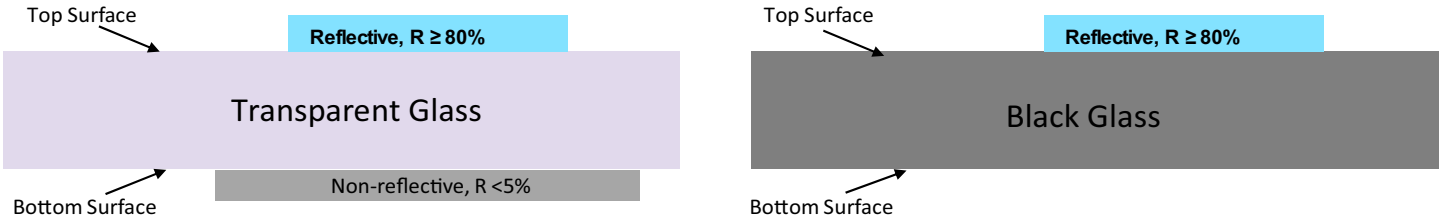



**Figure 14: Glass Code Wheel and Code Strip Structure**



# DC Characteristics

**Table 5: DC Characteristics over Recommended Operating Range at 25°C (typical)**

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit | Notes |
|---|---|---|---|---|---|---|---|
| $V_{DD}$ Supply Current | $I_{DD}$ | $V_{DD}$ = 3.3V | — | 75 | — | mA | |
| | | $V_{DD}$ = 5.0V | — | 85 | — | mA | |
| Absolute Single-Turn Resolution | $ST_{bits}$ | — | 1 | — | 32[a] | Bit | |
| Incremental Resolution | — | — | 1 | — | $2^{nmax}$ | CPR | $n_{max}$ = 26 |
| Protocol I/O Drive Strength | $I_{DIO}$ | $V_{DD}$ = 3.3V/5V | 5 | 20 | 40 | mA | Differential driver |
| Differential Transceiver Hysteresis | $V_{hys}$ | $V_{DD}$ = 3.3V/5V | — | 100 | — | mV | 220Ω termination |
| Differential Transceiver Opening | $V_{open}$ | $V_{DD}$ = 3.3V/5V | 200 | — | — | mV | |
| Differential Transceiver Voltage Peak-to-Peak | $V_{PP}$ | $V_{DD}$ = 3.3V/5V | — | 2 | — | V | |
| Output High Voltage | $V_{OH}$ | $V_{DD}$ = 3.3V | 2.4 | — | — | V | No load |
| Output Low Voltage | $V_{OL}$ | | — | 5 | 0.4 | V | |
| Input High Voltage | $V_{IH}$ | | — | — | 2 | V | |
| Input Low Voltage | $V_{IL}$ | | 0.8 | — | — | V | |
| Output High Voltage | $V_{OH}$ | $V_{DD}$ = 5.0V | 4.4 | — | — | V | No load |
| Output Low Voltage | $V_{OL}$ | | — | 5 | 0.5 | V | |
| Input High Voltage | $V_{IH}$ | | — | — | 3.5 | V | |
| Input Low Voltage | $V_{IL}$ | | 1.5 | — | — | V | |

a. The maximum number of bits is set in the AR55 device.

# Encoder Characteristics

**Table 6: Incremental Characteristics over Recommended Operating Condition at 25°C with Interpolation Factor of 32x**

| ABI Parameter | Symbol | Min. | Typ. | Max.[a] | Units |
|---|---|---|---|---|---|
| Cycle Error | ΔC | — | — | 45 | °e |
| State Error | ΔS | — | — | 45 | °e |
| Index Pulse Width | Po | — | 90,180, 270, 360 | — | °e |

a. Maximum values represent the encoder performance across the range of recommended mounting tolerance.

**Table 7: Commutation Characteristics over Recommended Operating Condition at 25°C with 32 Pole Pairs**

| Commutation (UVW) Parameter | Symbol | Min. | Typ. | Max.[a] | Units |
|---|---|---|---|---|---|
| Commutation Accuracy (Middle of Channel I to Channel U) | ΔI | –0.1 | — | +0.1 | °mechanical |
| Commutation Accuracy (Channel U,V, and W) | ΔUVW | –0.1 | — | +0.1 | °mechanical |

a. Maximum values represent the encoder performance across the range of recommended mounting tolerance.

**Table 8: Rotary Encoder Raw Accuracy Characteristics over Recommended Operating Condition at 25°C**

| Parameter | Symbol | Min. | Typ.[a] | Max. | Units |
|---|---|---|---|---|---|
| Raw Accuracy (AR55) | — | — | ±600 | — | arcsec |
| Accuracy_AutoCal (Speed)[b] | — | — | ±120 | — | arcsec |
| Accuracy_ManualCal (Reference Encoder)[c] | — | — | ±30 | — | arcsec |

a. Typical values represent the encoder performance with shaft TIR <20 µm, pattern eccentricity <60 µm for 1500 CPR.

b. Typical values represent calibration with the motor speed ripple of <0.1%.

c. Typical values represent the accuracy and repeatability when calibrated with a reference encoder having 10× higher accuracy than the AR55. (AR55 = 32-bit; reference encoder ≤3 arcsec).

**Table 9: Linear Raw Accuracy Characteristics over Recommended Operating Condition, at 25°C with 1m Code Strip Length**

| Parameter | Symbol | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| Raw Accuracy (AR55) | — | — | ±50 | — | µm |
| Accuracy_AutoCal (Speed)[a] | — | — | ±10 | — | µm |
| Accuracy_ManualCal (Reference Encoder)[b] | — | — | ±5 | — | µm |

a. Typical values represent calibration with the motor speed ripple of <0.1%.

b. Typical value represent the accuracy and repeatability when calibrated with a reference encoder having 10× higher accuracy than the AR55. (reference encoder ≤0.5 µm).

# Analog Signal Characteristics

**Figure 15: Analog Waveform**

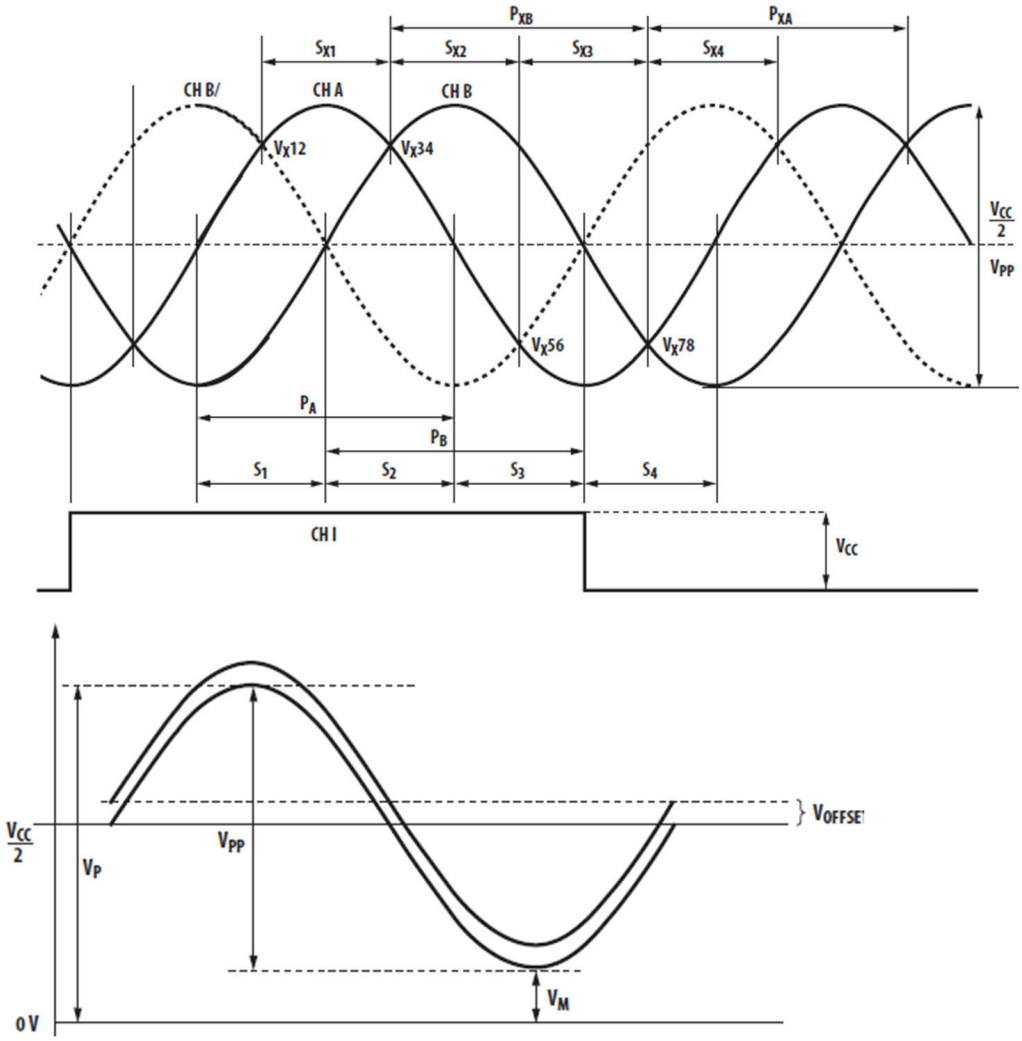



**Table 10: Test Parameter Definitions**

| Parameter | Symbol | Description |
|---|---|---|
| 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 | $V_{PA}$, $V_{PB}$,$V_{MA}$, $V_{MB}$ | The value in V of the peak/valley of the analog signal (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. |
| Analog Crosspoint Voltage | $V_{X12}$, $V_{X34}$, $V_{X56}$, $V_{X78}$ | The intersections in V of channel A analog waveform with that of either channel B or its component. |
| Analog Offset Voltage | $V_{OFFSETA}$, $V_{OFFSETB}$ | The offset in mV from the midpoint of the analog peak-to-peak signal to Vpp/2. |

**Table 11: Analog Signal Characteristics**

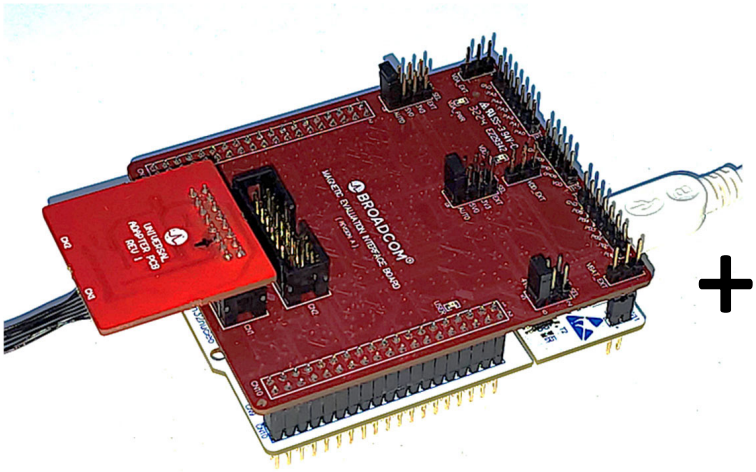
| Parameter | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| Peak-to-Peak Voltage (Average) | $V_{PPA}$, $V_{PPB}$ | 0.9 | 1 | 1.1 | V |
| Analog Offset Voltage | $V_{OFFSETA}$, $V_{OFFSETB}$ | 0.45Vcc | 0.5Vcc | 0.55Vcc | V |
| Voltage Reference (Midpoint of Signal Vpp) | Vref | — | Vcc/2 | — | V |
| Index Pulse Width | I | — | 360/270/180/90 | — | °e |
| State Width Error | ΔS | — | ±10 | — | °e |
| Pulse Width Error | ΔP | — | ±10 | — | °e |
| State X Width Error | ΔSx | — | ±5 | — | °e |
| Pulse X Width Error | ΔPx | — | ±5 | — | °e |

**NOTE:**

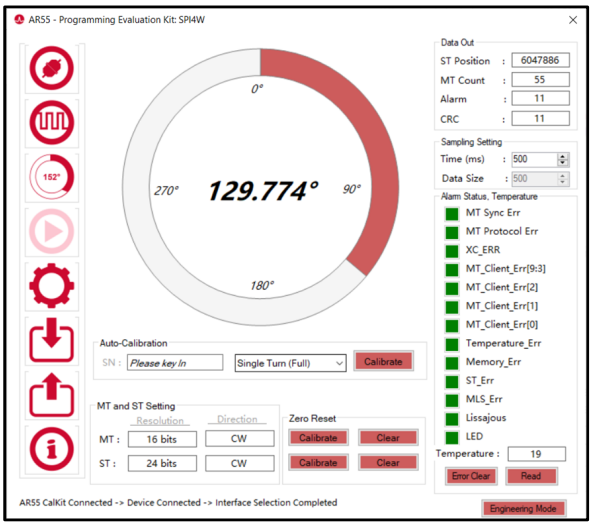
- Typical values represent the average value of encoder performance in our factory-based setup conditions.
- The optimal performance of the encoder depends on the individual customer's motor/system set-up conditions.

# Evaluation Board and Accessories

**Figure 16: AR49-M49-E01 Calibration Kit and User Interface Software**



The Programming/Calibration Kit with a USB PC Interface Cable and an Encoder Connecting Cable




The Programming/Calibration GUI Software

**Figure 17: AR55 Encoder Evaluation Board**

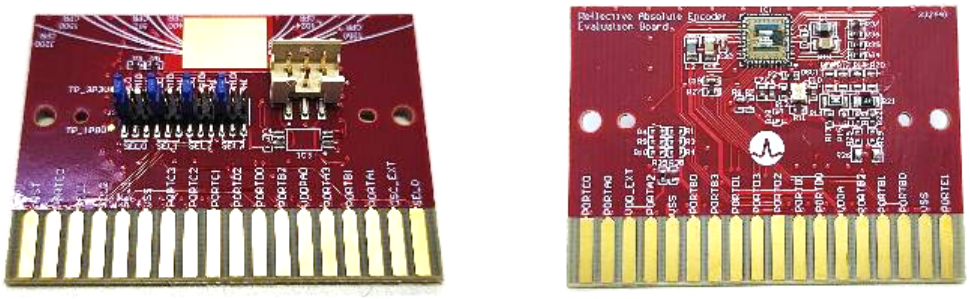


**Figure 18: AR55 Metal Code Wheel or Code Strip**

**Figure 19: AR55-EVBR with Evaluation Board and a 1250-CPR Metal Code Wheel**

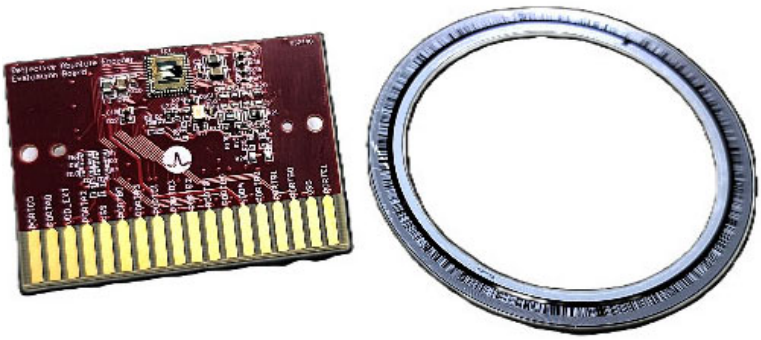
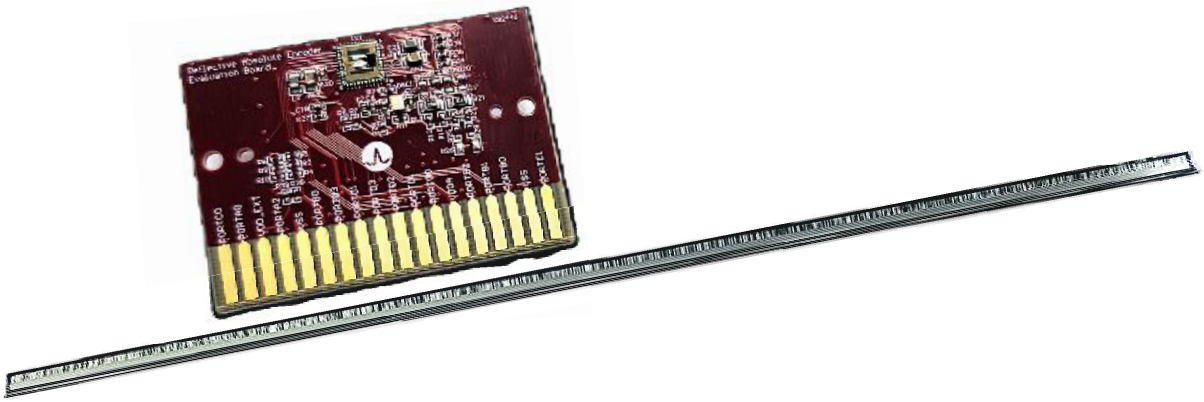


**Figure 20: AR55-EVBL with Evaluation Board and a 200-mm Linear Code Strip**



# Ordering Information

**A R 5 5 – A [Y] 0 1 – T R 0 [X]**

| Code | Description | Option | |
|---|---|---|---|
| Y | Communication Protocol | B | BiSS-C (10 MHz) |
| | | S | SSI (10 MHz)<br>SPI 4-wire (10 MHz)<br>ESL (10 Mb/s)<br>RS-485 (2.5/5/10 Mb/s) |
| X | Tape and Reel Quantity | 1 | 100 pieces |
| | | 2 | 1000 pieces |

| Part Number | Description |
|---|---|
| AR55-EVBR | AR55 Evaluation Board (All Protocols) and Metal Code Wheel, 1250 CPR. |
| AR55-EVBL | AR55 Evaluation Board (All Protocols) and Metal Code Strip, 200 mm. |
| AR55-R30S | Code Wheel 1250 CPR, ID 41 mm. Metal. |
| AR55-R60S | Code Wheel only 1850 CPR, ID 65.4 mm, Metal. |
| AR55-L20S | Code Strip only 1640 CPR, 200 mm, Metal. |
| W1202-495249 | Bearing Stage AR55 + R30S + QP39-T254. |
| AR55-AS01-TR01 | AR55 ASIC Protocol SSI/SPI/485/ESL, Tape and Reel 100 pieces. |
| AR55-AS01-TR02 | AR55 ASIC Protocol SSI/SPI/485/ESL, Tape and Reel 1000 pieces. |
| AR55-AB01-TR01 | AR55 ASIC Protocol BiSS-C, Tape and Reel 100 pieces. |
| AR55-AB01-TR02 | AR55 ASIC Protocol BiSS-C, Tape and Reel 1000 pieces. |
| AR49-M49-E01 | Universal Programming Kit (applicable for all protocol options).<br>Contents: 1 unit of MCU-based programming kit, 1 unit of USB cable for PC interface, DUT cable and the associated programming software. |
| AR25-AC25 | Accuracy Calibration Station for AR18/AR25/AR35/AR49/AR55 Series Rotary Reflective Encoder.<br>Contents: Mechanical setup including servo motor control, high accuracy reference encoder, programming kits, associated cables assemblies (for PC interface, motor handler communication, DUT encoder connection), and the associated GUI programming software. |

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