DATASHEET

Celera MOTION
A Novanta Company

Aura Series Datasheet

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Celera MOTION
A Novanta Company

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1 General Information

1.1 Revision History

Revision	Release Date	Changes
1.0	Jan 26 2021	Initial Release
1.1	Mar 1 2021	Storage temperature. BiSS daisy-chain.
1.2	May 28 2021	Electrical Interface update. Communications added.
1.3	Jun 23 2021	Changed Function naming on Electrical Interface page to be consistent with schematic.
1.4	Aug 31 2021	Updated requirement for digital/analog calibration.
1.5	Oct 26 2021	Aura-C and Aura-B 26mm specifications added.
1.6	Mar 30 2022	Aura-L specifications and calibration instructions added. Communications information updated.
1.7	Aug 8 2022	Added pin-specific voltage level thresholds and recommended circuitry.

1.2 Disclaimers and limitations of liability

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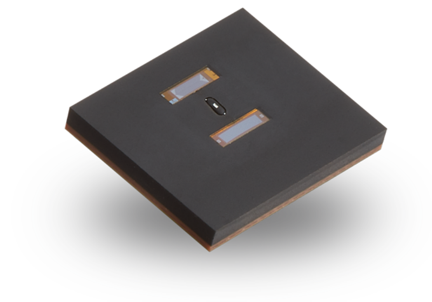
2 Overview

Aura employs a short wavelength LED for precise absolute position decoding. An incremental scale track and advanced sensor produce pure sinewave signals enabling high resolution interpolation with run-speeds up to 83,721 rpm. High repeatability and accuracy satisfy the most demanding applications.



1 Aura Absolute Optical Encoder

The small, low power consumption SMT package integrates easily into an OEM PCB. Generous alignment tolerances facilitate installation. Built-in scale eccentricity compensation improves production efficiency and eliminates the cost of dual averaging encoders.

High speed BiSS-C delivers the minimal latency required for high bandwidth control loops. SSI, SPI and AqB interfaces complete the comprehensive connectivity options. AqB provides the flexibility to operate incrementally after initial absolute position is determined. AqB also enables interface redundancy when safety is an issue.

SmartPrecision III is intuitive software for calibration, alignment and status monitoring. Encoder data can be sampled and recorded in a CSV file. To simplify installation, Celera Motion also provides hubs with pre-mounted encoder scales. For fast prototyping, a compact, easy-connect Evaluation Board is available in limited quantities (consult your sales representative). Note that the Evaluation Board accessory is in the beta stage of release.

2.1 Benefits

- True absolute position - no wake-and-wiggle
- Small, low power SMT package
- High resolution and accuracy
- High run-speed
- Wide alignment tolerances
- Eccentricity compensation
- Low communications latency
- Comprehensive connectivity

3 Specifications

3.1 Performance Specifications - Rotary

System Data	AUR-R-B			AUR-R-C	
Scale Sizes (OD)	18.0 mm	26.0 mm	33.0 mm	51.8 mm	63.5 mm
Resolution	18-22 bits	18-22 bits	18-22 bits	20-22 bits	20-22 bits
Accuracy [1]	± 0.01 °	± 0.01 °	± 0.01 °	± 0.005 °	± 0.005 °
Fly Height (Air Gap)	1.75 mm	1.75 mm	1.75 mm	1.75 mm	1.75 mm
Alignment Tolerances: Tan (X), Rad (Y), Z	± 0.20, ± 0.20, ± 0.40 mm	± 0.30, ± 0.20, ± 0.40 mm	± 0.50, ± 0.20, ± 0.40 mm	± 0.50, ± 0.25, ± 0.40 mm	± 0.50, ± 0.25, ± 0.40 mm
Theta Tolerances: X, Y, Z	± 2 °, ± 1 °, ± 1 °	± 2 °, ± 1 °, ± 1 °	± 2 °, ± 1 °, ± 1°	± 2 °, ± 1 °, ± 1°	± 2 °, ± 1 °, ± 1°
Concentricity Tolerance [2]	50 um	100 um	100 um	100 um	100 um
Max. Speed	83,721 RPM	56,250 RPM	41,983 RPM	18,922 RPM	15,859 RPM
Repeatability	1 LSB	1 LSB	1 LSB	1 LSB	1 LSB
Jitter (Position Noise)	±1 LSB	±1 LSB	±1 LSB	±1 LSB	±1 LSB
Jitter Averaging Sample Size [3]	19 bits = 4, 20 bits = 12, 21 bits = 45, 22 bits = 287			21 bits = 4, 22 bits = 65	

1. Specification assumes eccentricity error after installation has been corrected.
2. The center of the scale pattern circumference should align with the axis of rotation within the concentricity tolerance.
3. Position sample averaging in the drive/controller can be used to eliminate jitter at higher resolutions. The recommended number of samples depends on the resolution. In noisy environments it may be necessary to increase the averaging sample size. Averaging is not recommended for closed-loop systems.

3.2 Performance Specifications - Linear

System Data	AUR-L-C
Scale Lengths	custom lengths (glass scales)
Resolution[1]	± 12.5 nm to ± 200 nm
Accuracy [2]	± 2.0 um
Fly Height (Air Gap)	1.75 mm
Alignment Tolerances Y, Z	± 0.25 mm, ± 0.50 mm
Theta Tolerances X, Y, Z	± 2 °, ± 1 °, ± 1 °
Max. Speed	50 m/s
Repeatability	1 LSB
Jitter (Position Noise)	±1 LSB
Jitter Averaging Sample Size [3]	± 12.5 nm: 112 ± 25 nm: 27 ± 50 nm: 7 ± 100 nm: 2 ± 200 nm: no averaging

1. Higher resolution can be achieved by increasing averaging sample size. See Jitter Averaging Sample Size in table above for specific sample sizes.
2. Accuracy is measured using a glass scale with 250 mm of measurable length.
3. Position sample averaging in the drive/controller can be used to eliminate jitter at higher resolutions. The recommended number of samples depends on the required resolution . In noisy environments it may be necessary to increase the averaging sample size.

3.3 Electrical Specifications

Electrical Data	
VAA Supply Voltage	4.5 VDC to 5.5 VDC
VDDIO Supply Voltage	2.5 VDC to 5.5 VDC Note: If the Supply Voltage is 2.5V or 3.3V, you will need to change the VDDIO Supply Voltage setting in SmartPrecision III or using registers (contact a Celera Motion representative for access). This will update the low voltage threshold and prevent erroneous “low voltage” errors.
Supply Current	45 mA
Input Voltage Thresholds	Low: 10 % VDDIO; High: 90 % VDDIO for Pin 1 (BiSS/SSI/SPI) Low: 30 % VDDIO; High: 70 % VDDIO for the following input pins: • Pin 6 (SPI_CS) • Pin 7 (MA/SCLK) • Pin 8 (SLI/MOSI) • Pin 22 (Reset)
Output Voltage Thresholds	Low: 0.4 VDC; High: (VDDIO - 0.4 VDC) for the following output pins: • Pin 9 (SLO/MISO) • Pin 13 (Z) • Pin 18 (B) • Pin 19 (A) • Pin 20 (GPIO_1) • Pin 21 (GPIO_0)
BiSS Max. Clock Rate	20 MHz (single) 10 MHz (daisy-chaining)
BiSS Latency	< 5 µsec
SPI Max. Clock Rate	12 MHz
SPI Latency	< 5 µsec

Electrical Data	
SSI Max. Clock Rate	10 MHz
SSI Latency	< 30 µsec
AB Min. Edge Separation	37.5 nsec

3.4 Mechanical Specifications

Mechanical Data	
Size	9.0 x 7.0 x 1.1 mm
Fly Height	1.75 mm
Weight	1.5 g

3.5 Environmental Specifications

Environmental Data	
Operating Temperature Range	-20°C to 85°C
Storage Temperature Range	-40°C to 110°C
Soldering Peak Temperature	245°C < 20 sec, convection reflow
Moisture Sensitivity Level	5a
Contamination Immunity*	Tolerant to fingerprints from clean hands. Recommended that optics are kept clean at all times.

Environmental Data	
Storage Humidity Range	10-85 % RH Non-Condensing

* See Storage and Handling(see page 13) for guidelines on minimizing contamination

3.6 Reliability Specifications

Reliability Data	
MTBF	> 77,000 hours (@ 55°C operating temperature)

4 Storage And Handling

Aura is a precision electronic instrument. It has been designed to function in a wide range of applications and environments. To take full advantage of the encoder design, allow easy access to the sensor for service and/or replacement. For optimal performance and reliability:

- DO follow standard ESD precautions while handling the sensor.
- DO allow proper clearance for sensor head alignment.
- DO follow setup and alignment instructions for the encoder system.
- DO, where possible, install the scales in an inverted or vertical position to minimize accumulation of dust.
- DO NOT store sensors in an uncontrolled environment.
- DO NOT electrically overstress the sensor (power supply ripple/noise).
- DO NOT intentionally "hot swap" the sensor if the device is energized.
- **DO NOT hand solder**. Hand soldering can cause damage to the device.

4.1 Safety Considerations

Depending on the mode of operation, Aura can emit a highly concentrated visible blue light which can be hazardous to the human eye. Products that incorporate this device should follow the safety precautions given in IEC 60825-1 and IEC 62471.

4.2 Chip Handling Considerations

Follow Electrostatic Discharge (ESD) precautions at all times. Prior to reflow soldering, pay particular attention to preventing ESD damage as the damage threshold is 500 V.

Avoid contact with optics to prevent contamination. For more information on cleaning encoder optics, please see our technical paper: https://www.celeramotion.com/microe/support/technical-papers/cleaning-encoder-optics/ .

4.3 Scale Handling Considerations

Gloved handling is strongly recommended. If gloves are not used, hands should be clean and contact with scale tracks avoided.

4.4 Moisture Sensitivity Level

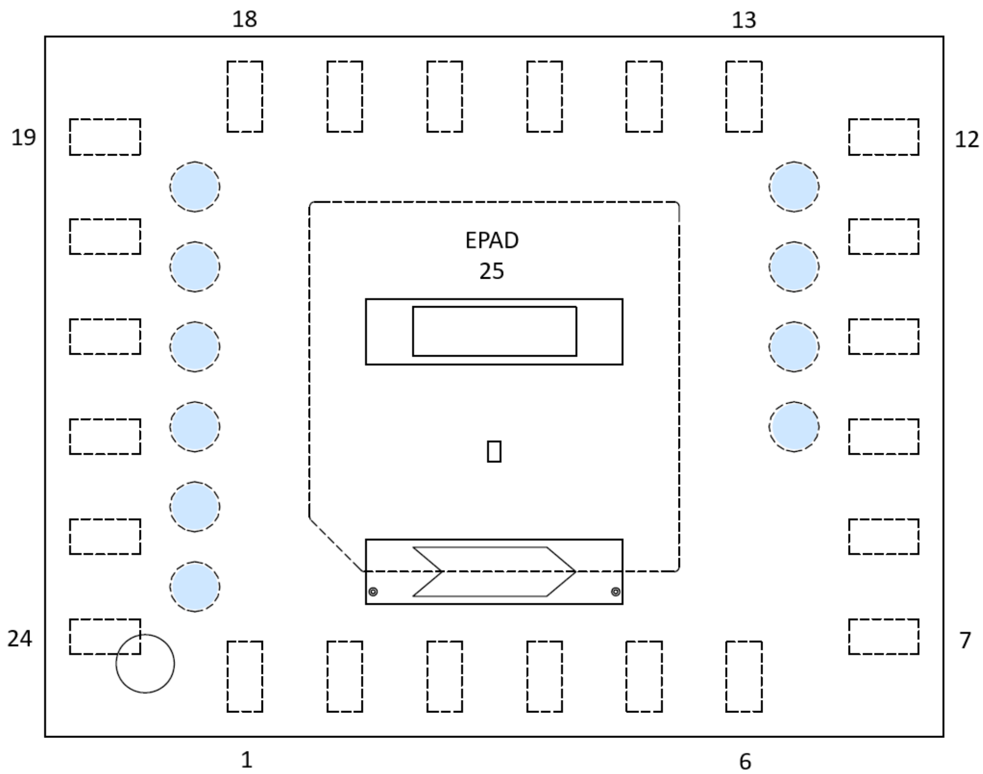
Aura is an MSL 5a component and must go through a bake out procedure prior to being soldered in place. Please refer to IPC/JEDEC J-STD-033 for appropriate MSL 5a bake conditions.

4.5 Surface Sensitivity

When handling Aura, do not allow the pickup device to touch anywhere in the Keep Out Zone - LED surface and glass windows. Scratches or 'digs' in the Keep Out Zone can affect the encoder performance.

5 Electrical Interface

5.1 Pinout



NOTE: Round test pads highlighted in blue above are for manufacturer testing only. Conductor is NOT allowed in contact with these test pads.

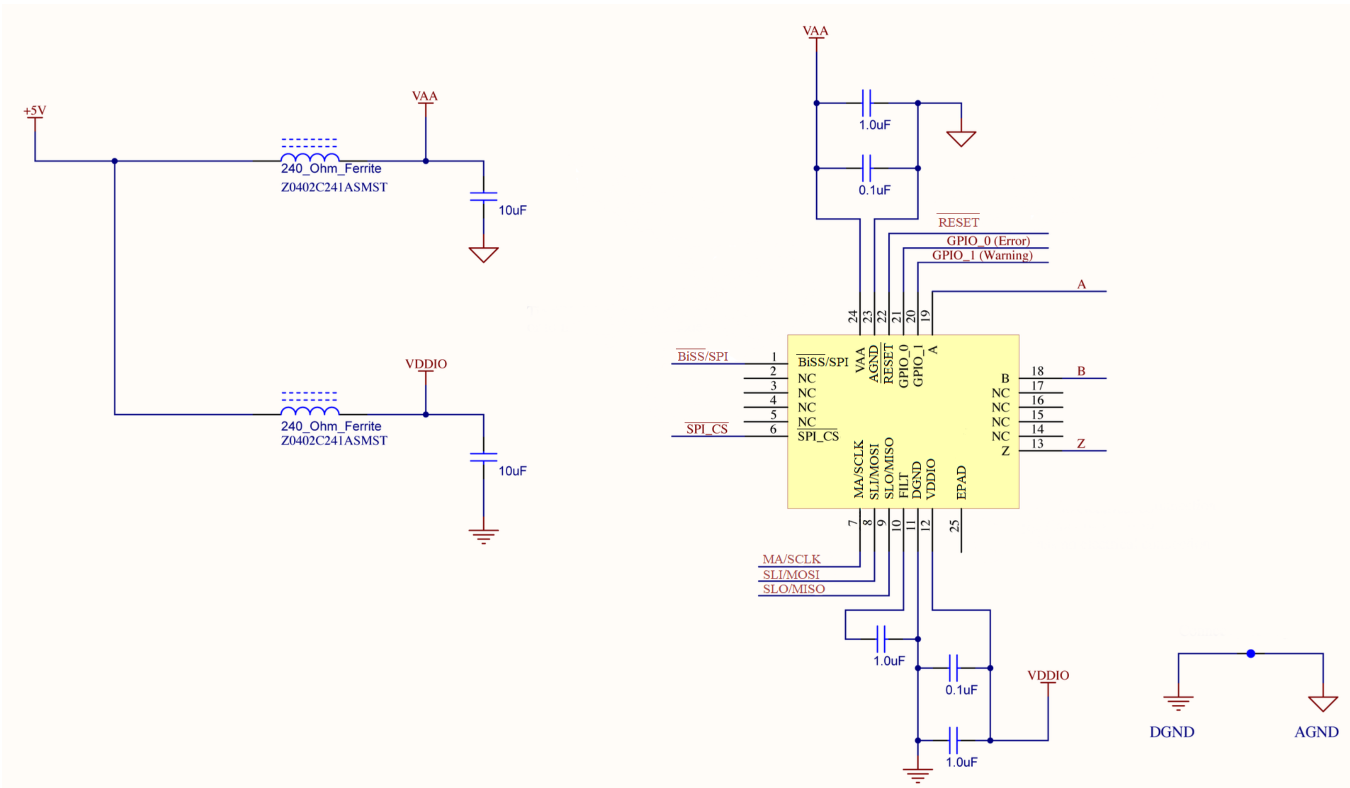
Pin	Function	Pin	Function
1	$\overline{\text{BiSS}}$/$\overline{\text{SSI}}$/SPI[1]	14	NC
2	NC	15	NC
3	NC	16	NC
4	NC	17	NC
5	NC	18	B
6	$\overline{\text{SPI\_CS}}$[2]	19	A
7	MA/SCLK	20	$\overline{\text{GPIO\_1}}$ (Warning)[4]
8	SLI/MOSI	21	$\overline{\text{GPIO\_0}}$ (Error)[4]
9	SLO/MISO	22	$\overline{\text{RESET}}$[5]
10	FILT [3]	23	AGND
11	DGND	24	VAA
12	VDDIO	25	EPAD
13	Z		

2 Aura Chip Pinout

1. For BiSS or SSI mode, pin must be pulled low (DGND). For SPI mode, pin must be pulled high (VDDIO).
2. For SPI, Chip is selected when pin is pulled low. Chip is not selected when pin is pulled high. For BiSS or SSI mode, pin should be pulled high.
3. Decoupling capacitor pin - see Recommended Supporting Circuitry
4. GPIO_1 and GPIO_0 are active low in Aura Chip configuration file versions 3 and later. Aura Evaluation Boards maintain and active high configuration in all versions.
5. To reset, RESET pin must be pulled low. Reset should be pulled high if not in use.

5.2 Recommended Supporting Circuitry

- Proper pull-up and pull-down resistors (10k ohms recommended) are critical to ensure voltage level threshold requirements are met. See Specifications section for more information.
- Separate VAA and VDDIO via ferrites.
- Connect DGND and AGND at star point close to chip.
- For BiSS or SSI modes, connect Pin 1 (BiSS/SSI/SPI) to DGND. For SPI Mode, connect Pin 1 (BiSS/SPI) to VDDIO.
- Solder EPAD to PCB Pad for heat dissipation only. **Do not make electrical connection to EPAD.**



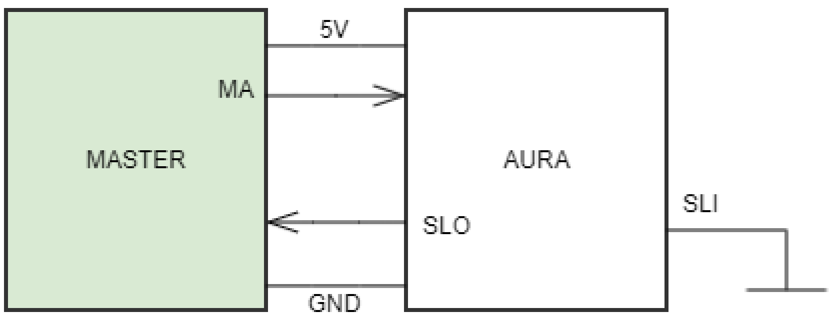
5.3 SmartPrecision III Connectivity

SmartPrecision III requires access to Aura's BiSS-C interface via the MB5U BiSS/USB converter. Users who require SSI communication protocol can switch from BiSS-C to SSI in SmartPrecision III or using registers. Users who require SPI interface and want to utilize SmartPrecision III must design in a switch for Pin 1 (BiSS-C/SSI/SPI mode) in order to return to SPI mode after calibration. See SmartPrecision III(see page 28) for more information.

6 Communications

6.1 BiSS-C

6.1.1 Single Slave Operation

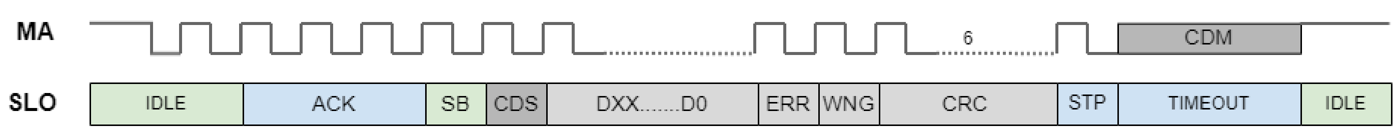


Aura employs a bidirectional implementation of BiSS-C. BiSS-C can incorporate a channel embedded in the operational frame for control, configuration and status. This method is initiated by the state of the master clock (CDM - Control Data Master) at the end of a data frame. The response (CDS - Control Data Slave) is embedded in subsequent frames one bit per frame. This technique is used for accessing Aura registers while the encoder is reporting position.

The BiSS profile identification (ID), which can be used for establishing the communication automatically with the controller, is stored in the read-only direct access register 0x42 and 0x43 based on the factory configurations per BP3 Standard Encoder Profile guidelines[1].

Please note that any BiSS profile changes (e.g. data size; enabling working counter) will make the BP3 profile ID invalid.

The BiSS-C BP3 protocol sequence is outlined below. Note that CDS and CDM are included for completeness.



Note: green=1, blue=0, grey=0/1

1. Master initiates communication, clock active
2. ACK Acknowledge [0] - slave responds on second rising clock edge, begins to compile data
3. SB Start [1] - slave is ready to transmit data after three clocks
4. CDS Control Data Slave - one bit of data packet transferred over multiple cycles in response to CDM
5. Default data size: 18 bits for AUR-B, 20 bits for AUR-C, 25 bits for AUR-L. Data size can be configured in SmartPrecision III.

[1] https://www.ichaus.de/upload/pdf/BiSS_BP3_profile_A3en.pdf

6. ERR Error [0 if error]
7. WNG Warning [0 if warning]
8. CRC Cyclic Redundancy Check - 6 bits
9. STP Stop [0] + Timeout [0]
10. During Stop and Timeout, Master can transmit CDM (Control Data Master) by bringing MA high or low - note the slave interprets the clock state as a single control/data bit
11. MA & SLO [1] - idle, slave ready

The duration of the BiSS timeout is determined by the master clock interval. The minimum timeout is equal to 1.5 x the master clock interval and the maximum timeout is equal to 1.5 x the master clock interval plus 200ns. For example, if your master clock interval is 100ns (10MHZ), then the BiSS timeout will be between 150-350ns.

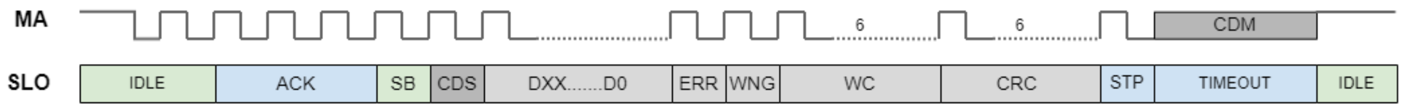
Control data commands (CMD) do not need to be sent on the user end. The following commands are implemented:

- Addressed CMD '00': activate single-cycle data channels
- Broadcast CMD '00': deactivate single-cycle data channels

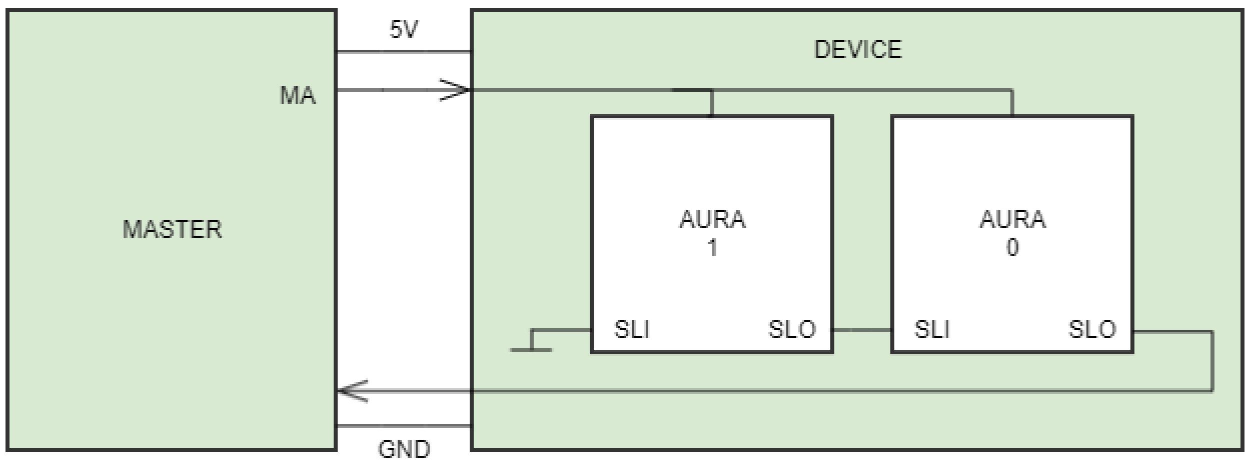
When interfacing with an Ingenia servo drive, set the following parameters in MotionLab 3. Note that the frame size does not include ACK, Start, CDS, Stop.

MotionLab 3 Feedback Settings	**AUR-B**	**AUR-C**
Protocol	BiSS-C	BiSS-C
Frame Type	BP3	BP3
Frame Size	26	28
Position Bits	18 (default)	20 (default)
Single-turn Bits	18	20
Position Start Bit	8	8

If working counter (also known as sign-of-life counter) bits are needed, use SmartPrecision III to reconfigure your Aura encoder. If registers are preferred, please contact a Celera Motion representative for access to the Aura Registers document. If enabled, the working counter is initialized at 0, then counts each frame from 1 to 63 skipping the 0 when wrapping. The modified BiSS protocol sequence below shows the BiSS frame with the working counter (WC) bits included.

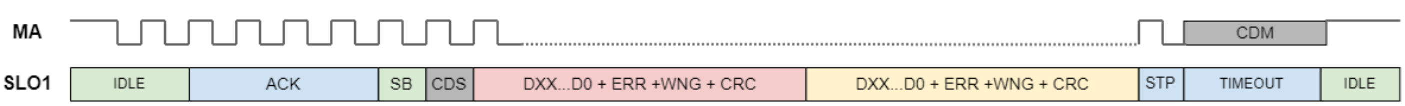


6.1.2 Daisy-Chained Slave Operation



Up to eight (8) slaves can be connected in a daisy-chained configuration. Data is captured at exactly the same time on each slave. The first slave, Aura A, clocks out its data packet first while buffering the data packet from Aura B. Aura A then clocks out the buffered packet from Aura B. Note that the last slave, Aura B, must have its SLI input tied to zero.

The BiSS BP3 daisy-chain protocol sequence is outlined below. Note that CDS and CDM are included for completeness.



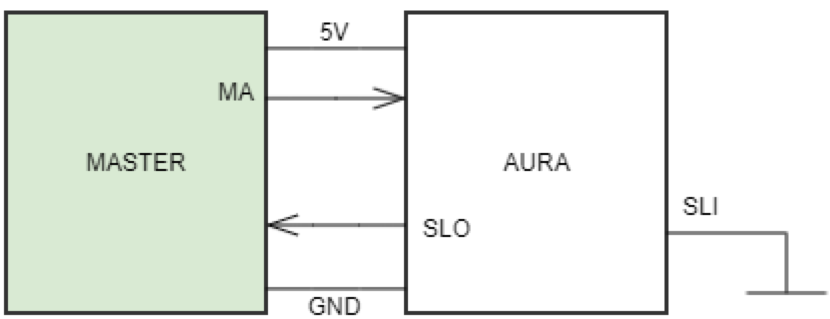
Note: green=1, blue=0, grey=0/1, pink=data packet Aura A, yellow=data packet Aura B

1. Master initiates communication, clock active.
2. ACK Acknowledge [0] - Aura A responds on the second rising edge of MA clock. Aura A and B are latched simultaneously. The ACK increases by one clock cycle for each additional Aura in daisy-chain (e.g. Single slave: ACK is 3 clock cycles; Two slaves: ACK is 4 clock cycles; Three slaves: ACK is 5 clock cycles).
3. SB Start [1] - Aura A is ready to transmit data after ACK.
4. CDS Control Data Slave - one bit of data packet from the addressed slave transferred over multiple cycles
5. Default data size A: 18 bits for AUR-B, 20 bits for AUR-C, 25 bits for AUR-L. Data size can be configured in SmartPrecision III.
6. ERR Error A [0 if error]
7. WNG Warning A [0 if warning]
8. CRC Cyclic Redundancy Check A - 6 bits

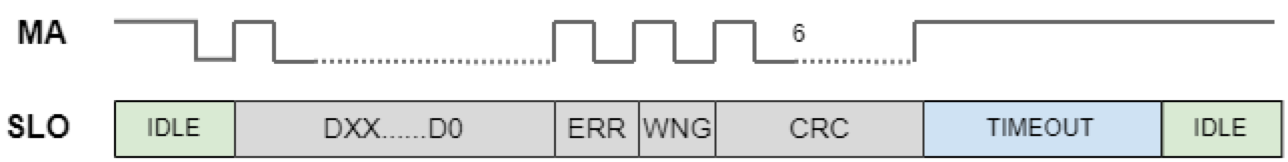
9. Default data size B: 18 bits for AUR-B, 20 bits for AUR-C, 25 bits for AUR-L. Data size can be configured in SmartPrecision III.
10. ERR Error B [0 if error]
11. WNG Warning B [0 if warning]
12. CRC Cyclic Redundancy Check B - 6 bits
13. STP Stop [0] + Timeout [0]
14. During Stop and Timeout, Master can transmit CDM (Control Data Master) by bringing MA high or low - note the slave interprets the clock state as a single control/data bit.
15. MA & SLO A - idle, slave ready

Aura configuration using SmartPrecision III must be performed in single-slave mode for each slave. The slaves can then be connected in a daisy-chain.

6.2 SSI



- Unidirectional - position data only, no register access. For SSI communication, first use BiSS protocol to calibrate in Smart Precision III or via registers.
- Pure binary data
- Fixed timeout



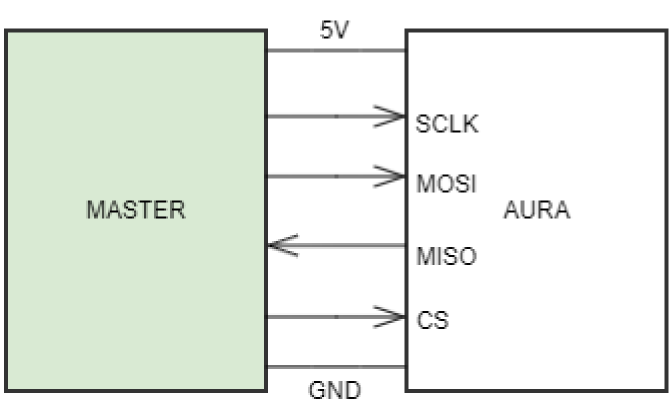
Note: green=1, blue=0, grey=0/1

1. Master initiates communication, clock active
2. Default data size: 18 bits for AUR-B, 20 bits for AUR-C, 25 bits for AUR-L. Data size can be configured in SmartPrecision III.
3. ERR Error [0 if error]
4. WNG Warning [0 if warning]
5. CDC Cyclic Redundancy Check - 6 bits
6. MA [1], SLO [0] fixed timeout (16 - 24 µsec)
7. SLO [1] - idle, slave ready

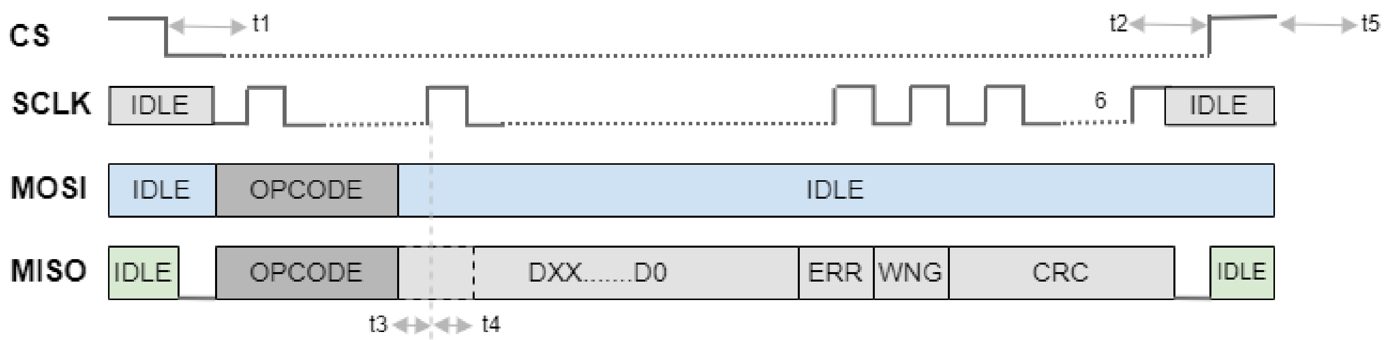
When interfacing to an Ingenia drive, set the following parameters in MotionLab 3:

MotionLab 3 Feedback Settings	AUR-B	AUR-C
Protocol	SSI	SSI
Frame Type	RAW	RAW
Frame Size	26	28
Position Bits	18	20
Single-turn Bits	18	20
Position Start Bit	8	8

6.3 SPI



- One operating mode - Read Position
- Clock Mode idle state defined by Master: Mode 0 - normally low, Mode 3 - normally high
- MISO should be pulled up or down (pullup assumed in timing diagram)



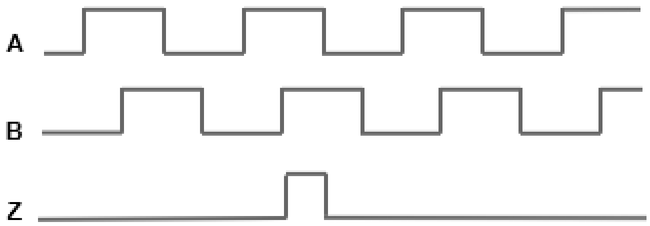
Note: green=1, blue=0, grey=0/1

1. Master initiates communication - CS active low
2. Master sends Opcode (0xA6) via MOSI which slave echoes on MISO
3. Default data size: 18 bits for AUR-B, 20 bits for AUR-C, 25 bits for AUR-L. Data size can be configured in SmartPrecision III.
4. ERR Error [0 if error]
5. WNG Warning [0 if warning]
6. CDC Cyclic Redundancy Check - 6 bits
7. Master terminates communication - CS inactive high

Parameter	Description	Min Value
t1	CS low to MA clock rising edge setup time	42 nsec
t2	Last MA clock rising edge to CS high hold time	42 nsec
t3	Data setup time	15 nsec
t4	Data hold time	5 nsec
t5	Dwell time between cycles	200 nsec

6.4 ABZ Incremental

- AB = 11, Z = 0 during startup, until position found
- Index active at zero absolute position, A and B both high
- Zero AB hysteresis after a change in direction


A
B
Z

7 Aura Installation

7.1 General Installation Guidelines

- Please refer to Interface Drawings (see table below for ID numbers) during installation
- Alignment tolerances are listed in Specifications(see page 8)
- Z alignment in the interface drawings is defined by the distance from the scale to the chip mounting surface of the Customer PCB. Chip height variance is factored into the drawing.
- Radial and Tangential alignments are defined by the locations of the Aura **chip fiducials** relative to the scale centerlines. Do not use pad centerlines as an alignment reference.

7.2 Rotary Installation

1. Ensure optics (scale and optics window on chip) are clean before installation.
2. Alignment
   a. Scale to center of rotation:
      i. Use alignment tolerances in Specifications (see page 8)to properly align the scale relative to the center of rotation with run out less than the concentricity tolerance. Refer to Alignment Guidelines[2] for more information.
      ii. Where possible, install the scales in an inverted or vertical position to minimize accumulation of dust. If the patterned side of the scale must be oriented upwards, consider designing a labyrinth seal into your assembly design to further protect against debris build-up. If contamination is present, follow the clean guideline in Cleaning Optics[3].
   b. Aura chip to PCB:
      i. Define precision benching edges on customer PCB that can be used for chip to scale alignment.
      ii. Precisely place the Aura chip relative to the benching edges by aligning the chip fiducials with fiducials or other reference markers on the customer PCB during the SMT process.
      iii. Employ the customer PCB benching edges to accurately position the chip relative to the scale.
3. Optional rough alignment verification: check if the scale zero position, indicated by the reflective bar on the inner diameter of the tracks, is read as zero in SmartPrecision III before proceeding to the calibration. Checking that the reading matches the zero scale position ensures the chip is approximately within tolerance.
4. Once the scale and encoder are aligned, perform the mandatory misalignment and GOP calibration using Smart Precision III as described in Calibration(see page 33) . If you would prefer to use registers, please contact your Celera Motion representative for access to our registers document. If the mandatory calibration is not performed, the encoder will likely report a position read error.
5. Perform optional eccentricity calibration if higher accuracy is needed.
6. Follow steps in Confirming Alignment(see page 35) to verify the alignment is within tolerance.

> Alignment tolerance budget is reduced if fiducial guided placement is not employed and the chip is merely allowed to settle on the pads during the SMT process.

7.3 Linear Installation

1. Ensure optics (scale and optics window on chip) are clean before installation.
2. Alignment
   a. Scale to benching edge:

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2 https://www.celeramotion.com/microe/support/technical-papers/rotary-scales-alignment/
3 https://www.celeramotion.com/microe/support/technical-papers/cleaning-encoder-optics/

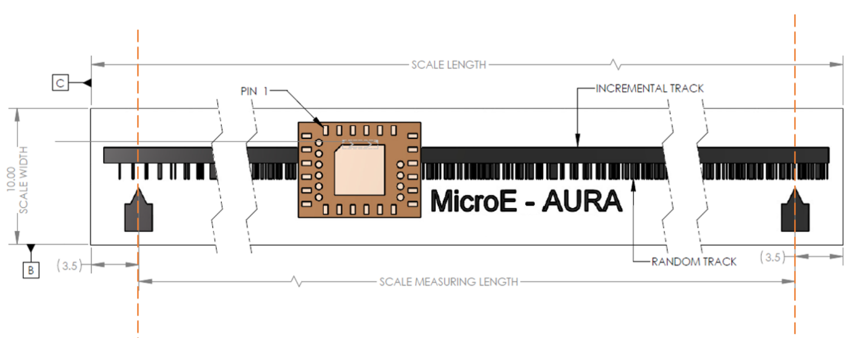
   i. Use alignment tolerances in Specifications(see page 8) to properly align the scale relative to the application benching surfaces.
   ii. Where possible, install the scales in an inverted or vertical position to minimize accumulation of dust. If the patterned side of the scale must be oriented upwards, consider designing a labyrinth seal into your assembly design to further protect against debris build-up. If contamination is present, follow the clean guideline in Cleaning Optics[4].
b. Aura chip to PCB:
   i. Define precision benching edges on customer PCB that can be used for chip to scale alignment.
   ii. Precisely place the Aura chip relative to the benching edges by aligning the chip fiducials with fiducials or other reference markers on the customer PCB during the SMT process.
   iii. Employ the customer PCB benching edges to accurately position the chip relative to the scale.

3. Optional rough alignment verification: check if the scale zero position, indicated by the reflective bar on the inner diameter of the tracks, is read as zero in SmartPrecision III before proceeding to the calibration. Checking that the reading matches the zero scale position ensures the chip is approximately within tolerance.
4. Once the scale and encoder are aligned, perform the mandatory misalignment and GOP calibration using Smart Precision III as described in Calibration(see page 33). If you would prefer to use registers, please contact your Celera Motion representative for access to our registers document. If the mandatory calibration is not performed, the encoder will likely report a position read error.
5. Follow steps in Confirming Alignment(see page 35) to verify the alignment is within tolerance.

> Alignment tolerance budget is reduced if fiducial guided placement is not employed and the chip is merely allowed to settle on the pads during the SMT process.

7.3.1 Linear Scale Measuring Length

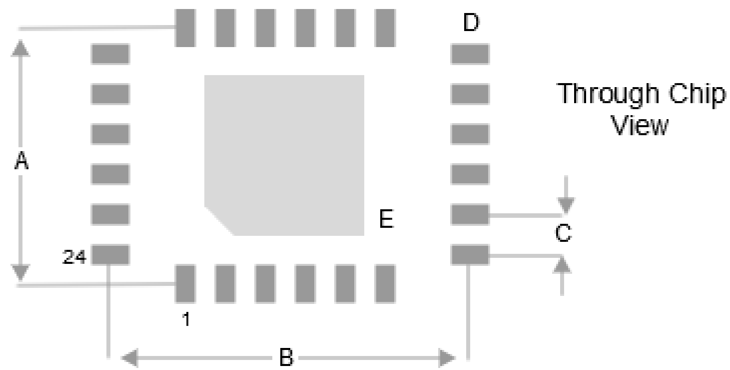
The measuring length of the scale is 7.0 mm less than the overall length of the scale. There are 3.5mm buffer zones on either end of the scale indicated by the pointer boxes shown in the picture below. The center line of the chip should never go beyond the orange dashed lines. The absolute reading may be erroneous if the center line of the chip is in the buffer zone.

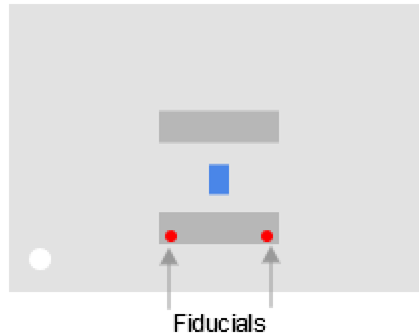


3 Aura Linear Scale With Measuring Length

4 https://www.celeramotion.com/microe/support/technical-papers/cleaning-encoder-optics/

7.4 Recommended PCB Footprint





Parameter	Description	Dimensions
A	Y Distance Pads	5.80 mm
B	X Distance Pads	7.80 mm
C	Step Size Pads	1.00 mm
D	Pads Size (L x W)	0.70 mm x 0.35 mm
E	EPAD Size (L x W)	3.70 x 3.70 mm

- A-D dimension tolerances are ± 0.02 mm, E tolerance is ± 0.1 mm
- EPAD is centered in Y (A) and X (B) with +/- 0.02 mm centering tolerance

7.4.1 Interface Drawing Numbers

Scale Part Number	Scale Size	Interface Drawing Number
AUR-R-G-0002	18 mm	ID-00414
AUR-R-G-0001	26 mm	ID-00412
AUR-R-G-0003	33 mm	ID-00415

Scale Part Number	Scale Size	Interface Drawing Number
AUR-R-G-0006	51.8 mm	ID-00419
AUR-R-G-0004	63.5 mm	ID-00416
AUR-L-G-XXXX	Linear (All)	ID-00422

8 SmartPrecision III

8.1 Software Features

- Calibration Routines:
  - Misalignment
  - Gain, Offset, and Phase
  - Eccentricity
- Angle Plot and Strip Plot viewer
- Storing and uploading Aura configuration files
- Data saving capabilities for characterization and analysis

8.2 Prerequisites

1. Win10 (64 bit) PC
2. BiSS-USB converter and cable: IC Haus, https://www.ichaus.de/MB5U
3. MB5U Driver-6.2_libusb1.0.21 installed on PC
4. Aura Carrier Board mounted to scale
5. Cable from Carrier Board to BiSS-USB converter
6. **Aura must be in BiSS or SSI mode**

Ensure that the USB 2.0 computer output can supply the standard 500 mA. If a suitable USB port is not available, external 5V must be provided.

For rapid prototyping, consult your sales representative for an Evaluation Board and BiSS-USB cable. Ensure that the switch settings are as described in Evaluation Board.

8.3 Quick Start

1. Connect Carrier Board or Evaluation Board to MB5U adapter and MB5U adapter to PC
2. Download SmartPrecision III installer here[5]
3. Run installer and launch SmartPrecision III application
4. Three windows should be visible: Setup Tool, Strip Plot, Angle Plot
5. **<Connect>** (Setup Tool window, Settings tab)
6. Once connected, **<Start Polling>** (Setup Tool window, Settings tab)
7. Move scale relative to sensor and observe position (degrees and raw counts) in the Encoder Status tab
8. Move through the full range of motion and ensure there are no faults or warnings
9. **<Stop Polling>** then move on to calibrating the encoder(see page 33)

8.4 Smart Precision III Setup Tool

8.4.1 Encoder Status

The **Encoder Status** tab in the Smart Precision III Setup Tool window displays the following:

- Connection Status
- Position Reading (e.g. angle, counts)

5 https://go.celeramotion.com/SmartPrecisionIII

- Concentricity: measured concentricity (0.1um resolution) populated after Eccentricity Calibration is performed. Ensure that the concentricity after calibration is below the tolerance listed in Specifications(see page 8). If it is greater than the concentricity tolerance, align your scale such that the center of the scale pattern is concentric to the center of rotation within tolerance then repeat the calibration.
- Warning and Error Descriptions

Please note that the fields in this tab are grayed out until you are connected and **<Start Polling>**.

See chart below for Error/Warning descriptions and corrective action.

Error/Warning	Description	Solution
Warning	Not Ready	Wait until startup complete
Warning	Under-Temperature	Check ambient temperature
Warning	Over-Temperature	Check ambient temperature
Error	No Scale	Install on scale and verify in alignment tolerance
Error	Detector Saturated	Eliminate strong ambient light
Error	Low Voltage	Increase supply voltage, check current rating
Error	Initialization Timeout	Faulty unit, return to factory
Error	EEPROM Failure	Faulty unit, return to factory
Error	Position Read Error	Clean optics. Make sure no stray light enters the sensor window. Ensure chip and scale are installed within tolerance range and misalignment calibration is done successfully.

8.4.2 Settings

- Device Port: displays the device that is used to interface with Aura (MB5U)
- Launch Angle Plot at Startup?: **<Yes>** if you would like the angle plot to open automatically upon next startup.
- Launch Angle Plot Now: **<OK>** to open the Angle Plot window.
- Launch Strip Plot at Startup?: **<Yes>** if you would like the Strip Plot to open automatically upon next startup.
- Launch Strip Plot Now: <**OK>** to open the Strip Plot window.
- Reset Program Settings to Default Values: **<Set Defaults...>** to reset any parameters such as Angle Plot Persistence back to their default values.

- Reset Window Sizes and Positions to Defaults: **<Set Defaults...>** to reset window size and location to defaults.

8.4.3 Configuration

At startup, Smart Precision III reads the the Aura configuration from the chip. The **Configuration** tab can be used to view and edit certain parameters. The following parameters are read-only and cannot be changed by the user:

- Encoder Type (i.e. AUR-R-B, AUR-R-C, or AUR-R-L)
- Chip ID: Unique manufacturer chip identification number
- Configuration: Aura configuration file (.acf) version (see Aura Configuration File Revision History document for more information)
- Scale Type: Rotary or Linear
- Scale ID: Indicates the scale size that has been used to create the configuration file stored on the chip.

The following parameters can be changed by the user:

- Resolution: The resolution can be reduced to shorten latency if the configured resolution is higher than required. Note that position noise is specified as <1 LSB at the preconfigured resolution. If the resolution is increased, the position noise would be >1 LSB. Averaging multiple samples would reduce the noise.
- Counts per Revolution: The resolution of the ABZ incremental output can be changed up to a maximum of the programmed resolution. Note that a “count” is defined as a transition on A or B.
- BiSS/SSI Communications: Aura is preconfigured for BiSS communication. SmartPrecision III communicates with Aura via BiSS. If Aura is reconfigured to SSI, the chip will remain in BiSS mode until power is cycled.
- VDDIO Supply Voltage: Adjust to match the VDDIO supply voltage (5V, 3.3V, or 2.5V). This will adjust the threshold for low voltage errors.
- Use of BiSS Sign-of-Life count: Use to enable 6 working counter bits in BiSS frame. See Communications(see page 17) for more information.

To change any of these parameters:

1. **<Stop Polling>** (if polling is active) to access the following Configuration function buttons:
2. **<Read Encoder>** to read the current Aura configuration from the EEPROM
3. Change the parameter of interest or **<Load File>** to load a previously saved configuration file (.acf)
4. **<Write Encoder>** to store the configuration to the EEPROM
5. **<Save File>** to save configuration as .acf file

Upload Aura Configuration File to Chip

To load a new Aura configuration file (.acf) or revert to an older configuration file, use SmartPrecision III and follow the steps below.

1. Download .acf file from the Aura product page[6].
2. Connect Aura to SmartPrecision III through MB5U BiSS adapter.
3. Go to the Configuration tab, then **<Load File>**.
4. Select the file from browser.
5. Once the file is loaded, **<Write Encoder>**, then **<Read Encoder>**.

8.4.4 Set Position to Zero

To define the current position as zero absolute position:

6 https://www.celeramotion.com/microe/products/optical-rotary-encoders/nano/aura-series/

1. **<Stop Polling>** (if polling is active)
2. **<Zero Position>**

The Angle Plot indicator is set to the 3 o'clock position after zeroing position.

8.4.5 Record Data in CSV File

Configure CSV File Content

Use the **CSV Fields** tab to configure parameters to record in the CSV file.

To select a field for CSV recording:

1. Click field in Available Fields
2. **<Add>>>**

To deselect a field:

1. Click field in Selected Fields
2. **<<<Remove>**

The selected fields will be placed in columns in the CSV file in the order seen in Selected Fields. To change the order click a field then **<Move Up>** or **<Move Down>**.

The number of samples taken can be defined in Record Count. The sampling rate is 60 Hz so a Record Count of 3600 would yield 1 minute of data sampling and recording. Note that setting Record Count to zero will disable the CSV record buttons.

Create a CSV File and Record

1. **<New CSV File>**
2. Define file name, location, then **<Save>**
3. **<Record CSV>** and observe Record Count
4. **<Close CSV>** File when count complete

Note that its is possible to pause the recording by clicking **<Pause CSV>**. **<Record CSV>** will resume and another recording of Record Count length will be appended. Similarly another recording can be appended to a completed recording before the file is closed (repeat Step 3 above).

8.4.6 Strip Plot Configuration

Use the **Strip Plot Fields** tab to configure parameters to display in the Strip Plot.

To select a field for display:

1. Click field in Available Fields
2. **<Add>>>**

To remove a field from the plot:

1. Click field in Selected Fields
2. **<<<Remove>**

The strip plot has two Y-axes on the left/right sides of the plot. This makes it possible to assign fields with similar value ranges to a specific axis. For example, ErrorState (0 to 1) could be assigned to the left axis and AngleDegrees (0 to 360) assigned to the right axis. Check the field in Selected Fields to assign to the left axis. Note that that when a field is removed from Selected Fields, the axis assignment is retained.

To configure Y-axes:

1. **<Set Y-axis Ranges>**
2. Set min/max values
3. Set display interval
4. **<OK>**

9 Calibration

The Aura Series absolute optical encoder provides three automatic calibration processes:

1. Misalignment calibration
2. Analog (GOP) calibration
3. Eccentricity correction (Rotary only)

Misalignment calibration corrects the mismatch between the incremental and random absolute track caused by the misalignment. The calibration is required to meet the stated alignment tolerances. This calibration does not require uniform speed. A speed of at least 300 RPM is recommended to minimize the time of the calibration routine, but low speed or manual calibration is feasible.

Analog (GOP) calibration corrects the distortions from misalignment and circuit design. This calibration reduces high frequency noise or subdivisional error (SDE) and thus reduces motor drive current consumption. Like the misalignment calibration, analog calibration does not require the scale to be driven at constant speed. In SmartPrecision III, misalignment and analog calibrations are a combined auto-routine.

The Aura Series absolute optical encoder also offers an optional eccentricity calibration for rotary encoders that helps to improve the accuracy of the position reading. The accuracy specification stated in the datasheet assumes an eccentricity error of 0, so for the highest accuracy possible, the eccentricity calibration should be completed. This calibration procedure requires the scale to be rotated at a constant speed greater than 30 RPM. However, we recommend speeds greater than 300 RPM for optimal results.

Velocity variations can compromise eccentricity calibration accuracy. A slotless motor is recommended with a high resolution feedback device and high bandwidth servo. Bearings should be high quality with minimal runout. Please note that the eccentricity calibration cannot calibrate out non-repeatable run out.

9.1 Misalignment and GOP (Required)

Misalignment Calibration: The absolute track with random code is linked with the interpolated incremental track to provide high resolution absolute position. Misalignment can compromise the linkage between two tracks. Misalignment calibration can compensate for this error as long as the encoder and the scale are within the tolerance range.

GOP Calibration: The incremental track generates sinusoidal signals which are subsequently interpolated. The fidelity of the signals is critical to encoder accuracy. Ideal signals are: undistorted, equal in magnitude or gain, without DC offset, 90° shifted in phase. The geometry of the encoder yields signals of low distortion. Misalignment and small internal circuit variances can cause gain imbalances (**G**), offsets (**O**) and phase (**P**) errors. The GOP calibration procedure compensates for these effects, improving encoder accuracy.

1. Open Smart Precision III
2. **<Connect>**
3. **<Stop Polling>** (if polling active)
4. Move the scale relative to the sensor:
   a. For Rotary Scales: Rotate the scale at a minimum average speed of 10 RPM to scan across the entire working area. Back and forth partial scanning (< 360 degree) is allowed.
   b. For Linear Scales: Move the sensor back and forth across the entire measurable length of the scale at a minimum average speed of 6.4 mm/sec. This can be done manually if necessary but you must adhere to the minimum average speed requirement. If this step fails, try increasing the moving speed and repeat.

5. **<Calibrate>**, then **<Yes>** when you are ready to begin the calibration routine. Continue rotating the scale at or above the minimum speed (10 RPM) until calibration is complete. If an error or warning is flagged, please refer to Alignment Troubleshooting(see page 0).
6. If you would like to calibrate for eccentricity, **<Yes>**. Note that the eccentricity calibration must be run at a constant speed of greater than 30 RPM (> 300RPM is recommended). If you would like to skip the eccentricity calibration, **<No>**.
7. If you are not running the eccentricity calibration and no errors or warnings are flagged, proceed to Confirming Alignment(see page 35).

9.2 Eccentricity (Optional)

Scale mounting eccentricity and bearing runout are typically the most significant contributors to overall accuracy in rotary encoders. The effects of scale eccentricity and repeatable bearing runout can be significantly reduced by eccentricity calibration. The procedure is an optional final calibration step. The entire procedure is repeated here for convenience.

1. Once the encoder has been successfully calibrated (misalignment and GOP), **<Yes>** in the message box shown above to calibrate for eccentricity. Make sure that the scale is rotating at a constant speed of greater than 300 RPM.
2. Once the eccentricity calibration is complete, you will be able to view the eccentricity error in the Encoder Status tab of the Setup Tool.

10 Confirming Alignment

It is critical to confirm the alignment of the encoder to the scale after installation to ensure proper performance and absolute position detection. Follow the instructions for your particular scale geometry below.

10.1 Rotary

1. Connect the encoder to SmartPrecision III software. If a custom software with API document is preferred, please contact Celera Motion to request access to the registers.
2. Once the encoder is connected, check if the approximate scale zero position (a once per revolution mark on the scale indicates position zero) is read as zero in the software. If zero is read correctly, proceed to the following steps. If not, please see the troubleshooting steps below.
3. Clear any latched error/warning signals by resetting the encoder.
4. Rotate the scale at an approximately constant speed (this can be done manually) for at least one minute and simultaneously check error and warning signals.
5. If a 'position read error' is not flagged while the scale is rotating, the encoder is installed properly.
6. If a 'position read error' is flagged, follow the troubleshooting steps below.

10.2 Linear

1. Connect the encoder to SmartPrecision III software. If a custom software with API document is preferred, please contact Celera Motion to request access to the registers.
2. Once the encoder is connected, check if the approximate scale left index position is read as 2.47 mm in the software.
3. Move a known distance within the measurable length of the scale and verify that the count difference is equivalent to the moved distance.
4. Clear any latched error/warning signals by resetting the encoder.
5. Once the distance has been confirmed, move the detector across entire measurable length of scale back and forth at least 20 times. Simultaneously check error and warning signals.
6. If a 'position read error' is not flagged while moving the sensor back and forth, the encoder is installed properly.
7. If a 'position read error' is flagged, follow the troubleshooting steps below.

10.3 Alignment Troubleshooting

The potential causes of the 'position read error' are:

1. Optics (scales and sensor windows on the encoder) are contaminated. Clean the optics.
2. Stray light enters the sensors. This is typically caused by rough, reflective surfaces under the scale pattern. Ensure the surface finishing of the substrate is better than 125 micro inches (Ra), ensure there are not any big features (edges, deep cuts, holes, etc.) under the pattern, shield the stray light, or contact a Celera Motion representative for light shield solutions.
3. The misalignment calibration is not successfully performed. Reperform the calibration.
4. The eccentricity error of the scale is out of the concentricity tolerance range. Verify the eccentricity error is within the tolerance range.
5. The chip is outside the misalignment tolerance range. Re-bench the customer PCB and verify the chip is within the tolerance range.
6. The encoder configuration is not compatible with encoder type.

10.3.1 Notes:

- To reboot encoder, cycle power or Disconnect/Connect in SmartPrecision III (if encoder power is supplied exclusively via BiSS/USB adapter)

- Record position using an external controller or SmartPrecision III
- Ensure scale is stationary relative to readhead during initialization.

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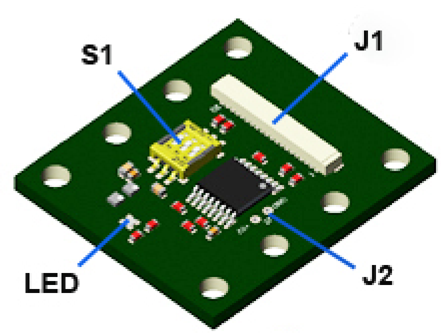
11 Evaluation Board

11.1 Overview

The Evaluation Board can be used to mount, test, and evaluate the performance of the Aura chip.

NOTE: The Evaluation Board is in the beta stage of release.



- 27.1 x 24.2 x 4.1 mm
- I/O support for BiSS, SPI, ABZ, and SSI
- User selectable BiSS/SPI
- User selectable single-ended or differential SPI
- Precision benching edges for ease of installation
- Error/Warning LED
- BiSS-USB cable

11.2 Mounting

Please refer to Interface Drawings on the Aura product page for the relevant scale dimensions.

Be sure to observe the datums A, B, and C shown in the figures when installing the evaluation board. The mechanical attachment of the evaluation board into your assembly should not intrude beyond the areas designated as "Mounting Pad".

Where possible, install the scales in an inverted or vertical position to minimize accumulation of dust. Ensure scale and sensor glass are free of contamination. If contamination is present, follow cleaning guidelines: Cleaning Optics[7]

7 https://www.celeramotion.com/microe/support/technical-papers/cleaning-encoder-optics/

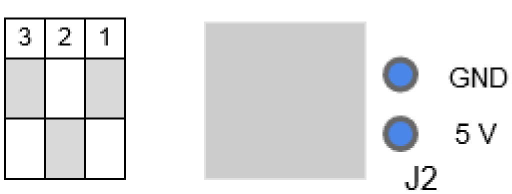
11.3 Electrical Interface

11.3.1 J1 (JST SM20B-XSRS-ETB)

Pin	Function	Pin	Function
1	SCLK/MA+	11	SPI_CS-
2	SCLK/MA-	12	5 V
3	GND	13	A+
4	MISO/SLO+	14	A-
5	MISO/SLO-	15	GND
6	GND	16	B+
7	MOSI/SLI+	17	B-
8	MOSI/SLI-	18	GND
9	5 V	19	Z+
10	SPI_CS+	20	Z-

11.3.2 J2 (Solder)

For connection of external 5V.



11.4 Hardware Interface

11.4.1 Hardware Configuration Switch S1

Position	On	Off
1	USB 5V (J1)	External 5V (J2)
2	Differential SCLK, MISO, MOSI, CS	Single Ended SCLK, MISO, MOSI, CS
3	SPI	BiSS

11.4.2 Status LED

The LED is three-color driven by GPIO pins mapped to error and warning status bits.

Error	Warning	LED Color
No	No	Green
Yes	No	Red
No	Yes	Yellow
Yes	Yes	Red

See SmartPrecision III(see page 28) for details on errors and warnings.

12 Ordering Information

NOTE: The Aura encoder is configured for a specific scale. Be sure to specify the correct encoder/scale pair.

12.1 Aura Rotary Encoder Part Numbers

This DOES NOT include the scale. This part number is for the encoder ONLY.

Part Number	For Use With Scale Size
AUR-R-B-0001-WP	26.0 mm
AUR-R-B-0002-WP	18.0 mm
AUR-R-B-0003-WP	33.0 mm
AUR-R-C-0004-WP	63.5 mm
AUR-R-C-0006-WP	51.8 mm

12.2 Aura Linear Encoder Part Numbers

This DOES NOT include the scale. This part number is for the encoder ONLY.

Part Number	For Use With Scale Size
AUR-L-C-0000-WP	Compatible with all linear glass scales

AUR - R - B - 0002 - WP

Corresponding Scale Size (OD)

0000 = Linear Glass Scales
0001 = 26.0mm Scale
0002 = 18.0mm Scale
0003 = 33.0mm Scale
0004 = 63.5mm Scale
0006 = 51.8mm Scale

Corresponding Scale Grouping

B = Small Rotary Scales (18, 26, and 33mm)
C = Large Rotary Scales (51.8 and 63.5mm) and Linear Scales

Corresponding Scale Geometry

R = Rotary
L = Linear

Optical Encoder Series

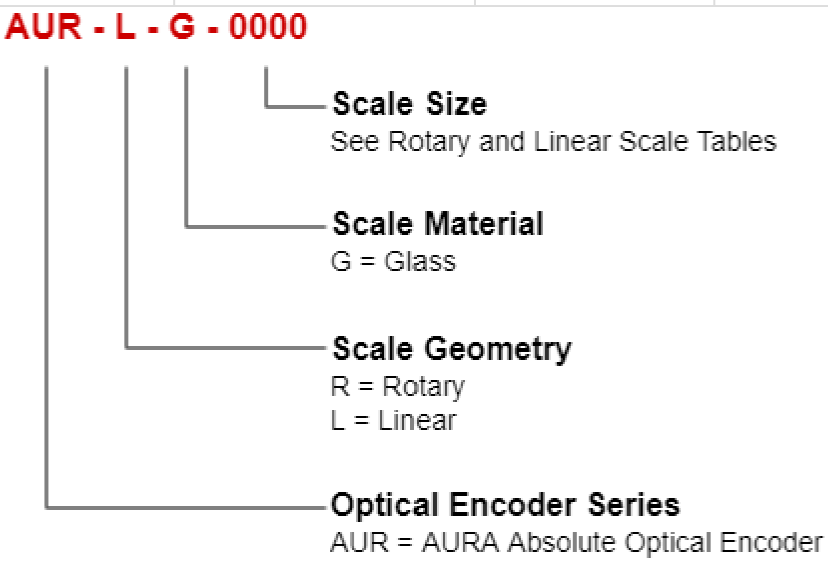
AUR = AURA Absolute Optical Encoder

12.3 Aura Rotary Glass Scale Part Numbers

Scale Part Number	Inner Diameter	Outer Diameter	Counts Per Rev (CPR)	Corresponding Chip Part Number
AUR-R-G-0001	12.0 mm	26.0 mm	256	AUR-R-B-0001-WP
AUR-R-G-0002	7.0 mm	18.0 mm	172	AUR-R-B-0002-WP
AUR-R-G-0003	21.0 mm	33.0 mm	343	AUR-R-B-0003-WP
AUR-R-G-0004	49.0 mm	63.5 mm	908	AUR-R-C-0004-WP
AUR-R-G-0006	38.0 mm	51.8 mm	761	AUR-R-C-0006-WP

12.4 Aura Linear Glass Scale Part Numbers

Scale Part Number	Scale Measuring Length	Overall Length	Thickness	Corresponding Chip Part Number
AUR-L-G-0001	9.0 mm	16.0 mm	2.29 mm	AUR-L-C-0000-WP
AUR-L-G-0002	50.0 mm	57.0 mm	2.29 mm	AUR-L-C-0000-WP
AUR-L-G-0004	195.0 mm	202.0 mm	2.29 mm	AUR-L-C-0000-WP



NOTE: Consult your sales representative for Evaluation Board availability

12.4.1 Ordering Examples

- Aura chip with 18mm rotary glass scale: AUR-R-B-0002-WP and AUR-R-G-0002
- Aura chip with 26mm rotary glass scale: AUR-R-B-0001-WP and AUR-R-G-0001
- Aura chip with 33mm rotary glass scale: AUR-R-B-0003-WP and AUR-R-G-0003
- Aura chip with 9mm linear glass scale: AUR-L-C-0000-WP and AUR-L-G-0001

For custom scale sizes, please contact your Celera Motion representative.