

# AksIM-4™

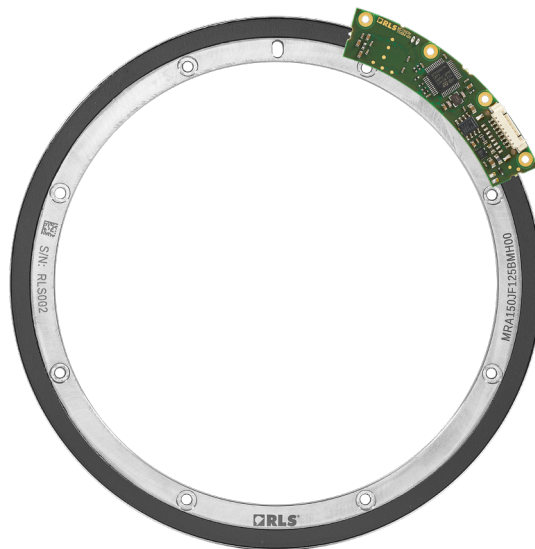
## Off-Axis Rotary Absolute Magnetic Encoders

AksIM-4 is a non-contact, high performance off-axis absolute rotary encoder. It is designed for integration into applications with limited space and for rotary systems with larger shaft diameters or requirements for large opening. A hollow ring, true absolute functionality and high-speed operation make this encoder suitable for many applications. The AksIM-4 encoder system consists of an axially magnetised ring and a readhead. The encoders are equipped with BiSS communication interface and offer binary resolutions up to 21 bits per revolution.

HIGH  
ACCURACY

21 BITS  
RESOLUTION

LARGE SIZE



### Features and benefits

- ▶ True absolute system
- ▶ Custom magnetic sensor ASIC
- ▶ Self-calibration option
- ▶ Resolution up to 21 bits
- ▶ High speed operation
- ▶ Low profile, non-contact
- ▶ Integrated status LED
- ▶ High repeatability



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INDUSTRIAL AUTOMATION

## General information

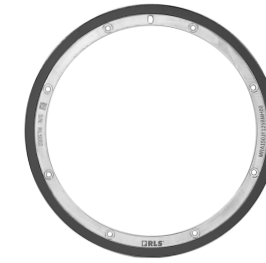
Dimensions and tolerances are in mm. Dimensions without tolerance values are in accordance with ISO 2768-m.



The AksIM-4 encoder operates in a temperature range between -40 °C and +105 °C and is highly resistant to shock and vibration. It has a built-in advanced self-monitoring function that continuously checks several internal parameters. Error reports, warnings and other status signals are available on all communication interfaces and visualised with the on-board LED.

The AksIM-4 encoder system is suitable for use in industry, medicine and logistics. A typical application is a rotary table or a large robotic arm joint with a cable feed through the ring.

A custom design service for OEM integration is also available.



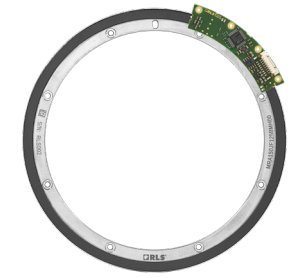
MRA axial magnetic ring

+



MC readhead

=



AksIM-4 system

Selection guide	Magnetic ring					Readhead				Max resolution	System thickness (Typ.)	Mass (g)
	Inner diameter	Circle for fasteners	Outer diameter	Thickness	Inertia (kg × mm <sup>2</sup> )	Inner diameter	Circle for fasteners	Outer diameter	Arc length			
<b>MC115 assembly</b>												
MC115						96	120	125	65°	20 bit	7.85	5
MRA115	90	97	115	2	110							45
<b>MC150 assembly</b>												
MC150						134	158	163	50°	21 bit	12.1	5
MRA150	125	132	150	5.8	1010							210

For other encoder sizes between ID 64 mm and ID 125 mm please **contact RLS**.

For encoder sizes with ID 64 mm or smaller see AksIM-2 portfolio in the document MBD01 in **RLS Media center**.

# Storage and handling

## Storage temperature



-40 °C to +105 °C

## Operating temperature

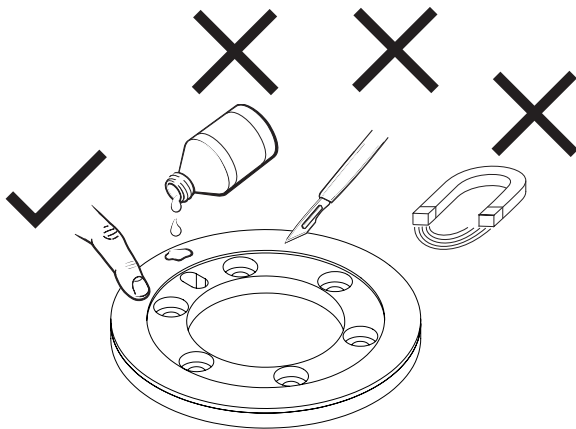


-40 °C to +105 °C

## Humidity



Up to 70 % non-condensing



**HANDLE WITH CARE.** This encoder system is a high performance metrology product and should be treated with the same care as any other precision instrument. Use of heavy duty industrial tools or exposure to strong magnets, such as a magnetic base, is unacceptable and risks of irreparable damage to the product.

**The magnetic ring should not be exposed to magnetic field densities higher than 50 mT on its surface, as this can damage the ring.**

Please see [Chemical resistance](#) or [contact RLS](#).



### Readhead is ESD sensitive - handle with care.

Do not touch electronic circuit, wires or sensor area without proper ESD protection or outside of ESD controlled environment.

## Packaging

There are two packaging options. Less than 20 products are packed individually in an antistatic box. If more than 20 systems are ordered, the parts are packed in antistatic plastic trays. Size 150 mm is only available individually packed in an antistatic box. Magnetic rings and readheads are packed separately.

Bulk packaging:

Readheads		
Part	Tray size	Box size
115	16 pcs	9 trays
150	NA	1 pc

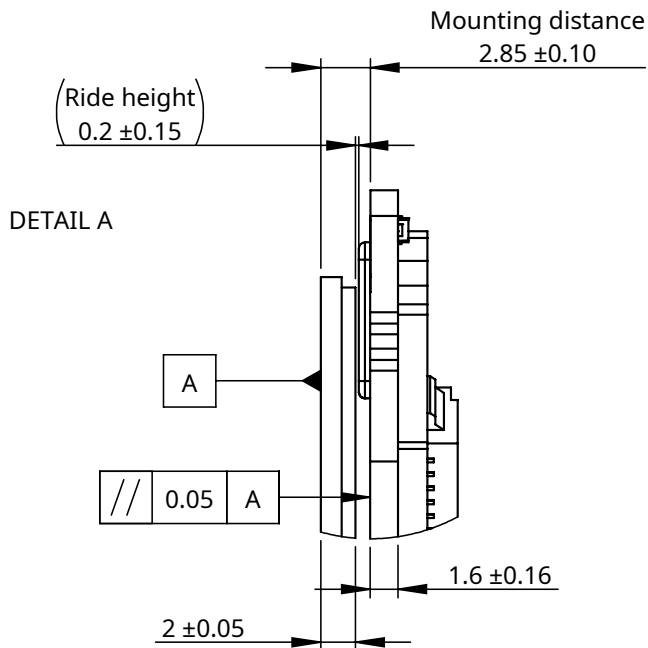
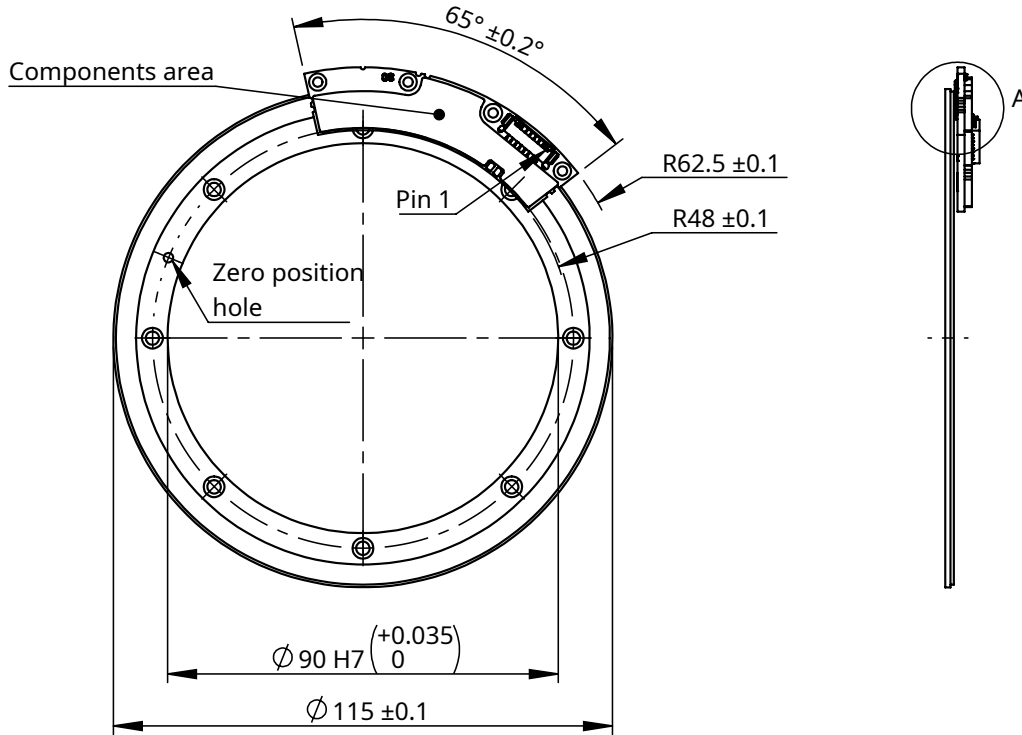
Magnetic rings		
Part	Tray size	Box size
115	2 pcs	7 trays
150	NA	1 pc

# Dimensions and installation drawings

Dimensions and tolerances are in mm. Dimensions without tolerance values are in accordance with ISO 2768-m.

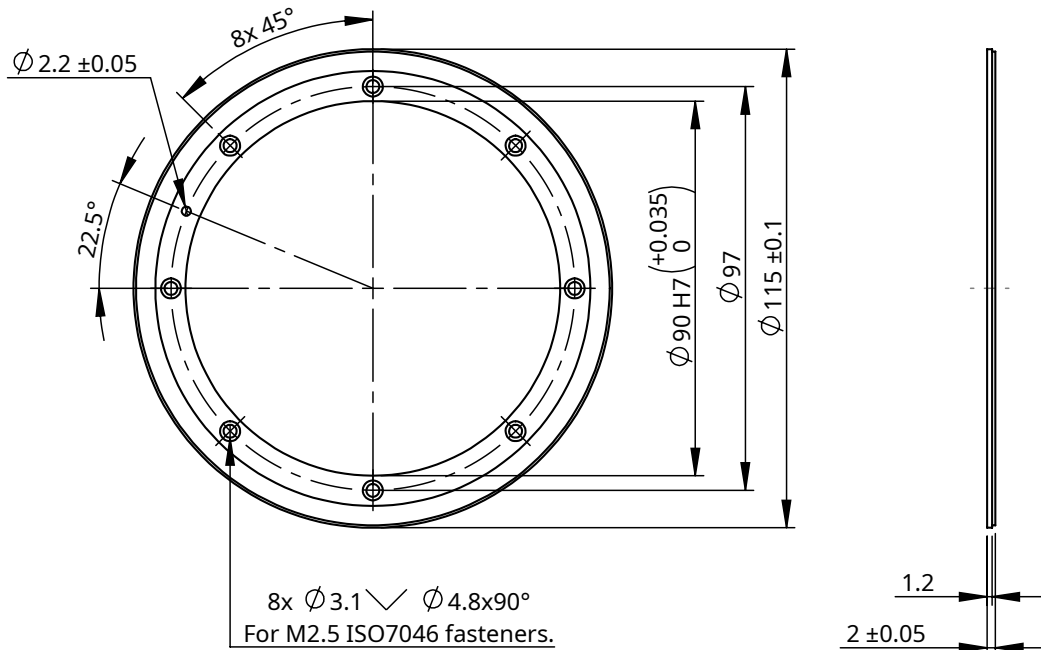


## Encoder assembly MC115DCB20BDNP00 readhead with MRA115 magnetic ring

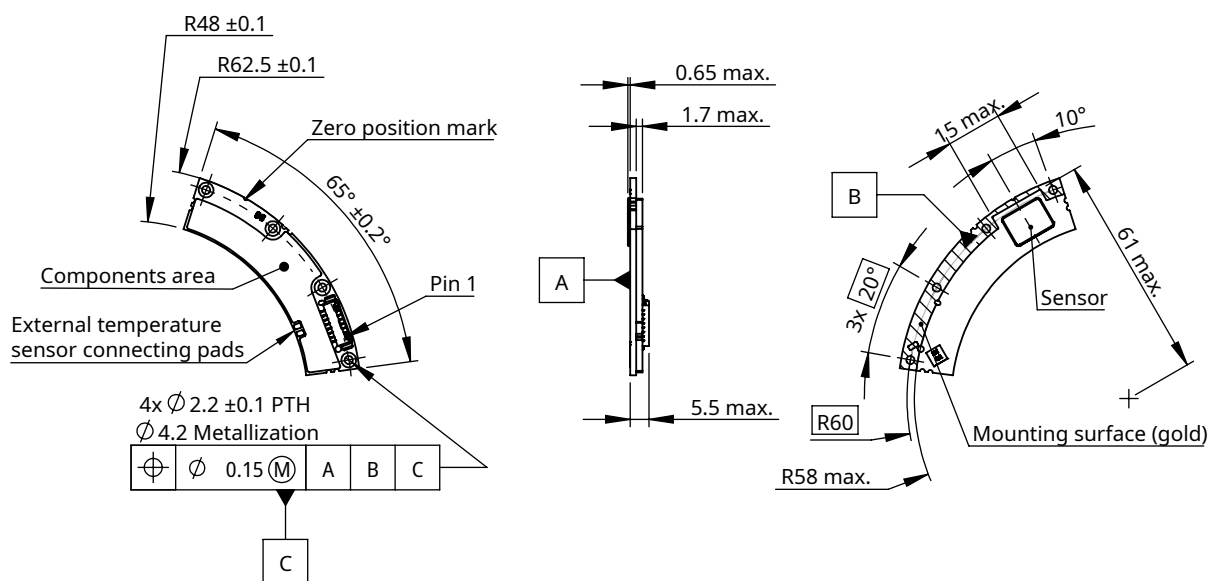


Ride height influences noise on the output. See chapter **Installation instructions** for details.

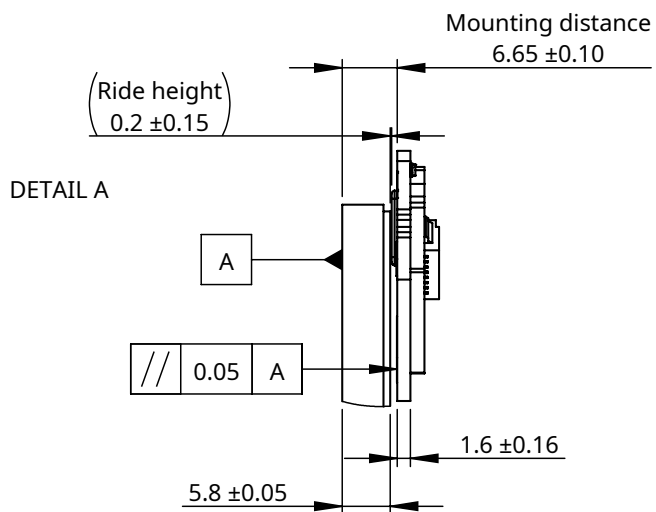
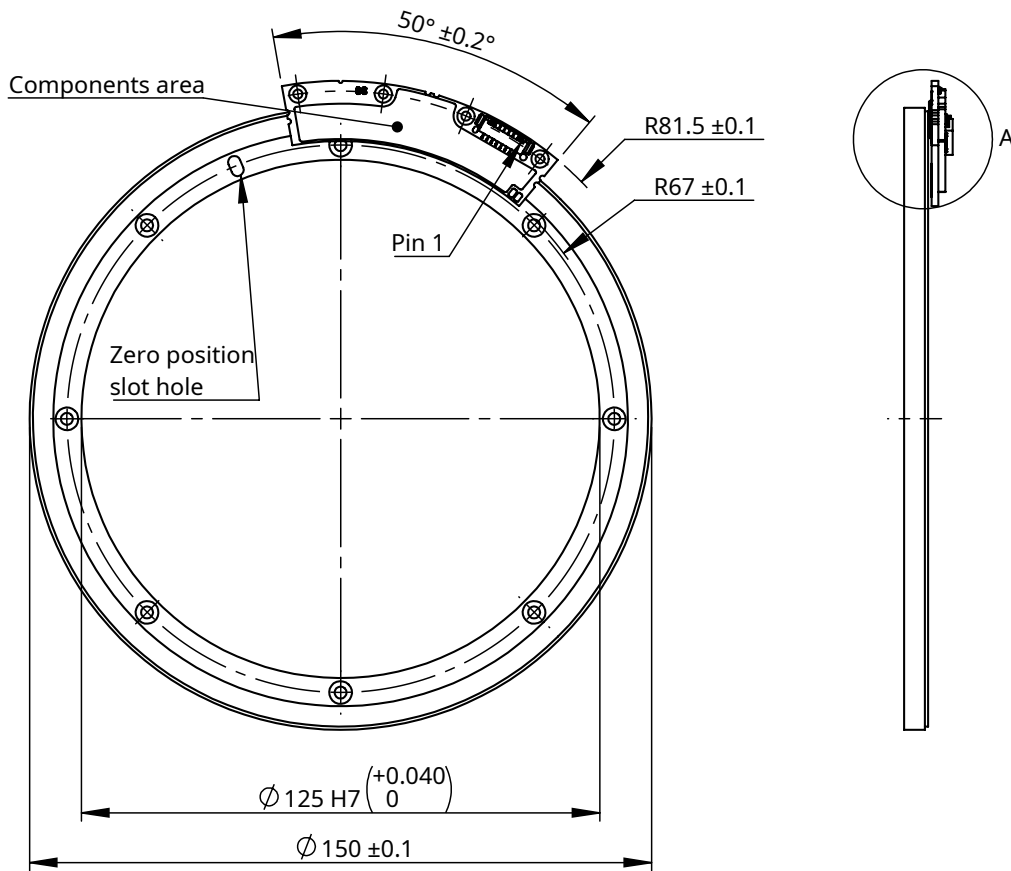
**MRA115 magnetic ring**



**MC115 readhead**

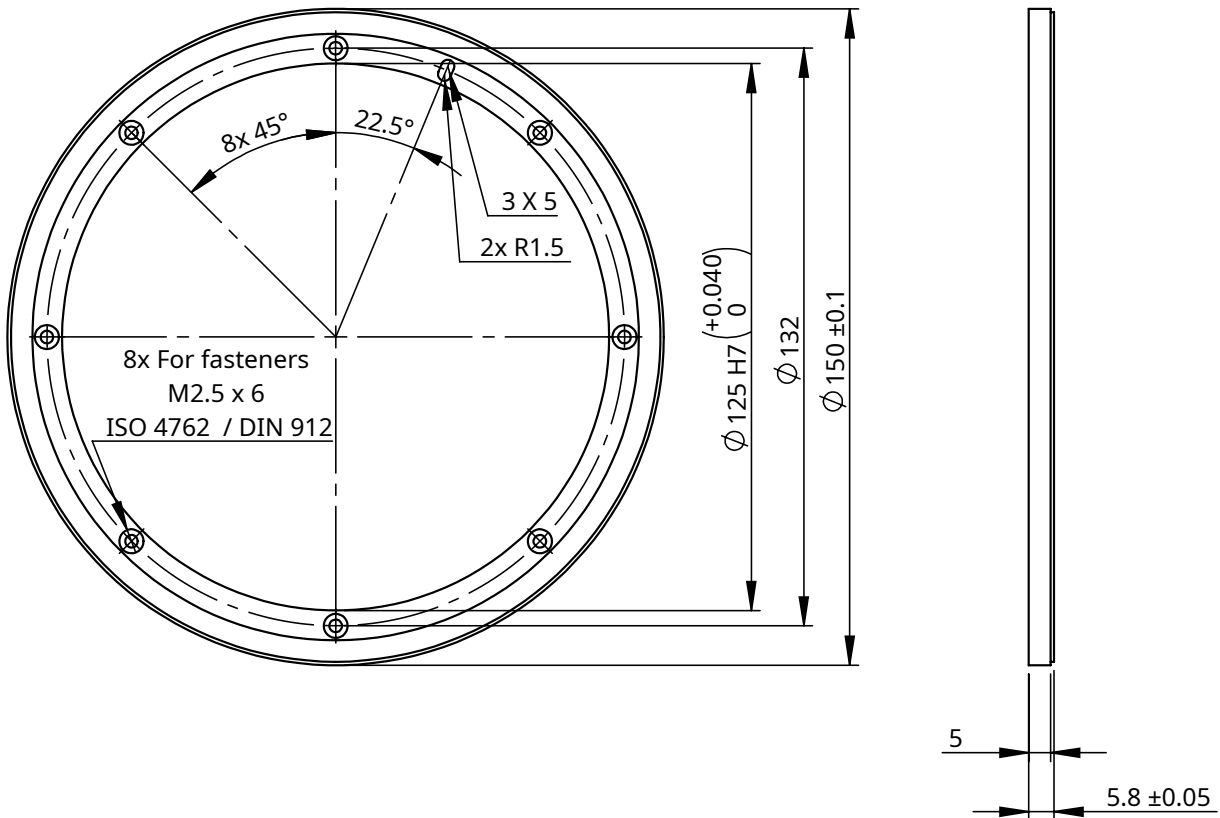


Encoder assembly MC150DCB21BDNP00 readhead with MRA150 magnetic ring

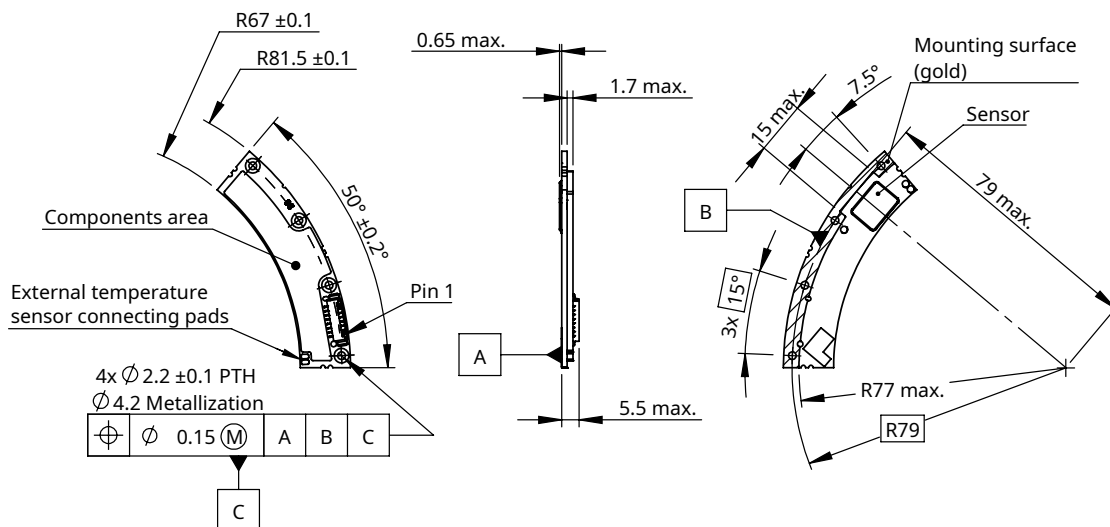


Ride height influences noise on the output. See chapter **Installation instructions** for details.

**MRA150 magnetic ring**



**MC150 readhead**







# Installation instructions

## Axial position adjustment (mounting distance)

The mounting dimension between the gold-plated surface at the bottom of the readhead and the bottom of the ring should be  $2.85 \pm 0.1$  mm for MC115 and  $6.65 \pm 0.1$  mm for MC150. See detail A on dimension drawings of encoder assemblies. It is recommended that the gold-plated surface on the bottom be used as the reference surface for mounting the readhead. If the top of the readhead is used as the reference surface, the thickness tolerance of the readhead must be taken into account.

The integrated LED can be used as an indicator. If the ride height is within the installation tolerances, the indicator LED will be green and will not change when the ring rotates. The center of the ring and the center of the readhead arc must be coaxial. The permissible eccentricity tolerances are given in the table below. Precise centering of the ring is essential, as the eccentricity of the ring mounting plays a major role in the overall accuracy.

## Installation tolerances (readhead to ring)

<b>Mounting distance</b>	See detail A on dimension drawings of encoder assemblies. Tight ride height is recommended. Increasing the ride height exponentially increases encoder noise even if it is within installation tolerances. See chapter <b>Resolutions</b> .	
<b>Tangential displacement of the sensor</b>	$\pm 0.5$ mm	
<b>Radial displacement of the readhead</b>	MC115: $\pm 0.5$ mm MC150: $\pm 0.5$ mm	
<b>Non-parallel mounting</b>	Tilt angle $< 0.2^\circ$	

## Measuring ride height between the ring and the readhead

The signal level information read out via the communication interface can be used to calculate the ride height (distance between the rubber on the ring and the sensor on the readhead).

The value is proportional to the distance between the sensor and the ring. To calculate the actual distance, use the following formula:

$$\text{Ride height} = K \times \text{Ln}(\text{SignalLevel}) + N$$

The calculated ride height has a tolerance of  $\pm 20$   $\mu\text{m}$ .

Encoder size	K	N
MC115, MC150	-71.62	730



## Installation tolerances (ring to shaft)

Ring / shaft fit	Encoder accuracy	
	MRA115	MRA150
H7/g6 worst case fit	±0.07°	±0.05°
H7/g6 best case fit	±0.02°	±0.015°
After self-calibration	Up to ±0.004°	Up to ±0.004°

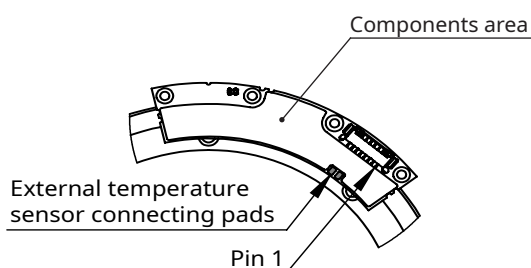
See table of recommended tightening torques for RLS products (document TTD01) available at [RLS media center](#).

## Electrical connections

Connector	BiSS C
1	5 V supply
2	0 V (GND)
3	Temperature sensor pin 1 *
4	Temperature sensor pin 2 *
5	MA+
6	MA-
7	SLO+
8	SLO-

\* See chapter [External isolated temperature sensor](#)

### Pinout

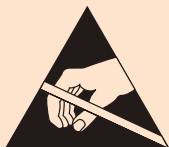


#### 8-pin low profile connector

FCI 10114830-11108LF

#### Counterpart mating connector:

FCI 10114826-00008LF  
and 10114827-002LF



#### Readhead is ESD sensitive - handle with care.

Do not touch electronic circuit, wires or sensor area without proper ESD protection or outside of ESD controlled environment.

## Technical specifications

### System data

<b>Reading type</b>	Axial reading
<b>Resolution</b>	20 bit and 21 bit (see chapter <b>Resolutions</b> )
<b>Maximum speed</b>	MRA115: 3,150 RPM MRA150: 2,400 RPM
<b>System accuracy</b>	Up to $\pm 0.004^\circ$ / $\pm 15$ arcsec after self-calibration Up to $\pm 0.015^\circ$ / $\pm 54$ arcsec without self-calibration For high-accuracy variants <b>contact RLS</b> .
<b>Hysteresis</b>	Less than unit of resolution
<b>Repeatability</b>	Within the range of position noise
<b>Encoder speed</b>	12.5 kHz bandwidth, 25 kHz sampling rate, up to 44 kHz refresh rate

### Electrical data

<b>Supply voltage (<math>V_{DD}</math>)</b>	4.5 V to 5.5 V at the connector
<b>Set-up time</b>	100 ms (first data ready after supply voltage is in range), worst case: 200 ms
<b>Current consumption</b>	Typ. 125 mA, max. 160 mA (without load on the outputs)
<b>Connection</b>	8-pin low-profile connector
<b>Output load</b>	$\pm 40$ mA
<b>ESD protection</b>	HBM, Class 2, $\pm 2$ kV (valid only on RS422 signals on connector; do not touch other components)

### Mechanical data








<b>Available ring sizes (inner diameter)</b>	90 mm, 125 mm
<b>Material type</b>	MRA115: EN 1.4016 / AISI430 with glued CPE rubber filled with ferrite particles MRA150: EN 1.4057 / AISI431 with glued CPE rubber filled with ferrite particles
<b>Mass, inertia</b>	See <b>Selection table</b>

### Environmental data

<b>Operating and storage temperature</b>	$-40$ °C to $+105$ °C
<b>Humidity</b>	Up to 70 % non-condensing (for higher with conformal coating <b>contact RLS</b> )
<b>External magnetic field</b>	TBT
<b>Shock</b>	100 g (6 ms, half-sine, EN 60068-2-27:2009)
<b>Vibration</b>	80 g (55 Hz - 2000 Hz, EN 60068-2-6:2008)
<b>Environmental compliance</b>	RoHS, REACH

## Status indicator LED

The LED provides visual feedback on signal strength, error status, and is used for setup and diagnostics. Flashing LED indicates that power is being supplied to the encoder, but communication has not been established. When communication is running at a rate of at least 5 readings per second, LED will be constantly lit.

LED signal	Status
 Green	Normal operation; position data is valid.
 Orange	Warning; position is valid, but the resolution and/or accuracy might be out of specification. Some operating conditions are outside limits.
 Red	Error; position data is not valid.
 Slow flashing	Communication has not been established. Position was not requested within last 200 ms. Color of flashing - see above.
 No light	No power supply.
 Continuously fast flashing red	System error during start-up or operation.
 3 sec. fast flashing	Self-calibration result - see chapter <a href="#">Self calibration after installation</a> .

## Chemical resistance

RLS products are commonly used in industrial applications and are exposed to chemicals that can affect their internal and external components. Although our products are designed to withstand many harsh chemicals and environments, long-term resistance depends on exposure, temperature and concentration. Most of the chemicals to which our products are exposed are not in constant contact. Therefore, a material that is not resistant when immersed in a chemical may be durable indefinitely if wiped with the same chemical once a day.

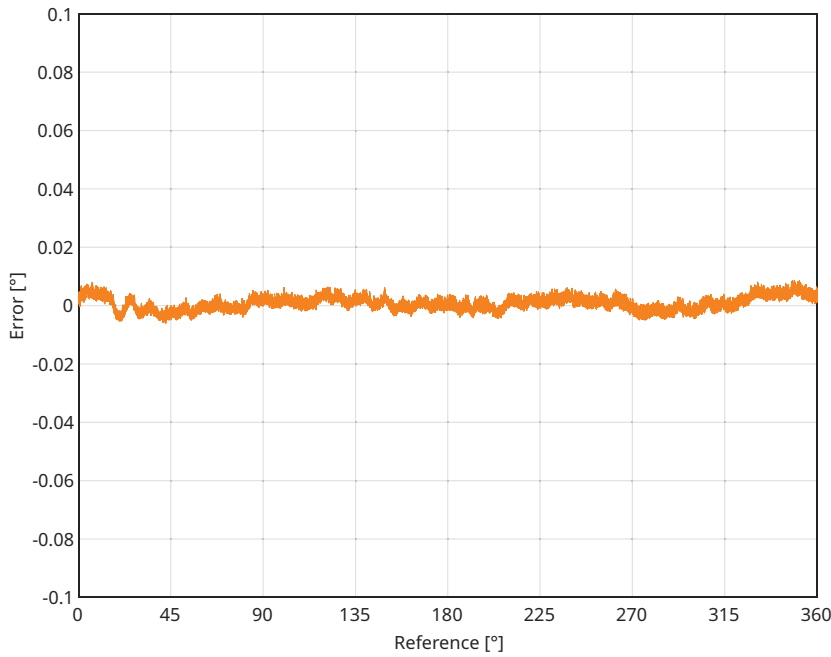
CPE rubber on the ring will not withstand exposure to most mineral oils and greases.

For more information, or to confirm compatibility with oils and other chemicals in the environment, please **contact RLS**.

## Accuracy of the encoder system

Accurate centering of the ring is key to good overall accuracy. Minimising the eccentricity of the ring assembly (using a gauge) and using a drive shaft with precision bearings can usually reduce the error. A typical accuracy chart after good installation (without eccentricity) is shown in the figure below. To improve accuracy after installation, we recommend performing the self-calibration function.

Example for encoder size MC115.



## Self-calibration after installation

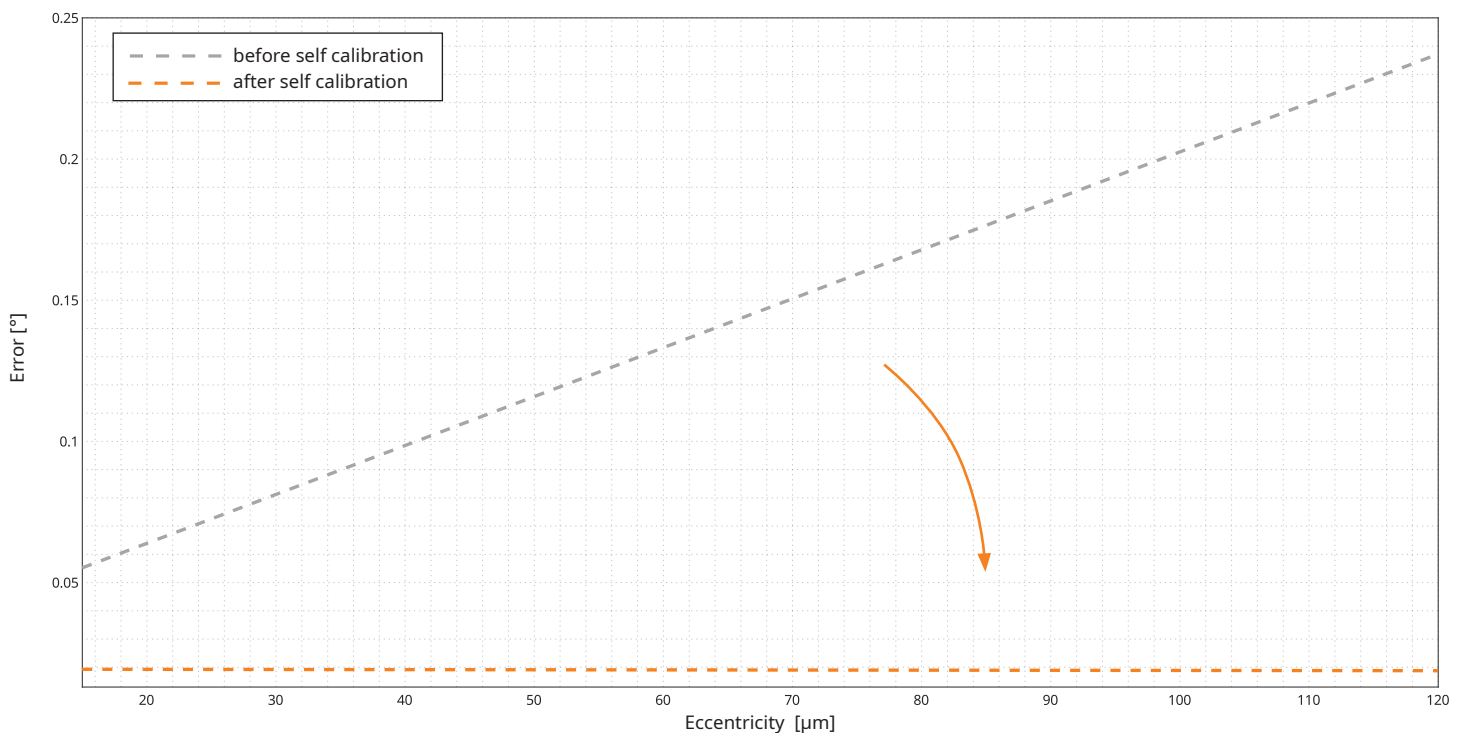
The self-calibration function eliminates the error caused by eccentricity, which is a dominant contributor to the accuracy of the encoder and is caused by the eccentric mounting of the ring. It cannot compensate for the magnetisation error between different rings. The Subdivisional Error (SDE) is negligible with AksIM. This function removes the error from one sine wave per revolution. The self-calibration function can be initiated by the user via selected communication interfaces or by using the appropriate USB encoder interface. Refer to the description of the selected communication interface for details. Self-calibration is not performed below 15 µm of eccentricity.

Requirements:

- Free mechanical rotation 360°.
- Good signal over the entire calibration angle.
- Maximum time available is 40 seconds.
- Variation of direction and speed are not important. Minimum speed depends on self-calibration timeout value. Default is 6 RPM.
- Suitable communication interface or adapter that enables the function to be triggered.

The graph below shows how much the accuracy of the encoder can be improved with the self-calibration function. The remaining minimum accuracy of  $\pm 0.004^\circ$  is influenced by magnetisation variations and noise of the readhead.

Example for encoder size MC115.



For typical accuracy values see chapter **Installation tolerances**.

When the self-calibration process is complete, fast-flashing LED indicates whether the process was successful.

LED	Self-calibration status
●●●●● Green flashing fast	Self-calibration successfully performed.
●●●●● Orange flashing fast	Ring positioning is already perfect - correction was not performed.
●●●●● Red flashing fast	Eccentricity or radial offset is very high. Timeout. Ring is rotating too slowly (<6 RPM).

## External magnetic field

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The operating principle of any magnetic encoder is to detect changes in the magnetic field of the magnetised ring. External magnetic fields generated by permanent magnets, electric motors, coils, magnetic brakes, etc. can affect the operation of the encoder. If external magnetic field is greater than 15 mT, it will temporarily cause the encoder to malfunction. Fields stronger than 50 mT may cause permanent damage to the ring.

Unwanted magnetic fields must be blocked at the source. If this is not possible, the encoder can be shielded with a ferromagnetic metal sheet. The ring can also be used for partial shielding. It is recommended that the bottom of the ring is mounted with the readhead facing away from the source of the escaping magnetic field. [Contact RLS](#) for more information.

## External isolated temperature sensor

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Encoders provide two pass-through signals for connecting an external temperature sensor in an application. These can be Pt100, Pt1000, NTC, 1-wire or a similar low-voltage analogue or digital sensor. The signals are isolated from the encoder circuitry and are only routed from the temperature sensor pins of the connector to the solder pads where the external sensor is to be connected in an application.

The purpose of this is to provide temperature monitoring in applications such as electric motors, gearboxes, etc. where precise monitoring is required in the vicinity of the encoder. This solution simplifies cable management as the existing encoder cable can be used to transmit these two signals. The voltage must be limited to  $\pm 30$  V relative to the other encoder signals and the current to  $\pm 500$  mA.

The position of solder pads for the temperature sensor for each readhead size is shown in the chapter [Dimensions and installation drawings](#).

## Resolutions

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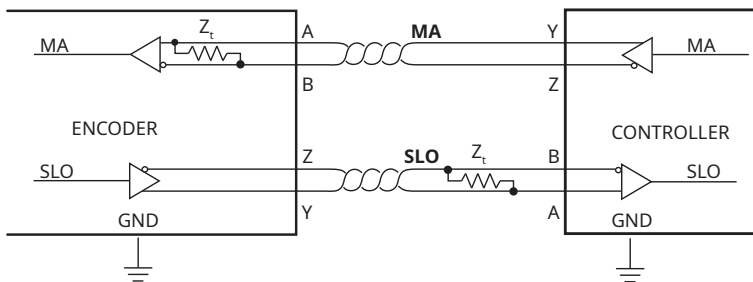
Resolution	MRA115	MRA150
Binary	20 bits per revolution	21 bits per revolution

# BiSS C interface

Encoder position in up to 21 bit natural binary code and encoder status are available via the BiSS C protocol. The position data is followed by two status bits (active low) followed by CRC (inverted).

BiSS is implemented for point-to-point operation, multiple slaves are not supported. Communication is bidirectional, the readhead is user programmable and user defined parameters can be stored in the readhead. Additional data can be read from the readhead.

## Electrical connection

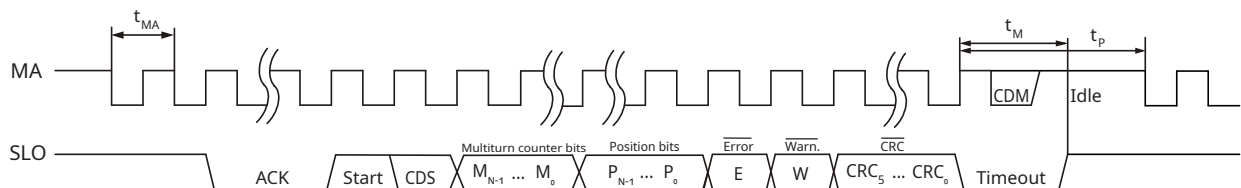


The signal MA is Master Clock with a maximum frequency of 5 MHz and SLO is Slave Out, whose data is transmitted on the rising edges on the line MA. The MA and SLO lines are 5 V RS422 compatible differential pairs. The RC termination on the MA line is built into in the encoder. If the total cable length exceeds 5 m, termination on the controller is required. The nominal impedance of the cable should be 120 Ω.

## Output protection

Excessive output current and power dissipation caused by faults or bus conflicts are prevented by two mechanisms. A foldback current limit at the output stage provides immediate protection against short circuits. In addition, a thermal shutdown circuit forces the driver outputs into a high-impedance state, if the chip temperature becomes too high.

## BiSS C timing diagram



## Data package description

Data	Length (N)	Description
$M_{N-1} - M_0$	0 (Available soon)	Multiturn counter value (length 0 when single turn option is selected)
$P_{N-1} - P_0$	20 bits or 21 bits	Absolute position inside one revolution
E	1 bit	Error status bit; inverted
W	1 bit	Warning status bit; inverted
$CRC_5 - CRC_0$	6 bits	Cyclic redundancy check; polynomial 0x43; inverted

## Communication parameters

Parameter	Symbol	Min	Typ	Max
MA period	$t_{MA}$	200 ns		2.5 $\mu$ s
MA frequency	$f_{MA} = 1/t_{MA}$	400 kHz		5 MHz
ACK length	ACK		13 bits	
Transfer timeout	$t_M$		13 $\mu$ s	
Pause time	$t_P$	$t_M + 1 \mu$ s		
Latency				10 $\mu$ s
Mechanical bandwidth*				12.5 kHz
Mechanical sample rate				25 kHz
Maximum request rate				44 kHz (singleturn)

\* AksIM samples at 25 kHz, so mechanical changes faster than 12.5 kHz cannot be detected at the output (Nyquist theorem). If the position request comes faster than the sampling frequency, the encoder recalculates the position at the time of the request based on the current ring velocity.

If number of clocks from master is less than specified, SLO within timeout is not necessarily in low state.

First valid frame is expected after encoder set-up time.

The request cycle starts with MA in idle state (MA is high). Its first falling edge initiates communication. The encoder responds by setting SLO to low on the second rising edge on the MA line and generating the ACK signal (Acknowledge). When the encoder is ready for the next request cycle, it indicates this to the master by setting SLO to high. The absolute position and the CRC data are available in binary format and are initially transmitted in MSB format.

## Encoder data packet structure

### For singleturn

<b>b28 : b8</b>	Encoder position – MSB first (for 21 bit resolution)
<b>b7</b>	Error – If low, the position data is not valid.
<b>b6</b>	Warning – If low, the position data is valid, but some operating conditions are close to limits.
<b>b5 : b0</b>	Inverted CRC, calculated by using 0x43 polynomial

When error is active (error bit is low) singleturn position data is replaced by detailed status bits. In case of active warning, position data is valid.



**Detailed status** (replaces position data while error bit is active)

**Clearing**

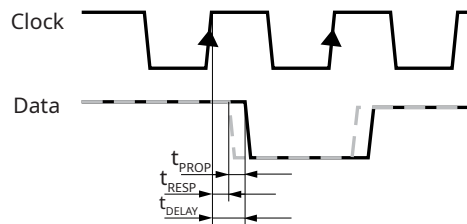
<b>b28</b>	Reserved	
<b>b27</b>	Reserved	
<b>b26</b>	Reserved	
<b>b25</b>	Reserved	
<b>b24</b>	Reserved	
<b>b23</b>	Warning - Rotational speed exceeds the limit.	
<b>b22</b>	Warning - Temperature out of range. The readhead temperature is out of specified range.	
<b>b21</b>	Warning - Signal amplitude low. The distance between the readhead and the ring is too large.	When absent
<b>b20</b>	Warning - Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present. There is also a possibility that encoder ring is touching encoder head. It is strongly recommended that user checks the encoder mounting immediately after this warning gets set.	
<b>b19</b>	Warning - Signal decoding close to threshold. Position readout might fail. Check installation tolerances (radial shift, tilt) and external magnetic field.	
<b>b18</b>	Reserved	
<b>b17</b>	Reserved	
<b>b16</b>	Error - Acceleration error. The position data changed unexpectedly or too fast. A stray magnetic field is present or metal particles are present between the readhead and the ring.	At communication
<b>b15</b>	Error - Magnetic pattern error. A stray magnetic field is present or metal particles are present between the readhead and the ring or radial positioning between the readhead and the ring is out of tolerances.	
<b>b14</b>	Error - Signal lost. The readhead is out of alignment with the ring or the ring is damaged.	When absent
<b>b13</b>	Error - Signal amplitude too high. External magnetic field is present.	
<b>b12</b>	Error - System error. Malfunction inside the circuitry. To reset the System error bit try to cycle the power supply while the rise time is shorter than 20 ms.	
<b>b11</b>	Error - Power supply error. The readhead power supply voltage is out of specified range.	
<b>b10</b>	Error - System error. Inconsistent calibration data is detected. To reset the System error bit try to cycle the power supply while the rise time is shorter than 20 ms.	At power-on
<b>b9</b>	Reserved	
<b>b8</b>	Reserved	

## Cable length compensation

The readhead needs 60 ns to respond to incoming clocks ( $t_{RESP}$ ). The change on the Data signal is delayed by 60 ns after the rising edge on the Clock line. An additional delay is caused by the time the signal takes to propagate through the cable to the readhead and back ( $t_{PROP}$ ). This delay is typically 14 ns per 1 meter cable. The total cable length from the encoder to the receiver must be considered.

The total delay ( $t_{DELAY}$ ) is calculated as in the formula below.

A proper implementation of BiSS Master should automatically measure  $t_{DELAY}$  and adjust the internal timing to compensate for it. BiSS Master without compensation for cable delay will work even with short wiring (up to 1 meter at 5 MHz clock frequency).



$$t_{DELAY} = t_{RESP} + t_{PROP} \times \text{cable length}$$

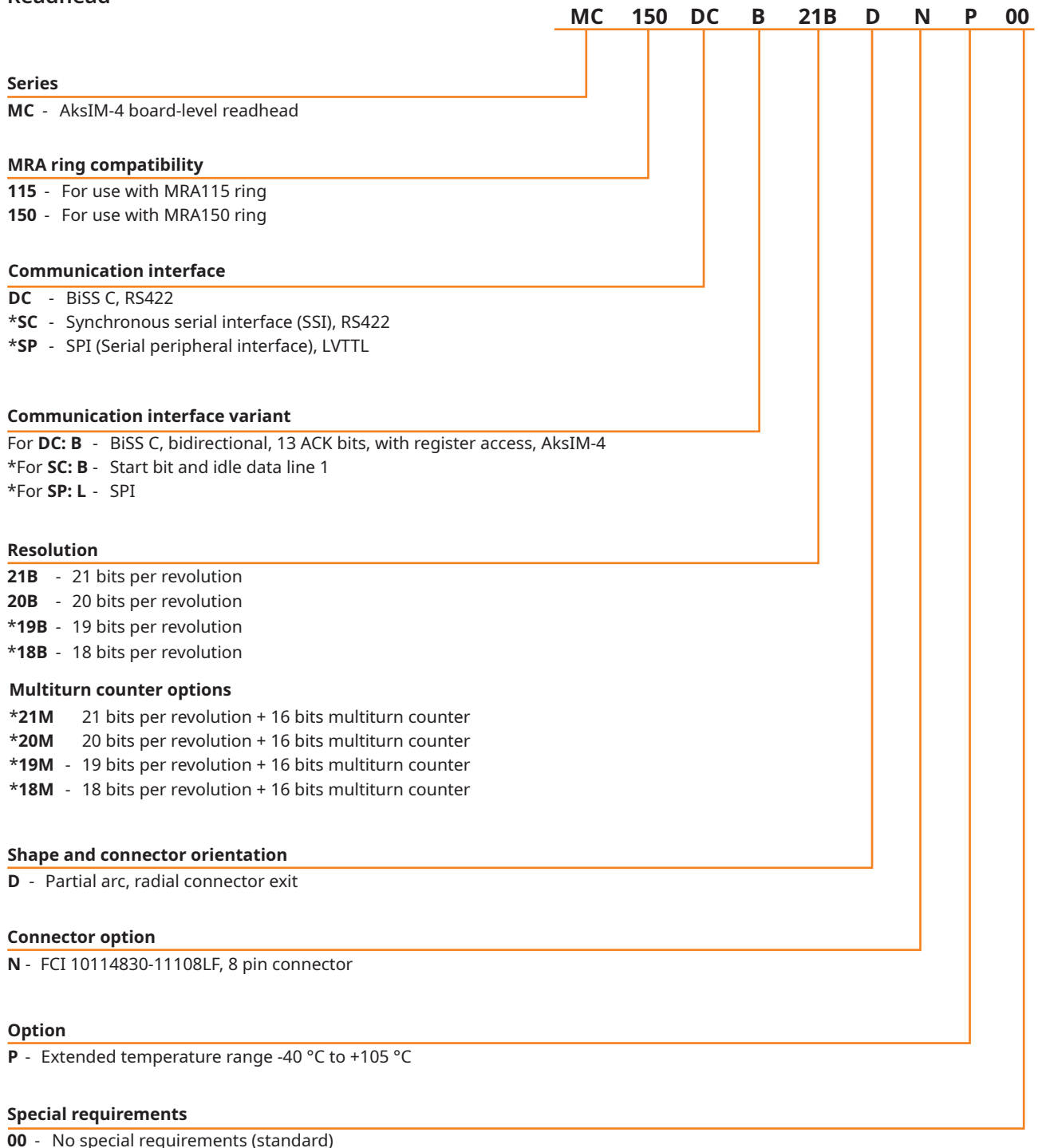
## Encoder programming

Encoder supports register access which allows setting zero position, running self-calibration function, configuring the encoder, reading signal level indicator, temperature, detailed status bits and electronic datasheet.

For more information refer to MCD02 available at [RLS Media center](#) or [contact RLS](#).

# Part numbering

## Readhead



## Available readhead part numbers

MC115DCB20BDNP00  
MC150DCB21BDNP00

\* Available soon

For more dimensions and configurations please [contact RLS](#).

## Magnetic ring

**MRA 150 J F 125 B M H 00**

### Series

**MRA** - AksIM magnetic ring

### Outer diameter and readhead compatibility

**115** - 115 mm

**150** - 150 mm

### Thickness

**B** - 2.0 mm

**J** - 5.8 mm

### Installation type

**C** - Countersunk holes type A (use flat-head fasteners DIN 965 / 7046)

**F** - Flat-bottom counterbored holes type H (use socket head fasteners DIN 912)

### Inner diameter

**090** - 90 mm

**125** - 125 mm

### Magnetization type

**B** - Standard for AksIM-4 (> 80mm outer diameter)

### Material

**M**- Machined stainless steel hub with CPE rubber

**S** - Stamped metal plate with CPE rubber

### Zero marking

**H** - Hole

### Special requirements

**00** - No special requirements (standard)

Not all part number combinations are valid. Please refer to the available ring part numbers below.

### Available ring part numbers:

MRA115BC090BSH00

MRA150JF125BMH00

For more dimensions and configurations please **contact RLS**.

## Accessories

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Cable assembly, 1 m

**ACC049**

See chapter **Cable assemblies**.



Cable assembly, 1 m

**ACC065**

See chapter **Cable assemblies**.



Cable assembly, 3 m

**ACC070**

See chapter **Cable assemblies**.



USB interface (for BiSS C communication interface)

**E201-9B**



USB interface (For SSI communication interface)

**E201-9S**

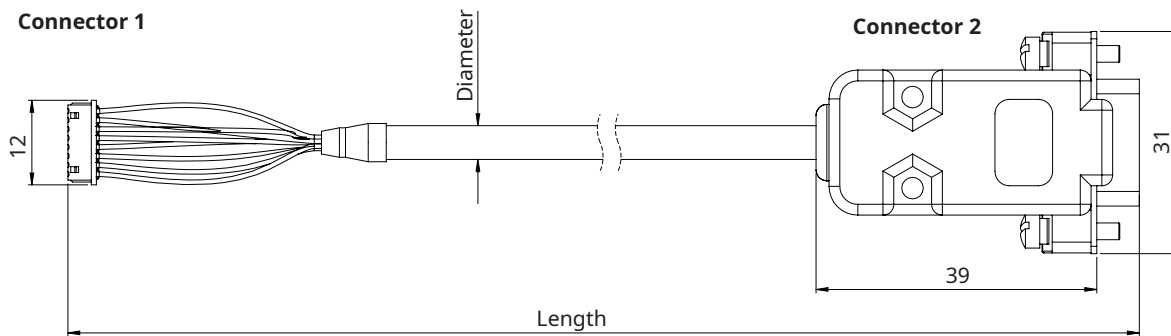


Magnet viewer

**MM0001**

## Cable assemblies

Compatible readhead	Part number	Diameter	Length	Connector 1	Connector 2	Notes
Every readhead with connector option "N"	ACC049	6.2 mm	1.0 m	FCI 10114826-00008LF and 10114827-002LF	Flying leads	Twisted pairs, shielded, up to +75 °C
	ACC065		3.0 m		DSUB-9 M	
	ACC070	Flying leads				



Dimensions in mm.

Connector 1 FCI 10114826-00008LF	Connector 2 DSUB-9 M	Wire color	BiSS C	SPI	SSI
Pin number					
	1	Shield			
1	5	Brown		5 V supply	
2	9	White		0 V (GND)	
3	8	Pink		Temperature sensor pin 1 *	
4	4	Grey		Temperature sensor pin 2 *	
5	2	Red	MA+	SCK	Clock+
6	3	Blue	MA-	NCS	Clock-
7	6	Green	SLO+	MISO	Data+
8	7	Yellow	SLO-	MOSI	Data-

\* See chapter [External isolated temperature sensor](#)

### Cable specifications

<b>Part numbers</b>	ACC049, ACC065, ACC070
<b>Cable specifications</b>	LiYCY (TP)
<b>Configuration</b>	4 × 2 × 0.14 mm <sup>2</sup> (twisted pairs)
<b>Rated voltage</b>	350 V
<b>Temperature range</b>	Operating -40 °C to +75 °C (fixed) -5 °C to +70 °C (bending) Storage -40 °C to +80 °C
<b>Environmental compliance</b>	RoHS and REACH compliant Flame-retardant according IEC 60332-1-2 Approvals based on VDE 0812 Classification ETIM 5.0 Class-ID: EC000104

ACC065 can be used for direct connection to E201-9S or E201-9B USB encoder interface.

## Head office

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## Global support

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Visit our [website](#) to contact your nearest sales representative.

## Document issues

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Date	Issue	Page	Description
3. 4. 2023	1	-	New document

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