AksIM-4™

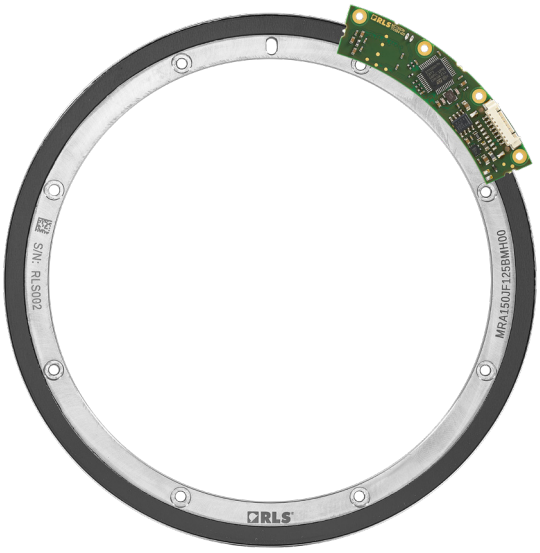
Off-Axis Rotary Absolute Magnetic Encoders

HIGH ACCURACY

21 BITS RESOLUTION

LARGE SIZE

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.



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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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						
Part number	**Inner diameter**	**Circle for fasteners**	**Outer diameter**	**Thickness**	**Inertia (kg × mm²)**	**Inner diameter**	**Circle for fasteners**	**Outer diameter**	**Arc length**	**Max resolution**	**System thickness (Typ.)**	**Mass (g)**
MC115 assembly												
MC115						96	120	125	65°	20 bit	7.85	5
MRA115	90	97	115	2	110							45
MC150 assembly												
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

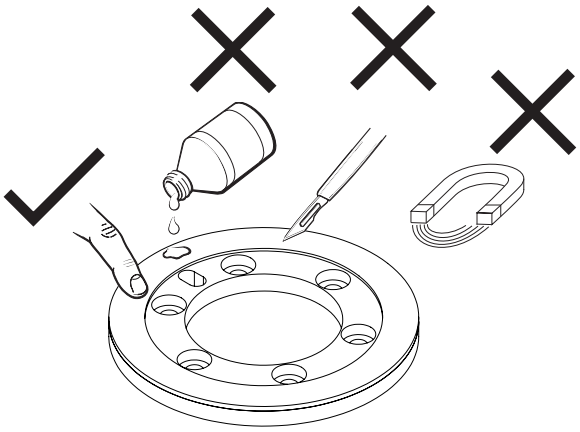
–40 °C to +105 °C

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

Technical specifications

System data

Reading type	Axial reading
Resolution	20 bit and 21 bit (see chapter **Resolutions**)
Maximum speed	MRA115: 3,150 rpm MRA150: 2,400 rpm
System accuracy	Up to ±0.004° / ±15 arcsec (see chapter **Accuracy**)
Hysteresis	Less than unit of resolution
Repeatability	Within the range of position noise
Encoder speed	12.5 kHz bandwidth, 25 kHz sampling rate, up to 44 kHz refresh rate
Thermal drift	None (accuracy does not change with temperature)

Electrical data

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

Mechanical data

Available ring sizes (inner diameter)	90 mm, 125 mm
Material type	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
Mass, inertia	See chapter **Selection table**

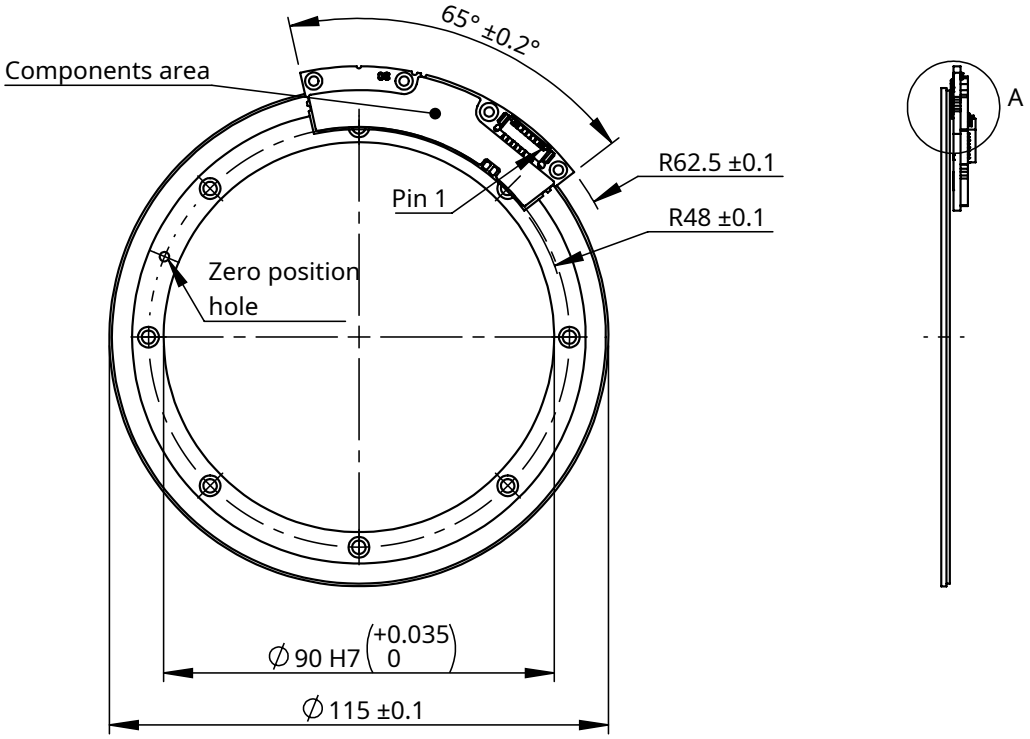
Environmental data

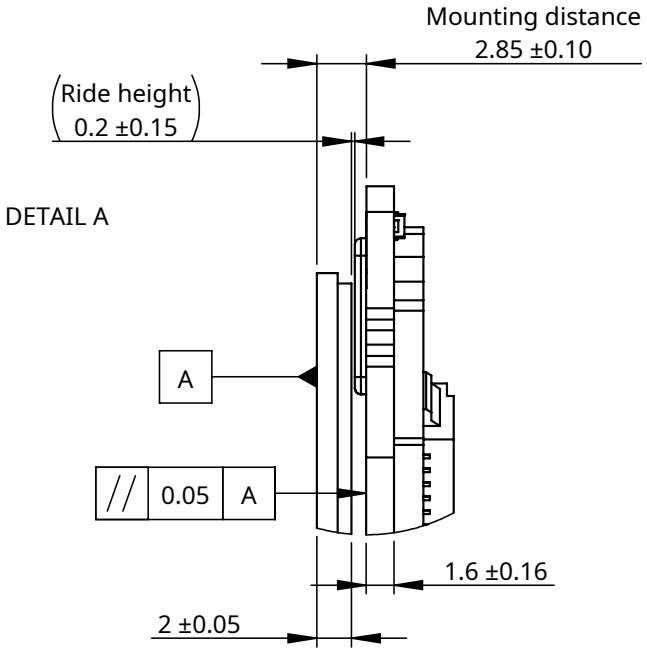
Operating and storage temperature	–40 °C to +105 °C
Humidity	Up to 70 % non-condensing (for higher with conformal coating **contact RLS**)
External magnetic field	±15 mT
Pressure	Up to 600 bar with special option (see chapter **Operation in high-pressure applications)**
Vacuum	1.0×10^{-7} Pa (see chapter **Operation in ultra high vacuum applications**)
Shock	100 g (6 ms, half-sine, EN 60068-2-27:2009)
Vibration	80 g (55 Hz - 2000 Hz, EN 60068-2-6:2008)
Environmental compliance	RoHS, REACH

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

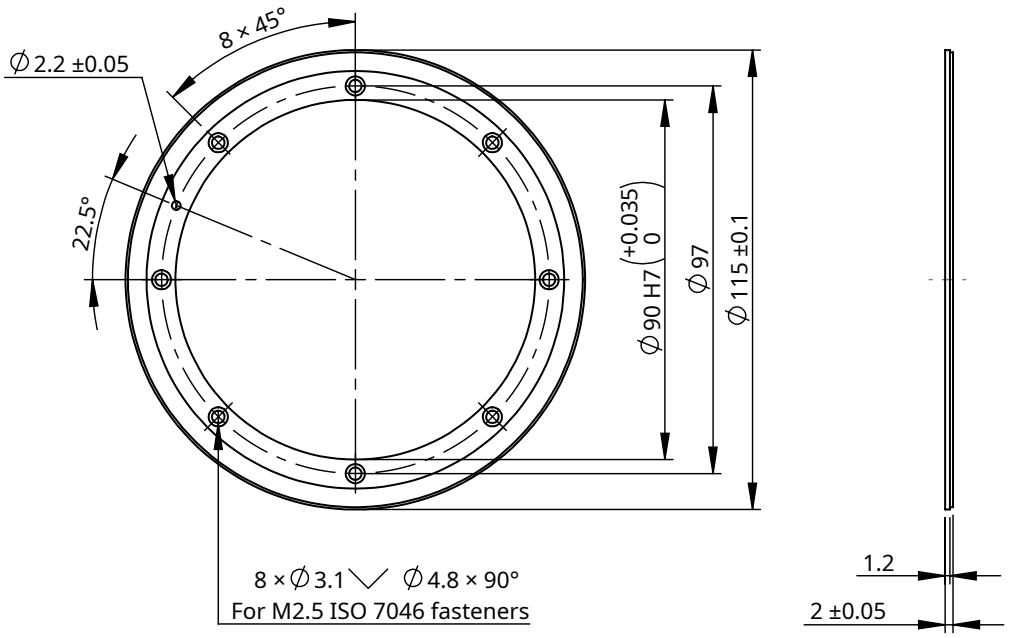




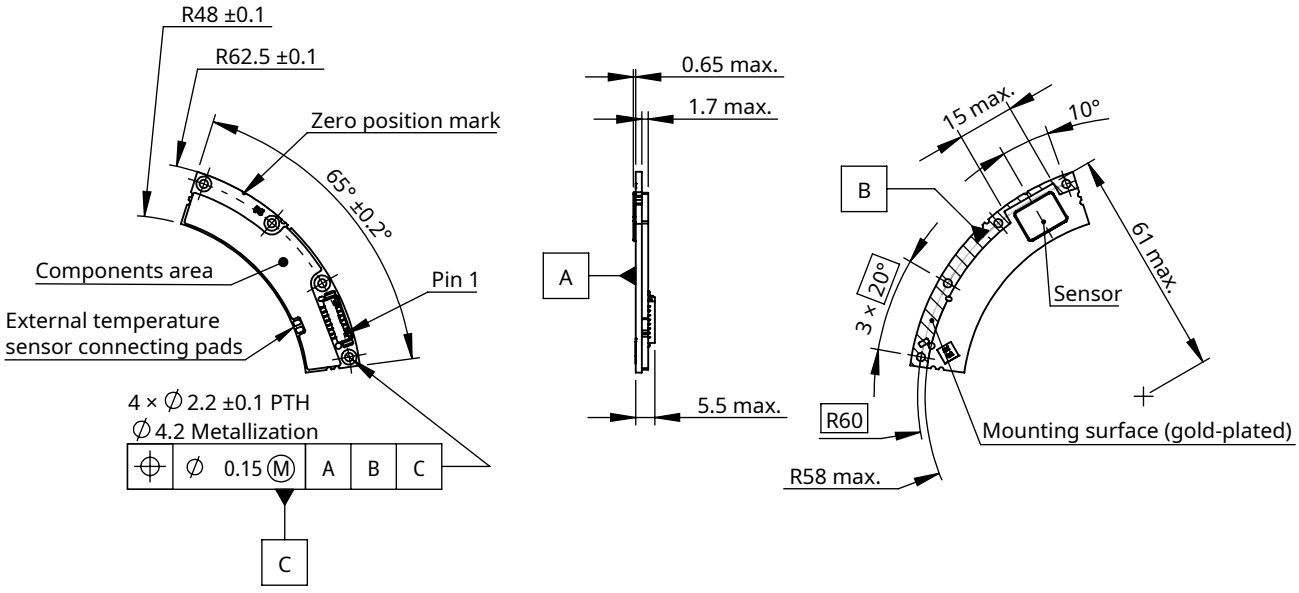
Ride height influences noise on the output. See chapter **Installation instructions** for details.

Dimensions and installation drawings continued

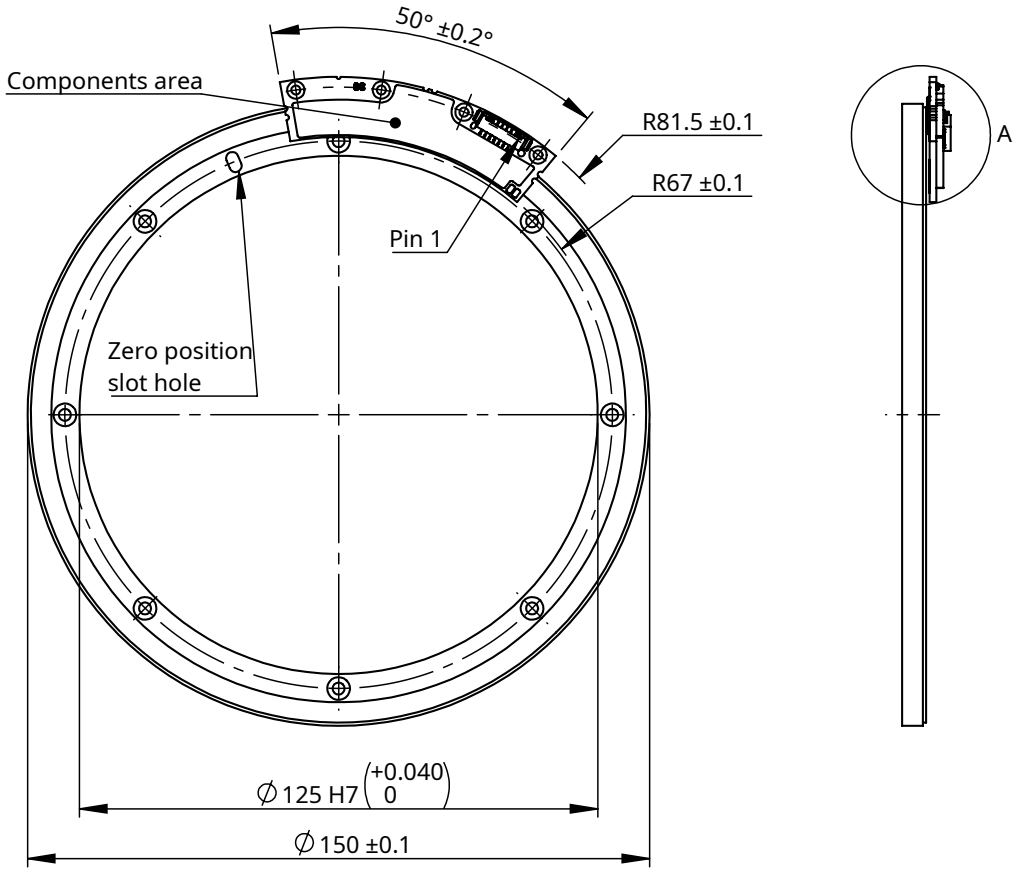
MRA115 magnetic ring

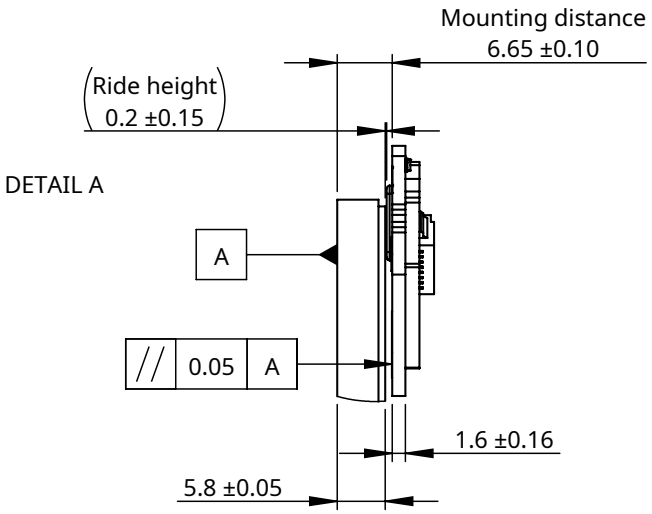


MC115 readhead



Encoder assembly MC150DCB21BDNP00 readhead with MRA150 magnetic ring

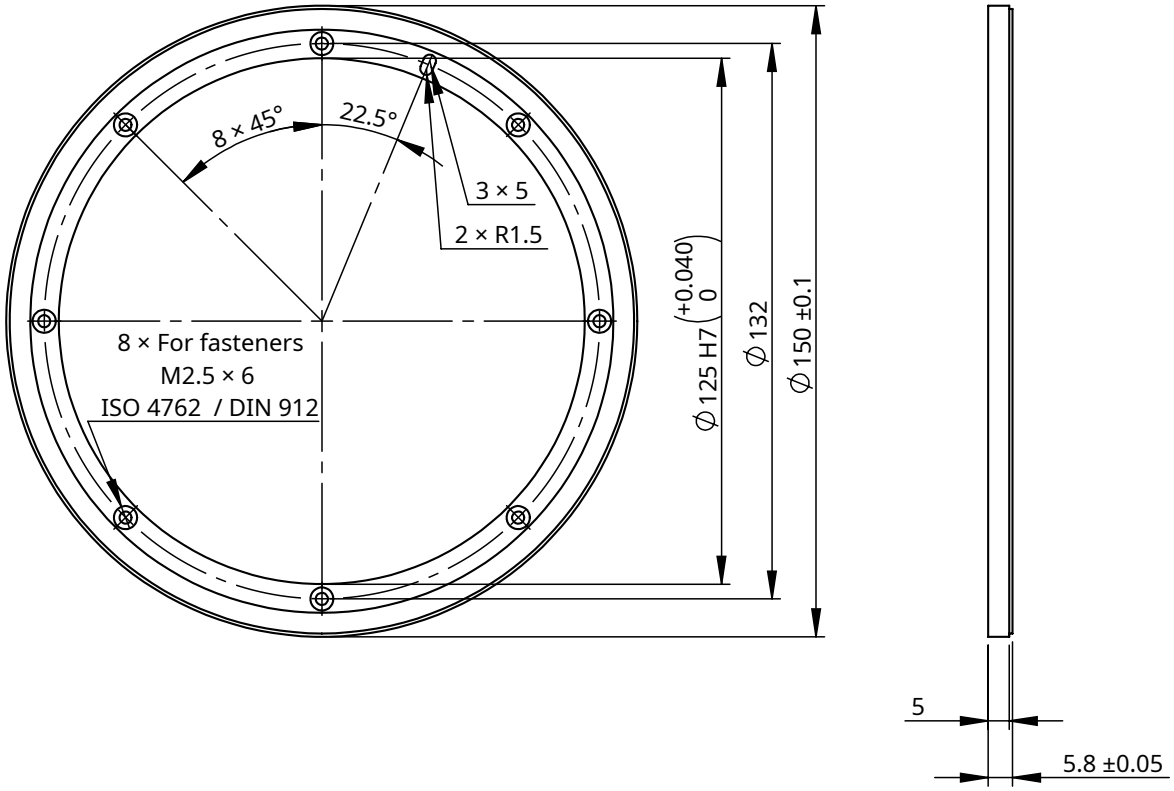




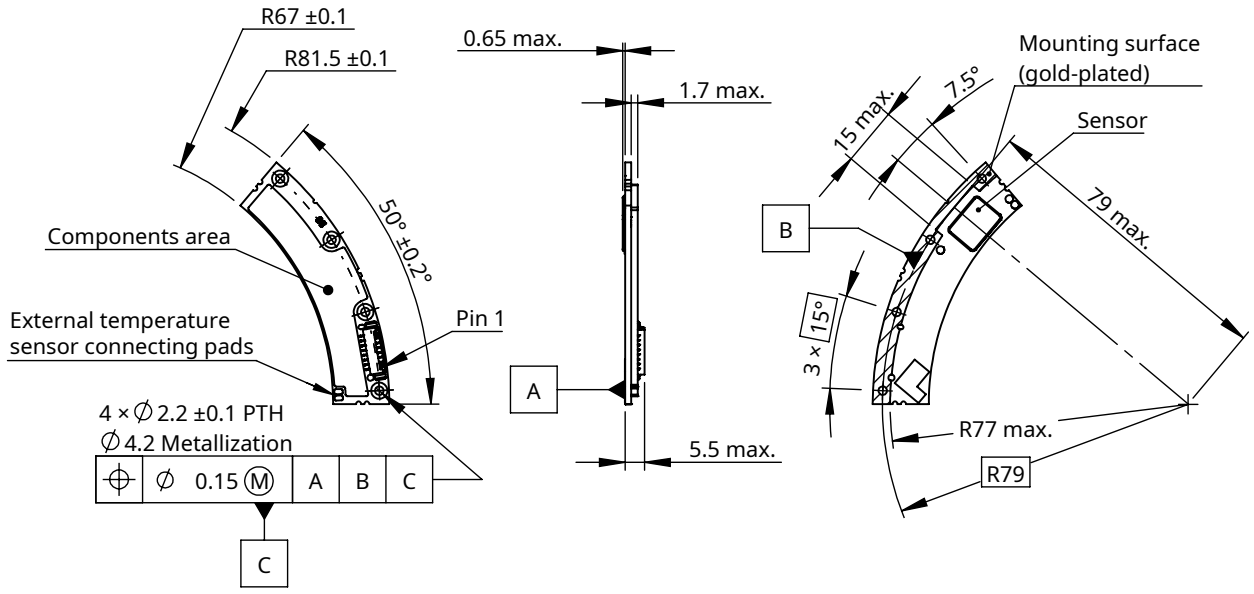
Ride height influences noise on the output. See chapter **Installation instructions** for details.

Dimensions and installation drawings continued

MRA150 magnetic ring



MC150 readhead



Installation instructions

Axial position adjustment (mounting distance)

AksIM installation video

The mounting dimension between the gold-plated surface at the bottom of the readhead and the bottom of the ring should be 2.85 ± 0.1 mm for MC115 and 6.65 ± 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)

Mounting distance	See detail A on dimension drawings of encoder assemblies. Tight ride height is recommended. Increasing the ride height exponentially increases encoder noise even when within installation tolerances. See chapter **Resolutions**.	
Tangential displacement of the sensor	±0.5 mm	
Radial displacement of the readhead	±0.5 mm	
Non-parallel mounting	Tilt angle <0.2°	

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:

Ride height = K × Ln (SignalLevel) + N

The calculated ride height has a tolerance of ±20 µm.

Encoder size	K	N
MC115	–71.62	760
MC150	–71.62	750

Installation tolerances (ring to shaft)

Recommended shaft tolerance is g6.

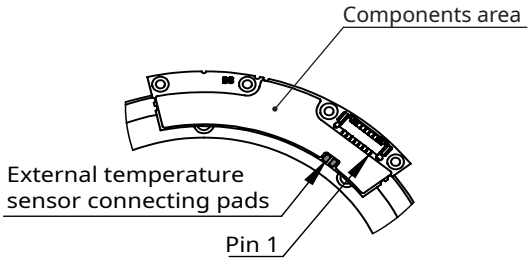
See table of recommended tightening torques for RLS products (document TTD01) available at **RLS media center**.

Electrical connections

Connector	BiSS C	SPI	SSI
1		5 V supply	
2		0 V (GND)	
3		Temperature sensor pin 1*	
4		Temperature sensor pin 2*	
5	MA+	SCK	Clock+
6	MA–	NCS	Clock–
7	SLO+	MISO	Data+
8	SLO–	MOSI	Data–

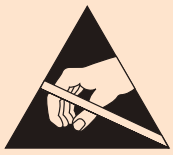
* See chapter **External isolated temperature sensor.**

Pinout



8-pin low profile connector
FCI 10114830-11108LF
For locking connector option **contact RLS.**

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.

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 **Self calibration after installation.**

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**.

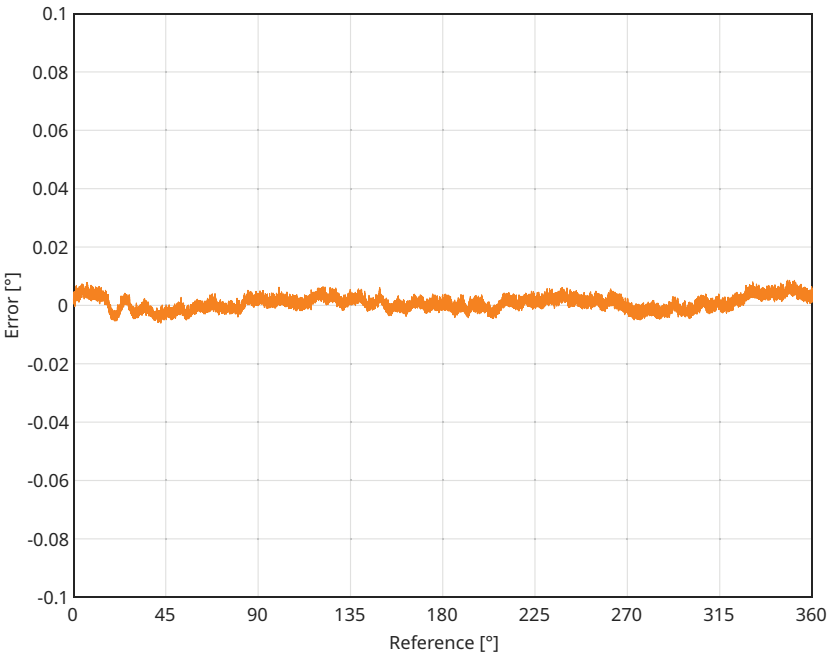
Accuracy

	MC115	MC150
System accuracy*	±0.004°	±0.004°
Typical installed accuracy - Calibrated	±0.006°	±0.006°
Typical installed accuracy - Uncalibrated	±0.029°	±0.020°

Total installed accuracy without calibration is influenced by mounting precision (e.g. eccentricity and bearing wander)
* System accuracy = Total installed accuracy when using two readheads = Max. achievable accuracy when using self-calibration

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.



For high-accuracy variants **contact RLS.**

Self-calibration after installation

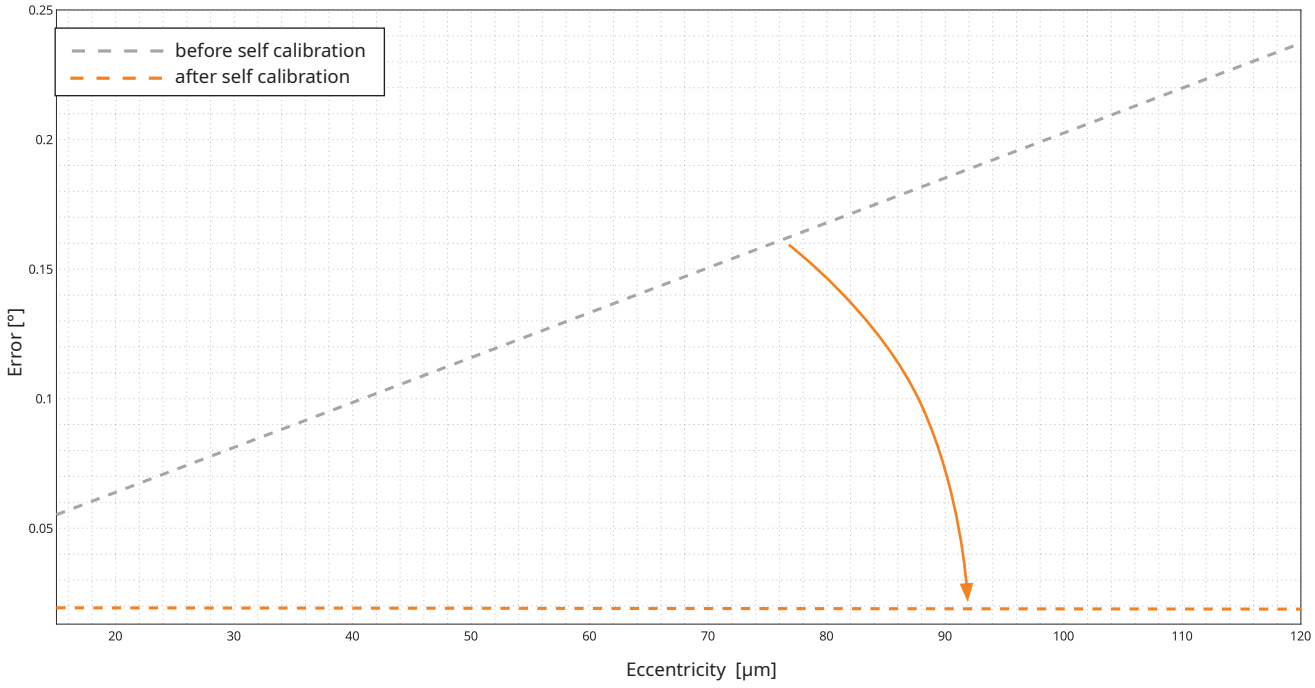
The self-calibration function eliminates the error caused by eccentricity, which is a dominant contributor to the accuracy of the encoder and is caused by the eccentric mounting of the ring. It cannot compensate for the magnetisation error between different rings. The Subdivisional Error (SDE) is negligible 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 when custom desired angle is selected instead of full 360° rotation.

Requirements:

- Free mechanical rotation between 180° and 360° (the desired angle can be selected via the communication interface). The performance of the self-calibration procedure is optimal at 360° rotation and is reduced if the arc length is reduced.
- 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 ±0.004° is influenced by magnetisation variations and noise of the readhead.

Example for encoder size MC115.



For typical accuracy values see chapter **Accuracy.**

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 succesfully performed.
●●●●●	Orange flashing fast	Ring positioning is already perfect - correction was not performed.
●●●●●	Red flashing fast	Self-calibration not performed. Possible reasons: • Eccentricity or radial offset is very high. • Timeout. Ring is rotating too slowly (<6 rpm). • Any error present during self-calibration procedure.

External magnetic field

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

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 ±30 V relative to the other encoder signals and the current to ±500 mA.

The position of solder pads for the temperature sensor for each readhead size is shown in the chapter **Dimensions and installation drawings.**

Operation in high pressure applications

The encoder can be configured to operate at ambient pressures of up to 600 bar. Typical applications include ROV submarines where the entire system is submerged in oil. All frequencies must be reduced and timings increased by 12 %. For more information or to confirm compatibility with oils and other chemicals in the environment, please **contact RLS**.

Operation in ultra high vacuum applications

AksIM encoders were tested for outgassing under ultra-high vacuum conditions with test parameters similar to the ECSS-Q-ST-70-02C (2008) and ASTM E595-15 (2021) standards. No critical outgassing was detected. The relative mass loss (RML) of the ring and readhead were 0.01 % and 0.09 %, respectively. The ultra-high vacuum test had no effect on the performance of the encoder. All frequencies must be reduced and timings increased by 12 %.

Resolutions

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

Multiturn counter

The multiturn option is selected with the resolution in the **Part numbering**. The multiturn counter is 16 bits (0 to 65535 counts). Counting is only available when the encoder is powered, but the counter state is stored in a non-volatile memory at power-down and is restored at power-up. Maximum permissible rotation during power-down is ±90°. If the rotation is greater than this, the encoder reports an error to indicate an invalid multiturn counter value. To reset this condition, it is necessary to apply a new multiturn counter value via the communication interface or cycle power to the encoder. If encoder is rotated for ±360° or for multiple rotations, this movement is not registered and no multiturn error is set. If any other error is set during a rotation of 90° or more, the multiturn counter value may become inconsistent with the mechanical position.

The user must implement the multiturn counter validation method by either:

- Activating the mechanical brake before the encoder goes into the power-down state and releasing the brake after the encoder is powered-up
- Presetting a new multiturn counter value each time the encoder is powered-up.
- Other user-implemented multiturn counter validation methods.

Multiturn - shaft turn counter limitations

Counter may have invalid value in following circumstances:

Possible reasons for failure	Solution
If encoder is rotated for ±360° or multiple rotations during off state.	Use mechanical brake.
If Error flag (red LED) is present for 90° rotation or more.	Read and evaluate Error bit.
When the encoder moves for 90° or more, or rotates 300 rpm or more when the encoder performs blocking operations (storing information in non-volatile memory, factory reset, write protect, self-calibration).	Stop rotation before performing these operations.
If user changes single-turn position offset for 90° or more.	Set new multiturn counter value right after setting zero position offset.
If any function for storing information to non-volatile memory (save configuration, factory reset, write protect, self-calibration) is active when power-down happens.	Keep power supply stable when performing those operations.

Multiturn error flag

Error flag is set in one of the following conditions:

- Detected movement of >90° and <270° when powered off.
- Detected speed of more than 300 rpm during blocking operation.
- High, unexpected positional difference detected (acceleration error).

Multiturn error bit can be cleared by writing new value into the encoder or by power cycle. On SSI interface only power cycle is available.

Communication protocols

Below you will find the data common to all communication protocols.

Detailed status bits

Bit	Description
b15	**Reserved**
b14	**Warning** - Temperature out of range. The readhead temperature is out of specified range (T_{min}, T_{max}).
b13	**Warning** - Signal amplitude low. The distance between the readhead and the ring is too large.
b12	**Warning** - Signal amplitude high. The readhead is too close to the ring.
b11	**Warning** - Signal decoding below certain threshold - position decoding might be inaccurate or fail.
b10	**Warning** - Overspeed. Ring rotation speed is too high.
b9	**Error** - Multiturn counter error (value always 0 when singleturn option is selected).
b8	**Error** - Acceleration error. The position data changed unexpectedly. A stray magnetic field is present or metal particles are present between the readhead and the ring.
b7	**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.
b6	**Error** – Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b5	**Error** – Signal amplitude too high. External magnetic field is present.
b4	**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.
b3	**Error** – Internal power supply error
b2	**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.
b1	**Reserved**
b0	**Reserved**

Encoder programming

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

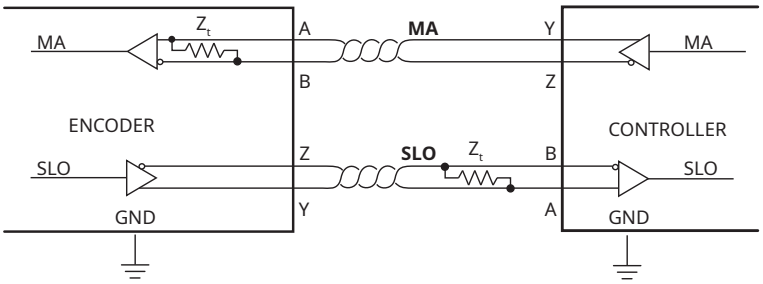
For more information refer to APP03 and APP04 available at **RLS Media center** or **contact RLS.**

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. Additional data can be read from the readhead.

Electrical connection

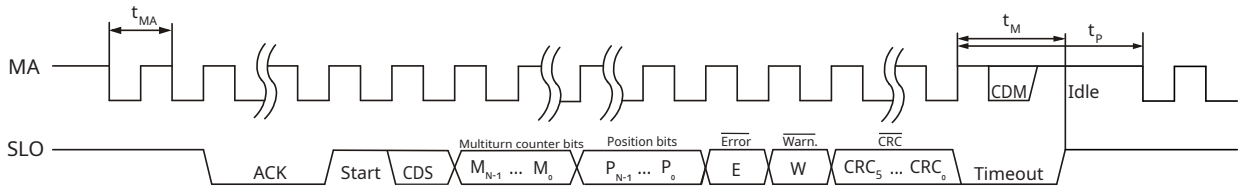


The signal MA is Master Clock with a maximum frequency of 5 MHz and SLO is Slave Out, whose data is transmitted on the rising edges on the line MA. The MA and SLO lines are 5 V RS422 compatible differential pairs. The RC termination on the MA line is built into in the encoder. If the total cable length 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	16 bits	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 µs
MA frequency	$f_{MA} = 1/t_{MA}$	400 kHz		5 MHz
ACK length	ACK		13 bits	
Transfer timeout	t_M		13 µs	
Pause time	t_P	t_M + 1 µs		
Latency				10 µs
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	
b28 : b8	Encoder position – MSB first (for 21 bit resolution)
b7	Error – If low, the position data is not valid.
b6	Warning – If low, the position data is valid, but some operating conditions are close to limits.
b5 : b0	Inverted CRC, calculated by using 0x43 polynomial

When error is active (error bit is low) singleturn position data (b23 : b8) is replaced by detailed status bits. Please refer to **Detailed status bits**. In case of active warning, position data is valid.

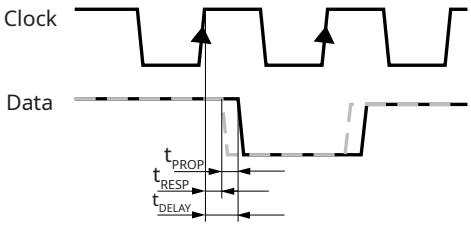
For multiturn	
b44 : b29	Multiturn counter
b28 : b8	Encoder position – MSB first (for 21 bit resolution)
b7	Error – If low, the position data is not valid.
b6	Warning – If low, the position data is valid, but some operating conditions are close to limits.
b5 : b0	Inverted CRC, calculated by using 0x43 polynomial

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).



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

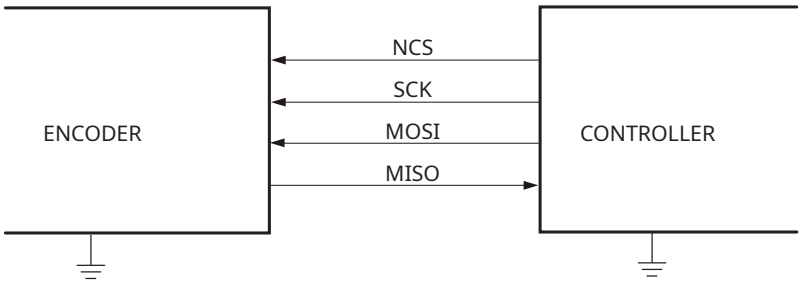
SPI EncoLink interface

The Serial Peripheral Interface (SPI) bus is a four-wire bidirectional synchronous serial communication interface, typically used for short distance communication. It operates in full duplex mode, where master (controller) selects the slave with NCS line, generates clock signal on SCK line, sends command over MOSI line and receives data over MISO line.

All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant. The maximum current sourced or sunk from signal lines should not exceed 5 mA. Single-ended signals should be as short as possible, especially when high frequencies are used.

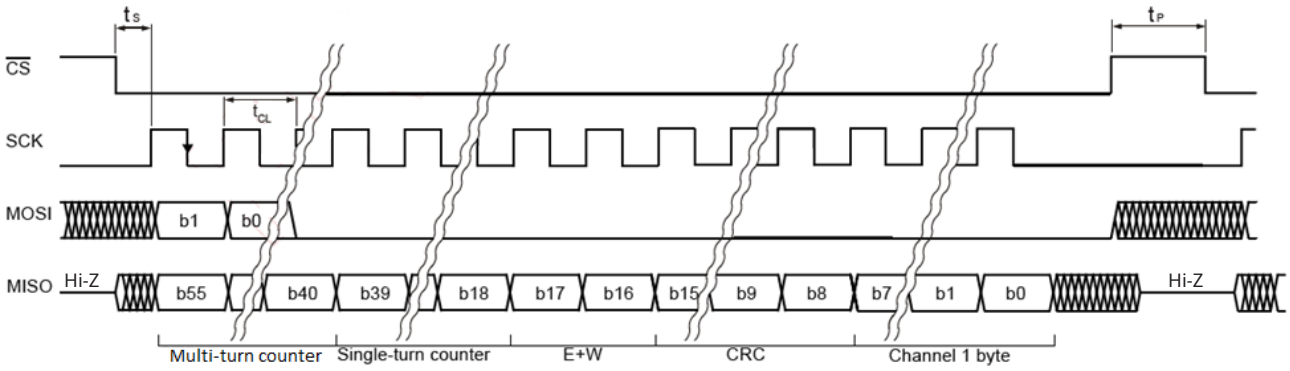
Signal termination: 100 Ω resistors are added in series with all SPI signals.

Electrical connection



Signal	Description
NCS	Active low. NCS line is used for synchronisation between master and slave devices. During communication it must be held low. Idle is high. When NCS is high, MISO line is in high-Z mode. This allows connection of multiple slaves in parallel, sharing all lines except NCS.
SCK	Serial clock. Shifts out the data on rising edge. Data is stable and valid on falling edge.
MOSI	Master output ⟶ Slave input. Command from the controller to encoder.
MISO	Master input ⟵ Slave output. Data is output on rising edge on SCK after NCS low. When NCS is high, MISO line is in high-Z mode.

SPI timing diagram



The controller starts the communication by setting the NCS signal low. A delay of t_s is required to allow the encoder to prepare the data which is then shifted to MISO output on rising edges of clock signal SCK.
Encoder Position and General Status (active low) data is transmitted, followed by CRC (inverted) of the entire data packet.

Communication parameters

Parameter	Symbol	Min	Typ	Max
NCS to SCK delay	t_S	2 µs		
Clock frequency	f_{SCK}			6 MHz*
Pause time (NCS high)	t_P	2 µs		
Sampling rate				50 kHz
Latency				10 µs
SPI settings	CPOL= 0 (clock idle is low)			
	CPHA = 1 (data is output on clock rising edge and sampled on clock falling edge)			

* With 500 mm cable or less.

SPI data structure

Data sent by the master on the MOSI line (b15:b0):

Byte	B1	B2
Bits	b15..b8	b7..b0
Data length	8 bits	8 bits
Contents	Command 0x00*	Data

Command and Data values should be always 0x00 if EncoLink register access is not in use.

* Special commands:
  0xAA Reset EncoLink channels
  0xBB Request Version information from encoder

Command 0x00 (Singleturn variant of the encoder)

Data received over the MISO line contain:

Bytes	Bits	Data length	Contents
B1, B2, B3	b39..b18	Singleturn resolution*	Encoder position / Detailed status (If b17 (General Error) is 0 (active) then position data is replaced by Detailed status.)
	b17	1 bit	Error (active low)
	b16	1 bit	Warning (active low)
B4	b15..b8	8 bits	CRC (inverted)
B5	b7..b0	8 bits	EncoLink register access (If EncoLink register access is not used, the last byte can be ignored and the SPI transaction ended after B4.)

* Encoder position is binary, left aligned, MSB first. Remaining bits are set to zero

Command 0x00 (Multiturn variant of the encoder)

Data received over the MISO line contain:

Bytes	Bits	Data length	Contents
B1, B2	b55..b40	16 bits	Multiturn
B3, B4, B5	b39..b18	Singleturn resolution*	Encoder position / Detailed status (If b17 (General Error) is 0 (active) then position data is replaced by Detailed status.)
	b17	1 bit	Error (active low)
	b16	1 bit	Warning (active low)
B6	b15..b8	8 bits	CRC (inverted)
B7	b7..b0	8 bits	EncoLink register access (If EncoLink register access is not used, the last byte can be ignored and the SPI transaction ended after B6.)

* Encoder position is binary, left aligned, MSB first. Remaining bits are set to zero

General status (next to Encoder position)

Bit	Description
b17	**Error**. If bit is reset (bit low), position is not valid. Red LED.
b16	**Warning**. If bit is reset (bit low), position is not valid. Red LED.

Error behavior and internal encoder speed measurement

Each time the Error bit is reset (bit low), the internal speed is invalidated and is set to 0.

Three consecutive encoder cycles after the error condition has been cleared (Error bit set change to Error bit bit high), the calculated speed is valid again.

CRC check

Length: 8 bits
Polynomial: 0x97
Value is inverted.

CRC calculation example is in application note document CRCD01, available for download at **RLS media center.**

Detailed status bits

See chapter **Communication protocols**.

Command 0xBB (Encoder identification request)

Request Version information from encoder: Encoder returns 19 bytes, presented in the table below.

Byte	Description	Value
B1	Protocol version	4 = Encolink v4
B2	Number of bytes in communication frame	5/7 bytes in communication frame (see command 0x00)
B3..B18	Part number	See chapter **Part numbering**
B19	CRC	Inverted

EncoLink Register access

Encoder supports running self-calibration function, reading signal level value, temperature, detailed status bits, identification information and other diagnostic values. Additional functions are available with use of EncoLink libraries. **Contact RLS** for details.
To access EncoLink registers it is recommended to use EncoLink library provided by RLS.
The self-calibration function and the description of the other registers can be found in document APP04, available for download at **RLS media center.**

> Make sure that you only execute commands that store parameters in non-volatile memory if the ambient temperature is below 105 °C.

Persistent detailed status

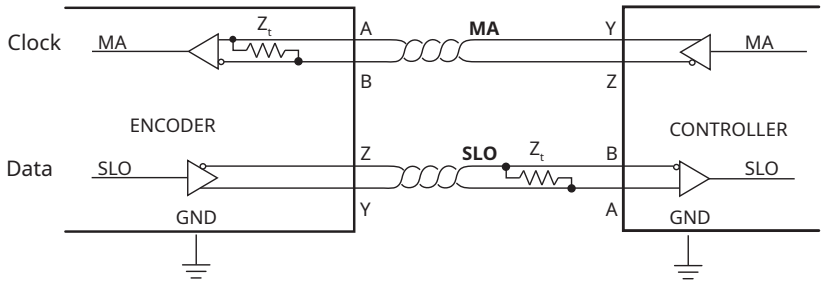
The EncoLink register 0x000A accumulates all status bits that were active during encoder operation in each internal encoder cycle, even if communication is not active. The format of the data is the same as standard Detailed status register.

Clearing the Persistent status register is performed by writing value 0x62 into Command register 0x00BD.

SSI - Synchronous serial interface

The encoder position in natural binary code and the encoder status are available via the SSI protocol. The SSI interface is not recommended for closed-loop applications and motor feedback because of the low update speed and the noticeable latency.

Electrical connection

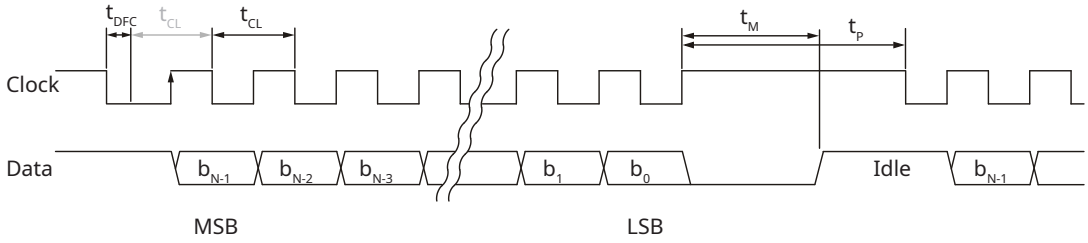


The Clock and Data signals are 5 V RS422-compatible differential pairs with RC termination within the readhead. If the total cable length is more than 5 m, termination on the controller is required. The nominal impedance of the cable should be 120 Ω.

Output protection

An excessive output current and power dissipation caused by errors or bus conflicts are prevented by two mechanisms. A foldback current limit on 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.

SSI timing diagram

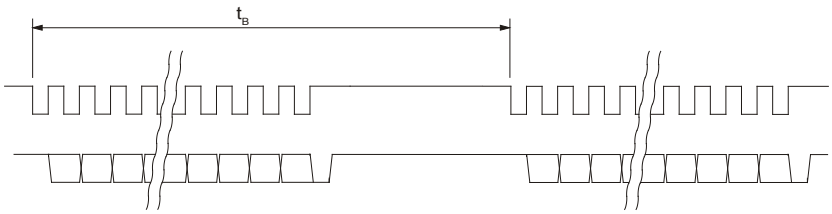


The controller requests the position and status data of the encoder by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge of the Clock latches the last position data available and on the first rising edge of the Clock the most significant bit (MSB) of the position is transmitted to the Data output. The Data output should then be read on the following falling or rising edge. On subsequent rising edges of the Clock signal the next bits are transmitted.

After the transmission of the last bit the Data output goes to low. When the t_M time expires, the Data output goes high. The Clock signal must remain high for at least t_p before the next reading can take place.

While reading the data, the half of a Clock period t_{CL} must always be less than t_M. However, reading the encoder position can be terminated at any time by setting the Clock signal to high for the duration of t_M.

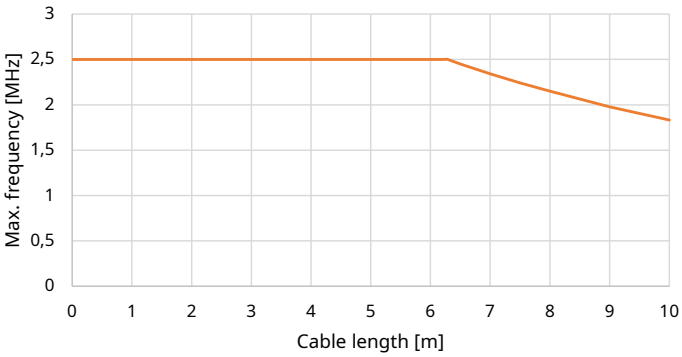
To allow updating of the position data at least t_B should pass between two subsequent readings. If the reading request arrives earlier than t_B after the previous reading, the encoder position will not be updated.

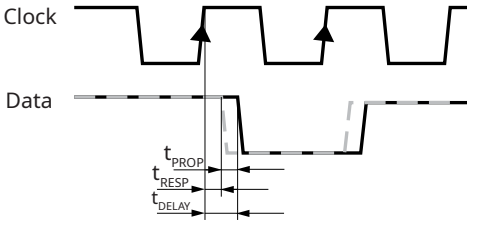


The power supply must be applied at least 100 ms before the clock sequence is being sent to the encoder.

Maximum frequency

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





$t_{DELAY} = t_{RESP} + t_{PROP}$ x cable length

Listed cable propagation delay is valid for ACC049, ACC065 and ACC070.

If the cable length is longer than 6 m, max frequency must be adjusted to the graph above.

Communication parameters

Parameter	Symbol	Min	Typ	Max
Delay first clock	t_{DFC}	1 µs		10 µs
Clock period	t_{CL}	2 µs		20 µs
Clock frequency	f_{CL}	80 kHz		500 kHz (2.5 MHz*)
Timeout (monoflop time)	t_M		20 µs	
Pause time	t_P		t_M + 2 µs	
Readhead response delay	t_{RESP}		60 ns	
Latency		40 µs		80 µs

* With *Delay First Clock* function on the controller.

Encoder data packet structure

For singleturn	
b37 : b18	Encoder position – MSB first (this is a 20 bit encoder example).
b17	Error – If set, the position data is not valid.
b16	Warning – If set, the position data is valid, but some operating conditions are close to limits.
b15 : b0	Detailed status

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

For multiturn	
b53 : b38	Multiturn counter (if specified in part number) – MSB first (this is for a 20 bit encoder example).
b37 : b18	Encoder position – MSB first (this is a 20 bit encoder example).
b17	Error – If set, the position data is not valid.
b16	Warning - If set, the position data is valid, but some operating conditions are close to limits.
b15 : b0	Detailed status

Part numbering

Readhead

MC 150 DC B 21B D N P 00

Series
MC - AksIM-4 board-level readhead

MRA ring compatibility
115 - For use with MRA115 ring
150 - For use with MRA150 ring

Communication interface
DC - BiSS C, RS422
SC - Synchronous serial interface (SSI), RS422
SP - SPI (Serial peripheral interface), LVTTL

Communication interface variant
For **DC: B** - BiSS C, bidirectional, 13 ACK bits, with register access, AksIM-4 style register map
For **SC: B** - Start bit and idle data line 1
For **SP: M** - SPI EncoLink

Resolution
18B - 18 bits per revolution
19B - 19 bits per revolution
20B - 20 bits per revolution
21B - 21 bits per revolution

Multiturn counter options
18M - 18 bits per revolution + 16 bits multiturn counter
19M - 19 bits per revolution + 16 bits multiturn counter
20M - 20 bits per revolution + 16 bits multiturn counter
21M - 21 bits per revolution + 16 bits multiturn counter

Shape and connector orientation
D - Partial arc, radial connector exit

Connector option
N - FCI 10114830-11108LF, 8 pin connector*
* For locking connector option **contact RLS.**

Option
P - Extended temperature range –40 °C to +105 °C

Special requirements
00 - No special requirements (standard)

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

Table of available combinations

Series	Ring compatibility	Communication interface	Communication interface variant	Resolution	Shape & connector orientation	Connector option	Option	Special requirements
MC	115	DC	B	18B / 19B / 20B / 18M / 19M / 20M	D	N	P	00
		SC	B	18B / 19B / 20B / 18M / 19M / 20M				
		SP	M	18B / 19B / 20B / 18M / 19M / 20M				
	150	DC	B	18B / 19B / 20B / 21B / 18M / 19M / 20M / 21M				
		SC	B	18B / 19B / 20B / 21B / 18M / 19M / 20M / 21M				
		SP	M	18B / 19B / 20B / 21B / 18M / 19M / 20M / 21M				

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.

Table of available combinations

Series	Outer diameter and readhead compatibility	Thickness	Installation type	Inner diameter	Magnetization type	Material	Zero marking	Special requirements
MRA	115	B	C	090	B	S	H	00
	150	J	F	125		M		

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

Accessories

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**.

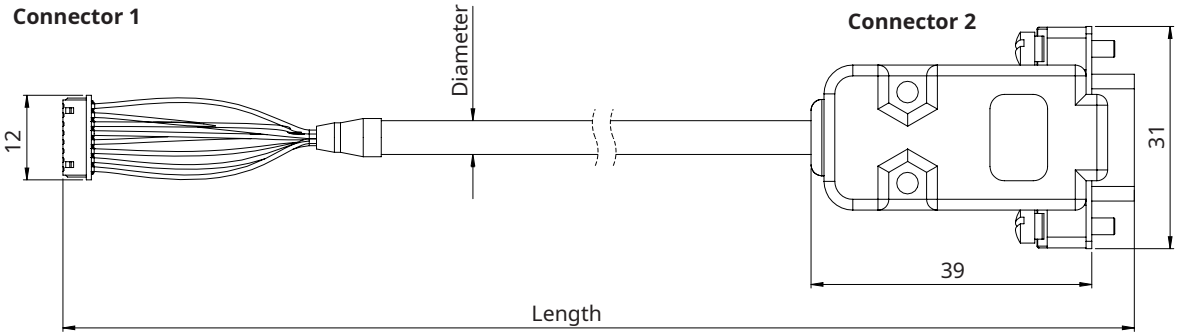
USB interface (for BiSS C communication interface)
E201-9B

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				DSUB-9 M	
	ACC070		3.0 m		Flying leads	



Dimensions in mm.

Connector 1 FCI 10114826-00008LF	Connector 2 DSUB-9 M				
Pin number		Wire color	BiSS C	SPI	SSI
	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

Part numbers	ACC049, ACC065, ACC070
Cable specifications	LiYCY (TP)
Configuration	4 × 2 × 0.14 mm^2 (twisted pairs)
Rated voltage	350 V
Temperature range	Operating –40 °C to +75 °C (fixed) –5 °C to +70 °C (bending) Storage –40 °C to +80 °C
Environmental compliance	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.

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Document issues

Issue	Date	Page	Description
1	3. 4. 2023	-	New document
2	20. 12. 2024	4, 10	System accuracy amended
		16	Communication protocol chapter added
		21-26	SPI and SSI communication chapters added
		28-29	Table of available combinations added
3	28. 8. 2025	10	Electrical connections added
		4, 14	High vacuum and high pressure added

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