AksIM-2

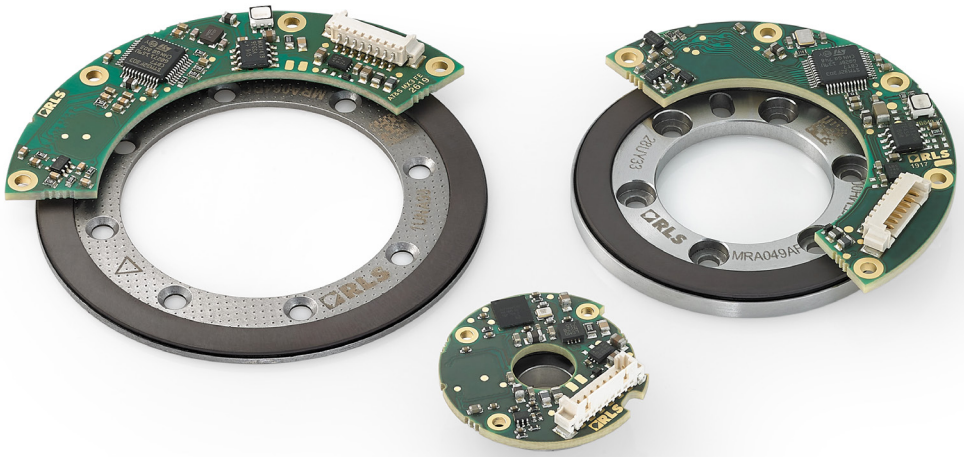
Off-Axis Rotary Absolute Magnetic Encoder

HIGH ACCURACY

HIGH SPEED

MULTITURN COUNTER

AksIM-2 is a non-contact, high performance off-axis absolute rotary encoder designed for integration into applications with limited space. A hollow ring, true absolute functionality and high-speed operation make this encoder suitable for many applications.
The AksIM-2 encoder system consists of an axially magnetised ring and a readhead. The encoders are equipped with BiSS, Asynchronous serial (UART), SPI, PWM or SSI communication interfaces and offer a range of binary resolutions up to 20 bits per revolution.



Features and benefits

- True absolute system
- Custom magnetic sensor ASIC
- Self-calibration option
- No hysteresis
- Resolution up to 20 bits
- Multiturn counter option
- High speed operation
- Low profile, non-contact
- Integrated status LED
- High repeatability

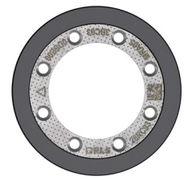
COLLABORATIVE ROBOTS | AGVs | GIMBALS | ROBOTIC JOINTS | AGRICULTURAL AUTOMATION

General information

The AksIM-2 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-2 encoder system is suitable for use in industrial and medical applications. A typical application is a robotic arm joint with a cable feed through the ring, or a precision gearbox where the ring is mounted on the main transmission shaft.

A custom design service for OEM integration is also available.



MRA axial magnetic ring

+

MB readhead

=

AksIM-2 system

Selection guide

Part number	Magnetic ring: Inner diameter	Magnetic ring: Circle for fasteners	Magnetic ring: Outer diameter	Magnetic ring: Thickness	Magnetic ring: Inertia (kg × mm²)	Readhead: Inner diameter	Readhead: Circle for fasteners	Readhead: Outer diameter	Readhead: Arc length	Max resolution	System thickness (Typ.)	Mass (g)
MB022 Assembly												
MB022 shape G						8.5	24	28.5	360°	17 bit		2.7
MRA022HP008DMN00	8	none	21.5	5.4	0.36						12.45	7.0
MB029 Assembly												
MB029 shape F						14	35.4	38	360°	18 bit		4.5
MRA029BC010DSE00	10	15	29	2.0	0.75						7.85	5.9
MRA029GP013DMN00	12.7	none	29	7.0	1.0						12.85	9.0
MB039 Assembly												
MB039 shape E						23	49	54	196°	19 bit		4.8
MRA039BC020DSE00	20	25	39	2.0	2.3						7.85	9.2
MB049 Assembly												
MB049 shape D						34	54	59	190°	19 bit		4.5
MB049 shape E						26	54	59	138°	19 bit		4.2
MRA049BC025DSE00	25	31	49	2.0	5.5						7.85	15
MRA049AF025EMH00	25	31	49	3.9	13						9.75	32
MRA049BG034DSN00	34	none	49	2.0	4.8						7.85	11
MB053 Assembly												
MB053 shape E						36	66	74	130°	20 bit		5.3
MRA053BC030DSE00	30	36	53	2.0	7.4						7.85	16
MRA053BG040DSN00	40	none	53	2.0	5.9						7.85	11
MB064 Assembly												
MB064 shape D						48	69	74	140°	20 bit		6.9
MRA064BC040DSE00	40	46	64	2.0	15						7.85	20
MRA064BG051DSN00	51	none	64	2.0	11.4						7.85	14
MB080 Assembly												
MB080 shape D						64.4	85	90	97°	20 bit		4.0
MRA080BC055DSE00	55	61.5	80	2.0	32						7.85	26
MRA080AF055EMH00	55	61.5	80	3.9	74						9.75	64
MRA080BG064DSN00	64	none	80	2.0	12.8						6.05	19
MRA080DF068DMH00	68	88	95	4.9	114						10.75	72

Storage and handling

Storage temperature

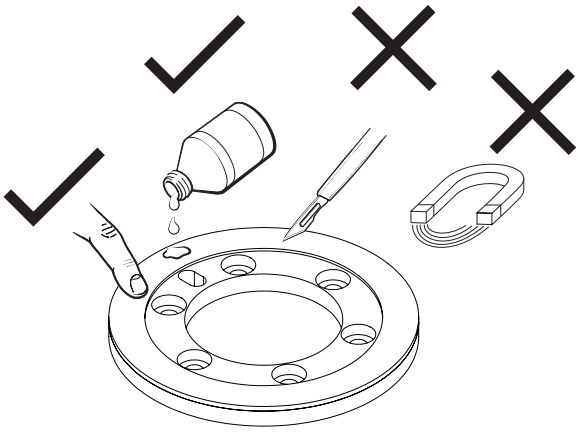
–40 °C to +105 °C

Operating temperature

–40 °C to +105 °C
–40 °C to +85 °C (MB022 only)

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.

Technical specifications

System data

Reading type	Axial reading
Maximum speed	Size 022/029/039: 10,000 rpm; size 049: 9,500 rpm; size 053: 7,500 rpm; size 064: 6,000 rpm; size 080: 4,700 rpm. For higher speeds **contact RLS**.
Hysteresis	Less than unit of resolution
Repeatability	Less than unit of resolution
Encoder speed	9 kHz bandwidth, 18 kHz sampling rate, up to 54 kHz refresh rate (see chapter **Communication interfaces**).
Thermal drift	None (accuracy does not change with temperature)

Resolution	MRA022	MRA029	MRA039/049	MRA053/064/080
Binary	17 bits per revolution	17 bits per revolution 18 bits per revolution *	17 bits per revolution 18 bits per revolution * 19 bits per revolution *	17 bits per revolution 18 bits per revolution 19 bits per revolution * 20 bits per revolution *

* High resolution options may contain noise on the output. These resolutions are suitable for smoother operation of the control loops or averaging to obtain a fine position. The noise margin increases exponentially with increasing ride height between the ring and readhead.

Accuracy	MRA022	MRA029	MRA039	MRA049	MRA053	MRA064	MRA080
System accuracy*	±0.020°	±0.014°	±0.012°	±0.007°	±0.006°	±0.004°	±0.004°
Typical installed accuracy - Calibrated	±0.030°	±0.023°	±0.016°	±0.015°	±0.012°	±0.010°	±0.009°
Typical installed accuracy - Uncalibrated	±0.100°	±0.070°	±0.048°	±0.045°	±0.040°	±0.032°	±0.029°

Total installed accuracy without calibration is influenced by mounting precision (e.g. eccentricity and bearing wander).
* Installed accuracy when using two readheads or best possible after self-calibration.

Electrical data

Supply voltage (V_{DD})	4.5 V to 5.5 V at the connector. Rise time should be shorter than 20 ms.
Set-up time	100 ms (first data ready after supply voltage is in range), worst case: 200 ms
Current consumption	Typ. 130 mA, max. 150 mA (without load on the outputs)
Connection	8-pin low-profile connector or soldering pads
Connector locking mechanism	Retention force 20 N (2 kg)
Output load	RS422: ±40 mA
	PWM, SPI: 5 mA (LVTTL logic level)
ESD protection	HBM, Class 2, ±2 kV (valid only on RS422 signals on connector; do not touch other components)

Mechanical data

Material type	2 mm thick rings	EN 1.4016 / AISI430 with glued CPE rubber filled with ferrite particles (for material S)
	3.9 mm and 4.9 mm thick rings	EN 1.4005 / AISI416 or EN 1.4104 / AISI430F with glued CPE rubber filled with ferrite particles

Environmental and operational conditions

Environmental data

Operating and storage temperature	Standard: –40 °C to +105 °C, MB022: –40 °C to +85 °C
Humidity	Up to 70 % non-condensing (for higher with conformal coating **contact RLS**)
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

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.

External magnetic fields

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 20 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.

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. A special version of the encoder must be used with the **P** option (see **Part numbering**). All frequencies must be reduced and timings increased by 12 %.

Operation in ultra-high-vacuum applications

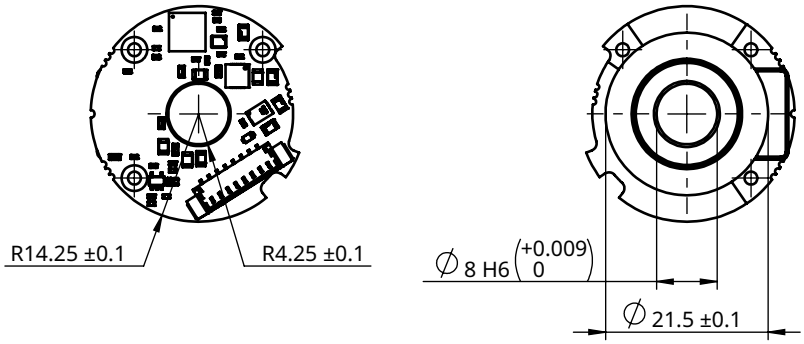
AksIM encoders are suitable for operation in ultra-high-vacuum environments down to 1.0×10^{-7} Pa. The encoders were tested for outgassing under ultra-high-vacuum conditions with test parameters similar to the ECSS-Q-ST-70-02C (2008) and ASTM E595-15 (2021) standards. No critical outgassing was detected. 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. A special version of the encoder must be used with the **P** option (see **Part numbering**). All frequencies must be reduced and timings increased by 12 %.

For additional details, please **contact RLS**.

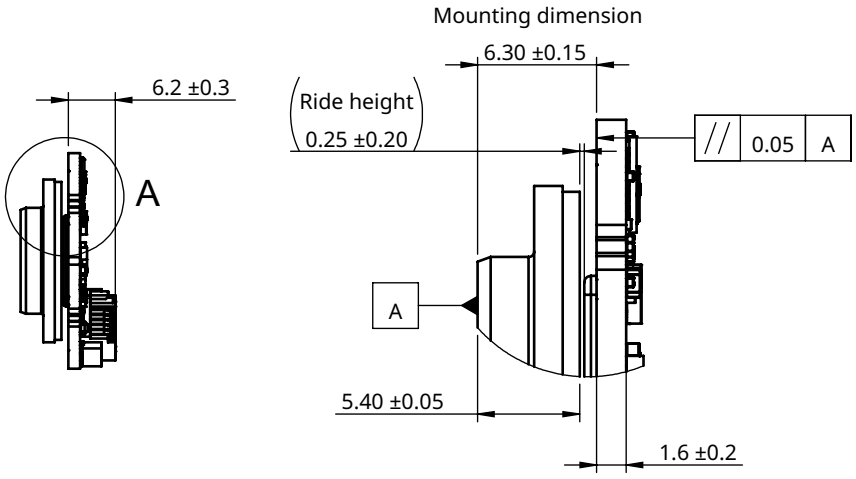
Dimension drawings

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

Encoder assembly MB022 readhead with MRA022HP008DMN00 magnetic ring

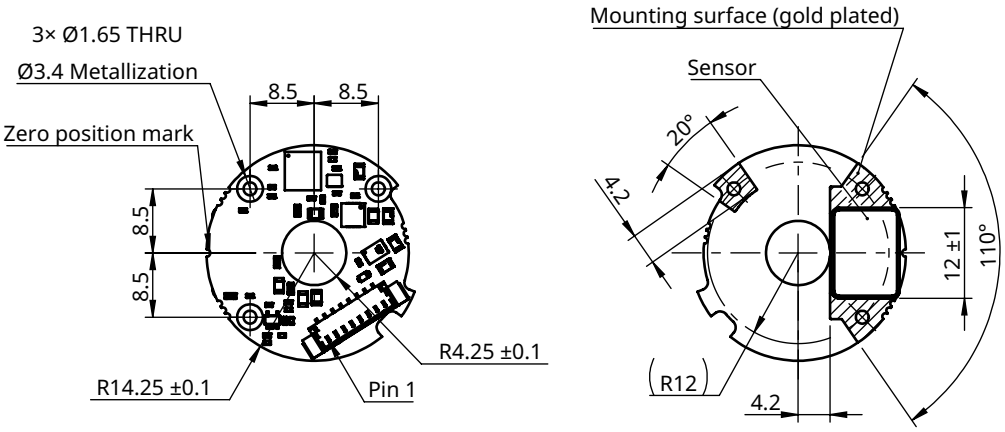


Detail A

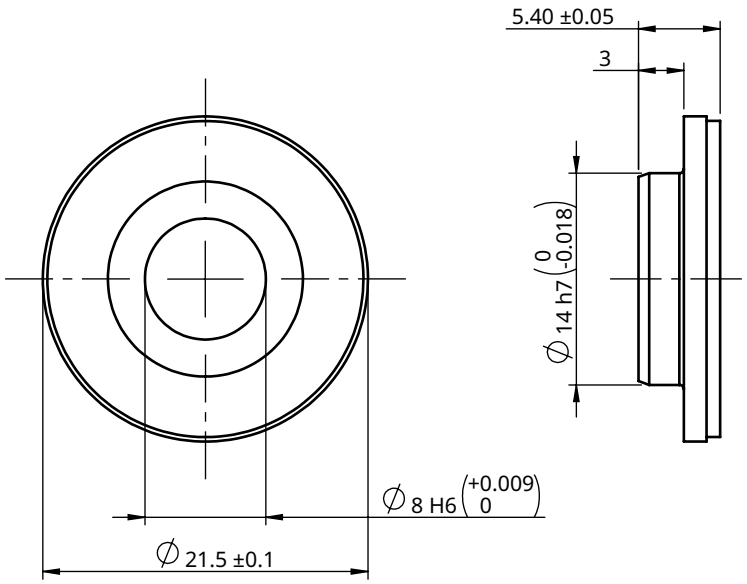


Ride height influences noise on the output. See chapter **Installation instructions** for details.

MB022 readhead



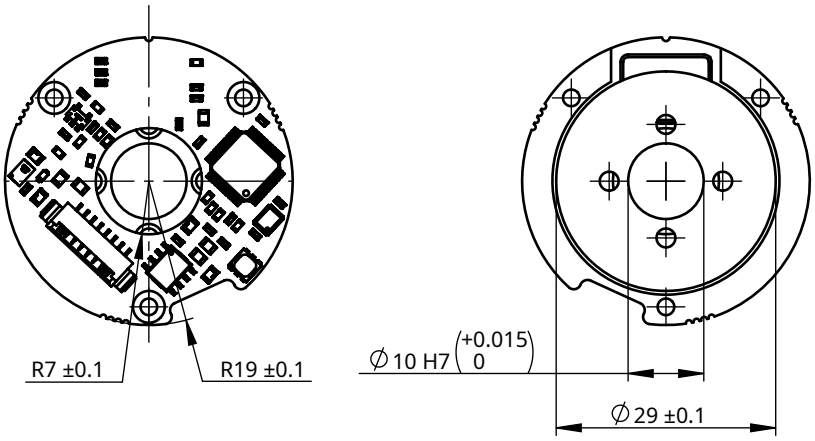
MRA022HP008DMN00 magnetic ring



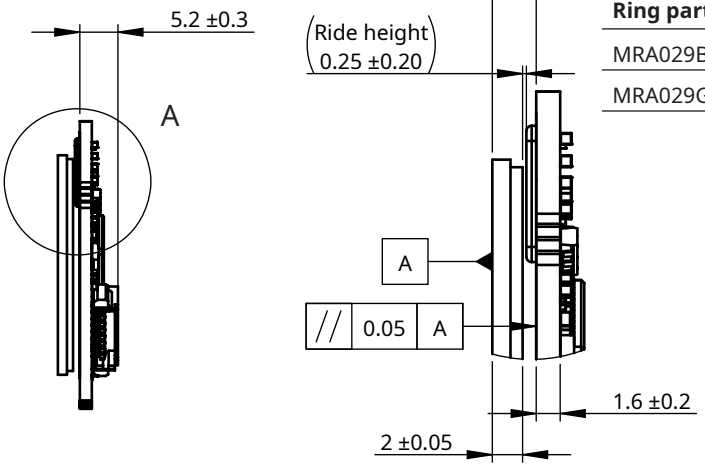
Press-fit mounting to shaft D8: recommended shaft OD tolerance is r6 (+0.019 / +0.028)

Dimensions and installation drawings continued

Encoder assembly MB029 readhead with MRA029BC010DSE00 magnetic ring



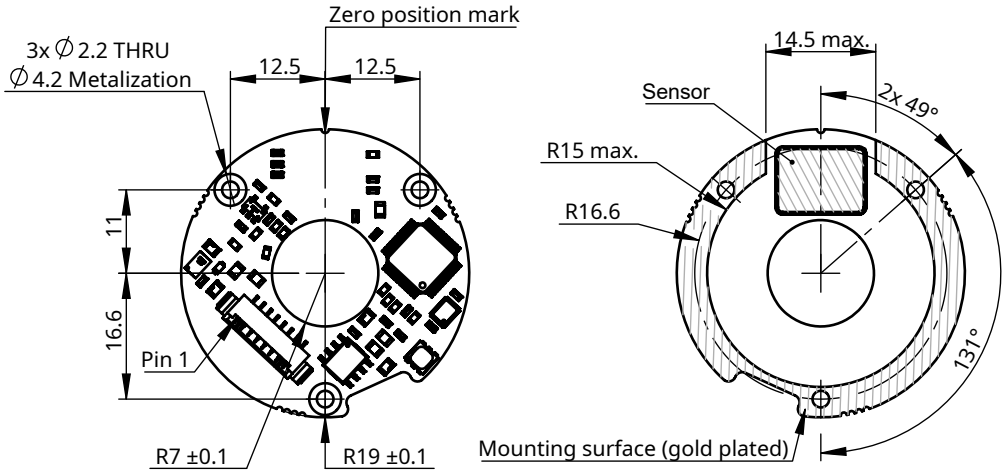
Detail A



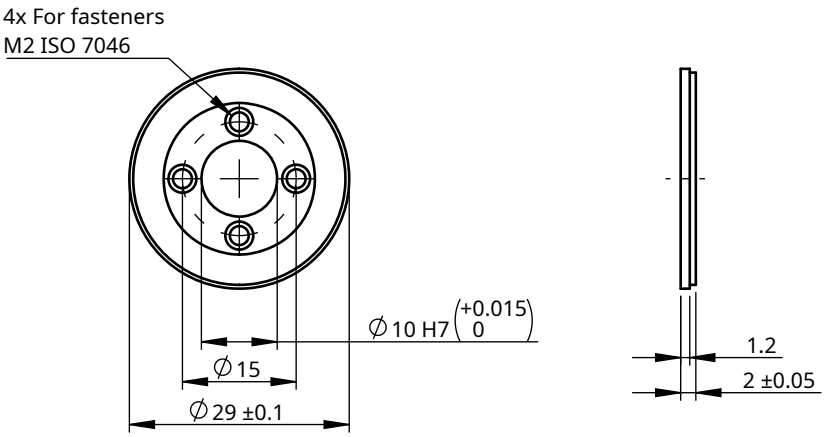
Mounting dimension:	
Ring part number	
MRA029BC010DSE00	2.9 ±0.15
MRA029GP013DMN00	7.9 ±0.15

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

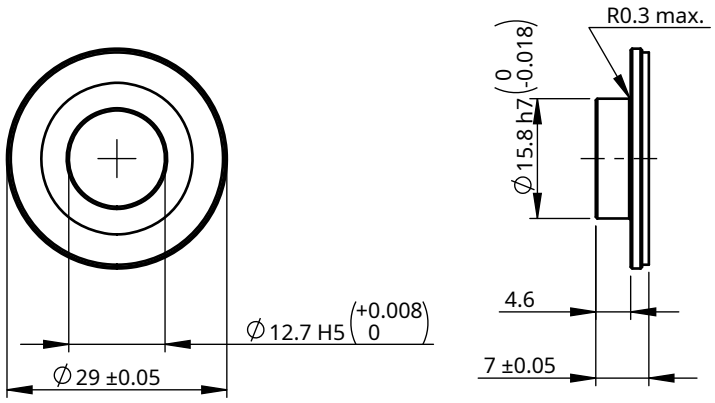
MB029 readhead



MRA029BC010DSE00 magnetic ring



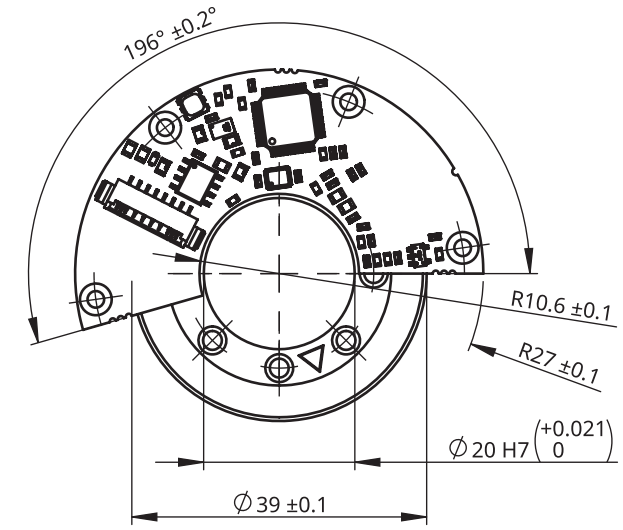
MRA029GP013DMN00 magnetic ring

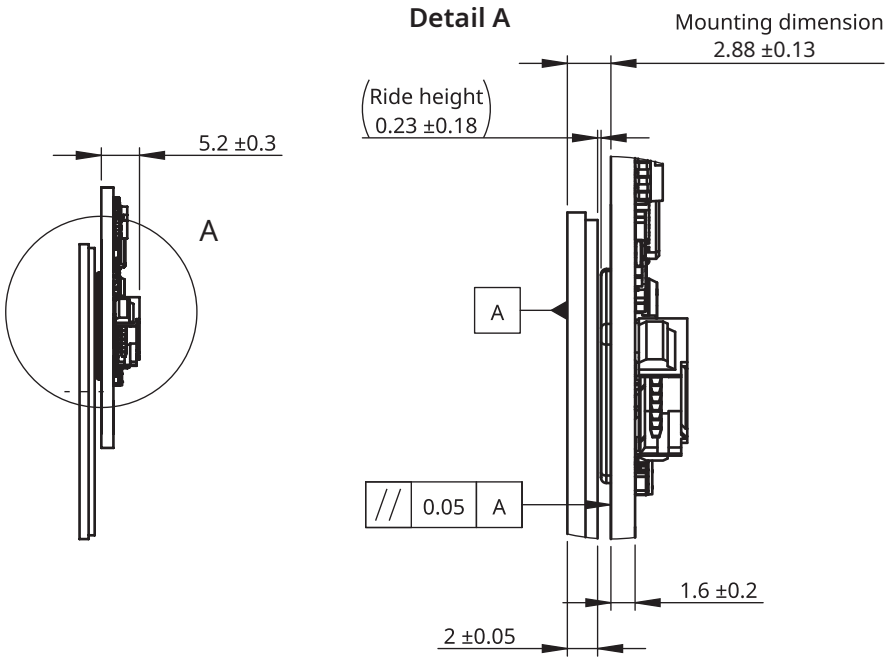


Press-fit mounting to shaft D12.7: recommended shaft OD tolerance is p7 (+0.018 / +0.036)

Dimensions and installation drawings continued

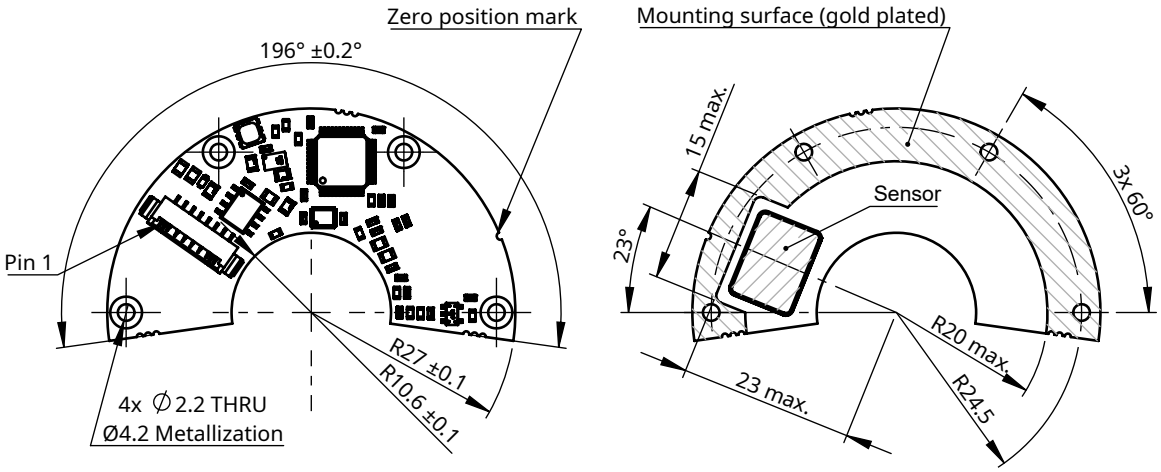
Encoder assembly MB039 readhead with MRA039BC020DSE00 magnetic ring



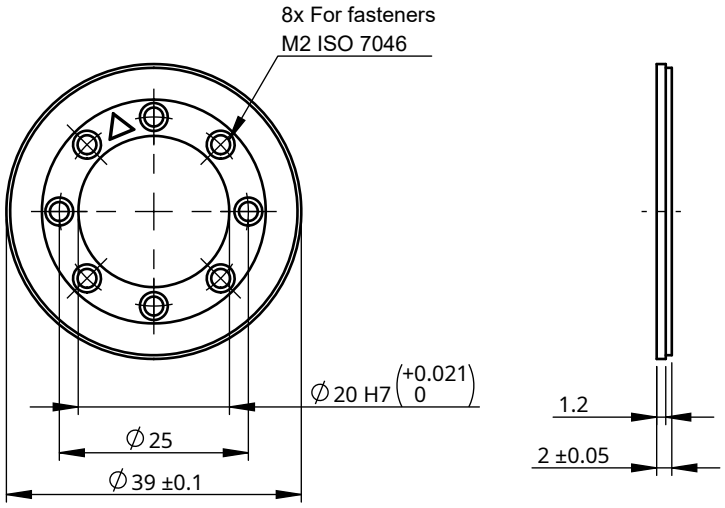


Ride height influences noise on the output. See chapter **Installation instructions** for details.

MB039 readhead



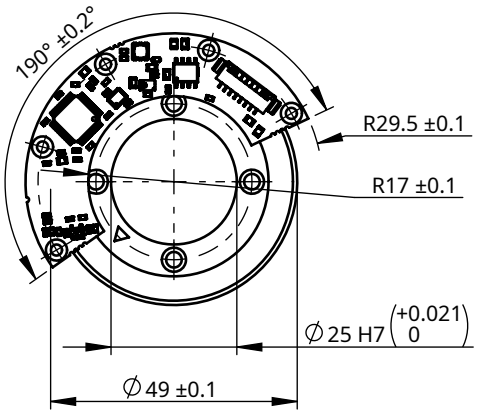
MRA039BC020DSE00 magnetic ring



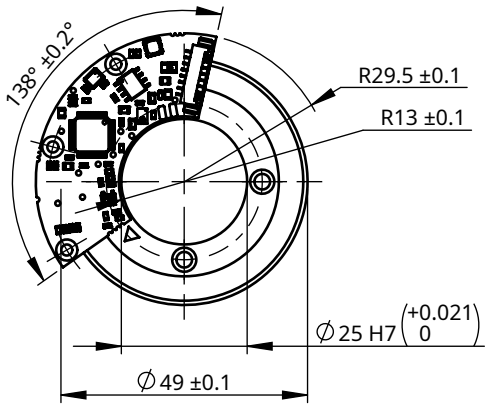
Dimensions and installation drawings continued

Encoder assembly MB049 readhead shape D and readhead shape E with MRA049BC025DSE00 magnetic ring

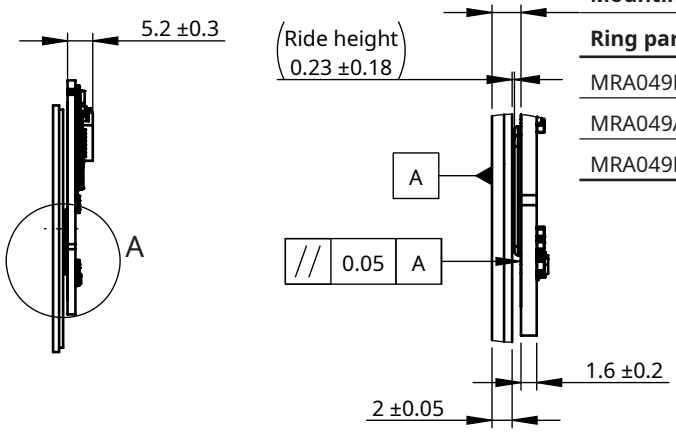
MB049 readhead size D with MRA049BC025DSE00 ring



MB049 readhead size E with MRA049BC025DSE00 ring



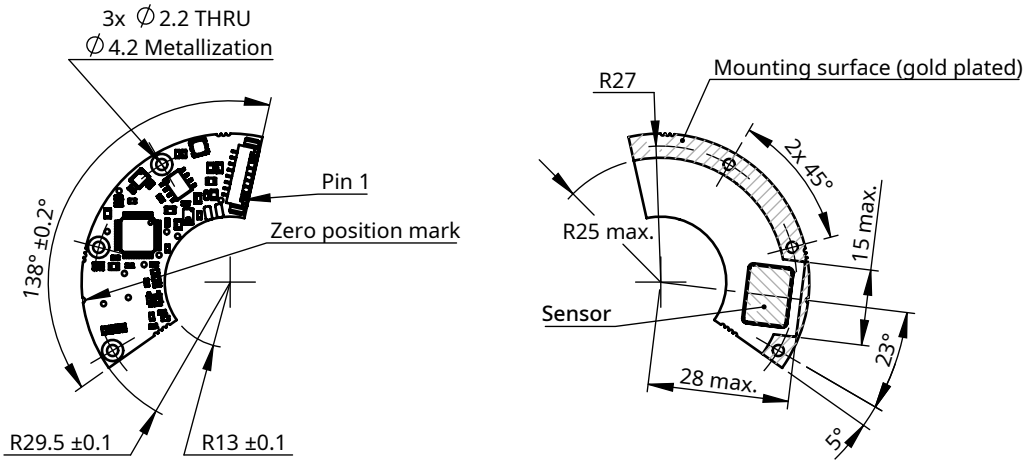
Detail A



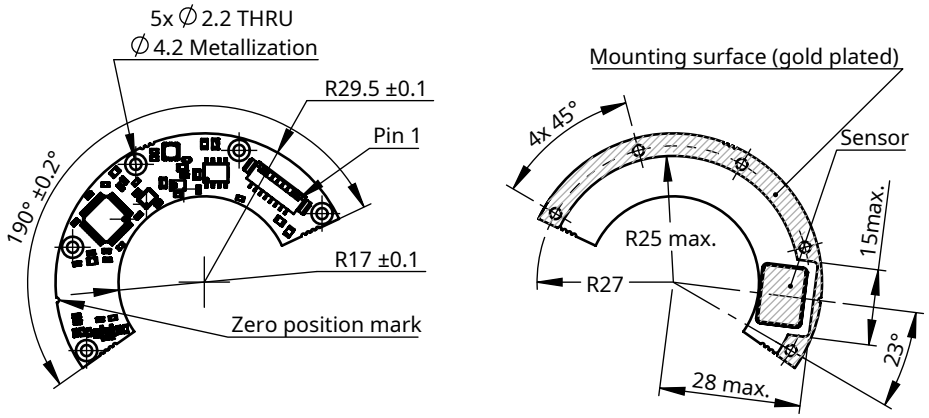
Mounting dimension:	
Ring part number	
MRA049BC025DSE00	2.88 ±0.13
MRA049AF025EMH00	4.78 ±0.13
MRA049BG034DSN00	2.88 ±0.13

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

MB049 readhead shape E

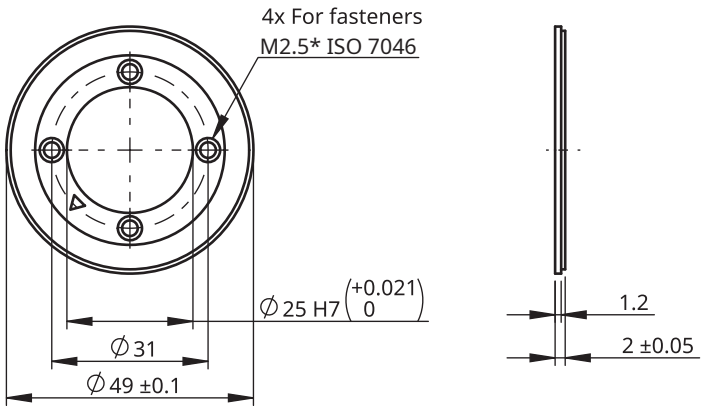


MB049 readhead shape D



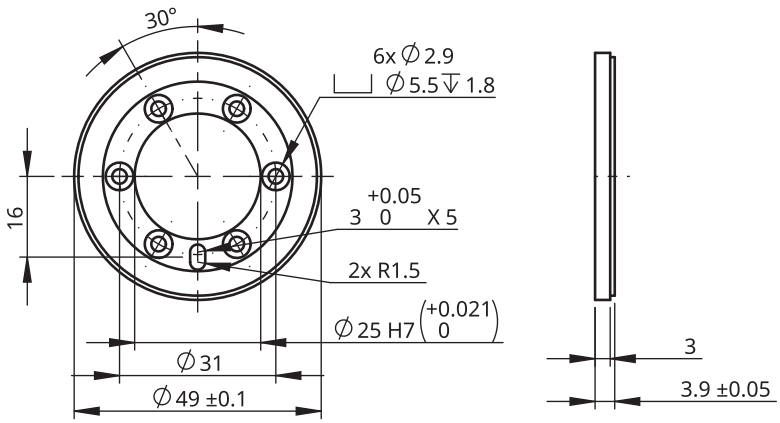
Dimensions and installation drawings continued

MRA049BC025DSE00 magnetic ring

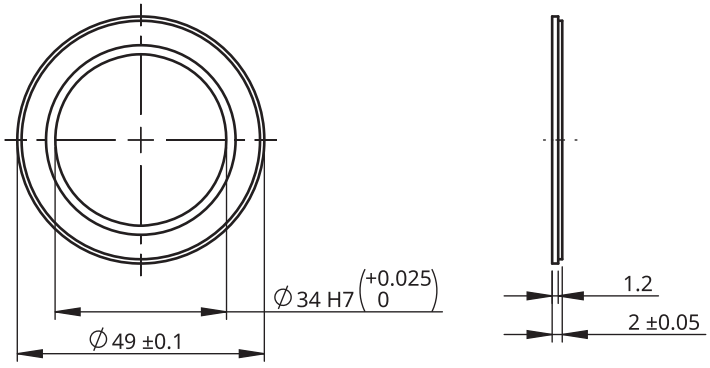


* Also possible with suitable M2.

MRA049AF025EMH00 magnetic ring

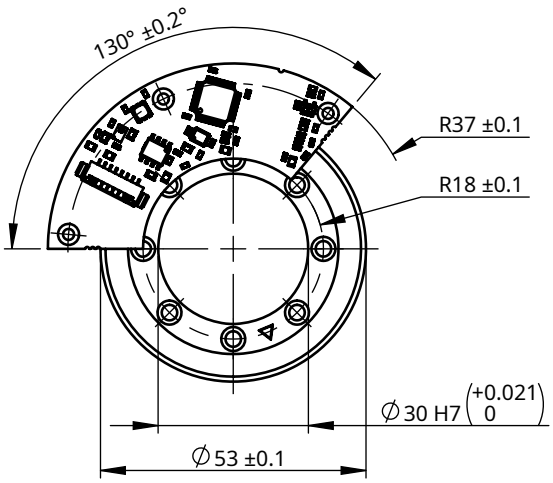


MRA049BG034DSN00 magnetic ring

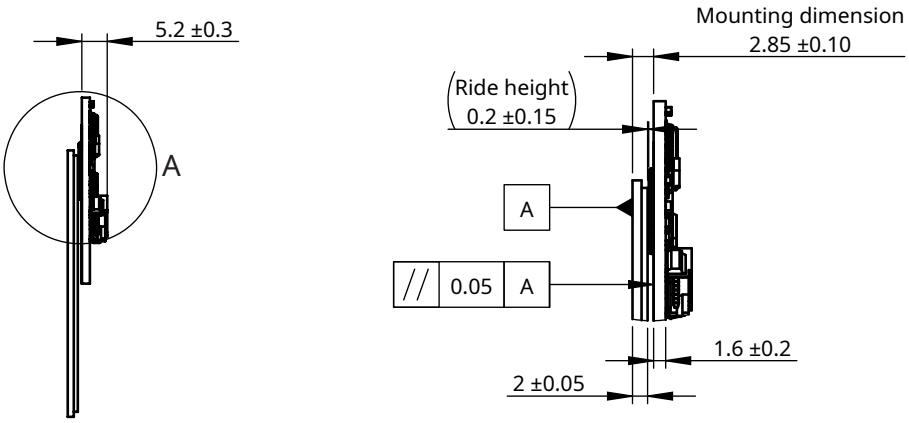


Mounting with glue. See chapter **installation instructions** for more details.

Encoder assembly MB053 readhead shape E with MRA053BC030DSE00 magnetic ring

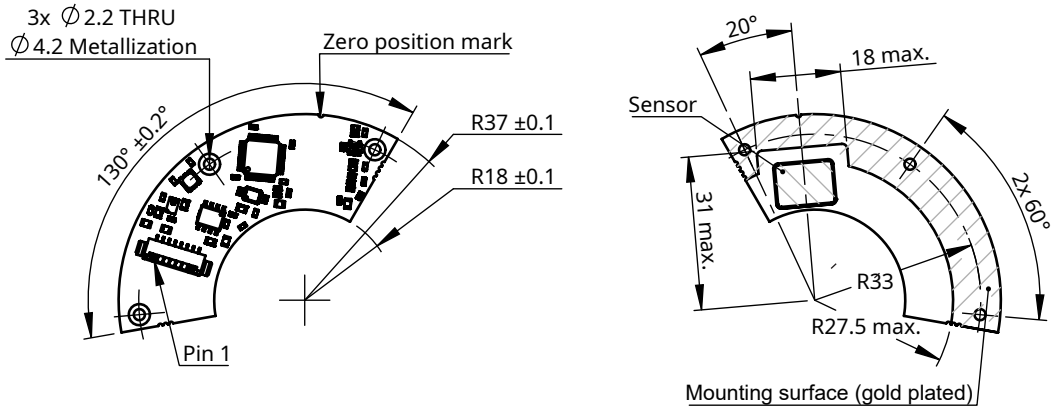


Detail A



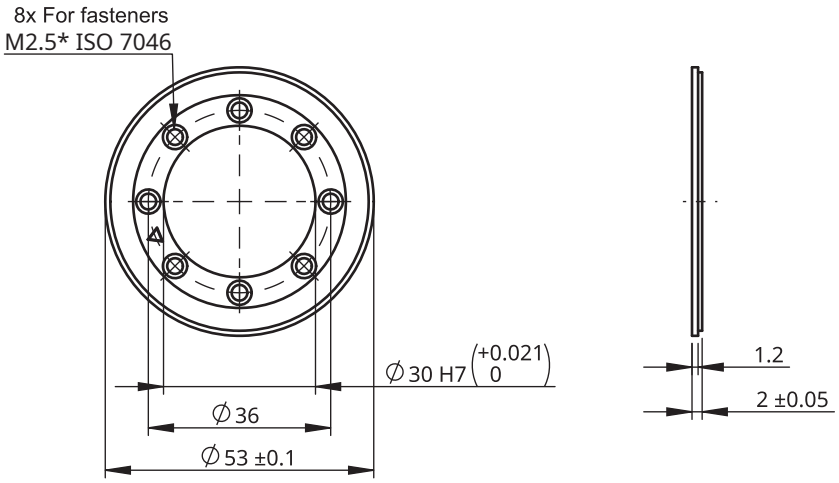
Ride height influences noise on the output. See chapter **Installation instructions** for details.

MB053 readhead shape E



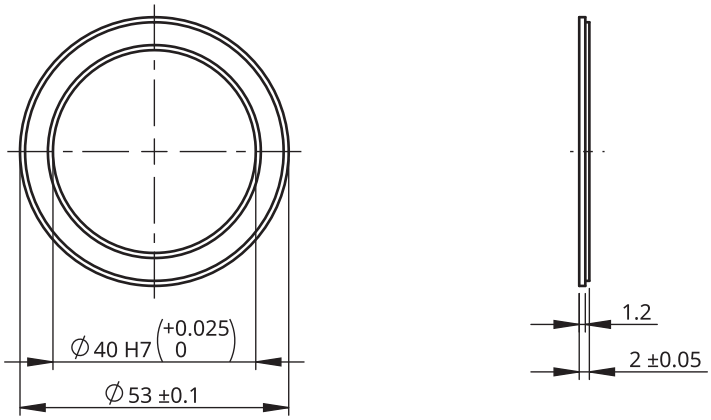
Dimensions and installation drawings continued

MRA053BC030DSE00 magnetic ring



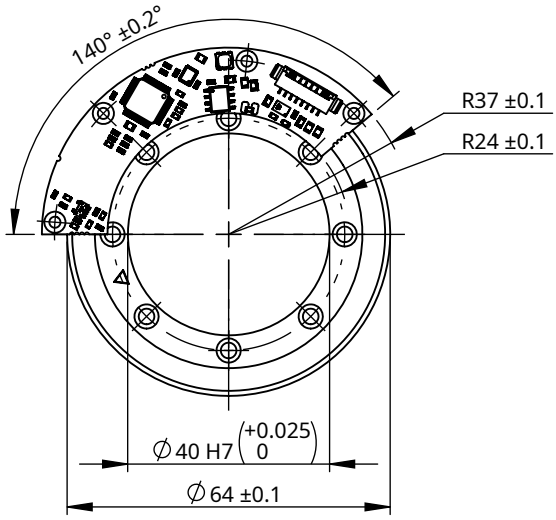
* Also possible with suitable M2.

MRA053BG040DSN00 magnetic ring

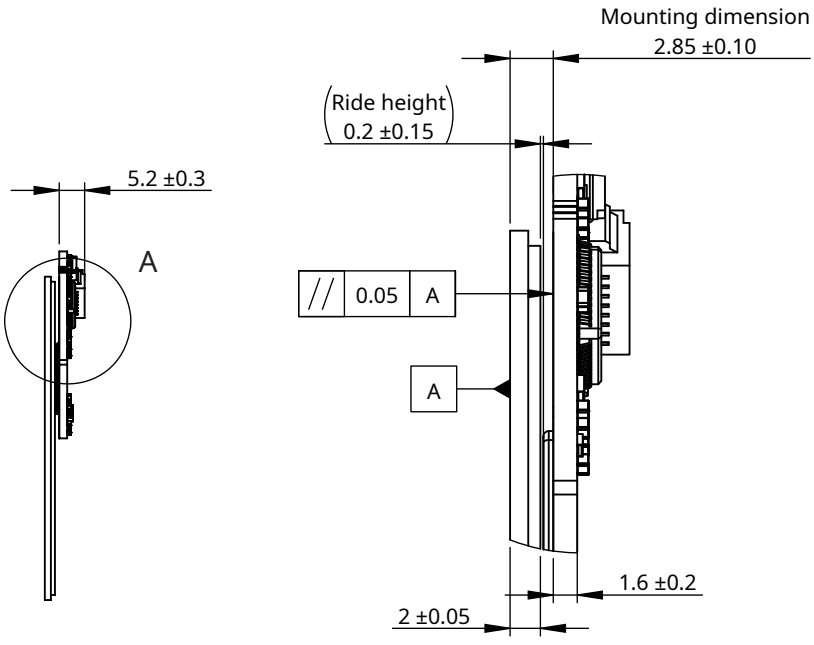


Mounting with glue. See chapter **Installation instructions** for more details.

Encoder assembly MB064 readhead shape D with MRA064BC040DSE00 magnetic ring



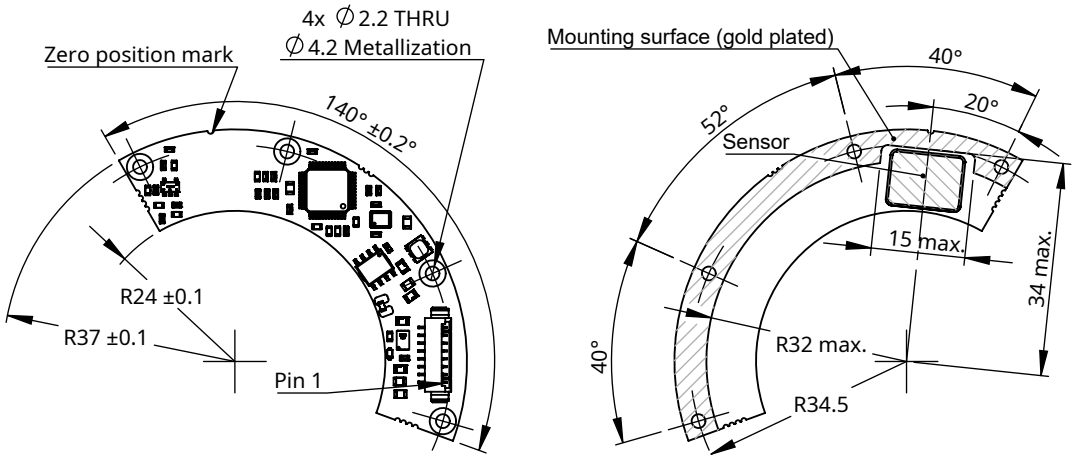
Detail A



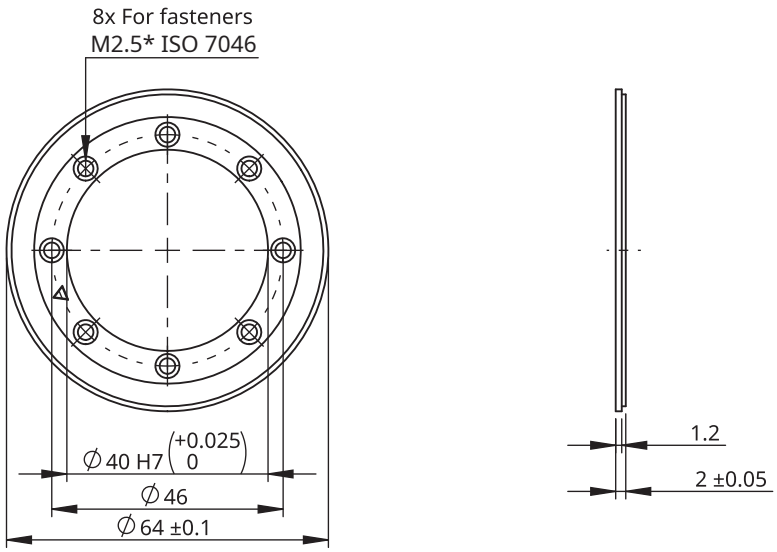
Ride height influences noise on the output. See chapter **Installation instructions** for more details.

Dimensions and installation drawings continued

MB064 readhead shape D

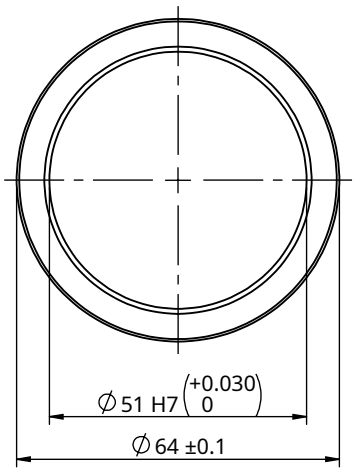


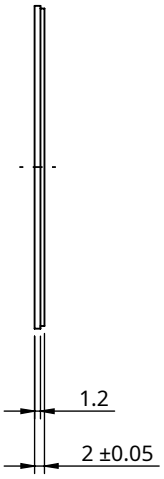
MRA064BC040DSE00 magnetic ring



* Also possible with suitable M2.

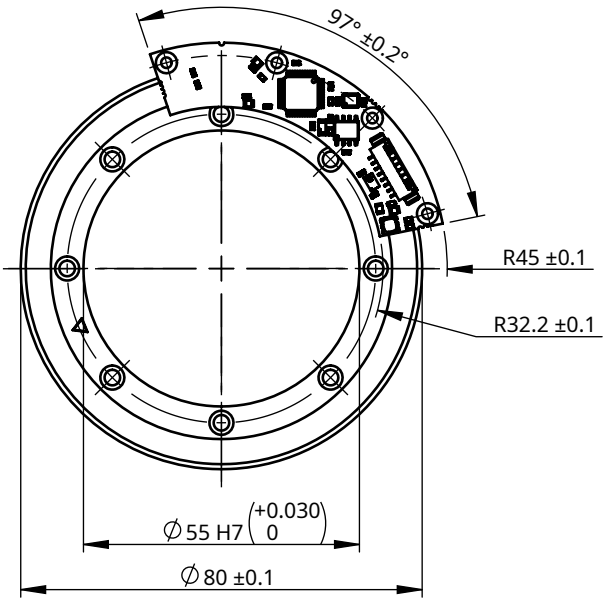
MRA064BG051DSN00 magnetic ring



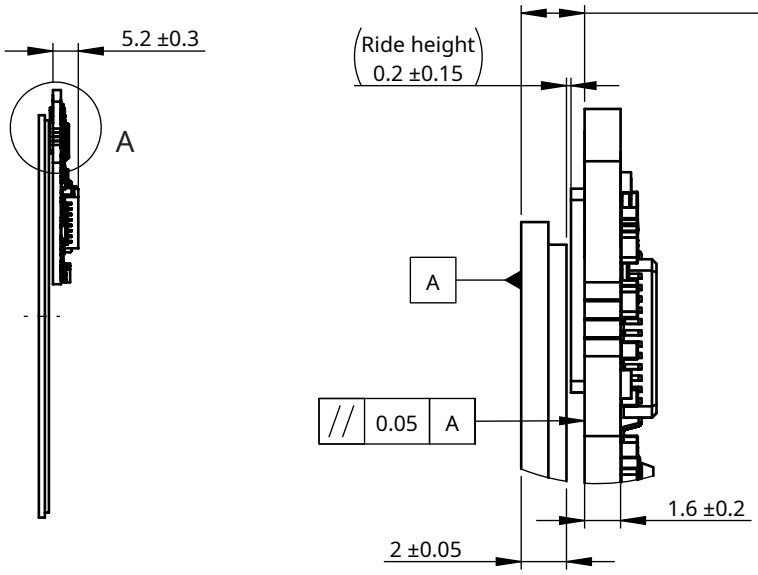


Dimensions and installation drawings continued

Encoder assembly MB080 readhead with MRA080BC055DSE00 magnetic ring



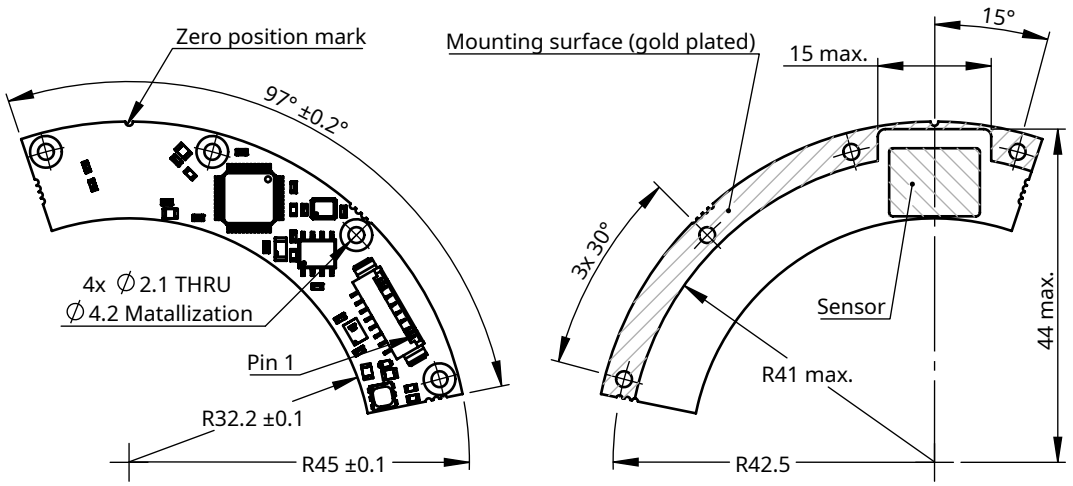
Detail A



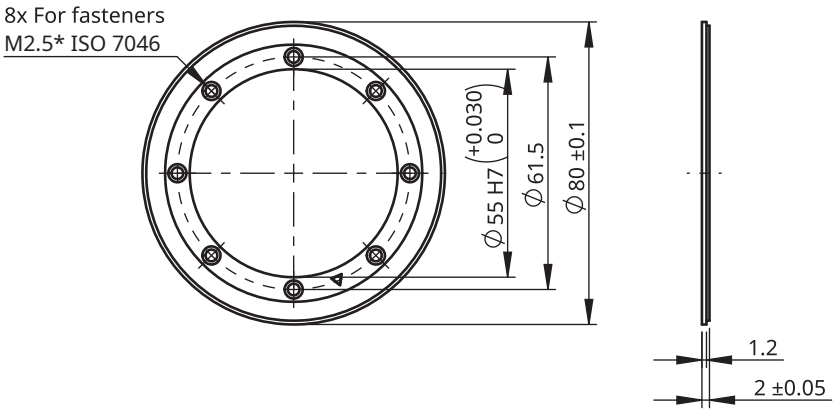
Mounting dimension:	
Ring part number	
MRA080BC055DSE00	2.85 ±0.1
MRA080AF055EMH00	4.75 ±0.1
MRA080BG064DSN00	2.85 ±0.1
MRA080DF068DMH00	5.75 ±0.1

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

MB080 readhead

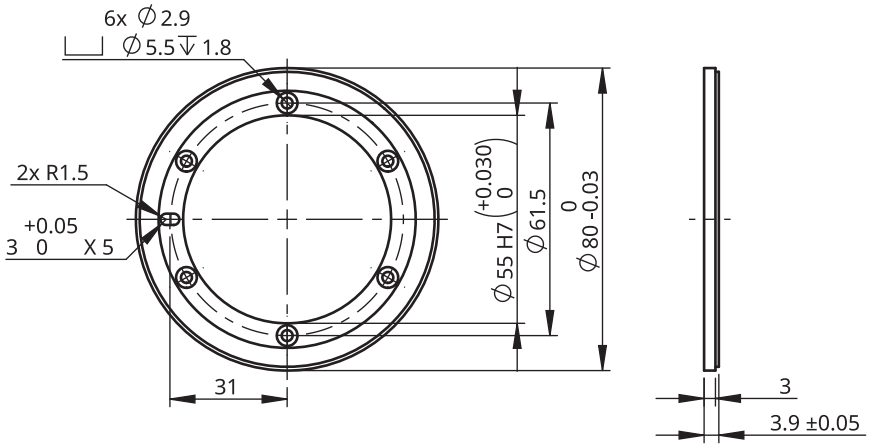


MRA080BC055DSE00 magnetic ring



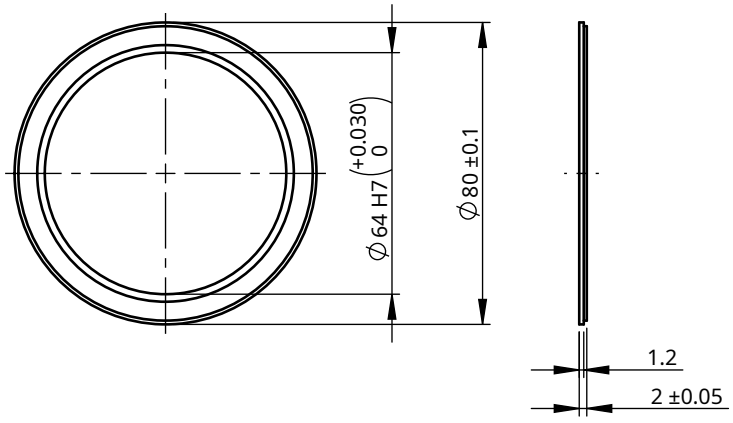
* Also possible with suitable M2.

MRA080AF055EMH00 magnetic ring



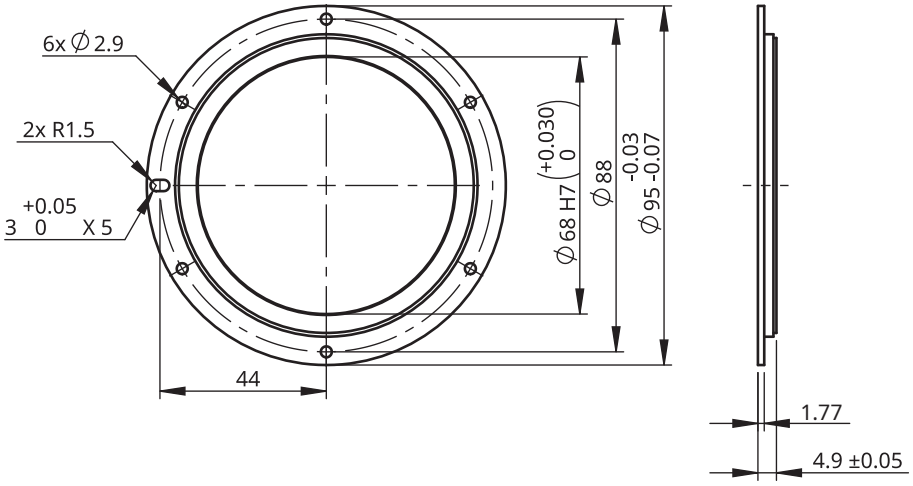
Dimensions and installation drawings continued

MRA080BG064DSN00 magnetic ring



Mounting with glue. See chapter **installation instructions** for more details.

MRA080DF068DMH00 magnetic ring



Installation instructions

Axial position adjustment (ride height)

The distance between the sensor and the ring should be between 0.05 mm and 0.35 mm. See detail A on dimension drawings of encoder assemblies. Using the gold-plated surface on the bottom as a reference surface for mounting the readhead is recommended. If the top side of the readhead is used as a reference surface, note that the thickness tolerance of the readhead must be taken into account. Also make sure that the signal traces and components are not in contact with mechanical assembly. Optionally, you may also use **shims** for height adjustment of the readheads.

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 installation 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)

Axial displacement / ride height	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 **Resolutions**.	
Tangential displacement of the readhead	±0.3 mm	
Radial displacement of the readhead	MB022: ±0.1 mm MB029: ±0.3 mm MB039: ±0.4 mm MB049, MB053, MB064, MB080: ±0.5 mm	
Non-parallel mounting	Tilt angle <0.2°	

AksIM-2 installation video

Measuring ride height between the ring and the readhead

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

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

Ride height = K × Ln (SignalLevel) + N

Encoder size	K	N
022, 029	–95.49	977
039, 049	–83.56	865
053, 064, 080	–71.62	748

Ln stands for natural logarithm.
Calculated ride height has tolerance of ±20 µm.
K and N are selected depending on the encoder size.
The SignalLevel value is available in the BiSS register at addresses 0x4E - 0x4F (see document APP11 available at **RLS Media center**), at the UART interface with command 'a' (**see page 37**) and in EncoLink register 0x004E (see document MBD08 available in **RLS Media center**).

Installation tolerances (ring to shaft)

Recommended shaft tolerance is g6. See table of recommended tightening torques for RLS products available at **RLS media center**.

Mounting rings with glue (option “G” in part number)

Rings that can only be mounted with adhesive:

- MRA049BG034DSN00,
- MRA053BG040DSN00,
- MRA080BG064DSN00.

While any AksIM-2 ring can be mounted with adhesive, RLS does not recommend or supply adhesive. Contact a local supplier for further assistance in selecting the correct type of adhesive.

Adhesive selection guidelines

When selecting the correct adhesive, consider the following:

- Good adhesion to the shaft material and to the metal part of the ring (see data sheet for the material).
- Required temperature range and material expansion.
- Acceleration of the shaft during final application.
- Minimum adhesive thickness (from the data sheet).
- The adhesive thickness must be very uniform to avoid variations in the air gap between the ring and the sensor.
- Mechanical shock and vibration tests as well as temperature cycles must be performed to validate the assembly and avoid future failures.

Mounting risks to avoid

- Hard adhesive is susceptible to breakage if the materials of the shaft and ring have very different thermal expansion coefficients and thermal variation is big.
- Soft adhesive, based on foam or double-sided tape, could have a limited temperature range or introduce measurement errors into the system.

Adhesive mounting procedure

Before starting installation, always refer to the adhesive manufacturer's instructions. These contain important details such as the preparation of the surface, the application method, the curing time and environmental conditions (temperature, pressure, humidity). If no specific instructions are available, you can follow the standard procedure as a general guideline.

Standard procedure for adhesive installation

1. Preparation of the surface
   Clean both the shaft and the contact surfaces of the ring with alcohol. The surfaces must be clean, dry and free of dust, oil and grease. Avoid any contact between the adhesive and the rubber part (black) of the ring.
   2. Applying the adhesive
   Apply a thin, even layer of adhesive to one or both surfaces (depending on the type of adhesive). Ensure the minimum adhesive thickness specified in the data sheet for the ring.
3. Assembly
   Mount the ring onto the shaft with even, controlled pressure. The ring must sit concentrically and without tilt to achieve an even air gap.
4. Curing
   Allow the adhesive to cure according to the manufacturer's instructions. This may include specific time, temperature, pressure or humidity conditions. Do not disturb or move the components during curing.
5. Checking the air gap
   Once the adhesive is fully cured, measure the air gap between the ring and the read head. It must be within the tolerances specified in the product documentation.

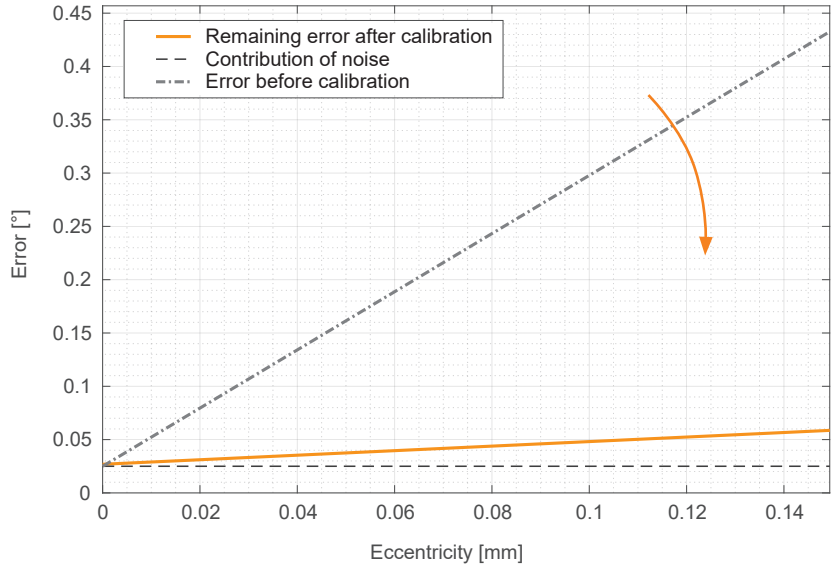
Self-calibration after installation

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. Not available with PWM and SSI outputs. Refer to the description of the selected communication interface for details. When the multiturn counter is used in the encoder, it may have an incorrect value after self-calibration if the speed is greater than ±300 RPM. In such a case, the multiturn error flag is set.

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. Calibration function for size 022 supports only full 360° rotation.
- Good signal over the entire calibration angle (no warnings or errors).
- Default time available is 10 seconds. Desired time (up to 40 seconds) can be set via the communication interface.
- Variation of direction and speed are not important. Minimum speed 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 is influenced by magnetisation variations and noise of the readhead.



For typical accuracy values see chapter **Installation tolerances (ring to shaft).**

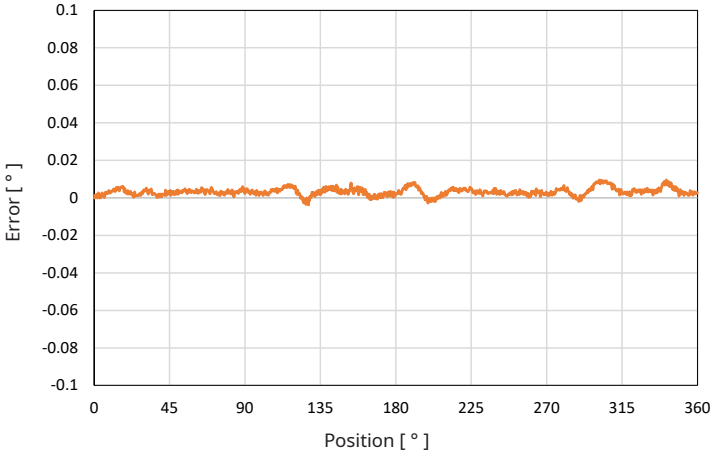
When the self-calibration process is complete, fast-flashing LED indicates whether the process was successful.

LED		Self-calibration status
●●●●●	Green flashing fast	Self-calibration succesfully performed.
●●●●●	Orange flashing fast	Ring positioning is already perfect - correction was not performed. Status bit 0x20 is set.
●●●●●	Red flashing fast	Input parameter out of range. Status bit 0x10 is set. Eccentricity or radial offset is very high. Status bit 0x08 is set. Timeout. Ring is rotating too slowly (<6 RPM). Status bit 0x04 is set.

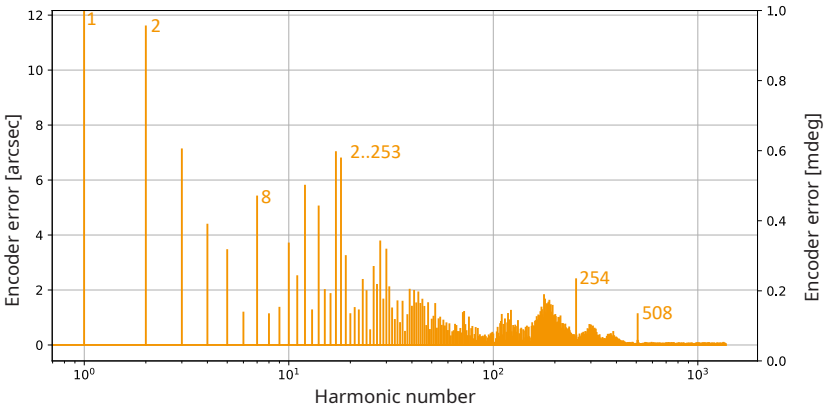
Explainer video: AksIM-2 self-calibration feature.

In the case of using two readheads, they must be mounted 180° apart. Their measured positions must be combined to improve the overall measurement accuracy by minimising the effects of individual readhead errors, caused by imperfect installation.

Precise centering of the ring is the key to good overall accuracy.
By minimising the eccentricity of the ring assembly (using a gauge) and using a drive shaft with precision bearings, the error can typically be reduced to ±0.05° for MRA080 rings and ±0.06° for MRA049 rings.
A typical accuracy diagram after good installation of MRA080 (without eccentricity) is shown in the diagram below.
To improve accuracy after installation, we recommend to perform the **self-calibration** function.



Encoder error typically consists of multiple higher-order harmonic components. Example below is from the MRA080 + MB080 encoder. Other encoder sizes have slightly different spectrum.



Harmonic number	
1	Eccentricity of the ring mounting
2	Oval shape of the ring
8	Number of mounting holes
2...253	Absolute code influence
254	SDE (offset)
508	SDE (amplitude, phase)

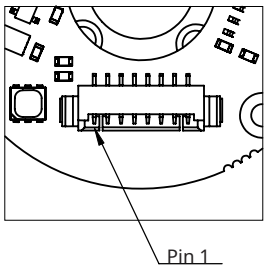
For typical accuracy values see chapter **Installation tolerances (ring to shaft)**.

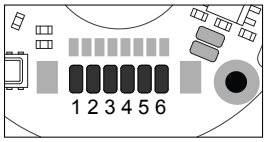
Electrical connections

Pinout

Connector	Soldering pads	BiSS C	Asynchronous serial	SPI	PWM	SSI
1	1	5 V supply				
2	2	0 V (GND)				
3		Temperature sensor pin 1 *				
4		Temperature sensor pin 2 *				
5	3	MA+	RX Command in+	SCK	Status out	Clock+
6	4	MA–	RX Command in–	NCS	-	Clock–
7	5	SLO+	TX Data out+	MISO	PWM out	Data+
8	6	SLO–	TX Data out–	MOSI	-	Data–

* See chapter **External isolated temperature sensor**





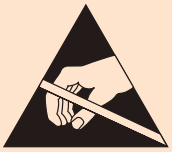
8-pin low profile connector
FCI / AMP 10114830-11108LF -horizontal
FCI / AMP 10114828-11108LF -vertical (readhead MB022 only)
Note: On some connectors there is “Pin 1” marking imprinted, which is sometimes in a wrong position and must be ignored.

Counterpart mating connector:
FCI / AMP 10114826-00008LF
and 10114827-002LF

Locking features of the connector: Retention system on the bottom side - bumps on the plug and dimples in the receptacle. High friction in the contacts. Make sure to use original parts that comply with these features.

Soldering pads
Dimensions: 2.54 x 1.14 mm
with 1.875 mm pitch

Soldering of the wires to the encoder must be done in accordance with IPC-A-610 Class 2 or 3 (or similar). Improper soldering will void the warranty.



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.
On encoder startup the LED briefly flashes red or orange. This is intended function for testing the LED.

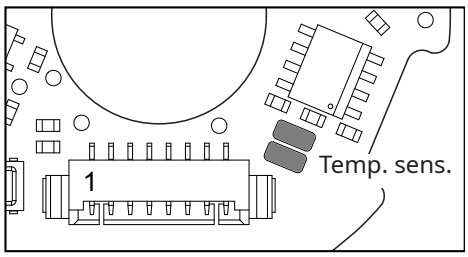
LED is not present on the readhead size MB022.

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 s ● 3 s ● 3 s	3 sec. fast flashing	Self-calibration result - see chapter **Self-calibration after installation.**

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 “Temp. Sens.” 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.



Communication interfaces

BiSS

Clock frequency	From 400 kHz to 5 MHz
Maximum request rate	44 kHz (38 kHz with multiturn counter option)
Mechanical sample rate	18 kHz
Bandwidth	9 kHz
Resolution	See chapter **Resolutions**.
Latency	<10 µs
Timeout (monoflop time)	13.5 µs

Asynchronous serial RS422 (UART)

Baud rate	115.2 kbps, 128 kbps, 230.4 kbps, 256 kbps, 500 kbps, 921.6 kbps, 1 Mbps (Configurable from 300 baud to 1 Mbaud)
Data format	8 bits, no parity, 1 stop bit
Request rate	On demand or continuous
Mechanical sample rate	18 kHz
Bandwidth	9 kHz
Resolution	See chapter **Resolutions**.
Latency	<10 µs

SPI

Clock frequency	Max 4 MHz
Maximum request rate	54 kHz (48 kHz with multiturn counter option)
Mechanical sample rate	18 kHz
Bandwidth	9 kHz
Resolution	See chapter **Resolutions**.
Latency	<10 µs

PWM*

Base frequency	122.07 Hz, 274.66 Hz, 366.21 Hz, 549.32 Hz, 1098.63 Hz
Update rate	Same as Base frequency
Resolution	16 bits
Latency	From 55 µs to 110 µs

SSI* (Not recommended for new design)

Clock frequency	Minimum 80 kHz Maximum 500 kHz with standard SSI (2.5 MHz with *Delay First Clock* function on the controller)
Mechanical sample rate	18 kHz
Resolution	See chapter **Resolutions**.
Latency	From 55 µs to 110 µs
Timeout (monoflop time)	20 µs

Interfaces with big or variable latency are not suitable for high-speed closed control loops.
* SSI interface is supported for legacy applications and is not recommended for new design.

Multiturn counter

The multiturn counter is available on the following communication interfaces: BiSS, Asynchronous serial (UART), SPI or SSI.
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.

Latency

Latency on BiSS and Asynchronous serial (UART) and SPI interface

BiSS and UART use an algorithm that recalculates the new position for each request. In this way, the request frequency can be higher than the internal cycle frequency of the encoder. Normally, the request rate can be up to 44 kHz. The position is latched at the first falling edge on the MA (clock) line or the first bit of the command byte or on falling edge of NCS signal and the new position value is calculated immediately, therefore the latency is shorter than 10 µs.

Latency on other type interfaces (SSI, PWM)

All interfaces transmit the last available valid data from the last internal cycle of the encoder. No additional recalculation takes place.
The internal cycle of the encoder is 55 µs. This is the delay between the time the mechanical position is latched by the sensor and the time the data is ready for transmission via the interface.
If the request comes immediately after the data is ready, the latency is 55 µs.
If the request comes shortly before the new data is calculated, the latency is 110 µs.

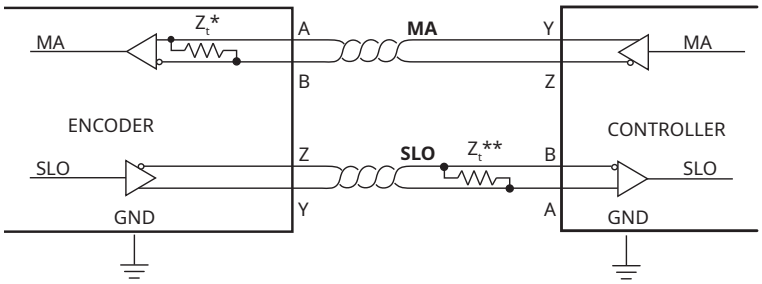
Example:
At t = 0 µs, the physical position is latched, but the position data is not yet calculated. It is then available at 55 µs.
When the request comes at t = 1 µs – 54 µs, the last available data is sent - that from the previous cycle when the position was latched at t = –55 µs.

BiSS C interface

Encoder position in up to 20 bit natural binary code and encoder status are available via the BiSS C protocol. The position data is left aligned. 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 and additional data can be read from the readhead.

Electrical connection



Signals	
MA	Master clock. Max clock frequency is 5 MHz.
SLO	Slave out. Data is output on rising edge on MA.

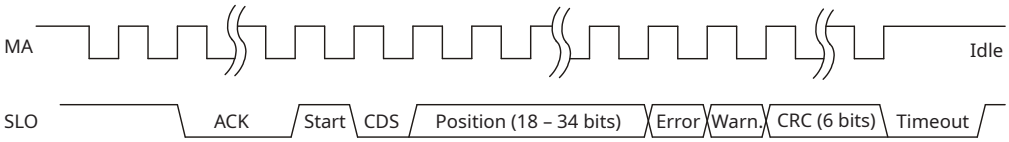
* The MA and SLO lines are 5 V RS422 compatible differential pairs. The termination resistor on the MA line is integrated inside the encoder.

** Termination at the controller is required, if total cable length is longer than 5 m. 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.

BiSS C timing diagram



MA is idle high. Communication is initiated with first falling edge.
The encoder responds by setting SLO low on the second rising edge on MA. ACK length is 13 bits.
When the encoder is ready for the next request cycle, it indicates this to the master by setting SLO high.
The absolute position and the CRC data is available in binary format and is first sent in MSB format.

Data package description

Data packet length depends on the resolution and can be from 25 to 44 bits long. It consists of 16 bits for the multiturn counter (if selected) and 17 to 20 bits of Position selected by (resolution), followed by 2 Status bits and 6 CRC bits (see table below).

Resolution	Multiturn counter	Position	Error Status	Warning Status	CRC (inverted)
17B	0 bits	17 bits	1 bit	1 bit	6 bits
18B		18 bits			
19B		19 bits			
20B		20 bits			
17M	16 bits	17 bits	1 bit	1 bit	6 bits
18M		18 bits			
19M		19 bits			
20M		20 bits			

Example: 18 bits of position + 2 status bits + 6 bits CRC = 26 bits long data packet.
Polynomial for CRC calculation of position, error and warning data is: $x^6 + x^1 + 1$. Represented also as 0x43. It is inverted and transmitted MSB first.
Example of calculation routine for 6-bit CRC can be found in the application note CRCD01 available for download at **RLS Media center**.
How to decode BiSS data packet: see document E201D02 available for download at **RLS Media center**.
BiSS data packet decoding and CRC validation can be tested with the application available at **RLS media center.**
For more information regarding BiSS C protocol see **biss-interface.com**.

Status bits

Type	Value 0	Value 1	Description
Error	Position data is invalid.	OK	Error bit is active low. If low, the position is not valid.
Warning	Position data is valid.	OK	Warning bit is active low. If low, the encoder operation is close to its limits. The position is still valid but the resolution and/or accuracy might be out of specification.

Communication parameters

Communication interface variant in the part number defines the functionality of the encoder.

Communication interface variant	Parameter	Value
C	MA frequency	Max. 5 MHz
	ACK length	13 bit
	Register access	Yes

Parameter	Value
Latency	<10 µs (recalculated on every transmission)
Bandwidth *	9 kHz
Mechanical sample rate	18 kHz
Maximum request rate	44 kHz (38 kHz Multiturn counter option)
Timeout	13.5 µs

* Bandwidth parameter is the mechanical bandwidth. AksIM samples at 18 kHz, so mechanical changes that are appearing faster than 9 kHz cannot be detected on the output (Nyquist theorem). If the position request comes faster than the sampling frequency, the AksIM encoder recalculates the position at the time of the request based on the current ring velocity.

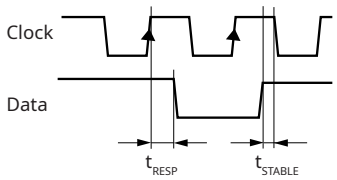
Encoder programming

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. It also allows storing up to 4 kB of user data into the encoder (eg. motor parameters, assembly data or similar).
This additional information can be found in the "Application note: AksIM-2 BiSS C register access", document number APP11 available for download at **RLS media center**.

Cable length compensation

The readhead requires 170 ns to respond to incoming clocks (t_{RESP}). The change on the Data signal is delayed by 170 ns after the rising edge on Clock line. An additional delay is caused by the time it takes for the signal needs to propagate through cable to the readhead and back (t_{PROP}). This delay is typically 14 ns per 1 meter of cable. The total cable length from the encoder to the receiver must be considered.

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

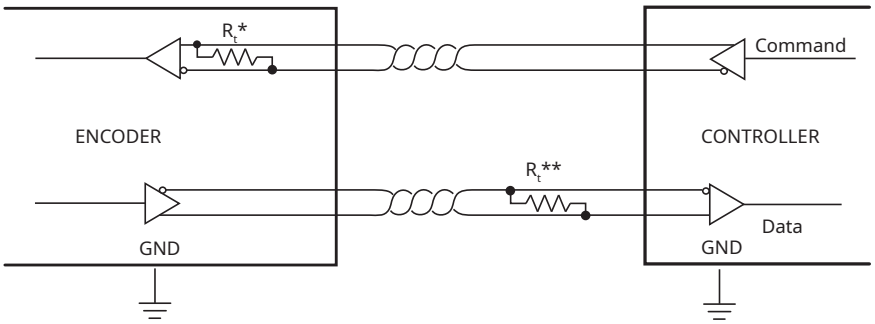


The data signal must be stable before the value is latched. Therefore, if the cable is longer than 1 meter and a clock frequency higher than 2.5 MHz, this delay must be compensated in the receiver (controller) to which the encoder is connected.

Asynchronous serial communication interface over RS422 (UART)

Encoder identification, position data and temperature are available with request-response type of communication over the asynchronous serial link. There are two unidirectional communication channels that form a full-duplex bidirectional data link. Each channel consists of a two wire differential twisted-pair connection conforming to the RS422 signalling standard. Data is transmitted LSB first; big-endian order.

Electrical connection



* The Command and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required if total cable length is longer than 5 m. The nominal impedance of the cable is 120 Ω.

Output protection

An excessive output current and power dissipation caused by faults or by bus contention 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.

Communication parameters

Character length	8 bits
Parity	None
Stop bits	1
Flow control	None
Request rate	Maximum achievable, depending on selected baud rate. Can be transmitted continuously without delays between packets.
Mechanical sample rate	18 kHz
Bandwidth *	9 kHz
Position latency	<10 µs (recalculated on every transmission)

* Bandwidth parameter is mechanical bandwidth. AksIM samples at 18 kHz therefore any mechanical changes that are appearing faster than 9 kHz are not detectable on the output (Nyquist theorem). If request for position comes faster than sampling frequency, AksIM encoder recalculates the position at the time of request based on current ring velocity. 9 kHz bandwidth is valid for high dynamic movements of 2 degrees or smaller.

Link speed is selectable by the *Communication interface variant* in the part number:

Communication interface variant	A	B	C	D	E	F	G
Link speed (baud rate) in kbps	115.2	128	230.4	256	500	1,000	921.6

Link speed setting can be changed in the field by following the procedure described in application note. See section **Encoder programming**. New settings are permanent until encoder is reprogrammed again with different settings.

Asynchronous serial communication interface over RS422 (UART) continued

Encoder supports a range of commands to read position data and additional information. In case multiturn option is selected, number in brackets must be used.

Command (ASCII)	Response
'1'	'1' + 3 (5) bytes (Position + E/W bits)
'3'	3 (5) bytes (Position + E/W bits)
'd'	'd' + 3 (5) bytes (Position + E/W bits) + 2 bytes (Detailed status)
'j'	'j' + 3 (5) bytes (Position + E/W bits) + 2 bytes (Persistent detailed status)
's'	's' + 3 (5) bytes (Position + E/W bits) + 3 bytes (Speed in RPM)
't'	't' + 3 (5) bytes (Position + E/W bits) + 1 byte (Sensor temperature in °C)
'a'	'a' + 3 (5) bytes (Position + E/W bits) + 2 bytes (Signal level)
'i'	'i' + 7 bytes (Self calibration status)
'v'	'v' + 58 bytes (Version info and serial number)

Command '3' is used as a request for the shortest possible response. In this case, only 3 bytes (or 5 bytes in multiturn variant) of position with integrated general error and warning bits are replied.
In case of any other command, the header byte, which should be equal to the command itself, is replied first. Then, regardless of the command, 3 bytes (or 5 bytes if multiturn) of position with Error and Warning bits are sent. After that additional bytes are transmitted that carry requested information.
Returned header byte should be equal to the command and can be used to determine which data packet format has to be decoded. In case of incorrect command, only header byte is returned with no other data.

Position data packet structure

Position data consists of 3 bytes if singleturn variant is selected or 5 bytes if multiturn variant is selected. Encoder position is always left aligned and starts with multiturn data (if available). Error and warning bits are always right aligned (bit 1 and bit 0 respectively). Between LSB of position and error bit are padding bits with value 0. The structure of position data bytes for each encoder resolution is presented in the table below.

Position data structure for singleturn variant

Encoder resolution	Position bits	Zero padding bits	Error bit, Warning bit
17B	b23 – b7	b6 – b2	b1, b0 (both active low)
18B	b23 – b6	b5 – b2	b1, b0 (both active low)
19B	b23 – b5	b4 – b2	b1, b0 (both active low)
20B	b23 – b4	b3 – b2	b1, b0 (both active low)

Position data structure for multiturn variant

Encoder resolution	Position bits	Zero padding bits	Error bit, Warning bit
17M	b39 – b7	b6 – b2	b1, b0 (both active low)
18M	b39 – b6	b5 – b2	b1, b0 (both active low)
19M	b39 – b5	b4 – b2	b1, b0 (both active low)
20M	b39 – b4	b3 – b2	b1, b0 (both active low)

Error and warning bits integrated into position data are always transmitted inverted (active low). Value '0' on error bit means that the position is not valid. Value '0' on warning bit means position is valid, but the encoder is near operational limits. In case of error, the last valid data is transmitted.

Commands and their respective responses for singleturn version
* For multiturn add 2 bytes to the length of position data.

Command '1'	
Byte transmitted	**Contents**
B1	ASCII header '1'
B2 - B4*	Position + E + W
Command '3'	
Byte transmitted	**Contents**
B1 - B3*	Position + E + W
Command 'd'	
Byte transmitted	**Contents**
B1	ASCII header 'd'
B2 - B4	Position + E + W
B5 - B6	Detailed status (refer to table on next page)
Command 'j'	
Byte transmitted	**Contents**
B1	ASCII header 'j'
B2 - B4*	Position + E + W
B5 - B6	Persistent detailed status (refer to table on next page)
Command 's'	
Byte transmitted	**Contents**
B1	ASCII header 's'
B2 - B4*	Position + E + W
B5 - B7	(Signed binary) Rotational speed in RPM.
Command 't'	
Byte transmitted	**Contents**
B1	ASCII header 't'
B2 - B4*	Position + E + W
B5	(Signed binary) Sensor temperature in °C. This value is typically 5 °C to 15 °C higher than ambient. Tolerance of readout is ±5 °C.
Command 'a'	
Byte transmitted	**Contents**
B1	ASCII header 'a'
B2 - B4*	Position + E + W
B5 - B6	(Unsigned binary) Signal level Value is proportional to the distance between the sensor and ring. To calculate real distance see formula in chapter **Measuring ride height between the ring and the readhead**.

Asynchronous serial communication interface over RS422 (UART) continued

Command 'i'	
Byte transmitted	**Contents**
B1	ASCII header 'i'
B2	Self calibration status - See document APP10 available for download at **RLS media center**
B3 - B4	(Unsigned binary) Ring eccentricity (µm)
B5 - B6	(Unsigned binary) Ring eccentricity phase (deg)
B7 - B8	(Signed binary) Readhead radial displacement (µm)
Command 'v'	
Byte transmitted	**Contents**
B1	ASCII header 'v'
B2 - B8	ASCII identification string 'AksIM-2'
B9	Space character
B10 - B17	ASCII serial number (8 characters)
B18	Space character
B19 - B34	ASCII part number (16 characters)
B35	Space character
B36	Binary firmware major version
B37	Binary firmware minor version
B38	Binary communication interface version
B39 - B42	Binary firmware revision number
B43	Space character
B44 - B59	ASCII extended serial number (16 characters)

Structure of Detailed status bits (two bytes)

Detailed status (part 1)		
Bit	**Status**	**Description**
b15	Error	Multiturn counter mismatch. Encoder was rotated for more than ±90° during power-down. Cycle the power to clear this error or apply new multiturn counter value.
b14	Error	Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b13	Warning	Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b12	Error	Magnetic sensor error. Cycle power to the encoder.
b11	Error	Sensor reading error, probably caused by electrical interference, ground loop or RFI.
b10	Error	Encoder not configured properly.
General status		
b9	Error	If bit is set, position is not valid.
b8	Warning	If bit is set, encoder is near operational limits. Position is valid. Resolution and / or accuracy might be lower than specified.

Error and Warning bits can be set at the same time; in this case Error bit has priority.
The colour of the LED on the readhead housing indicates the value of the General status bits:
● Red = Error, ● Orange = Warning, ● Green = Normal operation, ○ No light = no power supply.
The warning or error status is more closely defined by the Detailed status bits.

Detailed status (part 2)		
Bit	**Status**	**Description**
b7	Warning	Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b6	Warning	Signal amplitude low. The distance between the readhead and the ring is too large.
b5	Error	Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b4	Warning	Temperature out of range. The readhead temperature is out of specified range.
b3	Error	Power supply error. The readhead power supply voltage is out of specified range.
b2	Error	System error. Malfunction inside the circuitry or 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	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.
b0	Error	Acceleration error. The position data changed too fast. A stray magnetic field is present or metal particles are present between the readhead and the ring. Warning - Overspeed. Ring is rotating raster than the limit (10 000 RPM).

Persistent encoder status

This is similar to “Encoder status” but with the added functionality that all detailed statuses are accumulated. Any error or warning that appears in Detailed Status during operation of encoder is copied into Persistent detailed status. Even if value in Detailed Status has very short duration, the past statuses can be read from this Persistent register. It keeps the value as long as power is present. Clearing is possible either with power cycle or by sending Unlock sequence and command “b”. For details see document APP10 available for download at **RLS media center.**

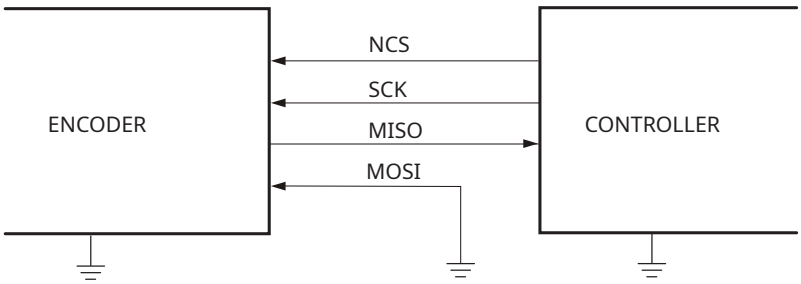
Encoder programming

Encoder supports changing default baud rate, running self-calibration function, reading signal level value, temperature, detailed status bits and setting automatic transmission of selected data packet at programmable frame rate. Additional information can be found in the "Application note: Programming encoders with Async serial interface", document number APP10 available for download at **RLS media center**.

SPI - Serial peripheral 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.
AksIM-2 encoders provide either only position information via the SPI interface only or full register access via the EncoLink high-level protocol. For more information, refer to the document MBD08 available for download at **RLS media center**.

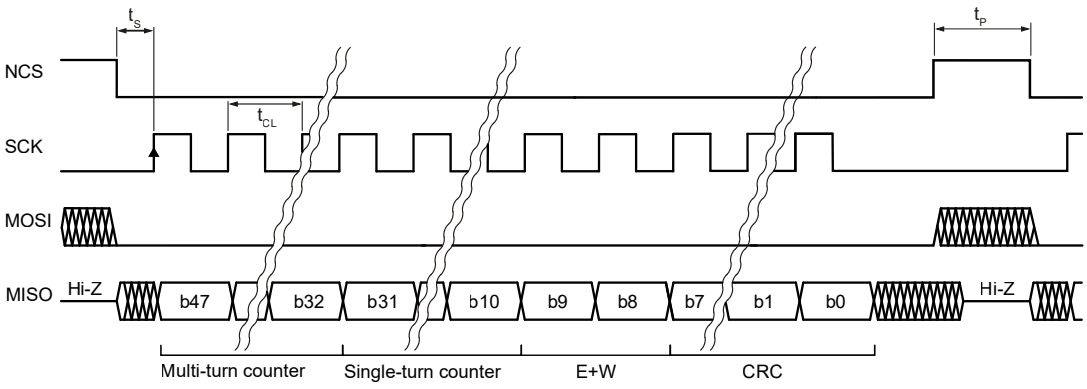
Electrical connection



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.

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 paralell, sharing all lines except NCS. Encoder position data is latched on falling edge of NCS signal.
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. If only position data is requred, this signal should always be zero. It can be tied to GND.
MISO	Master input ← Slave output. Data is output on rising edge on SCK after NCS low and must be sampled on falling edge. 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. At the same time the encoder position is latched. 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	Max
Clock period	t_{CL}	250 ns	
Clock frequency	f_{CL}		4 MHz
Time after NCS low to first SCK rising edge	t_S	5 µs	
Pause time	t_P	5 µs	
SPI settings	CPOL = 0 (clock is idle low)		
	CPHA = 1 data is output on clock rising edge and sampled on clock falling edge)		

Encoder position data structure

For multiturn			
2B	**b47 : b32**	Multiturn counter (if specified in part number)	Left aligned, MSB first.
3B	**b31 : b10**	Encoder position + zero padding bits	Left aligned, MSB first.
	b9	Error	If low, the position data is not valid.
	b8	Warning	If low, the position data is valid, but some operating conditions are close to limits.
1B	**b7 : b0**		Inverted CRC, 0x97 polynomial

For singleturn			
3B	**b31 : b10**	Encoder position + zero padding bits	Left aligned, MSB first.
	b9	Error	If low, the position data is not valid.
	b8	Warning	If low, the position data is valid, but some operating conditions are close to limits.
1B	**b7 : b0**		Inverted CRC, 0x97 polynomial

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

Encoder programming

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. In that case the MOSI signal must be connected between controller and encoder.
For more information please refer to document MBD08 available for download at **RLS media center**.

PWM - Pulse width modulation interface

The PWM communication interface consists of two digital signals: the Status signal and the PWM Out signal.

Electrical connection

The Status and PWM Out signals are 3.3 V TTL compatible. These signal outputs are weakly ESD protected, so the readhead must be handled with extra care and ESD protection in ESD controlled environment.
Maximum current sourced from or sunk into signal lines should not exceed 5 mA.

Status signal

The Status signal indicates the current status of the encoder. The Status signal is high for normal operation and valid position information. The low state of the Status signal indicates an error state of the encoder which may be caused by:

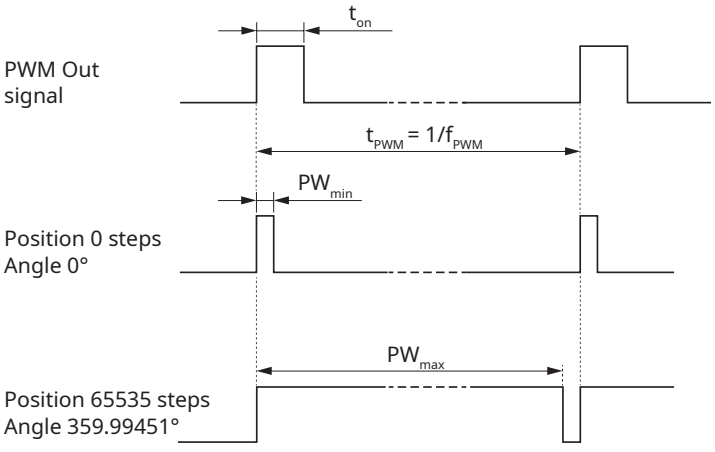
- Operation outside the installation tolerances
- Invalid or damaged magnetization of the ring
- Sensor malfunction
- System error
- No power supply

When the Status signal is low, the PWM Out signal is low and no pulses are output.
The encoder position is latched on the rising edge of the PWM Out signal. The Status signal should also be checked at the rising edge of the PWM Out signal. If the Status signal changes during the PWM period, this has no effect on the currently transmitted position information. Status output signal is not linked to the PWM output cycle and is updated with each internal cycle of the encoder. Pulses can be present as short as 50 µs.

PWM Out signal

The PWM Out is a pulse width modulation output with 16-bit resolution whose duty cycle is proportional to the measured position. The change of the pulse width by PWmin corresponds to a position change by one count (angle change for 360° / 65536 ≈ 0.00549°).

PWM Out signal timing diagram



Communication parameters

Communication interface variant in the part number defines the PWM frequency and all other dependent parameters.

		Communication interface variant						
Parameter	**Symbol**	**A**	**B**	**C**	**D**	**E**	**Unit**	**Note**
PWM frequency	f_{PWM}	122.07	274.66	366.21	549.32	1098.63	Hz	
Signal period	t_{PWM}	8192	3640.89	2730.67	1820.44	910.22	µs	
Minimum pulse width	PW_{min}	0.125	0.0556	0.0417	0.0278	0.0278 **	µs	Position 0 (Angle 0°)
Maximum pulse width	PW_{max}	8191.875	3640.83	2730.63	1820.42	910.20 **	µs	Positions 65534 and 65535 *
Min. counter frequency	f_{CNTR}	8	18	24	36	72	MHz	Receiving counter frequency
Resolution		16 Bit	16 Bit	16 Bit	16 Bit	16 Bit		Fixed; resolution in part number must be set as "16B"

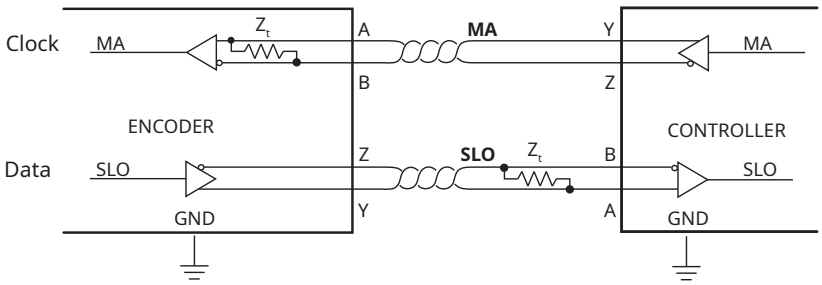
* Positions 65535 and 65534 are joined together; readout as 65534 (PW_{max}).
** At frequency 1099 Hz positions 0 and 1 are joined together; readout as 1 (PW_{min}). Positions 65535, 65534 and 65533 are joined together; readout as 65533 (PW_{max}).

$$\textit{Position}\ [\text{counts}] = \frac{t_{on} \times 65536}{t_{PWM}} - 1 \qquad \textit{Position}\ [°] = \frac{(t_{on} - PW_{min}) \times 360°}{t_{PWM}}$$

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

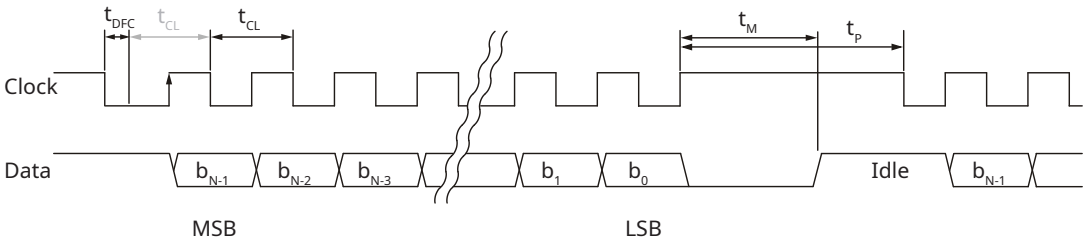


The Clock and Data signals are 5 V RS422-compatible differential pairs with RC termination within the readhead. If the total cable length is more than 5 m, termination on the controller is required. The nominal impedance of the cable should be 120 Ω.

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

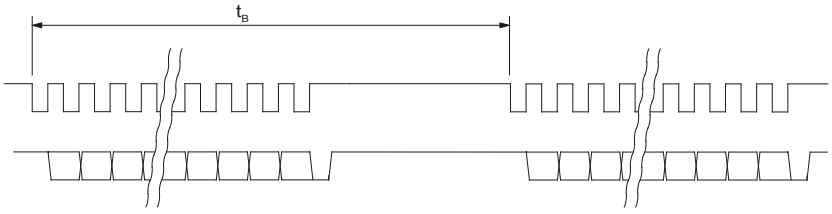


The controller requests the position and status data of the encoder by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge of the Clock latches the last position data available and on the first rising edge of the Clock the most significant bit (MSB) 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.

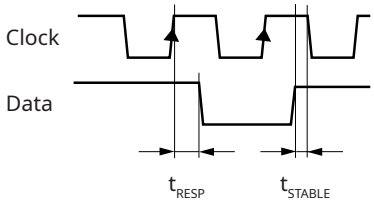
While reading the data, the half of a Clock period t_{CL} must always be less than t_M. However, reading the encoder position can be terminated at any time by setting the Clock signal to high for the duration of t_M.

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.

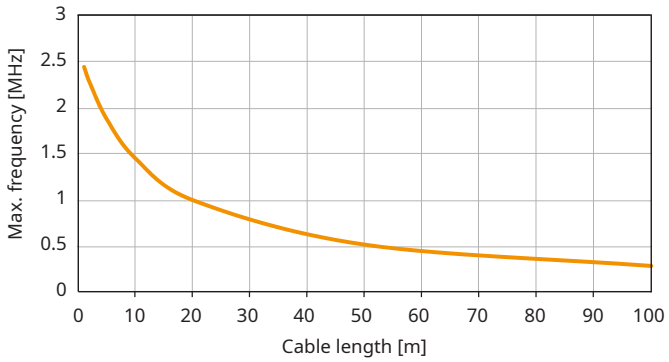
Maximum frequency



The readhead needs 170 ns to respond to incoming clocks (t_{RESP}). Change on Data signal is delayed for 170 ns after the rising edge on Clock line. Additional delay is caused by the time the signal needs to propagate through cable to the readhead and back (t_{PROP}). This delay is typically 14 ns per 1 meter of cable. Data signal must be stable for at least 10 % of the clock period length before the value is latched.
The clock frequency must be reduced with a longer cable. Total cable length must be taken into account, from the encoder to the receiver.

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

Frequency derating versus cable length:



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	
Request rate	t_B	70 µs		
Readhead response delay	t_{RESP}		170 ns	
Latency		55 µs		110 µs

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

Start bit and idle line value are defined by the *Communication interface variant.*

Communication interface variant	Line state selection	Usage
B	Start bit = 1; idle line = 1	Standard

SSI - Synchronous serial interface continued

Structure of data packet

	Bit number			
Singleturn resolution	**Multiturn counter***	**Encoder position**	**General status**	**Detailed status**
20 bits	b45 : b30	b29 : b10	b9 : b8	b7 : b0
19 bits	b44 : b29	b28 : b10	b9 : b8	b7 : b0
18 bits	b43 : b28	b27 : b10	b9 : b8	b7 : b0
17 bits	b42 : b27	b26 : b10	b9 : b8	b7 : b0

* If selected in part number

Multiturn counter (if selected in part number)		
First 16 bits (see table above)	Multiturn counter	Occupying full 16 bits. Can be interpreted as signed number (±32768) or unsigned number (0 to 65535) that represents number of shaft turns.
Encoder position		
Following 17 to 20 bits (see table above)	Encoder position	Left aligned, MSB first, LSB last.
General status		
b9	Error bit	If set, the position is not valid.
b8	Warning bit	If set, the encoder operational is close to its limits. The position is still valid, but the resolution and/or accuracy might be out of specification.

The Error and Warning bits can be set at the same time, in this case the Error bit has priority.
The colour of the LED on the readhead housing indicates the value of the General status bits:
● Red = Error, ● Orange = Warning, ● Green = Normal operation, ○ No light = No power supply.
The warning or error status is more closely defined by the Detailed status bits.

Detailed status		
b7	Warning	Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b6	Warning	Signal amplitude low. The distance between the readhead and the ring is too large.
b5	Error	Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b4	Warning	Temperature. The readhead temperature is out of specified range.
b3	Error	Power supply error. The readhead power supply voltage is out of specified range.
b2	Error	System error or Multiturn error. Malfunction inside the circuitry or 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	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.
b0	Error Warning	Acceleration error. The position data changed too fast. A stray magnetic field is present or metal particles are present between the readhead and the ring. Overspeed. Ring is rotating raster than the limit (10 000 RPM).

Part numbering

Readhead

MB 049 DC C 18B D N T 00

Series

MB - AksIM board-level readhead

MRA ring compatibility

022 - For use with MRA022 ring
029 - For use with MRA029 ring
039 - For use with MRA039 ring
049 - For use with MRA049 ring
053 - For use with MRA053 ring
064 - For use with MRA064 ring
080 - For use with MRA080 ring

Communication interface

DC - BiSS C, RS422
SF - Asynchronous serial, RS422
SP - SPI (Serial peripheral interface), LVTTL
PW - Pulse Width Modulation (PWM), LVTTL
SC - Synchronous serial interface (SSI), RS422 *

* Not recommended for new design

Communication interface variant

See table next to the description of the chosen communication interface for detailed information

For **DC**: **C** - BiSS-C, bidirectional, 13 ACK bits, with register access
For **SC**: **B** - Start bit and idle data line 1
For **SP**: **L** - SPI

For **SF**: Link speed in kbps:

A	B	C	D	E	F	G
115.2	128	230.4	256	500	1000	921.6

For **PW**: Base frequency in Hz:

A	B	C	D	E
122	275	366	549	1099

Resolution

16B - 16 bits per revolution
17B - 17 bits per revolution
18B - 18 bits per revolution
19B - 19 bits per revolution
20B - 20 bits per revolution

Multiturn counter options

17M - 17 bits per revolution + 16 bits multiturn counter
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

Shape and connector orientation

D - Partial arc, radial connector exit
E - Partial arc, tangential connector exit
F - Full circle, radial connector exit
G - Full circle, axial connector exit

Connector option

N - FCI / AMP 10114830-11108LF - 8 pin, horizontal connector
FCI / AMP 10114828-11108LF - 8 pin, vertical connector (readhead MB022 only)
P - Soldering pads

Option

L - Extended low temperature range, –40 °C to +85 °C
P - Ultra high vacuum and high pressure (up to 600 bar)**
T - Extended temperature range (standard)

** See chapter **Operation in high-pressure applications** and **Operation in ultra high vacuum applications.**

Special requirements

00 - No special requirements (standard)

Not all part number combinations are valid. Refer to the table of available combinations on the next page.

Table of available combinations

Series	Ring compatibility	Communication interface	Communication interface variant	Resolution	Shape & connector orientation	Connector option	Option	Special requirements
MB	022	DC	C	17B / 17M	G	N	L	00
		SF	A / B / C / D / E / F / G					
		SC	B					
	029	DC	C	17B - 18B 17M - 18M	F	N / P	T P *	
		SF	A / B / C / D / E / F / G					
		SP	L					
		PW	A / B / C / D / E	16B				
		SC	B	17B - 18B 17M - 18M				
	039	DC	C	17B - 19B 17M - 19M	E			
		SF	A / B / C / D / E / F / G					
		SP	L			N		
		PW	A / B / C / D / E	16B				
		SC	B	17B - 19B 17M - 19M		N / P		
	049	DC	C		D			
		SF	A / B / C / D / E / F / G					
		SP	L			N		
		PW	A / B / C / D / E	16B				
		SC	B	17B - 19B 17M - 19M		N / P		
		DC	C		E	N		
		SF	A / B / C / D / E / F / G					
		SC	B					
	053	DC	C	17B - 20B 17M - 20M		N / P		
		SF	A / B / C / D / E / F / G					
		SP	L					
		PW	A / B / C / D / E	16B				
		SC	B	17B - 20B 17M - 20M				
	064	DC	C		D			
		SF	A / B / C / D / E / F / G					
		SP	L			N		
		PW	A / B / C / D / E	16B				
		SC	B	17B - 20B 17M - 20M		N / P		
	080	DC	C					
		SF	A / B / C / D / E / F / G					
		SP	L			N		
		PW	A / B / C / D / E	16B				
		SC	B	17B - 20B 17M - 20M		N / P		

* Specific configurations only. See chapter **Operation in high-pressure applications** and **Operation in ultra high vacuum applications.**

Magnetic ring

MRA 049 B C 025 D S E 00

Series

MRA - AksIM magnetic ring

Outer diameter and readhead compatibility

022 - 22 mm
029 - 29 mm
039 - 39 mm
049 - 49 mm
053 - 53 mm
064 - 64 mm
080 - 80 mm

Thickness

A - 3.9 mm
B - 2.0 mm
D - 4.9 mm
G - 7 mm
H - 5.4 mm

Installation type

C - Countersunk holes (use flat-head fasteners DIN 965 / 7046)
F - Flat-bottom counterbored holes (use socket head fasteners DIN 912)
G - Glue
P - Press-fit

Inner diameter

008 - 8 mm
010 - 10 mm
013 - 12.7 mm
020 - 20 mm
025 - 25 mm
030 - 30 mm
034 - 34 mm
040 - 40 mm
051 - 51 mm
055 - 55 mm
064 - 64 mm
068 - 68 mm

Accuracy grade

D - Standard for stamped rings
E - Standard for machined rings

Material

M - Machined stainless steel hub with CPE rubber
S - Stamped metal plate with CPE rubber

Zero marking

E - Engraved
H - Hole
N - None

Special requirements

00 - No special requirements (standard)

Not all part number combinations are valid. Refer to the table of available combinations on the next page.

Table of available combinations

Series	Outer diameter and readhead compatibility	Thickness	Installation type	Inner diameter	Accuracy grade	Material	Zero marking	Special requirements
MRA	022	H	P	008	D	M	N	00
	029	B	C	010		S	E	
		G	P	013		M	N	
	039	B	C	020		S	E	
	049	A	F	025	E	M	H	
		B	C		D	S	E	
			G	034			N	
	053		C	030			E	
			G	040			N	
	064		C				E	
			G	051			N	
	080	A	F	055	E	M	H	
		B	C		D	S	E	
			G	064			N	
		D	F	068		M	H	

Available ring part numbers:

MRA022HP008DMN00
MRA029BC010DSE00
MRA029GP013DMN00
MRA039BC020DSE00
MRA049AF025EMH00
MRA049BC025DSE00
MRA049BG034DSN00
MRA053BC030DSE00
MRA053BG040DSN00
MRA064BC040DSE00
MRA064BG051DSN00
MRA080AF055EMH00
MRA080BC055DSE00
MRA080BG064DSN00
MRA080DF068DMH00

Accessories

Cable assembly, 1 m
ACC015
ACC049

Cable assembly, 1 m
ACC016
ACC065

Cable assembly, 3 m
ACC061
ACC070

Magnet viewer
MM0001

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

USB interface (for SSI communication interface)
E201-9S

USB interface (for SPI EncoLink and PWM communication interface)
E201-9P

Shims for height adjustment of the readheads
MB-ACC

For technical details about cable assemblies and pinout see chapter **Cable assemblies.**

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. Magnetic rings and readheads are packed separately.

Bulk packaging:

Readheads		
Part	**Tray size**	**Box size**
MB022	32 units per tray	8 trays per box
MB029	18 units per tray	10 trays per box
MB039	16 units per tray	
MB049-D	16 units per tray	
MB049-E	20 units per tray	
MB053	12 units per tray	
MB064	10 units per tray	
MB080	15 units per tray	

Magnetic rings		
Part	**Tray size**	**Box size**
MRA022	45 units per tray	10 trays per box
MRA029	10 units per tray	12 trays per box
MRA039		
MRA049		
MRA053		
MRA064	5 units per tray	12 trays per box
MRA080		

Cable assemblies

Cable specifications

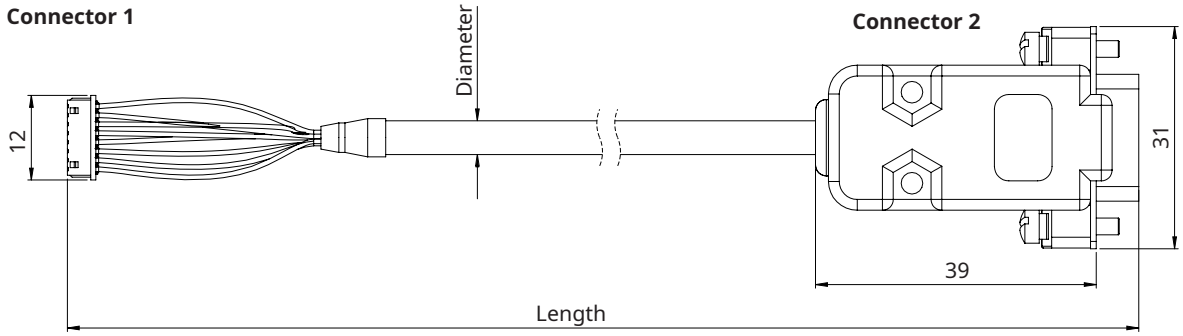
Part numbers	ACC015, ACC016, ACC061	ACC049, ACC065, ACC070
Cable specifications	LI12YC12Y	LiYCY (TP)
Configuration	4 × 2 × 0.14 mm² (twisted pairs)	4 × 2 × 0.14 mm² (twisted pairs)
Rated voltage	250 V	350 V
Temperature range	Operating –30 °C to +100 °C Storage –40 °C to +105 °C Not valid for cables with DSUB-9 M connector.	Operating –40 °C to +75 °C (fixed) –5 °C to +70 °C (bending) Storage –40 °C to +80 °C
Environmental compliance	RoHS conform 73/23/EWG-Guideline CE conform Halogen free REACH compliant	RoHS and REACH compliant Flame-retardant according IEC 60332-1-2 Approvals based on VDE 0812 Classification ETIM 5.0 Class-ID: EC000104

ACC016 and ACC065 can be used for direct connection to E201-9S or E201-9B USB encoder interface.
ACC015, ACC016 and ACC061 may be discontinued in future.

Compatible readhead	Part number	Diameter	Length	Connector 1	Connector 2	Notes
Every readhead with connector option “N”	ACC015	5 mm	1.0 m	FCI / AMP 10114826-00008LF and 10114827-002LF	Flying leads	Twisted pairs, shielded, up to +100 °C
	ACC016				DSUB-9 M	
	ACC061		3.0 m		Flying leads	
	ACC049	6.2 mm	1.0 m		Flying leads	Twisted pairs, shielded, up to +75 °C
	ACC065				DSUB-9 M	
	ACC070		3.0 m		Flying leads	

Dimensions

Dimensions in mm.



Pinout

Connector 1 FCI / AMP 10114826-00008LF	Connector 2 DSUB-9 M						
Pin number		Wire color	BiSS C	Asynchronous serial	SPI	PWM	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+	RX command in +	SCK	Status out	Clock+
6	3	Blue	MA–	RX command in –	NCS	-	Clock–
7	6	Green	SLO+	TX data out +	MISO	PWM out	Data+
8	7	Yellow	SLO–	TX data out –	MOSI	-	Data–

* See chapter **External isolated temperature sensor**

Head office

RLS Merilna tehnika d.o.o.

Poslovna cona Žeje pri Komendi
Pod vrbami 2
SI-1218 Komenda
Slovenia

T +386 1 5272100
E mail@rls.si

www.rls.si

Global support

Visit our **website** to contact your nearest sales representative.

Document issues

Issue	Date	Page	Description
12	18. 4. 2025	24	Accuracy data amended
		5, 28	Vacuum information added
13	4. 8. 2025	2	MRA064BG051DSN00 added
		18	MRA064BG051DSN00 dimension drawing added
		49 - 51	Part numbering amended
14	15. 9. 2025	5 - 6	MB022 and MRA022 drawings amended
15	13. 5. 2026	38	Command "i" amended