RLS®

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.
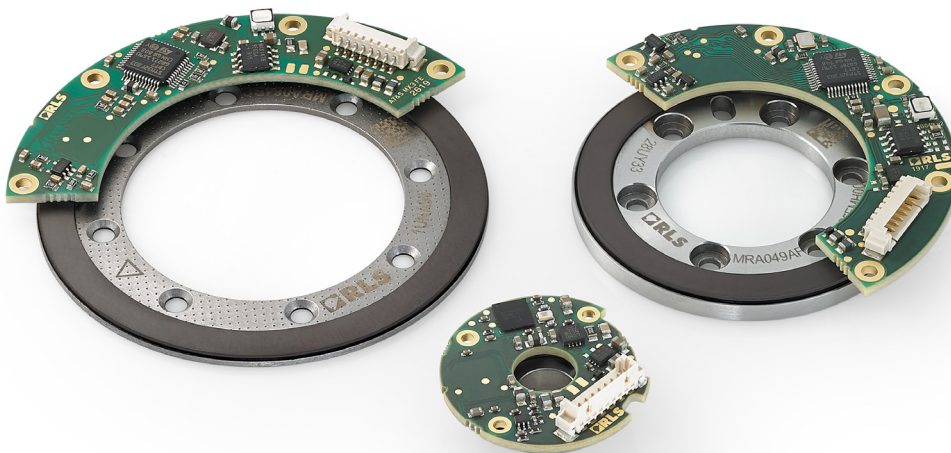
Features and benefits

- 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 robot 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**
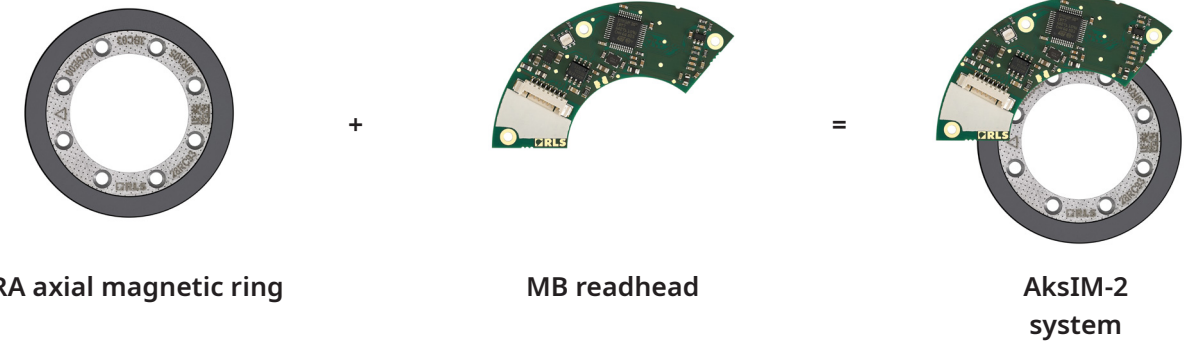
Selection guide	Magnetic ring					Readhead						
Part number	Inner diameter	Circle for fasteners	Outer diameter	Thickness	Inertia (kg × mm²)	Inner diameter	Circle for fasteners	Outer diameter	Arc length	Max resolution	System thickness (Typ.)	Mass (g)
MB022 Assembly												
MB022 shape G						8.5	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
MRA049BC025DPE00												
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
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

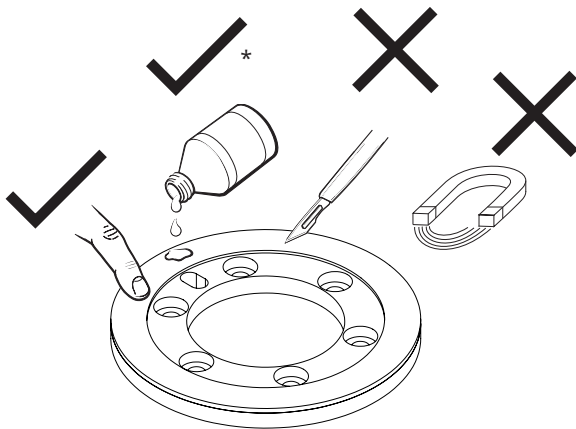| **Storage temperature**	**Operating temperature**	**Humidity**
–40 °C to +105 °C	–40 °C to +105 °C –40 °C to +85 °C (MB022 only)	Up to 70 % non-condensing

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.

* Only if MRA049BC025DPE00 is used.
  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. Magnetic rings and readheads are packed separately.
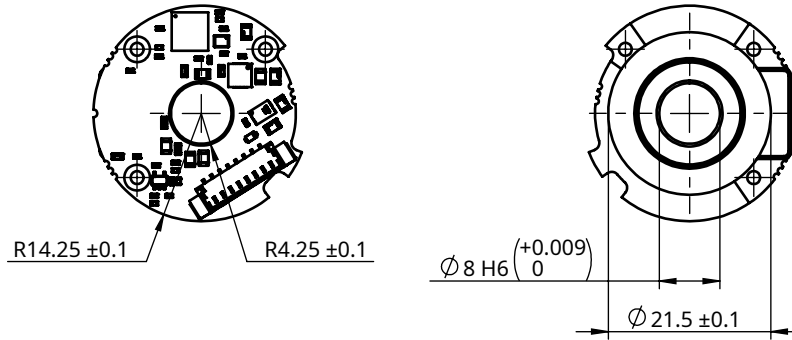
Bulk packaging:

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

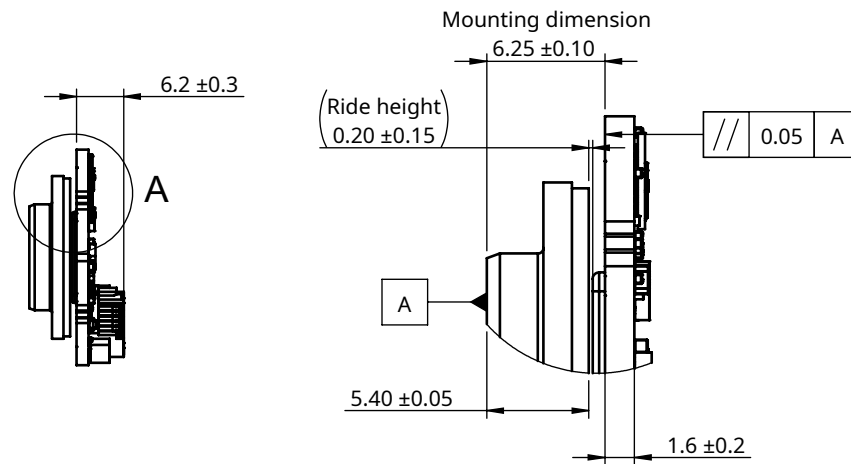| Magnetic rings		
Part	**Tray size**	**Box size**
MRA022	- (individually)	- (individually)
MRA029		
MRA039		
MRA049-D	10 units per tray	12 trays per box
MRA049-E		
MRA053		
MRA064-E		
MRA064-D	5 units per tray	12 trays per box
MRA080		

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Dimensions and installation drawings
Dimensions and tolerances are in mm.

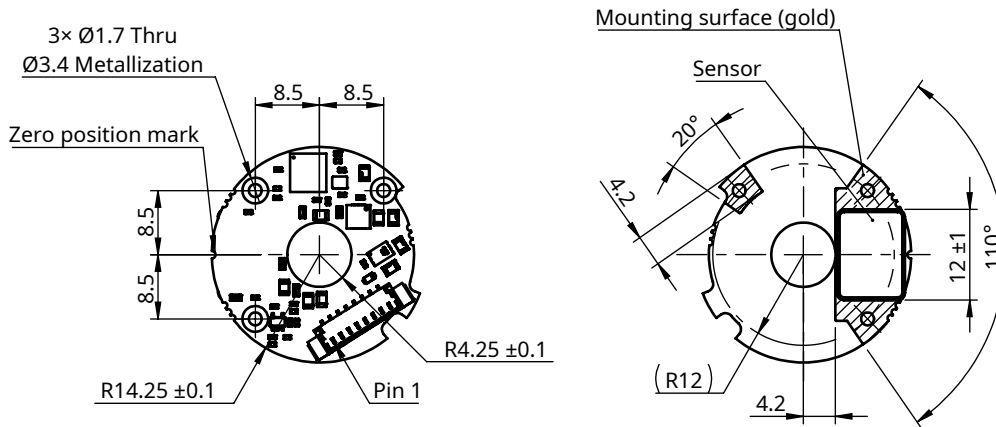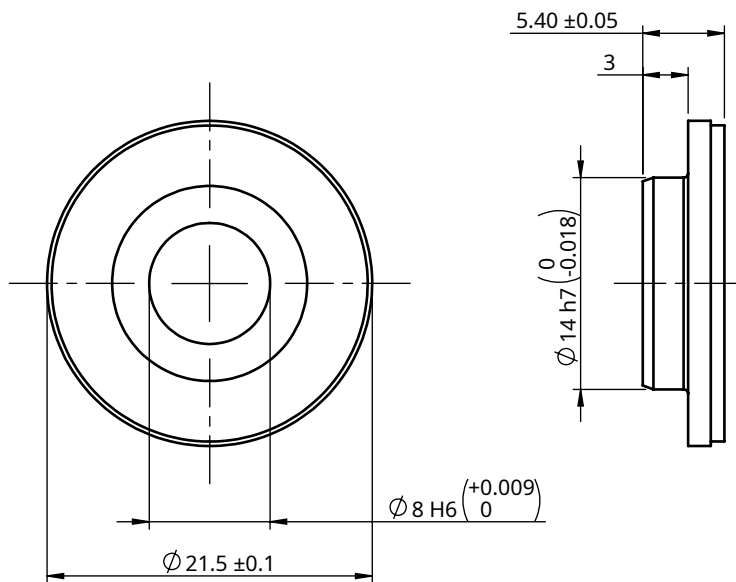## Encoder assembly MB022 readhead with MRA022HP008DMN00 magnetic ring

R14.25 ±0.1   R4.25 ±0.1

$\varnothing$ 8 H6 $\left(\begin{array}{c}+0.009\\0\end{array}\right)$ $\varnothing$ 21.5 ±0.1

Detail A

6.2 ±0.3

A

Mounting dimension
6.25 ±0.10

Ride height
0.20 ±0.15

// 0.05 A

A

5.40 ±0.05

1.6 ±0.2

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

MB022 readhead

3× Ø1.7 Thru
Ø3.4 Metallization
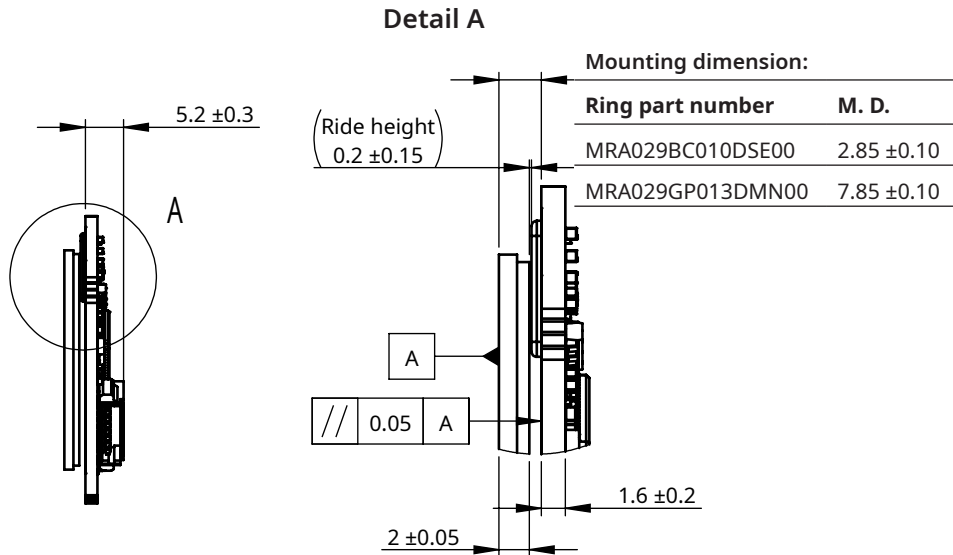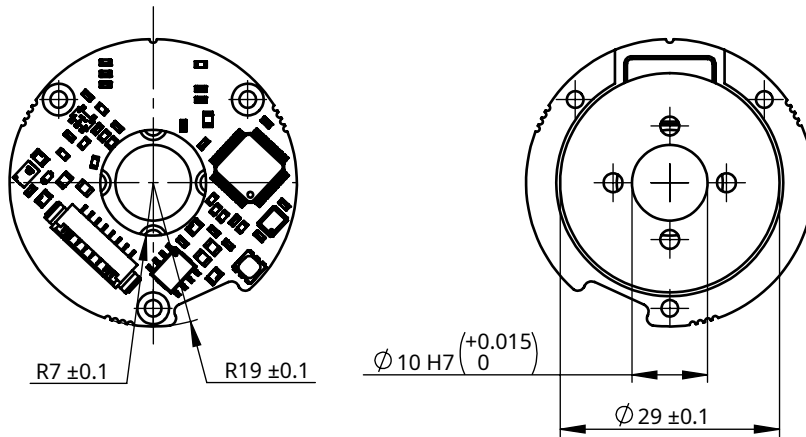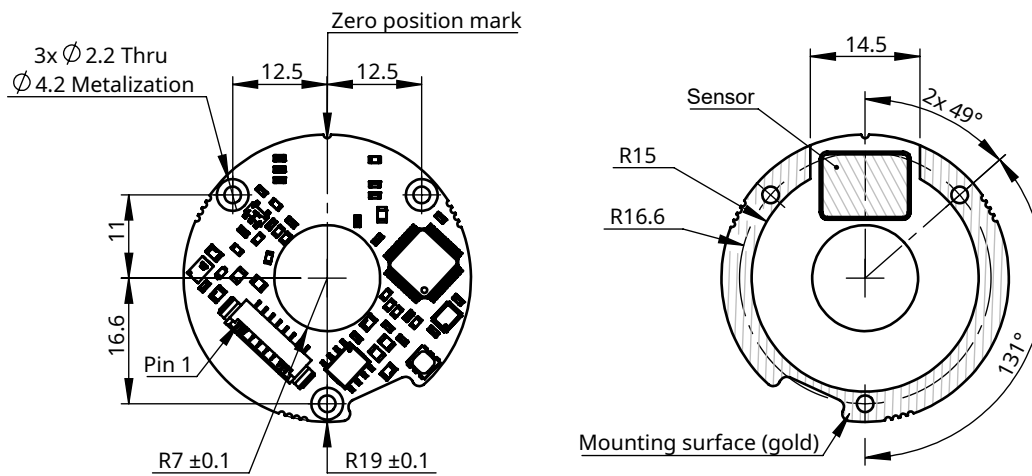
Zero position mark

8.5   8.5

8.5

8.5

R14.25 ±0.1

Pin 1

R4.25 ±0.1

Mounting surface (gold)

Sensor

20°

4.2

(R12)

4.2

12 ±1

110°

MRA022HP008DMN00 magnetic ring

5.40 ±0.05

3

$\varnothing$ 14 h7 $\left(\begin{smallmatrix}0\\-0.018\end{smallmatrix}\right)$

$\varnothing$ 8 H6 $\left(\begin{smallmatrix}+0.009\\0\end{smallmatrix}\right)$

$\varnothing$ 21.5 ±0.1

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

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Encoder assembly MB029 readhead with MRA029BC010DSE00 magnetic ring

R7 ±0.1   R19 ±0.1 $\varnothing$ 10 H7 $\binom{+0.015}{0}$

$\varnothing$ 29 ±0.1

Detail A

5.2 ±0.3

A

(Ride height)
0.2 ±0.15

Mounting dimension:

Ring part number	M. D.
MRA029BC010DSE00	2.85 ±0.10
MRA029GP013DMN00	7.85 ±0.10

A

// 0.05 A

1.6 ±0.2

2 ±0.05

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

MB029 readhead

Zero position mark

3x ⌀ 2.2 Thru
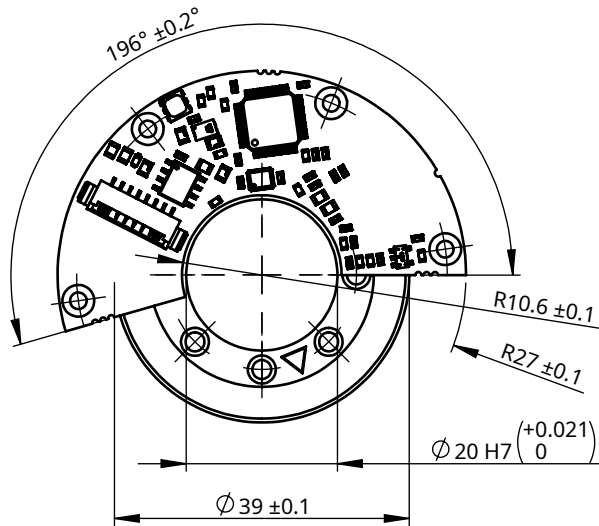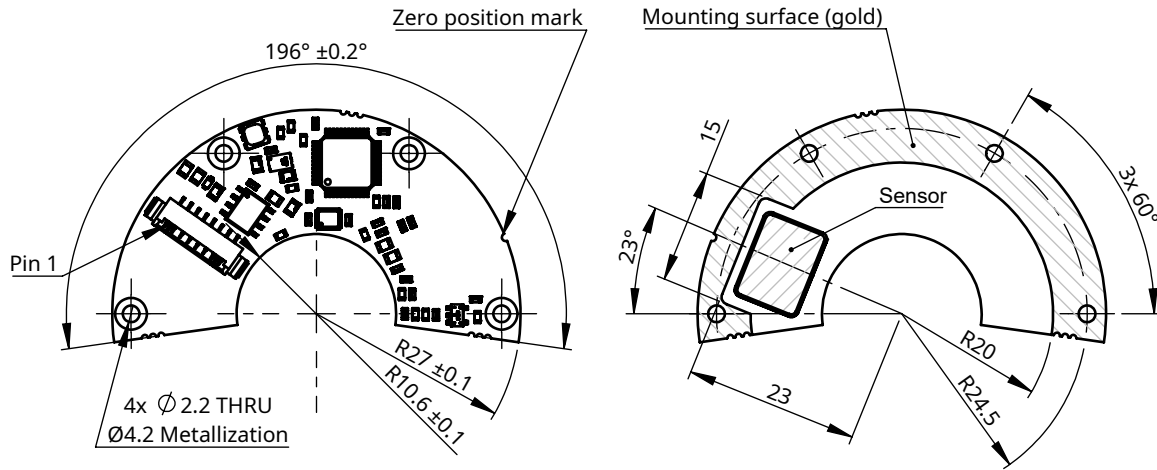⌀ 4.2 Metalization

12.5   12.5

14.5

Sensor

2x 49°

R15

R16.6

11

16.6

Pin 1

131°

R7 ±0.1   R19 ±0.1

Mounting surface (gold)

MRA029BC010DSE00 magnetic ring

4x For fasteners
M2 ISO 7046

⌀ 10 H7 (+0.015 / 0)

⌀ 15

⌀ 29 ±0.1

1.2

2 ±0.05
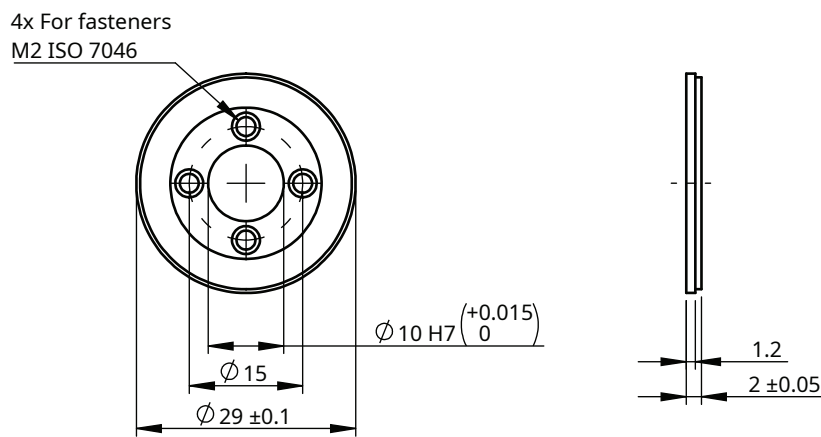
MRA029GP013DMN00 magnetic ring

R0.3 max.

⌀ 15.8 h7 (0 / -0.018)

⌀ 12.7 H5 (+0.008 / 0)

⌀ 29 ±0.05

4.6

7 ±0.05
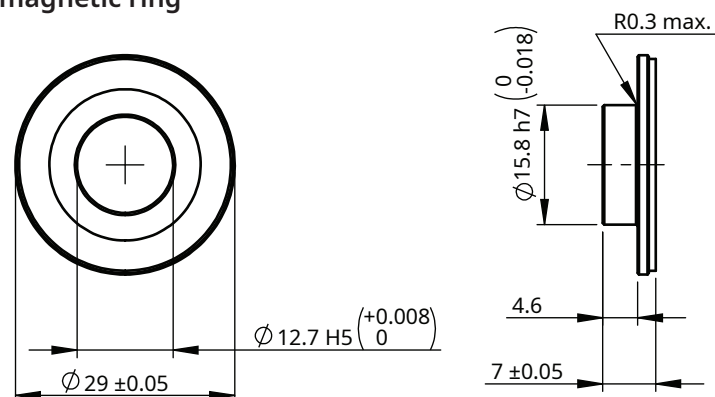
Press-fit mounting to shaft D12.7: recommended shaft OD tolerance is p7 (+0.018 / +0.036)

Rings with h7 tolerance on 15.8 mm dimension and R0.3 max. radius will be available in Q3 / 2022.
Contact your local sales representative for details.

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Encoder assembly MB039 readhead with MRA039BC020DSE00 magnetic ring
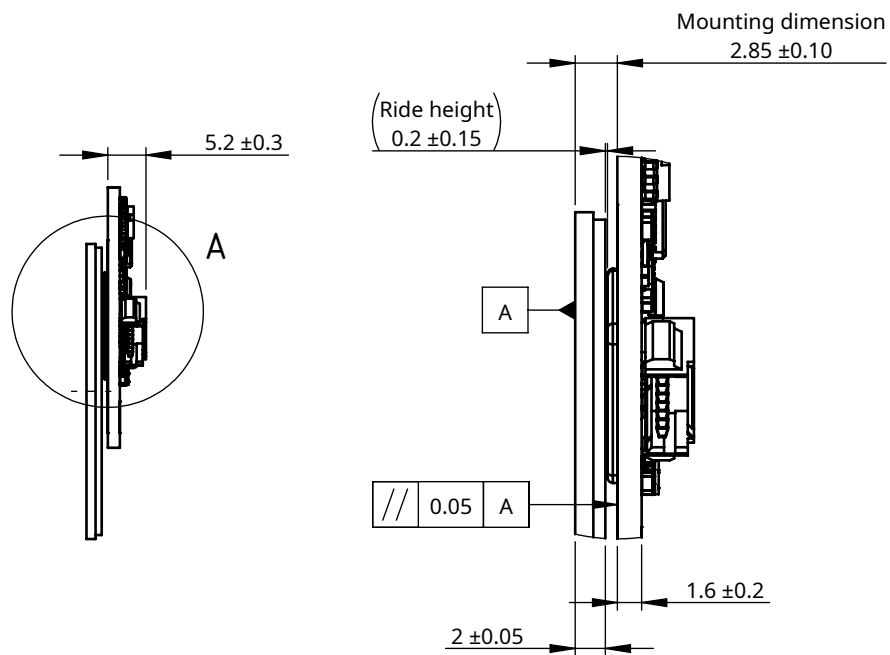
196° ±0.2°

R10.6 ±0.1

R27 ±0.1

$\varnothing$ 20 H7 $\binom{+0.021}{0}$

$\varnothing$ 39 ±0.1

Detail A

Mounting dimension
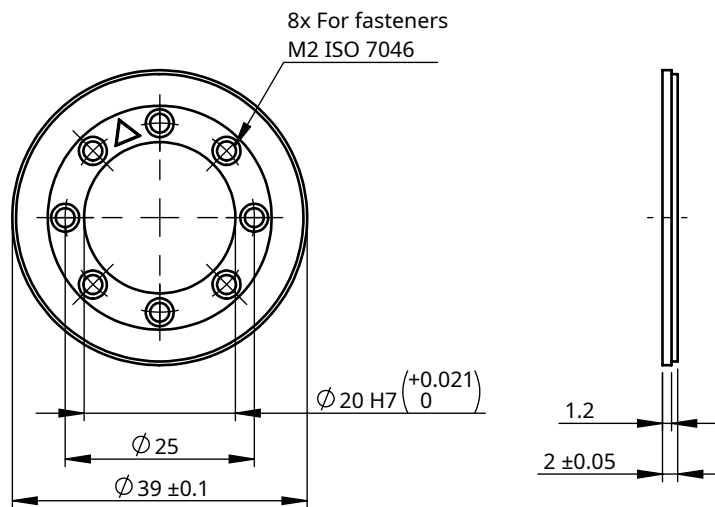2.85 ±0.10

Ride height
0.2 ±0.15

5.2 ±0.3

A

A

| // | 0.05 | A |

1.6 ±0.2

2 ±0.05

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

MB039 readhead

Zero position mark

Mounting surface (gold)

196° ±0.2°

Pin 1

Sensor

15

23°

3x 60°

R27 ±0.1

R10.6 ±0.1

4x Ø 2.2 THRU
Ø4.2 Metallization

R20

R24.5

23

MRA039BC020DSE00 magnetic ring

8x For fasteners
M2 ISO 7046

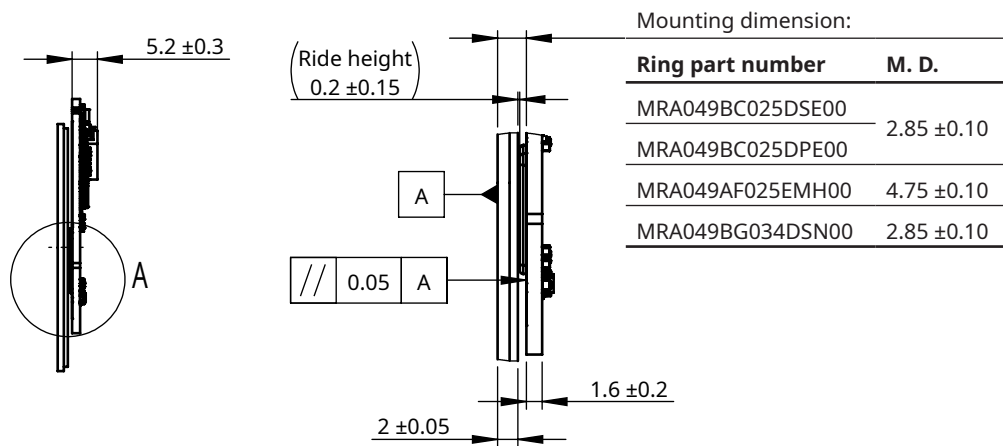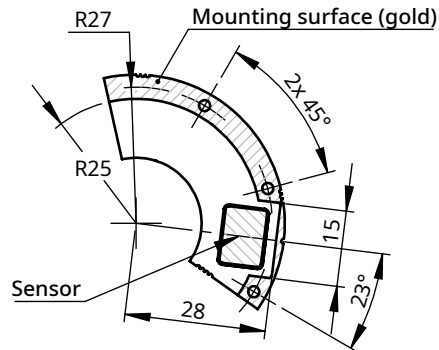Ø 20 H7 $\left(\begin{smallmatrix}+0.021\\0\end{smallmatrix}\right)$

Ø 25

Ø 39 ±0.1

1.2

2 ±0.05

Encoder assembly MB049 readhead shape D and readhead shape E with MRA049BC025DSE00 / MRA049BC025DPE00 magnetic ring

Detail A

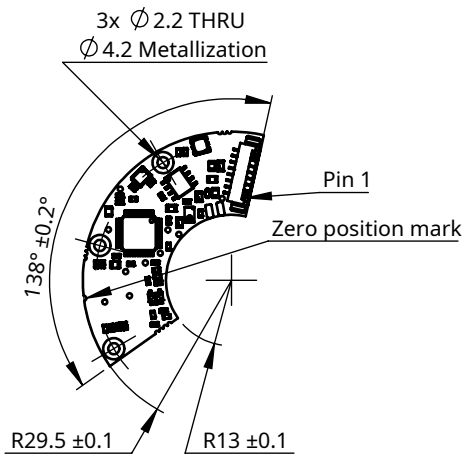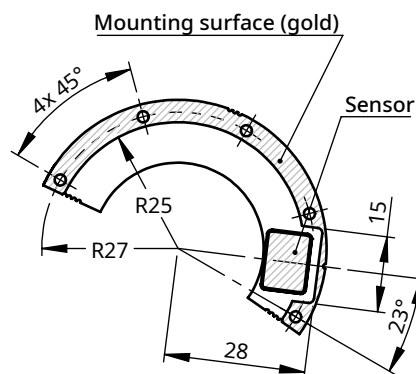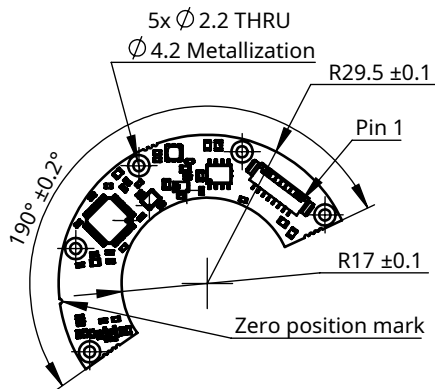| Mounting dimension:	
Ring part number	**M. D.**
MRA049BC025DSE00	2.85 ±0.10
MRA049BC025DPE00	
MRA049AF025EMH00	4.75 ±0.10
MRA049BG034DSN00	2.85 ±0.10

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

MB049 readhead shape E

3x ⌀ 2.2 THRU
⌀ 4.2 Metallization

Pin 1

Zero position mark

138° ±0.2°

R29.5 ±0.1

R13 ±0.1

R27

Mounting surface (gold)

R25

2x 45°

15

23°

Sensor

28

MB049 readhead shape D

5x ⌀ 2.2 THRU
⌀ 4.2 Metallization

R29.5 ±0.1

Pin 1

190° ±0.2°

R17 ±0.1

Zero position mark

Mounting surface (gold)

4x 45°

Sensor

R25

R27

15

23°

28

MRA049BC025DSE00 and MRA049BC025DPE00 magnetic ring

4x For fasteners
M2 ISO 7046

$\varnothing$ 25 H7 $\binom{+0.021}{0}$

$\varnothing$ 31

$\varnothing$ 49 ±0.1

1.2

2 ±0.05
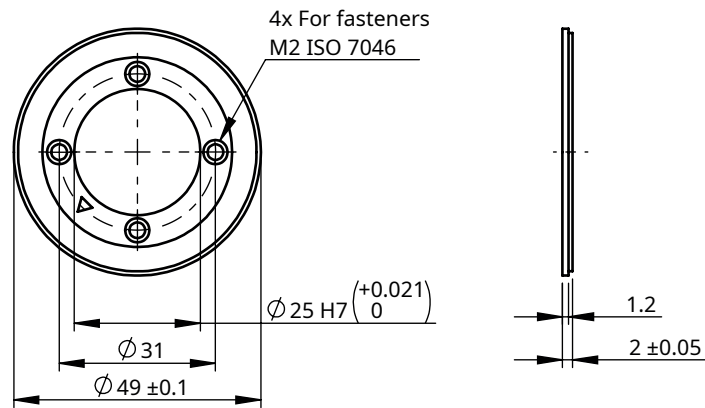
MRA049AF025EMH00 magnetic ring

30°

6x $\varnothing$ 2.9
$\varnothing$ 5.5 $\overline{\underline{\vee}}$ 1.8

16

$3 \begin{smallmatrix} +0.05 \\ 0 \end{smallmatrix}$ X 5

2x R1.5

$\varnothing$ 25 H7 $\binom{+0.021}{0}$

$\varnothing$ 31

$\varnothing$ 49 ±0.1

3

3.9 ±0.05

MRA049BG034DSN00 magnetic ring

$\varnothing$ 34 H7 $\binom{+0.025}{0}$

$\varnothing$ 49 ±0.1

1.2

2 ±0.05

Encoder assembly MB053 readhead shape E with MRA053BC030DSE00 magnetic ring
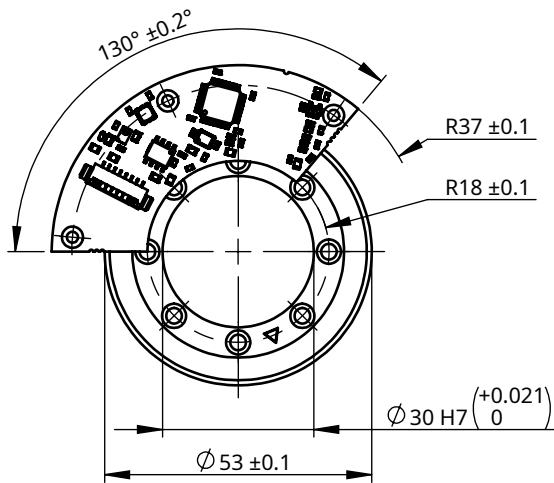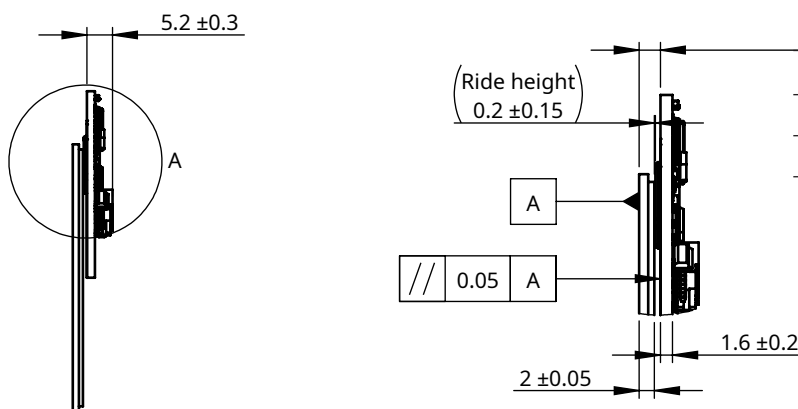
Detail A

Mounting dimension:	
Ring part number	**M. D.**
MRA053BC030DSE00	2.85 ±0.10
MRA053BG040DSN00	2.85 ±0.10

Ride height influences noise on the output. See chapter **Installation instructions** for details.
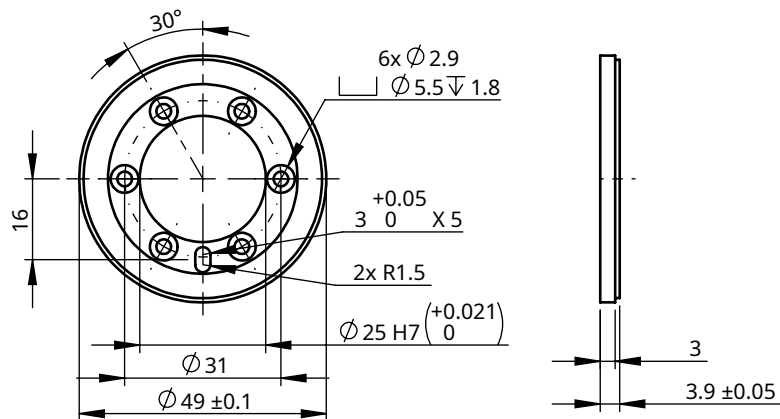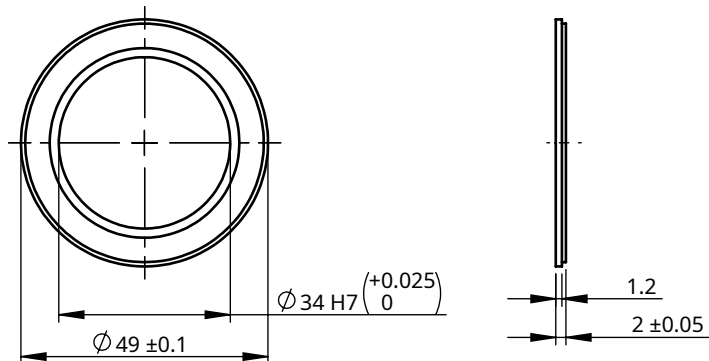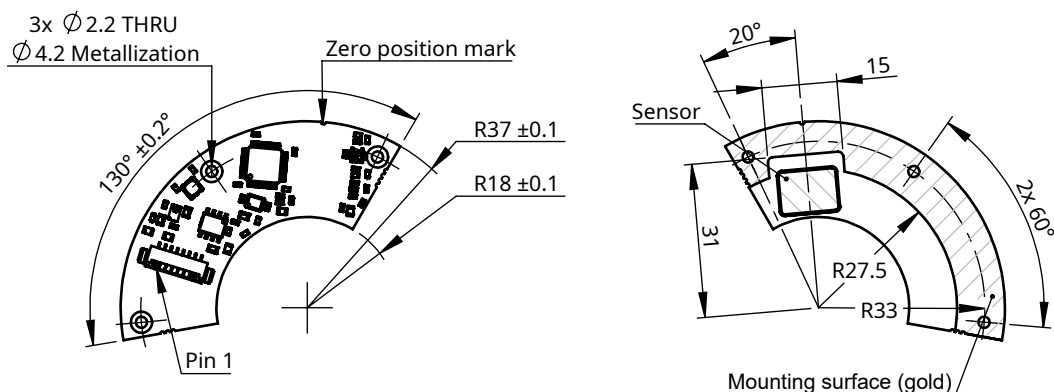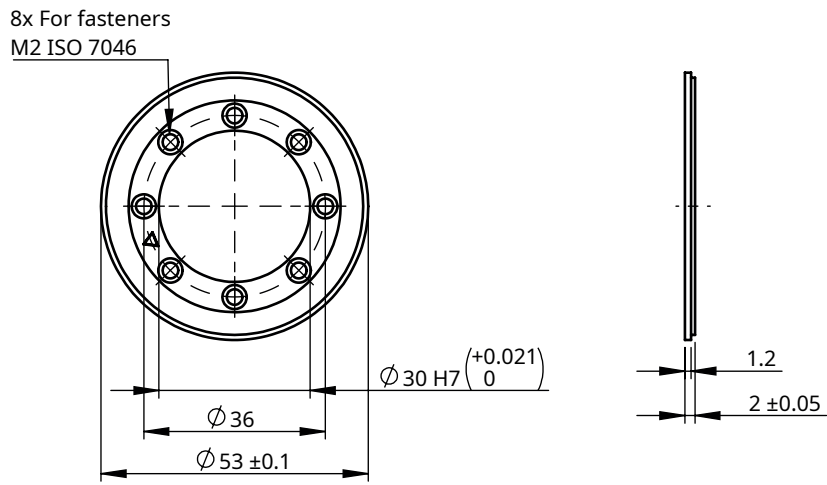
MB053 readhead shape E

Dimensions and installation drawings   continued

MRA053BC030DSE00 magnetic ring

8x For fasteners
M2 ISO 7046

$\varnothing$ 30 H7 $\left(\begin{smallmatrix} +0.021 \\ 0 \end{smallmatrix}\right)$

$\varnothing$ 36

$\varnothing$ 53 ±0.1

1.2

2 ±0.05

MRA053BG040DSN00 magnetic ring

$\varnothing$ 40 H7 $\left(\begin{smallmatrix} +0.025 \\ 0 \end{smallmatrix}\right)$

$\varnothing$ 53 ±0.1

1.2

2 ±0.05
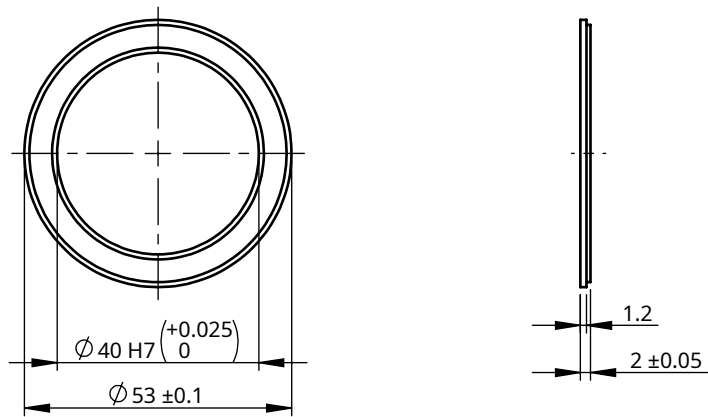
Encoder assembly MB064 readhead shape D with MRA064BC040DSE00 magnetic ring

Detail A

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

MB064 readhead shape D

MRA064BC040DSE00 magnetic ring
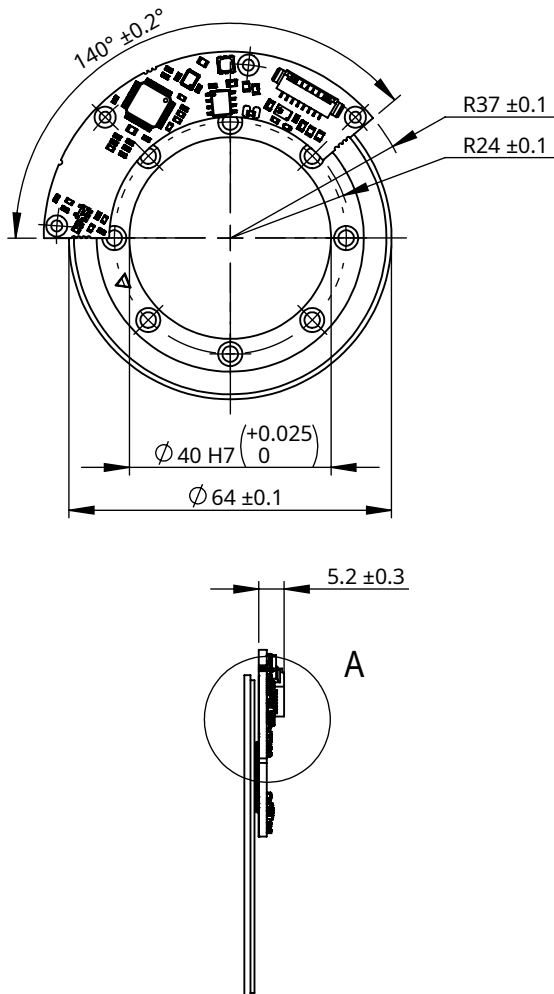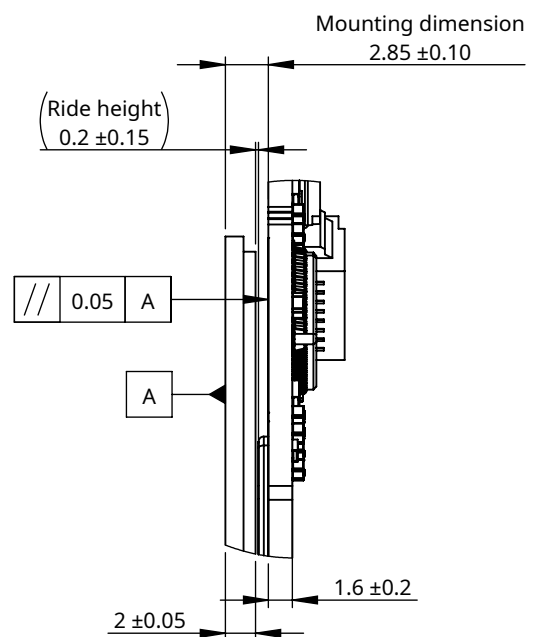
8x For fasteners
M2 ISO 7046

$\varnothing$ 40 H7 $\binom{+0.025}{0}$

$\varnothing$ 46

$\varnothing$ 64 ±0.1

1.2

2 ±0.05

Encoder assembly MB080 readhead with MRA080BC055DSE00 magnetic ring
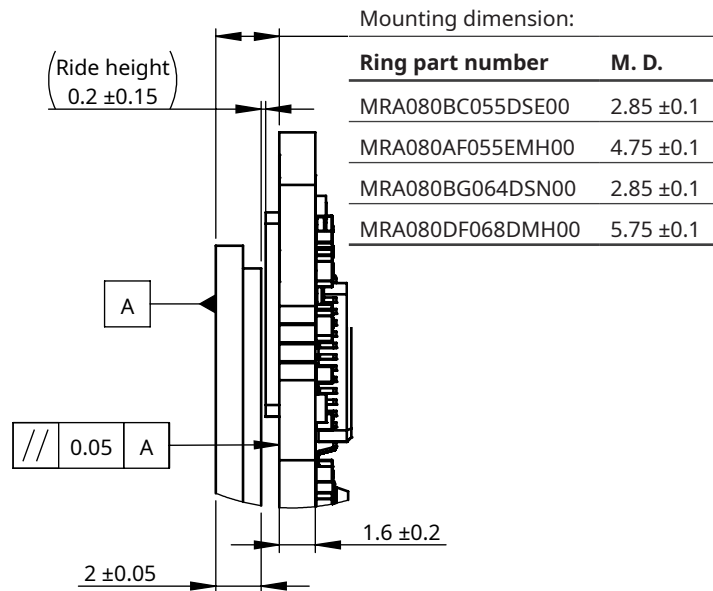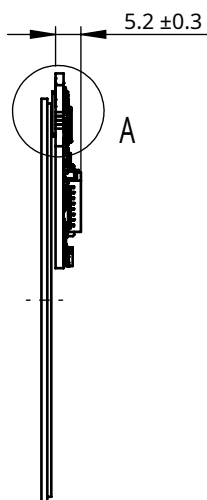
97° ±0.2°

R45 ±0.1

R32.2 ±0.1

$\varnothing$ 55 H7 $\left(\begin{array}{c}+0.030\\0\end{array}\right)$

$\varnothing$ 80 ±0.1

Detail A

5.2 ±0.3

A

(Ride height) 0.2 ±0.15

A

// 0.05 A

1.6 ±0.2

2 ±0.05

Mounting dimension:

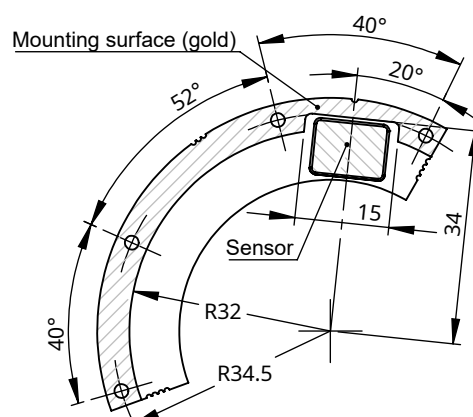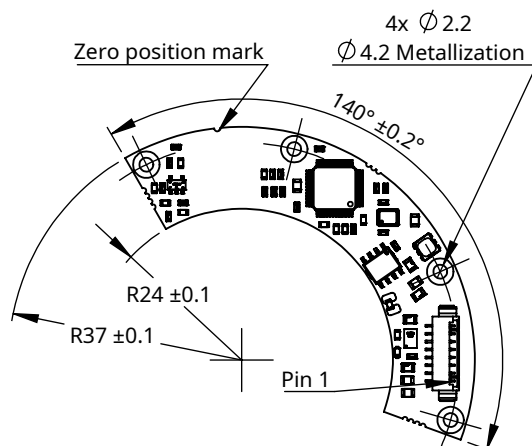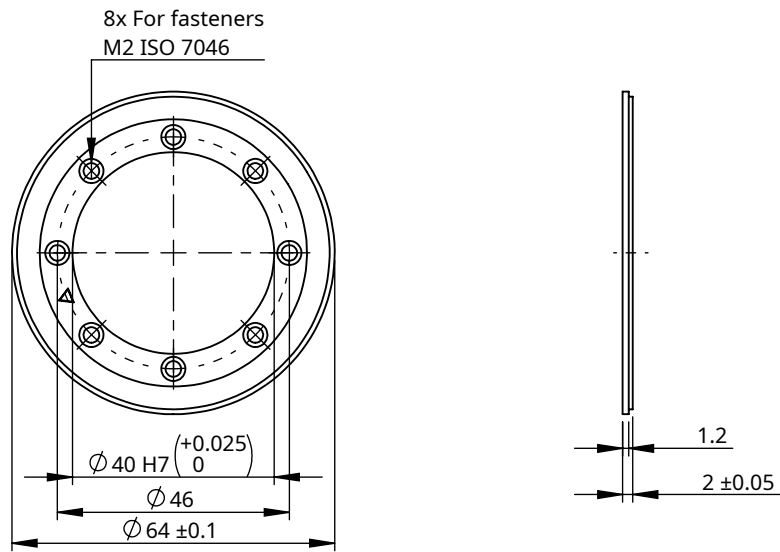| Ring part number	M. D.
MRA080BC055DSE00	2.85 ±0.1
MRA080AF055EMH00	4.75 ±0.1
MRA080BG064DSN00	2.85 ±0.1
MRA080DF068DMH00	5.75 ±0.1

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

MB080 readhead

Zero position mark

97° ±0.2°

4x ⌀2.1
⌀4.2 Metallization

Pin 1

R32.2 ±0.1

R45 ±0.1

Mounting surface (gold)

15°

15

3x 30°

44

R41

Sensor

R42.5

MRA080BC055DSE00 magnetic ring

8x For fasteners
M2 ISO 7046

⌀55 H7 $\binom{+0.030}{0}$

⌀61.5

⌀80 ±0.1

1.2

2 ±0.05
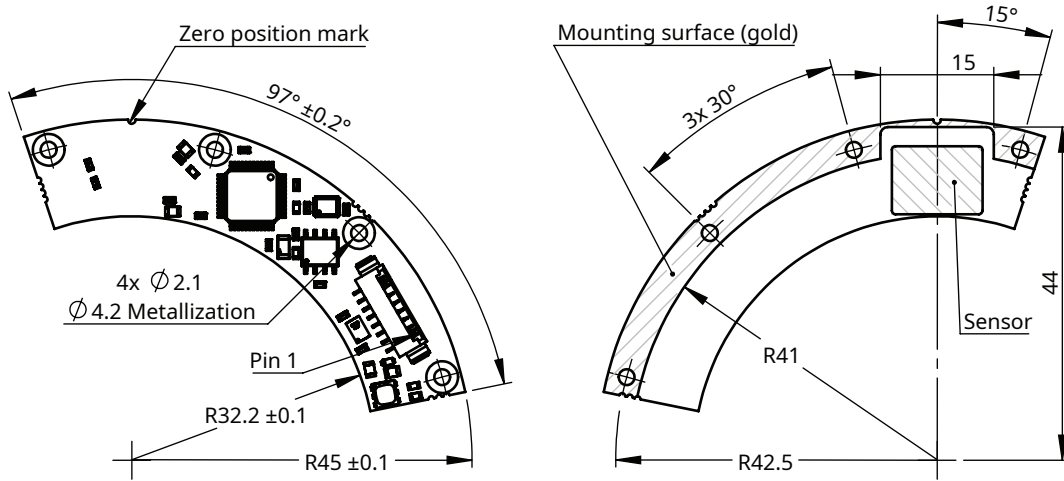
MRA080AF055EMH00 magnetic ring

6x ⌀2.9
⌀5.5 ⩒ 1.8

2x R1.5

3 $^{+0.05}_{0}$ X 5

⌀55 H7 $\binom{+0.030}{0}$

⌀61.5

⌀80 $^{0}_{-0.03}$

31

3

3.9 ±0.05
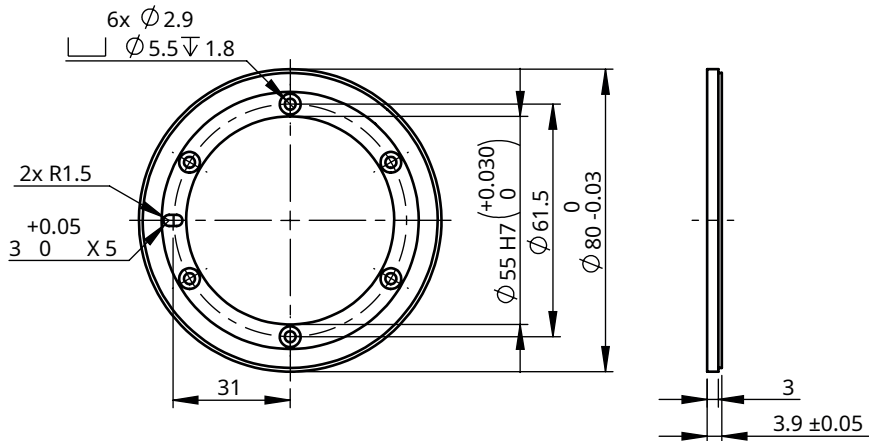
MRA080BG064DSN00 magnetic ring
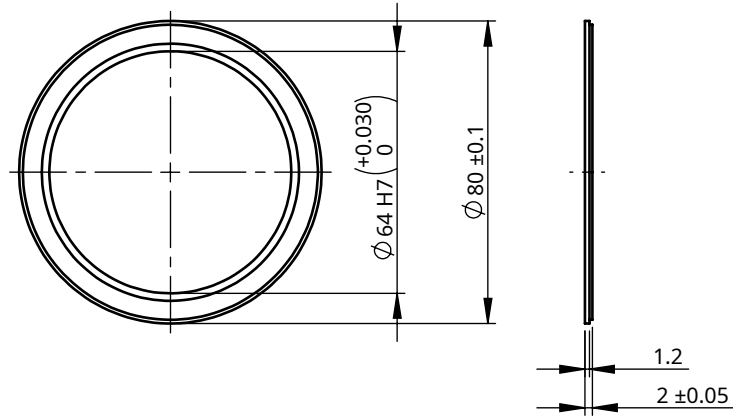
MRA080DF068DMH00 magnetic ring
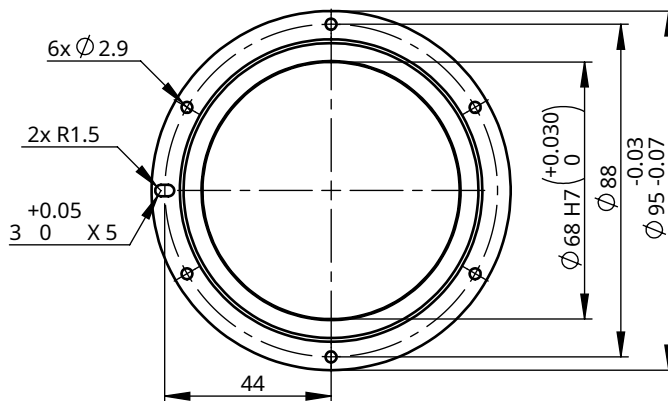
Installation instructions

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.

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)

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 sensor	±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
Calculated ride height has tolerance of ±20 µm.

Encoder size	K	N
022, 029	–95.49	977.1
039, 049	–83.56	846.1
053, 064, 080	–71.62	682.0

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 MBD02 available at **AksIM-2 website**) and at the UART interface with command 'a' ().

Installation tolerances (ring to shaft)

Ring / shaft fit	Encoder accuracy						
	MRA022	MRA029	MRA039	MRA049	MRA053	MRA064	MRA080
H7/g6 worst case	±0.15°	±0.15°	±0.15°	±0.11°	±0.11°	±0.10°	±0.09°
H7/g6 average	±0.08°	±0.08°	±0.07°	±0.06°	±0.06°	±0.05°	±0.05°
After self-calibration	N/A	±0.014°	±0.012°	±0.007°	±0.006°	±0.004°	±0.004°

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

Electrical connections

Connector	Soldering pads	Asynchronous				
		BiSS C	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**

Pinout

Pin 1
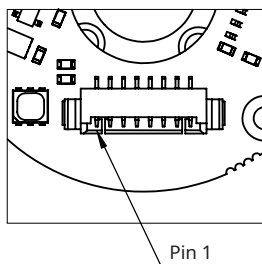
8-pin low profile connector
FCI 10114830-11108LF

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

1 2 3 4 5 6
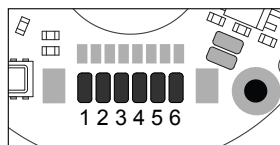
Soldering pads
Dimensions: 2.54 x 1.14 mm
with 1.875 mm pitch

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.
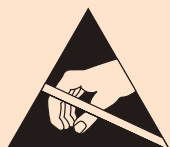
Readhead is ESD sensitive - handle with care.
Do not touch electronic circuit, wires or sensor area without proper ESD protection or outside of ESD controlled environment.

Technical specifications

System data

Reading type	Axial reading
Resolution	From 17 bit to 20 bit and 16 bit multiturn counter option (see chapter **Resolutions**)
Maximum speed	10,000 RPM (for higher speeds **contact RLS**)
Encoder accuracy	±0.004° to ±0.08° / 14 to 288 arcsec. Depending on ring size (before installation - errors caused by mounting inaccuracy of the readhead, ring and drive shaft are not included)
Final system accuracy	±0.004° to ±0.014° / 14 to 50 arcsec (after encoder self-calibration - see chapter **Installation instructions**). For high-accuracy variants **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 44 kHz refresh rate

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
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

Available ring sizes (inner diameter)		8 mm, 10 mm, 12.7 mm, 20 mm, 25 mm, 30 mm, 34 mm, 40 mm, 55 mm, 64 mm, 68 mm
Material type	2 mm thick rings	EN 1.4016 / AISI430 with glued CPE rubber filled with ferrite particles (for material S) EN 1.4016 / AISI430 with glued plastoferrite (for material P)
	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
Mass, inertia		**See Selection table**

Environmental data

Operating and storage temperature	–40 °C to +105 °C (standard), Readhead MB022: –40 °C to +85 °C
Humidity	Up to 70 % non-condensing (for higher with conformal coating **contact RLS**)
External magnetic field	±20 mT
Pressure	Up to 600 bar with special option - See chapter **Operation in high-pressure 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

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 s / ●●● 3 s / ●●● 3 s — 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. In this case, the use of plastoferrite magnetic ring is recommended.

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

Accuracy of the encoder system

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.
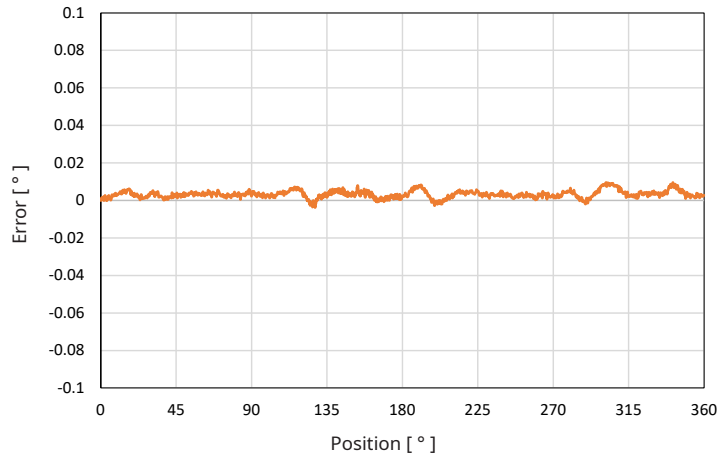
Higher harmonic components of the encoder error plot
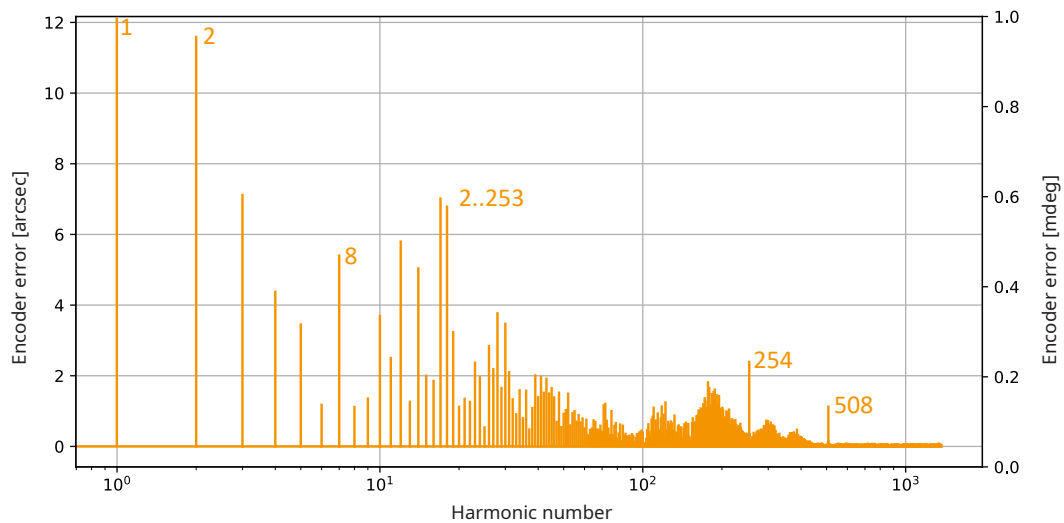
Typical encoder error has some definite higher harmonic components. Example is from the MRA080 + MB080 encoder.
Other encoder sizes have slightly different spectrum.

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)**.

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).
- Good signal over the entire calibration angle.
- Maximum time available is 10 seconds.
- 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 of ±0.02° is influenced by magnetisation variations and noise of the readhead.
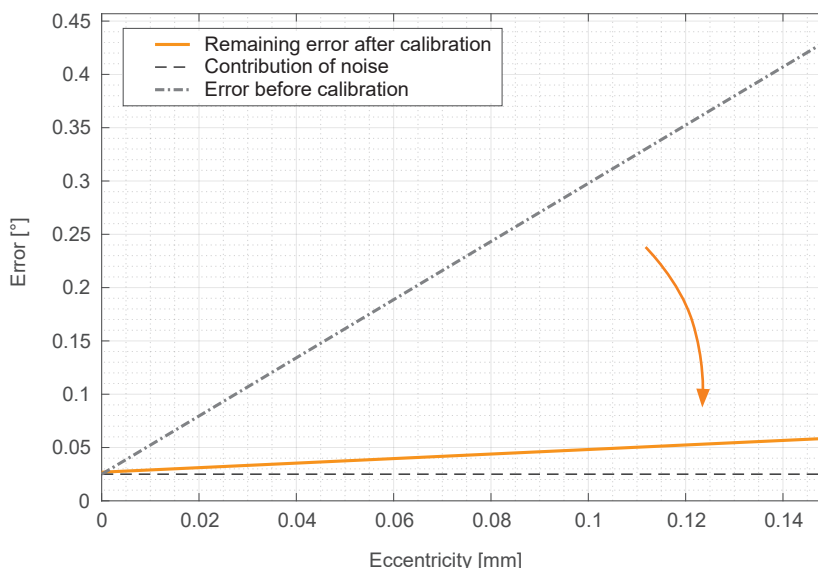
For typical accuracy values see chapter **Installation tolerances (ring to shaft).**

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.**

Encoder system size 022 currently does not support self-calibration.

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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 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. **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 "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.
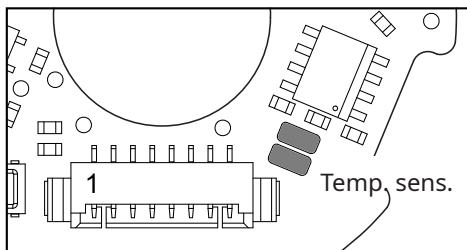
Operation in high-presure applications

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 %.

List of available part numbers:
- MB029DCC18MFNP00
- MB049DCC19BDNP00
- MB049DCC19MDNP00
- MB080DCC17BDNP00
- MB080DCC20MDNP00

Ring with plastoferrite (MRA049BC025DPE00) is most suitable for use in a oil bath.
For more information or to confirm compatibility with oils and other chemicals in the environment, please **contact RLS**.

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.

Resolutions

Resolution	MRA022	MRA029	MRA039, MRA049	MRA053, MRA064, MRA080
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.

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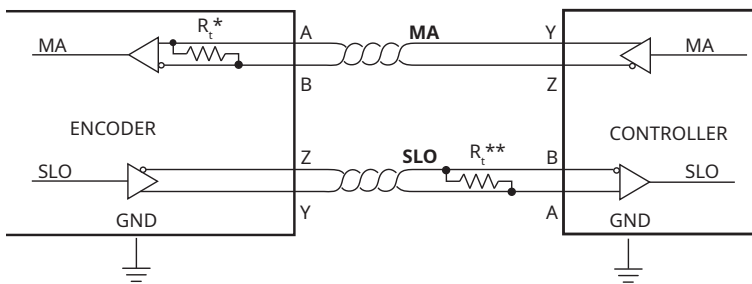
Signals	
MA	Master clock. Max clock frequency is 5 MHz.
SLO	Slave out. Data is output on rising edge on MA.

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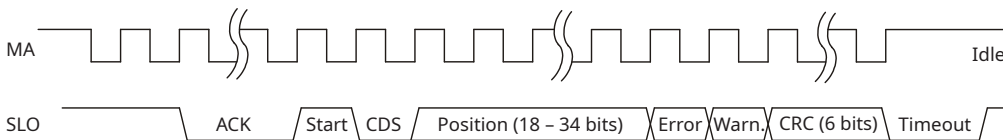
MA is idle high. Communication is initiated with first falling edge.
The encoder responds by setting SLO low on the second rising edge on MA. ACK length is 13 bits.
When the encoder is ready for the next request cycle, it indicates this to the master by setting SLO high.
The absolute position and the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

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.

$$t_{DELAY} = t_{RESP} + t_{PROP} \times \text{cable length}$$
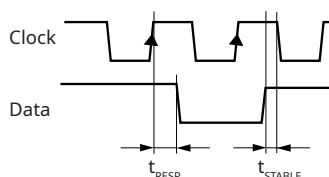
The data signal must be stable before the value is latched. Therefore, if the cable is longer than 1 meter and a clock frequency higher than 2.5 MHz, this delay must be compensated in the receiver (controller) to which the encoder is connected.

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
	MA frequency	Max. 5 MHz
C	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.

Data packet 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		17 bits			
18B		18 bits			
19B	0 bits	19 bits	1 bit	1 bit	6 bits
20B		20 bits			
17M		17 bits			
18M		18 bits			
19M	16 bits	19 bits	1 bit	1 bit	6 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 fro download on **RLS Media center**.

For more information regarding BiSS C protocol see **biss-interface.com**.

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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 MBD02 available for download at **RLS media center**.

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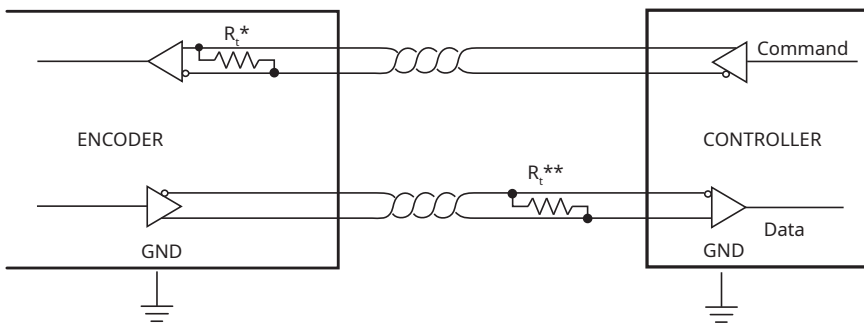
* The Command and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required if total cable length is longer than 5 m. The nominal impedance of the cable is 120 Ω.

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**.

> There is no easy way to revert to factory settings. New settings are permanent until encoder is reprogrammed again with different settings.

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)
'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 '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 on page 22**.

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Asynchronous serial communication interface over RS422 (UART)   continued

Command 'i'	
Byte transmitted	**Contents**
B1	ASCII header 'i'
B2	Self calibration status - See document MBD03 available for download at **RLS media center**
B3 - B4	(Unsigned binary) Ring eccentricity (µm)
B5 - B6	(Unsigned binary) Ring eccentricity phase (deg)
B7 - B8	(Unsigned 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)	
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)	
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.

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 MBD03 available for download at **RLS media center**.

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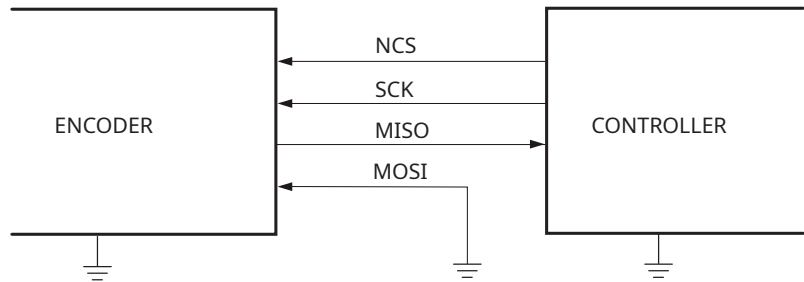
SPI - Serial peripheral interface

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.
MOSI	Master output $\rightarrow$ 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 $\leftarrow$ 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
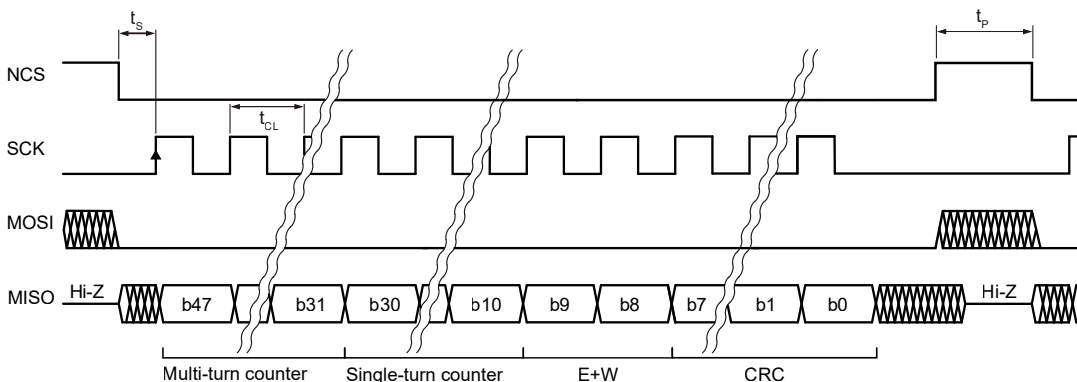
The controller starts the communication by setting the NCS signal low. At the same time the encoder position is latched. A delay of t_S is required to allow the encoder to prepare the data which is then shifted to MISO output on rising edges of clock signal SCK. Encoder Position and General Status (active 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	

Encoder position data structure

For multiturn

b47 : b32	Multiturn counter (if specified in part number) – Left aligned, MSB first.
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.
b7 : b0	Inverted CRC, 0x97 polynomial

For singleturn

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.
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 setting zero position and running self-calibration function.
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**.

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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 $360° / 65536 \approx 0.00549°$).

PWM Out signal timing diagram
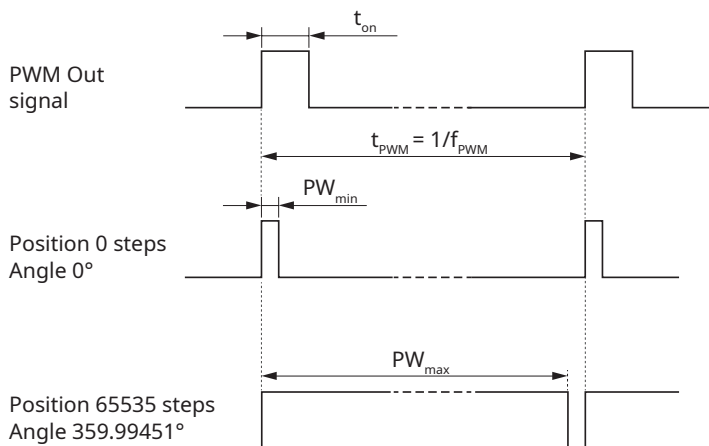
Communication parameters

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

Parameter	Symbol	Communication interface variant					Unit	Note
		A	**B**	**C**	**D**	**E**		
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}).

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

SSI - Synchronous serial interface

SSI interface is supported for legacy applications and is not recommended for new designs.

The encoder position in up to 20 bit natural binary code and the encoder status are available via the SSI protocol. The position data is left aligned. The position data is followed by two general status bits, followed by the detailed status information. SSI interface is not recommended for closed-loop applications and motor feedback due to low update speed and noticeable (variable) latency.

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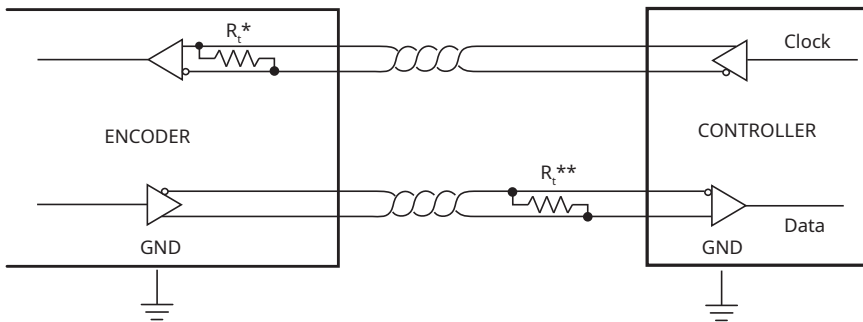
* The Clock and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required if total cable length is longer than 5 m. The nominal impedance of the cable is 120 Ω.

Output protection

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

SSI timing diagram
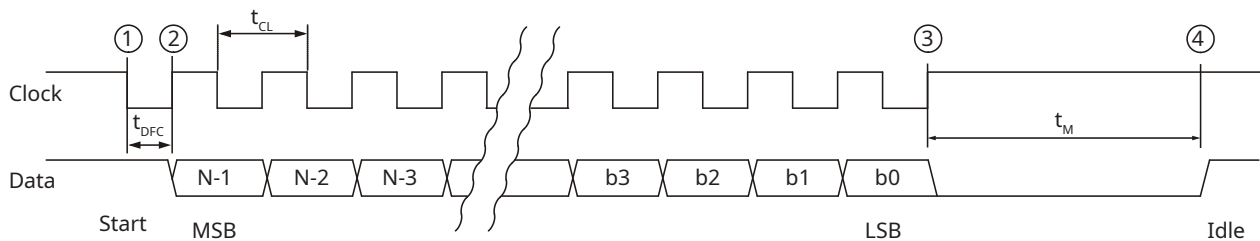

See table **"Structure of data packet"**.

The controller queries the readhead for its position and status data by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge ① latches the last available position data, and on the first rising edge ② the most significant bit (MSB) of the position is transmitted to the Data output. The Data output should then be latched on the next falling edge. On the following rising edges of the Clock signal the next bits are transmitted. If the time between ① and ② is extended for additional 1 µs, the maximum clock frequency limit is 2 MHz instead of 500 kHz. This function is called "Delay First Clock" and must be supported by the controller to which the encoder is connected.

After the transmission of the last bit ③ the Data output goes to low. When the t_M time expires the Data output is undefined ④. The Clock signal must remain high for at least tM before the next reading can take place.

While reading the data the 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.
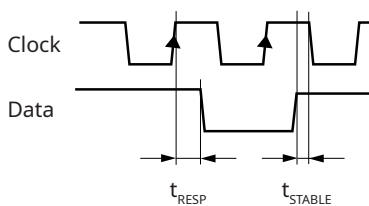
To allow updating of the position data at least t_B should pass between two subsequent readings. If the reading request arrives earlier than t_B after the previous reading, the encoder position will not be updated.
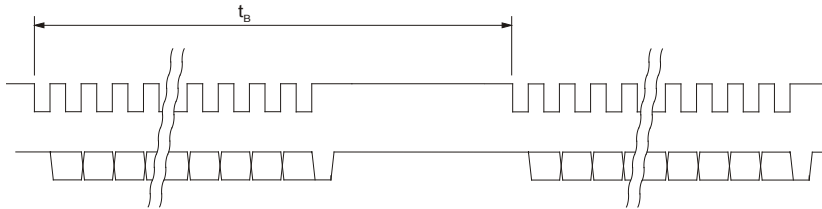
The power supply must be applied at least 100 ms before the clock sequence is being sent to the encoder.

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:
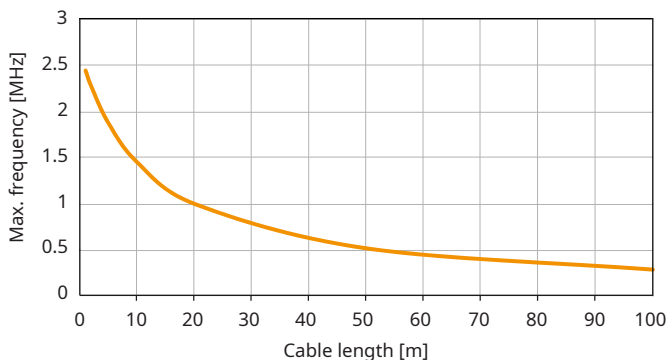
Communication parameters

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}	50 kHz		500 kHz (2.5 MHz *)
Timeout (monoflop time)	t_M		20 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.

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SSI - Synchronous serial interface   continued

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

Structure of data packet

Singleturn resolution	Bit number			
	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

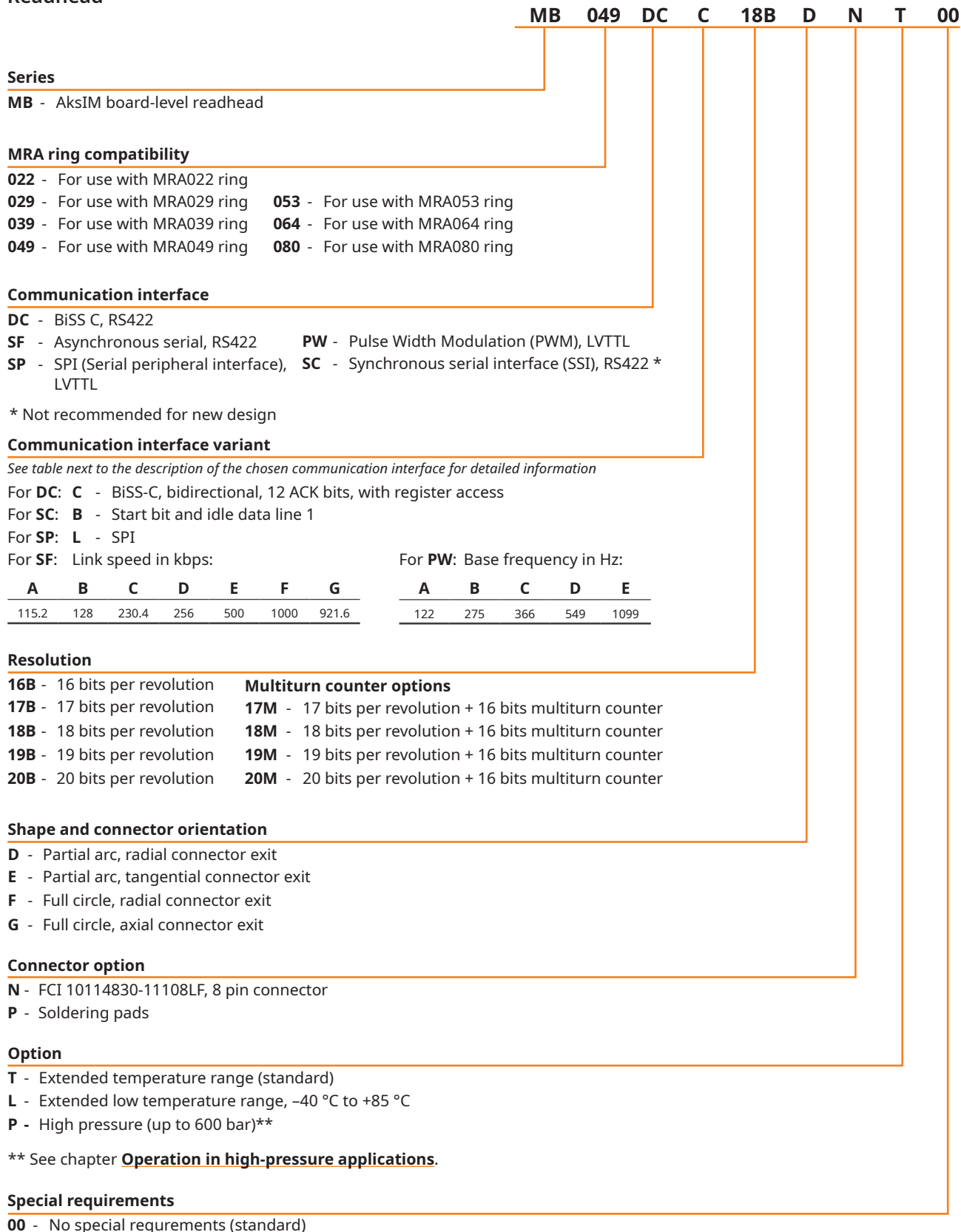| Multiturn counter (if selected in part number)	
First 16 bits (see table above)	Multiturn counter - Occupying full 16 bits. Can be interpreted as signed number (±32768) or unsigned number (0 to 65535) that represents number of shaft turns.
Encoder position	
Following 17 to 20 bits (see table above)	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 - 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.

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   **053** - For use with MRA053 ring
039 - For use with MRA039 ring   **064** - For use with MRA064 ring
049 - For use with MRA049 ring   **080** - For use with MRA080 ring

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

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

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

A	B	C	D	E
122	275	366	549	1099

Resolution
16B - 16 bits per revolution   **Multiturn counter options**
17B - 17 bits per revolution   **17M** - 17 bits per revolution + 16 bits multiturn counter
18B - 18 bits per revolution   **18M** - 18 bits per revolution + 16 bits multiturn counter
19B - 19 bits per revolution   **19M** - 19 bits per revolution + 16 bits multiturn counter
20B - 20 bits per revolution   **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 10114830-11108LF, 8 pin connector
P - Soldering pads

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

** See chapter **Operation in high-pressure applications**.

Special requirements
00 - No special requrements (standard)

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

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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		
		SF	A / B / C / D / E / F / G					
		SP	L					
		PW	A / B / C / D / E	16B		N		
		SC	B	17B - 18B 17M - 18M				
	039	DC	C	17B - 19B 17M - 19M	E	N / P		
		SF	A / B / C / D / E / F / G					
		SP	L					
		PW	A / B / C / D / E	16B		N		
		SC	B					
	049	DC	C	17B - 19B 17M - 19M	D	N / P		
		SF	A / B / C / D / E / F / G					
		SP	L					
		PW	A / B / C / D / E	16B		N		
		SC	B	17B - 19B 17M - 19M		N / P	T P *	
		DC	C	17B - 19B 17M - 19M	E	N		
		SF	A / B / C / D / E / F / G					
		SC	B					
	053	DC	C	17B - 20B 17M - 20M	E	N / P		
		SF	A / B / C / D / E / F / G					
		SP	L					
		PW	A / B / C / D / E	16B		N		
		SC	B					
	064	DC	C	17B - 20B 17M - 20M	D	N / P		
		SF	A / B / C / D / E / F / G					
		SP	L					
		PW	A / B / C / D / E	16B		N		
		SC	B					
	080	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		N		
		SC	B	17B - 20B 17M - 20M		N / P		

 * Specific configurations only. See chapter **Operation in high-pressure 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   **053** - 53 mm
029 - 29 mm   **064** - 64 mm
039 - 39 mm   **080** - 80 mm
049 - 49 mm

Thickness

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

Installation type

C - Countersunk fasteners
F - Flat-head fasteners
G - Glue
P - Press-fit

Inner diameter

008 - 8 mm   **025** - 25 mm   **055** - 55 mm
010 - 10 mm   **030** - 30 mm   **064** - 64 mm
013 - 12.7 mm   **034** - 34 mm   **068** - 68 mm
020 - 20 mm   **040** - 40 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
P - Stamped metal plate with plastoferrite

Zero marking

E - Engraved
H - Hole
N - None

Special requirements

00 - No special requrements (standard)

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

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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	D	S	E	
	029	G	P	013	D	M	N	
	039	B	C	020	D	S	E	
	049	A	F	025	E	M	H	
	049	B	C	025		S, P	E	
	049	B	G	034			N	
	053	B	C	030	D	S	E	
	053	B	G	040				
	064	B	C	040			N	
	080	A	F	055	E	M	H	
	080	B	C	055		S	E	
	080	B	G	064	D		N	
	080	D	F	068		M	H	

Available ring part numbers:

MRA022HP008DMN00
MRA029BC010DSE00
MRA029GP013DMN00
MRA039BC020DSE00
MRA049AF025EMH00
MRA049BC025DSE00
MRA049BC025DPE00
MRA049BG034DSN00
MRA053BC030DSE00
MRA053BG040DSN00
MRA064BC040DSE00
MRA080AF055EMH00
MRA080BC055DSE00
MRA080BG064DSN00
MRA080DF068DMH00

Accessories

Cable assembly, 1 m
ACC015
ACC049

See chapter **Cable assemblies**.

Cable assembly, 1 m
ACC016
ACC065

See chapter **Cable assemblies**.

Cable assembly, 3 m
ACC061
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"	ACC015	5 mm	1.0 m	FCI 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 in mm.
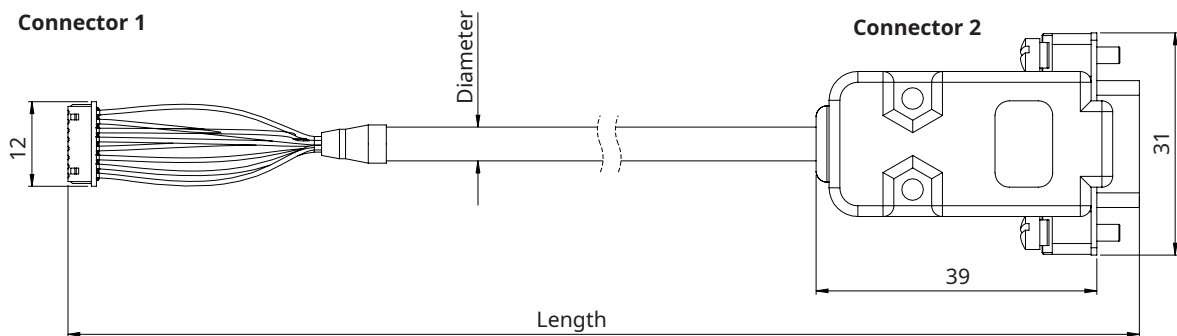
Connector 1 FCI 10114826-00008LF	Connector 2 DSUB-9 M	Wire color	BiSS C	Asynchronous serial	SPI	PWM	SSI
Pin number							
	1	Shield					
1	5	Brown		5 V supply			
2	9	White		0 V (GND)			
3	8	Pink		Temperature sensor pin 1 *			
4	4	Grey		Temperature sensor pin 2 *			
5	2	Red	MA+	RX command in +	SCK	Status 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**

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.

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Document issues

Date	Issue	Page	Description
12. 10. 2021	7	2, 3, 12, 23, 47, 48	New magnetic ring MRA049BC025DPE00 with plastoferrite material added.
		5	MRA022HP008DMN00 magnetic ring tolerances amended.
		9, 12, 14, 16, 18	Dimensions of the fasteners amended.
12. 11. 2021	8	19	MRA080DF068DMH00 drawing amended
8. 3. 2022	9	21	Encoder accuracy table
		49-51	Cable assemblies amended
21. 3. 2022	10	6-7	Amended tolerances on ring MRA029GP013DMN00

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